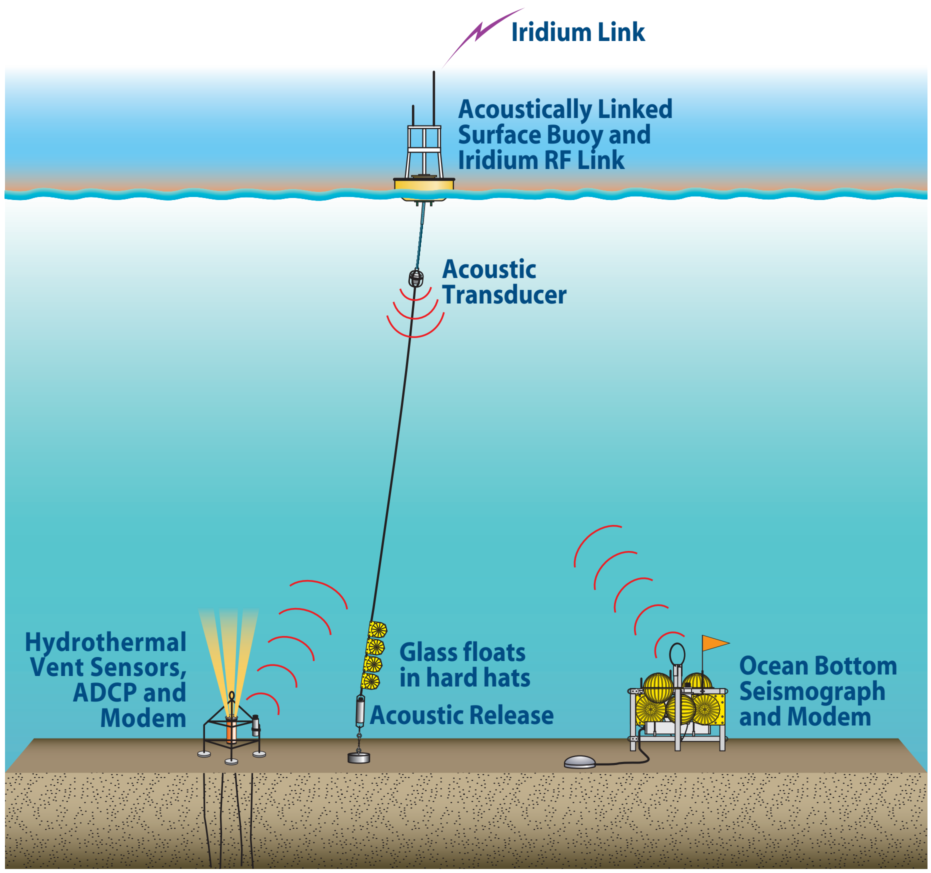
Deep Ocean Exploration Institute

INVESTIGATING EARTH'S DYNAMIC PROCESSES

Science Brief

Wireless Communication for Seafloor Observatories

One of the greatest challenges to scientists whose work involves studying seafloor dynamics is timely acquisition of underwater earthquake data. Modern Ethernet-linked seismic networks on land allow scientists to locate the source of an earthquake and determine its magnitude almost immediately. Unfortunately, the technology for rapid transmission of data from the ocean floor to shore lags far behind. Currently, seismic data collected on the seafloor is stored with ocean bottom seismographs for as long as a year after an earthquake occurs. Only after the instrument is recovered by ship and brought back to the laboratory is the data downloaded and analyzed.



Acoustically-linked data communications system developed by WHOI engineers for ocean bottom observatories.

To solve this time-lag problem, WHOI engineers Lee Freitag, Ken Peal, James Doutt and Matthew Grund of the Applied Ocean Physics and Engineering Department, along with John Collins, of the Geology and Geophysics Department, devised an acoustically-linked data communications system that allows for timely transmission of data from the seafloor to the laboratory via satellite.

With DOEI-funding, a method was developed to seamlessly connect a seismometer to an acoustic modem to transmit the data back to shore. The challenge is that modern seismometers are network appliances. They are designed to be connected to the Ethernet, and they serve files much like a standard Web site. Thus, the engineers had to develop a way to make an acoustic link look like an Ethernet link, and to do so, added a small computer (aptly named the Bitsy, because of its small size – 3 by 5 inches) to the glass ball that also houses the seismometer and modem for deployment on the ocean floor. The

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Woods Hole Oceanographic Institution
Woods Hole, MA 02543

Bitsy has an Ethernet connection for the seismometer and a serial port for the acoustic modem (just like a home computer with a telephone modem).

