President’s Message
Look Beneath the Surface

One of the most challenging aspects of studying oceans is that we land-adapted humans can only see the surface. Conditions at the interface between air and water can be serene and calm, serrated by whitecaps, or whipped into confused violence by gale winds. At depth, however, the ocean is a very different place. Marine “snow” made of the remains of animals sits down from sunlit layers, while volatile hydrothermal vents eject hot, often acidic fluid into the cold bottom water. On the sea floor, sediments collect and move, ocean ridges form and spread, and a twitch of a massive section of crust can trigger a tsunami.

Although we can’t usually follow any of these events and processes by sight, people have devised a fantastic array of instruments and methods to track them. Thanks to creative ideas, sustained physical efforts, and patient analysis, ocean sediments have yielded an array of impressive stories about Earth’s past, present, and possible future.

For example, when an earthquake happens on the sea floor, particles of all sizes are thrown up into the water column. Over time, larger particles settle out, then smaller and smaller sizes, until the finest particles settle long after the event, and the record of the disturbance is locked into the sediments. Those literate in the language of geology can read the story in cores of mud retrieved from the sea floor.

Climate studies represent one of the most important fields of research of our time. In order to

Finding a Lost City When You Can’t Ask For Directions
Hugh Powell, WHOI

Searches for Undersea Vents Bring New Finds

Twenty-eight years after the discovery that hydrothermal vents were spewing superhot water and rare chemicals into the deep ocean, the discoveries are still coming fast. A session on hydrothermal vents this morning -- coincidentally held two-escalators deep under the Marriott Hotel -- focused on new finds in the Arctic Ocean and detailed descriptions of chemistry and sea life around Atlantic vents.

For the self-motivated, Chris German even outlined how to go about finding new vents. (Step one: acquire an undersea robot like the Autonomous Benthic Explorer [ABE].)

(Powell cont on page 14)

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To access this journal on line, use the information on the back of your membership card. If you have difficulty, contact the editor at dimmick@esteacher.org

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Coming Issues
Spring 2008 - International Polar Year
Summer 2008 - Marine Mammals
Fall 2008 - Maritime History

Calendar 2007-2008

March 12, 2008
MME Board Meeting
MIT SeaGrant Office
Cambridge, MA.
bmmoran@mit.edu

March 19, 2008
High School Marine Science Symposium
UMass, Dartmouth
Contact: Margaret Brumsted
mbrumsted@dartmouth.edu

March 27-30, 2008
NSTA National Convention & NMEA Share-a-thon,
Boston, MA
MAST Host Organization

May 3, 2008
32nd Annual Woods Hole Conference
Woods Hole, MA
Contact: Bob Rocha
marinebiobob65@juno.com

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Exploring the Lost City Hydrothermal Field: A New Submarine Ecosystem

Kristin Ludwig and Dr. Deborah Kelley (Univ of Washington)

(Part 1 of 2 Parts)

In 1977, the discovery of hydrothermal vents near the Galapagos Islands astonished the scientific community. Images from the Alvin submarine revealed a new, bizarre world of chimneys of black rock, billowing “smoke” and chugging hot water at temperatures hot enough to melt the submarine’s temperature probes. Nearly 2500 m (~7000’) below the surface of the sea, in an area completely void of sunlight and thought to be void of life, large tube worms with brilliant red plumes swayed in the hot water, giant clams littered the seafloor, and mats of yellow-white bacteria covered the rocks. This area was not absent of life: it was a rich community of new species, digesting toxic chemicals to thrive without sunlight.

The discovery and follow-up investigations of hydrothermal vents had permanent ramifications in earth science, oceanography, and biology. These undersea hot springs provided new insights into the cycling of different elements in the ocean and explained seafloor heat anomalies and the origin of modern ore deposits: the discovery of hydrothermal systems resulted in a paradigm shift in biological sciences. No longer was the sun required to support life. At vents, as long as a magmatic heat source was nearby, life could thrive. The unique metabolisms of vent organisms and life in “extreme environments” continue to stimulate research in the search for life elsewhere in our solar system and ultimately may help explain the origin of life on our planet.

In December 2000, the scientific community was rocked again when the Lost City Hydrothermal Field (LCHF) was serendipitously discovered near the Mid-Atlantic Ridge. Marked by 18-story tall ghostly white towers, the first Alvin dive at Lost City quickly showed that the geology, chemistry, and biology of this system was completely different from anything previously found. The vent field is perched on an undersea mountain only ~800 m (about half of a mile) below the surface and chemical reactions within the underlying rock provide heat for hydrothermal circulation. The chimneys at the LCHF are the tallest vent structures known, towering 60 meters above the surrounding seafloor. In stark contrast to black smoker chimneys, they are made of white limestone and emit alkaline fluids at temperatures equivalent to those of a hot tub. Because of its different water chemistry, life at the LCHF is different than what is found at black smokers. Large groupers patrol the carbonate towers and deep-sea corals have attached themselves to the structures. Dense communities of microorganisms inhabit pore spaces of the chimneys, and rare, small mussels cling.

Credits for Articles
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Author Bios for Exploring the Lost City Hydrothermal Field are on page 9.
to the cracks and crevices of the chimneys. The microorganisms utilize methane and hydrogen as food for life, and live independent from the sun.

Since its discovery, only two major expeditions have explored the LCHF. Images from the 2003 and 2005 expeditions are found in the following pages along with preliminary results from research currently underway to decipher the unusual geology, chemistry, and biology of this remarkable site. Although we are still in the early stages of understanding this field, we do know that the LCHF is a new class of hydrothermal system that may yield insights into early life on Earth. The discovery of the LCHF is an excellent reminder of the value and excitement of ocean exploration and perhaps someday, many more “Lost Cities” will be found.

ANATOMY OF A HYDROTHERMAL VENT

Hydrothermal vents are deep-sea hot springs and they play an integral role in ocean heat and chemistry budgets. In hydrothermal environments, the geology, chemistry, and biology are intimately linked. Hot fluids, which may reach temperatures of 407°C (760°F), emitted from the vents deliver chemicals and gases that provide food for life. The chemistry of the fluids depends on the composition of the rock through which the fluids circulate. In turn, circulation is dependent on the state of sub-seafloor magma chambers, regional tectonics and eruptions. To understand the integrated roles of hydrothermal vent chemistry and biology, it is first essential to understand the geologic setting and seafloor “plumbing” of these environments.

Hydrothermal vents are typically found along the axis of the MOR (See figure). They form when seawater seeps into cracks, fissures, and faults in the ocean crust. Geothermal heat from below (typically from a nearby magma chamber) heats the water, which increases in temperature and becomes buoyant. As the hot water travels through the basaltic crust towards the surface of the seafloor, its composition changes and it becomes a “vent fluid.” Vent fluids are chemically different than seawater: they are hot (up to 407°C or ~ 760°F) and typically acidic (pH ~4). (By comparison, deep seawater is typically ~2-10°C with a near-neutral pH of ~8). Hydrothermal fluids contain high concentrations of magmatic gases such as carbon dioxide (CO₂), helium, and hydrogen sulfide (H₂S) (at many sites, the H₂S is so high that the fluid samples smell like rotten eggs!). Dissolved methane in the fluids is formed by alteration of volcanic gases and organic material in sediments, or produced by microorganisms that thrive in the crust. These volatiles provide food for life for the diverse organisms that inhabit the vent environment.

