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Building Blocks of Life, Atlantis Massif

How and where life began 3.5 billion years ago is still a mystery, but there are two things on which scientists are almost certain. First, for much of that time, life on Earth was almost exclusively microbial. Second, there must have been prebiotic precursor compounds such as amino acids, organic acids, and lipids available to jumpstart the formation of DNA, enzymes, and cell walls, and to set life on a path leading to the complex forms we see today. One place that may hold a window to those early, life-forming processes is the Lost City Hydrothermal Field (LCHF), which is famous for ghostly white vent chimneys the height of a house and alkaline vent fluids rich in hydrogen and methane—powerful sources of thermodynamic energy that may have fueled the formation of the first organic building blocks of life on Earth. Similar systems may also be present on "ocean worlds" such as Enceladus, one of the moons of Saturn that astrobiologists are looking to as a possible home for extra-terrestrial life. The LCHF sits atop the Atlantis Massif, an oceanic core complex (see Background below) at 30°N on the Mid-Atlantic Ridge. The Massif was formed by extensional faulting, bringing rocks from the lower crust and mantle up to the seafloor where they can be altered by seawater, producing the mineral serpentine and hydrogen. Previous ocean drilling and surveys of the Atlantis Massif has revealed, in addition to hydrogen, extensive generation of prebiotic compounds including organic acids, short-chain hydrocarbons, methane, and amino acids. These compounds may be feeding ancient forms of microbial life living in high temperature, high pressure, and extreme alkalinity inside the LCHF chimneys and even far below the seafloor. IODP Expedition 399 aims to discover where and how hydrogen, methane, and more complex compounds are being generated within the Massif, how these chemicals get into the hydrothermal vent fluids, and how the energy and nutrients needed to support microbial communities originate.

MORE INFORMATION:

About the expedition - IODP JRSO • Expeditions • Building Blocks of Life, Atlantis Massif (tamu.edu)
About the research program - www.iodp.org

BACKGROUND:

The Atlantis Massif: Earth's continental crust—the land on which most people live—is normally 30-40 kilometers (18-24 miles) thick, making it impossible to reach underlying mantle by drilling. The crust is thinner underneath the oceans, typically 6-7 kilometers (3.5-4 miles) thick, but still no hole has been drilled through the crust and into the mantle. Seafloor spreading at mid-ocean ridges is normally driven by volcanic activity: New crust is continually formed by eruptions and intrusions, creating a layered structure made of volcanic material and coarse-grained rock from the lower crust known as gabbro. However, in some places magmatism cannot keep up with the spreading rate, and large extensional “detachment faults” expose mantle rocks and lower crustal gabbros on the seafloor. An underwater dome-shaped mountain formed by this process is called an oceanic core complex, and these locations allow us to directly sample mantle rocks and gabbros by drilling. The Atlantis Massif is one such core complex.

Seawater-Rock Reactions: The drilling conducted on Expedition 399 will study the reactions between olivine, a major mineral in the Earth’s mantle, and seawater that are believed to actively occur at depth in the massif. We will deepen an existing hole from a previous expedition that reaches 1,415 meters (4,642 feet) below the seafloor and has a bottom temperature of 140°C (284°F). This temperature is above the currently known limit for microbial life, so we can be sure that any hydrogen, methane, or organic molecules produced at greater depths are not due to active microbial processes. We hope to reach 2,060 meters (6,760 feet) below the seafloor, where temperatures of ~220°C (428°F) are predicted. We will sample fluids in the borehole to look at active exchange of chemical components between fluids and rocks to better constrain elemental exchanges between the ocean and crust. The concentrations of volatiles such as hydrogen and methane will help identify the physical and geochemical properties that lead to their production. We will also drill a shallow hole closer to the Lost City hydrothermal field that we predict will access the subseafloor environments that reflect the reactions that lead to this remarkable system.

The expedition is led by Co-Chief Scientists Susan Lang (Woods Hole Oceanographic Institution, USA) and Andrew McCaig (University of Leeds, UK), and will core at two sites located in water depths ranging from 825 to 1656 meters (2,707 to 5,433 feet). They will sample serpentinite, gabbroic, ultramafic and faulted material to a depth of up to 2060 meters (6,762 feet) below the seafloor.

