2004–05 Academic Year

Distinguished Lecturer Series

Ridge 2000 Program

August 2004

Dear Host Institution:

The Ridge 2000 Program is pleased to offer you the opportunity to host a Ridge 2000 Distinguished Lecturer during the 2004–05 academic year. Sponsored by the National Science Foundation, Ridge 2000 is an interdisciplinary research program to explore Earth's oceanic spreading ridge system as an integrated whole, including tectonics, volcanism, petrology, geochemistry, hydrothermal venting, subseafloor and seafloor microorganisms, vent fauna, ecosystems, and the overlying oceans. The mid-ocean ridge research community is focused on understanding the dynamic mechanisms of energy and mass transfer from the mantle to the oceans, and how these processes sustain life at the bottom of the oceans without sunlight. The Ridge 2000 Distinguished Lecturer Series can bring to your campus and community the latest results of mid-ocean ridge research, presented by some of our best and most eloquent researchers.

Each lecturer is prepared to visit four institutions and give two lectures at each—one to the campus science community, and the other to the general public in the community. Sixteen institutions will be selected to host lectures in this cycle. The Ridge 2000 Program will cover the speaker's transportation expenses to and from each institution, and the host institution is asked to provide housing, meals, and local transportation.

For the science community lecture, which is similar to a departmental seminar, we ask the host department to personally invite faculty and students from other departments on your campus with an interest in mid-ocean ridge science (e.g., geophysics, geology, geochemistry, biology, microbiology, oceanography, ecology, etc.). Our program emphasizes the interdisciplinary nature of ridge science, as the cutting edge is often found at the disciplinary interfaces. We also recommend inviting relevant departments from nearby campuses, as well as professionals (e.g., geological society) in the area.

For the general public lecture, we recommend that you also personally invite local high school and middle school teachers, another target audience for the Ridge 2000 outreach program and the National Science Foundation. The science of the Ridge 2000 Program—deep-ocean exploration, black smokers, and tube worms, for example—is exciting in the same way as space exploration. Previous host institutions had success working with campus outreach and news agencies to organize and advertise the event, and they had overflowing lecture halls for the public lecture. The Ridge 2000 office can also help.

Applications to host a Ridge 2000 Distinguished Lecturer will be accepted from all U.S. colleges, universities, and nonprofit organizations. Please use the form in the back of this brochure to apply. **The application deadline is September 30.**

Thank you for your interest in the Ridge 2000 Distinguished Lecturer Series. We look forward to working with you and your institution.

Sharon Givens
Ridge 2000 Program Coordinator

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www.ridge2000.org/

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SCIENCE COMMUNITY LECTURE

Global Distribution of Seafloor Hydrothermal Fields

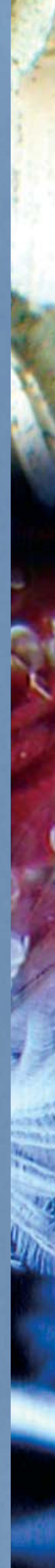
Seafloor hydrothermal circulation is the principal agent of energy and mass exchange between the ocean and the earth's crust. Discharging fluids cool hot rock, construct mineral deposits, nurture biological communities, alter deep-sea mixing and circulation patterns, and profoundly influence ocean chemistry and biology. This discharge requires both a crustal heat source (primarily magma) and adequate permeability for circulating fluids, but the relative influence of these two factors in controlling the global distribution of active hydrothermal sites is still debatable. In this talk, I will examine this question by summarizing our current state of knowledge of the global distribution of vent fields on oceanic spreading ridges and intraoceanic volcanic arcs. Approximately 10% of the 66,000-km-long global spreading ridge system and 40% of the 6900 km of intraoceanic arcs have now been surveyed in sufficient detail to quantify the distribution of active vent sites. These surveys reveal a robust linear correlation between the frequency of hydrothermal sites and the magmatic budget estimated from crustal thickness. Permeability appears to exert only a secondary control but may become increasingly important as spreading rates decrease and deep faults mine supplemental heat from direct cooling of the upper mantle, cooling gabbroic intrusions, and serpentinization of underlying ultramafics. Preliminary observations and theory suggest that hydrothermal activity is relatively deficient on ridges overlying mantle hotspots, although paucity of data precludes generalizing this result. While the validity of these conclusions depends upon further detailed study of vent field frequency, especially on slow-spreading ridges, they are consistent with global distributions of deep-ocean ^{3}He, an unequivocal tracer of magmatic activity.