Software engineers worked with a WHOI seismologist to understand how best to retrieve data from the seismometer and developed programs that could be executed with very simple commands sent over the acoustic link. The data from the seismometer is placed in an *outbox* (like mail ready to be picked up) on the Bitsy computer to await an acoustic connection from the buoy. Once the acoustic connection is made between the modem on the seismometer and the surface buoy, the data is transmitted to shore via an Iridium satellite link. With this system, the information gets to shore within minutes to hours of an event, as opposed to months.

This DOEI-funded project was accomplished in conjunction with a large National Science Foundation project that supported the buoy, satellite link and other sensors. The entire system was taken to sea and deployed in November 2003, then retrieved in January 2004. Over 50 Mbytes of data were sent over the acoustic link, and the seismometer network appliances worked flawlessly.

The final deployment of the communications system will occur in May 2004 near the Nootka Fault off the coast of Washington state. There, the system will be used to demonstrate the capabilities of acoustically-linked network sensor appliances and provide scientists with much-needed observations of seismic events recorded on the ocean floor and transmitted quickly back to shore. Lee Freitag's full report can be read on the DOEI Web site: http://www.whoi.edu/institutes/doei/research/research_01freitag.htm.

Postdoc Spotlight

Olivier Rouxel describes his path to WHOI and his science interests

Before becoming involved in oceanographic research, I earned a French engineering degree in 1998 in petroleum geology from the Ecole National Supérieure de Géologie in Nancy. During engineering studies, I took advantage of the close relationship between the Engineering School and the French National Center for Petrographic and Geochemical Research (CRPG-CNRS) to discover the exciting world of scientific research and pure Earth Sciences. At this time, I confirmed a desire to dedicate my future to a career in academia, and I undertook an M.S. degree in geochemistry at the National Polytechnic Institute of Lorraine at Nancy, before starting a Ph.D. thesis, in 1998, at the CRPG-CNRS.

During my Ph.D. studies, I was involved in various projects and earned experience in analytical geochemistry through the development of isotopic analysis by multi-collector ICP-MS (Inductively Coupled Plasma Mass Spectrometry). Multi-collector ICP-MS makes the determination of high precision isotope ratios of a wide range of elements possible. With this instrumentation, I completed one of the first studies related to the natural variations of iron (Fe), copper (Cu) and selenium (Se) isotopes and their use as geochemical tracers. I also discovered that antimony (Sb) isotopes might be used to trace redox changes (oxidation and reduction reactions) in natural systems.


Olivier Rouxel at his desk.

(Antimony is a toxic, semi-metallic element that has two naturally occurring stable isotopes.) I applied these poorly-known isotopic systems to the study of seafloor hydrothermal systems and the alteration of the oceanic crust, in collaboration with colleagues at the IFREMER oceanographic center (French Research Institute for Exploitation of the Sea), located at Brest, France. These projects gave me the opportunity to be involved in two oceanographic cruises in 2000 and 2001—one including a ***Victor*** (remotely operated vehicle) dive on the Rainbow hydrothermal vent field on the Mid-Atlantic Ridge and another on an Ocean Drilling Program (ODP) Leg in the West Pacific.

After my Ph.D. thesis defense in September 2002, I moved to the Department of Earth Sciences at the University of Cambridge to develop new isotopic tracers in paleoceanography. During this postdoctoral period, I investigated the use of germanium (Ge) isotopes in marine diatoms to provide new insights into past glacial/interglacial transitions and the fate of nutrient levels in past oceans. In 2003, I received a Woods Hole Oceanographic Institution Postdoctoral Scholar Award, funded by the DOEI, and I joined the Department of Marine Chemistry and Geochemistry to investigate the use of iron (Fe) and other heavy stable isotopes to trace microbial processes in the oceanic crust.

The role of iron-oxidizing bacteria in weathering seafloor crustal materials—including basaltic glass and sulfide minerals—has been recently identified. However, it is not yet known if the products of weathering reactions, which often persist for millions of years, can be attributed to bacterial activity. The search for new geochemical tracers to determine the extent to which microbes were involved in rock alterations may ultimately find applications for the identification of life in extreme environments, such as those found on an early Earth or on other planets.

Deep Biosphere Seminar Series, summary by Wolfgang Bach

Between September 2003 and March 2004, the Deep Ocean Exploration Institute (DOEI) hosted a seminar series for national and international research experts titled, "The Deep Microbial Biosphere." Scientists hypothesize that microorganisms living within the Earth's crust are as varied as those found on the planet's surface. Study of these microbes may help scientists understand Earth systems, such as global carbon and hydrologic cycles. The research also has implications for learning how life began and how it has evolved.

