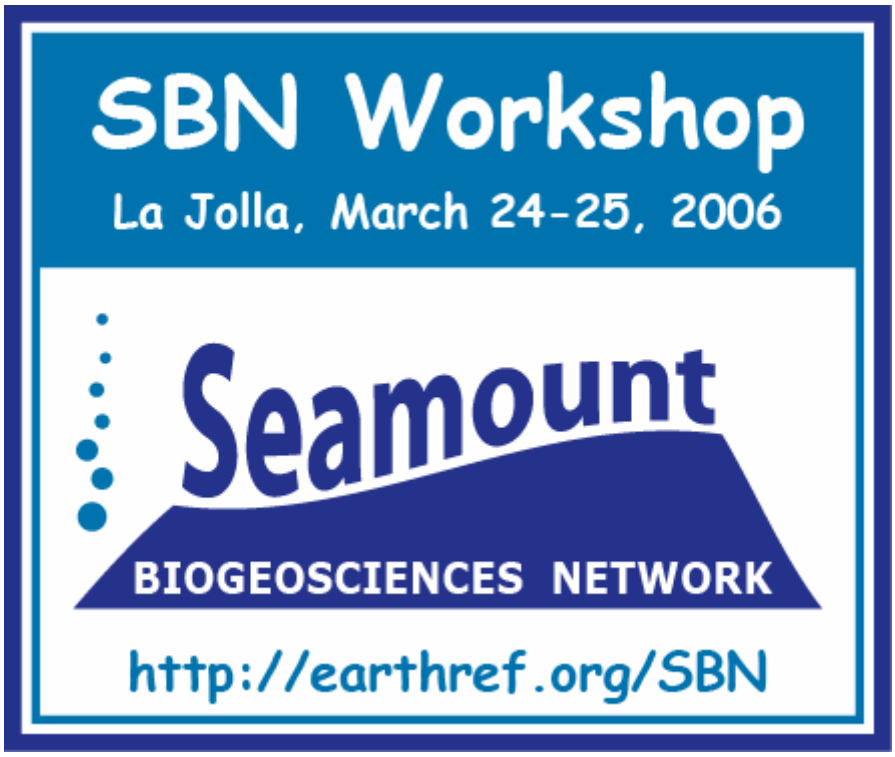
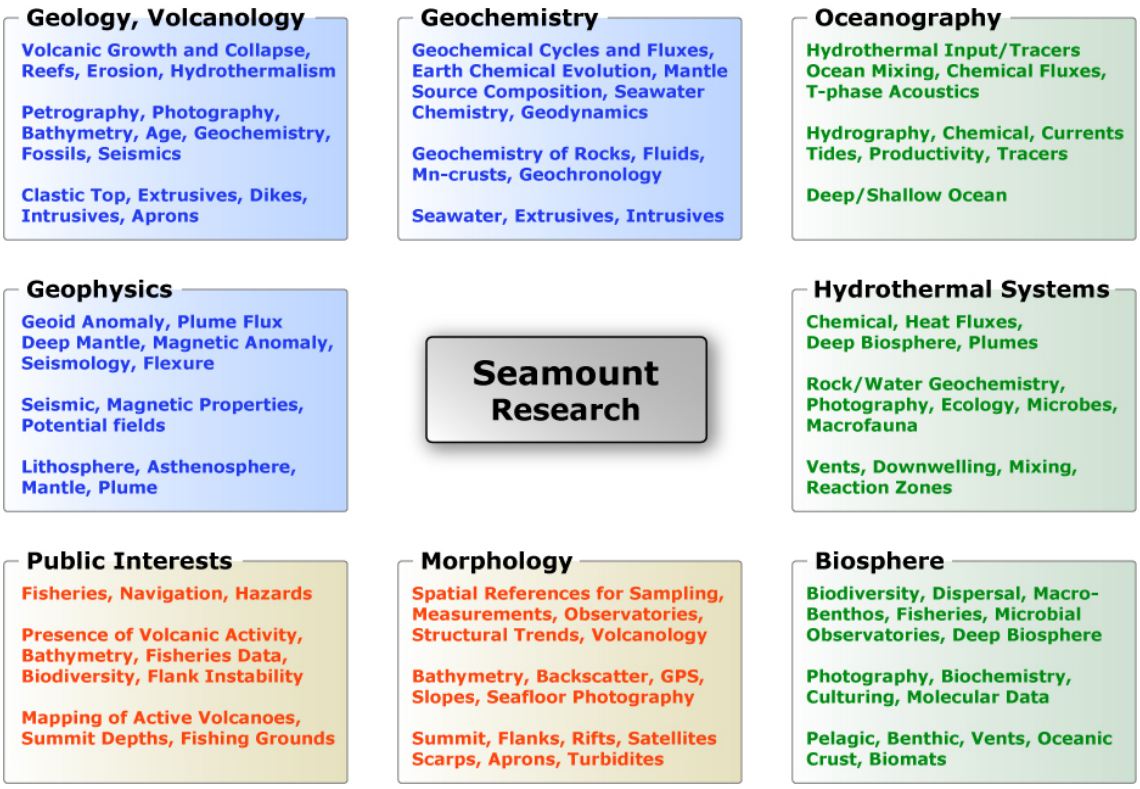
Workshop Volume



SBN Workshop

La Jolla, USA
March 24-25, 2006



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Welcome to the Seamount Biogeosciences Network (SBN) Workshop in La Jolla

This is the first of two SBN workshops that aim at establishing a dialogue between all science disciplines concerned with seamounts, including the ocean sciences, fisheries and conservation. The goals of these workshops are to allow the seamount science communities to educate each other about their respective work, to help with access to each other's data, and to explore means for how to use the internet in networking these communities.

We will work hard to accomplish these networking goals, but we depend on you to give us feedback and support in bringing this network to fruition. Most importantly, however, we would like to encourage you to become an active member of the SBN. You can contribute by writing review articles in your discipline to help the rest of us understand what is important and how major issues are researched. You could help us maintain a newsletter by becoming a SBN Editor for your discipline, by compiling and maintaining an up-to-date bibliography for your discipline, and/or by becoming the SBN Liaison in your community. Foreign participants may want to consider creating a local SBN network that is based in their home country or continent. As an IT-expert you may either want to help us with the Seamount Catalog or you may wish to maintain your own internet resource and work with us on a seamless interoperability. This way, we all could become part of a much larger, distributed seamount cyber-infrastructure and network. Please speak up and voice your concerns, offer your help, share your data, and tell each other about your plans and intentions. This workshop is a great opportunity to coordinate efforts, to avoid redundancy, and to give each other mandates for how to further this network in a most effective manner.

It has been extremely rewarding for us to help building the SBN network, largely due to the enthusiastic responses we received from you and some others who could not be here this time. Thank you very much for your support and for coming to this workshop !!!

Hubert Staudigel, Anthony Koppers and Katrina Edwards

For the SBN Steering Committee and Senior Personnel

Thank You

SBN and this workshop were funded by the National Science Foundation (NSF) through the Biology Research Coordination Network (RCN) program and the Ocean Sciences section. Further contributions were made by the NOAA Oceans Exploration Program, the Scripps Institution of Oceanography (SIO) Earth Sciences and Marine Biology divisions, and the Center for Earth Observations & Applications (CEOA). We thank Patty Keizer who organized almost every detail of this workshop and our lab-crew that is always there when needed. Lastly, we want to thank you, the conference participants and the many members of the network who showed their support and helped at many occasion throughout the inception and the development of the SBN.

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Workshop Program — Morning

March 23 2006	March 24 2006	March 25 2006
	Continental Breakfast 08:15	
	9:00 – 10:30 Hubbs Hall	9:00 – 10:30 Hubbs Hall
	Welcome: John Orcutt **Introduction:** Workshop Goals and Logistics Breakout Session Goals Introduction to Posters	**Benthic Ecology And Oceano-graphic Controls** Keynote Speakers: Lauren Mullineaux Karen Wishner William Lavelle Discussion Leader: Christian Mohn
	Coffee Break 10:30 – 11:00	
	11:00 – 12:30 Hubbs Hall	11:00 – 12:30 Hubbs Hall
	Seamounts From Space, Their Ages and Life Cycles Keynote Speakers: David Sandwell Jerry Winterer Robert Duncan Discussion Leader: Dawn Wright	**Fisheries, Conservation and Endemism** Keynote Speakers: Malcolm Clark Karen Stocks Les Watling Bernd Christiansen Discussion Leader: Adele Pile
	Lunch Break 12:30 – 13:30	

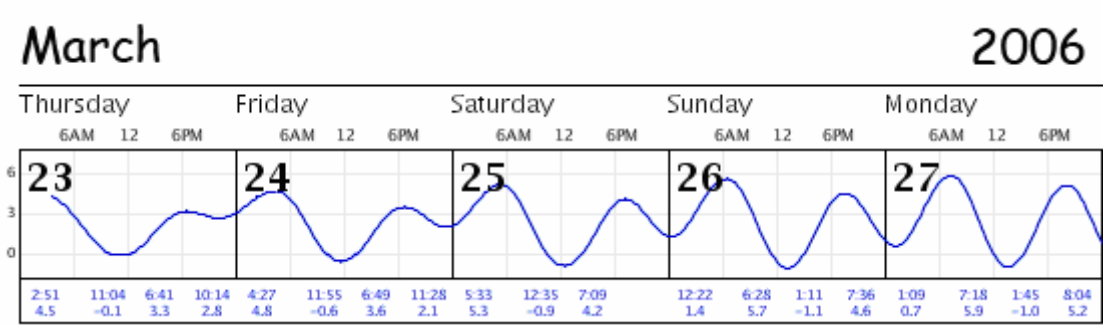
Workshop Program — Afternoon

March 23 2006	March 24 2006	March 25 2006
	Lunch Break 12:30 – 13:30	
	13:30 – 14:30 Hubbs Hall	13:30 – 14:20
	Integrated Seamount Studies: Vailulu'u Seamount Keynote Speakers: Stanley Hart Craig Young Discussion Leader: Alexis Templeton	**Breakout Session II** **Observatories** (Munk) **Data Base Needs** (Board Room) **Seamount White Paper** (Hubbs Hall) **SBN Goals and Tasks** (Sun City)
	14:30 – 16:00 Hubbs Hall	14:30 – 15:30 Hubbs Hall
	Microbial Community Characterization Keynote Speakers: Katrina Edwards David Emerson Craig Moyer Discussion Leader: Bradley Tebo	**Hydrothermal Systems: Physics and Chemistry** Keynote Speakers: Geoff Wheat Andrew Fisher Discussion Leader: Rachel Dunk
15:00		
WORKSHOP REGISTRATION **PUTTING UP THE POSTERS**		
	Coffee Break 16:00 – 16:30	**Coffee Break 15:30 – 16:00**
17:00	16:30 – 17:30	16:00 – 17:30 Hubbs Hall
POSTER SESSION I **ICE BREAKER RECEPTION**	**Breakout Session I** **Observatories** (Vaughn 100) **Data Base Needs** (Board Room) **Seamount White Paper** (Hubbs Hall) **SBN Goals and Tasks** (Sun City)	**PLENARY SESSION** **Breakout Session Synthesis** (15 minutes each) **SBN - Quo vadis**
	17:30	
	POSTER SESSION II **Wine and Cheese Reception**	

Workshop Program — Evening

March 25 2006
18:00 **Mexican Conference Dinner at Tecolote Canyon** **22:00** **Transportation back to the hotel**

La Jolla Tides Calendar



Breakout Sessions

Breakout sessions address key infrastructure issues in seamount bio-geosciences, in particular, how we can help develop as a network, what tools or features are needed to bridge the gaps between seamount science disciplines, how to facilitate open access to all types of seamount data, and how we can be more successful at explaining the value of studying seamounts, much like how the RIDGE and MARGINS programs made the case for studying the mid-ocean ridges and subduction zones.

Such networking has the potential to substantially improve the seamount science funding and seamount science and its contribution to our understanding of how the oceans and solid earth work as a physical, chemical and biological system.

We defined four breakout sessions that will address key topics of seamount science infrastructure. There will be some overlap and feedback between these groups, but all have a defined product.

We will have an amazing depth and breadth of expertise on seamount research at the workshop that we hope to distribute over these sessions, so we are minimally redundant with a maximum of expertise in each one of the groups. Each group has two co-chairs, who will lead the session and report the breakout results to the plenary session at the end. In addition, we have identified a series of panelists who take on the responsibility of disciplinary representation and expertise in these breakout sessions. Non-panelist workshop participants may choose to participate in either one or several of these break-out sessions, but the network is counting on everybody to contribute, voice ideas and share opinions.

Each breakout group will establish a group-mailing list for everybody who wishes to contribute and/or be informed after the workshop. During the final wrap-up plenary session there will be a 15 minute discussion time slot for each breakout group to discuss what has been accomplished, to ask for input from workshop participants who had to attend other sessions, and to plan future activities.

1. Creating a Seamount BioGeoscience Network: Needs and Goals

Lead: K. Edwards, D. Clague; **Panelists**: E. Winterer, Th. Hansteen, J. O'Connor, G. Wheat, D. Sandwell, W. Lavelle, M. Sogin, B, Tebo, K. Wishner, A. Pile; **Place**: Sun City

SBN was funded by NSF to create a network of seamount scientists to foster cross disciplinary communication and to facilitate data exchange through workshops and the establishment of a database and a website. Other options include newletters, metadata exchanges, online discussion forums, online message boards, organization of seamount related workshops, summer schools on seamount research, student exchange programs, etc. This panel will explore the most appropriate steps that SBN can take to accomplish this NSF mandate, including cost-benefit considerations.

2. Seamount Observatory: Interdisciplinary Needs and Goals

Lead: L. Mullineaux; **CEOA Representative**: J. Orcutt; **Panelists**: M. Perfit, A. Kluegel, R. Blake, A. Malahoff, R. Pinkel, A. Templeton, T. Shank, B. Christiansen; **Place**: Vaughn 100 (fri) and Munk Lab (sat)

A key goal in seamount research includes long term observatories that may focus on the seamount itself, or the ocean around them. Seamount observatories may dovetail with mid-ocean oceanographic observatories or global seismology observatories, for example. CEOA Director J. Orcutt will outline the procedures involved in proposing such an observatory, and offer advice for a successful application. Breakout session participants will outline the key reasons why seamount observatories are needed, which technologies would be required and which path should be taken towards an observatory proposal.

3. White Paper: From Conference Report to Seamount Science Vision

Lead: H. Staudigel; **Panelists**: R. Stern, R. Duncan, W. Bach, C. Mohn, J. Huber, C. Moyer, L. Levin, C.M. Young, M. Clark; **Place**: Hubbs Hall

Much can be gained from the publication of a document that describes SBN. This may include a formal white paper submitted to NSF as a glossy science planning document and/or a conference report in a scientific journal. In either case such a document may serve any conference member in placing their own science in a wider context. This breakout session will first decide on the primary purpose of this documents and then break up in subgroups that will outline sections for this document.

4. SBN Database Needs, CyberInfrastructure and the Seamount Catalog

Lead: A. Koppers, K. Stocks; **Panelists**: D. Wright, J. Helly, D. Emerson, B. Bailey, J.Smith; **Place**: Board Room

Creating a data network and cyberinfrastructure is one of the major SBN goals. This working group will explore the current state of databases and cyberinfrastructure and explore its long term future development. The main goal of this breakout session is to discuss our NSF mandate on how to use the Seamount Catalog and the EarthRef.org web portal to the benefit of the SBN network. Other key issues will focus on metadata and interoperability between existing and planned resources. In addition, new projects and online tools will be proposed and discussed, including the use of bulletin boards, shared bibliographies, cruise planning, etc.

Introduction to the Seamount Catalog and the EarthRef.org Web Portal

Anthony Koppers, Hubert Staudigel, John Helly, Rupert Minnett, Jake Perez, Patty Keizer

One of the major SBN mandates concerns the development of a community website and database that integrates a wide range of seamount data. In order to establish a cyber-infrastructure on seamounts we are hosting the SBN home page on EarthRef.org (http://earthref.org/SBN) and we will use the Seamount Catalog (http://earthref.org/datbases/SC) as the main resource for finding basic information and maps about seamounts. More importantly, we will design the SBN website so that it will effectively become a "portal" or "springboard" on the web, where researchers can find out what kinds of data are available for each seamount and guide these users to the "authoritative" web resources on, for example, seamount macro fauna and biodiversity (SeamountsOnline), geochemistry data (EarthChem.org), cruise-related data (SIOexplorer.org), paleomagnetic data (MagIC), and so on. This means that SBN is not planning to collect any "real" data on the macro fauna or geochemistry of seamounts, for example. Instead it only seeks to include the necessary "metadata" (i.e. data about data) that will allow it to know what kind of data are available and where to find it on the web.

Besides the establishment of the above seamount cyber-infrastructure, the SBN website will also provide tools that will help the seamount science communities in other important networking tasks. These tools may include bulletin boards, online discussion forums, list servers, online seamount white papers, cruise planning tools and assistance in the organization of seamount-related workshops.

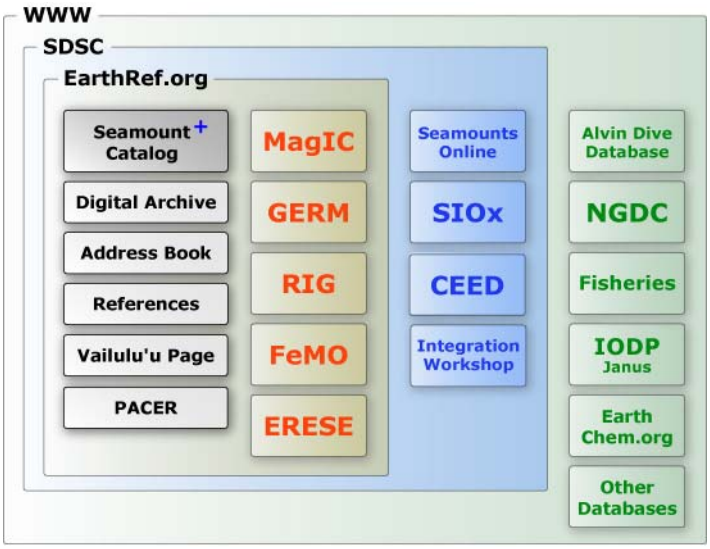


Figure 1. The Seamount Catalog and EarthRef.org in relation to other internet resources. Our focus will be to establish an integrated database structure within EarthRef.org using MagIC (magnetics), GERM (geochemistry), RiG (Geochronology), FeMO (biology) and the Seamount Catalog (bathymetry and morphology). Common EarthRef resources include a digital archive, address book and reference database. EarthRef.org is served from within the SDSC that also includes SeamountsOnline (biodiversity), SIOExplorer (SIOx), the Caveat Emptor Ecological Database (CEED) and other resources. Outside internet sources on the world wide web (WWW) include a range of institutional and national marine data repositories.

The EarthRef.org web portal is well suited to handle these tasks (Figure 1). Its databases and web servers all reside within the San Diego Supercomputer Center (SDSC) reassuring the longevity of the seamount data storage in the most professional manner. On top of that, many important facilities required to run an international network are already in place, with the existence of the EarthRef Digital Archive (ERDA), the EarthRef Address Book (ERAB), the EarthRef Reference Database (ERRD) and of course the Seamount Catalog (SC).

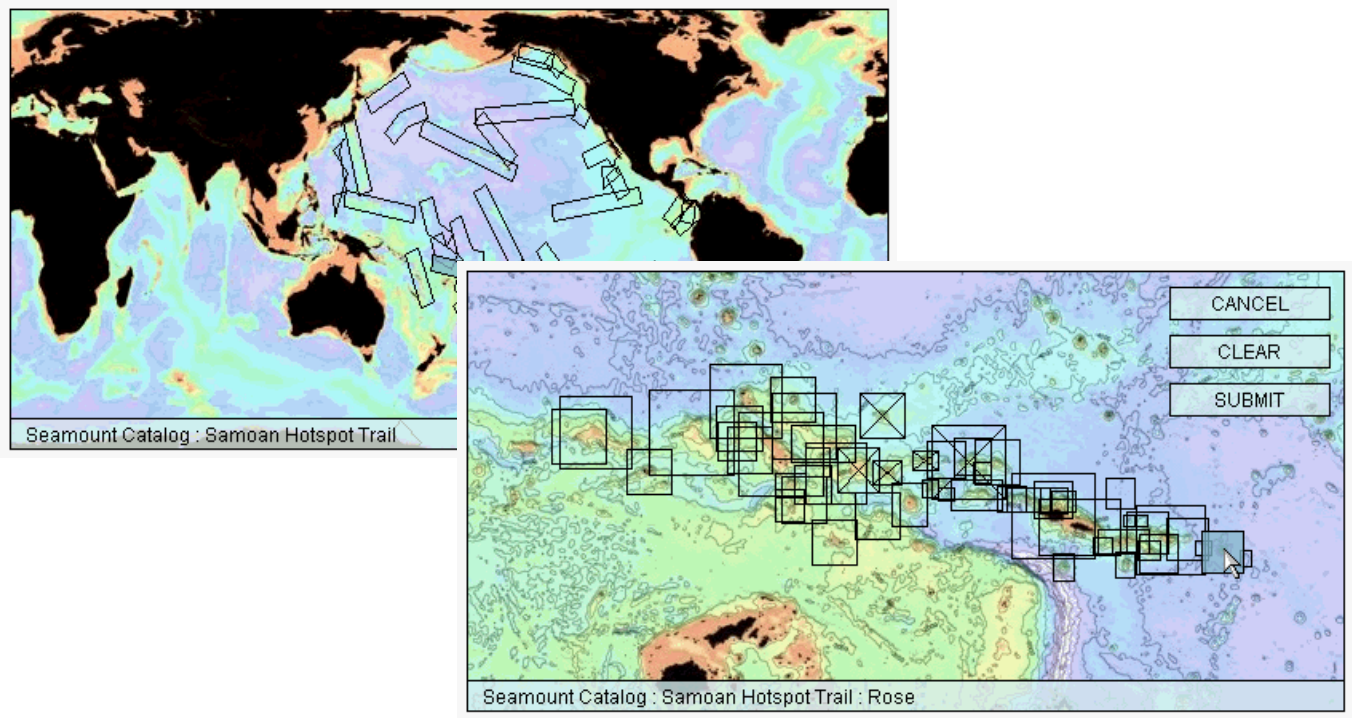


Figure 2. Simple interface to finding seamounts in the Seamount Catalog. This two step search tool allows you to select a seamount trail or region of interest, after which the user can select multiple seamounts of interest and submit the query to the database. The results of such a query are shown in Figure 3.

The EarthRef.org Web Portal and Databases

The EarthRef.org website originally has been developed as the host website for GERM (the Geochemical Earth Reference Model initiative), but it is now a very substantial website for a wide range of Earth science data that spans from geochemistry to paleomagnetism to geochronology and more. A variety of EarthRef.org tools and databases will be immediately available to the SBN network: The **ERAB** is a much used directory for Earth scientists address information (~2,000 registered users) that is frequently visited by users using web search engines such as Google. It features password protected updating privileges for the individuals listed and it can easily be expanded into a "Yellow Pages" for seamount researchers, simply by adding searchable personal information, including field(s) of research, analytical techniques applied and sample interests. The **ERRD** includes a very substantial number (~95,000) of publications, archived with complete reference information, abstracts and, in many cases, Microsoft Excel files of tables and appendices. The **ERRD** has a well defined data population protocol for data upload that can be directly applied to a seamount reference library linking publications to the seamounts

studied. Finally, **ERDA** is a fully functional database that archives any digital object with a critical number of metadata to make it efficiently searchable by seamount researchers. To upload your own seamount-related data files please follow the http://earthref.org/cgi-bin/erda-c0-start.cgi link or start from the SBN home page. Your contributions can be linked to the seamounts you studied and the papers in which you published these data, whichever is applicable.

Seamount Catalog

The Seamount Catalog already carries a series of key products that will serve the SBN network, including access to a wide range of map products that range from simple downloadable bathymetric maps to the XYZ NetCDF grids and the original data files (multibeam, sidescan) that may be recombined with other data sets to upgrade or re-plot the maps, according to the users own needs and expertise. The Seamount Catalog features an easy-to-use search interface (Figure 2 and 3) that displays available data for download and some vital statistics for more than 1800 seamounts, such as summit depth, seamount length/width and volume, shape, elongation, age, ocean floor depth and age, multibeam coverage, etc.

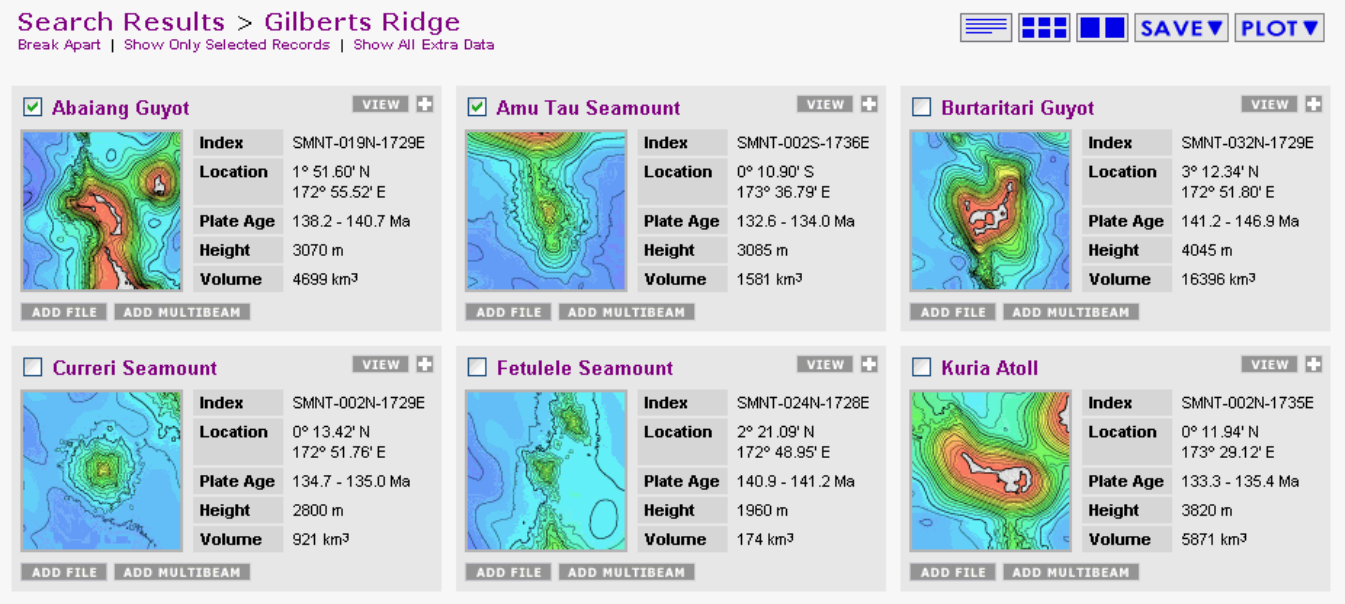


Figure 3. Thumbnail view of seamounts in the Seamount Catalog. When searching for seamounts the results are either displayed in a small thumbnail view (shown), a large thumbnail view or in a text-only view (see blue buttons in upper right corner). The results can be further refined by breaking this view apart, only showing selected seamounts or by showing all extra data. These latter extra data can also be shown for each seamount individually by clicking on the [+] button. Click on the thumbnails, or check multiple seamounts and hit the Continue button, to get maps, grids, multibeam data and a detailed morphology analysis for each seamount.

Users also can add their own data files to the Seamount Catalog and link it to a particular (set of) seamount(s). To link one of your own data files to a seamount, you simply click on the "Add File" buttons (Figure 3) that popup with each seamount in your searches. You will be guided through a few web forms that require you to fill in five requisite fields only, but where you can add optional fields to provide extra metadata. If you want your multibeam (or sidescan) data to be incorporated in the archives of the Seamount Catalog and to be used for making more up-to-date maps, please click on the "Add Multibeam"

buttons (Figure 3) and you will be guided to our FTP server where you can upload these (large) data files. This will also be the place where you can upload lists of (new) seamounts with lat-lon information, so that we can add the correct names to the correct seamounts in the database.

Currently the Seamount Catalog carries four different base maps (Figure 4). For each seamount it provides a map based on the predicted bathymetry (derived from satellite altimetry data) provided by Smith and Sandwell (1997) and, whenever available, it will provide maps based on multibeam data collected during seagoing cruises. Most multibeam data is from the NGDC, but the Seamount Catalog also contains data collected outside the US. Finally, a merged map is available that combines the first two maps and a residual map is available depicting the differences in depth between the multibeam and predicted bathymetry maps. Sample locations from dredging, tv grabs, piston coring, wax coring, ODP and DSDP coring, and other sampling techniques can be plotted on top of these maps, whereas a comprehensive gazetteer of oceanic features and islands is being assembled to plot on these maps as well.

As a final point, the Seamount Catalog enables geospatial cross correlation between different databases through an unique seamount identifier, whereby we assign a unique catalog number (e.g. SMNT-123N-1234W) to every seamount based on its geographic coordinates (degree, one tenth of a degree) that will be used in all databases involved, avoiding redundancy in seamount names and offering search capabilities based on this code alone. In other words, by using these catalog numbers we are able to find and identify seamounts that otherwise may be unnamed, have similar names, have more than one name, or have multiple names that are spelled slightly different. This makes possible a transparent interoperability with other databases, it makes possible a more robust archiving of seamount-related data files and it reduces confusion between researchers studying the same underwater features.

SeamountsOnline and Other Related Databases

This online resource allows researchers to seek data on the biodiversity of seamounts and is closely related to the Seamount Catalog and SBN. The goal of this database is to bring together data on species that have been sampled and studied from seamounts, and make these data available through a searchable online website (http://seamounts.sdsc.edu). The data are compiled from many literature publications, data holdings of individual researchers and institutions working on seamounts. This database covers seamounts globally and includes fish, invertebrates and plants. Through the web portal, users can view a list of the species that have been found on a particular seamount, a list of all the seamounts from which a particular species has been found, find out what amount of research has been done on a particular seamount, and search a bibliography of over 1,200 literature references on seamounts. Seamounts-Online is currently serving data on 2,700 species (or higher taxonomic groups) from over 200 seamounts, and is expanding continually.