GENERAL PUBLIC LECTURE

Unseen Volcanoes: New Perspectives in Ocean Exploration

HMS *Challenger* unfurled sail at Portsmouth in 1872 to begin the first scientific exploration of the deep sea, an environment so remote that not even its depths were imagined. The legacy of that expedition fuels ocean exploration yet today, when even after 130 years research cruises retrieve surprises from the depths. A principal objective of the *Challenger* voyage was accurate knowledge of the shape and nature of the seafloor. Their 362 deep-sea soundings were a modest but stunning beginning to our understanding of the ocean floor, which we now know is ceaselessly created and consumed in the most active volcanic environments on the planet. Seafloor is created where molten lava from the mantle erupts and forms the mid-ocean ridge, a 66,000-km-long volcano that snakes through all the ocean basins. Seafloor is equally consumed where it collides with a continent or adjacent seafloor and sinks back into the mantle, only its most volatile components escaping to stimulate volcano growth. Just 27 years ago, the discovery of hydrothermal vents by scientists in the submersible *Alvin* revealed that these seafloor volcanoes could harbor sanctuaries of warmth and life in the unyielding cold of the deep sea. Several recent expeditions to unexplored volcanoes along the boundaries of the Pacific basin have used specialized mapping equipment and sampling vehicles in a successful search for undiscovered hydrothermal vent fields. New visualization tools can now virtually transport a wide scientific and public audience to this unseen volcanic landscape. Just as in 1872, we are embarking on the challenge of another era of ocean exploration.

Edward T. "Ed" Baker is a supervisory oceanographer at NOAA's Pacific Marine Environmental Laboratory in Seattle, where he specializes in studies of active seafloor hydrothermal systems and their effect on the deep ocean. Dr. Baker studied geology at the University of Notre Dame and earned his Master's and Ph.D. in Geological Oceanography at the University of Washington. He helped develop NOAA's hydrothermal research program, VENTS, 20 years ago, and two of his more than 130 published papers have won NOAA's Outstanding Scientific Paper award. He has participated in more than 30 hydrothermal research cruises on vessels from three countries, 20 as Chief Scientist, along oceanic ridges and island arcs throughout the Pacific Ocean. Dr. Baker's research focuses on the thermal evolution of vent fields created by seafloor eruptions, and the global pattern of vent field distribution along ridges and island arcs. Most recently, he has participated on several cruises to the western Pacific, conducting the first systematic exploration for hydrothermal sites on submarine volcanoes of both the Kermadec-Tonga and Mariana intraoceanic arcs.