Scientists in the fields of geochemistry, microbiology, astrobiology, paleontology and molecular biology came to Woods Hole, Massachusetts, to discuss this new and challenging research theme, as well as meet with faculty from WHOI and the Marine Biological Laboratory. Their discussions focused on a number of broad questions:

- How abundant and metabolically active is the deep biosphere?
- What fuels the deep biosphere: photosynthetic products, inorganic energy from the deep interior, or non-biological, chemically-produced organic matter?
- What are the research implications for origin-of-life questions?
- What role does the deep biosphere play in present and past biogeochemical cycles that control ocean and atmospheric chemistry and climate?

Wolfgang Bach summarized each participant's contribution to the seminar series with the following comments:

Jeff Alt (University of Michigan) started the seminar series by discussing sulfur and carbon isotope data that indicate microbial activity deep in the crystalline rocks that form the ocean crust.

Marco Coolen (Royal Netherlands) presented a unique molecular chemical and biological study that showed that the analysis of fossil gene sequences may enable the reconstruction of ancient microbial communities and the identification of sources for lipid biomarkers at the species-level.

Tom McCollom (University of Colorado) and **George Cody** (Carnegie Institution) reported on recent laboratory and theoretical studies aimed at investigating pathways for synthesis of organic molecules from inorganic components under hydrothermal conditions. Their research highlights the importance of surface catalysts, some of which are produced during water-rock reactions at elevated temperatures.

John Baross (University of Washington) stressed the importance of studying modern submarine hydrothermal systems on mid-ocean ridges for understanding life in Earth's ancient geological history.

Kai Hinrichs (University of Bremen) and **Steve D'Hondt** (University of Rhode Island) reported their results from the first "Deep Biosphere" projects within the international Ocean Drilling Program. Their results revealed how microbial life is supported by fluid flow and transport of chemical species, such as iron and sulfate, which microorganisms "breathe" or respire.

Roger Summons (MIT) lectured on how complex organic molecules can be traced back to specific microorganisms. He also discussed "biomarker" techniques that can be used to unravel historical microbial evolution.

Ruth Blake (Yale University) showed how oxygen isotope signatures of phosphate – a vital component for microbial life – are used to detect microbial activity in iron-oxide formations and determine the temperatures at which they form.

John Parkes (Cardiff University) one of the pioneers of deep biosphere research, gave his perspective on the abundance and importance of microbial life in marine sediments, before **Karsten Pedersen** (University of Göteborg) took the audience to caverns on land that store radioactive waste in the hard rock basement of Sweden. They showed astonishing evidence of microbial life located kilometers below the surface.

Read Wolfgang's review on the DOEI Web site.

ORION Workshop reviewed in *Science*

The prospect of building a sophisticated underwater network of sensors for oceanographic research was the subject of the ORION Workshop, which took place in San Juan Puerto Rico, 4-8 January 2004. As we mentioned in our January 2004 Newsletter, ORION stands for Ocean Research Interactive Observatory Networks, and DOEI fellow, Meg Tivey, served as co-organizer and co-chair, along with Oscar Schofield of Rutgers University.

Over 300 scientists participated in the 5-day event, which allowed numerous voices to be heard on how to formulate the science priorities and educational opportunities that can be addressed using ocean observatories. An initial infrastructure investment of over $200 million dollars is planned over the next five years, as part of the Ocean Observatories Initiative (OOI), with funding projected to begin in 2006.

NSF has endorsed the goal of creating a three-pronged global observing effort for the oceans that includes an array of moveable moored buoys for the deep seafloor, a set of nearshore sensors for shore-to-shelfbreak research, and a cabled network of sensors to span a regional underwater setting.

Some scientists worry that such an ambitious and expensive NSF program will siphon funds from existing projects, and many are concerned that their projects would not fit into the new science plan.

