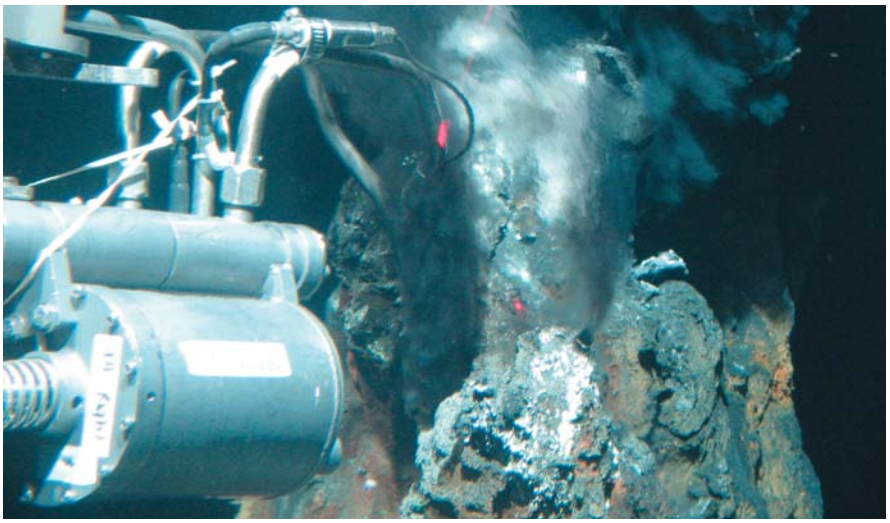
Ridge 2000 Events

A Newsletter of Ridge 2000 Program

VOLUME 2, NUMBER 1 APRIL 2004

In this Issue

Masthead Photo—Sampling water from vent Bio9' at 9°50'N on the East Pacific Rise. Courtesy of Karen Von Damm, from January 2002 EPR cruise.



On the cover

Top—**New at EPR . . .** The *Alvin* low-temp probe is being inserted into a snow blower in a newly discovered vent field located in a collapse structure at 10°44' N on the East Pacific Rise. Maximum temperatures reached only 9.5°C. Photo from forward-looking digital camera, *Alvin* dive 3937. See J.R. Voight et al. Cruise Report, page 22.

Bottom—**And Continuing at EPR . . .** M vent continues to be vigorously venting fluids, at measured temperatures of up to 366°C at the time of fluid sampling in November 2003. While fluids were first collected from M vent in 1992, M vent was observed to be actively smoking on images collected with ARGO in late 1989 (Haymon and Fornari, 1990). See K. Von Damm et al. Cruise Report, page 25.

FROM THE CHAIR

Charles Fisher
Ridge 2000 Program Chair

Dear Colleague,

As of this writing the Ridge 2000 program is 2.5 years old and going strong. Twenty-two Ridge 2000 proposals have been funded to date and many of these programs will be going to sea in 2004. Currently, our average overall success rate is above the average for both MG&G and BioOce, and this is a strong testimony to the quality of science proposed by our community. In addition, a variety of research activities funded outside of R2K are being integrated into the Integrated Studies Sites (ISS) and the Time Critical Studies (TCS) components of our program. Some of this work is funded by core programs in OCE, some by interdisciplinary programs at NSF, and an ever-increasing amount from outside of NSF. Some work is even funded by other countries. Check out the ISS and TCS sections of our new Web site for more details of these projects. In this time of tight NSF budgets and expanding research costs, these synergistic efforts are critical to the continued growth of our program. As the diversity of studies at each ISS continues to grow, the possibilities for collaborations that enhance research addressing cross-disciplinary questions will also increase. As a result, we can expect to see an increase in the participation of scientists funded outside of R2K, but contributing to the goals of the R2K Science Plan.

As most of you are aware, tight budgets at NSF required significant changes in the schedules of the larger ships in the UNOLS fleet for 2004. As one of the major users of these ships, the Ridge 2000 program could have been seriously and negatively affected by the changes. We worked with NSF to minimize the long-term impact on R2K. The result of this effort is a compromise schedule that has a relatively small impact on our overall program goals, but these changes allowed NSF to meet the required cost cuts. Three cruises scheduled for the Lau Basin ISS were delayed from late 2004 into early 2005. Two of these programs were funded through R2K and the third is an example of a project not funded through R2K, but which involves outside collaborative studies at one of our IS sites. The two initial cruises will go forward on schedule, and we anticipate that we will make excellent progress toward choosing a bull's eye for this ISS by the end of 2004.

In preparation for the Lau cruises, we have established strong ties with the Tongan Ministry of Lands, Survey, and Natural Resources, and we will be hosting scientists from this Ministry on our cruises and in the laboratories of some R2K scientists. R2K also has put together a vibrant Education and Outreach program to be conducted in concert with the Lau research effort. E&O activities will include not only our usual US audiences, but also the University of the South Pacific and other regional audiences.

It was clear at the November workshop that each ISS has its own distinctive strengths and that all three are showing excellent promise for success in meeting the goals of their respective Implementation Plans in a timely manner. This newsletter provides updates on each of the IS sites and on the Time Critical Studies component of the program. Each ISS has a strong core of work funded, a rich field season ahead, and a wealth of opportunities for additional investigators to get involved. Particularly exciting news from the Time Critical Studies group is the return of the SOSUS array in the NE Pacific to close to 100% of its original capabilities.

Ridge 2000 investments in Education and Outreach are really beginning to pay off and our commitment to these efforts is now recognized at many levels, both within and outside of NSF. I have received a lot of recognition for our E & O activities, but always point out that Liz Goehring is the driving force behind our efforts. In this issue, Liz and others share news about a few of the many E&O projects throughout our community, something we would like to do more regularly. In addition, R2K communitywide E&O efforts, such as the Student Experiments At Sea (SEAS) and RODES DataTips, are ramping up. These projects could not happen without your contributions. The new R2K Web site provides links to these and other outreach efforts. So, stay tuned, or better yet, contact Liz to see how you can get more involved.

I see am nearing the end of my allotted space, but I must at least touch on several other subjects and direct your attention to the rest of this newsletter for more information. The Ridge 2000 data management office has been funded and established at LDEO. The RODES (Ridge Open Data Exchange System) group is moving forward quickly and will be pilot testing their metadata forms on R2K cruises this year as well as incorporating existing compilations of historical data for the sites. This group will also be integrating the Ridge Multibeam Bathymetry Synthesis, PetDB, and MARGINS focus site data into the data management system. This summer, the RODES group, along with the DLESE Data Access group, is holding a workshop on educational uses of Ridge data. The Ridge Postdoctoral Program has been expanded slightly to encourage young scientists already involved in interdisciplinary activities to apply. And finally, our Distinguished Lecturer Series has been inaugurated and the first lectures of the series are underway.

Once again, thanks to all of you. We have a vibrant program. R2K is off to a great start. Keep those ideas and proposals coming.

Sincerely,

Chuck Fisher
Chair, Ridge 2000 Program Steering Committee

Ridge 2000 Education and Outreach

Liz Goehring, *Ridge 2000 Education and Outreach Coordinator*

One of the most gratifying aspects of the job of outreach coordinator is hearing about the wonderful ways this community shares its work with public audiences. The deep-sea world of hydrothermal vents is fascinating to kids and adults alike, as many of you discover when you have the opportunity to work with these folks. As E&O coordinator, I have been collecting your outreach work in one place to help make it more widely available to these audiences and to identify complementary offerings. Teachers, for example, love to feature research as it happens via cruise Web sites, but also are interested in related curricula, student programs, and career information. The quality of ridge-related outreach work is impressive. The public outreach page on the new Ridge 2000 Web site is designed to feature all ridge-related outreach offerings to public audiences. We are sharing this Web page via a new teacher listserve, at NSTA conferences, with informal science centers, and with as many new audiences as possible. Check it out by clicking on Education and Public Outreach on our new Web site at http://www.ridge2000.org. And please let us know if you have something to add!

Outreach in Action

This issue of *Ridge 2000 Events* features examples of recent outreach efforts to inform you of E&O resources and opportunities, and give you ideas as you consider making your own outreach plans to fulfill "broader impact" criteria. Remember, you don't always need to start from scratch—there are communitywide efforts that need your input and expertise.

In this issue, Debbie Kelley (U Washington), chief scientist on the April 2003 Lost City cruise, describes their "Adopt a Classroom" program and cruise Web site, which is an excellent example of coordinated efforts to share the excitement of discovery with the K-12 community. Sharon Franks (SIO) and Andrea Thurrold (WHOI) describe regional resources and opportunities available to you through the newly established COSEE Network (Centers for Ocean Science Education Excellence). These Centers offer a major advancement in helping the scientific and educational communities work together effectively. A third article, by Kim Kastens (LDEO), presents an upcoming workshop for scientist/educators interested in developing lessons that are based on using ridge data. The workshop is the first step in establishing a collection of Ridge 2000 DataTips. We will highlight more examples in future issues, as well as on the new Ridge 2000 Web site (access "Opportunities for Scientists" on the home page).

SEAS Pilot Program

At midway in the pilot, the SEAS program—an education program to engage middle and high school students in the process of scientific research on mid-ocean ridges—is receiving positive feedback. SEAS stands for Student Experiments At Sea. Students participating in the SEAS program study the ridge environment (Figure 1) and submit proposals of their ideas for experiments. For the pilot, 14 student proposals were submitted, ridge scientists reviewed them, and 5 have been selected and will be conducted on an April cruise to the EPR. Data from these student experiments will be posted to the SEAS Web site and students will analyze data and report their findings. The entire program is designed to enable student participation via the Web. Please have a look: http://www.ridge2000.org/SEAS, and send us your feedback.

Fig. 1. Students in Mellie Lewis' class at Atholton School (Columbia, MD) pour over images of vent fauna (mussel beds) to study correlations and scientific sampling. This activity is from the Ridge 2000 SEAS curriculum being pilot tested this year. Photo used by permission.

Important note: Many thanks to all the scientists willing to contribute to this pilot program (e.g., SEAS cruise hosts, proposal reviewers, curriculum reviewers, "Ask a Scientist" volunteers). SEAS is a Ridge 2000 program, and participating scientists are encouraged to cite their contributions to SEAS as helping to meet "broader impacts" criteria.

E&O Advisory Committee

Developing a vision and plan for E&O for the Ridge 2000 Program requires input and direction from experienced members of our community. As we enter the third year for R2K, I'd like to thank the members of the first E&O Advisory Committee for their contributions and expert guidance. Debbie Smith (chair), Véronique Robigou, Sharon Franks, Mike Perfit, Matt Smith, and Peter Rona each volunteered their time and unique perspectives to help mold the vision for R2K Education and Outreach. Given the diversity of our community, this has not been an easy task, and their efforts have been greatly appreciated! Thanks, too, for offering to continue contributing to our E&O effort. You all are great.

As our E&O efforts continue to evolve, a new committee, nominated by the R2K Steering Committee, has formed: Mike Perfit (chair; U Florida), Anna-Louise Reysenbach (Portland State), Jeff Karson (Duke), Shana Goffredi (MBARI), Dan Scheirer (USGS), and Scott White (U South Carolina). In addition to providing fresh insights and direction, their most important task will be to ensure that R2K E&O efforts meet the needs of our scientific community. Already we have begun working on ideas to reach undergraduate audiences. Please feel free to contact any member of the committee or me, and share your thoughts/feedback regarding Ridge 2000 education and outreach.

Status Report on the Endeavour ISS

David Butterfield *(U Washington/PMEL), Oversight Committee Chair*
Deborah Kelley *(U Washington), Site Coordinator*

Recent multichannel seismic reflection surveys of the R2K Integrated Studies Site on the Endeavour Segment, Juan de Fuca Ridge, show that a narrow magma chamber exists under all 5 hydrothermal fields at a depth of 2.3-2.6 km beneath the seafloor (Detrick et al., 2002). These new results challenge the hypothesis that the robust hydrothermal system is driven by an active cracking front into solid hot rock, and provide strong justification for further imaging of the deep crust and mantle.

The ISS bull's eye is focused on the Main Endeavour hydrothermal field (MEF), located on the central portion of the Endeavour Segment (Figure 1). This vent field is one of the most vigorously venting systems along the global mid-ocean ridge spreading network, hosting at least 18 large sulfide structures with more than 100 smokers. In addition to the MEF, there are four other known high-temperature vent fields spaced approximately 2 km apart along the segment (with hints of more) and numerous areas of diffuse flow, both nearby and distal to the high-temperature venting. Diffuse flow vents on sulfide structures and at a variety of basalt-hosted sites provide rich habitats abundant with diverse microbial and macrofaunal communities. Endeavour also shows well-developed gradients in volatile concentrations along axis, which may reflect influence from a sedimentary source to the north or east, and high-chlorinity fluids venting from the most southern (Mothra) and northern fields (Sasquatch).

Twenty years of research provide a strong foundation for the R2K 5-year plan at this site, which includes examining the response of this segment to perturbations induced by tectonic and magmatic events; identifying the reservoirs, fluxes, and feedbacks of mass and energy; and predictive modeling coupled with field observations. In the past 10 years, more than 45 investigators from at least 18 US academic institutions and 6 Canadian institutions have studied many aspects of the hydrothermal systems at Endeavour. Since being designated as an IS site, high-resolution bathymetric mapping (EM300) and an extensive multichannel seismic survey have been conducted along the entire segment (Figure 2). Smaller focused areas have also been mapped at meter resolution by SM2000 sonar. Intense field programs in 2003 established the first in situ seismic array along a mid-ocean ridge, which includes a buried broadband seismometer on the sedimented western flank and 7 short-period seismometers emplaced within basaltic bedrock along the flanks of the segment and within the axial valley (Figure 2). It is anticipated that this network will be in place for many years. In addition to monitoring seismic activity, in situ fluid and particle samplers have been deployed in 2 of the vent fields for a year, temperature monitoring devices are installed in 3 fields, and 2 high-temperature prototype incubators were emplaced in the walls of active sulfide chimneys for long-term monitoring and sampling of microbial communities. Macrofaunal colonization and larval transport studies were continued with the deployment of associated instruments in the MEF and within the diffuse hydrothermal site known as Clam Bed. Discrete fluid sampling in 4 of the 5 fields and sampling of microbial and macrofaunal communities were also conducted for shipboard and laboratory studies. To examine the transfer of fluid and heat along the axial valley, a fence of current meters and up-looking acoustic current profilers bounding the MEF were installed. Data collected with these instruments will be coupled to intense water column surveys by ABE in 2004.