Because they are warm, vent fluids rise in a cloud above a vent field typically 200 m (~650’) or more above the seafloor. This cloud is called a hydrothermal plume, and has a shape of reminiscent of a plume rising from a smoke stack on a cold day. The temperatures of the plumes are slightly above ambient seawater and the plume fluids contain high amounts of fine-grained sulfide minerals and they are enriched in the gases methane and hydrogen. These characteristics are commonly used today to explore for new hydrothermal vents.

The low pH of vent fluids enables them to leach metals from the surrounding rocks. Consequently, the fluids are laden with dissolved

(Exploring cont on page 3)

Global map indicating sites of known hydrothermal vents (courtesy D. Kelley, University of Washington)

A cross section of a hydrothermal vent (courtesy D. Kelley, University of Washington)

(Exploring cont on page 5)
metals and gases. Upon mixing with cold seawater, the metals precipitate, forming sulfide-rich chimneys and jet-like plumes that look like black smoke. Almost all black smokers form on basaltic ocean crust. Common minerals in sulfide chimneys contain high amounts of semi-precious metals such as iron, copper, iron, lead, and zinc and that form the minerals pyrite (iron disulfide, commonly known as fool’s gold), chalcopyrite (copper-iron sulfide, commonly known as “peacock ore”), sphalerite (iron-zinc sulfide) and galena (lead sulfide). Many of the world’s ore deposits being actively mined today are ancient hot spring deposits now exposed on land through long-lived faulting.

Although basalt composes most of the surface of the seafloor, the entire ~6-10 km thickness of oceanic plates is not basalt. There are three ways for marine geologists to learn about seafloor geology beneath the glassy basalt surface we see from a submarine or robot: 1) seismic profiling, 2) drilling, and 3) investigating cross-sections of the seafloor that have been tectonically exposed either on land or underwater.

Seismic waves travel at different speeds through different types of rock and can therefore be used to examine the geologic layering of the Earth’s crust. In the ocean, instruments called seismic air-guns towed behind a research vessel produce acoustic signals that penetrate into the seafloor. These seismic profiling experiments reveal the thickness of the crust, the location of magma chambers, the presence of tectonic faults, and distinguish the different layers in the ocean crust. It is a tool commonly used to survey a site before drilling. To study the layers of the ocean crust in detail, scientists use a 471’ long drill capable of drilling kilometers into the seafloor. This ship, operated by the Integrated Ocean Drilling Program (IODP, http://www.iodp.org/), recovers cores of rock used to examine the history of formation of the Earth’s ocean crust.

Marine geologists don’t always have to work at sea to study the seafloor. In some places, natural tectonic processes have exposed deep sections of the ocean crust on land. These terrestrial

![A black smoker named Sully vents vigorously on the Juan de Fuca Ridge (University of Washington)](image)

exposures of the ocean crust are called ophiolites and are found in many areas including the Italian Alps and Appenines, Oman and Cyprus, California, and on the Canadian and Washington coast in the Pacific Northwest. Compared to the seafloor, ophiolites are easy to access and have played an important role in helping geologists to understand the formation of the Earth and our oceans.

Using information from seismic profiling, drilling, ophiolites, and seafloor investigations, marine geologists have devised a general geologic cross section of the seafloor. There are four primary layers in this cross section. The top ~800 m (~0.6 mi) are composed of pillow basalts. Below this is a 2 km (~1.2 mi)-thick section called sheeted dikes, which are also composed of basalt and are the pipes that feed eruptions at the mid-ocean ridge. Below the sheeted dikes are 3-4 km (~2 mi) of gabbro.

![The ODP Drill ship "Resolution" has collected cores from the seafloor all over the world. (courtesy ODP-TAMU)](image)
Gabroic rocks form at temperatures >700°C and are the intrusive equivalent of a basalt. They are commonly composed of the minerals calcium-rich feldspar, pyroxene, and olivine. Finally, the deepest rocks are called peridotites. These rocks are part of the Earth’s mantle and are rich in iron and magnesium. Peridotites typically contain the minerals olivine, pyroxene, and chrome spinel. Olivine is a green iron-magnesium silicate. Common examples include the gemstone peridot (pure olivine): Hawaii’s green sand beaches are composed of a high abundance of olivine grains. The four types of rock that make up the seafloor are important because they influence the composition of hydrothermal fluids, which directly impact the type of life that can be supported by vents.
A TECTONIC WINDOW TO THE SEAFLOOR: THE ATLANTIS MASSIF

Underwater, deep sections of the seafloor are exposed by tectonic uplift. The powerful forces of tectonic stretching and uplift create "oceanic core complexes" which form tall (>4000 m or ~14,000') undersea mountains. During the formation process, the top 2-3 sections of the seafloor have essentially been "scraped off", commonly leaving domes of exposed gabbro and peridotites. Although the mechanisms of their formation remain poorly understood, these oceanic core complexes (OCCs) create a "tectonic window" to the deep seafloor. Marine geologists study these exposures to better understand earth formation processes.

Core complexes form in regions of dynamic tectonic activity, and are commonly found along slow and ultra-slow-spreading centers. A typical example of an OCC is the Atlantis Massif (massif is another word for mountain), which is located at 30°N, 15 km west of the Mid-Atlantic Ridge.

In December 2000 scientists from many institutions including the Scripps Institute of Oceanography (SIO), the University of Washington, Duke University, and the ETH-Zurich joined Dr. Donna Blackman (SIO) to embark on a 30-day geological expedition to map and sample the Atlantis Massif for future plans to drill into the mountain (http://earthguide.ucsd.edu/mar/) and to understand how the mountain formed.

During the day, scientists used the submarine Alvin to observe the seafloor and collect geologic samples. At night, they used a towed underwater camera to collect additional imagery. During this expedition, the scientists successfully mapped the area and collected samples to investigate the formation of the massif. However, they did not expect to come across an entirely new kind of hydrothermal field: the Lost City, see the original NSF press release at http://www.nsf.gov/od/lpa/news/press/00/pr0093.htm)

The LCHF is located 15 km west of the axis of the Mid-Atlantic Ridge and is perched on top of a large undersea mountain called (below) the Atlantis Massif. (Two Images courtesy D. Kelley, University of Washington and RIDGE Multibeam Synthesis by Deb Glickson, respectively)
DISCOVERY OF A NEW CLASS OF HYDROTHERMAL SYSTEM: THE LOST CITY HYDROTHERMAL FIELD

The Lost City Hydrothermal Field (LCHF) was serendipitously discovered in late 2000 near the summit of the Atlantis Massif. On the night of December 4, Dr. Gretchen Früh-Green and Dr. Barbara John (University of Wyoming) were monitoring the live video from the towed deep-sea camera called “Argo-II.” Under their watch, scientists and crew made routine “sweeps” across the south face of the Atlantis Massif to collect seafloor imagery and make photomosaics of the large, steep cliffs that characterized the south face of this mountain. Suddenly, large, white towers loomed out of the darkness. Dr. Jeff Karson (Duke University) and Deborah Kelley (University of Washington) joined the team late in the evening and continued to guide the camera around the pinnacles; it rapidly became apparent that the structures were some type of a hydrothermal vent. The science party and crew on board the research vessel Atlantis had just made an astounding discovery.