“The Atlantis Massif is one of the most scientifically exciting places on Earth,” said Lang “Every time we return, we discover more about the conditions that may have been present on early Earth, and how the earliest steps on the path to life may have proceeded.”

“During the upcoming expedition we will sample previously inaccessible portions of the rocky subseafloor that will help us identify the processes that occur as water passes through mantle rocks. Most of what we know about what happens at these depths must be inferred by looking at material carried to the surface by natural events, which can alter important chemical signatures. By directly accessing the subseafloor we have the opportunity study these fundamental reactions in rocks and fluids that have not undergone subsequent modification. We will also gain new insights into the interactions among water, rocks, and microbes that will help us understand the origin and early evolution of life on Earth and other planetary bodies.”

Co-chief McCaig commented “The reason the Atlantis Massif is so important is that it hosts the Lost City Hydrothermal Field, the best example so far discovered of a low temperature (up to 90 °C) hydrothermal system venting highly alkaline fluids rich in hydrogen and methane, as well as more complex molecules such as carboxylic acids. These chemicals have formed because of alteration of olivine-rich mantle rocks by seawater, and the Atlantis Massif is an unusual place where mantle rocks have been brought to the seafloor by faulting. There is already a drill hole 1415m deep in the Massif, and we know that the temperature at the bottom is over 140 °C. By drilling deeper, we can access temperatures up to 220 C, where these reactions are actually happening, and where any hydrogen and methane being produced cannot possibly be biogenic”

SCIENTIFIC OBJECTIVES:
The overall objective of IODP Expedition 399 is to better understand the processes of formation of the Atlantis Massif oceanic core complex.

Some of the specific scientific objectives include the following:

- Assessing the structure of the prebiotic chemical “kitchen of life” and how the distribution and abundances of organic compounds not directly associated with biological processes may have set the stage for early life on Earth
- Determining the diversity and extent of “extremophile” microbes that can live in high alkalinity environments, and how their presence has implications for the early evolution of life.
- Characterizing the life cycle of an oceanic core complex, especially the fluid-rock interactions and the processes of deformation and alteration of detachment faults and the underlying massif.
- Characterizing the magnitude and history of chemical exchanges between the ocean crust and seawater, and the processes by which they occur.
- Looking for microbial activity and growth at temperatures above the known upper temperature limits of life.
- Characterizing the origin, composition and global significance of deep subseafloor microbial communities.
- Constraining the processes that govern the flow and storage of carbon in the seafloor.

SCIENTIFIC OPERATIONS:
The expedition is conducted by the *JOIDES Resolution* Science Operator (JRSO) as part of the IODP. The IODP is a multidecadal, international research program supported by 22 nations, with the goal of exploring Earths history and structure recorded in seafloor sediments and rocks and monitoring sub-seafloor environments. Expedition 399 will sail with 26 scientists from 8 countries [USA, UK. France, Germany, India, China, Japan and Australia], with expertise in a range of geoscience disciplines. While at sea, the *JOIDES Resolution* laboratory infrastructure will be utilized for intensive sampling and investigation of the cores retrieved. This includes splitting, describing, and analyzing the cores, which will be made available to non-expedition scientists after a one-year moratorium. Data from these core samples will be used by scientists all over the world.

Throughout the expedition, the *JOIDES Resolution* can provide personalized ship-to-shore live broadcasts to school, community, and museum groups, the media and the general public. Interested parties should contact thejoidesresolution@gmail.com for more information.

Get involved:
Twitter - @TheJR
Instagram - joides_resolution
Facebook - JOIDES Resolution

Contact / Interviews / Images:
Lesley Anderson
Sarah Treadwell
Exp 399 Onboard Outreach Officers

Email: thejoidesresolution@gmail.com

Carol Cotterill
Assistant Director, Education and Outreach
US Science Support Program
Email: ccotterill@ldeo.columbia.edu

Peter Blum
Expedition Project Manager 399
JOIDES Resolution Science Operator
Email: blum@iodp.tamu.edu OR jr_blum@ship.iodp.tamu.edu