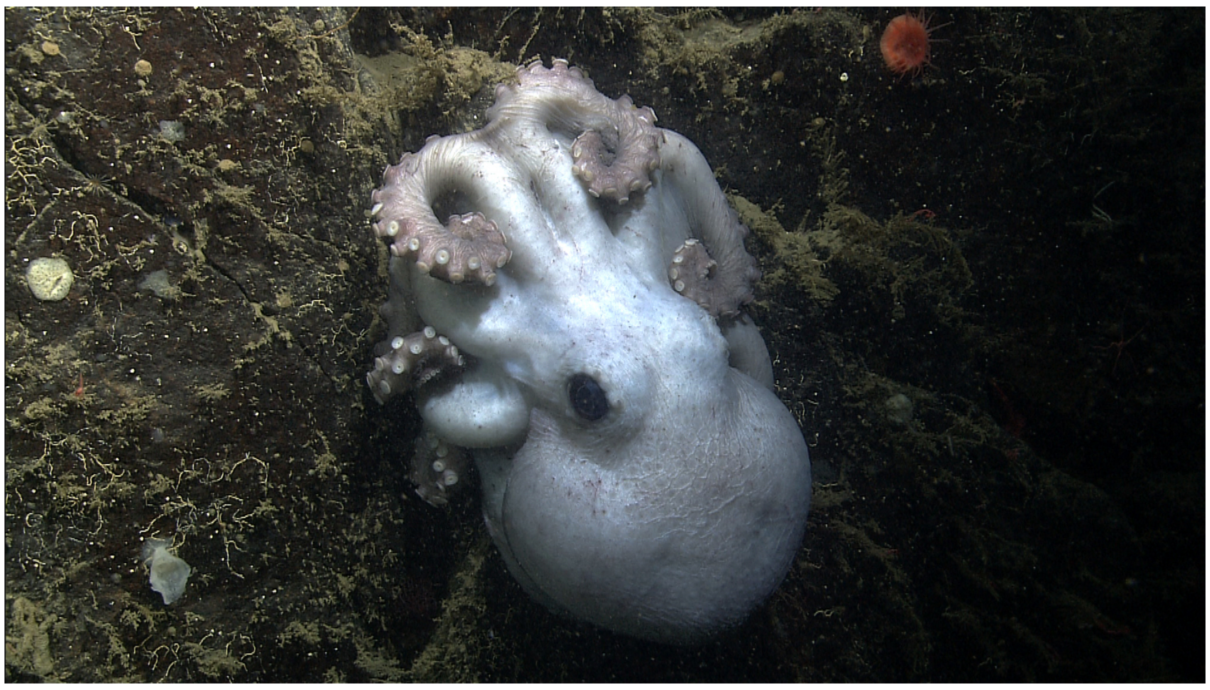
Archived: Longest-Living Octopus Found, Guards Eggs for Record 4.5 Years

If you thought nine months was long, consider watching over your eggs for four and half years—only to die at the end. A deep-sea octopus, Graneledone boreopacifica, has set a new record for brooding stamina—53 months, the longest developmental period known for any organism, according to a study published July 30 in the journal PLOS ONE....

July 30, 2014

If you thought nine months was long, consider watching over your eggs for four and half years—only to die at the end.

A deep-sea octopus, *Graneledone boreopacifica,* has set a new record for brooding stamina—53 months, the longest developmental period known for any organism, according to a study published July 30 in the journal *PLOS ONE*.



This female octopus brooding her eggs on a ledge near the bottom of Monterey Canyon in fall 2007, about seven months after she laid her eggs. Photograph by MBARI

This beats the 14 months on record for an octopus, and really *any* animal, including the estimated 48 months of gestation in the alpine salamander. Octopuses that live in shallow waters, which are better studied, care for their eggs for only a few months.

What's more, life spans for nearly all cephalopods—a group containing squid, nautilus, octopus, and cuttlefish—are a short one to two years, which *G. boreopacifica* outlives by its brooding time alone. Thus, this species also snatches the title of longest lived.

"She's Still There!"

The discovery comes down to observational luck. In 2007, study leader Bruce Robison was using a robotic vehicle at about 4,500 feet (1,400 meters) deep off the coast of central California. He captured video of a purple octopus crawling toward a rock wall favored by brooding octopuses. (See "Journey of Octopus Discovery Reveals Them to Be Playful, Curious, Smart.")

A month later, Robison, a deep-sea biologist at the Monterey Bay Aquarium Research Institute, and his team noticed the same female, easily identifiable by distinctive scarring, firmly attached to the rock and protectively curled over her fragile, transparent eggs.

The team returned 18 times over the next 53 months to record the incredibly slow growth of the babies in 37-degree-Fahrenheit (3-degrees-Celsius) water, as well as the gradual wasting away of their motionless mother.

After two years, the consensus was that she wouldn't last much longer—but she kept proving them wrong. Robison would frequently exclaim, "Holy sh*t, she's still there!"

Finally, in October 2011, she was gone, and more than 150 eggs lay broken open.

Remainders of the octopuses' eggs are still attached to the rock after the young hatched. Photograph by MBARI

"This is the only opportunity that anybody has ever had to trace a brooding period" of a deep-sea octopus, said Robison. "We had a start date and we couldn't let go until we got to the end."