The next day, scientists Kelley and Karson dove in Alvin submarine to explore and sample this remarkable site. Patrick Hickey, the expedition leader, piloted Alvin up and around the tall white pinnacles. During the one 4 hour dive, they recovered a few samples of the chimneys, a few samples for microbiological investigation, and 3 samples of the shimmering fluids emanating from the top of a large chimney. It was on this cruise that the tallest chimney in the oceans was found: Poseidon, which reaches 60 m above the seafloor. Inspired by the name of the ship (the R/V Atlantis); nearby transform fault (the Atlantis Fracture Zone), and the Atlantis Massif on which the field rests, Dr. Kelley named the field the “Lost City,” after the myth of the lost city of Atlantis.

Preliminary observations and analyses of these first samples from the Lost City Hydrothermal Field (LCHF) indicated that the geology, chemistry, and biology of this venting system were strikingly different from anything previously found. The National Science Foundation (NSF) sponsored a team of scientists led by Dr. Deborah Kelley and Dr. Jeff Karson to return to the LCHF in 2003 for an intense 32-day expedition. The expedition included 18 dives using the Alvin submarine to collect samples and extensively image the field, and an autonomous underwater vehicle called “ABE” to create a high resolution bathymetric map (http://www.lostcity.washington.edu/). During this expedition, a highly interdisciplinary team of microbiologists, fluid chemists, macrobiologists, and geologists collected extensive suites of rocks fluids, and biological samples to understand the linkages among geology and life in this system. In 2005, the team returned to the LCHF with Dr. Robert Ballard during a 10-day “virtual” expedition sponsored by the National Oceanic and Atmospheric Administration (NOAA)’s Office of Ocean Exploration to further explore the field (http://www.oceaneplorer.noaa.gov/explorations/05lostcity/).

In a future issue, we will print part 2 of this article, describing the Lost City Hydrothermal Field and some of the findings from these expeditions.

Bios for Kristin Ludwig and Dr. Deborah Kelley are on page 9 of this Journal.

One of the first images of the LCHF chimneys from the ARGO-II tow cam. (University of Washington)
Kristin Ludwig
Emerging Scientist
Ph.D. Student, University of Washington School of Oceanography

Kris is a Ph.D. student in the School of Oceanography at the University of Washington in Seattle. She received her B.S. in Earth Systems from Stanford University and her M.S. in Oceanography from the University of Washington. Kris went on her first research cruise at age sixteen with the JASON Project off the coast of Baja, Mexico, where she was introduced to the unusual world of deep sea hydrothermal vents. She has since participated in expeditions in the northeast Pacific and central Atlantic studying vents and gas hydrates. Kris has also worked on several research expeditions in Antarctica. Her doctoral training is in marine geochemistry and her research focuses on the formation, evolution, and age of the Lost City Hydrothermal Field. Kris joined the NSF-funded 2003 expedition to the Lost City and in 2005 participated as a shore-based geologist during the unique NOAA-sponsored “virtual” expedition to Lost City using telepresence technology.

Deborah Kelley, PhD
Professor
University of Washington

Dr. Deborah Kelley, is an associate professor in the School of Oceanography and Astrobiology program at the University of Washington, where she specializes in investigation of seafloor hydrothermal systems and geobiological processes. She has been involved in the discovery of numerous hydrothermal fields, which most recently includes that of the Lost City Hydrothermal Field and was Co-Chief scientist during the Alvin-ABE 2003 expedition to first investigate this site in detail. Dr. Kelley’s work currently focuses on examination of the linkages between geological and biological processes in systems supported by underwater volcanoes. She is developing prototype in situ microbial incubators that are yielding new insights into the conditions under which life thrives, survives and expires in extreme black smoker environments. Kelley is also helping to develop a new submarine fiber-optic cabled underwater observatory called "NEPTUNE" that will revolutionize how we interact with Earth and it's oceans. She routinely uses the human-occupied submersible Alvin and robotic vehicles Jason, ROPOS, and Tiburon, and has been co-chief and chief scientist on numerous expeditions. She is a member of the Extreme Environments working group at the University of Washington, and greatly enjoys working with undergraduate and graduate students.
The 25th Annual High School
Marine Science Symposium

A Quarter Century of Marine Science For High School Students

Wednesday, March 19, 2008
8:00 am – 1:00 pm
UMass–Dartmouth

Featuring Keynote Speaker: TBA

Sponsored by:
The University of Massachusetts at Dartmouth
New Bedford ECHO Project
Massachusetts Marine Educators, Inc.

Keeping the same format as last year with Introductions and Welcome at 8:45, 30 minute Keynote speeches at 9 and 11:45, sandwiching two 45 minute workshops with approximately 20 titles to choose from plus a cafeteria available for lunch at 12:15.

The workshops are designed for High School Students and presented by experts in their respective fields. Recent symposiums have attracted up to 400 local high school students.

For more updated information visit the MME website, [www.massmarineeducators.org](http://www.massmarineeducators.org). Download complete program, registration packet and directions to UMASS Dartmouth, available mid January-mid February.

More information may be obtained by contacting Co-chairs Margaret Brumsted, mbrumsted@dartmouthps.org, Trina Crowley, pcrowley@umassd.edu, or George Duane, geoduane@rcn.com.

If you have any suggestions for presenters of the 45 minute interactive sessions, please pass their contact information to Margaret or George

Save the Date and encumber the bus money today!!
THE BOSTON HARBOR EDUCATORS’ CONFERENCE-2007

This year’s conference took place on Saturday, October 13, 2007 on a beautiful, blustery day on the Harbor. The theme of the conference: Fifteen Years and Moving Forward celebrated milestones in the history of Boston Harbor, the marine waters off the shores of Massachusetts and Stellwagen Bank National Marine Sanctuary. It was in fact fifteen years ago that Congress designated Stellwagen Bank as a protected area for the breeding grounds of humpback and other species of whales. It was also fifteen years ago that the MWRA stopped the dumping of sludge into the harbor, and ten years ago that the islands became a national park area. These milestones were represented at the conference in the variety of workshops offered from the moon jellies to the right whale, from oxygen in the water to mapping depths, from sounds in the sanctuary to the poetry of the ocean. A stimulating and informative address by Dr. David Wiley provided participants with the new ways scientists are learning to study whales in order to gain new insights into marine mammal behavior.