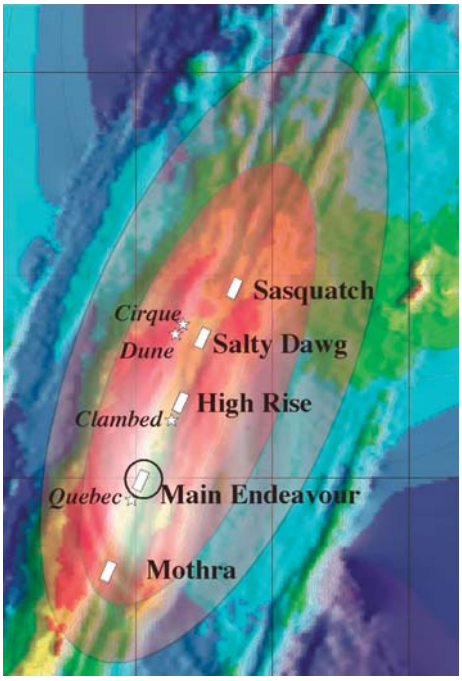


Fig. 1. Map of Endeavour Segment and bull's-eye for ISS

Review of funded programs

There is currently a healthy combination of studies taking place at the Endeavour ISS, thanks to a variety of funding sources. The W. M. Keck Foundation is funding a 5-year program (proto-NEPTUNE Observatory) with the goal of understanding the links between seismicity and crustal deformation, and changes in fluid chemistry and microbial productivity. The Keck project has funded the EM300 bathymetric survey, the seafloor seismic network, and the time series fluid/microbial sampling. NSF funded a major multi-institutional hydrothermal field program at Endeavour in 2000, and is currently supporting hydrothermal modeling work, vent-field-scale heat and fluid volume flux measurements, and in situ sulfide incubation pilot studies. The NOAA West Coast and Polar Regions Undersea Research Center has funded a number of biological projects, and is currently sponsoring a detailed petrological sampling program and a study of vestimentiferan physiology and ecology. Canadian investigators continue to pursue long-term projects in hydrothermal biology, mineralogy, and geochemistry. With the announcement that Canada has received ~Can$62M to begin

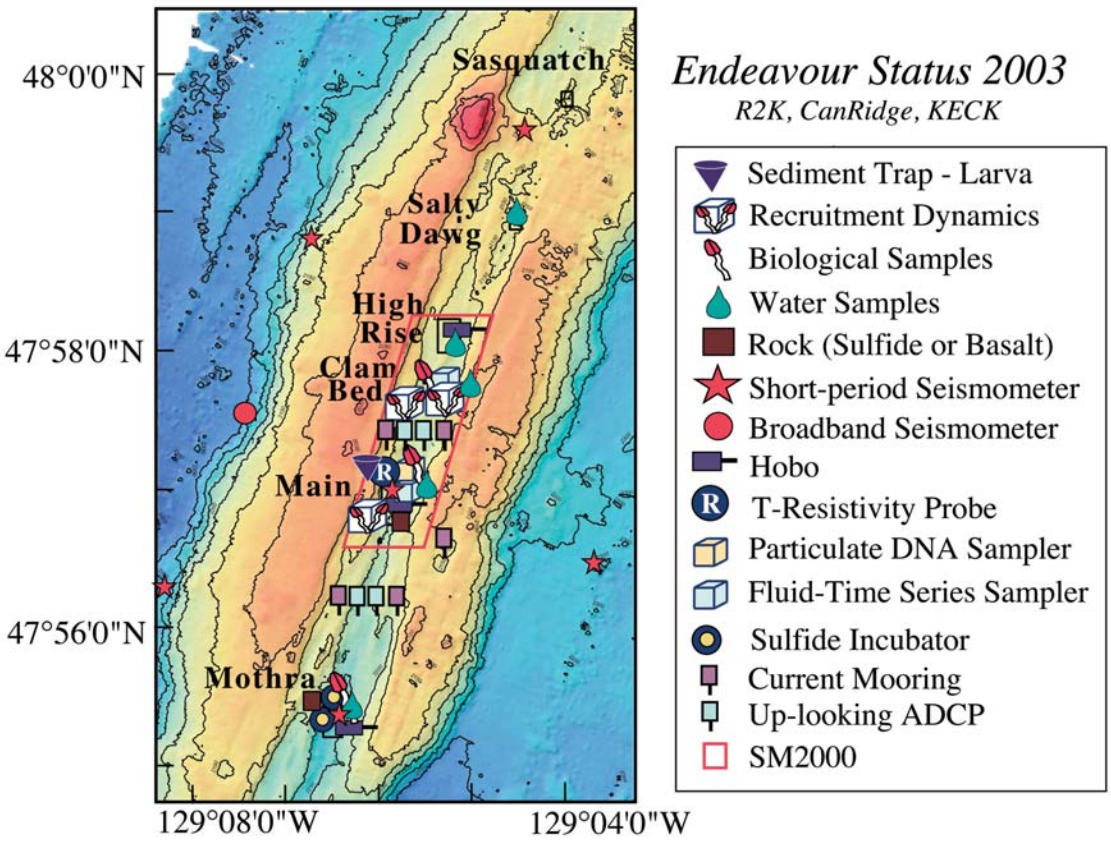


Fig. 2. Locations of sampling sites and instruments in place at Endeavour 2003-2004. A variety of instruments are installed now. One broadband and 7 short-period seismometers, temperature sensors, time-series fluid and DNA samplers at MEF and Clam Bed, and resistivity-temperature sensors are all part of the W. M. Keck Foundation Observatory project. Current meter moorings are in place as part of the R2K-sponsored "Sea Breeze" project to measure fluid and heat flux. Sulfide incubators are installed in the walls of sulfide chimneys at the Mothra field.

installation of the fiber-optic cabled observatory NEPTUNE, the Endeavour IS site is in a key position to leverage long-term in situ crustal, chemical, and biological studies.

Table 1 lists the research cruises scheduled for the Endeavour area in 2004. Kelley (UW) will continue to work on the sulfide incubator project and will use 3 dives to clean up the MEF and deploy an integrated set of markers. Brown and Hilton (UCSD) will deploy prototype flow meters and chemical analyzers in diffuse sites at the MEF. McDuff (UW), Yoerger (WHOI), and Thomson (U Victoria) are leading a project to quantify heat and fluid flux with moorings and the ABE AUV. DeLong, Stakes, and McGill of MBARI are working on microbiological, petrological, and seismological studies, respectively. During the MBARI-Keck seismological portion of the program, seismic data will be downloaded from the broadband and short-period seismometers, and battery packs will be switched out. The array will remain in place for at least another year, and may be linked to NEPTUNE. As part of the Keck project, two additional buried broadband seismometers will be deployed this summer, one on the Explorer Plate and the other either near the subduction zone adjacent to the Nootka transform fault or on the eastern flanks of Endeavour. In May, an intermediate-period seismometer will be deployed, in concert with a WHOI prototype mooring and hydrothermal node at Nootka. These two packages will augment the Endeavour seismic and instrument

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Table 1: 2004 Endeavour Cruise Schedule

Dates	Region (# of Dives)	PI (Funding)	Ship/ Vehicle	Port
May 23–June 9	Endeavour (9) Endeavour (2) Endeavour (3)	Kelley (OCE0221900) Brown (OCE0241998) Hilton (OCE0242034)	*Atlantis* *Alvin*	Seattle
June 14–July 13	Endeavour (34)	McDuff (OCE0242736)	*Atlantis* ABE	Seattle
July 30–August 12	Endeavour (10)	McGill/Wilcock (KECK-MBARI)	*Western Flyer* Tiburon	Astoria
August 16–August 26	Endeavour (9)	DeLong (MBARI)	*Western Flyer* Tiburon	Astoria
August 30–September 6	Cleft (5) Endeavour (6)	Gill/Stakes (NURP)	*Western Flyer* Tiburon	Astoria
September 1–20 September 21–24	Endeavour (20) Nootka IODP Flanks (3)	Delaney (KECK) Becker/Davis (NSF)	*Thompson* ROPOS	Portland — Seattle

Status Report on the East Pacific Rise ISS

Suzanne Carbotte *(LDEO), Oversight Committee Chair*
Maya Tolstoy *(LDEO), Site Coordinator*

Work at the East Pacific Rise Integrated Studies Site is off to a good start with upcoming programs targeting several of the critical objectives identified in the site implementation plan. In this report, we review the recently funded work and the 2003 and 2004 field seasons, and summarize the needs for future work at the site as identified at the November R2K Community Workshop in Boulder, CO.

The four programs most recently funded include monitoring studies for the next three years of vent fluid chemistry, fauna, and seismicity at the site "bulls-eye," as well as three-dimensional multichannel seismic imaging of the crustal magma lens and shallow crustal structure.

- **Temporal variations in hydrothermal fluid chemistry at 9-10˚ N East Pacific Rise: Elucidating ties to crustal and biological processes.** PI: Karen Von Damm (UNH).
- **Integrated studies of biological community structure at deep-sea hydrothermal vents.** PIs: Rich Lutz (Rutgers), Tim Shank (WHOI), Constantino Vetriani (Rutgers), and George Luther (U Delaware).

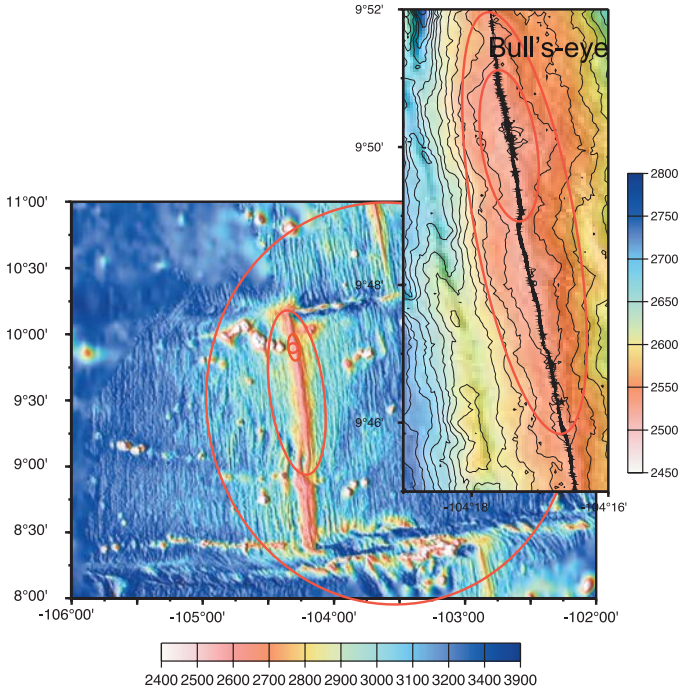

Fig. 1. *(above)* Bathymetry map of the EPR site. Red ellipses encompass different scales of ridge segmentation which characterize the site. *(right)* Detailed bathymetry map of the site "bulls-eye" where monitoring and biological studies are focused (innermost red ellipse). The next red ellipse encompasses the entire fourth-order segment along which eruptions occurred in 1991-1992. Black stars correspond with vent fields and black line shows the location of the axial summit trough.

- **Seismic monitoring at the EPR Ridge 2000 Integrated Studies Site.** PIs: Maya Tolstoy and Felix Waldhauser (LDEO).
- **3-D/4-D seismic reflection imaging of the internal structure of the magmatic-hydrothermal system at the East Pacific Rise Integrated Studies Site at 9˚50' N.** PIs: John Mutter, Jackie Floyd, Suzanne Carbotte, and Roger Anderson (LDEO), and Bob Detrick (WHOI).

Descriptions of these projects, along with previously funded R2K programs, can be found on the R2K Web site (http://www.ridge2000.org).

2003 Field Programs

During 2003, three cruises visited the EPR ISS (Table 1). Film director James Cameron ran an expedition to the site as part of his Xtreme Life IMAX film project. Science projects during this cruise included shipboard studies of live vent animals in high pressure aquaria (Jim Childress and students, Dijanna Figueroa and Michael Henry) and deployment of a suite of closely spaced ocean bottom seismometers for long-term monitoring of seismicity (Maya Tolstoy). Samples were collected for microbiological, astrobiological, and geochemical studies of the vents and surrounding rocks for 'remote' scientists as part of a NASA analog study led by Kelly Snook, an aerospace engineer at NASA's Ames Research Center, and Kevin Hand, a graduate student at Stanford University. In October-November, Janet Voight led a biological sampling expedition *(see cruise report, this issue)* that included both discovery of vent communities at 8˚37' N where hydrothermal signals and an earthquake swarm event had been detected previously, and collection of at least 20 species of undescribed vent animals from the 4 sites visited. Fluid sampling at vents in the 9˚50' N area was carried out by Karen Von Damm to complete her resampling program of the previous year, and Chuck Fisher's student, Brea Govenar, recovered artificial tube worm aggregations deployed in 2002 *(see cruise report, this issue)*. In November-December, Craig Cary and colleagues carried out the second of their three-cruise program focused on the biogeochemistry of hydrothermal fluid and the biology of *Alvinella pompejana.*

2004 Field Programs

2004 will be a busy field season for the EPR ISS. All R2K programs funded during 2002-2003 for field work at the site will be at sea in 2004, as well as a number of projects funded from other programs (Table 2). Steve Constable's magnetotelluric (MT) study will occur in February and will involve a high-resolution transect at 9˚50' N with a controlled-source EM experiment as well as MT imaging. A MT-only transect at 9˚30' N targeting deeper mantle structure will also be carried out. Beginning in January, Schouten and colleagues have 9 *Alvin* dives at 9˚50' and 9˚30' N in support of their ongoing volcanological/

Table 1: 2003 Cruise Schedule for the EPR ISS

PI – Program	Dates	Ship	Purpose
J. Cameron – IMAX (outreach) Childress/Tolstoy – NSF/NASA	9/25/03-10/6/03	*Keldysh*	Biology (physiology)/ OBS deployment
Voight – NSF	10/31/03-11/24/03	*Atlantis*	Biology (systematic/ taxonomy)
Von Damm – NSF	With Voight		Vent fluid chemistry
Fisher – NSF	With Voight		Biology (ecology)
Cary – Biocomp.	11/29/03-12/21/03	*Atlantis*	Biology (ecology/ physiology)
Cavanaugh – NURP	With Cary		Biology (microbiology/ ecology)

geophysical investigation. During this program, Seyfried and Ding will test their in situ sensors for monitoring vent fluid chemistry, and Edwards and Bach will deploy sample collections plates at 9°50' N for their study of the role of microbes in the weathering of ocean crustal rocks. Von Damm's vent fluid chemistry program will follow with sampling of all high temperature and some diffuse flow vents within the bull's-eye and at 9°46' N. The Lutz et al. program in April involves photo-imaging along the Biogeotransect, along with fluid chemistry measurements via an in situ voltametric analyzer, vent fluid temperature measurements, microbiological studies, and manipulative experiments targeting macrofaunal ecology. Also during the Lutz program, 9 OBSs deployed for the Tolstoy microseismicity monitoring experiment spanning 9°49'-9°51' N will be recovered, data downloaded, and redeployed for another year, along with 3 additional instruments. In addition, the R2K Student Experiments At Sea (SEAS) program will be pilot tested during the Lutz cruise. The Booksh program in November is a NSF Biocomplexity funded study that was originally sited in the Endeavour region and described in the Endeavour ISS report of the last *R2K Events* (vol. 1). Cary's program, also funded through NSF Biocomplexity, is the third cruise of his biogeochemistry/*Alvinella pompejana* study and also will include recovery of Edwards and Bach's microbial sample collections plates. The 3D MCS program of Mutter and colleagues will image the axial magma body and upper crustal structure from 9°37' to 9°52' N, but has not been scheduled for 2004.

Summary of recommendations from November R2K Workshop

At the R2K community workshop in November, the current status of work at the EPR site was reviewed. During the two break-out group discussion periods, workshop participants were asked to consider two related questions: What are the important science themes that are missing or underemphasized in the current suite of questions driving work at the EPR? What are the highest priorities for new work at the site that are needed to demonstrate significant progress at the NSF

Table 2: 2004 Cruise Schedule for the EPR ISS

PI – Program	Dates	Ship, Vehicle Dives	Purpose
Schouten, Tivey, Fornari – NSF	01/28/04-02/21/04	*Atlantis, Alvin* 9 dives	Geology/geophysics
Seyfried – NSF	With Schouten	*Alvin* 4 dives	In situ chemical sensors
Constable – NSF	02/09/04-03/09/04	*Revelle*	MagnetoTelluric study
Von Damm – NSF	03/15/04-04/01/04	*Atlantis, Alvin* 16 dives	Vent fluid chemistry
Lutz et al. – NSF	04/06/04-04/30/04	*Atlantis, Alvin* 16 dives	Microbiology/ ecology/ in situ chemical analyses
Tolstoy – NSF	With Lutz		OBS recovery and redeployment
Booksh – NSF Biocomp.	11/04/04-11/25/04*	*Atlantis, Alvin* 8 dives+ 5 dives–Edwards	Microbiology
Cary – NSF Biocomp.	11/30/04-12/16/04*	*Atlantis, Alvin* 12 dives	Biology/ Chemistry

review of the program in 2-3 years? The highest priority needs for new work at the site identified at the workshop are summarized below. The full workshop report will be posted on the R2K Web site.

Highest priority needs

Water column and heat flux work. Water column measurements are of high priority for the EPR site for constraining heat and particulate fluxes associated with the hydrothermal system, and for plume and larval dispersal issues. There is need for continuous monitoring via moorings and for broad-scale water column mapping both on and off axis.

Subsurface biosphere. Programs that target the subsurface biosphere are underrepresented in work currently ongoing and planned at the EPR site, and new dedicated studies are needed.

Geodetic studies. Geodetic data on surface deformations are of high priority for the EPR site. Geodetic monitoring is standard for terrestrial volcano monitoring, providing important constraints on the depth and volumes of magma movements in the subsurface as well as stress distributions within the crust. Repeat high-resolution mapping surveys should complement geodetic measurements with quantitative estimates of seafloor deformation fields and eruptive volumes if an eruption event occurs.

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Status Report on the Lau Basin ISS

Doug Weins *(Washington U–St. Louis), Oversight Committee Chair*
Geoff Wheat *(U Alaska, Fairbanks), Site Coordinator*

More than 30 interested researchers, including funded and pending PIs, participated in the Lau breakout groups during the R2K Community Meeting in November in Boulder. The PIs presented their goals and methods, and the sessions were opened for general discussion. Questions addressed selecting a bull's eye[1] vent field where the smallest scale fieldwork will be co-located, and identifying future needs for the Lau Integrated Studies Site (ISS).