SCIENCE COMMUNITY LECTURE

The Mid-Ocean Ridge Subseafloor: Prime Microbial Real Estate

Deep-sea hydrothermal vents are famous as oases of abundant life in the deep ocean desert. At vent sites, microbial mats and macrofauna with chemo-synthetic symbionts cover the metal sulfide deposits and litter the seabed. Our opportunity for visual observation of the prolific life ends at the ocean floor, but for microorganisms, this boundary is arbitrary. The crustal rocks underneath the ridge contain centimeter-sized (or greater) gaps and cracks, which allow seawater and hydrothermal fluid to flow through the oceanic crust. This fluid flow creates environments within the crust that have physical and chemical characteristics conducive to life. The first evidence that microorganisms might take advantage of these subseafloor habitats came after volcanic eruptions on the East Pacific Rise at 9˚50' N and on the Juan de Fuca Ridge at the CoAxial Segment. Other evidence from further eruptions as well as from stable hydrothermal systems showed that the life within the crust shares similarities with life above the seafloor, but intriguing differences separate the two groups. Microorganisms cultured from the subseafloor can be interrogated to provide more information about the physicochemical nature of their preferred habitat. Geochemical modeling can also contribute insights into the range of habitats available in the crust. The geochemical disequilibria that provide energy sources to chemosynthetic microorganisms vary with rock type, temperature, and the sources and mixtures of fluids in the crust; these disequilibria should determine the dominant microbial metabolisms in the different subseafloor environments. The testing of these predictions of microbial metabolism in the ridge-crest subseafloor awaits technological advances in subseafloor sampling; similar predictions are currently being tested in terrestrial hot springs at Yellowstone National Park, where bison present the most formidable obstacles to sample collection.

GENERAL PUBLIC LECTURE

Seafloor Volcanoes, Surly Bison, and the Ecology of Life in Boiling Water

Life on Earth seems almost infinitely adaptable. On every mountain peak, in every ocean abyss, in deserts, within sea ice... and in hot springs, life, large or small, is present. Temperature is one of the few physical or chemical variables that has the capability to render an environment completely sterile, but our everyday experience concerning cooking, boiling, and sterility is somewhat misleading. Medically malicious microorganisms and other commonplace bacteria die in your simmering stewpot, but in hot springs and other volcanic environments, heat-loving microbes thrive, specifically adapted to these high temperatures. There are even microorganisms known to live at 120˚C—above the temperature at which water boils at atmospheric pressure. Human society has already benefited from these heat-loving microbes, known as thermophiles; modern molecular biology and forensic DNA technology is dependent on an enzyme from a thermophile.

Many thermophiles live in volcanic environments, where the volcanoes can provide both food and shelter. At the mid-ocean ridge, a system of linear volcanoes that circles the globe, the hot springs created by these volcanoes provide homes for thermophiles. Thermophiles also live in volcanic hot springs on land: at Yellowstone National Park, which is located over a supervolcano, thermophiles enjoy government protection along with the grizzly bears, bison, and wolves. Earthquakes and eruptions create cycles of destruction and colonization in volcanic environments that are akin to those in a pine forest that is routinely swept by fire. After the eruption of Mount St. Helens, Washington, in 1981, newly formed hot springs were quickly colonized by thermophilic microbes. Submarine lava flows have been observed to engulf and entomb seafloor hot springs and their denizens, large and small, while creating fresh habitat where thermophiles fountain from the seabed into the surrounding ocean. Determining the relationship between thermophilic microorganisms and their volcanic environment is an ongoing challenge that has far-reaching implications. If thermophilic microorganisms can live in habitats that are created solely by volcanoes, then volcanoes on other planets might also support life.

Melanie Holland is a faculty research associate in the Department of Geological Sciences at Arizona State University, where she investigates the interaction between biology and chemistry in geological systems. Dr. Holland is fascinated by the interconnected and reflexive nature of ecosystems, which permits the geochemistry of a location to be used to derive information about the biology, and conversely, the biology to be used to derive information about the geochemical and physical characteristics of the system. Her current research at terrestrial and marine hot springs combines theoretical geochemistry, microbiology, and molecular biology to make and test predictions regarding the transfer of energy between the nonliving and living components of hydrothermal systems. Dr. Holland received her bachelor's degree in Biology from the Massachusetts Institute of Technology but was bewitched by the ocean after spending a semester doing ocean science from a sailing vessel with the Sea Education Association. Her doctorate in Oceanography is from the University of Washington, where she was surrogate mother to many spoilt and pampered thermophilic microbes from deep-sea hydrothermal systems. She has worked at disparate hydrothermal vent sites along the Juan de Fuca Ridge on research cruises with manned submersibles, remotely operated vehicles, and scientific drilling vessels. Lately, her field expeditions have expanded to include terrestrial hot springs at Yellowstone National Park, where she dodges bison annually.