The day was capped off with a delightful trip aboard the M/V Columbia Point the whale watching vessel of the New England Aquarium. The ship brought participants to one of the most successful ventures in searching out and seeing these great ocean creatures in their natural habitat. Many thanks to so many people for a spectacular day and a special thanks to Anne Smrcina of Stellwagen Bank National Sanctuary for all the effort she gave to making the day such a wonderful learning experience.

Pat Harcourt
President, Massachusetts Marine Educators

predict how climate is likely to change in the future, we need to understand past conditions and the factors influencing past changes. Ocean sediments have provided invaluable evidence for learning about past temperatures, ice extent, and how the distribution of species varies with climate, as well as surprising data about sudden changes in ocean surface currents, which have a major influence on climate.

Investigations in marine geology have provided clues about the causes of mass extinctions, the movements and interactions of tectonic plates, and the changing levels of the ocean over millennia. This issue of Flotsam and Jetsam offers a variety of articles highlighting work in marine geology and inviting teachers to share the ideas, stories, and projects with their students. It is clear that if we remember to look beneath the surface of the ocean – or any other complex system – we will gain a much richer and more complete understanding of it.

Whale sightings during the BHEC cruise.
(Photos courtesy of Joe LaPointe, MME Board Member)
Despite the strong waves, high winds, and rain from a nor’easter (formerly Hurricane Noel) outside, 32 marine educators gathered inside the Seacoast Science Center in Rye, New Hampshire to explore the variety of exhibits and experience the unique educational programs offered by the center. Participants were members of Massachusetts Marine Educators, Gulf of Maine Marine Education Association, and elementary educators who participated in the program as part of a course offered by Joel Rubin (MME board member). The event was hosted by Erin Hobbs (MME board member) and Perrin Chick, SSC’s education director.

In SSC’s brand new Gregg Interactive Learning Studio, Erin walked the educators through the Center’s Crustacean Program. In addition to a hands-on look at SSC’s rare blue and orange speckled lobster specimens, the lesson was enhanced the center’s state of the art video and computer technology.

A tour of the aquarium and exhibits followed the Crustacean Program. We explored the variety of aquaria which depict various aquatic habitats and highlight the unique lifestyles of many underwater creatures. The large tide pool afforded us the opportunity to hold and examine local marine invertebrates and there was even an aquarium that you could walk underneath and observe seastars feeding.

Next we toured the exhibits mainly devoted to physical oceanography. These included presentations on remote sensing, Seasons in the Sea, and a unique interactive exhibit which models tidal flow from Great Bay to the Gulf of Maine.

Our afternoon concluded back in the Gregg Interactive Learning Studio as we participated in SSC’s “new multi-media interactive theatre experience”... GeoAdventures Assignment: Gulf of Maine. The presentation allows participants to join teens on a mission to search and find geocaches from Mt. Washington to the Gulf of Maine with touch screen computer monitors at every station. Through this experience, participants learn that...
everything in the environment is interconnected; that our lives influence the oceans and the oceans influence our lives.”

The Seacoast Science Center is without question a wonderful resource to marine educators and their classes. It offers a wide variety of programs that can be tailored to the unique needs of any school group. To learn more visit their website at www.seacoastsciencecenter.org.

Thanks to Erin and Perrin for a great afternoon and ask to see Erin’s office.

A donation of $100 was made to the Seacoast Science Center from MME and several T-Shirts were given to Perrin for the staff.

Rising tides intensify non-volcanic tremor in Earth’s crust
Vince Stricherz Nov.2007 | Science
vinces@u.washington.edu

For more than a decade geoscientists have detected what amount to ultra-slow-motion earthquakes under Western Washington and British Columbia on a regular basis, about every 14 months. Such episodic tremor-and-slip events typically last two to three weeks and can release as much energy as a large earthquake, though they are not felt and cause no damage. Now University of Washington researchers have found evidence that these slow-slip events are actually affected by the rise and fall of ocean tides.

“There has been some previous evidence of the tidal effect, but the detail is not as great as what we have found,” said Justin Rubinstein, a UW postdoctoral researcher in Earth and space sciences. And while previous research turned up suggestions of a tidal pulse at 12.4 hours, this is the first time that a second pulse, somewhat more difficult to identify, emerged in the evidence at intervals of 24 to 25 hours, he said.

Rubinstein is lead author of a paper that provides details of the findings, published Nov. 22 in Science Express, the online edition of the journal Science. Co-authors are Mario La Rocca of the Istituto Nazionale di Geofisica e Vulcanologia in Italy, and John Vidale, Kenneth Creager and Aaron Wech of the UW.

The most recent tremor-and-slip events in Washington and British Columbia took place in July 2004, September 2005 and January 2007. Before each, researchers deployed seismic arrays, each containing five to 11 separate seismic monitoring stations, to collect more accurate information about the location and nature of the tremors. Four of the arrays were placed on the Olympic Peninsula in Washington and the fifth was on Vancouver Island in British Columbia. The arrays recorded clear twice-a-day pulsing in the 2004 and 2007 episodes, and similar pulsing occurred in 2005 but was not as clearly identified. The likely source from tidal stresses, the researchers said, would be roughly once- and twice-a-day pulses from the gravitational influence of the sun and moon. The clearest tidal pulse at 12.4 hours coincided with a peak in lunar forcing, while the pulse at 24 to 25 hours was linked to peaks in both lunar and solar influences.

The rising tide appeared to increase the tremor by a factor of 30 percent, though the Earth distortion still was so small that it was undetectable without instruments, said Vidale, a UW professor of Earth and space sciences and director of the Pacific Northwest Seismograph Network. “We expected that the added water of a rising tide would clump down on the tremor, but it seems to have had the opposite effect. It’s fair to say that we don’t understand it,” Vidale said. “Earthquakes don’t behave this way,” he added. “Most don’t care whether the tide is high or low.”

The researchers were careful to rule out noise that might have come from human activity. For instance, one of the arrays was near a logging camp and another was near a mine. “It’s pretty impressive how strong a signal those activities can create,” Rubinstein said, adding that the slow-slip pulses were recorded when those human activities were at a minimum.

The work was funded by the National Science Foundation, and instruments were provided by the Incorporated Research Institutions for Seismology, Istituto Nazionale di Geofisica e Vulcanologia and Earthscope.
German's team programmed ABE to traverse a classic zig-zag search pattern (called "mowing the lawn") every 2 km over an area they suspected harbored hydrothermal vents. Sensors on ABE continually sniffed for characteristic temperature or chemistry signals that a vent was near. After the initial broad search, the team refined the search mission, and ABE slowly zeroed in on four new vent areas. The onboard camera took pictures of the sites, revealing billowing clouds of black smoke above rock pillars, with ghostly shrimp swimming around the warm rock.