The SeamountsOnline database has been adopting the SMNT-123N-1234W catalog identifiers to facilitate interoperability with the Seamount Catalog. Similar cooperation's have already been initiated with the EarthChem.org website that will allow us to share information about available chemical data on seamount basalts and sediments.

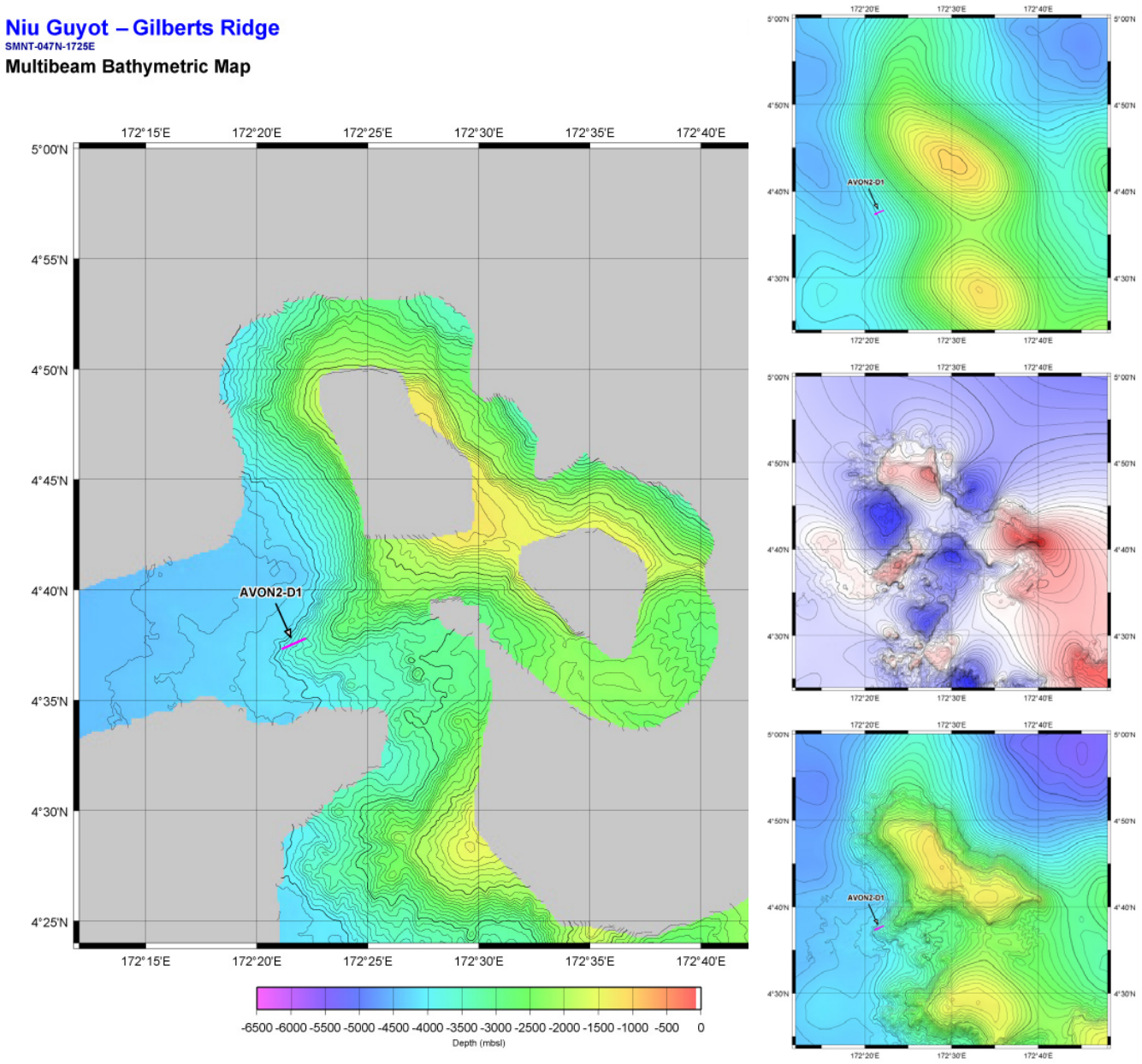


Figure 4. Basics maps in the Seamount Catalog. In total four basic maps are available for downloading: **(i)** a global bathymetric map based on the Smith & Sandwell (1997) satellite altimetry database, **(ii)** a map based on multibeam, **(iii)** a residual map between these two previous maps, and **(iv)** a merged map. The Smith & Sandwell 8.2 Image File is used to achieve complete coverage for the seamounts (see the upper right map). The same image file is also used through the GINA or JJB bathymetric data compilations that are a combination of the Smith & Sandwell database, the bathymetry of the Artic, the GTOPO30 database for continents, and the multibeam syntheses for RIDGE. In these global databases the resolution is effectively 2 minutes for the ocean floor and 30 seconds for the continents and the continental shelfs. The multibeam maps of course have a much higher resolution and in the standard maps these data is gridded on the 0.1 minute (or 180 m) resolution.

Abstracts

Listing in alphabetical order

The Economic Model Of The Fe-Mn Crust Exploration On The Seamount

Asavin, A M; Chesalova, E I

After the 1980 years, attention on the Fe-Mn crust on the oceanic bottom as ore potential source slowly decreased. This decrease resulted in the failed operation of exploration and mine workings on Fe-Mn nodules for the Clarion-Clipperton region, Hawaiian ore region and other regions on oceanic bottom and regions of oceanic ridge by USA firms. The investigation of Fe-Mn core on the seamounts and other intraplate magmatism objects is causing a rebirth of interest in this ore type. High concentration of the Co, MnO, NiO and Platinum group elements (EPG) make it a perspective product on the world market. From the other side, technology of mine workings from seamounts ore zone are more complex and consistence of the ore material (kg/m2) less then for nodules on the oceanic bottom. The present paper is dealing with methodic procedures of estimation useful mineral reserves on the seamounts by GIS method.

Type of slope	Horizontal	1-5 grad	5-15 grad	>15 grad	Total
Area (km^2)	163	124	1465	177	
Volume m^3	4645500	5096400	64606500	8619900	82968300
Gross weight dry ton.	29340	38440	454150	60180	582110
Co wt%	0.52	0.52	0.24	0.27	
Co ton reserves	152	199	1090	162	1603
Mn wt%	25.22	27.45	25.22	17.58	
Mn ton reserves	7400	10552	114537	10580	143068
Ni wt%	0.31	0.49	0.26	0.18	
Ni ton reserves	92	187	1190	105	1574
Co conventional	1.74	1.88	1.46	1.12	
Co conventional ton.	511	723	6609	671	8515
Pt ppm	10.00	2.00	0.60	0.50	
Pt kg reserves	2934	768.8	2724.9	300.9	6728.6

Table 1. Calculation reserve volume of Fe-Mn crusts for Karter seamount.

For calculation area of the seamounts slope we used GIS program ArcInfo 8.2. As initial information we used GEBCO (General Bathymetric Chart of the Oceans). The result of 3-D computers models are shown in the Figures 1, 2. We use triangulation method, calculate area (as degree) for each of the triangle and categorized data from the four class (0-1, 1-5, 5-15, >15 degree of the slope). From the software ArcInfo we used two methods to build model of the surface: GRID and TINs (triangulated irregular network). The raster show surface as regular network with known or interpretative value of argument Z. The surface represent by TINs are sets of points. The irregular network of this points form as a sequence of triangles. TINs are designed to capture and represent surface features such as streams, ridges and peaks. Tins represent surfaces as contiguous non-overlapping triangular faces. You can estimate a surface value for any location by sample or polynomial interpolation of elevations in a triangle. Because elevations are irregularly sampled in the TINs, we can apply a variable point density to areas where the

terrain changes sharply, yielding an efficient and accurate surface model. Linear features such as ridges are represented by a connected set of triangle edges. Mountain peaks are represented by a triangle node. The TIN models are distinguished by raster representation with continues exposed of the surface. From TIN models we can handled and stored rise, slope and, break lines of the nature relief also.

Expense of capitalized (mln$)		s.vessel	200			
		Explorer	30			
		Factory	10			
	A	Total	**230**			
Expense of the year (mln$)	**B**	Ore mining effective 500 ton per day	Working days per year =200 (day)	Total volume of ore from year = **100** (thousand ton)		
	C	Exploitation expense	5-30 mln$	**20**		
		Other Transport				
	D	Transport of the tank ship (50 thousand ton of the cargo capacity)	Cruises per year =**B/D** (100/50)	**2**		
	E		0.5 mln. $ for cruise	**1**		
	F	For stores ore and factory operation		**4**		
	G	Total per year		**25**		
Total time of working off (year)	**H**	Stock thousand ton ore (as 1 s.m. ample)	500			
	I	Year	**H/B**	**5**		
Advantageous for 1 s.m. (Price mln.$ for product on the year)		Total Stock of ore ton	for year ton	Price thousand $ (for 1 ton metal)	Total price	
	Ni	1574	270.4	10	2.7	
	Co	1603	275.4	35	9.6	
	Mn	143069	24577.7	1.7	41.8	
	Pt	6.729	1.2	20000	23.1	
	Pd	4	0.7	30000	20.6	
	J			Summa	**97.9**	
	K	Profit from year		=**J-G**	**67.9**	
Profit mln$	**L**	total period of work off		=**J*I**	**109.5**	
Time work off	**M**			A/(J-G)=	**3**	

Table 2. Calculation efficiency of operation of exploration and mine workings.

Since the relief surface are irregular network we used TINs models. The other advantages of the TINs are support a precise location and shape of surface features. Arial features such as lakes and islands are represented by a closed set of triangle edges. Linear features such as ridges are represented by a connected set of triangle edges. Mountain peaks are represented by a triangle node. TIN support a variety of surface analyses such as calculation and creating profiles on alignments. TINs are well suited for large-scale mapping applications where positional accuracy and shapes of surface features are important.

We use different 3 kinds of the surfaces as has been suggested with the classification [2] of ore places by the seamount slope – flat surface and node of slope, 1-5 degree declination, 5-15, >15. Many researchers believed that density and thickness of the ore core on the basalt is almost directly proportional to type of surface [1,2]. On Figure 1 we show different kinds of surface by their color, and from Table 1 we calculate the area and volume of the ore (m3). There is total opinion that horizontal surface more productively then other type of surface, but it type compose about 10% only. The main part of the ore surface com-

posed 5-15 degree (about 80%). But the concentration of the ore component (Co, Pt, Ni, Mn) also depend of the type of surface. If we take into account this fact we can see that for Pt ore stock for horizontal and 5-15 degree surface similar (40, 44 %). For this reason we can simplify ore mining of this type ore.

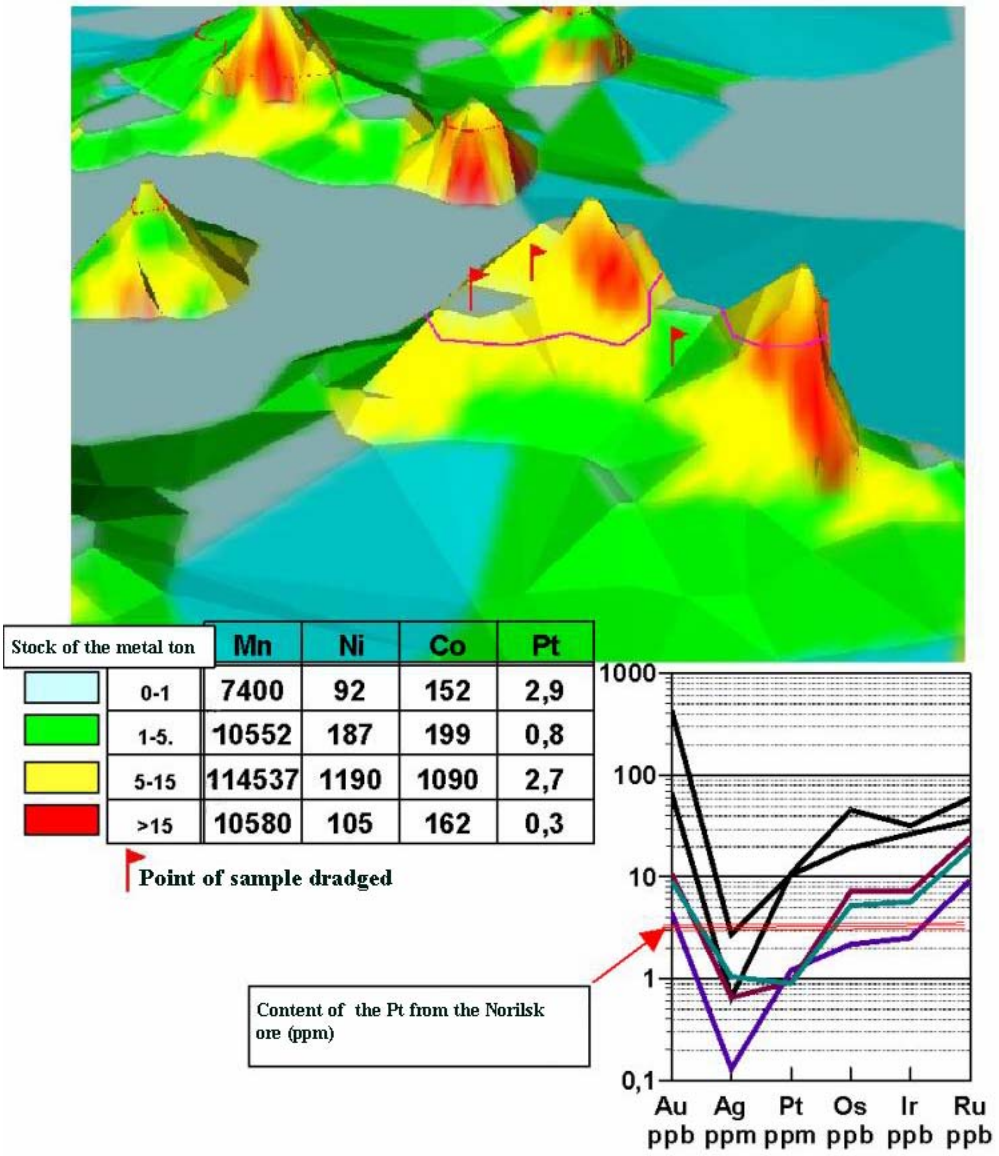


Figure 1. 3D model of ore body from Sierra Leone seamount (Atlantic Oceon). At the lower right inset the contents of the Pg group are zone for the Fe-Mn cores.

From Table 2 we calculate approximate economic effective of the ore mining only for 1 seamount from Sierra Leone rise. There is the simple evidence of the perceptivity mining of the seamount as ore object. Certainly the most values of the input parameters from this calculation very rough. But the main conclusion from this calculation is even so one seamount ore field we can found enough high profit for exploration and mine working. There are two lines of evolution costs and profit exposed on Figure 2. The point of the cross this lines show the time of paying back. There is about 3 year in our case. The important conclusion of our analysis is the exchange the order metal from list of profit component. As shown on Figure 2 the main worth from ore consist from Pt, Pd metal (about 50%) whereas the Ni, Co less than

15% from total profit. Another word without extraction Pt, Pd from this type of ore, the efficiency of work mine drops two orders.

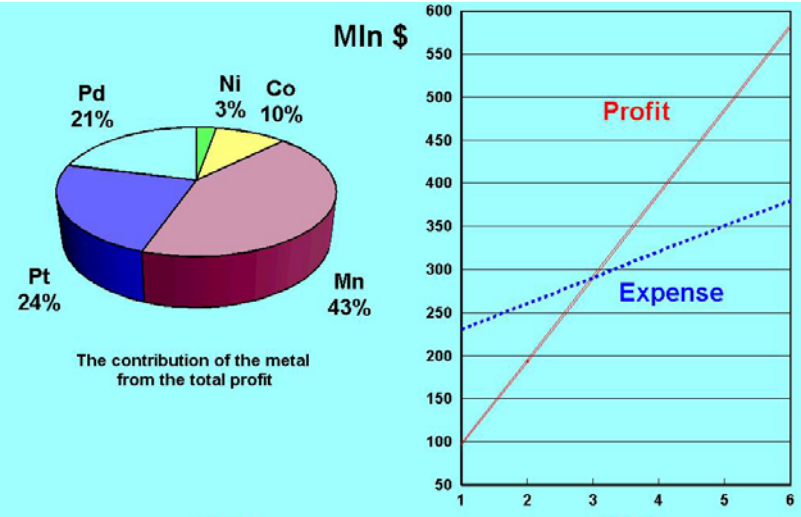


Figure 2.

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The Concentration Of PGE And Trace Elements In Manganese Crust On The Alkaline Basalts Magelan Seamounts

A.M. Asavin; A M, Melnikov; M Y, Sapozhnikov, D Y

New data of the concentration trace elements and platinum group elements (PGE) from the ferric manganese crust and ground basalts from Magelan seamounts (Pacific Ocean) was obtained. There are typical alkaline basalts which are presented from trachybasalt to trachy-andesite (Table 1). The samples of basalt are covered by thick ferric manganese crust (up to 10-15 cm) but the underlay basalt is quite fresh. The ground mass of basalt is like a glass and looks in some samples as obsidian .The basalt alteration and Mn mineralization exposed around globules partly intruded with aragonite and zeolites and there are contraction cracks with thin vernadite veinlets. A phenocrysts of olivine and magnetite looks as alteration centers. From that centers manganese mineralization started as thin vernadite veinlets. All this observation and cooling structure of the basalts are evidence of underwater explosive alkaline lavas on the seamount. There are peculiarities of the explosive were very rapid cooling and fluid saturation of the melts.

We used neutron activation method of analysis. Additionally some samples were analyzed with preliminary upgrading by NiS sweat ball. After that we estimated concentration PGE – Pt, Ir, Os, Ru. There is a normalized (C1 chondrite) concentration of the trace elements in alkaline basalts (Figure 1). The form of the spider diagram is ordinary for the other alkaline oceanic intraplate basalt. There is a wide interval of the concentration in basalts, but the curves are similar. There are high concentration of Sr, Ba, Th, U and

LTR more than HTR. There is not negative Ir anomaly (as from manganese crust) from PGE spectrum and light PGE lower than heavy PGE (Figure 2). A comparison between other basalts and our samples shows that whole concentration of PGE in our samples is higher.

Sample	15D233	15D203	15D202-1	35D209	35D240-1	35D233-2	35D242
SiO_2	47.4	41.3	44.67	35.56	41.21	46.84	44.6
TiO_2	3.2	3.52	2.92	1.32	1.81	2.32	3.44
Al_2O_3	17.59	15.36	14.5	12.15	16.05	17.36	15.25
MnO	0.24	0.818	0.307	0.112	1.001	0.455	2.609
FeO	9.85	13.04	13.61	8.65	13.61	13.73	11.7
MgO	1.86	3.03	5.54	3.47	2.35	1.16	5.24
CaO	6.02	6.83	5.22	21.9	6.77	6.01	10.7
Na_2O	2.91	2.62	2.37	2.1	2.48	3.35	2.42
K_2O	2.43	1.64	1.45	0.72	2.59	2.07	1.3
Cr_2O_3	0.003	0.005	0.007	0.049	0.07	0.003	0.02
P_2O_5	1.353	1.024	1.32	0.3	1.409	1.398	0.572
Ppp	6.24	6.12	8.18	13.6	10.22	4.9	1.88
Sum	99.096	95.307	100.094	99.931	99.57	99.596	99.731

Table 1. Silicate analysis of the alkaline basalt from Magelan seamounts (RFA wt%).

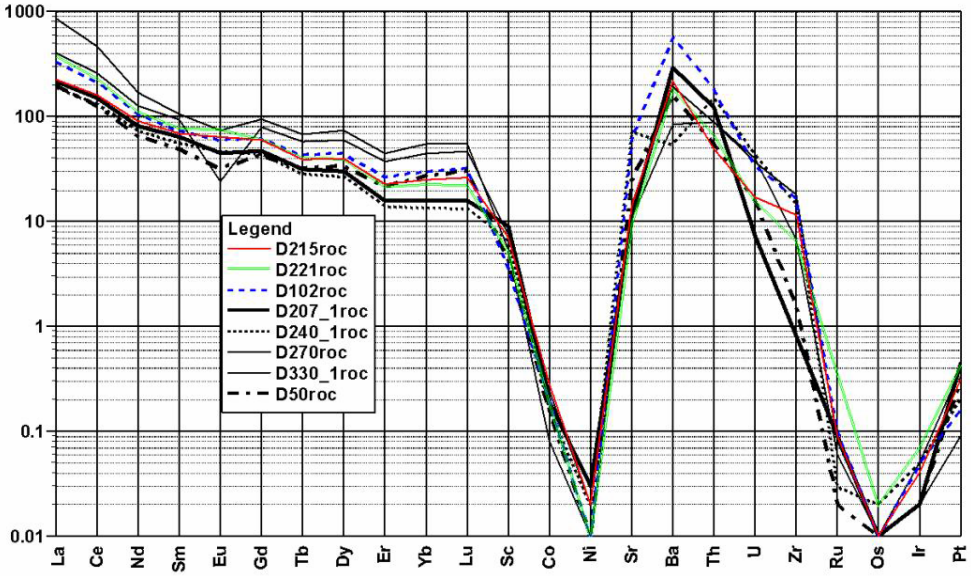

Figure 1. Concentration of trace elements normalized by C1 (Barnes et al 1985) from basalts of Magellan seamount (INNA measurements).

Sample		36D50	30D102	15D215	15D221	35D240_1	35D270	35D330_1	35D207_1
La	ppm	177.7	310.5	245	280.8	451.9	274.3	294.6	339.2
Ce	ppm	848	1656.2	1174.2	862.2	2171.6	1369.7	1265.8	1124.7
Pr_	ppm	29.8	57.8	46.9	55.2	69.6	51.4	56.3	69.2
Nd	ppm	101.8	205.5	178	200	218	191	205.5	250.8
Sm	ppm	23.8	47.2	40.5	46.6	45.2	43.6	48.7	61.1

Eu	ppm	3.76	12.4	12.1	12.8	14.2	9.82	11.5	15.6
Gd_	ppm	31	54.7	47.7	59.4	60.8	54.3	57	71.4
Tb	ppm	4.91	7.99	7	8.71	9.17	7.98	8.13	10.2
Dy_	ppm	30	46.9	40.2	50.1	57.9	46.8	47.2	60
Ho_	ppm	6.92	10.4	8.1	12.1	12.7	10.7	10.4	12.6
Er_	ppm	19.9	27.4	22.2	30.4	36.7	27.5	27.2	33.6
Tm_	ppm	3	3.98	3.07	4.45	5.5	4	3.9	4.7
Lu	ppm	2.89	3.45	2.52	3.88	5.1	3.4	3.3	3.77
Yb	ppm	17.3	20.8	16.4	24.7	30.8	21.3	20	25
Co	ppm	2063.8	2189.2	2230	3726.9	2514.3	3525.7	4730.1	3062
Ni	ppm	4450	6000	3180	3530	3180	4410	6980	3470
Ba	ppm	1900	2890	2960	1730	4380	2300	465	2690
Sr	ppm	425	775		285	775	790	425	370
As	ppm	224.6	182.3	208.1	236.7	228.2	226.4	220.4	292.7
Sb	ppm	49.6	46.6	45.7	37.2	53.1	52.2	49.8	38.9
Zr	ppm	510	47	60	96	1020	160	835	225
Hf	ppm	11	8.6	5.95	4.76	4.09	12.1	0.89	3.39
U	ppm	7.32	9.36	2.99	11.9	11.5	13.4	15.9	12.5
Th	ppm	15.9	11.9	17	30	20.1	30.9	26.2	43.1
Ru	ppb	422.6	171.9	418.5	1856.2	205	322.4	473.1	165.9
Os	ppb	63.9	29	20.4	186.2	13.8	47.5	32.5	13.4
Ir	ppb	22.1	70	28.8	86.7	39.2	86.2	41.6	36.8
Pt	ppm	2.2	1.905	1.86	0.95	1.77	3.23	0.8865	1.244
Ag	ppm		1.81	2.89	24.3	11.1	1.83	19.2	0.42
Au	ppb	5.2	30.6	3.65	10.3	6.68	3.76	4.93	9.85

Table 2A. Concentration trace elements in manganese crusts. INNA method all elements and PGE element, Au by preliminary upgrading.

Sample		**36D50**	**30D102**	**15D215**	**15D221**	**35D240_1**	**35D270**	**35D330_1**	**35D207_1**
La	ppm	62.7	107.6	72	121.5	61.7	129.1	275.4	69.2
Ce	ppm	109.8	183	138	200	115	223	401	129
Pr_	ppm	11.3	19.3	14.2	20.6	12.2	22.9	35.9	13.5
Nd	ppm	41.8	67.1	57	70.2	46.8	79.8	106.6	51.1
Sm	ppm	10	15.3	14.1	15.9	11.7	19	21.5	13.1
Eu	ppm	2.41	4.55	4.83	5.7	3.58	1.82	5.59	3.39
Gd_	ppm	12.4	17.8	17.2	17.5	12.7	22.7	27.1	13.5
Tb	ppm	1.93	2.63	2.36	2.46	1.76	3.5	4.11	1.91
Dy_	ppm	11.4	15.1	13.5	13.4	9.25	20.2	25	10.2
Ho_	ppm	2.51	3.4	2.88	2.76	1.86	4.47	5.23	2.03
Er_	ppm	7.08	8.82	7.51	7.1	4.62	12.3	14.7	5.2
Tm_	ppm	1.08	1.27	1.07	0.99	0.61	1.75	2.2	0.68
Lu	ppm	0.98	1.06	0.86	0.73	0.44	1.53	1.82	0.52
Yb	ppm	5.91	6.57	5.46	4.98	3.01	9.7	12	3.49
Co	ppm	69.6	88.3	133.3	90.9	77.5	113	38.1	91.5
Ni	ppm	140	100	210	100	220	190	0	250
Ba	ppm	495	1730	660	560	165	255	580	885
Sr	ppm	290	740	165	110	865	125	170	130

As	ppm	27	24.1	26.9	43.9	35.8	72.7	39.5	69.7
Sb	ppm	4.31	6.46	7.48	10.5	6.83	17.2	8.3	7.48
Zr	ppm	22	230	160	91	205	250	93	
Hf	ppm	3.04	6.95	7.01	4.7	6.45	5.92	4.35	6.73
U	ppm	1.96	4.19	2.1	1.94	5.4	4.54	4.92	0.9
Th	ppm	2.95	9.72	2.58	3.53	7.99	4.67	4.67	6.44
Ru	ppb	16.9	71.9	60.6		20.6	57.8	40.1	64.2
Os	ppb	2.72	7.3	5.84	12.2	9.32	5.64	3.29	3.06
Ir	ppb	12.8	28.3	23.9	35.3	27.2	28.8	8.78	8.9
Pt	ppm	0.3321	0.1656	0.32	0.4395	0.2181	0.3975	0.0878	0.45
Ag	ppm	0.18		0.42	0.23	0.38	0.15	0.31	0.22
Au	ppb	5.41	1.05	0.95	3.23	1.65	1.48	1.14	0.81

Table 2B. Concentration trace elements in basalts. Concentration of elements estimated by interpolation of neighbors elements.

There are two important questions of the genesis of platinum manganese crust, one is a source of the noble elements (rock or water) and other is mechanism of trace element concentrating. Our measurement offer a clearer view of how the concentration of the trace elements exchange from underlay basalt to Fe-Mn crust on the underwater condition. The ratio concentrations trace element crust/rock show on Figure 3. A crust is enriched by trace elements as whole in order. There are hydrogenise elements - Co, Ni, Ce, which connected with hydrochemistry reaction in sea water, and demonstrated strong positive anomaly (concentration in crust up to 2 order high than in basalt). It is interesting to note a high Ag anomaly in some samples, a high Pt concentration from the crust. In totally ferric-manganese crust has more varia-

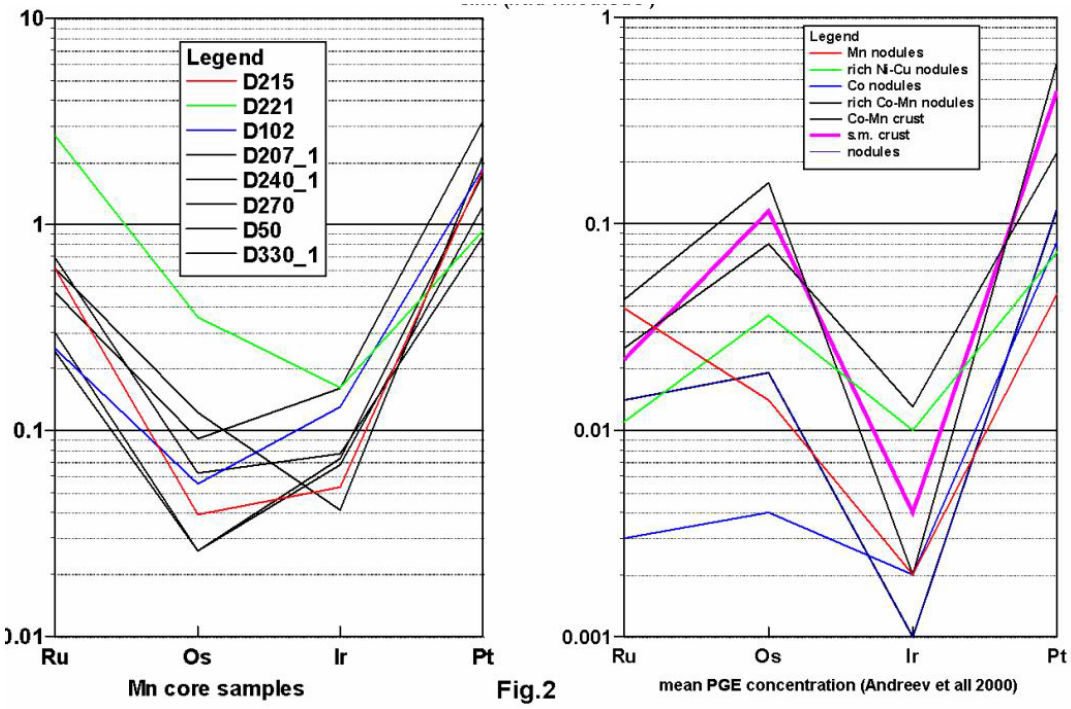

Figure 2. Concentration of trace elements normalized by C1 (Barnes et al 1985) from manganese crusts of Magellan seamount (INNA measurements).

tion from the trace element composition. It is directly related to the complex genesis of it's and heterogenic nature of substance sources. In comparison of the mean PGE crust composition [1] we observed that our sample have Ru abundance more than Os, which emphasizes the transmittance of hereditary traits of the basalt. In the same time we marked negative Ir anomaly (probably connected with hydrochemistry reaction from sea water). There is no one from basalt. The concentration PGE in the crust in several orders more than mean concentration, especially for Ru abundance. We explain these peculiarities by the influence of the underlay basalts from Magelan seamounts, which characterize high abundance of these elements from the alkaline melts.