The group concluded that the programs funded to date would provide enough data to support selection of a focal area "bull's eye," although hydroacoustic data might benefit the selection process. In general, participants thought that a bull's eye site centered on an "end member" location would allow for interesting comparisons with "typical" MOR hydrothermal systems (i.e., low pH and high metal fluid content in an area with a magmatic signature from the down-going slab). However, it was recognized that many other factors would also weigh heavily in this decision.

The Tivey et al. and Childress et al. R2K cruises planned for November and December 2004 to the East Lau Spreading Center have been postponed by the National Science Foundation and are now expected to go to sea in early 2005. The schedule changes may postpone a decision on selecting a bull's eye for integrated studies at the site. The Martinez et al. and Langmuir et al. cruises will proceed as scheduled.

Selecting the LAU ISS Bull's Eye

The series of funded expeditions (see Table 1) to the East Lau Spreading Center (ELSC) will conduct a coordinated sequence of investigations to characterize various aspects of the site. Data from the Martinez et al. cruise in April will be available to the Lau Oversight Committee, funded Lau ISS chief scientists, and the R2K Steering Committee to aid in the discussions for more detailed work on later cruises. A town meeting will be held at the American Geophysical Union Fall Meeting to discuss the results to date; however, some cruises will not have occurred. No date has been set for a decision on the bull's-eye vent field. It is anticipated that community input will be solicited via an open, Web-hosted forum, or if needed, in an open workshop (schedule to be determined).

Future Needs for the Lau ISS

The Lau ISS needs a variety of additional sampling and experimental studies. Some of the essential regionally based work proposed includes across-strike petrologic sampling and mapping, and studies of seismic tomography, seismic anisotropy (for determining mantle flow patterns), and crustal structure. Additional projects requiring finer-scale sampling (e.g., fluids and biology) should evolve after selection of the bull's eye.

Also discussed was an effort to complement the R2K Lau program with a long-term observatory either utilizing a moored surface buoy or modifying an existing telecommunications cable. An existing cable that could be repositioned may be decommissioned in the next two years. The Lau ISS also may be a prime location for IODP drilling targets, which also would address geologic, hydrologic, and microbial questions.

International Relations and Outreach

The Lau group meetings concluded with discussions of international relations and education and outreach. R2K studies must include our Tongan and Fijian hosts, not only for the success of the Lau ISS program, but more importantly for the benefit of the local governments, which need to make informed decisions about resources in their exclusive economic zone (EEZ). In addition, colleagues from New Zealand, Australia, Japan, Korea, Germany, France, and the United Kingdom will likely play key roles in addressing issues at this site.

The R2K office is planning an integrated E&O effort for the Lau ISS program. The program will include a variety of educational (K-12) and media experts, some of whom will participate on the seagoing operations, as well as lectures and tours during port stops.

Lau Basin ISS Oversight Committee

Chair: Douglas Wiens, seismology, Washington University, St. Louis, <doug@shetland.wustl.edu>

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[1] The term *bull's-eye* does not designate a high-priority area, but rather the vent field where studies conducted at vent-field scale and smaller will be co-located. Studies requiring larger spatial scales will nest around this designated focal area and expand outward in a series of elliptical bands to meet scientific needs.

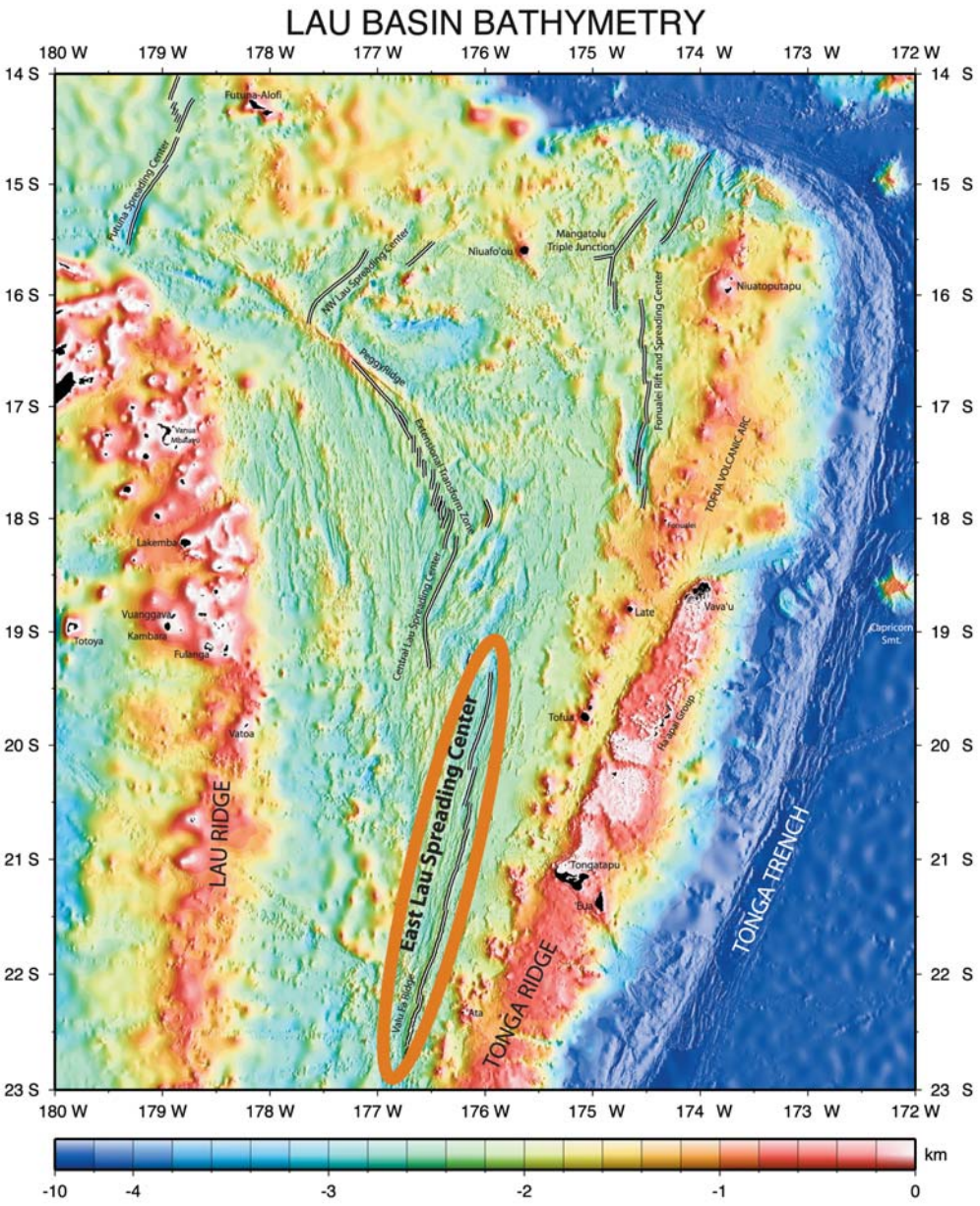

Fig. 1. The East Lau Spreading Center has been designated as the Ridge 2000 Integrated Studies Site in the Lau Basin, but a "bull's eye" hydrothermal vent field where the smallest scale studies will be co-located will be designated with community input following the current field season. Image courtesy of B. Taylor and F. Martinez, U Hawaii.

Table 1. Funded Proposals for the Lau Integrated Studies Site

PI (Program)	Date	Ship	Equipment/Goals
Martinez, Taylor, Resing, Baker (R2K)	Apr 6–May 9	*Kilo Moana*	Deep Tow Multibeam& Sidescan Sonar (IMI-30; DSL-120)
Langmuir, Edmonds, Michael, Bradley, Shank, Goldstein, Graham (R2K) German (SOC)	Sep 8-Oct 15	*Kilo Moana*	Tow-yos, Autonomous Benthic Explorer (ABE), Dredging, Camera Sled
Thurnherr, Speer (R2K)	With Martinez OR with Langmuir	*Kilo Moana*	LAU-FLEX: Deep Circulation and dispersal in the Lau Backarc Basin using Floats
Tivey, Seewald, Kim, Mottl, Reysenbach, Wheat (R2K)	To be scheduled	*Revelle*	*Jason II,* CTD, hydrothermal vent characterization
Childress, Fisher, Hourdez, Kim, Luther (R2K)	To be scheduled	*Revelle*	*Jason II,* Biological sampling
Vrijenhoek (NSF)	To be scheduled		Multispecies Phylogeography of Lau/Fiji Basin Vent Fauna

Status Report on Time Critical Studies

James P. Cowen *(U Hawaii), Chair, TCS Ad Hoc Committee*

The Time Critical Studies (TCS) theme focuses on observations of the immediate geochemical and geobiological consequences of magmatic and tectonic events along the global mid-ocean ridge system. To date, funding has centered on the Juan de Fuca and Gorda Ridges, which are within range of the US Navy's NE Pacific Sound Surveillance System (SOSUS). The NOAA-Pacific Marine Environmental Laboratory (PMEL) Acoustic Monitoring Program has accessed SOSUS in real-time since 1993, providing the TCS community with detection of seismicity associated with eruptive or tectonic activity along these two ridges. This remote detection of earthquake swarms along the NE Pacific mid-ocean ridge system, coupled to NSF funding for pre-event staging equipment and supplies, has allowed directed and increasingly well-organized field responses to event sites. Major rapid and follow-up response cruises have been successfully mounted to study magmatic episodes in 1993 at CoAxial, 1996 and 2001 at Gorda Ridge, 1998 at Axial Volcano, and 2001 at Middle Valley.

Time Critical Studies of magmatic events have significantly influenced our ideas of the nature of crustal accretion. The RIDGE/Ridge 2000 TCS programs have led to the discovery and preliminary documentation of a previously unrecognized biomass reservoir that lives below the seafloor and is swept out during these cataclysmic events. TCS also has increased our appreciation of the formation and thermal, chemical, and biogeochemical implications of the "event plumes" commonly associated with seafloor magmatic events. The logistical strategy required to study these events has been greatly facilitated by the collaboration between university, NOAA, and Canadian investigators.

Current Status

The SOSUS system available to PMEL is comprised of a network of 10 independent hydrophone arrays. PMEL uses this real-time hydrophone data to form beams directed at NE Pacific spreading centers in order to significantly increase the detection capability for small and moderate-size earthquakes (>2.5-3.0 m_b). In the previous R2K *Events* newsletter, we reported that the SOSUS detection and location capability had deteriorated due to the failure of two out of the three Navy hydrophone arrays closest to the Juan de Fuca Ridge. The great news from our PMEL colleagues is that the US Navy has restored the SOSUS hydrophone arrays to essentially fully operational status, renewing their ability to reliably locate epicenters of activity and assuring long-term remote real-time detection capabilities for the Juan de Fuca and Gorda Ridges.

Since the intensive 2001 Middle Valley event, the only recent significant seismic event detected with SOSUS occurred on West Valley in July 2003. Bob Dziak (PMEL) reported a relatively small, but intense earthquake swarm on the eastern side of West Valley along the northern Juan de Fuca Ridge (Figure 1). The swarm occurred on 21 July at 06:36Z, lasted for ~4 hours, and produced 87 detectable earthquakes.

Table 1. Currently funded TCS programs for Northeast Pacific

Parameter	Method	Responsible Institution
Event Detection	SOSUS	PMEL
Plume Mapping	XBTs	UH
Plume Geochronology	Isotopic half-lives	RSMAS
Particle Dynamics	Particle size/conc.	UH, PMEL
Geochemistry	Dissolved/ particulate chemistry	UW, UH, PMEL
Geomicrobiology	Microbially mediated chemistry	UH, UW
Microbial Diversity	Genetic/Microscopic	OSU, UH
Event Plume Tagging	RAFOS floats	SFSU
Seafloor Imaging	Digital camera sled (TowCam)	WHOI, PMEL

Because of the limited number of SOSUS hydrophones available at that time, only 15 of these events could be located. None of the earthquakes appears to have been detected by land-based seismic networks along the western US or Canada. Earthquake swarms along the West and Middle Valleys are not common, but a dedicated response cruise did not seem warranted because of the short duration and relatively few earthquakes (by comparison the 1998 Axial eruption produced >8,200 earthquakes in 11 days and the 2001 Middle Valley produced >14,000 in 26 days!).

Earl Davis, Kier Becker, John Cassidy, Marv Lilley, and Bob Dziak will soon publish an update on the 2001 Middle Valley seismic swarm event. The TCS community responded to that event by ship with the assistance of Canadian colleagues aboard the CSS *J.P. Tulley* (Tom Juhasz and Steve Milhaly, cochief scientists), but that survey revealed no evidence of enhanced hydrothermal activity in the water column. This past summer, Davis and Becker found evidence explaining the apparent absence of a water-column hydrothermal signature when they serviced the CORK hydrologic observatory operating in Hole 857D at the southern limit of the seismic swarm. The data they recovered indicated that coseismic dilation of the crust beneath the sediment fill had produced a strong and long-lived negative pressure change (on the order of 10% of the total pressure driving flow at the Dead Dog hydrothermal system 1.6 km north of the CORK site, and lasting for several months). In this instance, a spreading event appears to have temporarily diminished the axial hydrothermal output.

Thanks to WHOI's Dan Fornari, TCS now has a rapid response towable camera for photographing the seafloor (Figure 1). The new multifunctional "TowCam" consists of a digital camera with strobes, a Seabird CTD, and a rosette of multiple wax-corers and 1.2 liter Niskin bottles. The bulkier components of the TowCam (frame, batteries, junction boxes, charger, cables) are now stored in Seattle (PMEL),

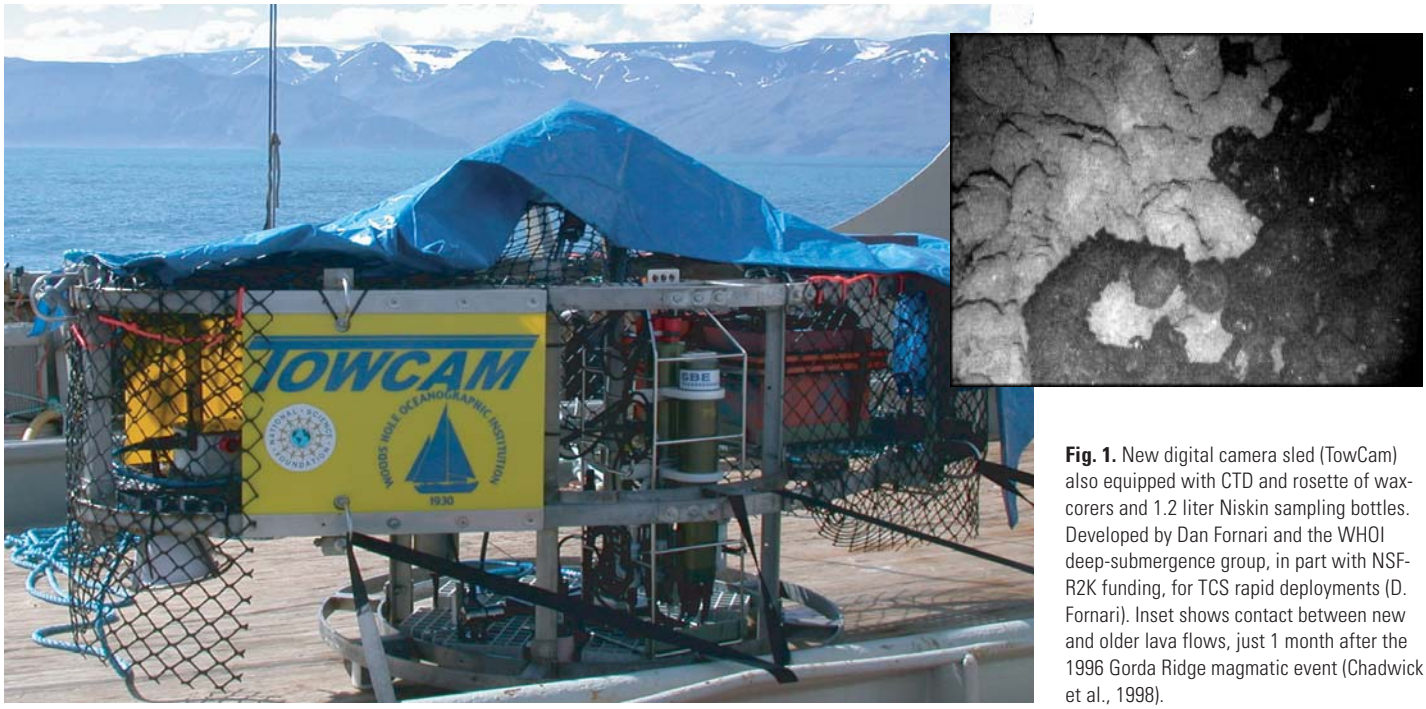

Fig. 1. New digital camera sled (TowCam) also equipped with CTD and rosette of wax-corers and 1.2 liter Niskin sampling bottles. Developed by Dan Fornari and the WHOI deep-submergence group, in part with NSF-R2K funding, for TCS rapid deployments (D. Fornari). Inset shows contact between new and older lava flows, just 1 month after the 1996 Gorda Ridge magmatic event (Chadwick et al., 1998).

while the more mobile components (digital camera, strobes, CTD, rock corers, and Niskins) will be express mailed the moment they are needed for a rapid response cruise.