The search took about 30 days, after which German's team came ashore and handed over the new locations to Karsten Haase of the University of Kiel, Germany, for a more detailed reconnaissance. His instruments measured the chemistry and temperature of the water and sampled shrimp and mussels to see how similar they were to the creatures clinging to vents elsewhere in the ocean.

A scale model of a deep sea hydrothermal vent mound in the Atlantic

How the TAG model might appear on a flyby from a survey robot. (Photo by Hugh Powell, WHOI)

The teams named the new sites Red Lion, the Turtle Pits, Wideawake Field, and Lilliput, following a tradition of giving whimsical names to deep-ocean discoveries. Pumping out 396°C water (nearly four times as hot as water boiling on your kitchen stove), the Red Lion vent was hot enough to singe the protective skin of ABE.

Deb Kelley of the University of Washington described the Lost City hydrothermal vents and presented reasons why further searches might reveal that similar vents, despite their otherworldly looks, are fairly common. After all, along the giant ridges that divide the major ocean basins, seismic thrashing is constantly bringing new rock and volcanic material up to the seafloor.

The session expanded on a press conference yesterday that described new finds in the TAG mound (see sidebar for a description in 3-D), the first hydrothermal vent discovered in the Atlantic Ocean 20 years ago. Details of how minerals are deposited around hydrothermal vents, such as the TAG site, have been described in Oceanus magazine.

http://www.whoi.edu

Situ Studios makes scale models of landscapes you'll never walk on, like this one of the TAG hydrothermal mound at the bottom of the North Atlantic. (Photo by Hugh Powell, WHOI)
Biologist Tim Shank of the Woods Hole Oceanographic Institution (WHOI) was “at sea” once again studying marine life at the bottom of the ocean, but this time it is via television monitors in real time from the comfort of a shore-based facility thousands of miles away. Shank and most of the researchers investigating the Lost City hydrothermal vent field, about 2,500 feet below the surface of the Atlantic Ocean, are ashore in a classroom outfitted as a command center at the University of Washington (UW) in Seattle.

Chief Scientist for the cruise, Deborah Kelley of UW, and the other researchers from more than six research institutions are able to direct sampling efforts and be in constant communication with four scientists, students, remotely operated vehicle pilots and other team members on the NOAA vessel Ronald H. Brown. Oceanographer Robert Ballard is co-chief scientist with Kelley and is leading the efforts at sea.

The expedition marks the return to the Lost City vent field discovered in 2000 during a National Science Foundation cruise about the WHOI research vessel Atlantis. The vent field is on top of an underwater mountain the size of Mt. Ranier, called the Atlantis Massif, on the Mid-Atlantic Ridge about 3,000 miles east of Florida. It is named for WHOI’s first research vessel and the vessel of the same name that discovered the vent field. The Mid-Atlantic Ridge is part of an underwater chain of mountains known as the mid-ocean ridge system that circles the Earth for 40,000 nautical miles. The ocean crust here is about 1.5 million years old, and scientists believe the Lost City field has been active for thousands of years. There are more than 30 active and inactive chimneys in the field, which is about 1,300 feet long and 1,000 feet wide at a depth of about 2,500 feet. Some of the chimneys are very small and others 60 to 100 feet tall. The largest structure is about 18 stories, or 200 feet, tall and is unlike any found at other vents.

Hydrothermal vents were discovered in 1977 on the Galapagos Rifts in the eastern Pacific, part of the mid-ocean ridge system where the great crustal plates of the Earth are in constant motion and new ocean crust is formed, often by magma reaching the ocean floor. Black smokers spewing superheated water more than 700 degrees Fahrenheit were found on the East Pacific Rise south of Baja California in 1979. But the Lost City vent field is different. It is based on heat as seawater reacts with rocks below the field, not on volcanism, and the fluids are much cooler and nearly 100 percent carbonate, like limestone found in caves, ranging in color from white to gray.

Shank was part of the original expedition, as are most of the scientists involved in the current cruise, which began July 23 and ends August 4. He has studied hydrothermal vents in the Atlantic, Pacific and Indian Oceans, looking at the evolution of animals between oceans. Unlike other vents, where animals can be many feet long or the size of dinner plates, most of the animals at the Lost City vents are very small, less than a half-inch with translucent or invisible shells. Shank wants to know if they are unique to Lost City or if they are found at other vent systems around the world.

Other WHOI staff on the expedition include engineers from the Deep Submergence Laboratory, graduate students and postdoctoral fellows. All the WHOI researchers except for Shank are among the 31 expedition members at sea.

“This has been a very interesting experience,” Shank says. “I was a college student when Bob Ballard, then a scientist at WHOI and a member of the teams that found the hydrothermal vents and black smokers in the late 1970s, first suggested the idea of telepresence, taking people to sea remotely but in real time. He and WHOI colleagues demonstrated that vision with the first JASON Project in 1989, enabling students to drive the remotely operated vehicle JASON in real time via
satellite and sharing the excitement of exploration with the public at museums and science centers. Scientists were able, for the first time, to direct sampling in real time from the command center at WHOI. I heard those stories, and now I am participating in the realization of that vision on a much bigger scale."

Shank says he is anxious to study the samples collected at sea, and to talk with his colleagues who experienced first hand the expedition at sea. "We have come a long way since conducting the telepresence of 1989. This expedition has demonstrated that telepresence technology is now providing magnificent opportunities to include many more scientists, students and the public in first hand exploration of the sea. Conducting in-depth scientific investigations through remote research teams will require more time and experience to reach its full potential. There is no doubt that telepresence is clearly an exciting way to bring the global public to explore the depths of our oceans. This is an extremely exciting time in ocean exploration."

Major partners in the expedition are the National Oceanic and Atmospheric Administration, University of Washington, University of Rhode Island, Institute for Exploration, Jason Foundation for Education, Immersion Presents, and the National Geographic Society. Immersion Presents broadcasts are being seen at select Boys and Girls Clubs, aquariums and museums.

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**Furry 'lobster' found in Pacific**

excerpt from

http://news.bbc.co.uk/2/hi/science/nature/4785482.stm

Marine biologists have discovered a crustacean in the South Pacific that resembles a lobster or crab covered in what looks like silky fur.

*Kiwa hirsuta* is so distinct from other species that scientists have created a new taxonomic family for it.

A US-led team found the animal last year in waters 2,300m (7,540ft) deep at a site 1,500km (900 miles) south of Easter Island, an expert has claimed. Details appear in the journal of Paris' National Museum of Natural History.

The diving expedition was organised by Robert Vrijenhoek of the Monterey Bay Aquarium Research Institute in California.

The "Yeti Crab", as it has been dubbed, is white and 15cm (5.9in) long, according to Michel Segonzac of the French Research Institute for Exploitation of the Sea (Ifremer).

In what he has described as a "surprising characteristic", the animal's pincers are covered with sinuous, hair-like strands. It seems to reside around some Pacific deep sea hydrothermal vents, which spew out fluids that are toxic to many animals.