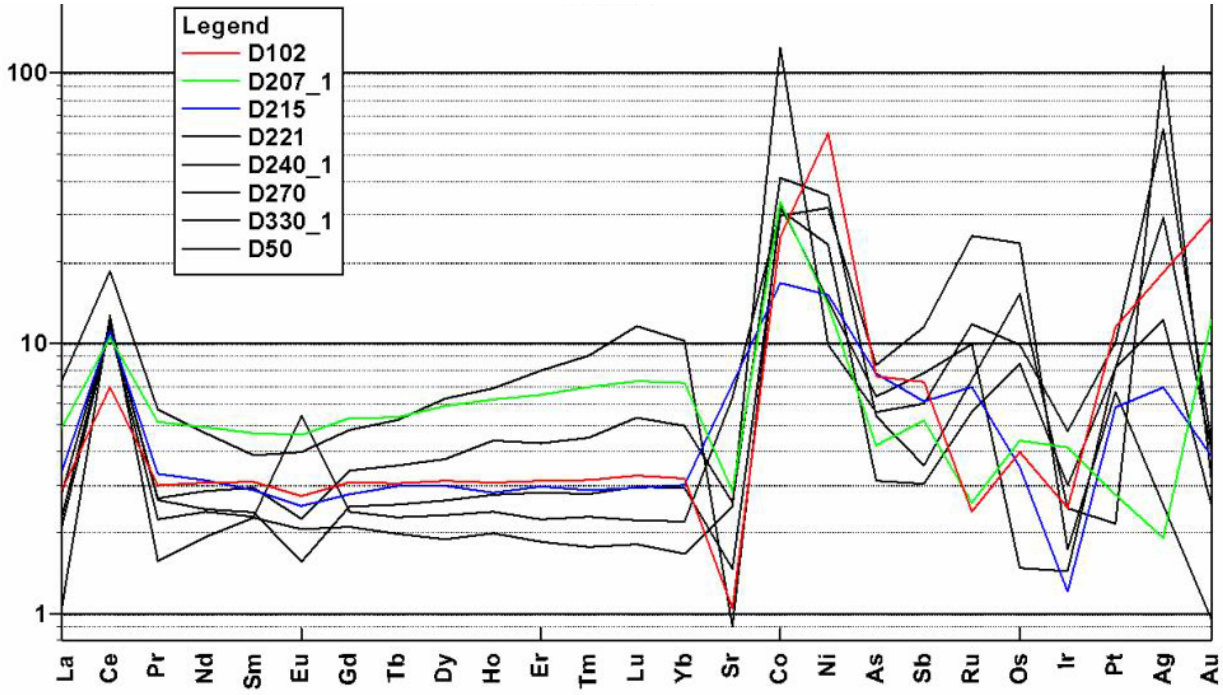

Figure 3. Ratio trace element concentrations between manganese crusts and underlying basalts.

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Microbial activity and temperature recorded in 18O/16O ratios of iron oxide-bound phosphate at Loihi and Larson's Seamounts

Blake, R; Moyer, C; Dogru, D

Phosphate has a strong biological oxygen isotope signature in natural waters and sediments due to its intense cycling by biota and requirement as an essential nutrient. Phosphate does not undergo oxygen isotope exchange with water at low temperature without enzymatic catalysis, making the oxygen isotope ratio ($^{18}O/^{16}O$) of phosphate, $\delta^{18}O_P$, an attractive biosignature in the search for life in the deep-sea biosphere. Recent studies demonstrate that the $\delta^{18}O_P$ value of dissolved inorganic phosphate (PO_4) can record specific microbial activity and enzymatic reaction pathways, both in laboratory cultures and in natural systems (Blake et al., 2005; Colman et al 2005; Liang and Blake, 2005). Oxygen isotope ratios

of phosphate bound to iron-oxide phases at actively venting hydrothermal sites at Loihi Seamount and both active/inactive sites at Larson's Seamounts, record temperature and also indicate microbial metabolism of phosphate following adsorption of dissolved inorganic phosphate (DIP) from ambient seawater. Nearby phosphate sources such as basaltic oceanic crust and ambient seawater DIP are distinct isotopically from one another and from iron-oxide-bound phosphates. In addition to morphological and microbiological evidence of iron-oxidizing bacteria playing a role in iron oxidation and formation of hydrothermal iron oxides, the $\delta^{18}O_P$ values of iron-oxide bound phosphate provide strong geochemical evidence of a microbial origin for these deposits.

OASIS - Oceanic Seamounts: an Integrated Study

Christiansen, B

OASIS is a research project which describes the functioning characteristics of seamount ecosystems. It is funded by the European Union and involves 9 institutions from 5 European countries.

OASIS' holistic approach to investigate seamount ecosystems integrates hydrographic, biogeochemical and biological information. Based on two case studies, OASIS yields an advanced mechanistic understanding of the processes characterizing seamount ecosystems, and their influence on the surrounding ocean. The scientific results, condensed in conceptual and mass balanced ecosystem models, are applied to outline a model management plan as well as site-specific management plans for the seamounts investigated.

OASIS addresses five main objectives

Objective 1: To identify and describe the physical forcing mechanisms effecting seamount systems. This objective addresses the hydrographic processes that control the circulation, mixing and exchange of fluid in the vicinity of seamounts. These are key requirements for an understanding of the biogeochemical and biological processes, and they are essential for the design of an effective biogeochemical and biological sampling strategy.

Objective 2: To assess the origin, quality and dynamics of particulate organic material within the water column and surface sediment at seamounts. The organisms below the euphotic zone depend, with a few exceptions, on (particulate) organic material that has been produced in the surface ocean. During its descent to the seafloor this material is altered in many ways, for example by ingestion and egestion by pelagic animals, by microbial degradation or aggregate formation. Within the benthic mixed layer, sedimentation and resuspension will strongly influence the availability of this material. All these processes will affect the nutritional value of the organic matter for organisms living at or close to the seafloor.

Objective 3: To describe aspects of the biodiversity and the ecology of seamount biota, to assess their dynamics and the maintenance of their production. Seamounts often accommodate enhanced stocks of commercially valuable species. Several hypotheses exist regarding how these stocks are maintained, e.g. by trapping of particles in Taylor columns, by enhanced primary production due to upwelling, or by trapping of the vertically migrating deep scattering layer fauna. This objective addresses the major faunistic groups (zooplankton, micronecton, benthos and fish) at seamounts and their interactions, with special emphasis on the bottom mixed layer fauna.

Objective 4: Modeling the trophic ecology of seamount ecosystems. Under this objective, the information from objectives 1-3 is synthesized in a continuously updated conceptual ecosystem model, which provides a common platform for the presentation of the primary scientific results of the project. In addition, the full OASIS dataset will feed into a mass-balanced trophodynamic model, based on the ECOPATH suite.

Objective 5: Application of scientific knowledge to practical conservation. This objective acknowledges the critical need for the timely input of appropriate scientific advice to the development of marine policy. Policy makers and advisors as well as other stakeholders require applicable results in the form of easy-to-use products. The design of scientifically sound and practicable management plans is the most difficult but essential part of the implementation of protected areas. Drawing on the scientific results of the project, OASIS acts as an interface to practitioners.

OASIS workplan

The OASIS consortium has selected two seamounts in European waters: Sedlo Seamount and Seine Seamount. The seamounts are located between Portugal and the Azores. Both are isolated, minimizing the influence of other elevations, and lie within the same biogeochemical region, but differ significantly in their summit depths and state of fisheries exploitation.

OASIS is subdivided in 6 workpackages

Work Package 1: Characterization of topographical and hydrographical properties. Workpackage 1 quantifies the key hydrographic processes that control the circulation, mixing and exchange of fluid in the vicinity of seamounts. These processes control the bio-geochemical interactions at the seamount and which ultimately define the 'sphere of influence' of the seamount over the adjacent oceanic waters.

Workpackage 2: Influence of kilometer-scale seafloor topography on water-column biogeochemistry. Work Package 2 is concerned with production and biogeochemical fluxes at kilometer-scale seafloor features. It estimates the sphere of influence of individual abyssal hills/knolls/seamounts on biogeochemical processes and assesses a carbon budget within this sphere. These issues are pivotal in understanding the energy "supply" and transfer terms for ecosystems potentially controlled by topographic elevations, and scientific results feed in directly to Workpackages 3 and 4. Furthermore, the proposed approach combining bulk, isotopic and molecular (pigment and lipid) composition, and visual appearance of particulate matter (Scanning electron microscopy pictures; SEM) provides information on the provenance and fate of the OM.

Work Package 3: Seamount Biota. WP3 comprises the major biological science components of OASIS. OASIS addresses both water column and seabed communities across the full span of habitats that comprise the seamount system. Tasks include the dynamics of the deep scattering layer and benthic mixed layer communities, zooplankton and benthos, demersal and pelagic fish, aspects of biodiversity.

Workpackage 4: Seamount ecosystems: Integration, modeling and management. WP4 draws together the work of WP3 and the syntheses of environmental and primary productivity data from WP1 and WP2. Through ecosystem modeling, this WP addresses questions of seamount ecological function-

ing and management. This WP also addresses the evolutionary isolation and degree of external recruitment to seamount stocks, which is critical to the understanding of seamount biodiversity and zoogeography, and consequently is of critical importance to fisheries and other environmental management / conservation measures.

Workpackage 5: Developing a common understanding of seamount ecosystems, their conservation and sustainable use. WP5 acts as an interface between the continuously growing scientific knowledge within the project team and the permanent need for non-technical, easy to handle but scientifically justified advice and information to policy makers and the public. Therefore, WP5 will uses input from all other workpackages, in the final stages of the project in particular of WP4.

Workpackage 6: Co-ordination and management of the project. The multidisciplinary project requires a highly integrated workflow between workpackages, tasks and partners. Workpackage 6 establishes a co-ordination and management structure which ensures the scientific progress of the project, the communication between partners and to the EC, the harmonization between tasks, and the solution of possible problems or conflicts. A subcontractor to the coordinator is responsible for the data management.

"CenSeam": a new Census of Marine Life project: working towards a global baseline and synthesis of seamount data

Clark, M; Rowden, A; Stocks, K; Consalvey, M

Seamounts are prominent features of the world's underwater topography. It is estimated that there are potentially up to 100,000, seamounts over 1 km high and many more of smaller elevation (Figure 1). Seamounts are known to support high biodiversity and unique biological communities, and can have high levels of endemic species. They may also play an important role in patterns of marine biogeography. They are often highly productive ecosystems, and act as feeding grounds for fishes, marine mammals and seabirds. They are the target of human interest for fisheries and mining, yet are vulnerable to exploitation. However, relatively few seamounts have been studied, with only about 350 having been sampled, and less than 100 in any detail. On a global scale their biodiversity is poorly known.

The Census of Marine Life (CoML) is a growing global network of researchers in more than 70 nations engaged in a ten-year initiative to assess and explain the diversity, distribution and abundance of marine life in the oceans (past, present and future). There are 16 field projects investigating various habitats, and a new project commenced in 2005 on seamounts. This project, termed "CenSeam", aims to provide a framework to prioritize, integrate, expand, and facilitate seamount research efforts in order to significantly reduce the unknown, and build towards a global understanding of seamount ecosystems, and the roles they have in the biogeography, biodiversity, productivity, and evolution of marine organisms. Three main themes are the focus of the science plan, to determine (1) What factors drive seamount community structure, diversity, and endemism, both at the scale of whole seamounts and individual habitats within seamounts (2) What key processes operate to cause differences between seamounts, and between seamount and non-seamount regions (3) What are the impacts of fisheries on seamount community structure and function. To date seamount research has largely had a regional focus, and CenSeam will promote the integration of previous/future research efforts to provide global answers to these questions.

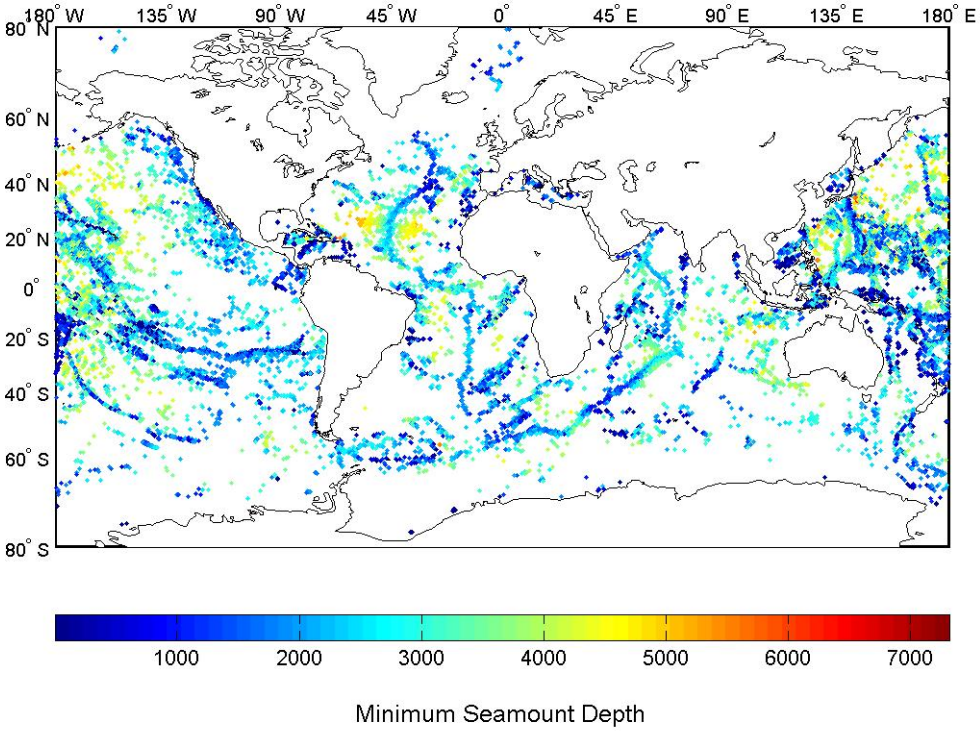


Figure 1. The global distribution of seamounts (elevation > 1km) based on satellite altimetry data (data from Seas Around Us Project, 2005).

CenSeam is currently in its first phase (planning and expansion 2005-2006) which will be followed by phase II (field expeditions 2006-2009), phase III (analysis and information integration 2009-2010) and finally phase IV (final report to the Census of Marine Life 2010).

As part of the planning and expansion phase a key activity has been to establish a community list of seamount researchers and two working groups, the Standardization and Data Analysis Working Groups (SWG and DAWG). The SWG is discussing methods already in existence and, where possible, will explore means of standardizing sampling gear and survey design as well as subsequent reporting. The potential uses and standardization of new technologies will also be investigated e.g. remote sensing, non-invasive observational methodology. The DAWG will utilize SeamountsOnline and OBIS to evaluate and review the data that are available and the techniques to analyze these and other data. Mini-grants have been made during phase I to expand the scope of already funded research and to encourage data recovery and accessibility.

In May 2005 (Azores) a CenSeam community workshop was held in conjunction with a planning meeting for the book "Seamounts: ecology, fisheries and conservation" (eds. T. Pitcher, P.J.B. Hart, T. Morato, M. Clark and R.S. Santos to be published by the Blackwell Science Fish and Aquatic Resources Series in 2006 and which is co-sponsored by CenSeam). The meeting enabled formal and informal discussions to begin the prioritization of regions and types of studies, identify proposal opportunities and plan future seamount work.

Community outreach lists have been established and education and outreach promotional material has been prepared e.g. website (http://censeam.niwa.co.nz), descriptive leaflet. A list of taxonomic expertise is also being compiled.

SeamountsOnline continues to be expanded and has proven a valuable tool in identifying priority areas as well as the focus for fast-track data analyses. The global sampling effort is biased - high latitude as well as equatorial seamounts are currently under sampled, as are deep seamounts (summit depths >500 m). On the basis of an initial assessment of data contained in SeamountsOnline, potential target areas for CenSeam phase II include the Indian Ocean and the Mid/South Pacific (Figure 2).

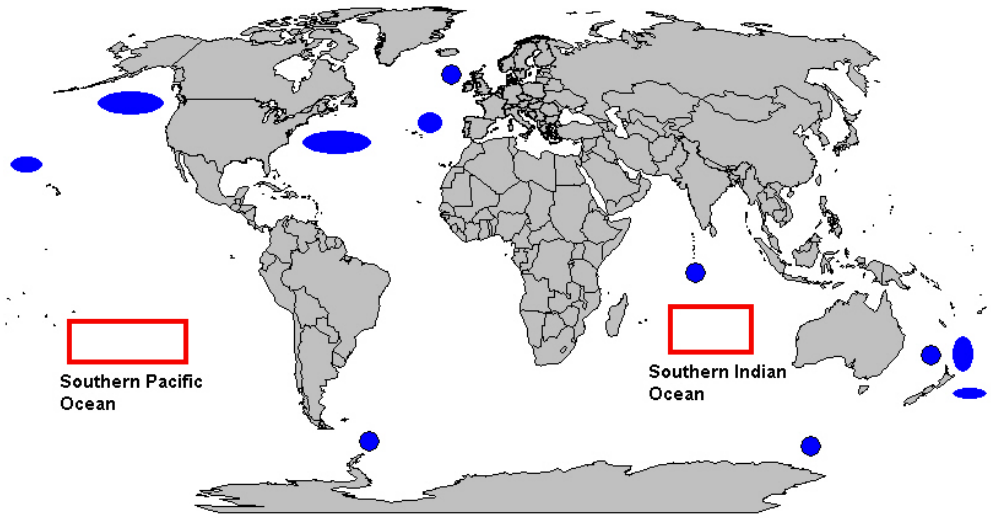


Figure 2. Distribution of existing research programs investigating seamount ecology (blue) and identified areas (red rectangles) of major gaps in the present and past sampling effort.

The DAWG has been active, undertaking work in early 2006 on the distribution of deep-water corals on seamounts throughout the world, and their vulnerability to high seas fishing. This work will be reported to the UN discussions on high seas fishing in mid-2006. Further analyses of biodiversity of seamount fauna will be conducted at a workshop supported by the International Seabed Authority in March 2006, where some of the best data sets on seamounts will openly be examined. Analyses will help to determine sampling distribution, seamount selection and sampling design. The latter will be of particular benefit to the SWG who will produce a report to guide current as well as new sampling programs. This will be utilized in a CenSeam promoted survey off New Zealand in May 2006, and late in 2006 with CenSeam support of major new surveys planned on seamounts in the western South Pacific.

Much will remain unknowable by 2010, given the large number of seamounts, their widespread distribution, and large variability in physical characteristics and habitat type. But under CenSeam much progress can be made to improve our understanding of seamount ecosystems.

Sustainable Deep-Sea Seamount Fisheries: Wishfull Thinking Or An Attainable Goal? A New Zealand Perspective

Clark, M

The deep sea environment has generally been regarded as a system of low energy and low productivity. Historically the world's major marine fisheries have taken place on the relatively narrow and shallow continental shelf. But over the last 2-3 decades deepwater fisheries have developed on the upper continental slope, and are an important component of commercial fisheries in a number of countries, and continue to be of potential interest to nations whose coastal and shelf fisheries are fully or over- exploited, These fisheries include well-known species like orange roughy, cardinalfish, oreos, and grenadiers, and often take place on seamounts. Typically the catch histories of these show rapid development to a relatively high level, and then a dramatic decline. Associated with such apparent boom and bust type situations, have come concerns about the sustainability of seamount fisheries, and the deepwater benthic habitat.

New Zealand orange roughy — a case study

Orange roughy around New Zealand are often associated with seamount-type features, and can form dense aggregations, either for spawning or feeding. Fisheries initially developed on the slope, but over time they have become more focused on seamounts. The catch of orange roughy from these features has increased from about 30% of the total catch in 1985 to 80% by 1995, and has since stabilized at 60–70%, or about 10,000 t. There has been active searching for seamount habitat, and the number of features fished has steadily increased (Figure 1). By 2000 about 80% of known seamounts in the appropriate depth range for roughy had been fished. Many seamounts were heavily exploited, with several hundred km of trawls per square km of seamount area. Trawls can be carried out in many directions, so with bottom trawling for these deep species there is a considerable environmental impact on the benthic habitat to consider as well as the effects on the fish stocks themselves.

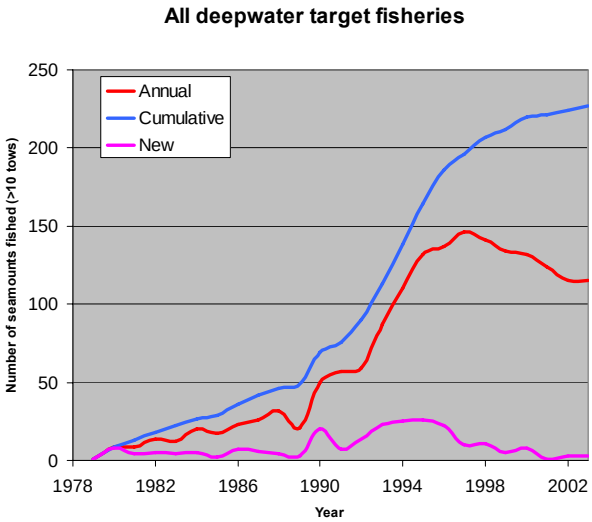


Figure 1. Number of seamount features in New Zealand that have been fished (>10 tows): cumulative total, each year, and number of new features exploited. The total number of known seamounts in the New Zealand region is about 800.

Most New Zealand orange roughy stocks on seamounts have shown strong and rapid declines (Figure 2). Of the 9 orange roughy stocks which have been assessed in New Zealand, 5 show depletion to low levels, and these are often the seamount stocks (South Chatham Rise, Puysegur, East Cape, Mercury-Colville, Challenger). Management response has been to cut catch levels dramatically, and although most catch limits are now at levels thought to be sustainable, time is required to see if this is really the case.

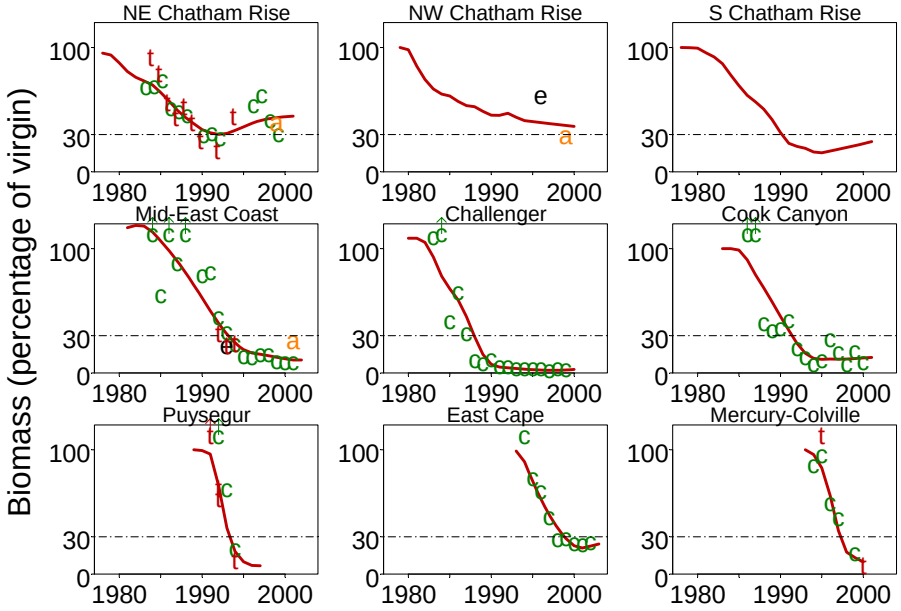


Figure 2. Trends in orange roughy stock size in several areas around New Zealand (as assessed in 2003).

A number of lessons have been learnt from the New Zealand experience:

1) There are inherent fish and fishery characteristics that we can't change (e.g. low productivity of many seamount species, ease of capture, high economic value), but by being aware of the pressures that these can create, we can prepare for them.
2) Lack of information: there are a lot of aspects of biology and ecology that we still do not know. With orange roughy, one of the key aspects is recruitment, because after 30 years of fishing there are still no signs of strong recruitment entering any of the fisheries. Recruitment could be highly episodic. Stock structure, environmental influences, and ecosystem requirements are poorly understood for most deep-water species and seamount ecosystems.
3) Assessment techniques: Obtaining reliable estimates of abundance is still elusive for orange roughy. Time series are important to monitor trends in biomass with fishery levels, but often small seamount stocks don't allow much time to achieve this.
4) Management issues: The primary management challenge is to use all available information and experience to balance the fishing interests of catches as high as possible, with the need to ensure the target biomass is not overshot, and to account for the broader conservation of the environment. Removal of a competitive catching system (by ITQ) has improved management. Expectations need to be tempered early on, and both fishers and managers need to think small. There has to be a flexible management approach that can address issues like the spatial scale of management required to avoid, for example, serial depletion of seamount aggregations within a widespread stock.

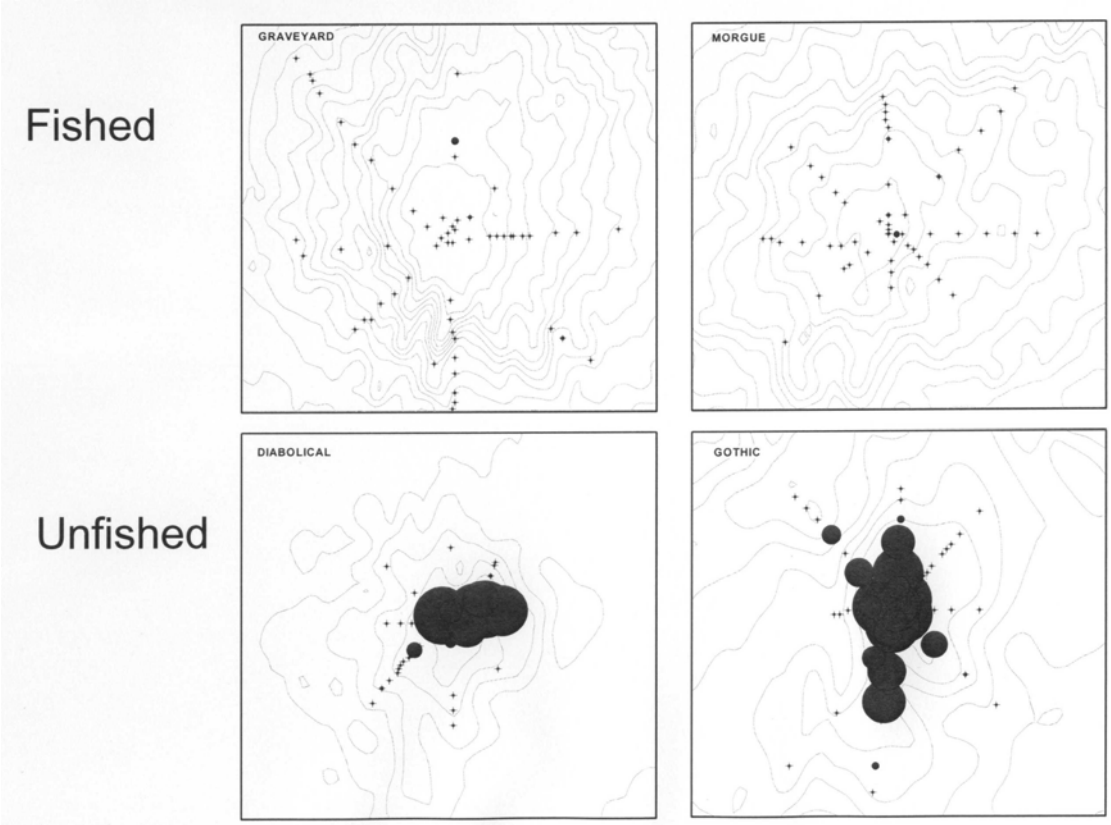


Figure 3. Distribution of live coral on fished seamount (top 2 panels) and unfished seamounts (bottom 2 panels). The expanding symbol plot represents the proportion of live coral in still photographs taken at intervals along transects across the seamounts.

In New Zealand these problems have been tempered a bit by the evolution of a range of options beyond just the TAC output control. These include: (a) Adaptive management Programs, where catch levels can change for a fixed term, and monitoring takes place to measure the effects of the change (b) Feature limits, to help avoid overfishing localized populations on seamounts. This also limits the amount of effort on seamounts. (c) Voluntary seasonal closures (e.g. NE Chatham Rise 1992-96 to protect the spawning fish). Although it has since reopened. (d) Voluntary area closures (e.g. Puysegur Bank) where seamount stocks have been overexploited.