As reported in the last *Events* newsletter, PIs from 6 NSF–R2K-supported institutions and the NOAA-PMEL Vents Program are currently funded to maintain readiness to detect and rapidly respond to major magmatic and tectonic events in the NE Pacific (Juan de Fuca and Gorda Ridges). The currently funded core parameters are listed in Table 1. Most response equipment and supplies are now stored at PMEL (Seattle) for rapid deployment, including the new multifunctional TowCam.

Table 2: Event Response Contacts

Organization/Person	Affiliation[1]	Email
R2K Office		ridge2000@psu.edu
Jim Cowen, Chair	TCS/NSF-PI	jcowen@soest.hawaii.edu
Keir Becker	TCS	kbecker@rsmas.miami.edu
Bob Dziak	TCS/PMEL-PI	dziak@pmel.noaa.gov
Melanie Holland	TCS	melanie.holland@asu.edu
Marv Lilley	TCS/NSF-PI	lilley@u.washington.edu
Maya Tolstoy	TCS	tolstoy@ldeo.columbia.edu
Geoff Wheat	TCS	wheat@mbari.org
Steve Giovannoni	NSF-PI	steve.giovannoni@orst.edu
Dave Kadko	NSF-PI	dkadko@rsmas.miami.edu
Toby Garfield	NSF-PI	garfield@sfsu.edu
Ed Baker	PMEL-PI	baker@pmel.noaa.gov
Joe Resing	PMEL-PI	resing@pmel.noaa.gov
Bob Embley	PMEL-PI	embley@pmel.noaa.gov

[1]TCS: TCS Oversight Committee; NSF or PMEL funded Principal Investigator

The Ridge 2000 Program is seeking proposals for innovative ways to augment and extend existing Time Critical Studies. Even the most rapid shore-to-event site response will not be fast enough to record the earliest subsurface and water column expressions of magmatic events. The development of alternate, ultrarapid response methods is needed to extend the ship response efforts. These might range from air-droppable monitoring devices (e.g., vertical profilers, moorings, AUVs) to in situ sensors. The latter include continuous recording instruments, as well as more sophisticated autonomous instruments/vehicles that are preprogrammed to respond to signals detected by an array of physical, chemical, and biological sensors. In this regard, Time Critical Studies should get a helping hand from the increasing instrument deployments at R2K's Integrated Studies Sites. If a future event occurs at an established ISS, it is likely that the earliest perturbations will be captured by in situ monitoring instruments, providing data that could be acquired in no other way.

Time Critical Studies are logistically supported by both the R2K office and the TCS ad hoc committee. The R2K Web site includes a TCS page, with information on submitting proposals for TCS research and links to the NOAA-PMEL Vent's Acoustic Monitoring Program. R2K proposals are encouraged for all aspects of TCS, including event detection, rapid response efforts, and instrument development. Coordination of response efforts is particularly critical due to the condensed time frame of planning and staging for unpredictable rapid responses and to potential space limitations. Interested investigators are encouraged to contact currently funded TCS PIs, members of the TCS Ad Hoc Committee (Table 2), or the R2K office for more information.

References

Chadwick, W. W., R. W. Embley, and T. M. Shank. 1998. The 1996 Gorda Ridge eruption: Geologic mapping, sidescan sonar, and SeaBeam comparison results. *Deep-Sea Res.* 45:2547-2570.

Status Report on the Ridge Multibeam Bathymetry Synthesis

Suzanne Carbotte, Suzanne O'Hara, William Haxby, and William B. F. Ryan *(LDEO)*

The Ridge Multibeam Bathymetry Synthesis (RidgeMBS) is a compilation of multibeam bathymetry data, digital elevation models, and shaded relief images of the seafloor from the world's mid-ocean ridges. This effort was initiated in 1993 with the support of the NSF-sponsored RIDGE program in recognition of the importance of bathymetry data as a baseline data set for understanding crustal creation and as an integrating framework for multidisciplinary studies at ridges.

New Content and Structure

In the last 3.5 years, we have approximately doubled the data holdings to include bathymetric coverage encompassing ~24,000 km of the world's MOR (close to half the total length of the global system). Data recently added are from the Northern and Southern East Pacific Rise, Mid-Atlantic Ridge, Pacific-Antarctic Ridge, Southwest and Southeast Indian Ridges, the Gorda plate, and the Lau Basin. In addition to expanding the content of the synthesis, we have also migrated the compilation from its early structure—a series of flat files and static premade maps and grids—into a modern relational database with the capability to generate on-the-fly grids and images of user-defined regions. We are using an open source relational database server (PostgreSQL®) and Federal Geographic Data Committee (FGDC) metadata standards.

New Access to the Database

With the new structure of the RidgeMBS, Web access to the database has changed and is now provided through a simple text-based search page and a new map browser called GeoMapApp© (Figure 1). The keyword page permits searches to locate data by geographic area, PI, cruise number, dates, or ship. From this page, users can find and download multibeam ping files within an area of interest as well as all premade maps from the original version of RidgeMBS. Users can also enter geographic bounds to generate custom maps and grids, which will incorporate all bathymetry data available within our database.

GeoMapApp© is a Java™ application that permits both dynamic interaction with the database starting from a global view of the entire data holdings and the capability to generate custom grids and images. The bathymetry database is composed of grid and image tiles of global extent, at a variety of grid node spacings, which are accessed across the Internet by GeoMapApp© to dynamically compose seamless grids and images for analysis and viewing. As new data are added to the database, they are immediately visible to users worldwide without the need to download a new version of GeoMapApp©. The Smith and Sandwell (1997) predicted topography compilation is used as a regional background map and can be dimmed to display the areas of multibeam data coverage. Users can zoom and focus on color-shaded relief images to a nominal pixel resolution of 100 m. Bathymetric maps can be contoured at a user-defined interval. Bathymetric profiles can be digitized and downloaded. Grids corresponding to the user map view can be downloaded as ASCII lat-long-depth files or as GMT-compatible NetCDF grid files either with (unmasked) or without (masked) the background regional bathymetry compilation.

GeoMapApp© also provides access to a variety of other data types. Land topography data from the NASA Space Shuttle Radar Topography Mission (Farr and Kobrick, 2000) can be viewed for North and South America (3-arc second, 90 m data). Isochrons from Muller et al. (1997) can be superimposed on bathymetry to show seafloor age. Earthquake locations from the International Seismological Center can be plotted. The ocean seismicity data set of the NOAA, Pacific Marine Environmental Laboratory (e.g., Fox et al., 1995; Dziak et al., 1995) can be loaded and explored. Users can create animations of seismic events, which can be saved as QuickTime movies for use in presentations and for educational purposes. The map browser provides access to ship-acquired trackline geophysical data with the ability to select a trackline of interest and view corresponding profiles of gravity, magnetics, or topography. GeoMapApp© also links to the Ridge PetDB petrology database (Lehnert et al., 2000) and enables a user to view, select, and download geochemical data within a map view of interest. Access to all these data types is available through the same map browser as the multibeam data, which allows the user to explore diverse data sets and generate custom maps from a single interface.

Future Plans

The RidgeMBS will continue to grow as part of the new integrated data management system for the Ridge 2000 program (RODES: Ridge 2000 Open Data Exchange System; PIs: Chayes, Carbotte, Lehnert, and Ryan (LDEO), and Shank (WHOI)). Bathymetry data from each of the Ridge 2000 Integrated Studies Sites (ISS) are currently served from RidgeMBS and new data will be added as it is contributed. In addition, the synthesis will be expanded to include data from the focus sites of the MARGINS program as part of a developing integrated data system, which is independent of scientific focus, for MG&G research across programs. In parallel with expanding the data holdings to other areas of the global ocean, GeoMapApp© will be further developed to provide access to new data types in support of R2K science.

To access the RidgeMBS database visit http://data.ridge2000.org/bathy/. To download GeoMapApp© visit the main page, http://data.ridge2000.org

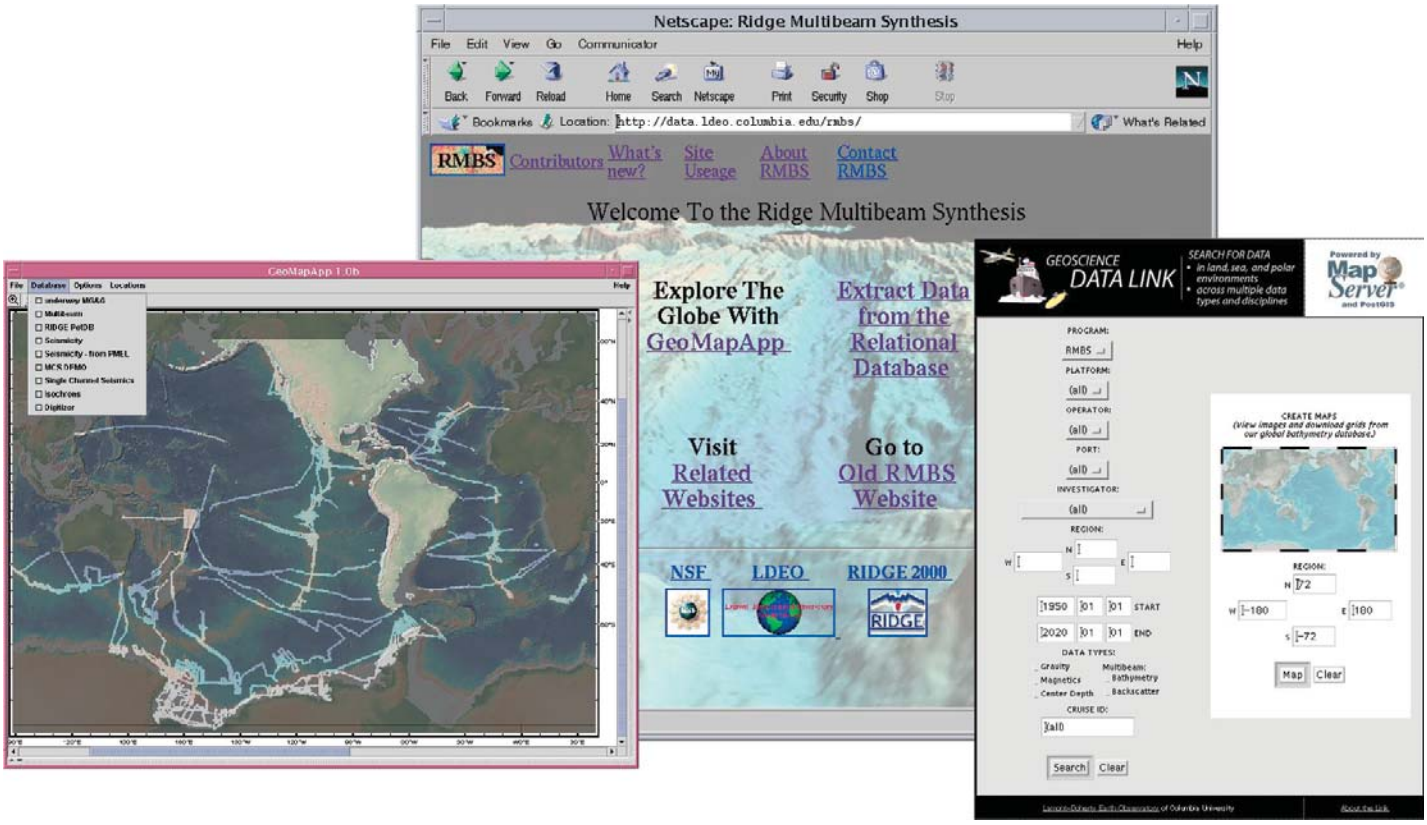

Fig. 1. New database interface for RidgeMBS (http://data.ridge2000.org/bathy). Left panel shows the GeoMapApp© interface with areas of multibeam bathymetry coverage and high-resolution continental data highlighted. Right panel shows the keyword search page to the database. Custom images and grids for a user-defined area can also be made using this page (Create Maps).

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Dziak, R. P., C. G. Fox, and A. E. Schreiner. 1995. The June-July 1993 seismo-acoustic event at CoAxial segment, Juan de Fuca Ridge: Evidence for a lateral dike injection. *Geophys. Res. Lett.* 22(2):135-138.

Farr, T. G., and M. Kobrick. 2000. Shuttle Radar Topography Mission produces a wealth of data. *Eos, Trans., AGU* 81:583-585.

Fox, C. G., W. E. Radford, R. P. Dziak, T. K. Lau, H. Matsumoto, and A. E. Schreiner. 1995. Acoustic detection of a seafloor spreading episode on the Juan de Fuca Ridge using military hydrophone arrays. *Geophys. Res. Lett.* 22(2):131-134.

Lehnert, K., Y. Su, C. H. Langmuir, B. Sarbas, U. Nohl. 2000. A global geochemical database structure for rocks, *G-cubed* 1:1999GC000026.

Muller, R. D., W. R. Roest, J. Y. Royer, L. M. Gahagan, and J. G. Sclater. 1997. Digital isochrons of the world's ocean floor. *J. Geophys. Res.* 102:3,211-3,214.

Smith, W. H. F., and D. T. Sandwell. 1997. Global seafloor topography from satellite altimetry and ship depth soundings. *Science* 277:1,957-1,962.

Could Your Ridge Data Serve as the Basis of a Learning Activity?

Kim Kastens *(LDEO)*

The Ridge 2000 Education & Outreach Plan (Goehring, 2002) calls for a multifaceted effort to increase awareness and understanding of mid-ocean ridge science among educators and students. As our contribution to the R2K outreach agenda, the Ridge 2000 Open Data Exchange (RODES) group at Lamont-Doherty Earth Observatory has taken responsibility for fostering the development of a suite of student activities built around ridge-related data sets.

Although it sounds simple in principle, it is actually quite challenging to create data-enhanced learning activities that appropriately address national science standards, work well for a majority of students, and have a favorable ratio of time invested to insights gained. To help build this capacity in the R2K community, we are planning a dedicated 3-day workshop on educational uses of mid-ocean ridge data in the summer of 2004 at Lamont. This event is modeled on the workshops of the DLESE (Digital Library for Earth System Education) Data Core Services group, and will be lead by staff members from that group who have expertise in learning through data and technology-enriched instruction. Participants will include the RODES science PIs, the RODES technical staff, R2K E&O staff, K-12 science teachers, and R2K scientist/educators who teach at the undergraduate level. Funds are available to support travel and subsistence expenses for a limited number of participants.

Following the workshop, the scientist-educators will work at their own institutions to produce at least one data-based activity, which they will try out in their classrooms during the 2004-05 academic year. Activities will be revised based on the trial results and with guidance from project staff. Revised activities will be disseminated broadly through DLESE and R2K.

If you are interested in innovative approaches in education, or perhaps if you are concerned about how to meet your obligations for 'broader impact' on your NSF-funded grant, please consider participating in this workshop as a scientist/educator. The workshop will be held the third week of July. To express interest or ask questions, email Kim Kastens of the RODES group (kastens@ldeo.columbia.edu), or Liz Goehring in the Ridge 2000 office (exg15@psu.edu).

Resources

Digital Library for Earth System Education (DLESE): www.dlese.org.

Goehring, L. 2002. Ridge 2000 Education and Outreach Plan. www.ridge2000.org/E&O/E&OPlan.pdf.