Read the full article at

news.bbc.co.uk/2/hi/science/nature/4785482.stm

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Yeti Crab - Picture from http://news.bbc.co.uk/2/hi/science/nature/4785482.stm
Finding Lost City
by Carolyn Scarch

Marine geologists studying ocean temperatures at the 2500 meter deep spreading center of the Galapagos Rift acquired their first definitive evidence for the existence of hydrothermal vents in May, 1976.

Scientists discovered a new class of hydrothermal vents in the Atlantic as recently as December of 2000. Geologists performing a deep-water camera survey of the terrain near the undersea mountain known as Atlantis Massif serendipitously recorded the Lost City site (Kelly, 2005). The geological processes that drive venting at Lost City are different from those at other known sites. Consequently, the physical and chemical characteristics are also different. Generally, when searching for hydrothermal sites, scientists concentrate on the margins within 1-5 km of spreading centers.

Atlantic ocean & surrounding continents.
Map showing location of Lost City

The Lost City hydrothermal field is located 15 km from the Mid Atlantic Ridge spreading center at the latitude of 30 degrees N. Instead of the black smoker formations built up by the precipitating fluids exposed to basalt, Lost City’s formations are composed of large white carbonate chimneys. Here vent fluids are exposed to uplifted peridotites and are serpentinized. The pH is higher-basic rather that acidic-- carbon dioxide levels are extremely low, and the temperature of vent fluids ranges only between 40-90 degrees C rather then in excess of 300 degrees C. Microorganisms acquire their energy from methane and pure hydrogen instead of the oxidation of hydrogen sulfide. Carbon 14 studies indicate that the vent field has been around for approximately 30,000 years. Scientists speculate that these newly discovered vent fields may last for hundreds of thousands of years (Boeius, 2005).

‘beehive’ deposit Carbonate chimney from Lost City

Due to differences in the geology and chemistry of this vent site, the nature of the community associated with Lost City is substantially different from black smoker communities. Instead of large clusters of sessile invertebrates, organisms are smaller and are found in less densely aggregated groups (Kelly, 2005). Currently, no evidence suggests the existence of symbiotic relationships between animals and the chemosynthetic microorganisms forming the bottom of the food chain. Instead it appears that the marine invertebrates gain energy from grazing on vent-associated carbonates and microbial biofilms. Gastropods and amphipods have been found living in channels of actively venting carbonate sites that range in temperatures between 10-40 degrees C. Polychaetes, nematodes, ostracods, stromatopods and bivalves inhabit hydrothermally active flanges and spires. Larger, more mobile animals found at the site include wreckfish, cut-throat eels, and geryonid crabs (Kelley et al, 2005).

At this point, no one knows how common serpentine hydrothermal vent systems may be. Peridotites can exist in extensive ranges and, with the right geological conditions, it is possible there may be many as yet undiscovered hydrothermal vent systems and communities similar to those found at Lost City.

www.csa.com/discoveryguides/vent/review6.php

(Finding cont from prev column)
Missing the science of teaching
By Diane Carman
Denver Post Staff Columnist
Article Last Updated: 09/30/2007

Last Sunday, Jo O'Brien was reading a story in The Denver Post and something in it hit her like a fist to the jaw. "I literally let out a gasp," she said. It was a statement by a principal about how her rural Colorado elementary school was spending five hours a day teaching reading and math to get its CSAP scores up. As a result, only 22 percent of fifth-graders had scored proficient in science. "There's only so much time in a day," the principal said.

For O'Brien, assistant commissioner for assessment in the state Department of Education, this was cause for alarm. If in 2007 educators still don't realize that teaching science is teaching reading and math, well, maybe the U.S. really is doomed to look to India, China and Europe for innovation in the 21st century. Sure, O'Brien has seen the numbers that show the poor performance by students on tests of basic skills. "The state is not doing well in reading and math," she said. "But that's not because we're giving too much attention to science." Quite the contrary, with no statewide high school graduation requirements, historically weak science admission requirements to state universities, and no statewide assessments in science until a couple of years ago, science instruction is on the verge of collapse.

Schools districts have slashed budgets for textbooks, labs and specialists, neglected science curricula and, for a lot of kids, science became an elective, like beading. O'Brien said that many Colorado kids had little or no science instruction in elementary or middle school, "so it was no surprise when they would sit down with a high-school counselor and say, 'No, I don't want to be doing science.'" We let 14-year-olds determine our future and created an epidemic of scientific illiteracy in the process. Now some of those once science-challenged 14-year-olds are teachers, so it's no surprise that many educators believe science can't be integrated into reading and math instruction.

"If the teachers are feeling allergic or uncomfortable or unsettled about their own scientific knowledge, sure they will say, 'That's something we can scuttle,'" O'Brien said. "At this point what we need is science education for teachers."

As Archimedes would say, Eureka.

On Friday, President Bush, who's no Archimedes himself, called for the creation of a global fund for research into clean-energy technology. Yes, after years of dissing scientists, now he's counting on them to get us out of the global-warming mess. At the same time, Colo Gov. Bill Ritter has made it clear he wants Colorado in the forefront in the competition for contracts, grants and businesses involved in alternative energy.

With his STEM (Science, Technology, Engineering and Math) agenda, O'Brien said, he has created "a forced focus on science. "We don't want to have to import scientific thinkers to this state anymore."

Nationwide, study after study has shown declining science achievement since at least 1983. The Center for Education Reform recently ranked the U.S. 19th out of 29 industrialized nations in science proficiency. Meanwhile, the generation of scientists that was inspired and nurtured by generous educational scholarships after the launch of Sputnik in 1957 isn't getting any younger.

I know something about this. I was in first grade at Philipp Elementary School in Milwaukee when the news broke that the Russians had just wallowed us with Sputnik. Ms. Francisco gathered her class of rambunctious 6-year-olds and told us that we were going to go to the moon. For weeks she taught us about planets, stars and moons. We learned the meaning of words like light year, gravity, oxygen, precipitation and atmosphere. We drew a solar system roughly to scale on the classroom wall. We built a spaceship out of cardboard and spacesuits out of aluminum foil.

Then we invited our parents to watch the mission. We counted down and blasted off. Each of us had to deliver a report on our scientific research as we walked on our imaginary moonscape. All of this involved reading, writing, math and science and, honestly, I'll never forget it.

How could I? I learned how to say cumulonimbus.

Did I mention I was 6?

Diane Carman's column appears Sunday, Tuesday and Thursday. Reach her at 303-954-1489 or dcarman@denverpost.com.
FOCUS
Biological communities at the Lost City Hydrothermal Field

GRADE LEVEL
5-6 (Life Science)

FOCUS QUESTION
What organisms are found at the Lost City Hydrothermal Field, and how are they different from organisms found at hydrothermal vents associated with volcanic activity?

LEARNING OBJECTIVES
Students will be able to compare and contrast living organisms typically found at hydrothermal vent communities associated with volcanic activity with those found at vent communities of the Lost City Hydrothermal Field.