Effects of fishing

The physical effects of trawling in deepwater, especially on seamounts where effort is highly concentrated, can be severe (Figure 3). This figure shows 4 seamounts that are closely clustered on the Chatham Rise. The top 2 have been heavily trawled, the bottom 2 less so. On the fished seamounts, there was hardly any live coral whereas on the largely unfished one the entire top of the seamount was covered in coral. The physical impact of bottom trawling is clear, but the linkages between habitat and fishery production are not. Such habitat changes don't appear to affect the distribution of orange roughy adults, which still spawn on the main seamounts. Linkages with other stages of the life cycle, and other species, are unknown.

It is a situation where to be precautionary, management is needed before there is sufficient information to prove a case. In 2001 New Zealand closed 19 seamounts to bottom trawling, and total protection is an increasing element of seamount management in many countries.

Overall orange roughy and other deepwater species have an uphill battle. Their biology works against them all the way. The fisheries are still relatively new, much less than a generation time. Fish that were spawned when the fishery began have still not recruited into the fished population. We have limited understanding of natural variations in stock size, what changes are fishery-induced, and what might be happening anyway, without fishing. However, we do know that fishing can drive populations down rapidly, so we can devise controlled development that can reduce that risk. Unfortunately, it is still unclear what it takes to make them rebuild, and our uncertainty about recruitment makes this a serious issue. Considering the broader ecosystem is a widespread objective of fisheries management, but is clearly a hard one in the deep sea. Protected areas and feature limits are options that can address some of the physical-disturbance issues from the outset in the absence of other information.

The overall experience in New Zealand with orange roughy is one of mixed results, but a lot of fishery, research, and management lessons have been learnt, and with these being applied there is good reason to believe that deepwater fisheries on seamounts can prove resilient, and exploitation and conservation can co-exist.

Deep-Sea Seamounts In The Southwest Pacific: Fisheries, Management, And Conservation

Clark, M

Seamount fisheries

The world's major marine fisheries have generally taken place on the relatively narrow and shallow continental shelf. But over the last 2-3 decades deepwater trawl fisheries have developed on the upper continental slope and offshore seamounts, and are an important component of commercial fisheries in the Southwest Pacific. These fisheries include well-known species like orange roughy, oreos, cardinalfish, and alfonsino. New Zealand and Australian catches of these species total several thousand tonnes per year, with orange roughy being the largest fishery at about 20,000 t.

Orange roughy around New Zealand and Australia are often associated with seamount-type features, and can form dense aggregations, either for spawning or feeding. Fisheries initially developed on the slope, but over time they have become more focused on seamounts. The catch of orange roughy from these features increased during the 1990s as technical and navigational developments opened up more fishable habitat. In New Zealand the seamount catch of orange roughy increased from about 30% of the total catch in 1985 to 80% by 1995, and is currently about 60–70%.

Most orange roughy stocks on seamounts have shown strong and rapid declines. Of 9 orange roughy stocks which have been assessed in New Zealand, 5 show depletion to low levels, and these are often the seamount stocks (South Chatham Rise, Puysegur, East Cape, Mercury-Colville, Challenger). The main Australian fisheries off Tasmania have also shown strong decreases in stock size, and fisheries off St Helens and the South Tasman Rise are now very small. Management response to falling catches and sci-

entific evidence of overfishing has been to cut catch levels dramatically, and although most catch limits are now at levels thought to be sustainable, time is required to see if this is really the case.

Fisheries management

A number of lessons have been learnt about seamount fisheries from the Southwest Pacific experience:

1) There are inherent fish and fishery characteristics that we can't change (e.g. low productivity of many seamount species, ease of capture, high economic value), but by being aware of the pressures that these can create, we can prepare for them.
2) Lack of information: there are a lot of aspects of biology and ecology that we still do not know. Recruitment could be highly episodic. Stock structure, environmental influences, and ecosystem requirements are poorly understood for most deepwater species and seamount ecosystems.
3) Assessment techniques: Obtaining reliable estimates of abundance is still elusive for orange roughy. Time series are important to monitor trends in biomass with fishery levels, but often small seamount stocks don't allow much time to achieve this.
4) Management issues: The primary management challenge is to use all available information and experience to balance the fishing interests of catches as high as possible, with the need to ensure the target biomass is not overshot, and to account for the broader conservation of the environment. Removal of a competitive catching system (by ITQ) has improved management. Expectations need to be tempered early on, and both fishers and managers need to think small. There has to be a flexible management approach that can address issues like the spatial scale of management required to avoid, for example, serial depletion of seamount aggregations within a widespread stock. In New Zealand these problems have seen the evolution of a range of options beyond just the TAC output control. These include: (a) Adaptive management Programs, where catch levels can change for a fixed term, and monitoring takes place to measure the effects of the change (b) Feature limits, to help avoid overfishing localized populations on seamounts. This also limits the amount of effort on seamounts. (c) Voluntary seasonal closures (e.g. NE Chatham Rise 1992-96 to protect the spawning fish). (d) Voluntary area closures (e.g. Puysegur Bank) where seamount stocks have been overexploited.

Habitat conservation

During the 1980s-1990s the number of seamount features fished around New Zealand steadily increased, and about 80% of known seamounts in the appropriate depth range for roughy have been fished. Many seamounts have been heavily exploited, with several hundred km of trawls per square km of seamount area. Trawls can be carried out in many directions, so with bottom trawling for these deep species there is a considerable environmental impact on the benthic habitat to consider as well as the effects on the fish stocks themselves. The physical effects of trawling in deepwater, especially on seamounts where effort is highly concentrated, can be severe. Changes in benthic invertebrate species diversity, distribution and abundance have been demonstrated on seamounts in both Australian and New Zealand fishing grounds.

The management response to evidence of the effects of bottom trawling has been to protect the benthic habitat by banning trawling on a selection of seamounts. In 1998 the Tasmanian Seamounts Marine Reserve was first developed, and formalized in 2000. This covered an of 370 km2, and protected 12 deep seamounts adjacent to the orange roughy grounds. In 2001, under a draft Seamount Management Strat-

egy, New Zealand protected 19 seamounts from trawling. These were not solely deepwater seamounts, but a representative selection which included a wide range of area and depth characteristics. The closed area of seamounts totaled about 40,000 km2. Australia is currently investigating further Marine Protected Areas which will include seamount features.

Reconciling fisheries and conservation can be difficult with deepsea fisheries on offshore seamounts. However, in the Southwest Pacific some hard lessons have been learnt about both the fish stocks and their habitat. The emerging pattern of a mixture of seamounts open to fishing (where habitat changes have already occurred) and protected from fishing (where little fishing has occurred) is hopefully a successful one in which and exploitation and conservation can co-exist.

Rodriguez Seamount, a non-hotspot ocean island volcano located at the continental slope of the California Borderland

Davis, A S; Clague, D A; Paduan, J B; Cousens, B L

Volcanic rocks were collected from Rodriguez Seamount at the outer margin off the Continental Borderland with MBARI's ROV Tiburon in October 2003 and April 2004. Six dives recovered lava and volcaniclastic samples from the deep flanks at 2120 m to the summit at 630 m. Whole rock compositions of lava samples are predominantly alkalic basalt (<8% MgO) and hawaiite but include compositions as evolved as trachyte. Glass compositions of pillow rims and of volcaniclastic fragments in breccia and bedded sandstone are predominantly hawaiite, mugearite and minor evolved alkalic basalt. The lava samples include also one rhyolite and one basaltic andesite with subduction-related chemistry; they are probably erratics. Other clearly identifiable erratics include granite, quartzite, amphibolite, and bored, erosion-sculpted sandstone, resembling typical beach deposits. Most of these erratics are pebble- to small cobble-size and occur in conglomerate and crossbedded sandstone that surround the summit at a break in slope that most likely marks the shoreline when Rodriguez was an island. The lava outcrops on the gently domed platform of the summit which include the trachyte are dense, oxidized 'a'a-like flows without glassy rinds. Sulfur content of glass, collected from the flanks of the volcano, ranges from 1300 ppm of a glass inclusion in an olivine crystal to ~160 ppm of volcaniclastic grains, indicating extensive degassing.

Petrographically and chemically these lavas are virtually identical to those erupted on Miocene seamounts offshore central California (e.g. Davidson, Guide, Pioneer, Gumdrop seamounts, Davis et al, 2002) as well as Northeast Bank on the continental shelf south of Rodriguez and seamounts farther offshore from the Continental Borderland (e.g. Little Joe, San Marcos, San Juan seamounts, Clague et al, unpublished; Davis et al., 1995). Trace element abundances and ratios of the lavas (e.g. LREE, Zr/Nb, Ta/Nb) completely overlap with those from the other seamounts and, in conjunction with Sr, Nd, and Pb isotopic data, suggest similar origins by small percentage of melting of somewhat enriched MORB-like sources.

New Ar-Ar ages for these samples ranging from 9.9 Ma to 17.8 Ma extend the range of ages published previously (10.1-11.4 Ma, Bohrson and Davis, 1995; Davis et al, 2002). This volcanism postdates the change from a subduction-related regime by millions of years. Synchronous episodes of volcanism occurring at geographically widely separated locations along the continental margin indicate sporadic eruptions during the late Miocene that can not be related to migration of a single triple junction. Compa-

rable lava ages and chemistry, extending from the continental shelf out to the seamount province, suggest similar tectonic processes. Episodes of localized extension in response to movement along the transform fault systems, allowing small degree of decompression melting of mantle rising along zones of weakness, may provide a better explanation

Hotspot and Non-Hotspot Origins for the Age-Distribution of Volcanism in Pacific Seamount Chains

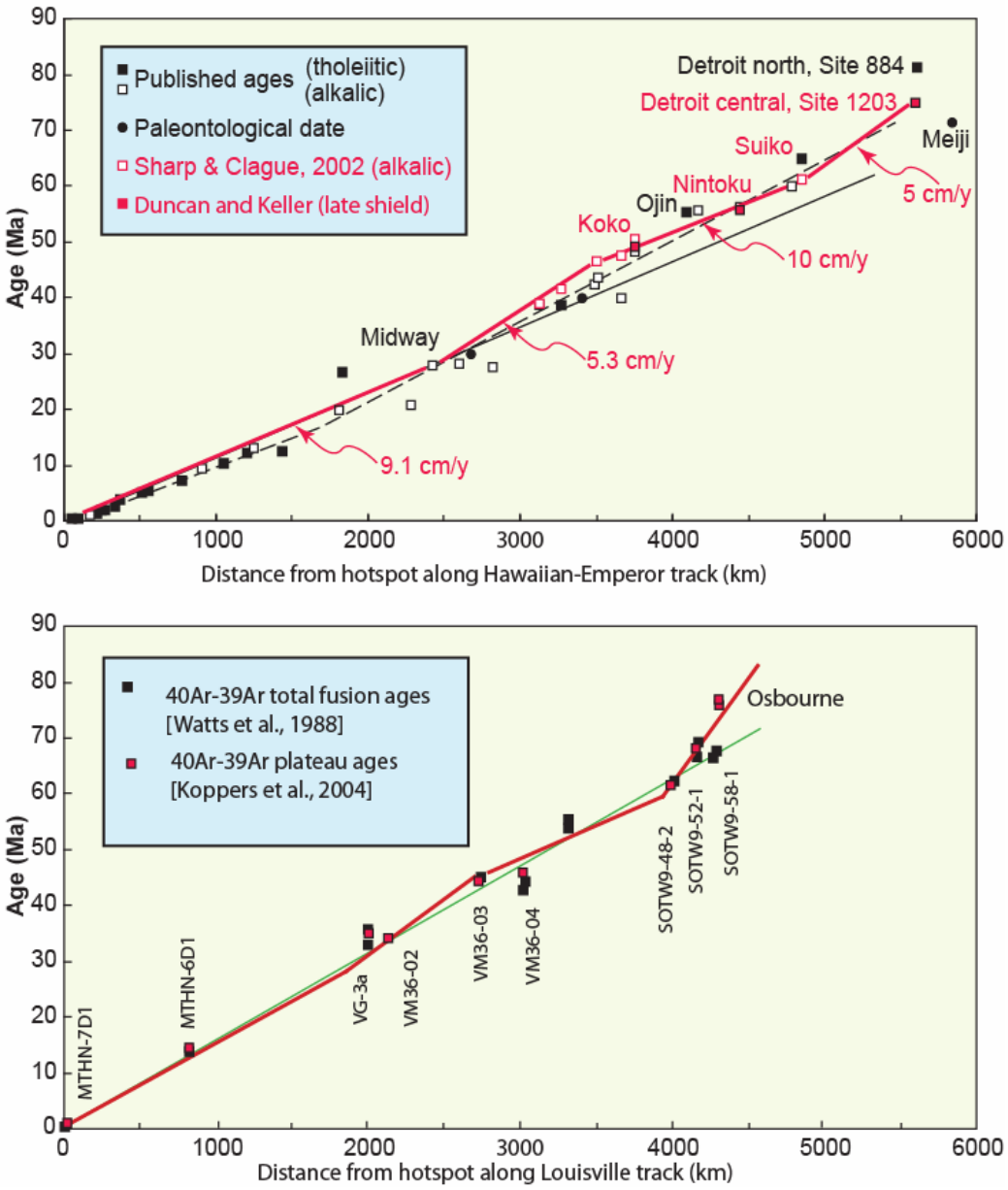
Duncan, R A

The Hawaiian-Emperor seamount chain is the "type" example of an age-progressive, hotspot-generated intraplate volcanic lineament. However, our current knowledge of the age distribution within this province is based largely on radiometric ages determined several decades ago. Improvements in instrumentation, sample preparation methods and new material obtained by recent drilling warrant a re-examination of the age relations among the older Hawaiian volcanoes. Plateau and isochron age determinations (40Ar-39Ar incremental heating method) on whole rocks and feldspar separates from deep drilling sites (ODP Leg 197) in the Emperor seamounts, together with similarly modern data from dredged rocks from volcanoes near the prominent bend (47-49 Ma) in the lineament (Sharp and Clague, 2002), confirm the overall trend is increasing volcano age from south to north, consistent with the hotspot model (see Figure). There are important departures from the earlier reported simple linear age progression, which are related to changes in Pacific plate motion and the rate of southward motion of the Hawaiian hotspot. Recent studies of dredged volcanic rocks from the Louisville seamount chain (Koppers et al., 2004) show many of the same features within an overall, age-progressive trend, illustrating the utility of a hotspot reference frame adjusted for slowly advected mantle plumes (Steinberger and O'Connell, 1998).

Although less well documented, several other major Pacific seamount chains appear to be age-progressive and consistent with hotspot origins (e.g., Easter-Salas y Gomez, Galapagos, Gulf of Alaska), while others present complex age patterns (e.g., Line Islands, Gilbert-Tokelau, and Western Pacific). The Tokelau seamount chain exhibits an age progression close to that predicted from Hawaiian and Louisville trends, but the Gilbert distribution, if interpreted as an age progression, would be "ultrafast". The Gilbert and Tokelau seamount chains also display possible Hawaiian-Emperor-type bends. Both trails seem to have formed predominantly during the NNW-trending Emperor stage of Pacific plate motion and have pronounced inflections at their southern ends (bends?), ending abruptly after beginning the Hawaiian stage of Pacific plate motion. The timing of these putative bends is asynchronous with the HEB at 67 and 57 Ma, indicating that fixed (or slowly moving) hotspots and a uniform change in Pacific plate motion cannot explain the formation of these seamount chains (Koppers and Staudigel 2005). Instead, short periods of plate extension over the southwestern portion of the Pacific plate are proposed to explain aspects of the age distributions. An important additional consideration is the general applicability of the Hawaiian volcano evolution model, and superposition of rejuvenescent volcanism on older lineaments.

Some smaller volcanic lineaments that occur on young, thin and weak lithosphere (e.g., Puka Puka ridges) show an easterly younging that is faster than the expected plate motion, possibly formed by extension via crack propagation due to slab pull on the Pacific plate (Sandwell et al., 1995) or horizontal thermal contraction (Sandwell and Fialko, 2004). These short chains seem to form at regularly spaced gravity troughs, consistent with local thinning or cracking of the lithosphere. Alternatively, volcanic

lineaments like the Puka Puka ridge may be caused by flow of relatively hot mantle material from the south Pacific Superswell region towards the East Pacific Rise. The morphology of these volcanic ridges is quite different from seamount trails such as the Hawaii-Emperor, Louisville, Gilbert and Tokelau seamount trails, which are more voluminous and contain more discrete, conical volcanic systems. They are distinguishable, too, with geochemical data that are consistent with shallow, passive mantle upwelling vs. deep, active (plume) activity (Courtillot et al., 2003).



Our understanding of the origins of intra-plate seamount chains is currently limited by several factors. Complete multibeam bathymetric mapping is needed to evaluate morphology, volumes, and tectonic structures. Geophysical surveys (seismic reflection, gravity, heat flow) provide constraints on dynamic models. Deep drilling is the only way to fully sample the volcanic history at critical locations, and to obtain ideal material for geochemical, geochronological and paleomagnetic data.

The Characteristics, Behavior and Fate of a Stream of CO2 Released Into the Ocean

Dunk, R M; Peltzer, E T; Brewer, P G

With the recent discovery of a number of sites where venting of volcanically derived CO_2 from the seafloor occurs, questions arise as to the chemical characteristics, physical behavior, and ultimate fate and impact of this vented flow. We now have a great deal of information regarding the behavior of CO_2 in the ocean, derived from small-scale experiments carried out to investigate the possibilities of direct oceanic sequestration of fossil fuel CO_2.

The phase transitions for CO_2 in the ocean are shown in Figure 1. CO_2 is a highly compressible fluid, where the gas to liquid transition occurs at ~400m in Pacific Ocean waters. Furthermore, CO_2 readily forms a gas hydrate, where the phase boundary is well known, and in the Pacific Ocean typically occurs at ~325m depth. Hydrates are a solid ice-like phase formed at low temperature and high pressure by Van der Waals forces between the 'host' water molecules and the 'guest' gas molecules, where the water forms a molecular cage that traps the gas. CO_2 forms a structure 1 hydrate, which consists of 2 small cages (512) and 6 large cages (51262) and has an approximate ratio of 1 CO_2 molecule to 6 H_2O molecules. The increase in density of liquid CO_2 (ρ_{CO2}) with increasing hydrostatic pressure (depth) is shown in Figure 2 in comparison to the density of seawater (ρ_{SW}). The point of neutral buoyancy ($\rho_{CO2} = \rho_{SW}$) occurs at ~2600 dbar. Thus at depths below this point CO_2 is more dense than seawater and will form a sinking plume, and at depths above this point CO_2 is less dense the seawater and will form a rising plume.

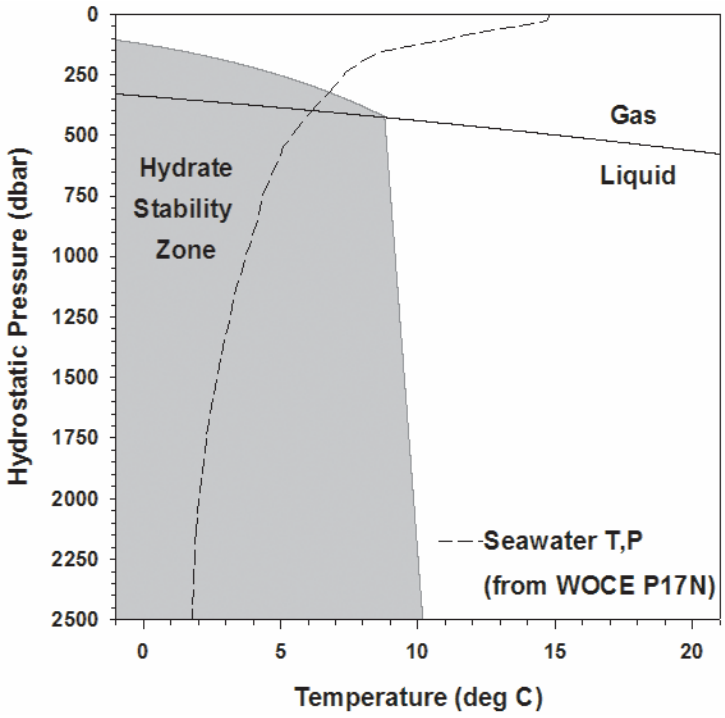


Figure 1. CO_2 phase diagram

The critical point of CO_2 occurs at 31.3°C and 738.9 dbar. Thus volcanically derived CO_2 will begin its transit to the seafloor as a supercritical fluid and will acquire chemical signatures consistent with this as it progresses through the pore space. As it approaches the cooler sediments and the seafloor, it con-

denses to the highly immiscible liquid phase. As a non-polar fluid, liquid CO_2 has a remarkable ability to dissolve other non-polar species, thus the magmatic gas He will tend to be strongly enriched in the CO_2 liquid phase. Equilibrium calculations may be carried out on this process with considerable accuracy (see Table 1 for example calculations performed using Infochem Multiflash assuming chemical equilibrium between equal volumes of an aqueous and CO_2 phase under varying P,T conditions,). However, the extent to which the CO_2 reaches equilibrium with the surrounding pore fluids during transit is unknown. Furthermore, He is not incorporated into CO_2 hydrate (due to the small atomic radius of He). Thus in the case of a CO_2 liquid phase separated from the aqueous phase by a hydrate membrane, there is the potential for exceedingly complicated partitioning processes.

On venting to the seafloor, hydrodynamic instabilities quickly result in CO_2 droplet formation with droplet diameters on a cm scale. The three known sites where venting of liquid CO_2 occurs (Champagne vent site NW Eifuku, 1650m; JADE hydrothermal site, Okinawa Trough 1335 to 1550m; Vailulu'u seamount, 940m), are located above the point of neutral buoyancy and within the hydrate stability zone. Thus a rising plume of CO_2 droplets is formed, where a thin hydrate skin forms on the ascending droplets. As the hydrate coated droplets rise through the water column, they dissolve at a rate of ~3 μmol/cm^2/sec, lowering local pH, where ~90% of the droplet mass dissolves on a length scale of about 200m.

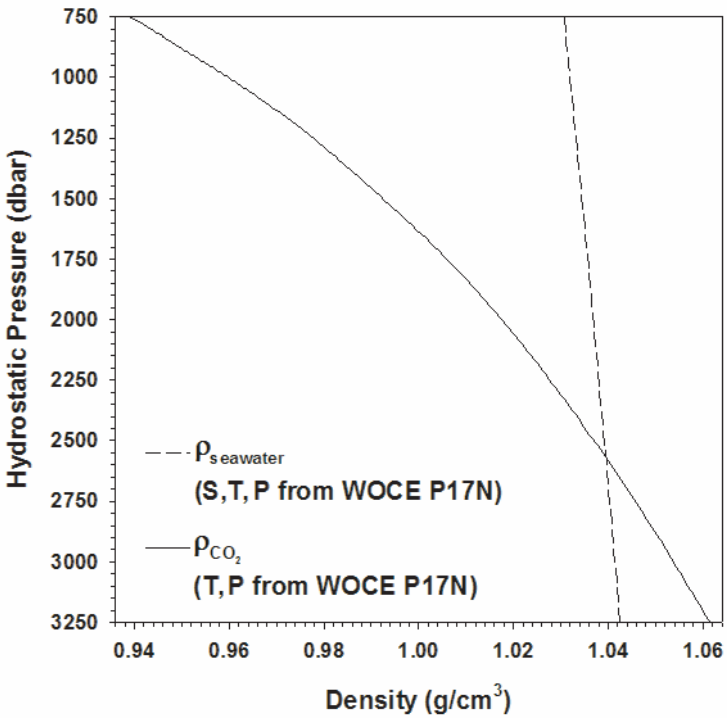


Figure 2. The density of CO_2 and seawater

Two important questions regarding these natural CO_2 vents come to mind: firstly, are these vents a common feature of seamounts; and secondly, what impact have they had on the development of the benthic communities? Although the presence of thermal and sulfidic anomalies may confound the purely CO_2 associated signal, answers to these questions will be important, especially with regards to how well

CONDITIONS	COMPONENT	H_2O (mol)	CO_2 (mol)	He (μmol)	Ar (mmol)	N_2 (mol)
T = 50°C	H_2O	54.631	0.753	0.002	0.074	0.006
$P_{hydrostatic}$ = 1515 dbar	Supercritical CO_2	0.004	15.964	0.998	16.426	0.596
Depth ~ 1500 m	TOTAL	54.635	16.717	1.000	16.500	0.602
	X_{CO2} (%)			***99.78***	***99.55***	***99.02***
T = 2°C	H_2O	54.314	1.171	0.001	0.028	0.013
$P_{hydrostatic}$ = 1009 dbar	CO_2 liquid	0.000	21.833	0.999	16.472	0.588
Depth ~ 1000 m	TOTAL	55.314	23.003	1.000	16.500	0.602
	X_{CO2} (%)			***99.93***	***99.83***	***97.81***
T = 2°C	H_2O	55.314	0.566	1.000	0.019	0.014
$P_{hydrostatic}$ = 1009 dbar	CO_2 hydrate	44.810	6.668	0.000	16.481	0.588
Depth ~ 1000 m	TOTAL	100.124	7.234	1.000	16.500	0.602
	X_{CO2} (%)			***0.00***	***99.88***	***97.72***

Table 1. Example partitioning of He, Ar and N2 between aqueous and CO2 phases.

these natural environments provide an analogue for processes associated with (i) the potential leakage of CO_2 from sub-seafloor geologic sequestration sites (e.g. Sleipner in the North Sea); (ii) direct oceanic CO_2 sequestration, and; (iii) the impacts of a high CO_2-low pH ocean.

CARD-FISH approaches for characterizing endolithic rock-hosted microbial populations

Edwards, K J; Banning, E

We are studying the process of basalt-weathering as promoted by endolithic microbes that colonize volcanic rocks at seamounts and on the flanks of mid-ocean ridge spreading centers at and below the seafloor. We hypothesize that the activities of autotrophic Fe- and S-oxidizing prokaryotes play important roles in the initial colonization and weathering of ocean crust. This process results in: 1) the development of sharp redox gradients associated with seafloor-exposed surfaces, or subseafloor surfaces exposed to recirculating fluids along fractures, and 2) a flux of fresh organic C (Corg) to ridge flanks that may be used for respiration by endolithic heterotrophic (including Fe- and S-reducing) prokaryote communities. Our objectives are to define this succession on basalt during the aging/weathering process, and to identify and quantify key constituents of these communities and understand the physical and mineralogical associations between microbes and dissolution features and secondary weathering products.

To address our objectives and test the above hypothesis we are using a combined experimental, computational, molecular, and microscopic approach. DNA sequencing of 16S genes for phylogenetic identification of bacteria associated with altered basalt has been done for Loihi and East Pacific Rise 9°N basalts. Both show similar communities associated with more altered basalt, which is distinct from the communities associated with incipiently weathered basalt. Based on the sequences revealed through

this environmental survey and sequences of cultured strains from Loihi, probes for use in fluorescent in-situ hybridizations with catalyzed reporter deposition (CARD-FISH) are being identified/designed. CARD-FISH is a highly sensitive technique that has been used successfully in a wide variety of environments such as in aquatic systems (e.g., Pernathler et al., 2002; Sekar et al., 2003), soils (Ferrari et al., 2006), and in deeply-buried marine sediments (Schippers et al., 2005). We have adapted methods for CARD-FISH for use on environmental basalt samples and on mineral chips that have been incubated on the Loihi seamount. Results show that high-quality 3-dimensional Z-stacked images can be used with CARD-FISH to map out physical and biological information that can be used for image analysis.

In order to tap all extractable data from 3-dimensional CARD-FISH images we are developing a MATLAB algorithm to process images and produce quantitative measurements of total cell populations, and to establish associations with specific topographic and textural features as well as with other cell populations in order to automate processing of large numbers of images. The algorithm can be modified iteratively as new information about important features is added to the databases regarding specific styles of etch pits, for example, or secondary features that have characteristic mineralogy or chemistry.

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Cultivation of novel marine Fe-oxidizing bacteria from the Loihi Seamount.

Emerson, D

Iron is one of the most abundant energy sources for lithotrophic organisms on Earth,yet very few cultures exist of Fe-oxidizing bacteria (FeOB) that can utilize Fe(II) as a sole energy source at circumneutral pH. Much of the work that has been done on FeOB is from freshwater habitats, so marine FeOB are even less well understood. The advent of a variety of molecular techniques now make us much less dependent on culturing microbes to understand their diversity, abundance and role in the environment. At the same time those techniques underscore the importance of having representative isolates available in culture that can provide context for the interpretation of molecular methods. The culture of FeOB represents a special case in point, where specialized culturing conditions that mimic the host environment are essential to achieving success. We have focused studies on the extensive mats of (FeOB) at the summit of the Loihi Seamount (1100m deep) that are associated with low to intermediate temperature (10° to 65°C) vents whose fluids contain 10's to 100's of μM Fe(II). The mats contain 107 to 108 bacterial cells/cc and the morphology of the Fe-oxides is indicative of biological origins. We have isolated an obligately lithotrophic FeOB from Loihi, Mariprofundus ferroxydans. Phylogenetic analysis shows that M. ferroxydans is the first cultured representative of a proposed new Bacterial division, the zeta-Proteobacteria. Molecular evidence from Loihi, based on clone libraries and terminal restriction length polymorphism (tRFLP) analysis of 16S rRNA genes, indicate this lineage of FeOB is the most abundant inhabitant in the Fe-mats. Furthermore, this lineage is ubiquitous at diverse Fe(II)-driven ecosystems at hydrothermal vent sites throughout the Pacific.