Manduca, C., and D. W. Mogk. 2003. Issues in teaching quantitative skills in the geosciences, Using data in undergraduate science courses: Report from an Interdisciplinary Workshop, Carleton College, April 2002. http://serc.carleton.edu/research_education/usingdata/report.html.

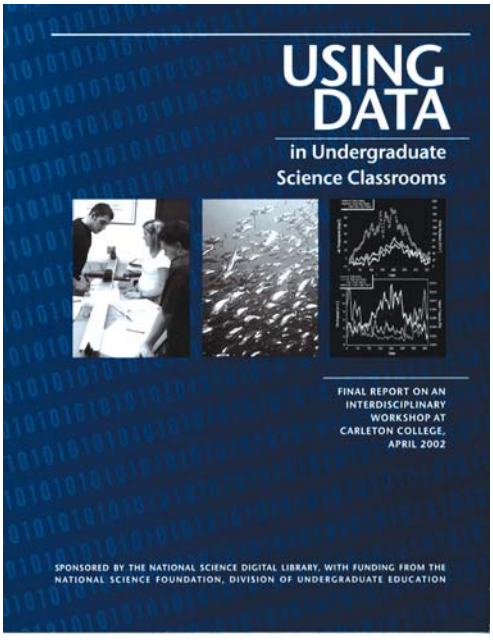

Fig. 1. A report on the most effective uses of data in the undergraduate classroom. Available on line at http://serc.carleton.edu/research_education/usingdata/

Fig. 2. An example of a databased activity exploring the diversity of organisms on the Juan de Fuca Ridge. Available via the R2K E&O Web page link to BRIDGE, the Ocean Sciences Teacher Resource Center.

Adopting Classrooms as a Component of Educational Outreach

Deborah Kelley *(U Washington)*

In April-May 2003, the Lost City Hydrothermal site was revisited on a 32-day interdisciplinary cruise using *Alvin* and the autonomous vehicle ABE. Nineteen dives were completed in the field with *Alvin* and 17 missions were flown with ABE, covering ~ 200 km of seafloor. Ten actively venting carbonate towers were co-sampled for fluids, rocks, and micro- and macrofauna.

As part of an outreach program for this expedition, cruise participants hosted an interactive Web site that highlighted the results of the cruise, tracked daily activities, and provided a content library (http://www.lostcity.washington.edu/). In a style similar to Web sites hosted by REVEL, WHOI Dive and Discover, and Extreme 2000, the Lost City site allowed the public, educators, and students to "Ask a Scientist" questions regarding the expedition while we were at sea. The Web site also provided background science information on the Lost City Field, a section on mapping the seafloor, and pages that described instruments and techniques for conducting analyses both shipboard and on land. By the end of the first week, more than 52,000 hits were made on the site and more than 150,000 occurred before the end of the cruise.

In an effort to better engage elementary, middle, and high school students, we explored a new outreach approach that involved shipboard scientists, oceanographers, and grad students "adopting" K-12 classrooms (http://www.lostcity.washington.edu/mission/classrooms.html). Through this network, 18 classrooms were adopted in the US and Switzerland. The adoption involved visiting classrooms before the cruise, corresponding with students and answering their questions during the cruise, and when possible revisiting the schools after the cruise to present highlights and share the excitement of the Lost City discovery. A few questions were selected each day from the schools for the Web, and a picture from each classroom was posted. To orient teachers and students before the cruise, an information package with video was provided to each classroom.

From dialogues during and after the cruise, we believe this outreach effort was highly successful. It was clear from the excitement of the children that the opportunity to meet "actual" seagoing scientists was important to them, and that the one-on-one contact and ship-based Web effort made them feel like they were part of the discovery and expedition process. Many classrooms were particularly responsive to interaction with the graduate students. It has been more than 6 months since we returned from Lost City and we are still receiving questions wondering what new discoveries have been made.

To other researchers interested in hosting similar programs, we offer the following advice. Classrooms should be contacted as early as possible so that teachers have the opportunity to incorporate the science and visits into their yearly planning. Because of strict requirements and testing guidelines, it is difficult for many teachers to integrate programs such as this into their curricula without significant notice. In addition, many of the teachers are starved for illustrative materials they can use; providing them with as much material and content prior to the cruise is a great help.

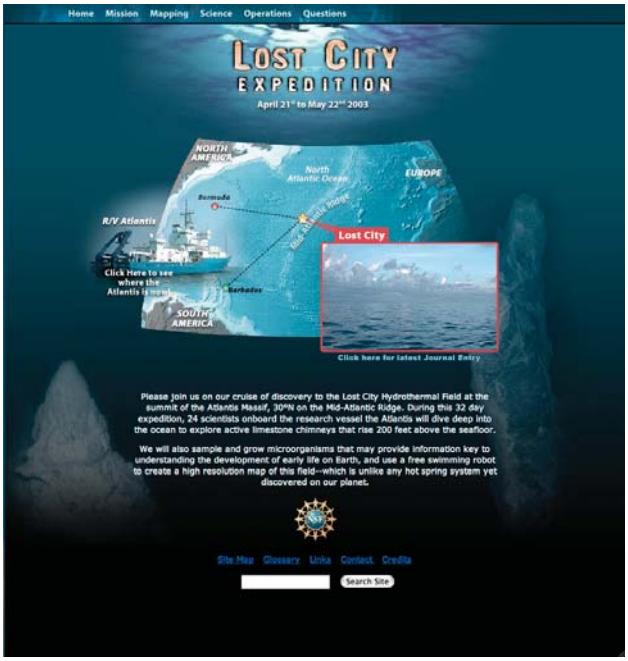

Fig. 1. Home page for the Lost City Expedition Web site, http://www.lostcity.washington.edu/.

Note from Liz Goehring (R2K E&O Coordinator)

Making personal classroom visits and developing Web sites such as Lost City literally brings science to life for students—something sorely needed in today's classrooms. The Lost City outreach project is a great example of what can be done to reach K-12 students. As mentioned, "teachers are starved for materials they can use" to help teach science. They need curricular materials (e.g., lessons, data- and lab-oriented activities) that will help them not only prepare their students to better understand the ridge scientists visiting their classroom, but also convey important scientific concepts such as inquiry. Ridge 2000 E&O is currently pilot testing middle and high school curricular materials to build on the excitement surrounding mid-ocean ridge science. If you are planning an outreach effort, please contact us so that we can make the most of your visits to schools. We will be presenting at NSTA conferences this year and want to include your outreach as part of the Ridge 2000 education offering.

Introducing COSEE and Opportunities for Ridge 2000 Scientists

Sharon Franks, *California COSEE*
Andrea Thorrold, *New England COSEE*

In COSEE—the Centers for Ocean Science Education Excellence, the Ridge 2000 community has a resourceful ally for pursuing its education and outreach (E&O) goals. The vision for COSEE sprang from a May 2000 NSF-sponsored workshop (http://www.ocean.washington.edu/cosee/) and took shape during the subsequent competition for funding among regional consortia. In late 2002, NSF announced the creation of seven regional Centers and a Central Coordinating Office (see www.cosee.net).

The goals of COSEE are to promote effective partnerships between research scientists and educators, to disseminate successful ocean sciences programs and best practices that do not duplicate but rather build on existing resources, and to promote a vision of ocean education as a charismatic, interdisciplinary vehicle for creating a more scientifically literate workforce and citizenry. Each Center, reflecting the unique strengths of its partner organizations, has its own strategies for addressing these challenges, with the long-term vision of sharing the best and most effective throughout the network and with other major ocean science-based E&O efforts. Two of the Centers, California COSEE and New England COSEE, are featured below.

California COSEE marshals the institutional, programmatic, and human resources of four organizations that represent the research community as well as both informal* and formal science education organizations: Scripps Institution of Oceanography (and the Birch Aquarium at Scripps), the Lawrence Hall of Science at UC Berkeley, the Marine Advanced Technology Education (MATE) Center at Monterey Peninsula College, and California Sea Grant, the largest of the nation's 30 Sea Grant programs. Information on the California COSEE can be found on their Web site: www.cacosee.net.

How can a Ridge 2000 scientist tap into California COSEE efforts, perhaps to fulfill funding agencies' broader impact requirements as well as contribute to the overall prosperity of the Ridge 2000 Program? There are literally dozens of possibilities, and we at California COSEE would be pleased to offer options that fit your personal style. For starters, here are a baker's dozen, roughly in order of increasing level of involvement/time commitment. If none of these possibilities tickles your fancy, let us know, and we'll help you find something that does.

1. Provide data or imagery that, accompanied by interpretation, can be used in curricula or informal science center youth programs being created by skilled professional science educators.
2. Donate or lend samples or equipment to science centers.
3. Review appropriate sections of curricula, interpretive text, exam questions, or career information for scientific accuracy.
4. Speak informally with the staff of an informal science center about your research, the tools and techniques you use, and interesting findings you have made.
5. Make a presentation to students, live or via video-conferencing, about your work.
6. In a facilitated meeting, provide input on the design of science center exhibits, displays, or Web sites.
7. Engage a graduate student or technician in any of these activities.
8. Host a field trip for students or teachers to your lab.
9. Serve as a presenter or on-site facilitator during a local teacher professional development workshop.
10. Co-sponsor a *Communicating Ocean Science* course at your university (curriculum, materials, and co-instructors provided).
11. Co-author, with science education professionals, an NSF *Communicating Research to Public Audiences proposal* (up to $75K).
12. Mentor a high school student participating in a certification program offered by a local science center.
13. Take a mini-sabbatical (two weeks to two months) at an informal science center during which you would interact intensively with education staff.

Contact CA COSEE's Cheryl Peach (cpeach@ucsd.edu) or Sharon Franks (sfranks@ucsd.edu) for more information on any of these opportunities or if you would like assistance in crafting a broader impact plan. Your valuable contributions to E&O are not only a feather in your cap, but also a positive reflection on the whole Ridge 2000 Program.

The New England COSEE is a partnership between the Woods Hole Oceanographic Institution (PI Deborah Smith), the New England Aquarium (PIs Carolyn Levi and Billy Spitzer), and the University of

* Informal science educators (ISEs) are those who work in out-of-school settings, e.g. aquariums, museums, and with programs that enhance formal schooling. ISE organizations, in many cases, provide professional development for teachers, in addition to serving students. The rationale for this approach is that these ISE organizations provide an effective conduit and experienced professionals through which scientific concepts and discoveries are translated into compelling, widely disseminated materials and programs for nonscientists.

Massachusetts (PI Bob Chen), which together represent expertise in ocean science research and both formal and informal education.

Some current NE-COSEE initiatives range from providing workshops for scientists partnering with informal educators, to running Ocean Science Education Institutes for middle school teachers, to identifying and highlighting opportunities for scientists like you to get involved in education and outreach. Highlights of these programs are described below and details can be found on the NE-COSEE Web site: necosee.whoi.edu.

Telling Your Story, or How to Survive a Classroom Visit. NE-COSEE hosted a pilot workshop in January to help scientists work with teachers to plan, conduct, and follow-up elementary and secondary classroom visits, prepare materials, and focus presentations to engage and inspire a new generation of scientists. The workshop was run by TERC, a science education R & D nonprofit in Cambridge, MA. More workshops will be offered once the evaluation of this pilot is completed.

Ocean Science Education Institutes. The OSE Institutes are planned to develop an effective model of interactions for linking researchers and formal educators, specifically middle school teachers. For information on the summer 2004 OSEI and how you might get involved, contact Bob Chen at bob.chen@umb.edu.

Programming for Informal Science Education Institutions. This series of workshops will help overcome barriers to ocean science education programming in aquariums, science centers, and other informal science education institutions (ISIs). In the first workshop (March 2004), we will bring together informal science educators, researchers, and representatives of funding agencies to explore the types of partnerships/collaborations that will result in funded, high-impact products in ISIs. Later workshops will explore approaches to increasing the demand for ocean science in ISI programming. For information on these workshops, contact Carolyn Levi at clevi@neaq.org.

NE-COSEE is also tackling tough issues such as identifying high-quality ocean science education resources, creating long-lasting networks in the region, and grappling with a working definition of ocean literacy. We look forward to working with the Ridge 2000 community to address these needs.

In an effort to meet the needs of our large and diverse research community, the Ridge 2000 E&O office has been exploring how Ridge 2000 and COSEE can collaborate. Discussions with partners in California COSEE and the New England COSEE are turning up a number of exciting possibilities. For Ridge 2000, working with these two Centers is a natural first step, as many R2K scientists are physically based in their regions. Ridge 2000 welcomes additional interactions with the other five Centers in the COSEE network: Central Gulf of Mexico, West, Florida, Mid-Atlantic, and Southeast. Please keep the Ridge 2000 office informed of your ridge-related collaborations with any of the COSEE centers (Liz Goehring, exg15@psu.edu).

Ridge 2000 Distinguished Lecturer Series

Through the Ridge 2000 Distinguished Lecturer Series inaugurated this spring, 16 US institutions will host four ridge scientists to share the excitement of deep-sea ridge exploration. For this R2K Education & Outreach effort, two lectures will be given at each institution—one for a scientific audience of faculty and students, and the other for a general audience including teachers and the public—as follows:

- **Andy Fisher,** Hydrogeology, University of California Santa Cruz

  Science Lecture: Large-scale lateral fluid flow within oceanic crust and the importance of seamounts in driving global circulation

  General Lecture: Rivers of fluid and heat within the seafloor: The ocean below the ocean

- **Charlie Langmuir,** Geochemistry, Harvard University

  Science Lecture: Historic Arctic cruise yields new constraints on ocean ridge formation

  General Lecture: Is intelligent life a natural consequence of planetary evolution?

- **Meg Tivey,** Geochemistry, Woods Hole Oceanographic Institution

  Science Lecture: Using in situ measurements and geochemical models to identify the range of environmental conditions present within seafloor vent deposits

  General Lecture: The interplay of geology, physics, chemistry, and biology in seafloor hydrothermal vent systems

- **Cindy Lee Van Dover,** Biology, The College of William & Mary, Williamsburg, VA

  Science Lecture: Deep-sea hot springs: A shrimp's eye view

  General Lecture: Beyond *The Edge of the Sea:* Volcanoes and life in the deep ocean

Thanks to Andy, Charlie, Meg, and Cindy for their generous contributions to the community's E&O effort. The Steering Committee will select the next group of lecturers at its April meeting—watch for the announcement this summer.

Update from InterRidge

The InterRidge office is moving!

The IR office has finished its four-year term in Japan and moved to Germany in February 2004. The new Chair of InterRidge is Prof. Colin Devey from the University of Bremen, Germany. CONGRATULATIONS, Colin, we wish you the very best in continuing to expand the activities of InterRidge.

The initial 10-year science plan for the IR office ended with the year 2003. The success of the program on an international level is definitely something to elicit pride, and it is all a result of the cooperative spirit of the entire ridge community around the world. The new office will face a monumental task of implementing the "Next Decade Science Plan." Quite a number of changes are in store in the composition of the Working Groups and the new theme areas that will be the focus of IR activities in the upcoming years. To find out what's in store for the future of IR, you can download the Next Decade Science Plan from our Web site: http:/wwwinterridge.org/irnd.pdf.

New Working Groups of IR

The IR working group structure has undergone a major revision under the "Next Decade Plan." Principal themes in the InterRidge Next Decade Science Plan will include:

- Ultraslow-spreading Ridges
- Ridge-Hotspot Interactions
- Back-arc Spreading Systems/ Back-arc Basins
- Mid-oceanic Ridge Ecosystems
- Monitoring and Observatories
- Deep Earth Sampling
- Global Exploration

For many of these working groups new Chairs will need to be selected so please feel free to pass your nominations to the IR office. Information about IR working groups and projects can be found on the IR Web site: http://www.interridge.org/act2.html.

InterRidge meetings

IR Steering Committee meeting. The next IR Steering Committee meeting will be held in Seoul, Korea, 21-22 May 2004.

Joint R2K-IR Theoretical Institute: Interactions among Physical, Chemical, Biological, and Geological Processes in Backarc Spreading Systems. The Institute will take place May 24–28, 2004, on Jeju (Cheju) Island, Korea. See announcement in this issue or register at www.ridge2000.org.

InterRidge Workshop: Tectonic & oceanic processes along the Indian Ocean Ridge System. This IR workshop is planned for January 19–21, 2005, at National Institute of Oceanography, Goa, India. For information, see the Fall 2003 issue of *InterRidge News* or visit the IR Web site. Contact the IR office (coordinator@interridge.org) to pre-register interest in attending.

