POWER *the*

Do you know what lies deep, deep below the ocean floor? With the support of a $25 million grant from the National Science Foundation, Katrina Edwards and her team are determined to find out.

"I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth." These were the remarkable words spoken by President John F. Kennedy in 1961. They came true. In 1969, the *Apollo 11* mission landed on the moon and left behind this unforgettable statement: "Here men from the planet Earth first set foot upon the moon."

This was a heralded feat talked about around the globe. But yet, did we know much about what was happening right here on our own home planet? Very little indeed — particularly concerning our oceans.

PHOTO BY PHIL CHANNING

PROMISE of the OCEAN

BY SUSAN ANDREWS

What comes to mind when you think of the ocean? Perhaps a sweet breeze, a holiday on a luxury cruise liner or maybe you wonder if the "surf's up." But probably not science.

"If you think about the bottom of the ocean, and that is a big *if*, you probably think of one of two settings: abyssal, wafting plains of sediments or smoking hot hydrothermal vents," said Katrina Edwards, professor of biological sciences and earth sciences in USC College. "What lies in-between — hundreds of square kilometers in aerial extent, down kilometers below the ocean bottom, lies an active, living intraterrestrial ecosystem — this is what I think about almost all of the time.

"This is our space," she said. "The deep biosphere is the new moon for this team of researchers. The series of expeditions that we are putting together are our *Apollo* missions, and this new center provides us with exactly the launch pad we need to accomplish our ambitious goals."

And now Edwards, a driven and entrepreneurial deep ocean and subseafloor geomicrobiologist, has put together an amazing group of international researchers to explore what lies beneath the ocean floor. She is leading the team on a coordinated mission of exploration and discovery of the subseafloor biosphere as a result of the establishment of the Center for Dark Energy Biosphere Investigations (C-DEBI). The C-DEBI, headquartered in USC College, is a new science and technology center funded through a highly competitive National Science Foundation (NSF) proposal process.

Edwards believes the subseafloor is one of the greatest frontiers in science and exploration of planet Earth. "It's shocking," Edwards said, "You go below the very surface of the ocean and basically fall off the edge of our knowledge about this planet." She added: "In the present day we know much, much more about space and the surface of other planetary bodies than we do about the inner space of our world." >>

KATRINA EDWARDS: "Our mission is to understand the extent, function, dynamics and implication for the existence of a deep biosphere on Earth."

"Startlingly, but true," she said, "we have poorer maps of the bottoms of the ocean than surfaces of other planets in our solar system."

Edwards believes the timing of the NSF grant is ideal.

"Given the maturity of the field and the significant advancement in technology, this is an excellent time to establish the center," she said. "My team and I are thrilled to receive this extraordinary opportunity to collaborate with scientists from around the globe as we pursue our ambitious scientific, education and diversity goals."

"Our mission is to understand the extent, function, dynamics and implication for the existence of a deep biosphere on Earth," Edwards said. The center's research team will focus on that which is close to the living — in an *undead* kind of capacity. "The organisms metabolize very slowly; they are alive but not what we are used to thinking of in terms of *normal* life forms."

The center's researchers have a solid set of key scientific, educational and diversity goals to achieve in the next five years. Additionally, they will advance the suite of scientific tools; train and educate a new and diverse generation of undergraduates, graduate students and postdoctoral deep subseafloor biosphere researchers; and translate knowledge of the deep subseafloor biosphere and ocean sciences to a broad and diverse community that includes K-12 children.

Edwards and her USC team will partner with several major research universities and national laboratories to study the deep biosphere beneath the oceans. "We will focus on the marine realm because it is by far the biggest challenge in terms of potential habitat size," she said.

And big it is. A little-known fact is that nearly half of the total biomass on Earth may reside in sub-surface habitats that include mines, aquifers, soils on the continents, and sediments and rocks below the ocean floor.

The deep biosphere, tens to hundreds of millions of years old, has two different systems that interact with each other but are themselves different. The first is the sediment world of microbial communities that is controlled by the diffusion of molecules and chemical exchange with surrounding water bodies. The second is often referred to as the "subseafloor ocean." There the rock is cracked and fractured, according to Edwards, "like a solidified sponge cake that has been dropped onto the floor, allowing fluid to flow through the fissures and pores in the solid rock."

This massive area is what Edwards and her research partners plan to explore in three main field projects at North Pond (mid-Atlantic), Juan de Fuca (a strait that connects to the Pacific Ocean) and South Pacific Gyre.

She noted that staging, comparing and contrasting of experiments, in addition to setting up of long-term programs will take decades to complete.

"USC has a strong track record of success in winning these types of center excellence awards across the university," USC Executive Vice President and Provost C.L. Max Nikias said. "We have built a reputation for quality research that leverages our strengths in multidisciplinary collaboration between our schools, other institutions and industry.

"This highly competitive award demonstrates that Katrina Edwards, other College faculty and USC researchers are at the forefront of science in the exploration of the biosphere at the interface between the deep ocean and the Earth's crust."

Up until the 1960s the scientific community had mainly focused on the geological aspects of the ocean. According to Edwards, scientists were concentrating on big problems such as the original theories of continental drift and plate tectonics.

"Another driver then focused on sampling of the deep interior Earth — a boundary layer all over the globe referred to as the 'moho.' Scientists could *see* it geophysically but didn't know exactly what it was," she said. Microbiology did not debut in deep ocean drilling until the '80s when microbiologists managed to find their way to expeditions and obtain samples.