Seamounts Enhance the Global Influence of Ridge-flank Hydrothermal Circulation

Fisher, A T

Seamounts are recognized to influence global hydrothermal fluxes in at least three ways. First, volcanically active seamounts, generally located close to active spreading centers and/or associated with hotspot magmatism, are often hydrothermally active. These systems may vent both high-temperature and low-temperature hydrothermal fluids, although these fluxes are likely to be small compared to those at spreading centers (simply because spreading centers are spatially more common). Second, volcanically inactive seamounts provide access points for entry and exit of ridge-flank hydrothermal fluids, those extracting lithospheric heat on a regional basis across much of the seafloor. Fluid fluxes associated with these systems are much larger than those at spreading centers (probably by a factor of 100-1000), and the heat output of ridge-flank systems is also larger than that of systems at spreading centers, but the influence of ridge-flank circulation on global geochemical fluxes varies species by species and remains less certain. Third, volcanically inactive seamounts may host isolated hydrothermal circulation systems associated with local basement relief. A recent analysis of the dynamics of these systems suggests that they may result in globally-significant fluid fluxes (smaller than conventional ridge-flank fluxes but greater than those at spreading centers or volcanically-active seamounts). The primary thermal influence of these isolated, seamount circulation systems is likely to be local, but they may have biased measurements of seafloor heat flow during earlier studies (particularly in cases where the presence of seamounts was unknown), and their influence on geochemical fluxes remains uncertain. The influence of all of these systems on subseafloor microbiology also remains largely unknown and a focus of much ongoing research.

Recent assessments of satellite-based bathymetric data suggests a global population of ~15,000 large seamounts, but consideration of the size distribution of these features, and the few available studies of the hydrothermal influence of seamounts in specific field settings, suggests that there may be as many as 80,000-100,000 hydrologically-important seamounts on a global basis. Numerous field studies of heat transport through oceanic lithosphere during the 1960's-90's were conducted either without good maps of regional bathymetry (leaving the existence of basement outcrops such as seamounts uncertain) and/or tended to avoid these features (for fear that they would bias thermal measurements). However, until recently it was not recognized that hydrothermal circulation through seamounts can influence seafloor heat flow patterns to distances of tens of kilometers from areas of basement exposure, and thus many earlier thermal studies are probably influenced by seamounts (and additional outcrops such as fracture zones, LIPs, and other basement features having little or no sediment cover).

Examples are shown from two recent studies that illustrate the potential influence of seamounts on local and regional hydrothermal circulation and heat loss. Two basement outcrops separated by >50 km in the northeastern Pacific Ocean comprise paired recharge and discharge points for a flow-through hydrothermal system. Heat flow data around the margins of the outcrops show strongly contrasting thermal conditions, with heat flow being suppressed adjacent to the larger outcrop (into which recharge occurs), whereas the smaller outcrop is surrounded by crust that is warmed by discharging hydrothermal fluids. This fluid flow system is a hydrothermal siphon: self-sustaining, rapid flow driven by differences in pressure at the base of warm (discharging) and cool (recharging) columns of pore fluid. These pressure differences depend on the depth below the seafloor of the basement aquifer, and are no greater than a few tens to hundreds of kPa, an inference consistent with observations in sealed borehole

observatories. Heat flow through an even larger area of the seafloor in the eastern Equatorial Pacific Ocean was found to be controlled by hydrothermal flow between basement outcrops separated by 20-50 km. Numerous outcrops in this area allow hydrothermal fluids to extract ~70-90% of lithospheric heat over an enormous area. An adjacent area of seafloor of similar age lacks seamounts that penetrate through regionally-thick sediments and essentially all lithospheric heat is transported from the crust conductively.

Seamounts at the Cape Verde Islands: The Geosphere-Hydrosphere-Biosphere Connection

Hansteen, T H; Grevemeyer, I; Hanel, R; Kraus, G; Schneider, J; Masson, D G; Le Bas, T; Faria, B

Ocean islands and seamounts originate as small volcanoes on the ocean floor, grow by volcanism and intrusion, and are eroded by large landslides when slopes become instable. Uplift caused by intrusions or magmatic underplating, erosion by ocean waves and currents, and sea level changes, may also destabilize such large volcanic structures. The morphology, composition and structure of a seamount change during its evolution, thus influencing their suitability as habitat and biological hotspots. Thus, key questions for a better understanding of seamount systems include the interplay between seamount age and morphology, rock composition, state of rock alteration and the development of biodiversity.

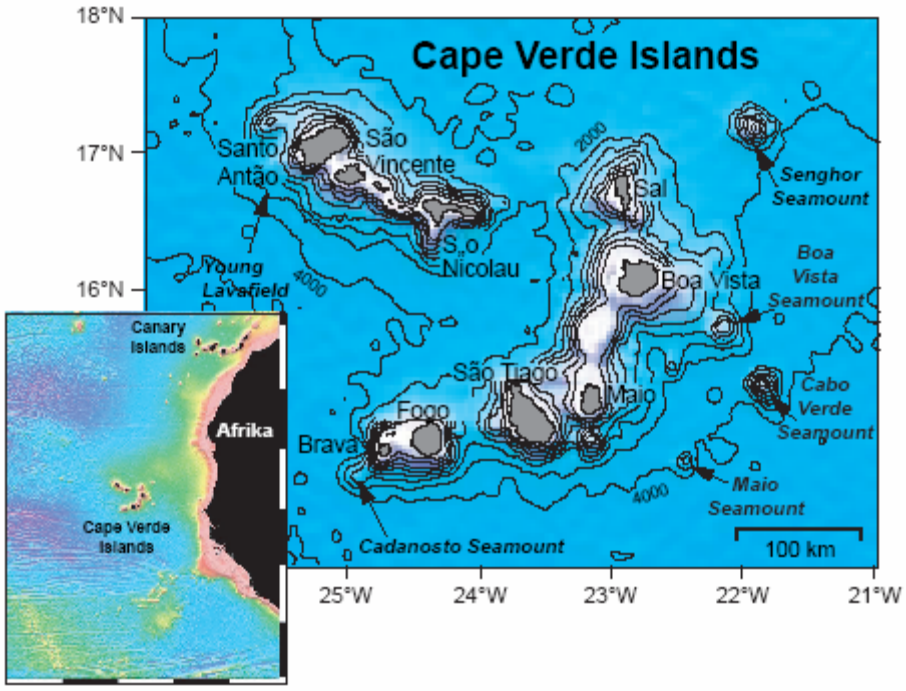

Figure 1. Location map of the Cape Verde Archipelago

We presently focus on seamounts and ocean islands in the eastern Atlantic ocean – the most recent effort includes the Cape Verde Archipelago (Figure 1) - to study the "Life cycle of ocean islands". The Cape Verdes include several old, flat-topped seamounts which are excellent fishing grounds, but also young volcanoes which show seismic and eruptive activity. Detailed seafloor mapping at the Cape Verdes was performed during three cruises with the research vessels Meteor (M62/3 in 2004), Charles Darwin (CD

168 in 2005), and Poseidon (Pos320/2 in 2005). Highlights include old, flat-topped seamounts, young active seamounts and a deep-sea lava field.

One of the most impressive witnesses of volcano growth and destruction is the steep-sided island Fogo which has produced a catastrophic landslide removing several hundred cubic km of its eastern flank, resulting in submarine deposits up to several hundred meters thick (Figure 2). The slope failure event is believed the have caused a giant tsunami hitting the adjacent island of Santiago. Several morphologically young and steep volcanic cones on the lower submarine flanks of Fogo and between the islands Fogo and Brava comprise fresh, basaltic glass, providing strong evidence for Holocene submarine eruptions. Thus Fogo also shows important volcanic activity in the submarine environment, in agreement with present-day earthquake data from the same areas.

The seismically active seamount Cadanosto (1200 mbsl; Figure 2) to the southwest of Brava island is characterized by local earthquakes, indicating ongoing construction of the seamount to - perhaps - the next ocean island in the Cape Verde archipelago. The rugged relief and state of alteration, however, suggest that the eruption rates are moderate. Rocks dredged during Pos 320/2 are typically phonolitic. A more than 100 km2 large submarine volcanic field (about 3500 mbsl; Figure 1) occurs southwest of the island Santo Antao, and lacks a sedientary cover. This testifies to widespread Holocene activity also in the northwestern part of the Cape Verde archipelago.

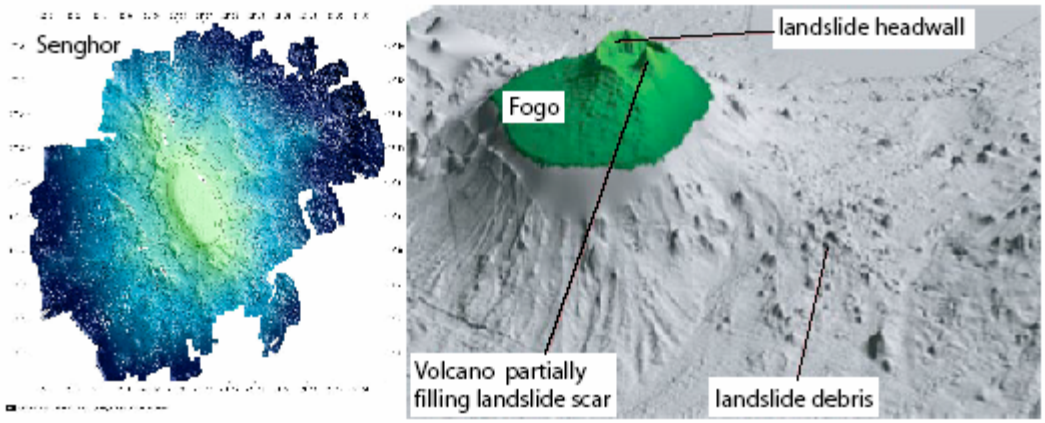

Figure 2. Detailed map of Senghor Seamount (left); landslide scar and deposits at Fogo (right).

The morphologically old, flat-topped Senghor Seamount (93 mbsl; Figures 1,2) in the northeast comprises a very smooth erosional summit area. Rocks dredged at several localities are intermediate to felsic, showing that Senghor represents a mature magmatic system, and thus turns out to be an extinct and submerged volcanic island. The deeper flanks of Senghor host abundant deepsea corals.

Shallow and isolated seamounts such as Senghor, reaching with their summits into the euphotic zone, are frequently characterized by higher biological productivity compared to the surrounding open ocean most likely being the result of local upwelling phenomena and entrapment of the nutrient enriched water masses by a circular flow field around the seamount. Biodiversity is in general great at the Cape Verdes, and with the local seamounts being productive biological hot-spots the region is a most rewarding study site to develop an integrated view on seamounts. Reconnaissance hydrographic measurements and biological samping has been performend at selected high-productivity sites. Samples under investigation

include fish, plankton, micronekton and chlorophyll. Planned studies at the Cape Verdes will focus on Geosphere-Hydrosphere-Biosphere interactions at seamounts.

Fluid Flow Through Seamounts: Implications for Global Heat and Mass Flux

Harris, R N; Fisher, A T

Hydrothermal circulation through the oceanic crust plays an integral role in governing the physical, chemical, and biological state of both the crust and ocean. Estimates of seafloor heat transfer indicates that fluid flow is responsible for 34% of the global oceanic heat flux, and is thermally significant, on average, to 65 Ma (Stein and Stein, JGR, 1994). Processes responsible for limiting advective heat flux between the oceanic crust and the ocean include increasing accumulations of low permeability sediments that cap relatively high permeability basement, decreasing thermal energy to drive flow, and decreasing crustal permeability with increasing crustal age.

Several factors make seamounts ideally suited to overcome these flow limiting processes. First, bathymetric relief associated with seamounts generates thermal buoyancy forces in excess of those present in flat seafloor. Second, seamount edifices are constructed mainly of extrusive basalt that likely have relatively high permeability. Third, seamounts tend to remain relatively sediment free much longer than the surrounding seafloor, thereby providing areas of exposed basement where fluid can exchange with the ocean unencumbered by low-permeability sediments.

Several marine geophysical studies demonstrate that seamounts can efficiently recharge and discharge hydrothermal fluids and cool the oceanic crust. However, flow through these features is poorly understood. Numerical models of coupled heat and fluid flow illustrate how basement relief coupled with a constant bottom water temperature condition generates horizontal temperature gradients within the oceanic crust sufficient to drive flow at modest permeability. Using the global database of seamounts we show that seamounts can contribute to globally significant hydrothermal fluxes. We estimate that the mass flux associated with global database of ~15,000 seamounts is ~10^{14} kg/yr, a number comparable to mass flux through mid-ocean ridges and flanks. Seamount generated advective heat flux may be locally significant well beyond the 65 Ma average age at which advective lithospheric heat loss on ridge flanks ceases. These flows may be important for facilitating heat loss, geochemical exchange between the crust and ocean and may affect sub seafloor microbial ecosystems.

Tumult In Samoa

Hart, S R; Staudigel, H; Koppers, A A P; Young, C M; Baker, E T

Is the Samoan volcanic chain the result of a hotspot or plume? Or not? Argued for decades, the discovery of volcanic activity at Vailulu'u seamount certainly supports the hotspot/plume model. Vailulu'u anchors the east end of the Samoan chain, much as Loihi anchors the Hawaiian chain's east end. The Samoan volcanic centers get older to westward, and are aligned with Pacific plate motion. This trend of aging is broken only by the voluminous young rejuvenated volcanism on Savai'i, a large island some 370 km west of Vailulu'u. Volcanism all along the chain has characteristic and unusual Sr, Nd, and Pb isotopic signatures, affirming a common Samoan pedigree.

Vailulu'u stands some 4500 meters above the seafloor, and its summit is 600 meters below sea level. The summit crater hosts active hydrothermal venting, with a power output of some 600 megawatts (measured by a dye release experiment). The crater waters are remarkably high in manganese, iron, helium-3 and particulates, and a resurgent volcanic cone ~300 meters high has grown in the crater since 2001. The hydrothermal power drives a remarkably complex and dynamic circulation system in and surrounding the summit crater.

Based on water chemistry, CTD and temperature logger data from 2000 and 2001, we formulated a model for the hydrothermal system in the crater involving a tidally-modulated "breathing" (Staudigel et al., 2004). During low stands of internal waves (exterior to the crater), the crater exhales warm buoyant hydrothermal water that forms a "halo" around the crater rich in Mn, 3He, and particulates. During "high tides", cold dense external water is inhaled into the crater through the three breaches, and cascades to the crater floor.

In April 2005, we used the HURL PISCES V submersible to deploy various temperature and particulate loggers and current meters in and around the crater; these were retrieved by Pisces V in July 2005. In addition, continuous CTD profiling was carried out over 12 hour tidal cycles at one location inside, and one outside, the crater. The accumulated data set fully reinforces our "breathing" model.

An ADCP, deployed for 93 days in the NW breach at 752m, showed dominant easterly inflow currents and westerly outflow currents, with maximum velocities of ~25 cm/s. The flows were coherent for distances up to 50-60m above the ADCP; the mean inflow velocity and azimuth (20-40 m interval above the ADCP) was 7 cm/s due east; the mean outflow velocity and azimuth was 5 cm/s at 260 degrees. Mean inflows were consistently colder than outflows (5.0° C vs. 5.2° C); the maximum observed range in temperature was 1.1 C, correlated with peak flow velocities. The coldest inflows would require very large regional internal wave amplitudes, up to 50-100 meters.

A 2-D acoustic current meter was deployed on top of the west crater rim summit (582m) for 90 days, and in the S breach (697m) for 4 days. The summit flows are presumed to represent the regional scale currents; these were largely from the SW quadrant, with typical velocities of 8-15 cm/s, and peaks to 25 cm/s. The S breach flows had a clear semi-diurnal tidal modulation, with strong NE quadrant inflows at high velocity (15-30 cm/s), separated by short outflow spikes of 1-2 hour duration at much lower velocity (<10 cm/s). The outflow water was typically warmer by 0.1-0.2 C; the maximum temperature range was 0.6° C, about half of that observed at the NW breach.

A 12-hour continuous profiling CTD-LBSS station was serendipitously sited on top of a large diffuse-venting hydrothermal field, in the crater moat just north of the new volcanic cone. The water column here was incredibly dynamic, with a 5-10m bottom boundary layer, 1° C above ambient, forming by diffuse flow from the basalt substrate in a matter of minutes; this layer would destabilize, detach, and rise with velocities of ~ 1 cm/sec. This buoyant water was both warmer and less saline than either the ambient crater water, or the cold outside water which occasionally cascaded onto this site from the nearby NW breach; it was also laden with particulates, with LBSS readings up to 1.7 NTU.

Water-Depth, Geographic, and Oceanographic Controls on Ferromanganese Crust Compositions Along a NW-SE Transect of the Equatorial Pacific

Hein, J R; Staudigel, H; McIntyre, B

Ferromanganese oxide (Fe-Mn) crusts occur throughout the global ocean on seamounts, ridges, and plateaus where currents have kept the rocks swept clean of sediments at least intermittently for millions of years. Crusts precipitate from cold ambient seawater (hydrogenetic) onto hard-rock substrates thereby forming pavements up to 25 cm thick. Fe-Mn crusts strongly concentrate most metals compared to their concentrations in the Earth's crust. Fe-Mn crusts grow at extremely slow rates (<1 to ~ 8 mm/Ma), have considerable specific surface areas (mean 325 m2 g-1), and have very high porosity (mean 60%).

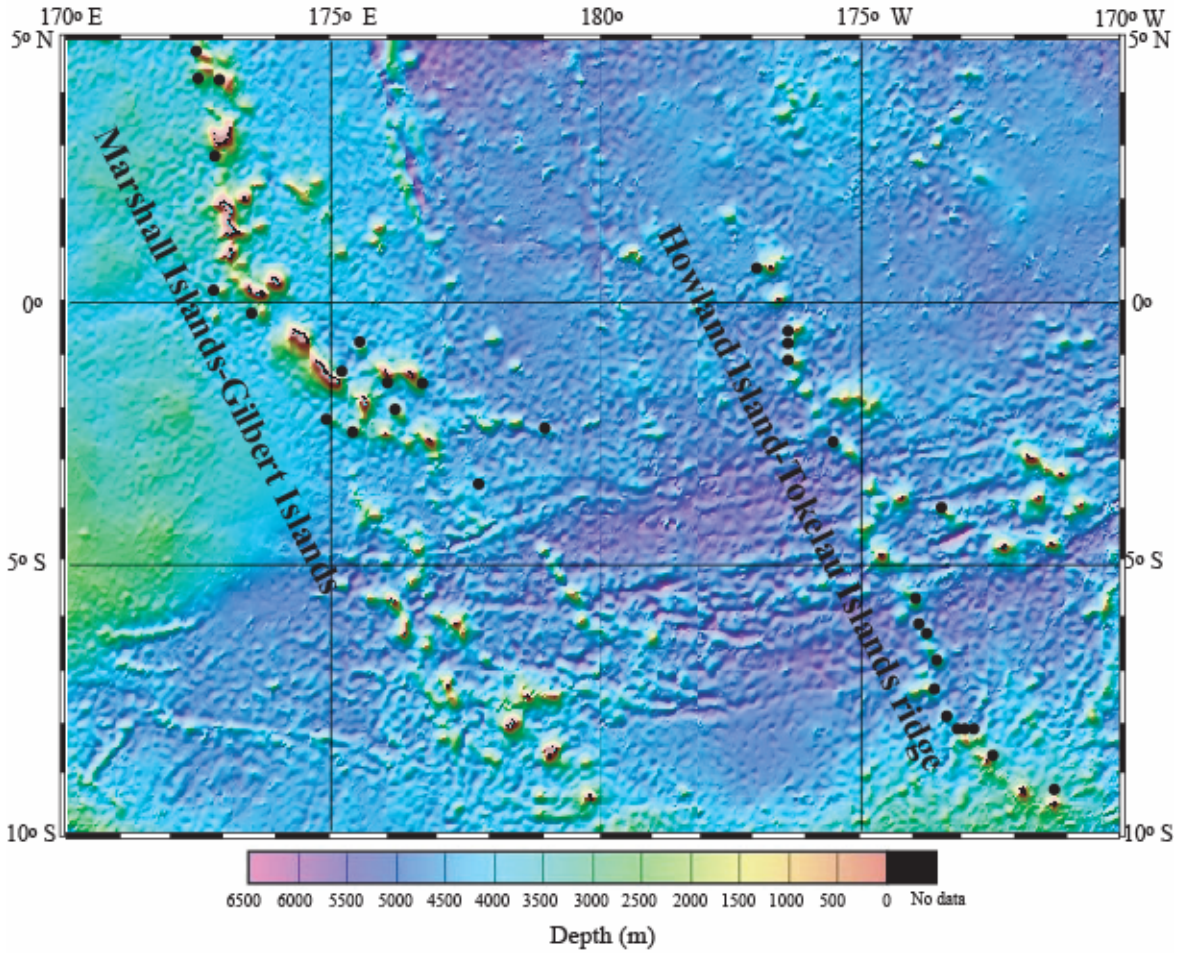

Figure 1. Study area, bathymetry, and dredge sites

We present the first study to analyze a large suite of elements in Fe-Mn crusts sampled during a latitudinal transect across the equatorial zone of high biological productivity. Samples were collected in January-March, 1999, during the AVON-2 cruise aboard the R.V. Melville, Scripps Institute of Oceanography. Samples were collected from 4.6º N to 9.2º S latitudes along two ridges, the Marshall Islands-Gilbert Islands ridge (4.6º N to 3.5º S) and the Howland Island-Tokelau Islands ridge (1º N to 9.2º S). The two ridges are offset east-west in the region of overlapping latitudinal sampling by about 466 km (Figure 1).

Concentrations of 48 elements were determined for 147 samples of Fe-Mn crusts from 33 seamounts that occur between the Marshall Islands and Samoa. Element concentrations in the crusts vary spatially and we examine those variations using statistical analyses. A mean Fe/Mn ratio of 1 and mean Co content of 4611 ppm are typical of West Pacific hydrogenetic crusts. In contrast, mean Cu (1540 ppm) and Ba contents (3107 ppm) are 35% and 40% higher than their regional central Pacific means (998 and 1876 ppm, respectively); but Ba is lower than in California margin crusts (mean 4085 ppm). Another striking difference is the 30% higher mean Zr (921 ppm) compared to its regional central Pacific mean (613 ppm). Zr has a strong positive correlation with Ba and a weak positive correlation with Mn.

Cu has a strong positive correlation with water depth of Fe-Mn crust occurrence, as do Fe, Sc, Si, Th, K, Li, and REEs to lesser extents, reflecting the aluminosilicate and biogenic phases (Figures 2, 3). In contrast, Co, Ni, Pb, Cd, Sr, Tl, Mn, Mo, Mg, and Sb decrease with increasing water depth, representing MnO2 associated elements.

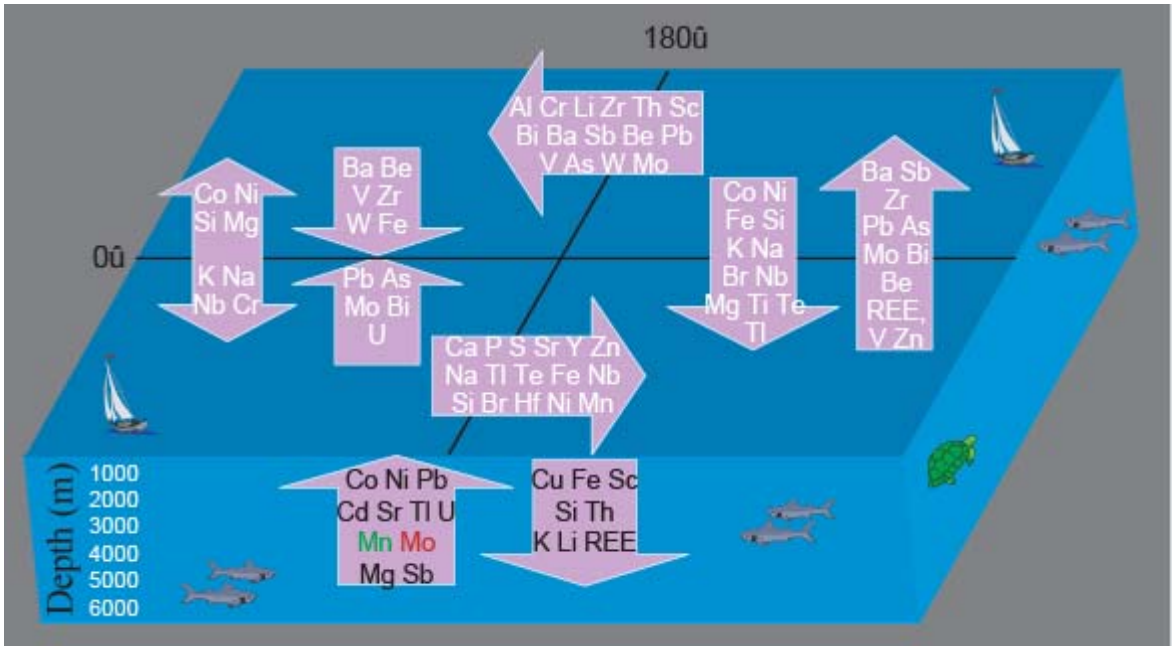

Figure 2. Geographic trends for elements as determined by correlation coefficients and Q-mode factor analysis. Trends are noted as occurring with proximity to the equator, NS trends, EW trends and with water depth.

Ba has a strong correlation with decreasing latitude (proximity to high primary productivity at the equator), as do Bi, Be, Pb, Zr, U, and elements that form oxyanions in seawater (V, W, As, Mo) (Figures 2, 3). These elements comprise the biogenic and FeOOH components. In contrast, Co, Ni, Mg, Si, K, Na, and Cr increase away from the equator. In general, Ba, Sb, Zr, Pb, As, Mo, and Bi decrease from north to south, whereas Co, Ni, Tl, Te, Si, K, and Na generally increase from north to south. Al, Ba, Sb, Be, Pb, V, As, W, and Mo increase to the west, whereas Mn, Co, Ni, Tl, Te, Si, Hf, P, Ca, and S increase to the east (Figures 2, 3). The opposite east-west trends for Si and Al indicate that there is a biogenic (diatoms and radiolarians) component for Si, as well as its detrital association. This idea is supported by the Si/Al ratios.

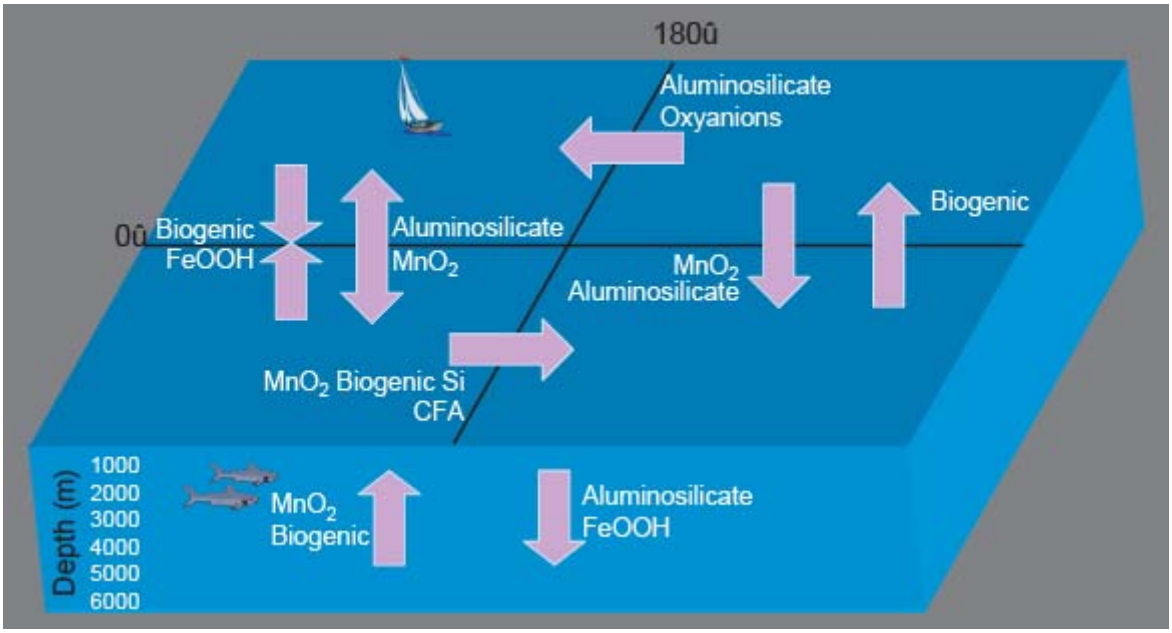

Figure 3. Geographic trends with crust components that host the elements displayed in the previous panel.

In summary, a strong spatial control for Fe-Mn crust chemistry is related to higher primary productivity near the equator and to the east; and to eolian input primarily from Asia at higher northern latitudes and from volcanic arcs at lower and southern latitudes. Ba is the best proxy for primary productivity in surface waters overlying regions of crust formation. Strong upwelling and productivity at the eastern Pacific margin results in Fe-Mn crusts with the highest known Ba contents; less strong but significant upwelling in the equatorial Pacific also supplied high Ba to crusts there. High Cu and Zr concentrations in our samples likely have a similar origin as the Ba.

The International Census of Marine Microbes (ICoMM) and a strategy for exploring microbial diversity throughout the world's oceans.

Huber, J; Morrison, H; Welch, D M; Huse, S; Neal, P; Sogin, M

The world's oceans are teeming with microscopic life forms. For more than three billion years, microscopic factories – initially anaerobic and later aerobic – have served as the essential catalysts for all of the chemical reactions within the biogeochemical cycles. Although early cultivation studies described prokaryotic population size to be only a few hundred cells per milliliter of seawater, the staining of cells with DNA-binding dyes (DAPI and acridine orange) coupled with epifluorescence microscopy demonstrated that nominal cell densities exceed 105/ml of sea water. Extrapolations of these numbers predicts that the oceans harbor 3.6 x 1029 microbial cells with cellular carbon of ~3 x 1017 grams. Given the enormous populations of microbes with seemingly unlimited metabolic diversity, the accumulation of mutations during the past 3.5 billion years should have led to very high levels of genetic diversity and phenotypic variation. Yet, traditional microbiological methods have described only 30,000 protists and fewer than 5,000 kinds of prokaryotes. The International Census of Marine Microbes (ICoMM) (http://icomm.mbl.edu/) is a field project of the Census of Marine Life (COML) (http://www.coml.org/) whose goal is to report what is known, what is unknown but knowable, and what may never be known

about the biodiversity of marine micro-organisms. ICoMM supports four working groups: (i) Open ocean and coastal systems, (ii) Benthic systems), (iii) Databases, and (iv) Technology. To be successful, ICoMM must work through coordinated activities of marine microbiologists throughout the world and it will be important to develop a high-throughput, molecular-based paradigm for describing microbial populations. We have made a significant step forward through the use of tag sequencing strategies. In a single experiment we captured information about the phylogenetic diversity of more than 100,000 organisms. Rarefaction analysis of these data reveal that microbial diversity in the oceans is at least two orders of magnitude greater than previously reported.