InterRidge meeting publications

Two recent volumes of workshop abstracts are now available on the InterRidge Web site. The abstracts volume from the symposium and workshop: "Ridge-hotspot interaction: Recent progress and prospects for an enhanced international collaboration," held September 2003 in Brest, France, is available at: http://www.interridge.org/rhi03absvol.pdf. The meeting report will also be available for download.

The abstracts volume from the IR workshop "Opportunities and contributions of Asian countries to the InterRidge Next Decade Initiative," held October 2003 in Beijing, China, is available at: http://www.interridge.org/absvolbeijing03.pdf.

Steering Committee membership

On behalf of the IR Steering Committee, I wish to thank Kensaku Tamaki for leading the InterRidge program for the past 4 years. Colin Devey is the new chair and two new German steering committee members will be selected. Thanks also to Catherine Mevel (France), Kim Juniper (Canada), Paul Dando (UK) and Enrico Bonatti (Italy) who have finished their terms as national representatives. Steve Scott from the University of Toronto will be the new national Canadian representative. Other national representatives have not been appointed. Special thanks to all the Working Group Chairs (current and past) who play such a crucial role in carrying out the InterRidge activities and have made the first decade of IR such a success.

I would like to express my gratitude and appreciation to all the people who have made it possible for me to get this job done, for without them I certainly could not have managed. First, I wish to thank Kensaku Tamaki for being so good to work with and for his trust, openness, and continued support. I also wish to thank all those who have over the past years provided their input, advice, and corrections when I erred, and I am sorry I didn't get a chance to meet more of you in person. Finally, I wish to thank all the people who have helped in the IR office and with the IR news, which was always an adventure!

— Agnieszka Adamczewska
InterRidge Coordinator
November 2003

Ridge 2000–InterRidge Joint Theoretical Institute

Interactions among Physical, Chemical, Biological, and Geological Processes in Back-arc Spreading Systems

May 24 – 28, 2004
Seogwipo City, Jeju Island, Korea

This 5-day Theoretical Institute will feature a short course and workshop on back-arc spreading centers, and a field trip around Jeju (aka Cheju) Island, a stratovolcanic island off the southern coast of the Korean peninsula where the institute will be held.

Two questions will focus lectures and discussions:

- What can we learn from back-arc spreading systems about larger, global geological, biological, and oceanographic systems?
- What can we learn from back-arc regions about the interconnectedness of and interplay among the solid earth, magmatic, hydrothermal, biological, and oceanic components of individual spreading systems?

The invited lecture topics and case studies for the short course include:

- Global overview of back-arc basins
- Regional-scale tectonics and mantle flow
- Back-arc basin kinematics—recent geodetic constraints
- Morphology and structure of back-arc spreading systems
- Geochemistry of back-arc hydrothermal systems
- Magmatism of back-arc spreading systems—petrology and rock chemistry
- Subsurface biosphere in the arc and back-arc basin
- Biogeography/biodiversity of back-arc basin fauna
- Physiological ecology of back-arc basin fauna
- Microbiology of back-arc basins
- Izu-Bonin and Mariana Trough; Manus Basin; Lau Basin/Fiji Basin; East Scotia Ridge

R2K is offering partial travel support to accepted applicants who present posters. A nonrefundable fee of $100 is required on acceptance. Application deadline is March 15 and abstract deadline is March 31.

Workshop Organizers

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For information and to register log on to: www.Ridge2000.org
Or contact the Ridge 2000 office, 814-865-RIDG or ridge2000@psu.edu.

Workshop Report

Biogeography of Chemosynthetic Ecosystems: Planning for the Future ChEss-CoML, Ridge 2000, NOAA Ocean Exploration, and InterRidge

Eva Ramirez-Llodra *(Southampton Oceanography Centre), ChEss Project Coordinator*

Three ocean regions were targeted for priority exploration and international collaborative relations were strengthened during the ChEss–CoML/Ridge 2000–NSF workshop on chemosynthetic ecosystems.

The Census of Marine Life (CoML) is a 10-year international program to assess and describe the diversity, abundance, and distribution of life in the oceans at the global scale (www.coml.org). ChEss is a pilot project within CoML, and focuses on the biogeography of deep-water chemosynthetic ecosystems.

The workshop, "Biogeography and Biodiversity of Chemosynthetic Ecosystems: Planning for the Future," was held in June 2003 at the Southampton Oceanography Centre, UK, where the ChEss office is located. InterRidge and NOAA Ocean Exploration cosponsored the event. More than 70 researchers from a wide range of nationalities and areas of expertise attended, and 15 invited speakers gave overviews of a diverse range of topics. Their presentations were followed by round-table discussions and 1.5 days of working group discussions. The full workshop report is available on the ChEss Web site (www.soc.soton.ac.uk/chess).

Perhaps the most significant outcome of the workshop was the selection of three target regions as priorities for the ChEss exploration phase. Each area encompasses a number of diverse chemosynthetic ecosystems and their investigations will require international cooperation and coordination. These areas are: (1) the Equatorial Belt, from Costa Rica to the African margin; (2) the SE Pacific off Chile; and (3) the region around New Zealand. A number of other potential "hotpsots" of chemosynthetic ecosystem biodiversity were also recognized by the workshop participants. Further, issues in taxonomy, search and sampling strategies, microbiology, and palaeontology were discussed in working groups. Recommendations were made by the international community for ChEss to take forward and ensure their implementation. For information on developing programs at these sites, refer to the "Field Programme" page on the ChEss Web site (www.soc.soton.ac.uk/chess/field.html).

Since the workshop in June, the ChEss community has submitted proposals for the three main target regions of the ChEss field program. The sites in the Equatorial Belt region are being studied by a number of national programs and cruises are already taking place and scheduled until 2007. ChEss offers to act as an umbrella program promoting collaboration and aiming to ensure a maximum return from the ongoing science that will benefit the community as a whole. For the SE Pacific region, Chris German (SOC, UK), Lisa Levin (SIO, USA), Chuck Fisher (Penn State, USA), and Victor Gallardo (U Concepción, Chile) are leading a proposal for a Worldwide University Network (WUN, www.wun.co.uk) "Grand Challenge Project." The aim of this project is to discover and investigate vents on the Chile Ridge, seeps of the Chile Continental Margin, communities of the Oxygen Minimum Zone on the Chile margin, and chemosynthetic communities that develop on large organic falls such as whales, kelp, and wood. In the NZ region, Amy Baco (WHOI), Craig Smith (U Hawaii) and Ashley Rowden (NIWA, New Zealand) have submitted a proposal to NOOA-Ocean Exploration to study chemosynthetic habitats.

ChEss recognizes that to understand the biogeography of species from deep-water chemosynthetic ecosystems, one must study not only hydrothermal vents and cold seeps, but also the communities that develop in other reducing environments, such as whale skeletons, sunken wood, subduction zones, and areas of the oxygen minimum zone.

Status Report on the Endeavour ISS *continued from page 5*

array. Gill (UC-Santa Cruz) is collaborating with Stakes on detailed petrological studies at Endeavour, using Tiburon for precise sampling. The Delaney cruise will involve ROPOS operations supporting the Keck project and will focus on maintenance of the seismic network, deployment of prototype chemical sensors, and cycling of fluid samplers. In addition to these studies focused on processes operating near/on the ridge axis, an IODP Leg is scheduled this summer to drill at flank sites

Community Workshop

Enthusiasm was high at the R2K Community Workshop in Boulder where one of the main goals was to discuss recent progress at the IS sites and identify key research areas needing attention. Details of the Endeavour discussions can be found in the workshop report, which is available on the R2K Web site, along with an updated bibliography of Endeavour research articles. The following highlights research areas that workshop attendees thought need more attention for the Endeavour ISS to be a truly interdisciplinary program.

Since the initial petrological characterization from 1980s dredge work by Karsten and others, there has been a lack of detailed petrological sampling and analysis on the Endeavour segment. This work is needed to address magma chamber and crustal formation processes relevant to integrated studies. J. Gill, D. Stakes, and others have begun this work.

One of the keys to understanding and modeling any hydrothermal system is to know the location and extent of the heat source and the

Continued on page 21

Status Report on the Endeavour ISS *continued from page 20*

properties of the overlying crust. Although studies of the mantle were not envisioned in the initial Endeavour ISS plan, the recent seismic reflection data from Detrick and others indicate that more work on magma chamber geometry and crustal structure is warranted and critical at this ISS, if we are to understand the relationships of hydrothermal circulation and volatile transport to magmatic heat sources and crustal structure.

Although there has been repeated sampling of hydrothermal fluids, sulfides, and macrofauna at Endeavour over the past 20 years, microbiological studies have been limited. A major effort in microbiological work has been focused on the 'Edifice Rex' sulfide recovery project (funded by the American Museum of Natural History and NSF), and has produced exciting new results about microbial communities within active sulfide structures. Another study has worked on symbiotic microbes. Missing is a systematic, in-depth sampling and analysis of microbial communities associated with different chemical and physical environments at Endeavour. This is a critical gap in the "mantle-to-microbe" goal of the ISS.

In summary, workshop attendees agreed that there is a vital core of ongoing research at the Endeavour ISS funded from a variety of sources, but important gaps exist in our knowledge, including mantle geometry, crustal structure, and microbiology. A more complete discussion of research needs at Endeavour can be found in the Boulder workshop report available on the R2K Web site (www.ridge2000.org). The community is encouraged to submit proposals for studies that address these needs.

Endeavour Oversight Committee

David Butterfield, UW/PMEL, hydrothermal chemistry, chair
Debbie Kelley, UW, geology, site coordinator and EXCOM liaison
Jim Cowen, U Hawaii, chemistry
Robert Lowell, Georgia Tech, modeling
Doug Toomey, U Oregon, seismology
Rick Thomson, U Victoria, physical oceanography

Reference

Detrick, R. S., S. Carbotte, E. Van Ark, J. P. Canales, G. Kent, A. Harding, J. Diebold, and M. Nedimovic. 2002. New multichannel seismic constraints on the crustal structure of the Endeavour Segment, Juan de Fuca Ridge: Evidence for a crustal magma chamber. *Eos Trans. AGU,* Fall Meeting Supplement, Abstract T12B-1316.

Status Report on the East Pacific Rise ISS *continued from page 7*

High priority programs and infrastructure needs in the near future

Off-axis sampling and mapping. Off-axis studies are needed to gain a better understanding of the contribution of hydrothermal processes on the ridge flanks and to address coupling between axial and ridge-flank processes.

Mantle imaging. Better imaging of mantle structure throughout the EPR ISS is needed to relate mantle structure to ridge segmentation and crustal/seafloor observations. A mantle imaging experiment at the EPR ISS would address high-priority goals for both R2K and the planned Ocean Mantle Dynamics program.

Long-range coupling and ridge segmentation. Moorings or other instrumentation outside the bull's-eye are needed for monitoring remote events, establishing regional baseline properties, and assessing the response within the 9°50' N bull's-eye site. Sampling and mapping at vent areas outside the bull's-eye are also needed to study long-range coupling of ridge events, ridge segmentation, and biological community dynamics.

Real-time telemetry. Because the EPR site is not a candidate for a cabled observatory, more infrastructure is needed to detect magmatic/tectonic events and their aftermath. Obtaining real-time telemetry at the site would allow rapid response to a magmatic event. A moored buoy with real-time telemetry for the EPR ISS should be pursued as a high priority program in conjunction with ORION.

Drilling. IODP or other shallow drilling programs are the only means to obtain direct observations on the vertical dimension of the system. A drilling proposal to IODP tied to the goals of the EPR ISS is needed.

Response Kits. Prepared response kits are needed that could be used in the event that recent volcanic activity is observed during a dive program. These response kits should include wish lists of sampling targets (see below), instructions on how to retrieve and store samples, and any needed nonstandard sampling devices.

Community wish list. A wish list for opportunistic sampling on upcoming cruises is needed (e.g., fresh lavas, organisms, hydrothermal deposits, fluids). A community wish list would formalize a request system for scientists not going to sea to request samples and/or science that might be done if time and opportunity allows during other funded field programs. A wish list could be implemented immediately through the site coordinator.

East Pacific Rise ISS Oversight Committee

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FIELD Cruise to the Northern EPR: Discoveries Made During Biological Investigations from 8°37' N to 12°48' N

Voight, J. R.[1], R. A. Zierenberg[2], J. McClain[2], and the Science Party:
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On October 31, 2003, the FIELD (Focused Investigations of Environment and Life at Depth) cruise, funded by NSF's Biotic Surveys and Inventories (DEB-0072695 to J. R. Voight) set sail on the R/V *Atlantis* for a series of *Alvin* dives on the East Pacific Rise. Objectives were to document and collect fauna from numerous hydrothermal vents along a 400-km section of the EPR, and to preserve the specimens acquired in museum collections for full taxonomic description and systematic study. Night operations included use of the WHOI towed digital camera system (Fornari et al., 2003) to refine dive target selection in unexplored areas, short plankton tows, and near-axis SeaBeam mapping to investigate abyssal hill topography and the mechanics of ridge-transform interactions near the Clipperton Fracture Zone. Funding from the Negaunee Foundation supported an outreach program that reported cruise results to a general audience via a Field Museum Web site, http://www.fieldmuseum.org/expeditions/janet2_expedition/about.html.

Complementary programs funded by NSF's Ocean Sciences Division (OCE-0002458 to K. Von Damm and OCE-0002729 to C. Fisher) used 6 dives at 9°50' N to continue ongoing studies of the EPR ISS bull's-eye. These dives continued the time-series investigations of hydrothermal vent fluid composition in response to the magmatic/tectonic evolution of the site and recovered experiments that were deployed in November 2002 to test the effects of physical structure and habitat on a *Riftia* community.

To ensure that vent-associated fauna were successfully collected from the classic EPR tube worm- and mussel-dominated habitats and that among-habitat diversity was well documented, we dove purposefully to make large collections at vent sites recently reported to support the targeted species assemblages and at exploratory sites to extend our knowledge of the distribution of vent-associated fauna. Fauna from vent peripheries were targeted for collections, as were species known only from areas with active hydrothermal flow. We made collections at Genesis and Parigo vents (near 12°48' N) where tube worms of the genus *Riftia* had been documented to dominate (Lallier et al., 1999). The tube worms were associated with extremely high densities of serpulids and octopuses of *Vulcanoctopus,* but relatively few mussels, consistent with trends that Lallier et al. (1999) noted.

Exploratory dives in the 13° N area targeted a near-axis shield volcano 2 km east of the ridge, referred to as Caldera (Lallier et al., 1999; Figure 1). Active vents at Caldera occur on one of the largest known seafloor massive sulfide deposits (Fouquet et al., 1996). Extensive weathering rinds on much of the outcropping sulfide and talus, and the difference between our high temperature measurement of 310°C and the peak temperature of 12°C recorded in 1992 (Fouquet et al., 1996), confirm that high temperature hydrothermal activity has been rejuvenated at this site during the last decade.