SCIENCE COMMUNITY LECTURE

Life within the Endeavour System: One of the Most Extreme Environments on Earth

The Endeavour Segment of the Juan de Fuca Ridge is an optimal natural laboratory to study the linkages between volcanically driven hydrothermal systems and the life that they support. The Endeavour hosts the highest density of hydrothermal venting of any system yet discovered on the global mid-ocean ridge spreading network. It represents one of the most extreme environments on Earth with numerous chimneys venting fluids at >370°C. Within one vent field alone, there are >100 active black smoker chimneys, which sprout from massive sulfide edifices that rise more than 20 m above the seafloor. The central 15 km portion of the ridge hosts five active hydrothermal fields and numerous distal sites of lower-temperature diffuse flow. The vent fields display well-developed chemical and thermal gradients from the north to the south, and all fields are affected by both boiling and condensation of brines in the subsurface. There is strong evidence that these sharp chemical gradients, high heat flux, and phase separation have been maintained for more than a decade. Stable periods of venting have been dramatically affected both by tidal processes and by earthquake activity. Tidal and storm forcing has resulted in transient decreases in venting temperatures by as much as 300°C. In contrast, earthquake swarms, perhaps associated with melt injection beneath the ridge axis in 1999, resulted in an increase in temperatures of many of the vents by 15°C, significant short-term injection of volatiles into the upwelling fluids, and an extensive microbial bloom that lasted for several months. New smoker systems were established, and within 3 years macrofaunal populations had dramatically increased at some of the vent sites. Supporting the macrofauna are rich communities of microbes flourishing in the subsurface and within the chimney walls. A recent study of very young sulfide material recovered from the 302°C black smoker, called Finn, in the most southern hydrothermal field has raised the upper temperature limit of life to 121°C. Yet, intact microorganisms have been detected in smoker fluids and within the hot interior walls of the active black smoker chimneys at temperatures considerably higher. Such findings raise important questions concerning conditions that permit growth and survival of microorganisms within the extreme environments of chimney walls and beneath the seafloor, the diversity of these organisms, and the novel strategies they develop to thrive under these conditions. It is anticipated that within the next 5 years, the Endeavour Segment will be networked into a fiber-optic regional cabled ocean observatory that will provide power to the seafloor and the capacity to interact in real-time with the environment. Such a system will transform the kinds of questions we will be able to ask about the connections between volcanoes and life, and how we respond to magmatic and tectonic events such as those that have occurred at Endeavour.

GENERAL PUBLIC LECTURE

Discovery of the Lost City Hydrothermal Field: Implications for Life in the Oceans of our Solar System

In 1977, the world was astounded by the discovery of black smoker chimneys hosting rich oases of biological communities supported by gases released from active submarine volcanoes. Since that pivotal find, more than 200 vent fields have been explored within the world's ocean basins. The associated metal deposits and diverse biota of clams, tubeworms, and swarming shrimp that have adapted to these extreme environments have become synonymous with submarine hydrothermal vents. In 2000, however, we serendipitously discovered a new kind of seafloor hot spring system as astounding as any black smoker field found to date.

This new ecosystem, called the Lost City Hydrothermal Field, is of stunning, ghostly beauty. Located at 30° N near the Mid-Atlantic Ridge, the hydrothermal complex hosts numerous diffusely venting limestone monoliths that tower more than 200 feet above the surrounding seafloor. Stalagmite-like parasitic growths three stories tall gently vent fluids at temperatures up to 93°C (200° F). Bathed in solutions with properties similar to Drano®, the chimneys are teeming with microbial life that thrives in the absence of sunlight. Surprisingly, these single-celled organisms obtain life-sustaining energy from hydrogen and methane gases and hydrocarbons formed through rock-alteration processes that occur at depth within the mountain.