Numerical Models Generate Time-varying (Periodic) Hydrothermal Discharge Through a Seamount

Hutnak, M; Fisher, A; Stauffer, P; Gable, C

Tens of thousands of seamounts scattered across the ocean basins on seafloor of many ages provide conduits that allow ridge-flank hydrothermal fluids to be exchanged between the crustal reservoir and the overlying ocean. Enormous volumes of fluids move between the crust and ocean far from seafloor spreading centers, at low to moderate temperatures, influencing a wide array of processes and properties, from lithospheric aging to the chemistry of the ocean to maintenance of a vast, sub seafloor biosphere in the crust. Seamounts provide windows through which these fluids, processes, and properties may be accessed. Despite the importance of seamounts to ridge-flank hydrothermal circulation on a global basis, there has to date been little attempt to quantify the physical processes by which fluids move between the crust and ocean using seamounts as highly-permeable pathways.

We use two-dimensional, finite-element models of coupled heat and fluid flow to investigate heat and fluid transport around and through a small seamount on a young ridge flank (Hutnak et al., 2006). The system geometry and properties are based on observations and measurements on 3.5 Ma seafloor east of the Juan de Fuca Ridge, where Baby Bare outcrop hosts hydrothermal discharge from the surrounding crust (Fisher et al., 2003; Mottl et al., 1998). Observations of crustal structure and bulk permeability, the distribution of seafloor heat flux adjacent to the outcrop, sub seafloor pressures determined with long-term borehole observatories, and basement fluid geochemistry from boreholes and sediments in area of fluid seepage constrain acceptable model results. In one set of simulations, we generated radially-symmetric models of Baby Bare outcrop and the surrounding seafloor (Figure 1), and forced fluid flow towards the outcrops at rates consistent with observations. In many of these models in which the basement permeability was 10-13 to 10-11 m2, values consistent with borehole experiments and constrained by other modeling studies, convection within basement was unstable and periodic, forming rolls that migrated towards Baby Bare outcrop.

Time-averaged discharge of 5-50 L/s, a range consistent with plume and outcrop measurements around Baby Bare outcrop, is needed to match seafloor heat flux patterns (Figure 2). In contrast to hydrothermal systems that respond to crustal strain variations induced by seismic events, atmospheric loading, or tidal perturbations, many numerical simulations include mixed convection, net through-flow upon which are superimposed migrating convective rolls. As a result of mixed convection, we see large variations in fluid discharge rates (+/- tens of m/yr) and fluid exit temperatures (+/- tens of degrees), with frequencies of thousands to tens of thousands of years. Mixed convection requires sufficient thickness in the basement aquifer (several hundred meters) and a bulk permeability that is neither too high nor too low (Fig-

ure 2). When basement permeability is too low, convection is suppressed and models include only lateral circulation and discharge through the outcrop. When basement permeability is too high, local convection is so vigorous that temperatures within the basement aquifer and outcrop become nearly homogeneous, and discharge becomes more steady and isothermal.

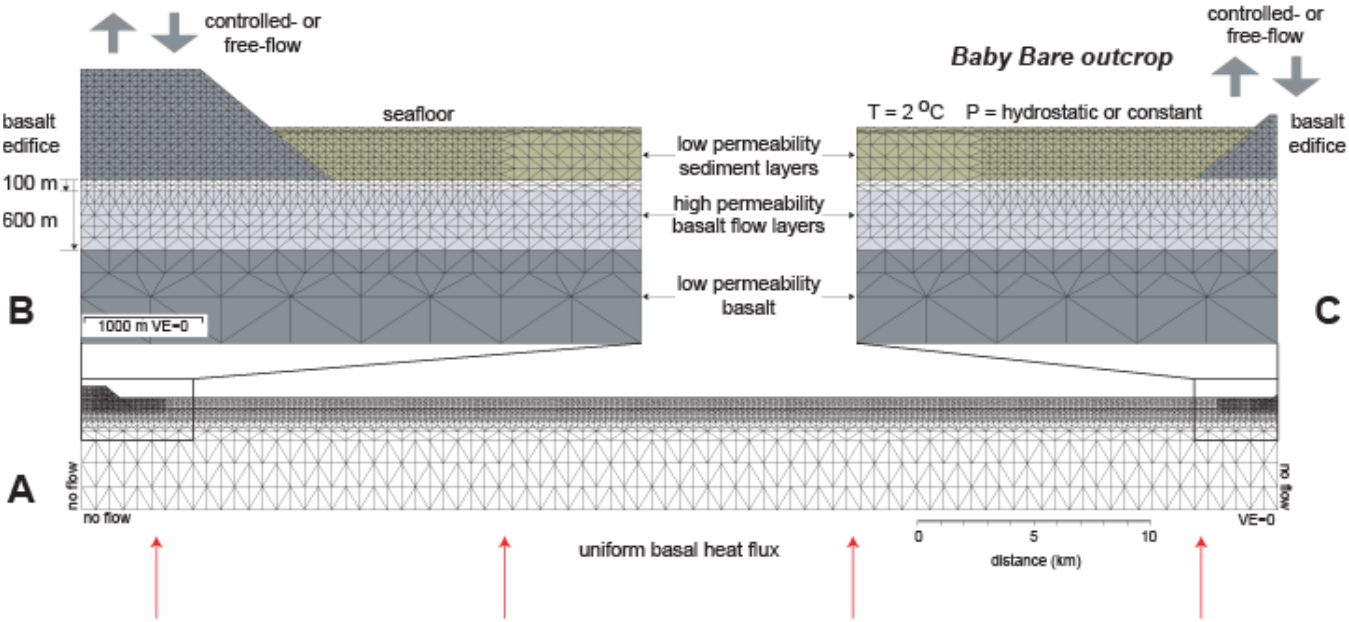

Figure 1. Model domain for simulations of coupled fluid-heat flow within and between seamounts. **A.** Complete model domain for dual-outcrop simulations illustrating layering of system, with system geometry and basement edifices based on interpretation of seismic data that cross Baby Bare and Grizzly Bare outcrops (50 km to the south). Single outcrop radial simulations of Baby Bare outcrop use the right half of the grid, with the axis of symmetry running through the center of the outcrop. **B.** Detail of region within and around the Grizzly Bare outcrop. **C.** Detail of region within and around Baby Bare outcrop, which is the focus of work presented in this poster. Fluid is forced into the grid along the farfield boundary and is allowed to exit through the top of the outcrop.

These preliminary numerical results suggest that hydrothermal circulation through seamounts may, in many cases, be highly transient. There may be large changes in flow rates (and perhaps even be reversals in flow direction). Understanding the processes by which transient flow processes within seamounts may occur is important for interpreting observations of vent fluid chemistry, temperature, and microbial content.

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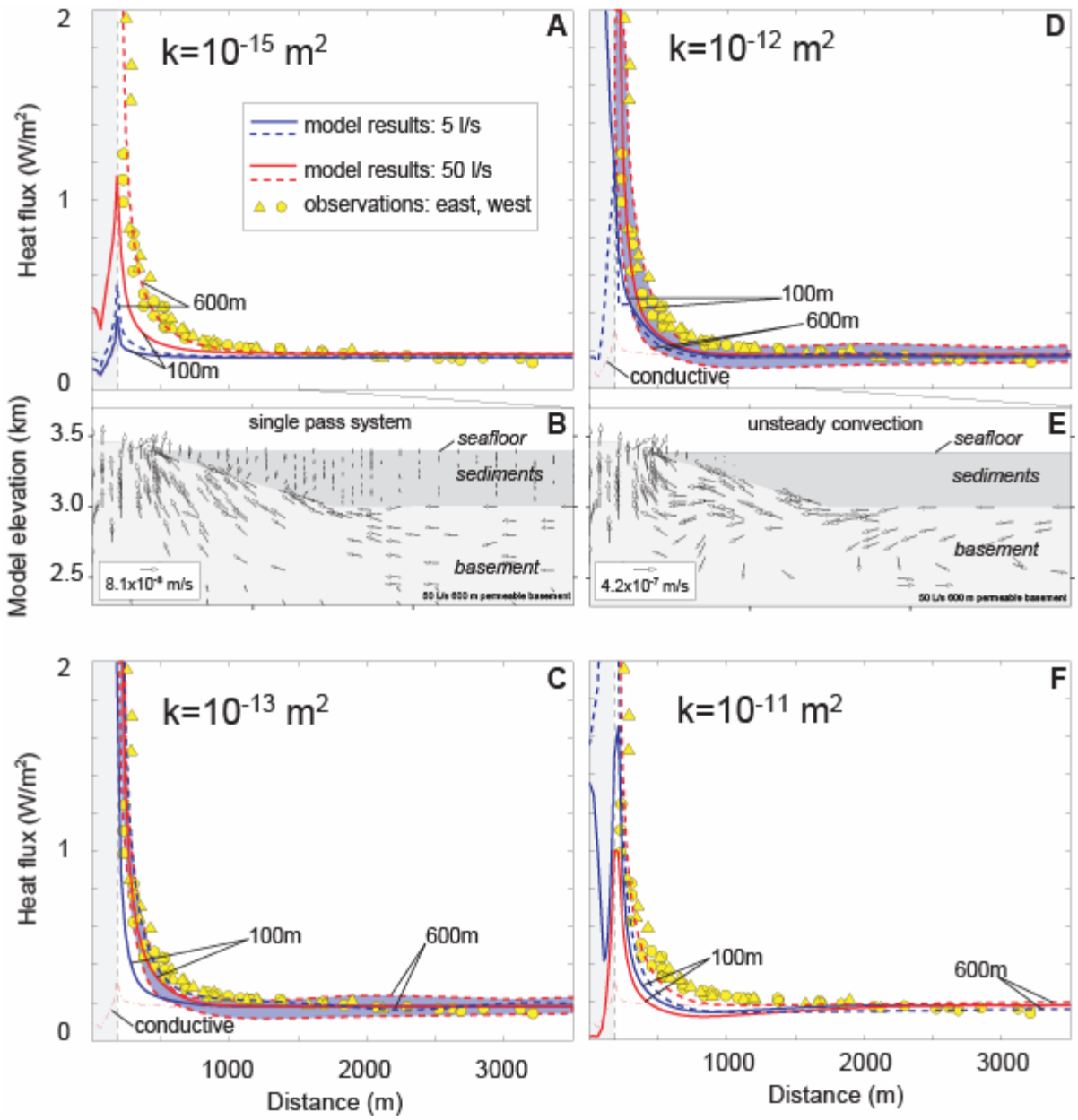

Figure 2. Results from fully-coupled numerical models of Baby Bare outcrop. Heat flux data collected adjacent to Baby Bare outcrop are aligned along the outcrop edge, the position for which is indicated with dashed vertical lines. Fluid was pushed into the model domain at the far boundary at 5 and 50 L/s (blue and red curves, respectively), through the upper 100-600 m of basement (solid and dashed curves, respectively), including the basalt edifice. **A.** Upper basement permeability is 10-15 m2. **B.** Random subset of normalized flow vectors within 1.5 km of the outcrop, showing a single-pass flow system. **C.** Upper basement permeability is 10-13 m2. Convection is mixed and unstable, leading to a range of heat flux values near the outcrop, as shown with shaded purple band, as fluid circulation rates and directions vary with time. **D.** Upper basement permeability is 10-12 m2. Convection was unstable in this model as well, leading to a range of heat flux values near the outcrop, as shown with shaded band. **E.** Random subset of normalized flow vectors, showing unstable convection in permeable basement. **F.** Upper basement permeability is 10-11 m2. Convection stabilizes in some simulations, but homogenizes temperatures locally, creating a heat flux moat near the outcrop, not seen in field studies.

Role Of Biomineralization In The Preservation Of Sheathed And Stalked Iron-Oxidizing Bacteria At Seafloor Hydrothermal Vents

James, R E; Scott, S D; Ferris, F G

Iron-oxidizing bacteria (FeOB), primarily in the form ferrihydrite, are associated with the precipitation of iron oxides at the circumneutral redox interface of hydrothermal seafloor environments (Scott, 1997; Cornell and Schwertmann, 1996). Recent interest in the identification of biogenic material in modern and ancient seafloor deposits has prompted research on the preservation potential for bacterial structure at these sites.

The following investigation involved an assessment of particle size distribution (PSD) and filament durability of FeOB from the Loihi Seamount, the youngest submarine volcano of the Hawaiian island chain. Scanning electron microscopy was used to examine two FeOB species: Gallionella ferruginea (G) and Leptothrix ochracea (L).

Assessment of filament durability involved the agitation of suspended samples at 100, 200, 300, 400 and 500 RPM for 60 and 120 min. Particle and filament dimensions were measured using electron microscopy. The average diameter for particles in association with biogenic filaments was 1.9 μm (L sheaths) and 3.2 μm (G stalks). The average dimension for G stalks was 2 μm x 40 μm and for L sheaths was 0.16 μm x 15 μm. Chemical and mineralogical characterization was examined using energy dispersive X-Ray spectroscopy (EDS) and powder X-Ray diffractometry (pXRD). The EDS spectra confirmed Fe as the only element present in association with biogenic material. Diffraction patterns from pXRD analysis established the dominance of 2-line ferrihydrite mineralogy, characterized by broad humps at 2.6 Å and 1.5 Å.

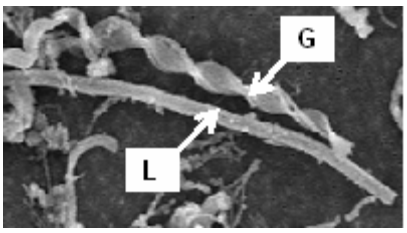

Figure 1. Ferrihydrite-coated Gallionella ferruginea stalk and Leptothrix ochracea sheath, (identified based on morphology).

Ferrihydrite-coated filaments were 68% (G) and 63% (L) longer than non-coated filaments after agitation at 500 RPM for 120 minutes. This indicates that biogenic filaments with mineralized surfaces are more resistant to fragmentation than those less mineralized. The results of this investigation suggest that stalked and sheathed filamentous bacteria like G. ferruginea and L. ochracea may have been preferentially preserved as microfossils in ancient rocks. The preservation of FeOB filaments at seafloor hydrothermal vents may provide insight into bacterial preservation in other marine deposits.

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Population genetics and ecology of seamount clam (Limidae: Acesta) populations in the northeastern Pacific Ocean.

Jones, W J; Tyler, P; Clague, D; Vrijenhoek, R

Seamounts along the California margin present unique and relatively shallow habitat islands surrounded by the abyssal plain. Benthic organisms such as corals, sponges, bivalves and echinoderms typically dominate southern California seamounts. This study examines two widespread species of Acesta clam (Bivalvia: Limidae) from northeastern Pacific seamounts. Samples of Acesta sphoni and A. morei were collected using the ROV Tiburon during expeditions spanning 2002–2004. Environmental temperature, salinity, oxygen and depth were recorded during each dive via sensors on the ROV. Ninety-two individuals of A. morei were collected from seven seamounts, and nine individuals of A. sphoni were collected from two seamounts. Six A. morei individuals from Rodriguez Seamount were preserved in 10% seawater formalin for analysis of reproductive condition. Genomic DNA was extracted from all other individuals. Examination of 663 base pairs (bp) of mitochondrial DNA cytochrome oxidase I (mtCOI) revealed approximately 10% sequence divergence between the two Acesta species and limited genetic difference within species, A. morei (<1%) and A. sphoni (<1%). The more widespread and abundant of the two species, A. morei, exhibited no significant genetic differentiation (as revealed AMOVA; Excoffier et al. 1992) across the 1700 km range sampled in this study. Too few A. sphoni were collected to assess geographical heterogeneity.

The two Acesta species appear to segregate by depth. When observed together on the same seamounts (NE Bank and San Juan), the less abundant species, A. sphoni, was restricted to warmer (>4.5 C), less saline (<34.3 ppt), and less oxygenated (<0.4 ppm) water at depths of 500–800 m. In contrast, Acesta morei was limited to colder and more oxygenated waters at depths greater than 1000 m, with the exception of one individual collected from NE Bank at 798 m. Nevertheless, the bathymetrically constrained populations of Acesta morei exhibit remarkable genetic uniformity across the sampled range. Similar patterns of bathymetric constraint and widespread geographical homogeneity were seen in vesicomyid clam populations from coastal seeps along the western margin of North America (Goffredi et al. 2003). The current lack of knowledge about larval life histories in both the limid and vesicomyid clams limits our ability to understand their means of dispersal throughout this region.

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Henry Seamount, Western Canary Islands: Old Structure or Recently Active Volcano?

Klügel, A; Hansteen, T H

Henry Seamount is a 8-km-wide, 660-m-high circular structure that rises from 3700 m deep seafloor southeast of El Hierro, the youngest of the Canary Islands (Figure 1). Mapping during Charles Darwin

cruise CD108 in 1997 revealed that Henry Seamount is dome-shaped with radiating gullies and ridges and shows a sharp break-of-slope with the surrounding flat seafloor (Gee et al., 2001; Figure 2). Because of these characteristics and because low backscatter indicates several meters of sediment coverage, the authors interpreted it as an extinct volcanic edifice possibly some hundred thousand years old. A similar minimum age was inferred for the southern submarine ridge of El Hierro further to the west. These interpretations are consistent with high radiometric Ar/Ar ages of some submarine samples from southern El Hierro and La Palma (van den Bogaard, unpubl. data), which suggest that volcanic activity at the western Canary Islands began much earlier than previously thought. In order to test this hypotheses, we sampled Henry Seamount by six dredge hauls during Meteor cruise M66/1 in 2005.

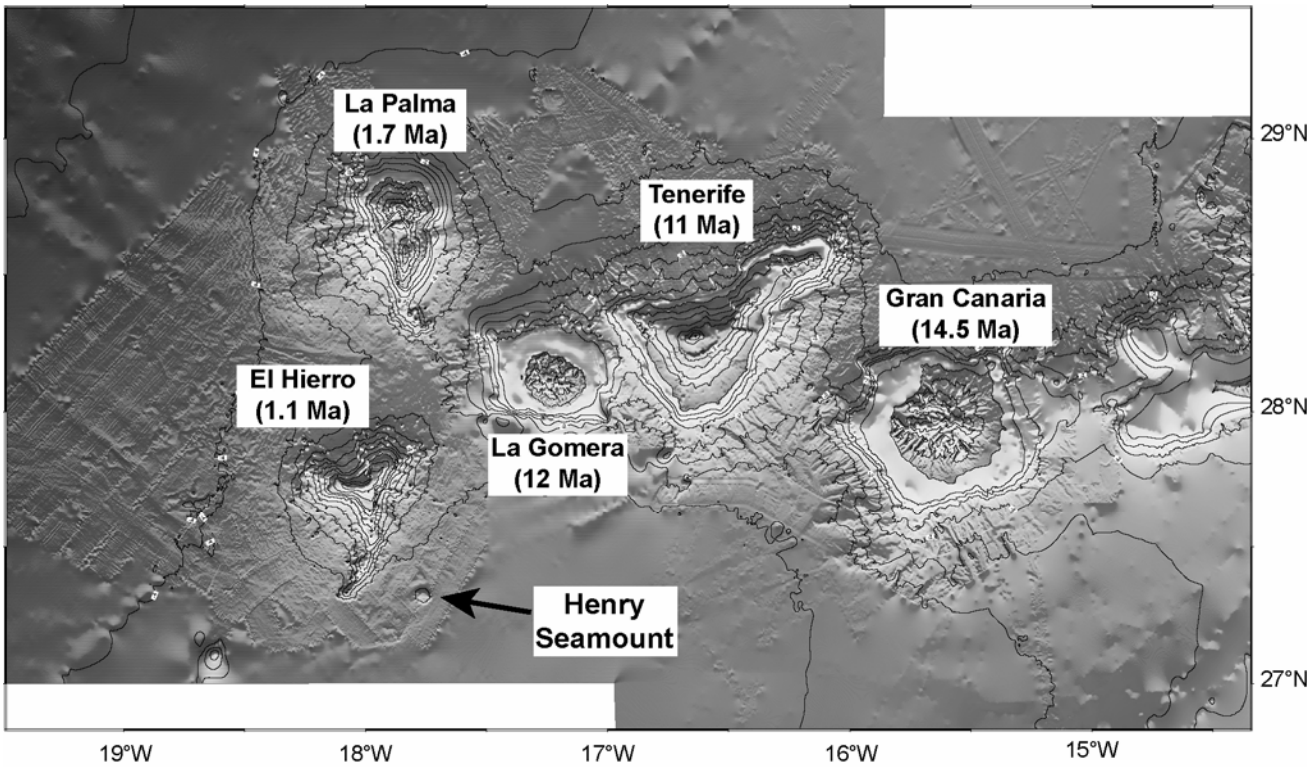

Figure 1. Bathymetry map showing the western Canary Islands and the locality of Henry Seamount. Oldest subaerial ages of the islands are from the literature. Bathymetric data of this and the following figure are based on Masson et al. (2002) and were compiled by S. Krastel, University of Bremen.

The paucity of dredging bites confirmed the inferred meter-thick sediment coverage. Only three dredge hauls yielded hard rocks, but all dredges contained soft silty to sandy sediment. The southern slopes of Henry Seamount apparently show thicker sediment coverage than the steeper northern slopes, which may be the result of deep-sea currents from northern directions. The dredged samples include:

- Felsic, probably trachytic rock fragments and pebbles covered by thin Mn-crusts. The samples are slightly to heavily altered, and the most altered ones are penetrated by carbonates.
- Vesicular fragment of glassy basalt.
- Volcaniclastic sandstones with abundant Globigerina foraminifers.
- Porous biogenic or abiogenic carbonates, partly associated with deep-sea corals (Figure 3).
- Fragments of cm-thick layered Mn-crusts.

- Abundant shell fragments of vesicomyid clams up to 15 cm in size within a dredge full of soft sediment. The shells are mildly corroded and locally show thin Mn-coatings (Figure 3).

The presence of shells from vesicomyid clams is surprising since this species is always associated with active hydrothermal vents or seep areas. To our knowledge, this is the first reported finding of vesicomyid clams within the Canary Archipelago and also the first direct or indirect evidence of venting activity. Their preservation state suggests that the shells are not very old, probably less than 100,000 years. Likewise, the texture, porosity and extreme freshness of a carbonate rock recovered from the summit plateau indicates a recent origin. It therefore appears that Henry Seamount is a recently active volcanic system related to the present location of the hotspot near El Hierro. This interpretation is supported by the small degree of alteration of the freshest dredged trachytes. The recovery of predominantly trachytic lavas at Henry Seamount is consistent with the observation that small seamounts erupt more differentiated lavas during their earliest stages of growth (Devey et al., 2003). But how can recent venting and possible volcanic activity be reconciled with the presence of some meters of sediment drape and gullied flanks? Does Henry Seamount currently show some kind of rejuvenated activity? Geochemical investigations as well as age determinations of the rocks and shells are on the way to resolve these questions.

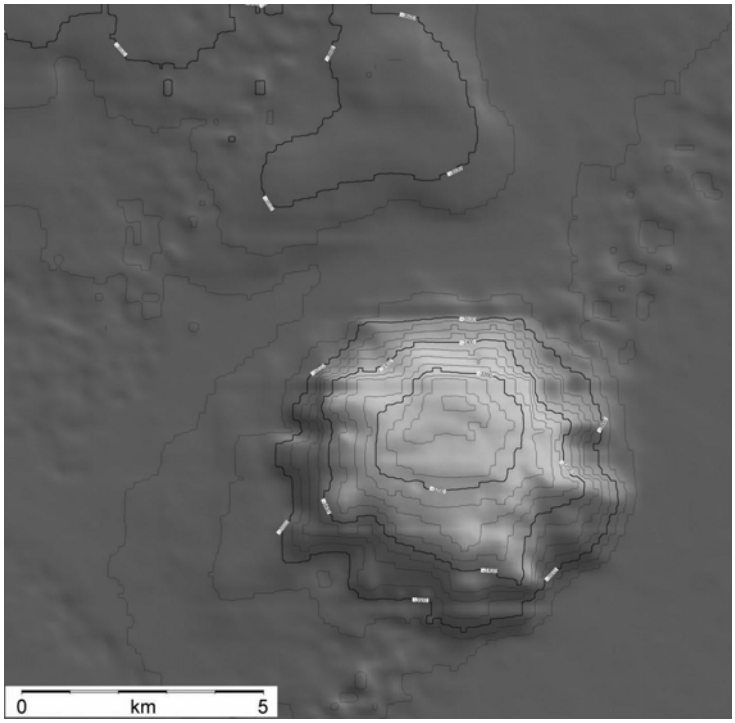

Figure 2. Detailed bathymetric map (50 m contours) of Henry Seamount.

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Figure 3. Fresh carbonate fragment with coral stem (left) and shell of vesicomyid clam (right).

A review of physical processes at seamounts

Lavelle, W

Ocean conditions at seamounts depend on topography, on ambient stratification, on latitude, and on the strength and periodicity of flows that sweep each object. Geometrical considerations include seamount summit size, shape, and proximity to the sea surface, as well as flank slope and overall water depth. Flow impinging on a seamount can be steady, quasi-steady as might be caused by meso-scale eddies, oscillatory with tidal flows being prominent, or intermittent as in wind-driven flows with inertial response. A wide range of flow, hydrographic, and turbulent energy responses at and around seamounts is consequently possible.

Here some of the basic physical oceanographic features at seamounts are identified and related to topographic and environmental factors. Emphasis is given numerical model results. Steady and tidally forced circulation both can lead to time-mean flows that are trapped around the seamount summit. In the case of tidal forcing, a short recirculation cell typically drives flow downward toward and radially outward from the center of the seamount apex. That flow is related to time-mean temperature anomalies, i.e. cold domes, that are often observed above the summit.

Seamounts are also known to be sites of amplified oscillatory flow and increased turbulent mixing, a quantity which bears on, among other things, the suspension time of detritus in the water

column. Increased turbulent mixing is a consequence of vertical velocity shear caused by internal tides, which seamount generate. Seamount latitude, more specifically Coriolis period, influences which oscillations contribute to time-mean flows or to internal tides.

Numerical experiments looking at material transport and retention of neutral tracers above seamount show that a column of material above a seamount can be sustained on the order of weeks.
Depending on steady flow strength and seamount fractional height other experiments have shown seamounts shedding eddies downstream.

Observations and comparisons of Californian seamount communities

Lundsten, L

Seamount communities were observed using remotely operated vehicles (ROVs) at the Monterey Bay Aquarium Research Institute (MBARI) and recorded using high-resolution video equipment. Twelve dives representing 120 hours of video observations from Davidson, Guide, Pioneer, and Rodriguez seamounts off the coast of California, USA, were annotated in detail using the Video Annotation and Reference System (VARS) in order to determine Seamount community composition. Queries of the VARS database yielded observational and ancillary data, which was spatially analyzed using ArcGIS in an effort to describe the community structure while comparing patterns of abundance and diversity between the different locales. Nearly 100,000 individual observations were annotated and added to the VARS database while reviewing these dives. The majority of the observations are biological, with more than 225 distinct species collected and identified by taxonomists, 33 of which were deep-sea corals.

A Darwinian View of the Diverse Habitats of Seamounts and Active Submarine Volcanoes from the Results of a Cross-Disciplinary, Multi-Institutional South Seas Expedition from Hawaii to New Zealand and Back

Malahoff, A

The Hawaii Undersea Research Laboratory (HURL) organized an international research team to explore the chemistry, geology, biology, hydrothermal venting processes, mineral deposition, and biodiversity of seamounts extending south from Hawaii to New Zealand, including the submarine volcanoes of the Tonga-Kermadec Island Arc. This expedition produced a continuum of unique data from a diverse line of seamounts and underwater volcanoes extending along the Pacific Basin from Hawaii to New Zealand.

Research team members came from a Consortium comprising principal investigators from the NOAA Pacific Marine Environment Laboratory (PMEL) and VENTS program; the Institute of Geological and Nuclear Sciences (now known as "GNS Science") and the National Institute of Water and Atmospheric Research (NIWA), both of New Zealand; the University of Kiel in Germany, the University of Mississippi, the University of Hawaii, the NOAA Marine Fisheries Service, Scripps Institution of Oceanography, the University of Oregon, Oregon State University, Stanford University, and the U.S. Fish and Wildlife Service. Funding came from member organizations of the Consortium and NOAA's Office of Ocean Exploration (NOAA/OE) and Undersea Research Program (NURP).

The expedition left Hawaii on 18 March 2005 and returned on 05 August 2005 aboard the R.V. Ka'imikai-o-Kanaloa with submersibles Pisces IV and Pisces V and the ROV RCV-150. Sixty-one science dives were executed during the eight legs of the expedition. Twelve active volcanoes in the Samoa to New Zealand legs, one in the Samoan hot spot chain, and the flanks of five islands and atolls on the legs between Samoa and Hawaii were investigated. Hundreds of specimens of new and unusual marine life, corals and other benthic organisms, extremophile micro- and macro-organisms, water samples for chemical analysis, polymetallic sulfides, and rock samples were collected during the expedition.

The active submarine volcano Vailulu'u in the Samoan chain was found to have a new 300-m high volcanic cone growing in its caldera that was not present when the edifice was last depth sounded in 2001. Turbid waters, hydrothermal activity and a "Medusa head" rock full of eels were additional noteworthy discoveries.