"We now know that life exists to great depths within the Earth, we know that it is a huge portion of the biomass, but we cannot say what the consequences are for biogeochemical cycles, the carbon cycle, the nitrogen cycle, the other elemental cycles and budgets," she said. "Yet a big question remains: What are the consequences for the evolution of life?"

Edwards explained that most of the evolutionary studies that have been conducted in microbiology utilize lab microcosm studies. "But we have not in the past been able to use the environment as our lab in the same way that Darwin used the Galapagos Islands," she said.

Edwards noted that scientists have had an extremely difficult time studying microbiology in the ocean because there is no physical laboratory. This changed with the drilling of holes deep in the ocean floor that essentially have become permanent working laboratories.

She emphasized the need to fully understand the impact or consequence of the deep biosphere. "For example, if we don't understand the carbon cycle as it exists in the biosphere, we won't understand the carbon cycle in its complete form, which has significant consequence for our understanding of fundamental problems that influence, for example, climate change," she said.

Deep biosphere researchers are doing something different than microbiologists who think on a local scale about microbial systems. "We try to understand microbes in the context of chemical, physical, hydrological and thermal regimes, and make long-term observations that allow you to study specific processes that are more of an earth system science type of construct within the life sciences," Edwards said.

The history of the field dates back to as early as the 1930s and to one of the grandfathers of oceanography, Claude ZoBell, who did collective

Katrina Edwards and fellow microbiologists complete a sampling in the mid-Atlantic aboard the German vessel *RV Maria S. Merian*. Last year Edwards and an international research team undertook a three-week expedition to a point about 20 degrees north and three miles above a lake of sediment on the sea floor known as North Pond.

PHOTO BY WIEBKE ZIEBIS

long coring in the mid-Pacific and conducted numerous studies on deep microbiology. "He was astounded and recorded that everywhere he looked he was able to find evidence for life," Edwards said. "He hypothesized the radiolysis [splitting] of water as a source of hydrogen that might be fueling communities. Several of ZoBell's hypotheses are experiencing a rebirth today and are being directly pursued."

There was no deep drilling for scientific research when ZoBell was conducting his research in the '30s. Deep sea drilling began in the '60s. The Ocean Drilling Program, now the Integrated Ocean Drilling Program (IODP), started in the '80s.

In 2010–11, the IODP will dedicate drilling time to sample this frontier habitat in three different areas and habitats: the Southern Pacific Ocean, a site off the Pacific Northwest of North America, and the mid-Atlantic. The average depth of the ocean is about 4 kilometers or roughly 2.5 miles.

"These studies herald a dedicated effort by scientific ocean drilling to, in the future, study the limits of extreme life on Earth. This quest will also address the question of how life can evolve on terrestrial planets," said Hans Christian Larsen, IODP vice president.

In the past, working with engineers and other academics was primarily about emergency response, according to Edwards. "We had both industrial and academic partners, but my field never actively engaged in ocean drilling that embraces the creative capacity of academic partners."

Said Howard Gillman, dean of USC College: "We are proud to be the lead institution and home for the center and are committed to supporting world-class, transformative research and entrepreneurial faculty who work collaboratively across disciplines and institutional boundaries to advance the frontiers of science and tackle the major issues of our time."

Edwards' team will collaborate with Gaurav Sukhatme, associate professor of computer science in USC Viterbi. "Katrina did an amazing job putting together a fantastic group of the world's best researchers to be part of the center," Sukhatme said.

Sukhatme's first challenge will be to push deeper into the ocean. His robotic work has focused in the upper column (nothing below 100 feet), and robots only communicate when they are above the water. The second challenge is therefore to develop algorithms that program robots to communicate with each other for longer periods of time.

"We will also collaborate with Ellis Meng, assistant professor of biomedical engineering in USC Viterbi, on microfluidics that provide important laboratory experimentation for our research cruises," Edwards added.

"This is the decade of the intraterrestrials — we have definitive, measurable deliverables that contribute to our knowledge of really big questions: Is there a consequence for all that life down there, or is there none?" Edwards said. The answer will be the C-DEBI's mission.

British poet Edward Young wrote, "In chambers deep, Where waters sleep, What unknown treasures pave the floor."

So the next time you feel the wind in your hair, the sun on your face, and the cool of the azure ocean water, take a moment to think about what is deep, deep below your feet. That is where Edwards and her team will be spending much of the next decade — drilling, coring, examining and comparing — to find answers that affect the future of life on our planet and perhaps beyond. ■

The funding for Katrina Edwards' research comes from a $25 million grant from the National Science Foundation to develop a new science and technology enterprise called the Center for Dark Energy Biosphere Investigations (C-DEBI). Additional funding and infrastructure support is being provided by the Dean of the College and the Provost's Office.

Partner universities and laboratories include University of Alaska Fairbanks; University of California, Santa Cruz; University of Hawaii at Manoa; Pacific NW; University of Rhode Island; Lawrence Berkeley National Laboratory; Japan Agency for Marine Earth Science Technology; Harvard University; and the University of Bremen.

To learn more about the groundbreaking work of Edwards and her co-researchers, visit *darkenergybiosphere.org*, the Dark Energy Biosphere Institute: Research Coordination Network.

To view a blog maintained by Edwards during her February 2009 three-week cruise in the mid-Atlantic, visit *northpondexpedition.usc.edu*.