Our explicit goal for dives at Caldera was to collect *Riftia* with rust-colored tubes and any associated fauna. So-called "rusty *Riftia*" typify areas of relatively elevated Fe/H_2S fluid concentrations that can indicate waning hydrothermal activity. Tube worms of genus *Tevnia,* in contrast, are generally considered to be early colonizers of hydrothermal vents (Lutz et al., 1994). At this site, rusty tube worms of both genera were found together in several habitats, including massive sulfide talus and 6 m tall sulfide chimneys with temperatures up to 310°C. Collections

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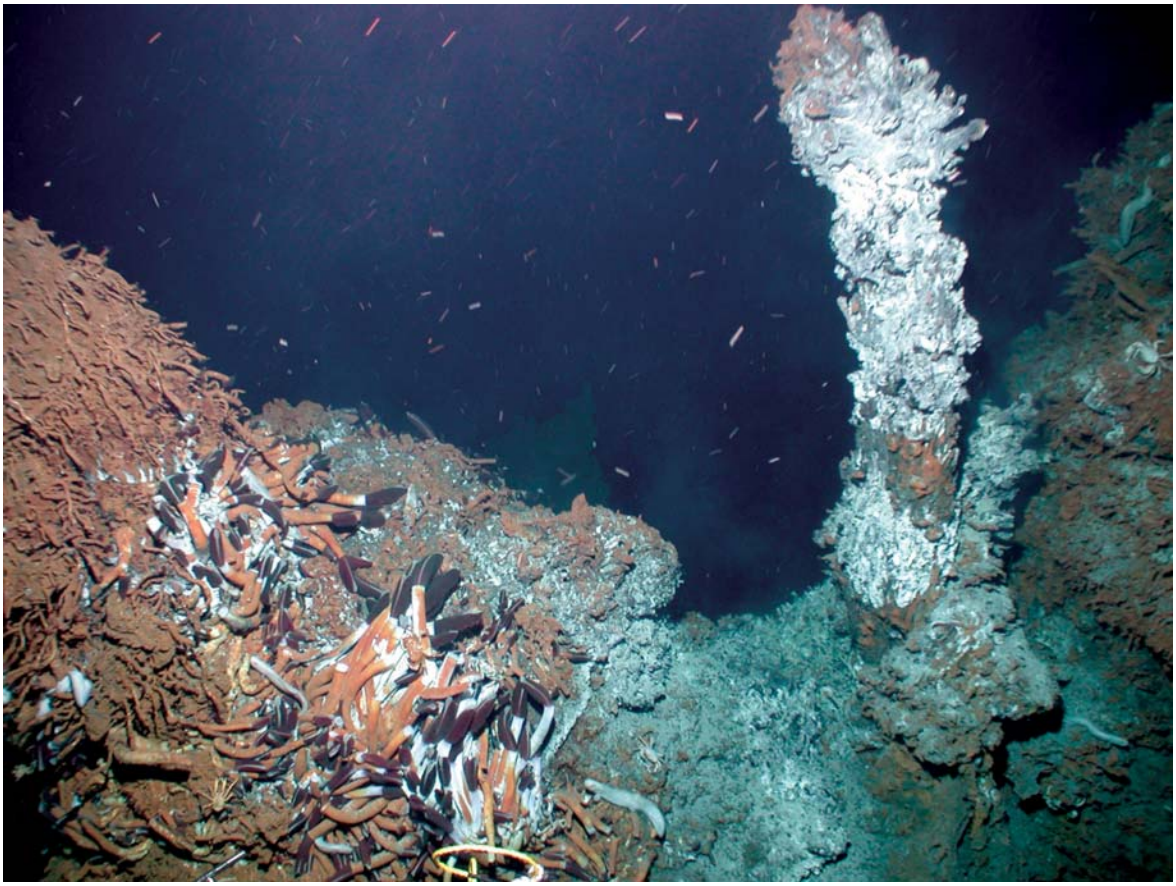

Fig. 1. View of Caldera with rusty-colored *Tevnia* and *Riftia* with adjacent chimney. Note the abundance of predatory taxa, including galatheids, vent crabs, and zoarcids. Photo from forward-looking digital camera, *Alvin* dive 3940. Courtesy of J.R. Voight.

revealed that the high-temperature chimney areas supported unusually large individuals of *Alvinella* and associated species. Detailed shore-based investigations will be required to determine if any faunal differences exist between the collections from the off-axis Caldera site and from Genesis and Parigo.

Dense communities of clams and mussels at 11°24' N in the BuckField vent field (C. L. Van Dover, pers. comm.) were thoroughly sampled, and two exploratory areas, 8°37' N and 10°44' N, were targeted. Hydrophone data indicated the occurrence of a seismic swarm with characteristics consistent with a volcanic eruption in March 2001 near 8°37' N. A follow-up CTD survey in December 2002 detected a weak plume, identified primarily by decreased optical transmissivity and slightly elevated manganese concentrations (Bohnenstiehl et al., 2003). At 10°44' N a magma-starved ridge segment extends north from the Clipperton Transform to south of the BuckField vent site. These areas were targeted in anticipation of discovering evidence of a recent lava flow and new hydrothermal activity, respectively.

Our first dive near 8°37' N found very cloudy diffuse flow that appeared to sustain a macrofaunal assemblage dominated by Stauromedusae, similar to those reported from 21° N and 7° S (Lutz et al., 1998; Halanych et al., 1999). Camera tows imaged additional areas with cloudy water and abundant Stauromedusae, marginal to a lava lake collapse. One site also supported tube worms of *Tevnia jerichonana* and limpets of *Eulepetopsis vitrea.* The venting areas are located in fissured terrain of partly sediment-dusted lavas, south and west of Bohnenstiehl et al.'s (2003) primary seismic swarm. In the southernmost area of the seismic swarm, we found no indication of recent volcanic activity or hydrothermal venting, either in the axial valley or on the andesite-capped ridge east of the spreading center.

Providing a surprising contrast, the first dive at 10°44' N landed amid clear evidence of a recent volcanic eruption. This previously unexplored region occupies a local, along-axis topographic high where towed camera operations documented vent fauna in the 1980s (ARGO-RISE GROUP, 1988). Our three dives in this area encountered a very young basalt flow that extends at least 4 km along the axis. Wherever glassy flow was observed, it was associated with diffuse hydrothermal flow, bacterial mats, and snow-blower vents (3°-9.5°C; Figure 2) issuing from collapsed areas of the lava flow. Bythograeid and galatheid crabs and zoarcid fishes *(Thermarces cerberus)* were abundant, but no other vent macrofauna were observed from *Alvin.* Nematocarcinid shrimps, a background taxon, were also abundant. The only evidence seen of the previously photographed hydrothermal system was the top of an extinct sulfide chimney rising from the glassy lava flow. The absence of macrofaunal communities and the preponderance of filamentous bacteria and formless, gelatinous material, considered to be a microbial by-product, are all strikingly reminiscent of observations made at Axial Volcano six months after its eruption. The vagile macrofauna we saw are the same as those reported post-eruption at 9° N (Shank et al., 1998). We also found a previously unknown species of polynoid polychaete associated with the bacterial mats. *Continued on page 24*

FIELD Cruise *continued from page 23*

Fig. 2. The *Alvin* low-temp probe being inserted into a snow-blower located in a collapse structure at 10°44' N on the East Pacific Rise. Maximum temperatures reached only 9.5°C. Photo from forward-looking digital camera, Alvin *dive 3937.* Courtesy of J.R. Voight.

The results of this cruise, outlined here, offer a new perspective on the 8° to 11° N Ridge 2000 Integrated Studies Site and adjacent ridge segments. Our preliminary shipboard observations indicate that our collections are rich in species new to science. Although many determinations await shore-based research, we conservatively estimate that our collections contain representatives of 15 to 20 new species, including up to 4 new genera. Cnidaria provided 7 of the new species, several of which were collected from or near vents. Among crustaceans, 5 of the 19 species documented on board are either new or show greater morphological variation than previously reported. Conservatively, representatives of 3 new species of polychaetes were collected. Of the 3 octopod taxa collected, only one has been previously collected in the Pacific from within 30° in any direction of our dive sites; a leech that appeared to have been associated with *Vulcanoctopus* is likely new. Bryozoan colonies collected were a surprise addition to the vent fauna.

Clearly, one of the more successful aspects of this cruise was the complete inclusion of taxon specialists in the cruise. The presence of taxonomic experts in *Alvin* had a favorable impact on sampling priorities and allowed us to fully exploit unanticipated sampling opportunities. The biological collections will be deposited at The Field Museum, loaned to experts for determination, and become the basis for an on-line taxonomic key that will be made available in CD-ROM format to UNOLS ships. These specimens will provide an invaluable resource for systematic studies of hydrothermal vent fauna.

Acknowledgments

We thank the captain and crew of the R/V *Atlantis,* the Expedition Leader and the *Alvin* group, and the WHOI Marine port office for all their assistance. National Science Foundation PEET grants DEB-9978193 to J. W. Martin and D. Jacobs and DEB-9978106 to D. Fautin supported participation by T. A. Haney and M. Daly, respectively. The National Undersea Research Program of the National Oceanographic and Atmospheric Administration provided support via Grant POFP005001/AK-99-13, for R. Zierenberg and via PO FP206164/CA-02-04 for J. McClain.

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Update on the Hydrothermal and Biological Status of the EPR ISS "Bull's-Eye" at 9°50' N

K. Von Damm, C. Parker, and K. Beers (University of New Hampshire) and B. Govenar, C. Fisher (Pennsylvania State University) and the FIELD03 Science Party

The EPR ISS bull's-eye site continues to be a very dynamic system. In November 2003 during the FIELD03 expedition on the East Pacific Rise, we completed 6 *Alvin* dives between ~9°49-51' N, from Tube Worm Pillar north to Biovent (Figure 1). The dives were used to

- recover the artificial tube worm aggregation experiments (Fisher Lab),
- resample the high-temperature hydrothermal vent fluids and measure their temperatures (Von Damm Lab),
- recover the HOBO probes left in 2002 and deploy new probes in all of the high-temperature vents as part of ISS baseline data (Von Damm Lab), and
- deploy two replacement transponders at the site for general ISS work.

Each successive sampling trip to EPR shows significant changes from the previous one, irrespective of the exact time interval. The hydrothermal system shows an apparent decreasing (or cessation) of fluid flow toward the southern end of the (BIOGEO) Transect, a continued "hot spot" of activity in the Hole-to-Hell area, and some signs of increased activity to the north. This is evidenced by both the amount and temperature of the fluid flow, and the nature and abundance of the animal communities. Specific examples from the November 2003 cruise of these observations are the cessation of fluid flow at Tube Worm Pillar, the initiation of a new black smoker at Tica, and an expanded areal extent of hydrothermal communities at Tica. We would also describe most of the high-temperature vent fluids as "fizzy," which suggests that the high CO_2 levels observed in these fluids since ~1993-4 continue into 2003.

The following changes were noted in comparison to our most recent cruises at this site (Von Damm, January-February 2002; Fisher, December 2002).

The Tube Worm Pillar (TWP), which previously hosted a black smoker at its top and a lush community of tube worms supported by hydrothermal fluids leaking through the sulfide edifice built on top of a lava pillar, was found to no longer have noticeable fluid flow. Consequently, no live tube worms were noted on the structure, and the empty tubes had sloughed off the lower two-thirds of the structure and were lying on the basalt at the base of the pillar. Without the covering of tube worms, we were able to confirm for the first time our previous hypothesis that most of the 11 m height is sulfide, not basalt.

Moving north from this site, the robust biological community that has been located at BM141/2 for about a decade is now dominated by

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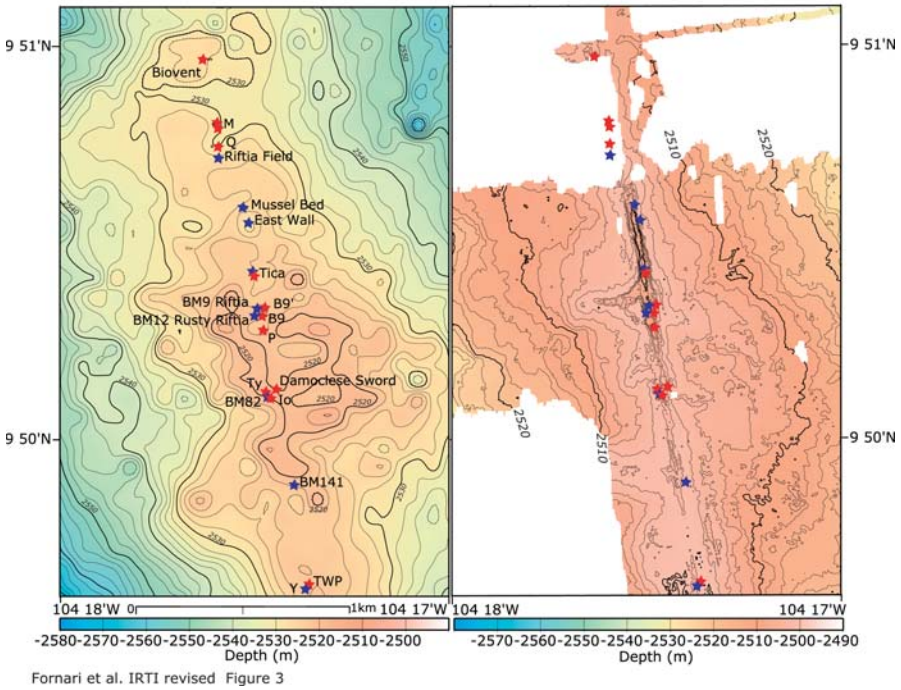

Fig. 1. Left map shows multibeam bathymetry for the EPR ISS bull's eye with high- and low-temperature vents (red and blue stars, respectively) labeled. Right map shows the detailed, 5-m gridded, 675 kHz Imagenex scanning altimetric data collected by ABE. Vertical resolution of the data is 1 m (Fornari et al., 2004). Vent symbols are same as on left map. [Fornari, D. J., M. Tivey, H. Schouten, M. Perfit, et al. In press, 2004. Submarine lava flow emplacement at the East Pacific Rise 9°50' N: Implications for uppermost ocean crust stratigraphy and hydrothermal fluid circulation. In *The Subsurface Biosphere at Mid-Ocean Ridges,* edited by W. Wilcock et al. AGU Geophysical Monograph Series. Washington, DC: American Geophysical Union.]

EPR ISS "Bull's-Eye" *continued from page 25*

mussels. Continuing northward, we revisited BM82, a site of a diffuse flow community that, since ~1997, also hosts two black smokers, Io and Ty. Although mussels dominate, some *Riftia* were observed at this location. Ty and Io remain quite active, although maximum measured fluid temperatures were 333 and 349°C, respectively, which is slightly lower than the values measured in early 2002 (350 and 356°C). Shore-based analysis will be required to discern if the lower temperatures may be a result of mixing within the chimneys. In 2002, fluids from Ty were slightly higher in Cl than seawater, while Io was a vapor; our 2003 shipboard results suggest this remains the case. The HOBO probe left in Ty vent in 2002 was not found.

The Hole-to-Hell area at 9°50' N, the location of the high-temperature P and Bio9 vents, remains extremely active. More than three high-temperature vents remain active at Bio9, and the chimney at P-middle vent has grown significantly since 2002. The HOBO probes deployed in P and P-middle vents in 2002 were recovered, but the one left in Bio9 was not located. Bio9, Bio9' and Bio9" vent fluids had maximum measured temperatures of 384°, 376°, 387°C, respectively, and P and P-middle measured 373° and 371°C (2002 values were 386°, 386°, 377°C for the Bio vents, and 386° and 385°C for the P vents, respectively). This area remains extremely hot, and the Bio9 vents continue to vent fluids with extremely low Cl contents. The P vents also continue to vent low chlorinity fluids compared to seawater. Whether the Cl values have changed since 2002 will require further shore-based laboratory analysis. In general, our impression is that Hole-to-Hell is re-invigorated, with much fluid flow and some *Riftia.* The amount of sulfide that has accumulated in this area since the eruptions in 1991–2, and particularly since ~1995, is notable.

Moving north, the next area of study was Tica. One of the surprises at Tica was the presence of a small black smoker vent. Although the 1–2 m high chimney was very friable, we were able to collect fluid samples from it. A maximum measured temperature of 342°C was recorded. One of the sulfide minerals in the chimney appears to be pyrrhotite, suggesting the fluids are quite reducing, and shipboard results suggest that Tica may be venting the lowest chlorinity fluids collected on this cruise, significantly less than half the seawater value.

Around the small smoker, robust *Riftia* are growing in close proximity to the high-temperature fluids. On the east wall of the Axial Summit Collapse Trough (ASCT) at Tica, the *Riftia pachyptila* individuals were larger and the populations more dense than in December 2002. In addition to this growth, *Bathymodiolus thermophilus* (mussels) have continued to settle among the *Riftia* and on the surrounding basalt. In some places, the mussels are large (> 8 cm) and form dense clumps, but *R. pachyptila* is still the visually dominant species. Aggregations of empty and decaying *R. pachyptila* tubes were present on the floor of the ASC. Tubes were unattached and apparently represent accumulated dead Riftia that have fallen from their original attachment points.

Two other sites that were sampled in December 2001 and December 2002 are Mussel Bed and Riftia Field. This year at Mussel Bed, the overall density and extent of mussels seemed to be decreasing, although there are still pockets of active diffuse flow where the mussel bed is thick and there are bacteria growing on the shells. At Riftia Field, the diffuse flow was still apparent from the presence of shimmering water, but few *Riftia* were still alive at the site. Anemones seemed to be more common at this site than in previous years.