Unusual processes were observed at the Kermadec submarine volcanoes, including the oozing of liquid sulphur onto the seafloor and profuse carbon dioxide venting into seawater. Extensive submarine hydrothermal venting, black smoker activity and extraordinary chimneys formations were studied in the caldera of Brothers volcano. In addition, extensive communities of animals consisting of giant mussels, long-necked barnacles, pogonopheran worms, crabs, vent fish, and mats of micro-organisms were mapped on the volcano flanks down to water depths of 2,000 meters. Of note was that each active volcano maintained its own characteristic mix and dominance of animals. New species of life forms were detected and 27 new species of extremophile bacteria have been analyzed.

A preliminary examination of data taken over the submarine volcanoes of the Kermadecs shows that each volcano appears to have a particular suite of dominant benthic organisms clustered around the hydrothermal vents and seeps. The shuffling of dominance is probably the result of the variability of the chemistry and water temperatures of hydrothermal venting from one volcano to the next. Variabilities in the local current regimes and the areal extent and duration of the venting processes likely play a role in the evolution of the localized, diverse benthic communities of each volcano. A systematic analysis of the physical, chemical and geological setting of each volcano will provide clues to the factors that have led to the natural selection of the dominant populations for that particular volcano. This unique multidisciplinary data set provides an excellent opportunity for biologists, geologists, geochemists, and geophysicists to examine these phenomena in a cross-disciplinary manner and lay the foundations for examining the progress of benthic colonization from active submarine volcanoes to their ultimate fate as volcanically inactive seamounts.

Spatial and temporal variability in microbial mat communities from pre- and post-eruption Loihi Volcano: A microbial observatory for the study of neutrophilic iron-oxidizing bacteria.

Moyer, C L

Loihi Seamount is an active submarine volcano that marks the southernmost extent of the Hawaiian hotspot. Loihi rises over 3000 meters from the seafloor and summits nearly 1000 meters below sea level. Hydrothermal activity was discovered at Loihi in 1987, yielding diffuse vent effluent (Tmax ~37°C) with associated high CO2 and Fe(II) concentrations and luxuriant microbial mats near the summit of the volcano. The Seamount erupted in 1996 forming a new 300m deep caldera (Pele's Pit) with hydrothermal

venting up to 200°C. Pele's Pit now contains multiple hydrothermal vents with hydrothermal fluids ranging from 8-65°C with concentrations of Fe(II) between 50 and 750µM. Community fingerprints from over 50 microbial mat samples collected from Loihi Seamount from 1993 to 2004, with temperatures ranging from ambient (4°C) up to ~200°C, were analyzed using cluster analysis of terminal restriction fragment length polymorphisms (T-RFLP) coupled with traditional clone library and sequence analysis. These mat samples form two distinct community clusters (Loihi Cluster I and Loihi Cluster II) representing a combined 82% of all samples collected. Loihi Cluster I is the largest group and contains the most mat samples collected over time. Loihi Cluster I is dominated by phylotypes closely related to the obligate lithotrophic Fe-oxidizing isolate "Mariprofundus ferroxydans" (of the newly proposed zeta-Proteobacteria) and contains lesser amounts of alpha-Proteobacteria, delta -Proteobacteria and Flavobacteria. Loihi Cluster II is comprised of only post-eruption communities that generally contain more diversity (in terms of richness) than Loihi Cluster I communities. Loihi Cluster II communities are dominated by a unique clade of phylotypes belonging to the Nitrospira division and by epsilon-Proteobacteria. Loihi Cluster II also contains phylotypes associated with Thiomicrospira spp. and from within the "M. ferroxydans" clade. The presence of epsilon-Proteobacteria and Thiomicrospira spp. in this group suggest these microbial mats are potentially more involved with sulfur-cycling than Loihi Cluster I, which are dominated exclusively by iron-oxidizing bacteria.

The Supply of Food and Larvae to Benthic Seamount Communities

Mullineaux, L S

Physical processes at seamounts influence the transport and retention of living and non-living particles. When fluxes of particles such as small plankton or detritus are enhanced near a seamount, the food supply to benthic organisms is increased. When particles such as larvae of benthic organisms are retained near a seamount, their recruitment into the natal populations may be increased, but their exchange with other seamount populations will be limited. This talk explores how the physical processes at seamounts appear to influence food supply to the populations of suspension-feeding corals and sponges that live there in dense aggregations. It also reviews the evidence for retention of larvae and other particles near seamounts and considers the implications of larval retention for population connectivity and endemism of benthic species.

Looking inside Loihi with Electrical Resistance Tomography

Myer, D

In July 2006 we will carry out a completely novel study of an active seafloor volcano (the Loihi Seamount). Electrical Resistance Tomography (or ERT), also known as electrical impedance tomography, is a medical technique used to image the human body, but is also used in geophysics to study the porosity of core samples in the laboratory, and map groundwater in borehole-to-borehole experiments. Here we propose to carry out a 3D ERT study of an active volcano, by deploying 20 or more seafloor electromagnetic recorders around the perimeter of Loihi seamount and towing an EM transmitter around the same path. Both receivers and transmitter will be at a depth of 1500 m, or 500 m below the summit of the volcano. The intersecting geometries of approximately 140 transmitter locations broadcasting to 20 receiver locations will allow us to build an electrical conductivity image of a horizontal slice through the volcano at a depth of 500-1000 m below seafloor. Since electrical conductivity is closely linked to the

presence of fluids, both magmatic and hydrothermal, we will effectively be peering into the plumbing of the volcano.

Evidence that Three Seamounts off Southern California were Ancient Islands

Paduan, J B; Clague, D A; Davis, A S; Huard, J

Eleven ROV Tiburon dives in 2003 and 2004 explored Rodriguez and San Juan Seamounts, and Northeast Bank off southern California. Now submerged, these seamounts appear to have been subaerially exposed while the volcanoes were active.

The summit of Rodriguez seamount, now at 630 m depth, is a smooth, gently domed platform. The shallowest points are low, rough hills standing above the platform and consist of thick, dense, degassed `a`a flows erupted and oxidized subaerially. Coarse bedded and cross-bedded sandstones and rounded cobbles interpreted to be beach deposits occur near the top of a major break-in-slope at about 700 m. Rodriguez stood at least 70 m above sea level and formed a small island 6.8 km2 in area prior to subsiding at least 700 m.

The summit of Northeast Bank, now at about 360 m, is another smooth, gently domed platform. Wave-sculpted lava flows, sandstone, and pebbly conglomerate beach deposits were observed between 510 and 554 m depth, below the sharp break-in slope at about 500 m depth. Although the bathymetry of the entire summit is poorly known, Northeast Bank was a large island perhaps 200 m above sea level and 90 km2 in area.

The summit of San Juan Seamount, now at 560 m depth, is a northeast-southwest trending series of rough ridges rather than a dome. However, subaerially oxidized `a`a-like lava flows were found above 700 m. San Juan's summit ridge emerged as a line of eight small islands with a total area of about 2.8 km2, and the tallest island rose 140 m above sea level.

Preliminary Ar/Ar dating on single samples from San Juan and Northeast Bank yield 18.7 and 7.2 million years, respectively, whereas five samples from Rodriguez had ages ranging from 9.9 to 17.9 million years. Similar subsidence of 550 to 700 m occurred on Northeast Bank within the California borderland, Rodriguez Seamount on the continental slope, and San Juan Seamount on the adjacent ocean crust, despite their dissimilar ages.

The Hawaii Ocean Mixing Experiment

Pinkel, R

The Hawaii Ocean Mixing Experiment (HOME) is a multi-investigator multi-year program to study tidal mixing processes on the Hawaiian Ridge. The goals of HOME include identifying the principal physical mechanisms active in barotropic-baroclinic conversion, as well as in the subsequent radiation and dissipation of baroclinic energy. Forming an energy budget for these processes is a unifying focus. Ultimately, we wish to understand the basic physics sufficiently well that the influence of sites such as Hawaii on the larger scale circulation can be assessed.

HOME started in 1998, with initial effort directed toward the analysis of existing data and the development of relevant numerical models. A survey of the Ridge in Fall 2000 identified strong barotropic-baroclinic conversion at French Frigate Shoals, near Nihoa Island and on the Kaena Ridge (which extends westward from Oahu toward Kauai). A subsequent "Farfield" experiment (2001-2002) focused on quantifying the energy lost from the barotropic tide as well as that radiated into the deep sea in low-mode baroclinic waves. The final HOME field effort was staged on the Kaena Ridge in fall 2002. This "Nearfield" investigation emphasized the conversion process, the local energy cascade and the various mechanisms which effect energy dissipation.

Intense mixing was identified in the 300 m above the 1100 m deep Ridge. One hundred meter tall overturns were seen. These appeared to be directly forced by flow over the sloping seafloor and exhibited a spring-neap cycle. Mid-water and upper-ocean mixing levels were enhanced within 25-50 km of the Ridge. Mid-water mixing appeared to be supported by energetic, high mode internal waves of ~24 hour period. These waves could be a sub-harmonic of the semi-diurnal internal tide. With the field phases of HOME complete, the focus has now shifted to the joint analysis of data and the assimilation of results.

The Global Distribution of Seamounts from Ship Depth Soundings and Satellite Altimetry

Sandwell, D T; Wessel, P

Seamounts are active or extinct undersea volcanoes rising more than 1 km above the abyssal plain. They represent a significant fraction of the volcanic extrusive budget for oceanic seafloor and their distribution gives information about spatial and temporal variations in intraplate volcanic activity. In addition, they sustain important ecological communities, determine habitats for fish, and act as obstacles to currents, enhancing tidal energy dissipation and ocean mixing. For all these reasons, it is important to locate and characterize seamounts. Two approaches are used to map the global seamount distribution. Depth sounds from single- and multi-beam echo sounders can provide the most detailed maps with up to 200 m horizontal resolution. However, soundings from the 5600 publicly available cruises sample only a small fraction of the ocean floor. Satellite altimeter measurements of the marine gravity field can detect seamounts taller than about 2 km and such studies have produced seamount catalogues holding almost 15,000 seamounts . Recent retracking of the radar altimeter waveforms to improve the accuracy of the gravity field has resulted in a two-fold increase in resolution. We predict that 45,000 smaller seamounts remain uncharted. Future altimetry missions could improve on resolution and decrease noise levels even further, allowing for an even larger number of small (1-1.5 km) seamounts to be detected. Mapping the complete global distribution will help constrain the hotly-debated models of seamount formation as well as aid in understanding of marine habitats and deep ocean circulation.

Reconnaissance Geological Mapping From First Multibeam Surveys and Submersible Dives at the U.S. Line Islands of Jarvis Island, Palmyra Atoll, and Kingman Reef

Smith, J R; Dunbar, R B; Parrish, F A

The Hawai‘i Undersea Research Laboratory (HURL) carried out the first dedicated multibeam surveys (Smith et al., 2006) and submersible dives (Mundy and Parrish, 2006) at the U.S. Line Islands of Jarvis Island, Palmyra Atoll, and Kingman Reef during July 2005. Rose Atoll in eastern American Samoa was also visited and existing survey coverage was extended up its flanks and more data were added to the regional bathymetric coverage surrounding Tutuila in American Samoa on its northern flank (Wright, 2005; Wright et al., 2006). A total of 16 submersible dives at the named locations provided enough nighttime survey opportunities to carry out a significant amount of mapping operations.

The coverage at each location included 190 km2 on the north side of Tutuila (Figure 1), 59 km2 at Rose (Figure 2), 51 km2 at Jarvis (Figure 3), 491 km2 at Palmyra (Figure 4), and 478 km2 at Kingman (Figure 5) for a total of 1269 km2 and in depths ranging from ~100 to 2000 m for almost complete circumferential coverage (except Tutuila) and to over 4000 m on transits around and between locations. Steep walls of ancient carbonate cut by reentrants were mapped with multibeam and ground-truthed during Pisces submersible dives where the terrain was even more complex than identified in the swath bathymetry. From submersible observations, the flanks of all three Line Islands exhibited steep slopes with ridges, canyons, overhangs, rock slides, and evidence of strong sediment scouring (Mundy and Parrish, 2006). No basalt or other volcanic outcroppings were found at the depths of this dive series.

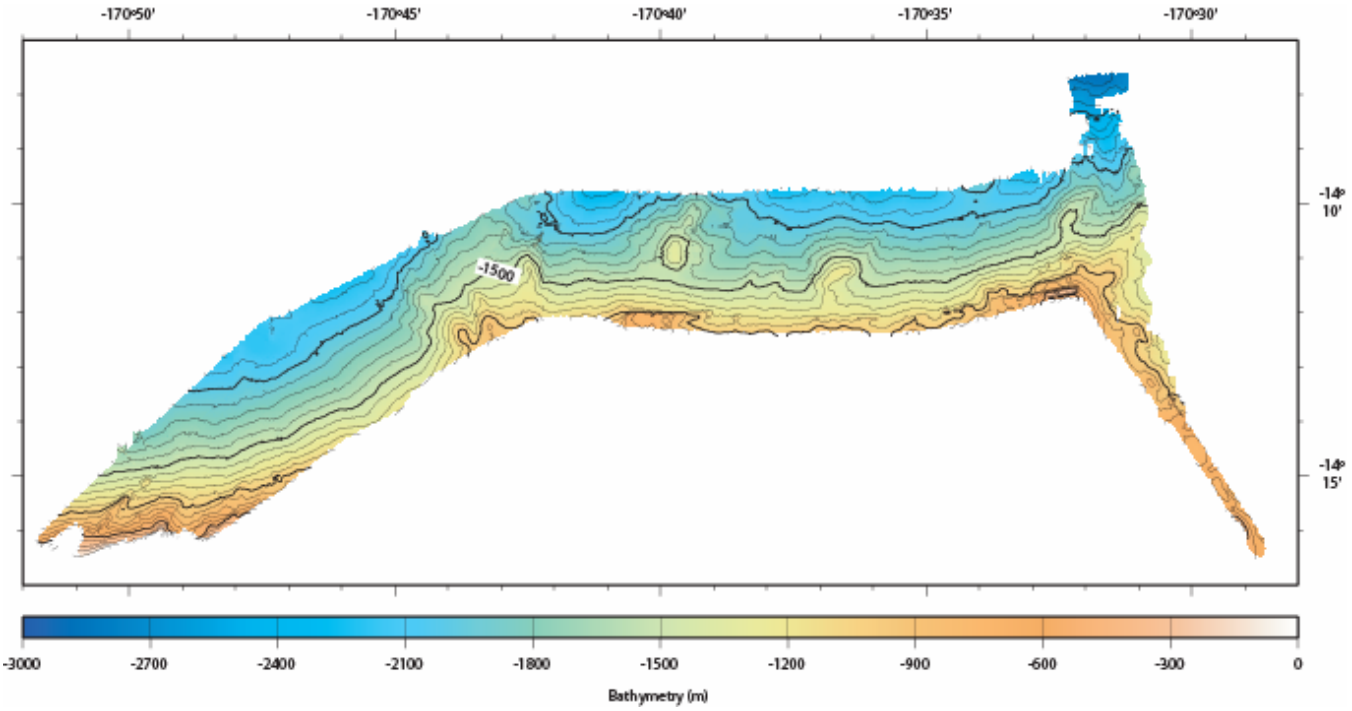

Figure 1. North flank of Tutuila, American Samoa. KoK0510 SeaBeam 210 bathymetry, 100 m contours.

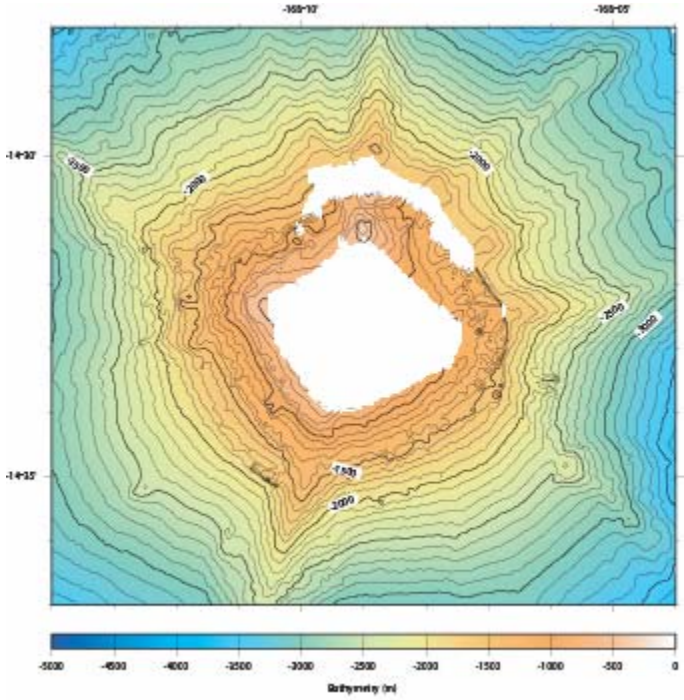

Figure 2. Rose Atoll, American Samoa - KoK0511 and SIO SeaBeam bathymetry, 100 m contours.

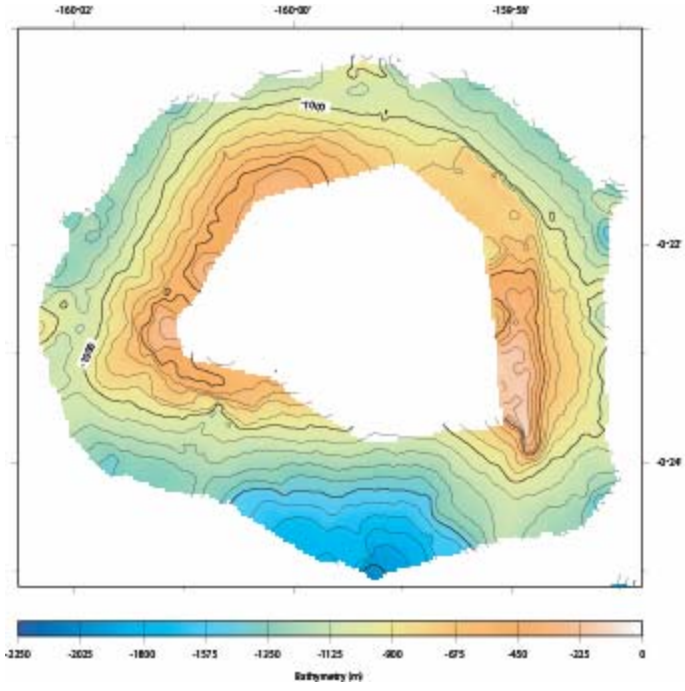

Figure 3. Jarvis Island - KoK0511 SeaBeam 210 multibeam bathymetry, 100 m contours.

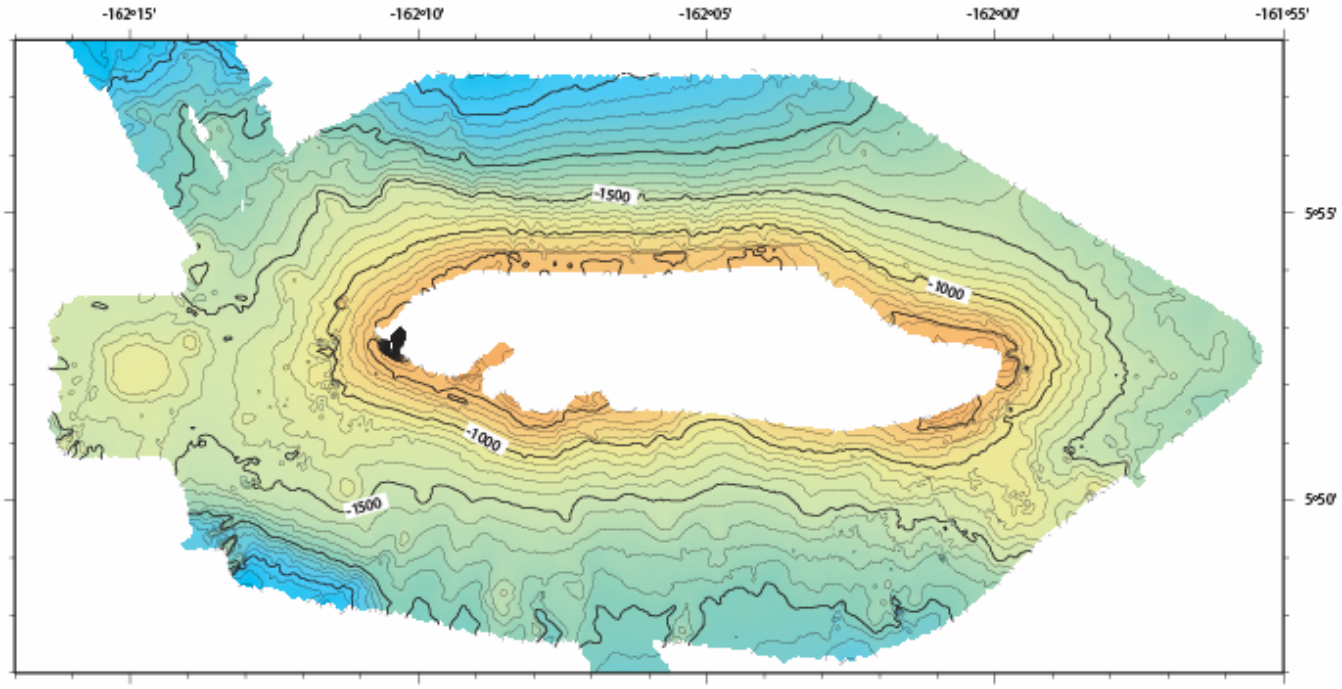

Figure 4. Palmyra Atoll - KoK0511 SeaBeam 210 bathymetry, 100 m contours. See Fig. 5 for color depth scale.

At Rose Atoll, pinnacles with tens to over a hundred meters relief ring the 500 to 1000-m water depth range, along with 7-8 steep rift zones beginning at approximately 1500 m radiating out and extending to abyssal depths. At Jarvis Island, measurements from ship's radar determined it is mislocated on the 1930's era nautical charts. Confirmed by the multibeam mapping, the island and its platform are located 1.4 nautical miles bearing 074 from the charted position. The south flank of the Jarvis Island platform contains a concave scarp and steep chute that may represent a landslide failure surface and several 1000-m deep pinnacles are evident on other sides of the platform. Observations from the submersible found that shallower than 400 m the terrain was composed of sedimentary rock outcrops (possibly Cretaceous given the age of the Line Islands), most likely limestones with a shallow water carbonate platform provenance. Vertical features were quite rugged and appeared to be current and/or sand swept. A spectacular 200-m wall between ~400 and ~600 m water depth was also observed.

Palmyra Atoll has a suite of pinnacles on its south and west flanks in addition to a flat-topped volcanic cone with 200-m relief, has a 3-km basal diameter, and a summit depth of 1160 m. This was the largest individual feature mapped. The atoll and its platform have a unusual east-west oriented elongated shape with no distinct rift zones extending offshore in these directions. Instead, a rift zone and/or ancillary cone(s) splits off to the southeast on the eastern end, possibly another to the northeast beyond the surveyed area, and one off the western end to the northwest. The northern flank is relatively featureless in the bathymetry and may represent the upper portion of a giant landslide amphitheater, explaining the present day elongate shape of the atoll platform. In contrast, the southern flank has numerous large reentrants or canyons between ridges, possibly representing rift zones and volcanic centers at depth.

At Kingman Reef, initial radar surveys also determined it is improperly positioned on the old nautical charts. Again, this was confirmed by multibeam mapping and the reef and its platform are located 1.3 nautical miles bearing 124 from the charted position. Kingman Reef has perhaps the most interesting geomorphology. The reef and its platform are triangular in shape with a field of about 30 pinnacles on

the western end, almost certainly volcanic cones, in the depth range of 1000-1800 m and probably extending deeper beyond the mapped area. The south flank is relatively broad and featureless whereas the northwestern and northeastern flanks exhibit numerous small landslide amphitheaters and potentially larger ones encompassing these entire flanks that extend beyond the mapped area. The regional outdated nautical chart showed a broad saddle with shallow bathymetry between Palmyra and Kingman, separated by approximately 40 nm. Three transits across this area while surveying with multibeam found only abyssal depths with no indication of a shallow bridge.

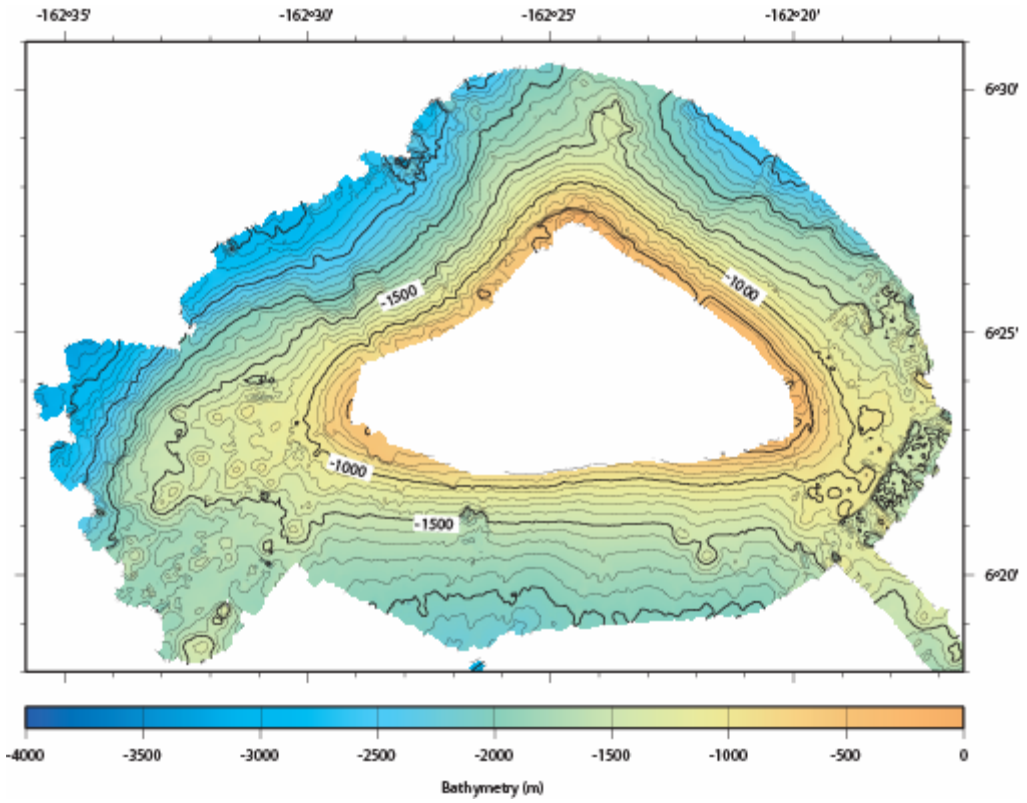

Figure 5. Kingman Reef - KoK0511 SeaBeam 210 bathymetry, 100 m contours.

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Seamount biodiversity, endemism, and biogeography: a review

Stocks, K I; Hart, P J B

One of the reasons why seamounts have been the focus of substantial ecological research is that they are thought to represent unique communities, supporting assemblages of species that are distinct form the surrounding seafloor. The authors conducted a literature review to examine three aspects of community structure – biodiversity, endemism, and biogeographic affinities – to ask how distinct seamount communities really are.

The topic has clear management implications, for example determining whether marine protected areas on seamounts are needed and how they should be placed. Describing and comparing seamount community structure also has theoretical implications: once patterns are determined, they can be compared to predictions from various biogeographic theories to understand how these theories may be useful for predicting from the handful of studied seamounts to the tens of thousands of unknown ones.

Biodiversity. With respect to overall biodiversity, comparable data were limited due to insufficient sampling on most seamounts and the lack of comparable methods across studies, but no clear trend of either elevated or depressed species richness emerged. The most complete data was found for benthic and near-bottom invertebrates: of the six studies comparing these fauna on seamounts to nearby continental margins of similar depth, two found higher diversity, two found lower, and two were similar. Of the four studies comparing seamounts with nearby deep seafloor, two found higher diversity, one found lower, and one was similar. Data on fishes and pelagic invertebrates were too sparse to evaluate.

Endemism. One of the most compelling arguments for seamounts as isolated communities is the high levels of endemism apparently found on many. Endemics are defined here as species that are found on a single seamount or seamount chain and nowhere else in the ocean. Even considering that our extremely limited sampling of the deep sea means that we have little knowledge of the true distribution of most, if not all, species, it is difficult to dismiss as purely artifact the levels that have been found. Large-scale studies have found that 10-50% of the bottom or near-bottom species found are endemics, which is similar if not higher than that for the marine communities around isolated pacific islands.

Biogeography. For those seamount species that are not endemics we asked how similar seamount communities are to the nearest continental margin (for bottom-associated species) or the surrounding open ocean waters (for pelagic species). Overall, when endemics were eliminated, in most cases seamounts support both benthic and pelagic communities that are comprised of a mix of regional and widespread species. While range extensions and exceptions have been found, the generality seems to be that seamounts share a similar pool of species as the surrounding region, making bioregionalization schemes such as Longhurst's provinces potentially useful management tools for classifying seamounts.

This abstract is drawn from a chapter that will be included in the forthcoming book "Seamounts: Ecology, Fisheries, and Conservation," due out in 2006 from Blackwell Publishing. The chapter will include full references and data appendices.

SeamountsOnline: an online information system for seamount biodiversity

Stocks, K I

SeamountsOnline (http://seamounts.sdsc.edu) is an online resource for researchers and managers seeking data on the biodiversity of seamounts (undersea peaks in the ocean's floor). The goal is to bring together data on species that have been sampled or observed from seamounts and make these data freely available through a searchable website.