Students will be able to explain the difference between geologic processes that produce the Lost City Hydrothermal Field and processes that produce previously-discovered hydrothermal vents.

MATERIALS
☑ Copies of background material on biological communities associated with the Lost City Hydrothermal Field and communities associated with hydrothermal vent fields based on volcanic activity, or references to appropriate materials (see Learning Procedure, Step 1)

☑ Materials for constructing murals (Bristol board, foamcore, etc.; colored markers or pencils); if the “What’s That?” lesson is to be completed, finished murals should measure approximately 76 cm x 85 cm (30 in x 36 in)

☐ (Optional, for demonstrating exothermic reactions) (a) chemical handwarmers (available from camping supply stores); or (b) polyester resin, catalyst, and disposable mixing container (available from hardware stores)

AUDIO/VISUAL MATERIALS
☐ (Optional) equipment for viewing online or downloaded video of vent communities

TEACHING TIME
Two 45-minute class periods, plus time for student research and work on murals and written reports

SEATING ARRANGEMENT
Groups of four to six students

MAXIMUM NUMBER OF STUDENTS
30

KEY WORDS
Lost City
Hydrothermal vent
Peridotite
Hydrothermal fluid
Chemosynthesis
Autotrophic

BACKGROUND INFORMATION
In 1977, scientists in the deep-diving submersible Alvin made the first visit to an oceanic spread-
ing ridge near the Galapagos Islands, and made one of the most exciting discoveries in 20th century biology. In the middle of deep, cold ocean waters, they found hot springs and observed black smoke-like clouds billowing from chimneys of rock; and nearby were communities of animals that no one had ever seen before.

These hot springs came to be known as hydrothermal vents, and since that first discovery, more than 200 similar vent fields have been documented in the world’s ocean. These systems are formed when seawater flowing through cracks in the seafloor crust enters magma-containing chambers beneath a spreading ridge. Intense heat from the molten rock causes a variety of chemical changes and many substances from the rocks become dissolved in the fluid. The heated fluid becomes less dense, rises upward, and emerges onto the sea floor to form a hydrothermal vent. When the heated fluid is cooled by cold water of the deep ocean, many of the dissolved materials precipitate, creating black clouds and chimneys of rock-like deposits. The hydrothermal fluid emerging from the vents is rich in sulfide, which is used as an energy source by chemosynthetic bacteria to produce essential organic substances. These autotrophic bacteria are the base of a diverse food web that includes large tubeworms (vestimentiferans), clams, mussels, limpets, polychaete worms, shrimp, and crabs.

In 2000, a different sort of vent field was serendipitously discovered on an underwater mountain called the Atlantis Massif near the Mid-Atlantic Ridge. This new field also had hot fluids venting from rocky chimneys. But these chimneys towered as much as 200 feet above the seafloor, much larger than chimneys found in other vent fields. In fact, the vent field was located 15 kilometers away from the spreading axis of the Mid-Atlantic Ridge and the chimneys looked so much like towers and spires of a fantastic city that the new vent field was named “Lost City.” And the fluids emerging from the chimneys, as well as the surrounding biological communities, were unlike any other known hydrothermal system. Subsequent investigations have shown that the newly-discovered hydrothermal fields are not formed by seawater reacting with molten magma. Instead, these fields are formed when seawater reacts with solid mantle rocks. These rocks, called peridotites, are formed deep inside the Earth, but a unique type of faulting can bring them close to the seafloor. Cracks in the seafloor can allow seawater to percolate down to the up-lifted peridotites. When this happens, numerous chemical reactions occur between seawater and minerals in the rock (a process called serpentinization). These reactions produce a large amount of heat that causes the fluids to rise and eventually vent at the surface of the seafloor. Mixing between the heated fluids and cold surrounding seawater causes additional reactions that include precipitation of calcium carbonate (limestone), which forms the towering chimneys of Lost City. Because the reactions of seawater with peridotites are essential to these formations, the Lost City is called a “peridotite-hosted ecosystem.”

In contrast to the abundant biological communities of hydrothermal vents formed by volcanic activity, the Lost City Hydrothermal Field (LCHF) initially appeared to be devoid of living organisms. But when scientists took a closer look at the surface of the chimneys (they actually vacuumed the surface), they found large numbers of tiny shrimps and crabs. Because most of these animals are less than one centimeter in size, transparent or translucent, and tend to hide in small crevices, they were easily overlooked when the LCHF was first discovered. While the total biomass around the LCHF vents appears to be less than at other hydrothermal vents, scientists believe there is just as much diversity (variety of different species). Like previously discovered vent communities, the LCHF ecosystem is based on microorganisms that are able to use chemicals in the vent fluids as an energy source for producing complex organic compounds that are used as food by other spe-
cies (chemosynthesis). But again, the LCHF differs in that the fluids emerging from the chimneys has very little of the hydrogen sulfide and metals that are typical in hydrothermal fluids of other vent. Instead, LCHF vent fluids contain high concentrations of methane and hydrogen, and these chemicals appear to provide the energy source for chemosynthetic microbes.

In this lesson, students will create murals to compare and contrast biological communities of LCHF and hydrothermal vent fields based on reactions of seawater with molten magma. These murals may also be used in the accompanying lesson, “What’s That?”

**LEARNING PROCEDURE**

1. To prepare for this lesson:
   
   (b) If you want to provide student groups with background information needed to construct murals, make copies of relevant essays from sites listed in (a) above, as well as from one or more sites that provide information on hydrothermal vent fields based on volcanic activity ([http://www.oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html](http://www.oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html) and [http://www.bio.psu.edu/hotvents](http://www.bio.psu.edu/hotvents) offer virtual tours of hydrothermal vent communities; [http://seawifs.gsfc.nasa.gov/ OCEAN_PLANET](http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/) and [HTML_ps_vents.html](http://seawifs.gsfc.nasa.gov/ OCEAN_PLANET/HTML_ps_vents.html) has links to many other Web sites with information about hydrothermal vents). Alternatively, depending upon students’ research skills, you may want to simply provide students with these links and allow them to research relevant information on their own.

2. Briefly review the concepts of plate tectonics, being sure that students understand the processes that take place at convergent and divergent boundaries, and why these boundar-

ies are often the site of volcanic activity. Briefly review the discovery of hydrothermal vents, and describe the general appearance of hot fluids venting from chimneys or cracks in the seafloor. You may want to show video clips from some of the sites referenced in Step 1 to supplement this discussion. Be sure students understand that these vent communities were produced by seawater reacting with molten magma.

Tell students that in the year 2000 a different type of vent community was discovered in which heat results from reactions between seawater and solid rock (peridotite) that is brought close to the surface by faulting. Be sure students understand the difference between the two type of vents communities, and that the reactions that form the LCHF occur because the rock was originally formed deep inside the Earth’s mantle, and has a chemical structure that is not stable in the presence of seawater.