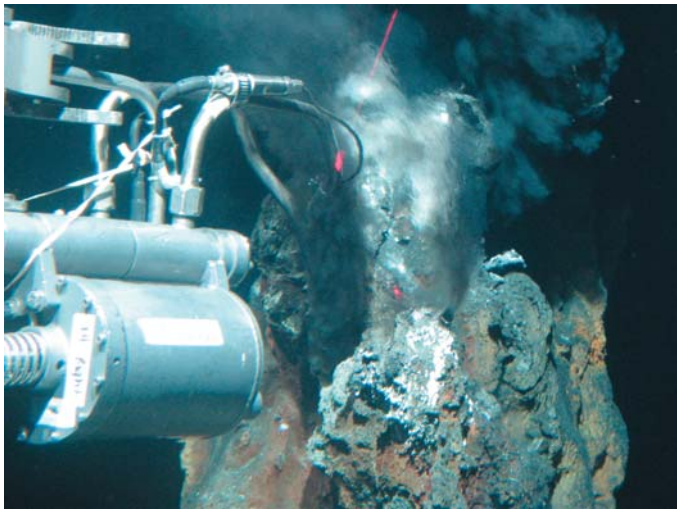

Fig. 2. M vent continues to be vigorously venting fluids, at measured temperatures of up to 366°C at the time of fluid sampling in November 2003. Photo courtesy of K. Von Damm, UNH.

Continuing northward, Q vent, M vent, and Biovent were also sampled. Q and M vent fluids are similar in chlorinity to each other, and about the same as the fluids from the more southerly Ty vent, demonstrating that the Cl-variations are not strictly a geographic trend at the EPR ISS. Unlike the fluids from Q and M vents, the vent fluids sampled from Biovent contain significantly less chloride than seawater. M vent (Figure 2) now hosts a number of smokers (at least 3) and our impression is of a very hydrothermally active area. M vent fluids were measured to be 366°, those from Q were 346°, and 342°C from Biovent, compared to 374°, 344°, and 345°C, respectively, in early 2002. Hence, fluids from Biovent and Q are unchanged in temperature, while those from M may have cooled slightly. The temperature of M vent fluids are basically the same as they were from 1995-1999; the measured value in 2002 was unusually hot. We will need to determine if the chemistry of the fluids has changed significantly to put this apparent temperature change into context. The temperature probe deployed in M vent in 2002 was recovered.

All of the high-temperature vent areas have now been re-instrumented with new recording temperature probes (HOBOs). The plan is to recover these, download their data, and re-deploy them in March 2004. We noted during the November cruise that many of the identifying markers at the high-temperature vents are no longer visible; to remedy this we plan to deploy new markers early in 2004.

Although this is a brief (and preliminary summary), we hope having this quick update of the current status will assist the community in planning their upcoming experiments at this site.

A Low Power, Low Cost, Underwater Optical Communication System

Maurice Tivey[1] *(WHOI, Geology and Geophysics),* Paul Fucile *(WHOI, Physical Oceanography),* and Enid Sichel *(WHOI and Massachusetts Maritime Academy, Buzzards Bay)*

Communicating with seafloor sensors is a fundamental need in marine science and particularly for deep submergence science (Seyfried et al., 2000). To facilitate this vital requirement, we have developed an optical communication system that can operate over the range of a few meters underwater. An optical communication system offers many intriguing opportunities for communicating with multiple devices, and allows two-way communications as well as use on a variety of platforms such as submersibles and ROVs. It is also feasible that an optical communication system could be used on an autonomous underwater vehicle (AUV) to communicate with seafloor instruments during a "fly-by" mission without the need for docking.

In a typical scenario today, sensors ranging from large on-bottom seismometers to small temperature probes such as HOBOs (e.g., Fornari et al., 1996) are deployed with built-in dataloggers to record their data for up to a year. Communicating with these devices once they have been deployed is often not possible, for many instruments must be recovered to download their data. For some sensor packages these are not critical issues, but for other sensors it means trusting that the deployed sensor is working when deployed and that it remains operational until recovered. There is no mechanism to check on sensor performance either during installation or after deployment. Ideally, it would be useful to interact with sensors in place on the seafloor without moving or disrupting the measurement environment. It is also good practice to check that an instrument is continuing to function or is set up correctly upon deployment.

A wireless communication system obviates the need for cables that tether sensors to submersibles or remotely operated vehicles (ROV), which while providing direct access to the sensor make deployment and manipulation challenging. A number of approaches have been used to interact with sensors without having to physically connect to the system. Acoustic modems (Herold and Johnson, 1994; Frietag et al., 1997), which can be accessed either from a surface ship or submersible, provide one method to communicate with a sensor or sensor system. Such systems require transducers capable of working at great depth and have power requirements in addition to the sensor itself. While this is an effective approach for large and long-term sensor installations, such as CORKS, for example (Davis et al., 1992), it poses a significant burden on smaller sensor systems and is clearly not feasible for small sensors like HOBOs. A recent development that is more applicable to small sensor systems is the inductively coupled loop (ICL) (Bradley et al., 1995; Fornari et al., 1997). This device uses a transmitter wire loop and separate receiver current loop to communicate via electromagnetic induction without physical contact between the transmitter and receiver. The ICL has a robust mode of operation, has a moderate baud rate capacity of about 9600 bps, and works under virtually all conditions, but requires close range (centimeters) to function. The ICL transmitter and receiver wire loops, or "wands," typically need to be almost touching to within 10 cm for the link to be reliably established. The smaller the loop, the closer the contact needs to be.

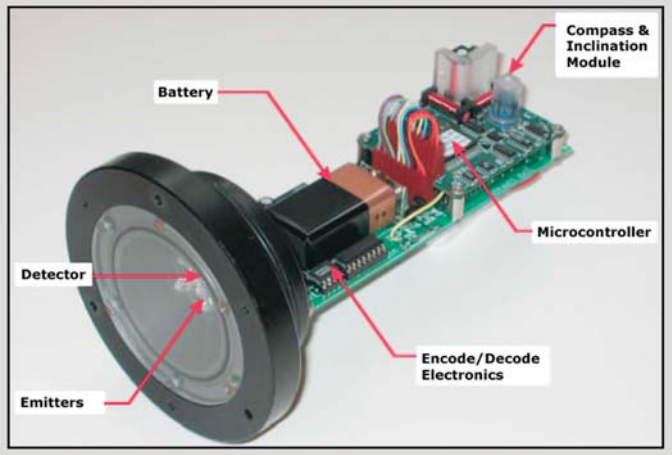

Fig. 1. Annotated photograph of test optical communication board as used in the tests.

We have developed an alternative communication approach that is low power and has minimal overhead requirements for a given sensor system. Our approach is based on underwater optical communication using low power, inexpensive devices that include: a light-emitting diode (LED) source, a silicon-based photodetector receiver, and off-the-shelf communication technology utilizing the IrDA protocol (Infrared Data Association, http://www.irda.org). Optical communications offer the potential for high data rates of up to 10 megabits per second and ranges up to 20 m for high-powered light sources and detectors (Bales and Chryssostomidis, 1995).

Device Description

We have built a "test-bed" board (Figure 1) to carry out a range of underwater tests. The hardware and circuitry is inexpensive and the physical dimensions of the transmitter and receiver are small, about the size of a small flashlight. The same board can be used as a transmitter or receiver, allowing for the possibility for two-way communication.

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Underwater Optical Communication System *continued from page 27*

For the transmitter, we use an array of 22 LEDs mounted on a disk (4.8 cm diameter) that mounts on the end of the circuit board. For the receiver, we use a silicon-based photodetector (PIN device) with an active area of 42 mm^2. A small fresnel lens in front of the photodiode helps to improve the light-gathering capabilities of the device off-axis. The photodiode is mounted at the center of the disk LED array. We utilize the IrDA communication protocol, which is based on infrared wireless "line-of-sight" communication that is now being used throughout the computer and consumer electronics industry for remote control functions and connections between peripherals and host computers.

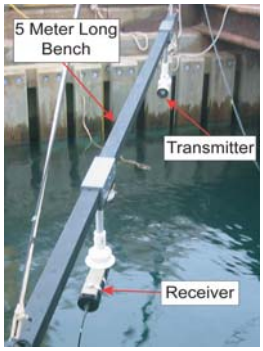
The IrDA protocol rejects ambient external light noise and provides a solid, robust communication link. This is important for our purposes because external submersible or ROV lights could be an interference source. In the current configuration, we use an asynchronous serial communication rate of 14.4 kbs, but the maximum baud rate supported by the IrDA protocol is 115.2 kbs. In practice, this rate would require a lower capacitance photodiode, which has less light-gathering capacity and would reduce the effective range of the device.

Test Results

We tested both blue and red LEDs as potential transmitter sources. A variety of physical phenomena and practical considerations favor our use of the red LEDs. The optical absorption of light by seawater is wavelength dependent. Blue light wavelengths (450 nm) theoretically suffer less transmission loss underwater than red (660 nm) or infrared wavelengths. However, blue light is more strongly scattered by particulates and minute bubbles in the water than is red light. This is the well-known Rayleigh scattering (Jenkins and White, 1950). In terms of the devices, the quantum efficiency of silicon photodiode detectors is twice as sensitive to red light than to blue light (Franz and Jain, 2000). In addition, red LED sources have a higher photoconversion efficiency (Sze, 1985).

For the range tests, we built a submersible 5-meter "optical bench" test facility. We deployed this test facility in seawater at the Woods Hole dock to conduct the range measurements (Figures 2 & 3). We performed two types of measurements: (1) transmitting and receiving a message, i.e., "communication," and (2) counting photons received at the photodiode. We used an integrating underwater photometer developed at Woods Hole Oceanographic Institution (WHOI) to measure the light energy received at the detector from the LED arrays. This photometer uses the same photodiode as our receiver. For the dock tests, we also measured the water clarity using a C-Star transmissometer, which gave an average percent transmission of ~75%.

We found that red LEDs offer superior optical characteristics over short ranges for sending/receiving signals underwater over distances of less than 5 meters compared to the blue LEDs (Figure 4). For the red LED system, we found that 100% communication was obtainable over a range to 2.7 meters. The maximum range with errors was ~3.7 meters. For the blue LED system, we found we could obtain 100% communication to a maximum range of 1.5 meters in seawater; the limit of communication was approximately 3 meters in seawater. Figure 4 shows clearly the attenuation of the red versus blue signals in water. The red LED source is more reliable over short ranges (0-5 m) but signal strength drops off relatively quickly with distance, while the blue LED system does not attenuate as rapidly underwater and thus for long distances we would expect the blue LED system to be more effective. Based on our results above for the small ~2-inch diameter array of 22 LEDs, we decided to determine the maximum range possible given a reasonably sized source disk of diameter 5 inches. We populated the 5-inch light source disk with 320 red LEDs, which we predict can give a communication range of approximately 5 meters. The power required to drive this source remains quite modest, drawing less than 100 milliwatts.



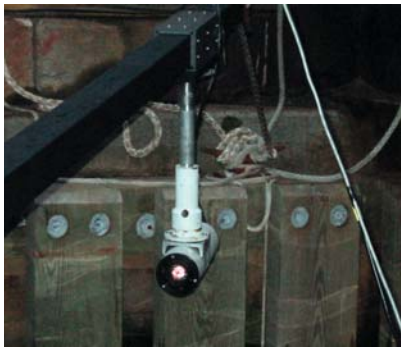


Fig. 2. *(Left)* Deployment of the 5 m optical bench at the WHOI dock with the detector and transmitter sensors mounted in watertight housings. Note, the actual size of the electronic boards is much smaller than the housings.

Fig. 3. *(Right)* The red LED source glows from the transmitter device during operation.

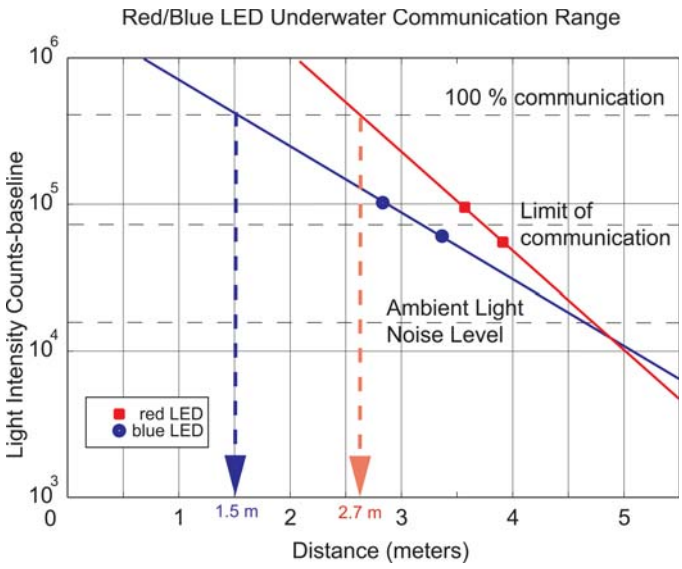


Fig. 4. Range test of underwater optical communication system. Red solid line indicates the attenuation curve of the red LED source, while the blue solid line indicates the blue LED source. The red and blue dashed lines indicate the range limit over which the device communication was perfect.

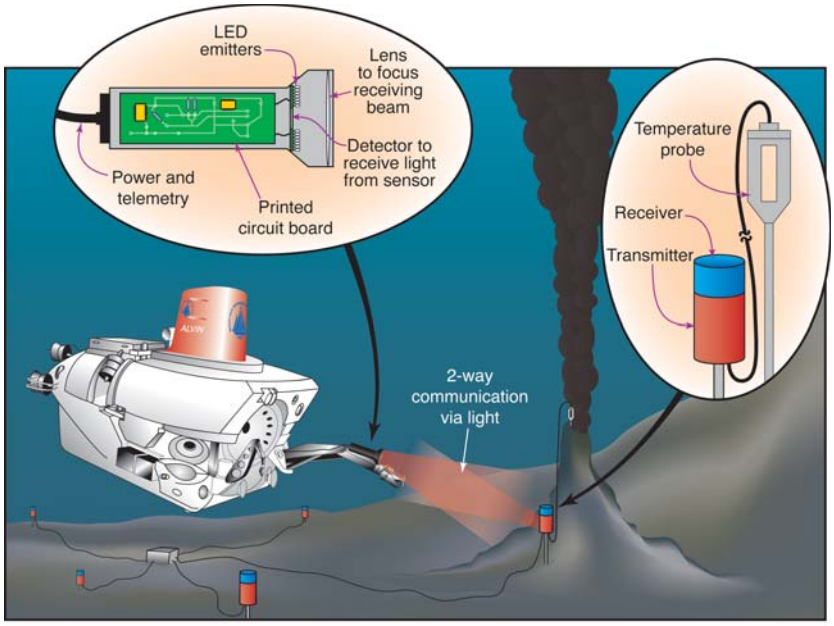


Fig. 5. Cartoon showing the submersible *Alvin* communicating remotely with a temperature sensor outfitted with an optical interface installed at a hydrothermal vent. Inset drawings show details of the transceiver mounted on the *Alvin* manipulator and a similar device located on the seafloor. Multiple optical transceivers could be located in networks servicing sensors and a central data logging unit.

Conclusions

We have demonstrated the ability to transmit data optically underwater using low power and inexpensive devices. We have used off-the-shelf components and the IrDA protocol to leverage the technology available today. We can build a relatively simple, low-impact communication device for ranges less than 5 meters. Such a system could be readily incorporated into small sensors with little overhead. To push this technology to further distances we would need greater light energy output, multiple photodetectors, focused beams, and more elaborate lensing systems. At present, we envision using this device with simple sensor systems such as temperature and chemical probes, tiltmeters, and compass devices (Figure 5). We believe this technology could easily be incorporated into many different applications, including networks of sensors and communication between sensors and a central data logging unit.

Acknowledgments

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** Welcome to our newest Steering Committee members!*

Thank you!

Our deep gratitude to the following retiring Steering Committee members for their service to Ridge 2000.

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Geology and Geophysics
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European Geosciences Union (EGU) First General Assembly—Nice, France • April 26-30, 2004, http://www.copernicus.org/EGU/EGU.html

American Geophysical Union — Canadian Geophysical Union 2004 Joint Assembly—Palais des Congres, Montreal, Canada • May 17-21. 2004, http://www.agu.org/meetings/sm04/

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American Society of Limnology and Oceanography 2004 Summer Meeting: The Changing Landscapes of Oceans and Freshwater— Savannah International Trade & Convention Center, Savannah, GA • Jun 13-18, 2004, http://aslo.org

VI International Larval Biology Conference— Hong Kong University of Science and Technology, Hong Kong, SAR China • Jun 21-25, 2004, http://www.larval2004.ust.hk

Asia–Oceania Geosciences Society Annual Meeting—Singapore, Singapore • July 5-9, 2004, http://www.asiaoceania.org/confer.html

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