The discovery of Lost City highlights that extensive, unexplored regions of the ocean basins may host novel life forms, which do not require volcanoes for their support. Lost City is also important because it may be our closest analogue to hot spring systems active during early Earth. If this is true, examination of geo-biological processes operative within this hydrothermal field may provide new insights into how life evolved on this planet. Recent discoveries on Mars hint that similar environments could have been present during its evolution. With these thoughts in mind, it is likely that within the next decade profound, unimaginable discoveries will be made not only about our oceans, but about the oceans of our solar system as well.

Deborah S. "Debbie" Kelley is an associate professor in the School of Oceanography and the Astrobiology program at the University of Washington. She specializes in seafloor hydrothermal systems and geobiological processes, and she has been involved in the discovery of numerous hydrothermal fields, which most recently included the Lost City Hydrothermal Field (http://www.lostcity.washington.edu/). She received her Ph.D. in Geology from Dalhousie University in 1990 and she was a postdoctoral scholar at Woods Hole Oceanographic Institution for two years. In 1992, she returned to the University of Washington to continue her research and begin teaching. Dr. Kelley's work currently focuses on exploration of new vent fields and examination of the linkages between geological and biological processes in systems supported by volcanoes and by rock-altering reactions. She is also developing prototype instruments that may yield new insights into the conditions under which life thrives, survives, and expires in the extreme environment within the walls of black smoker chimneys. She has participated on four Ocean Drilling Program cruises; she routinely uses the human-occupied submersible *Alvin* and robotic vehicles *Jason, ROPOS,* and *Tiburon*; and she has served as 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. She also serves on the Ridge 2000 Executive Committee.

Linkages Between Tectonics, Volcanism, Hydrothermal Activity, Vent Animals, and Segmentation on Mid-Ocean Ridges

The plates of plate tectonics are created primarily at submarine mid-oceanic ridges that encircle the globe. Recent surveys and dives reveal that systematic variations occur along the crests of these ridges, and they are far more complex and interesting than the "railroad track" double lines that represent them in standard textbook illustrations. These variations indicate important linkages between volcanism, hydrothermal activity, magma supply, faulting, and the locations of exotic faunal communities, which can be understood in terms of a fundamental segmentation of the ridge. These variations have been carefully studied at fast-spreading ridges, and include the geomorphology of the ridge, crustal magnetization, density anomalies, magma chamber occurrence, eruption temperatures, lava morphology and age, high-temperature hydrothermal activity, degree of fissuring and faulting, and abundance of vent animals. These variations occur on length scales of 10–100 km. The shorter end of this length scale appears to be the manifestation of major dike intrusion events, the fundamental building block of crustal creation. "Volcanic segments" that occur on a length scale of ~10–30 km may bear some relation to along strike variations in the supply of melt, which exerts a common influence on volcanic, tectonic, and hydrothermal processes (White et al., 2000; Haymon and White, in press). Along-strike variations observed at length scales of ~100 km may represent large, long-term variations in melt supply on time scales of 10^5–10^6 years (e.g., Baker et al., 2002).

There are some fascinating and controversial exceptions to this "magma supply/segmentation" model for mid-ocean ridges, even for fast-spreading ridges, which are thought to be the simplest. For example, overlapping spreading centers on the East Pacific Rise near 9° N are a major tectonic discontinuity that is also manifested as a significant mantle geochemical anomaly, yet seismic data indicate no discontinuity in upper mantle melt distribution, and there is a substantial crustal magma chamber. Near 10° N, the Clipperton transform fault is a major tectonic and seismic boundary, yet it is inconsequential as a mantle geochemical boundary. Why? Perhaps the key is to consider the ridge system in all four dimensions of space and time. A new model that accounts for along-strike variations in melt supply as the ridge system migrates over melt anomalies in the mantle may hold some of the answers (Carbotte et al., 2004).