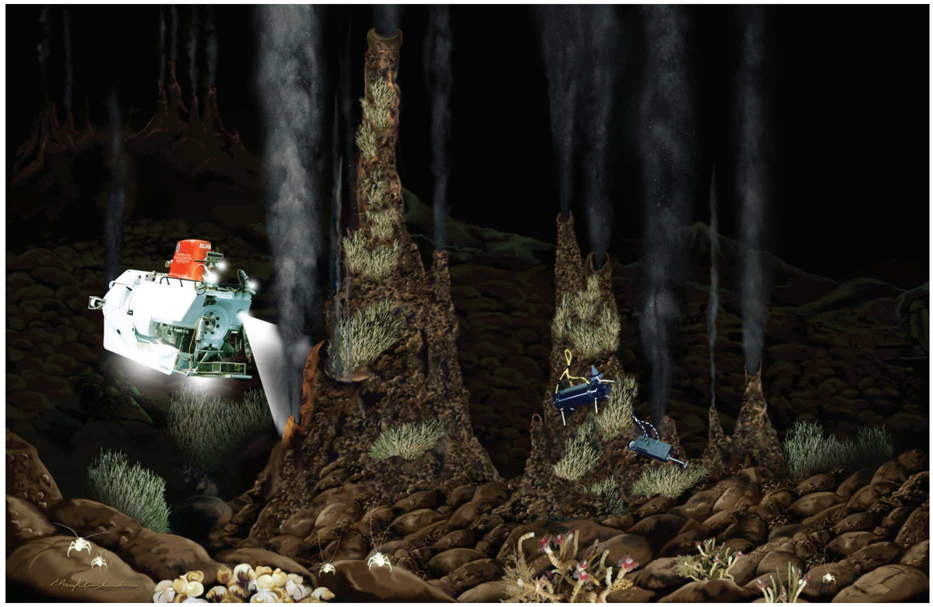
Ken Brink, Senior Scientist in WHOI's Physical Oceanography department, is leading the planning office, whose members are charged with the job of narrowing down the possibilities to a half-dozen compelling science goals, according to an article in ***Science*** (vol. 303, 16 January 2004).

Education Update

Dive and Discover Cruise

Beginning May 24, 2004, researchers diving in the submersible ***Alvin*** will explore hydrothermal vents off the Pacific Northwest coast – 200 miles west of Washington state. During the 17-day expedition to the Juan de Fuca Ridge, scientists and engineers will deploy new ocean instruments and gather samples of fluids and organisms from the vents to learn how microbes live in a high-pressure, super-heated environment.

This is the eighth ***Dive and Discover*** expedition, whereby anyone connected to the Internet can follow a research cruise as it is taking place. ***Dive and Discover*** is an interactive distance learning Web site designed to provide a stimulating and informative view into the daily experiences of an ocean research science team. Participants learn about life on the ship and can query scientists directly via email about their work. Background materials are provided as well as educational tips for teachers who use the site in their classrooms. ***Dive and Discover*** has introduced thousands of people to the field of oceanography since its inception in 2000.



http://www.divediscover.whoi.edu

This particular expedition in May will explore the life of extremophiles—extreme heat-loving organisms, which are the subject of the next section of this newsletter, ***In the News or Literature***.

In the News or Literature

Science

Extreme heat-loving organisms were featured in a ***Science*** magazine article titled, "Extending the Upper Temperature Limit for Life" (vol. 301, 15 August 2003). Researchers at the University of Massachusetts, Amherst, worked on an organism they called strain 121, which seemed to thrive at temperatures near 121°C. This temperature is routinely used in research and medical settings for sterilization, to kill all microrganisms. Strain 121 is a member of the Archaea domain of microbes and was found at a hydrothermal vent site on the Juan de Fuca Ridge in the Northwest Pacific Ocean.

Strain 121 was isolated at 100°C in culture from a water sample taken from an active black smoker chimney. When put in an autoclave (the standard equipment used for sterilization), the number of cells doubled after 24 hours at 121°C. At temperatures below 85°C, the cells of strain 121 remained viable but did not divide. At more extreme temperatures, around 130°C, no new growth was detected in strain 121, but the cells were still viable and began reproducing again when returned to temperatures around 103°C.

The factors that permit strain 121 to grow at such high temperatures are currently unknown. However, the uppermost temperature limit for life is a key parameter for determining when and where life might have evolved on a hot, early Earth. These extremophiles use Fe (III) as electron acceptors (i.e., iron reduction) in a form of respiration that does not involve oxygen – and may have been the first form of respiration, as life evolved. (See also **Postdoc Update**, Olivier Rouxel and **Deep Biosphere Seminar Series**.)

Oceanus

More than a dozen new articles for WHOI's ***Oceanus*** magazine have been posted on the Web since our January 2004 DOEI Newsletter. The articles cover a range of subjects, such as:

- the remarkable variety of life dwelling in hydrothermal vent systems
- the unusual chemistry of the deep sea
- unique new vehicles for underwater exploration and discovery
- pioneering undersea observatories and monitoring devices
- solving the evolutionary puzzle of seafloor life
- how drifting continents change Earth's climate, and more . . .

See the online version of ***Oceanus*** on WHOI's Web site at: http://oceanusmag.whoi.edu.