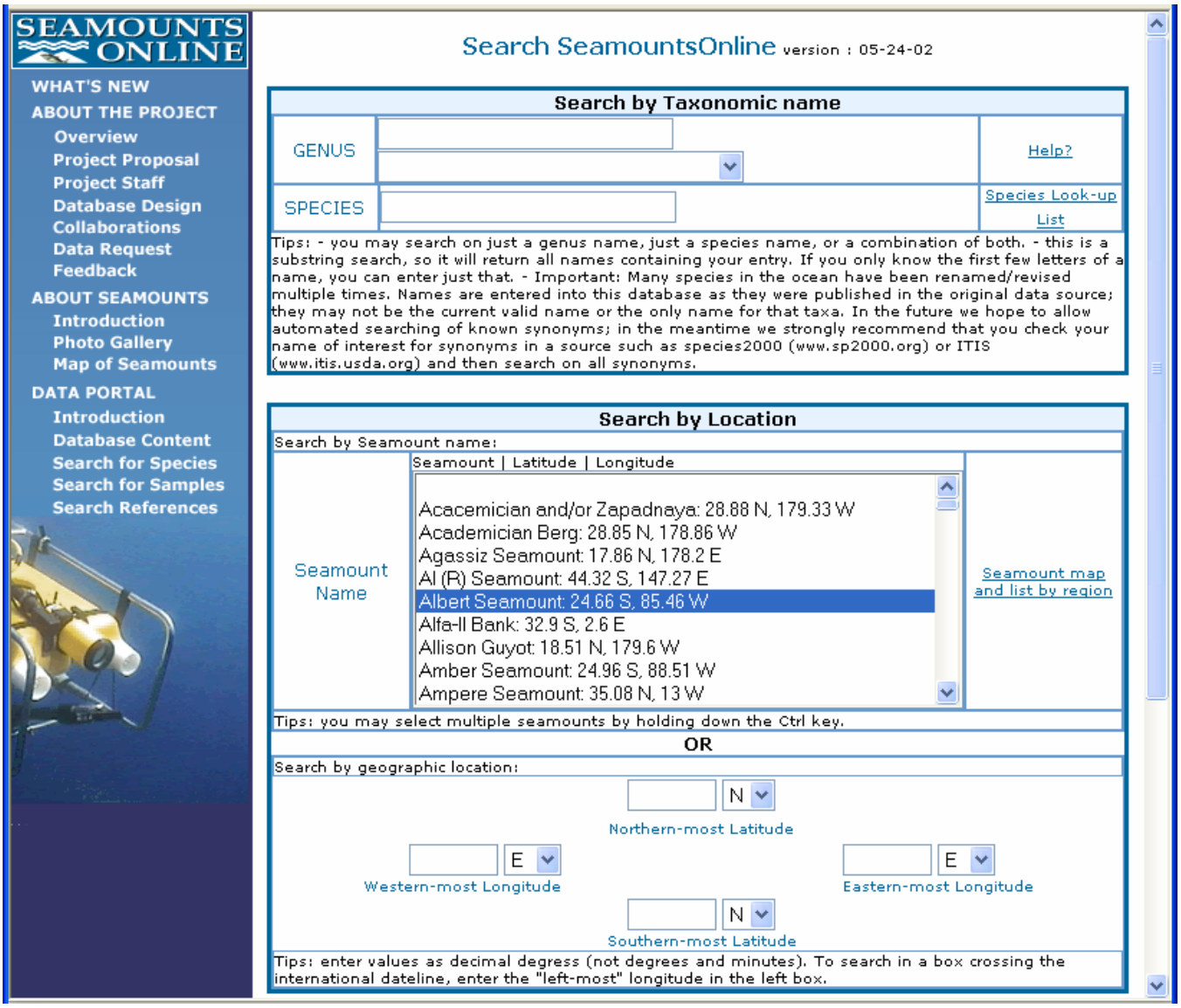

Figure 1. Interface for the "Search by Species" search option. The user can enter a genus or species of interest to retrieve a list of all the locations where that organism has been found, or they can select a location of interest (by either clicking a seamount name or entering a latitude-longitude box) to see all the species recorded from that seamount. The searches can also be combined to ask for "all records of Genus X in region Y."

Data Content. The data in SeamountsOnline are being compiled from literature publications and the holdings of researchers and institutions working on seamounts. The database covers seamounts globally and includes fishes, invertebrates, and plants. The core information that SeamountsOnline collects is a

species distribution record: this is a record of the observation or collection of a particular species from a known seamount location. Supporting each record is information on who provided the record and how and when the sample was collected or the observation made. At present, SeamountsOnline is serving 12,000 records covering over 3,000 species or higher taxa from 231 seamounts. The content is continually expanding; certain regions and groups of organisms are better represented than others, and the reader is referred to the 'Database Content' link on the SeamountsOnline webpage for a current description of the holdings.

Functionality. Through the website, users can 1) search on a species or genus and find all the seamounts from which it has been recorded (Figure 1); 2) search on a seamount and find a list of all species recorded there; 3) select a seamount and see details of sampling events on that seamount (e.g. locations, dates, gears used, and expedition names) with links to the species found in each sample; and 4) search a bibliography of over 1400 literature references on seamounts.

Future Expansion. SeamountsOnline is currently undergoing a major redesign and expansion. The new system will have a GIS interface for searching for data by location (including selecting data by Exclusive Economic Zone), will add fisheries and marine protected area data; will include habitat information such as substrate type; and will link to physical and environmental datasets such as climatologies for salinity, temperature, and surface productivity. Interested users are welcome to visit and comment on the development site as it evolves at http://aqua.sdsc.edu/seamounts (under the Development tab), but should not use it for research.

Partnerships. SeamountsOnline is the database component of the Census of Marine Life on Seamounts (http://censeam.niwa.co.nz), an international science program coordinating and catalyzing research on seamount communities. It is also a data contributor to the Ocean Biogeographic Information System, an international portal for marine species distribution data. Data in SeamountsOnline can be accessed through the OBIS website at http://www.iobis.org as well as through the SeamountsOnline website.

Data Request. SeamountsOnline is continually seeking new seamount data. Though data are being hand-entered from publications, this process is labor-intensive and often can access only summarized or condensed data. SeamountsOnline will grow most efficiently, and thus become most useful, if researchers and institutions are willing to provide electronic datasets for inclusion. These contributions are always fully acknowledged, and all intellectual property rights remain with the data provider. Please contact the author if you have data to contribute.

Deep-Dwelling Corals and Deep-Sea Fisheries on Seamounts in the North Atlantic.

Watling, L; Waller, R; Auster, P J; France, S C

Atlantic seamounts are not accorded the same level of attention as those in the Pacific. This is due in large part to the fact that there are not very many seamounts outside of the mid-Atlantic Ridge axis. One long chain of seamounts, however, runs from the Azores to the northeastern U.S. continental slope. We have had a series of cruises with the purpose of documenting the distribution and biology of the scleractinians, octocorals, and antipatharians found along this chain. Along the way we also saw evidence of

impacts from a deep-sea fishery that was conducted in the central part of this chain from the mid-1970s to mid-1990s.

The removal of coral and other large biogenic structures as a consequence of deep-sea fisheries is well documented for seamounts in the SW Pacific and is presently the focus for strong conservation measures across the globe. As continental shelf fish stocks decline and fisheries regulations become stricter, there is continual movement of fisheries vessels into the unregulated and unreported high seas making the true impact hard to determine. As in the Pacific, fishing on seamounts in the Atlantic is not without its habitat consequences, yet until now these were largely unknown.

While seamount fisheries have been relatively rare in the Atlantic there have been limited fisheries for species such as grenadiers (Macrouridae), alfonsinos (Berycidae), smoothheads (Alepocephalidae), codlings (Moridae), oreos (Oreosomatidae), cutlassfishes (Trichiuridae) and roughies (Trachichthyidae). The target species for most seamount fisheries, the orange roughy (Haplostethus atlanticus), has been strongly overfished in most of the North Atlantic, especially over Mid-Atlantic Ridge seamounts. For twenty years (1976-1996) there was significant effort expended in the area of the Corner Rise Seamounts, primarily targeting alfonsino (Beryx splendens) and oreo (Neocyttus rhomboidalis) using both pelagic and bottom trawls. Though many fish species were recorded in this fishery, there is no information on invertebrate bycatch.

During our Corner Rise cruise we saw multiple scars (~20cm width) from the ground gear of trawls on the top plateau of Lyman Seamount with mass upturning of scleractinian hard corals (Lophelia pertusa) and broken soft coral branches (Paragorgia sp.) running along the central ridge. Broken Paragorgia branches were also observed in abundance on the slope leading to the top plateau, possibly having been broken during trawling and thrown down-slope, or transported after breakage. The number of live corals seen on the plateau was minimal compared to other seamounts visited on the cruise (10 in total). Kükenthal Seamount showed more active and possibly recent trawling activity. This dive started with a traverse up a large agglutinated carbonate wall. On reaching the summit multiple, large scar marks were particularly evident on the edges, following onto the main plateau. This plateau was gently sloping and distinctly faunistically zoned. The deeper edges of the plateau consisted of sparse Parantipathes sp. (black coral) in a thin veneer of sediment. This zone was followed by multiple large white 'amphitheatre' sponges, many with associated morid fishes (Laemonema sp. and Physiculus fulvus). At ~730m the sponge zone ceased and sessile fauna were conspicuously absent. Numerous multi-directional trawl scars, displaced boulders (most likely glacial dropstones) and debris (shackles, metal cans, and bricks) were most prevalent.

We are in the process of identifying the octocorals and antipatharians collected during this and previous cruises, so the biogeographic data are still somewhat limited. Because of taxonomic "lumping" and other mistakes of identification, we cannot make definitive statements about levels of endemism for many of the coral species. The scleractinians are the best known, and all the species sampled are widely distributed around the North Atlantic. Within the octocorals, a few species such as Acanthogorgia armata and Paragorgia arborea are broadly distributed around the continental slope and adjacent ridges of the North Atlantic basin, but as our taxonomic work progresses most probably will not be found to occur on the central basin seamounts. In contrast, the plexaurid, Paramuricea biscaya, described initially from the Bay of Biscay, has been found to occur widely on the seamounts across the North Atlantic, but not on the continental slope and adjacent ridges north of 36 N either in the eastern or western parts of the North

Atlantic. More detail on distributions will be presented, but we are moderately certain that levels of endemism in the North Atlantic will be found to be very low and that it will be possible to delimit at least two North Atlantic deep ocean basin-wide biogeographic provinces that are tied rather closely to patterns of deep current flow.

The Role of Seamounts in Ventilating the Oceanic Crust: Geochemical Fluxes and Their Impact on Global Geochemical Budgets.

Wheat, C G

Ridge flank hydrothermal systems (RFHS) remove most of the convective heat loss from the oceanic crust. This heat loss and the associated fluid flow is almost completely confined to seamounts and guided by faults, because the permeability of basaltic basement is orders of magnitude greater than that of overlying sediment. The magnitude of this flow is the largest crustal fluid flux in the oceans, but it is only ~66 % of the riverine water flux. Yet even a small chemical anomaly, resulting from water-rock interactions or from diffusive exchange with the overlying sediment, coupled with this amount of flow could result in a chemical flux that is important (defined as >10%) to global budgets. For example, the entire riverine influx of Mg could be deposited within the oceanic crust in the form of secondary clays (primarily smectites), given this vast flow of seawater through the crust and only a 0.3% decrease in the seawater concentration. Although the calculated thermal and fluid fluxes from RFHS are fairly well constrained, chemical fluxes from RFHS are not well constrained because of the paucity of sites sampled to date.

The most thoroughly studied site is Baby Bare, which is a basement outcrop that overlies 3.5 million year old crust on the eastern flank of the Juan de Fuca Ridge. Springs have been sampled along faults on this basaltic outcrop, which penetrates about 70 m above the sediment plain that is typically several hundreds of meters thick. These warm springs (25.0°C) have cooled from warmer (~64°C), anoxic basement formation fluids and support microbial and clam communities. The source for these fluids is a seamount ~52 km to the south-southwest, where cool (2°C) oxygenated bottom seawater enters the crust. Along the flow path these fluids warm, react with basalt, and exchange diffusively with overlying sediment, before venting at the seafloor. A variety of redox conditions exist along this path, presumably supporting a variety of microbial communities. Coupled with other pore water studies of the Costa Rica Rift and the EPR eastern flank, warm (~60°C) RFHS generally have a similar composition. On the basis of this composition, calculated fluxes from these warm RFHS have an impact on global budgets for Mg, Na, K, Li, Ca, Sr, Sulfate, B, Mo, and Ge. These calculated fluxes are limited by the removal of Mg such that the removal flux cannot exceed the riverine input of Mg. This Mg-flux argument limits the amount of heat loss and seawater flow associated with warm RFHS; Only 7% of the entire ridge flank convective power output is associated with such warm RFHS. The remaining convective power output must occur at low temperatures (3-20°C), requiring most of the above mentioned seawater flux to cool the crust.

The importance of seawater flow through young, cool crust is highlighted in studies of basaltic alteration, based on samples recovered during deep sea drilling operations (DSDP, ODP and IODP). These studies show marked changes in the bulk composition of the crust, impacting global budgets for some elements. Similarly, several pore water studies of cool RFHS have been undertaken. Recently, pore water data has been acquired from two low temperature RFHS on the eastern flank of the East Pacific Rise;

one at 18°S (5°C) and the other at 9°N (10°C). Marked differences in the composition of these formation fluids relative to bottom seawater are evident in those chemical species that are highly reactive in sediment pore waters and typically associated with microbial processes (e.g., nitrate, phosphate, alkalinity, sulfate, Mn, and Fe). Other elements that are highly reactive in the sediment section such as F, Si, and Ge (?) also result in measurable chemical anomalies in basaltic formation fluids relative to seawater. Chemical anomalies for the major ions in seawater approach the limit of detection using surface coring techniques, yet global compilations of formation fluid compositions and temperatures suggest that low temperature (5-20°C) RFHS could have a profound impact on global geochemical budgets for the major ions in seawater, consistent with studies of rock alteration.

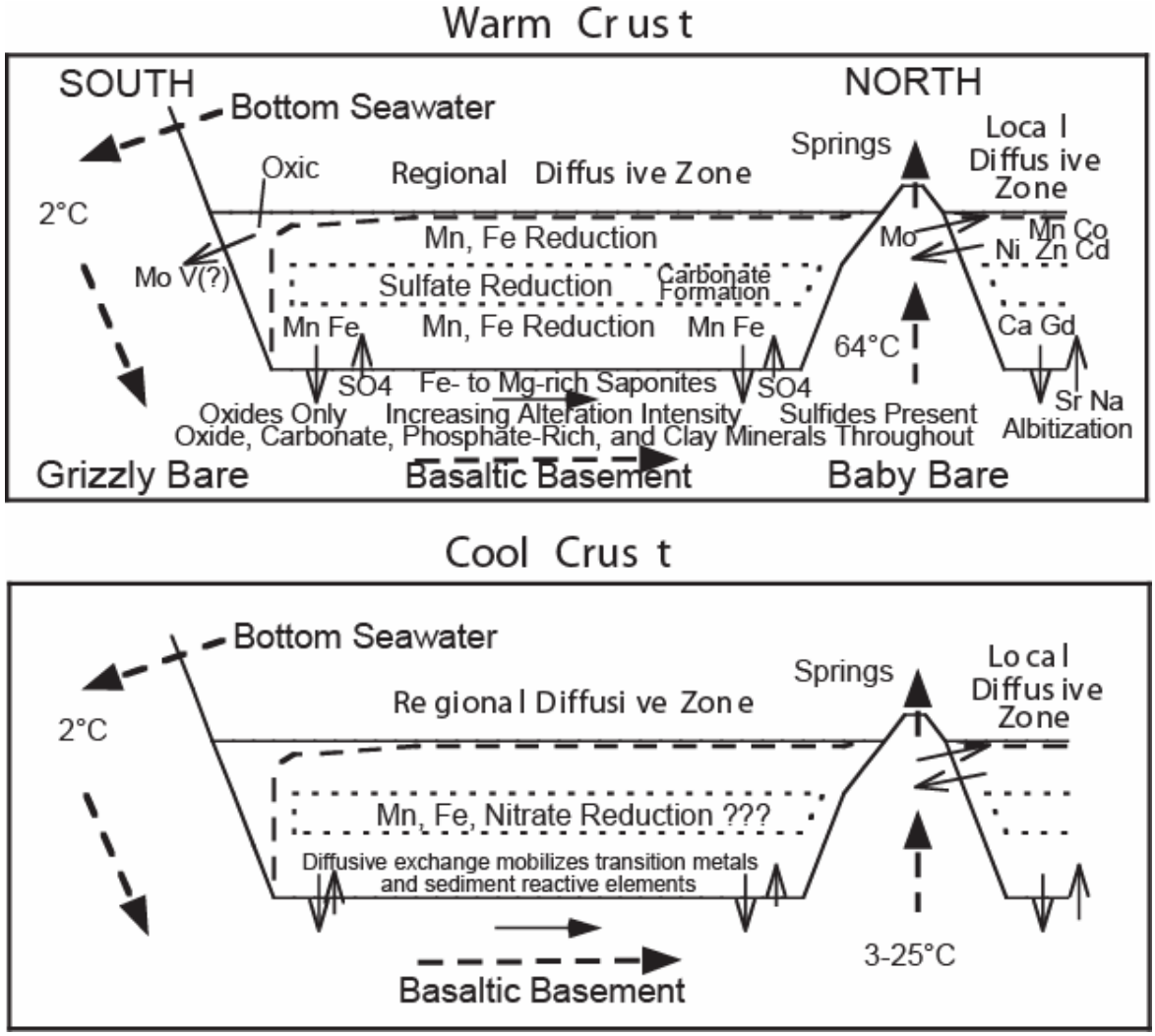

Figure A conceptual diagram of fluid flow and reaction within the crust for two scenarios; warm and cool crust. On the eastern flank of the Juan de Fuca Ridge bottom seawater enters basement at Grizzly Bare and flows to the north, northeast where it vents naturally at Baby and Mama Bares (dashed arrows). Along this flow path the seawater warms from about 2° to 64°C. The water also becomes more altered as the fluid reacts with basaltic basement and chemical exchange occurs from diffusive transport, resulting from differences in the pore water composition of overlying basal sediment and the formation fluid in basaltic basement. The same scenario exists in cool crust, which typically has a thinner sediment cover. Because flow is faster and temperatures are cooler, the extent of reaction within basaltic crust has a minor affect on altering the composition of the formation fluid. Diffusive exchange with the overlying sediment does however have an obvious impact on the formation fluid composition (modified from Wheat et al., 2002, GCA, 66: 3693 3705.).

In summary, our present state of knowledge of chemical fluxes from RFHS is derived from (1) ~10 boreholes that have penetrated at least 100 m of basalt, accounting for <1 trillionth of 1% of the area of the seafloor and have a rate of recovery that is often only 30%, (2) one hydrothermal spring that has been sampled directly at the seafloor, yet has an anomalous geologic setting compared to "typical" oceanic crust, and (3) a handful of sites where pore water studies document the advective seepage of formation fluids through the sediment section. Estimating a global budget or flux based on these data is equivalent to sampling and analyzing water from a local river, then extrapolating this result for an estimate of the global riverine flux. To make fundamental improvements upon our present estimates, we need to sample directly the equivalent of an "Amazon River" in the realm of RFHS. An "Amazon River" RFHS would be one that is cool (5-15°C), located on fast spreading crust, has surrounding sediment thicknesses consistent with average deep ocean depositional rates, and is within a region where the crust is extensively cooled by circulating seawater.

The history of seamounts that reach the sea surface: the formation of reefs, crags, barriers, atolls, guyots.

Winterer, E L

Only a tiny proportion — a few percent — of seamounts attain heights that bring their summits above sealevel where a post-volcanic history more complicated than mere subsidence can develop. Nearly all of these island volcanoes erupt on lithosphere older than 5 m.y, and most develop on crust at least several tens of m.y. old.

Isostatic subsidence is rapid during volcano construction but slows markedly to thermal rates afterward. Complex subsidence histories result from flexural effects of nearby seamounts. In middle and high latitudes seamount islands are eroded by waves and streams as they subside and they may become guyots if wave planation is especially severe; otherwise a variably eroded volcanic landscape drowns, generally attracting no scientific interest. During subsidence, extra-tropical seamounts commonly are encrusted with a thin cover of a cool-water biota: bryozoans, calcareous algae, and benthic foraminifers — the "crags". The Emperor seamounts typify this regime.

In tropical latitudes, calcareous reefs advance over the volcanic landscape as it erodes and subsides below sealevel. Reef growth rates rapid enough to keep up with subsidence are required, and thus corals with algal symbionts as well as certain calcareous algae are the main constituents of the reefs. Establishment of a continuous and nearly flat reef cover is generally gradual, the reefs extending ever farther inland as the volcano subsides. Once established, the reef can generally continue to keep up with subsidence. In some places, notably on western Pacific Cretaceous and Eocene reefs, as much as 1600 m of reefal carbonates accumulated. Final drowning results in a guyot.

Sealevel fluctuations complicate this simple picture. A fall of sealevel, if faster than the rate of tectonic subsidence, exposes and kills the reef but commonly the next sealevel rise will redrown the old platform and a new reef can grow. During exposure, rainfall partly dissolves the old reef, commonly creating a central depression that is left as a lagoon at the next sealevel rise. Where the reef was a fringing reef around the volcanic island, the lagoon separates the barrier reef from the island. Where the reef covers the entire island, repeated fluctuations of sealevel, particularly those of the magnitude a frequency of those in the Pleistocene, result in the formation of an atoll. This, rather than the Darwin model, is how

atolls are created. Few pre-Neogene atolls are known, possible because sealevel fluctuations were of insufficient amplitude (100 m) and duration (100 ky) to permit the necessary rainwater dissolution. The Early Cretaceous guyots of the Western Pacific preserve atoll morphology, possibly owing to final tectonic uplift that killed them.

Final reef drowning, owing to increased tectonic subsidence rates, or, more commonly, to drift of the seamount into higher latitudes unfavorable to healthy coral growth, is commonly succeeded by very slow accumulation of phosphorite, in moderate depths, or by manganese crusts, in deeper water. From here on, a Pacific seamount awaits tectonic drift toward subduction, while Atlantic and Indian Ocean seamounts mainly just keep subsiding.

Seamount Communities and Pelagic Interfaces: A Tale of Two Seamounts

Wishner, K F; Gowing, M M; Levin, L A

What happens when a strong pelagic chemical interface intersects a seamount? How do responses of zooplankton and benthos differ and what unique interactions are created by the seamount situation? We have opportunistically explored two examples of this phenomenon. The first deals with a seamount penetrating into the oxygen minimum zone; the second deals with hydrothermal vent effluent in a volcanic crater. In both cases, the chemical gradient seems to be spatially (horizontally) extensive, although varying in depth over time, and delineates a zone physiologically hostile to many animal taxa. This has created some unusual biological distributions.

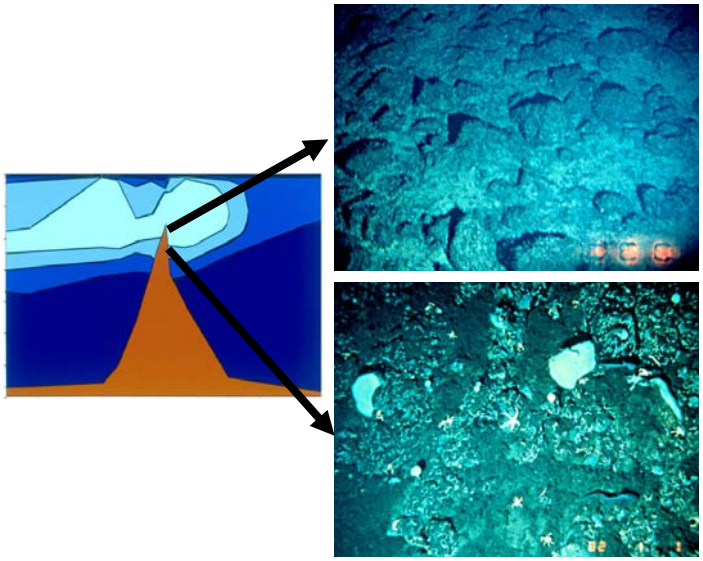

Figure 1. Photos from Volcano 7 showing the seamount summit within the lowest oxygen water (top) and slightly deeper in more oxygenated water (bottom) along with a schematic of the seamount.

At a geologically-inactive seamount, Volcano 7, in the Eastern Tropical Pacific, the lower boundary of the regional oxygen minimum zone oscillated with the internal tides at the seamount summit (~ 750 m). This resulted in strong vertical zonation of biomass and species of both benthic fauna on the seamount

and zooplankton in the water column (Wishner et al. 1990; 1995; Levin et al. 1991; Levin 2002). Biomass and species were sparse in the lowest oxygen water at the seamount summit and much higher slightly deeper in more oxygenated water. We hypothesized that zooplankton remained in their preferred oxygen regime and changed depth with the persistent but oscillating pelagic chemical interface, while the benthos integrated predictably changing conditions at a particular location over time. For the benthos, these varying conditions probably included not only the oxygen content of the water, but also suspended food availability from the plankton peak located at the moving oxygen interface.

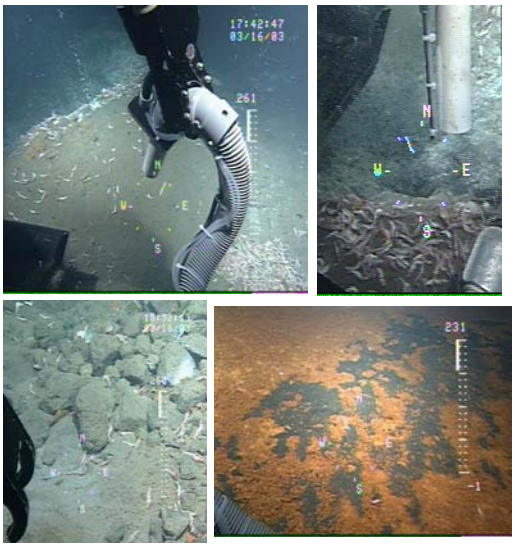

Figure 2. Photos from Kick'em Jenny showing the shrimp aggregations in the central crater near active venting (top) and lying on the seafloor (bottom left) and also a photo from outside the crater (bottom right) (Wishner et al. 2005).

At the geologically-active submarine arc volcano, Kick'em Jenny, in the Caribbean Sea near Grenada, we found aggregations of shrimp at hydrothermal vents in the volcanic crater (~250 m) (Wishner et al. 2005). However, the shrimp were not the typical vent species that one might expect. On the contrary, 3 species of midwater shrimp, never before found in a benthic situation, comprised the aggregations. Some of the shrimp were actively swimming while others lay immobile on rocks or sediment. No shrimp were seen in secondary craters that had no active vents. We hypothesized that the shrimp came from the deeper water populations of the Caribbean and were trapped within the central crater during their downward vertical migration. They may then have succumbed to the hostile chemical environment created by vent effluent (immobile individuals) or could even be potentially opportunistic vent residents (active individuals). But mysteries remain. Why were no other planktonic or nektonic taxa found with the shrimp, which would be expected if accidental trapping of vertical migrators occurred from noxious effects of vent effluent? Why were there no shrimp or other obvious vertical migrators in the inactive craters, if topographic entrapment were the only consideration?

Given the abundance of seamounts and submarine arc volcanoes worldwide, these examples suggest that there are many interesting modes of interaction between oceanic midwater and seamount communities yet to be discovered.

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The Biota of Vailulu'u Seamount, Samoan Archipelago

Young, C M; Lee, R W; Pile, A J; Templeton, A; Hudson, I R; Brooke, S D; Pietsch, T; Staudigel, H; Bailey, B E; Haucke, L; Tebo, B; Hart, S

Vailulu'u, the active seamount on the hotspot at the Eastern end of the Samoan volcanic chain, was the focus of two research cruises in April and June 2005 using the Pisces V submersible. The objectives of biological studies include the macrobiological and microbiological exploration of biota in a wide range of settings, including a newly formed volcanic cone, Nafanua forming a pronounced summit in the crater of Vailulu'u, a series of hydrothermal vents up to 80°C, and settings inside and outside the crater.

Warm-water vents on Nafanua, supported a low-diversity community dominated by thick microbial mats and the synaphobranchid eel Dysommina rugosa. Isotope and gut analyses indicated that the eels feed not on the mats but on planktonic crustaceans imported to the system from the overlying water column. Current meter data recorded in the nearby breaches of the volcano at a similar depth demonstrate periodic rotations that are consistent with the formation of a Taylor's column. If a Taylor's column is indeed present, it may concentrate midwater plankton and nekton at the summit of Nafanua, providing an explanation for the high concentration of eels in this location. The microbial mat on Nafanua exhibited isotopic signatures consistent with local chemosynthesis, but not methane-based chemosynthesis. Apart from the eels, only two metazoans were found near vents on the volcano summit, and the isotope composition of these (a copepod and a scale worm isolated from mat samples) were consistent with microbial mat as a source of dietary C and particularly N. The mats on Nafanua have very low carbon values and consist mostly of iron oxides in the form of tubular filaments and amorphous floc with a relatively small number of cells and low quantities of extracellular polysaccharides. Metal metabolizing isolates from these mats include strains phylogenetically related to Marinobacter and Pseudomonas.

Vents discovered in the deeper parts of the caldera, on the southern inside wall, and on the rift zone of the western flank supported no megafaunal vent communities. The deepest part of the crater contains toxic fluids, as evidenced by abundant fish, crustacean and cephalopod carcasses. Vents in these deep regions emitted "bubbles," apparently of liquid CO2 and water collected from this zone exhibited a very low pH. The only metazoan species that survives here is a bright red polynoid polychaete (scale worm) that that feeds on or near dead fish. Its color suggests a very high hemoglobin content, but the physiological mechanisms that permit its survival in this extreme environment remain unknown. Hexactinellids and demosponges were found on both the inside and outside walls of the volcano. The most abundant sponge, Abyssocladia bruuni, was particularly abundant in the SW breach. Isotopes indicate that those

individuals on the inside of the breach obtain nutrition from microbes of vent origin, while those on the outside feed on oceanic plankton.

The background megafauna of the outer flank was dominated by octocorals and hexactinellid sponges, with occasional asteroids, ophiuroids and crinoids. Most megafaunal organisms collected from the outer flanks were isotopically heavy, with isotope values similar to those of non-vent deep-sea animals. However, the octocoral Anthomastis collected from low-elevation breaches on the cauldera summit were intermediate in isotopic composition, indicating that they may consume particulate material derived from vent C and N.

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