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10,000 Leagues Under the Sea: Deep Dives to Explore the Underwater Volcanoes of the Global Mid-Ocean Ridge

The mid-ocean ridge is the longest mountain range and the largest, most active system of volcanoes in the world. In plate tectonic theory, the ridge is located between plates of the earth's rigid outer shell that are separating at speeds of ~10 to 220 mm/yr. The ascent of molten rock from deep in the earth to fill the void between the plates creates new seafloor and thousands of active volcanoes. This ridge system wraps around the globe like the seam of a baseball and is approximately 60,000 km long (more than 10,000 leagues). In this talk, I will focus on how this system of underwater volcanoes is mapped and how we use these maps to conduct submersible dives to depths of 8,000–15,000 feet to explore them.

Maps are powerful; they inform, excite, and stimulate. Just as the earliest maps of the world in the sixteenth century ushered in a vigorous age of exploration, the first high-resolution, continuous coverage maps of the mid-ocean ridge stimulated investigators from a wide range of fields, including petrologists, geochemists, volcanologists, seismologists, tectonicists, practitioners of marine magnetics and gravity, as well as researchers outside the earth sciences including marine ecologists, chemists, and biochemists. Marine geologists have found that many of the most revealing variations are to be observed by exploring *along* the axis of the active ridge. This along-strike perspective has revealed the architecture of the global rift system. The ridge axis undulates up and down in a systematic way, defining a fundamental partitioning of the ridge into segments bounded by a variety of discontinuities. These segments behave like giant cracks in the seafloor that can lengthen or shorten and have episodes of increased volcanic and tectonic activity.

Another important change in perspective came from the discovery of hydrothermal vents by marine geologists and geophysicists. It became clear that in studies of mid-ocean ridge tectonics, volcanism, and hydrothermal activity, the greatest excitement lies in exploring the unexpected *linkages between* these different fields. For example, geophysicists searched for hydrothermal activity on mid-ocean ridges for many years by trying to measure the temperature of deep ocean water with greater precision. However, in the 1970s and '80s hydrothermal activity was eventually documented more effectively by photographing the distribution of exotic vent animals. In the 1990s, during the aftermath of a deep-sea mid-ocean ridge eruption viewed from a submersible, divers did not see a slow-lumbering cascade of pillow lavas as observed by divers off the coast of Hawaii. What they saw was completely unexpected: white microbial matter billowing out of the seafloor, creating a scene much like a mid-winter blizzard and covering all of the freshly erupted, glassy, black lava with a thick blanket of white microbial "snow." In the current decade, strange life forms have been found off-axis in older crust on large fault scarps, which may provide "tectonic windows" into the deep biosphere. The exploration continues.

Ken C. Macdonald, professor of Marine Geophysics at the University of California, Santa Barbara, has been fortunate enough to participate in some of the first fine-scale explorations of the mid-Atlantic Ridge and East Pacific Rise, using swath-mapping sonars, remotely controlled vehicles, and research submersibles such as *Alvin*. He has contributed to a number of interesting discoveries and advances in understanding ocean ridge systems including: the fundamental segmentation of mid-ocean ridges and the significance of ridge-axis discontinuities, including overlapping spreading centers; the processes responsible for creation and deformation of oceanic crust particularly through the study of marine magnetic anomalies and quantitative geomorphology; the first measurements of heat flux from black smoker vents; and the interdisciplinary linkages between tectonic, volcanic, and hydrothermal processes on mid-ocean ridges. He graduated from U.C. Berkeley in Engineering and received a Ph.D. from the MIT/Woods Hole Joint Program in Oceanography. He has led more than 20 expeditions to the mid-ocean ridge and published more than 100 articles on the subject. When not exploring mid-ocean ridges or teaching about them at UCSB, he pursues windsurfing, flyfishing, and hiking in the mountains with his wife, Professor Rachel Haymon, another mid-ocean ridge explorer. Three general articles and video footage taken from *Alvin* relevant to his talks can be seen or downloaded at http://www.geol.ucsb.edu/faculty/macdonald

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