You can demonstrate an exothermic reaction with chemical handwarmers (follow directions on the package), or by catalyzing a small amount (100-200 ml) of polyester resin (follow directions on the resin container) in a disposable mixing cup (usually supplied with the resin). As the resin polymerizes, heat produced by the exothermic polymerization reaction is easily detectable by gently touching the container [NOTE: Be careful! Mix the resin and catalyst only in a suitable container, because enough heat is produced to melt ordinary plastic drinking cups].

Discuss chemosynthesis, and contrast this process with photosynthesis. (See the Entering the Twilight Lesson Plan: [http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_twilight.pdf](http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_twilight.pdf). Be sure students recognize that energy is required to synthesize essential compounds needed by living organisms; and that the key difference between photosynthesis and chemosynthesis is where the energy comes from.
3. Tell students that their assignment is to:
   (a) Write a brief research report describing the physical and biological features of a LCHF-type vent community or a vent community based on reactions of seawater with molten magma; and
   (b) Construct a mural that illustrates the features that would be seen by an observer inside a deep-diving submarine from a distance of about ten feet.

Assign each student group either a volcanic activity-based vent community or a LCHF-type activity-based vent community, and provide background information or references to sources of this information.

If you plan to use these murals for the “What’s That?” lesson, emphasize that each group should keep their information to themselves, and not share ideas for their illustrations with other groups. In addition, murals should include a reasonable amount of open space (that is, a mural of a LCHF community should have more than one carbonate chimney, and these should occupy no more than half of the total area of the mural). Viewing one or more of the virtual tours referenced in step 1 should give a reasonably good idea about how the overall mural should appear.

NOTE: It is particularly important that students working on murals of the LCHF understand that many of the organisms in these communities would not be visible at a distance of ten feet (which is why scientists initially thought there were very few animals at Lost City); so their murals will illustrate tall chimneys and hot fluids, but not much else. Their written reports, however, should contain a complete account of what is presently known about the organisms that inhabit these communities. Stress that studies of the LCHF are only beginning, while vent communities based on volcanic activity have been studied for more than 30 years. To provide an opportunity to make these points, you may want to require each group to discuss plans for their mural prior to actually preparing their illustration.

4. Proceed to the Learning Procedure for “What’s That” if you want students to complete that lesson.

5. Have each student group make an oral presentation of their research report, then lead a discussion of these results. The following points should be included:

   • The most prominent feature of LCHF communities are the tall chimneys of carbonate rock that may be 20 or 30 meters high.

   • Chimneys in hydrothermal vent fields formed by volcanic activity are much shorter that those found at LCHF, and are made of metallic rocks, particularly iron sulfide.

   • Hydrothermal fluids at vent fields formed by volcanic activity have temperatures as high as 403°C, are rich in dissolved metals and hydrogen sulfide, are highly acidic, and form “black smokers.”

   • Hydrothermal fluids at LCHF have temperatures between 40° – 90°C, contain high concentrations of methane and hydrogen, are highly alkaline (basic), and do not form “black smokers.”

   • Autotrophic bacteria are the base of the food web in both communities, but bacteria at vent fields formed by volcanic activity use hydrogen sulfide and metals, while bacteria at LCHF use methane and hydrogen.

   • Typical fauna at vents formed by volcanic activity include tubeworms (vestimentiferans) up to 3 meters in length, large clams and mussels (up to 30 cm long), limpets, poly-
chaete worms, shrimps, and crabs; suspension feeders (barnacles, anemones, "feather duster" worms, bivalves) dominate the benthic fauna a short distance away from the vent.

- Microorganisms are abundant in the LCHF biological community, as well as gastropods, amphipods, polychaete worms, nematodes, bivalves, and sponges; although the overall biomass of these communities is less than at vents formed by volcanic activity, the diversity (number of different species) appears to be just as high.

Briefly discuss the visibility, size, and habits of animals that initially led scientists to believe that there was very little fauna at LCHF. The important point here is that our powers of direct observation are not powerful enough to detect every organism that may be present. Many beaches, for example, appear to have very few species; but if we dig into the sand, use a microscope, and make observations at different times of day and night we are likely to see much more.

**The Bridge Connection**

[www.vims.edu/bridge](http://www.vims.edu/bridge) – In the “Site Navigation” menu on the left, click “Ocean Science Topics,” then “Habitats,” then “Deep Sea” for links to resources about hydrothermal vents.

**The “Me” Connection**

Have students write a short essay describing a real or imaginary example of how our limited powers of direct observation led (or might have led) to erroneous conclusions based on an initial set of observations.

**Connections to Other Subjects**

English/Language Arts, Geography, Physical Science

**Evaluation**

Groups’ murals, written reports, and oral presentations provide opportunities for assessment.

**Extensions**

Visit [http://oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html](http://oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html) to keep up to date with the latest Lost City Expedition discoveries.

Have students diagram a hypothetical food web for the LCHF, beginning with chemosynthetic bacteria that use hydrogen and/or methane from vent fluids.

Discuss the idea that chemosynthetic bacteria were the first life forms on Earth (see Rock Eaters of the Gulf of Alaska at [http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/rock_eaters9_12.pdf](http://oceanexplorer.noaa.gov/explorations/02alaska/background/edu/media/rock_eaters9_12.pdf) for more information).

**Resources**

[http://oceanexplorer.noaa.gov/explorations/explorations.html](http://oceanexplorer.noaa.gov/explorations/explorations.html) – Index page for Ocean Explorer expeditions, including the 2005 Lost City expedition

[http://www.oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html](http://www.oceanexplorer.noaa.gov/explorations/02fire/logs/magicmountain/welcome.html) – Virtual tour of Magic Mountain, a hydrothermal vent site located on Explorer Ridge in the NE Pacific Ocean, about 150 miles west of Vancouver Island, British Columbia, Canada.

[http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html](http://oceanexplorer.noaa.gov/explorations/03fire/logs/ridge.html) – 3-dimensional structure of a “mid-ocean ridge,” where two of the Earth’s tectonic plates are spreading apart

[http://www.bio.psu.edu/hotvents](http://www.bio.psu.edu/hotvents) – Virtual tour of hydrothermal vent communities

[http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML.ps_vents.html](http://seawifs.gsfc.nasa.gov/OCEAN_PLANET/HTML.ps_vents.html) – Links to many other Web sites with information about hydrothermal vents


Corliss, J. B., J. Dymond, L. I. Gordon, J. M. Edmond, R. P. von Herzen, R. D. Ballard,

**National Science Education Standards**

**Content Standard A: Science As Inquiry**
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

**Content Standard C: Life Science**
- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

**Content Standard D: Earth and Space Science**
- Structure of the Earth system

**Content Standard E: Science and Technology**
- Abilities of technological design
- Understandings about science and technology

**Content Standard F: Science in Personal and Social Perspectives**
- Populations, resources, and environments

**Content Standard G: History and Nature of Science**
- Nature of science

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http://oceanexplorer.noaa.gov