Go, Baby, Go!

Scientists know little about reproduction in the deep sea, but they speculate the octopus' long development is due to slow metabolism brought on by colder temperatures.

There's another result to this lengthy incubation: Baby *G. boreopacifica* are the most highly developed octopus hatchlings known to date, said Janet Voight, associate curator at the Field Museum in Chicago, who wasn't involved in the research.

Unlike some shallow-water octopuses that have a planktonic stage, *G. boreopacifica* pop out as small but complete versions of their parents, giving them a greater survival boost in the dark and lonely deep sea.

The mother's investment in her eggs also means she releases larger, but fewer, eggs—a few hundred versus thousands. (See "Social Octopus Species Shatters Beliefs About Ocean Dwellers.")

However, this study involved just one animal, which raises the question of whether the egg-rearing stint is an anomaly.

Voight said the lengthy brooding behavior is probably typical for the species. "Of course, more data are better, but it's the deep sea"—a challenging place to conduct research.

Parental Sacrifice

As with many deep-sea discoveries, another mystery has surfaced: Did this mother octopus not eat for nearly five years? After all, "as a rule, most octopuses never leave their eggs," said Robison. Voight added that octopuses brooding in warm water don't eat

(Related: "'Bizarre' Octopuses Carry Coconuts as Instant Shelters.")

No one knows. The study team never witnessed the mother feeding, but they observed only about 18 hours of a 53-month brooding cycle. The scientists even offered her crab, but she didn't take the bait. Robison surmised she might have occasionally eaten small crabs in defense of her eggs, a theory based on carcasses found close by.

But one thing for sure is that Robison and his team found an invertebrate making the ultimate sacrifice to care for its young.

"We tend to think of parental care only in higher life-forms, but here's a parent who is going all out to ensure the survival of her offspring."

Follow Amy West on Twitter.

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Archived: Going on a Rock Cruise

EVENTS

Imagine two, 60-mile-thick slabs of rock running into each other. Which gives first and why? This is what happens when two oceanic plates go head to head, and one must buckle down, or subduct into a trench. In the western Pacific Ocean south of Japan, this is thought to have first occurred 52 million years...

NATIONAL GEOGRAPHIC

July 18, 2014

The 471-foot drill ship, Joides Resolution.
Photo courtesy of Adam Bogus/IODP
Imagine two, 60-mile-thick slabs of rock running into each other. Which gives first and why?

This is what happens when two oceanic plates go head to head, and one must buckle down, or subduct into a trench. In the western Pacific Ocean south of Japan, this is thought to have first occurred 52 million years ago. But scientists don't really know how subducted ocean plates turn into continental crust millions of years later.

"It's the most important solid Earth process," says Robert Stern, a geoscience professor who has worked in the region since the 1970s. "Understanding how this system starts to form is essential to understanding how it operates."

A trio of two-month expeditions in 2014 will be in the region where the Pacific Plate is descending under the Philippine Plate to form the Mariana Trench and the deepest point in the ocean–the Challenger Deep. Scientists will get under the skin of the Izu-Bonin-Mariana Arc, which stretches nearly the distance from Los Angeles to Chicago. I will be along as a science writer and outreach specialist on this two-month journey in August and September, and help to connect educators worldwide to the ship via live video.

The plan is to send a drill pipe through 3 miles of water, then drill a half-mile into the side of the trench wall on the Philippine Plate. Scientists hope to bring up long tubes, or cores, of volcanic rocks. Looking closer at the chemical, magnetic and microbial features of these rocks from the beginning of subduction will enhance our knowledge of how ocean floor is recycled.

Chugging around these oceans to "core" out Earths' history is the drill ship, *JOIDES Resolution (JR)*, operated by the International Ocean Discovery Program (IODP). The program has changed its name a few times since the 1960s, most recently from the Integrated Ocean Drilling Program in 2013. But the only thing that IODP has in common with the oil industry is their drilling technology. Other than that, this ship is completely unprepared to deal with a flow of petroleum.

Having a look at cores brought up from the sea floor that have been cut in half and sectioned. Photo courtesy of Adam Bogus/IODP

"The biggest disaster that could possibly happen to IODP other than the ship sinking would be if they hit oil," says Stern.

So before any proposal can move forward, detailed seismic surveys are required to profile what the rocks hundreds of feet below the proposed drill site look like, which Japanese geoscientists did for this particular mission.

IODP has been poking holes into the ocean floor since the 1960s and storing these long tubes of earth's geological history in cold rooms in Germany, Texas and Japan, which now could reach more than 200 miles end to end. Such scientific missions have helped elucidate the theory of plate tectonics, and the fact that Antarctica has been covered with ice for at least 15 million years.

For this mission one must understand plate tectonics and the "art" of subduction. First, seafloor spreads from rifts on the ocean bottom (e.g. Mid-Atlantic Ridge in the Atlantic Ocean). As the seafloor inches along at about the rate your fingernails grow in a year, it cools and thickens. Millions of years later, it descends back into the Earth through a trench. As the plate sinks, it's cooked, squeezed, and transformed. The sinking plate also causes melting deep in the earth and magma to rise and erupt, forming an arc of volcanic islands parallel to the trench (e.g. the Izu, Bonin and Mariana Islands). We will be stationed in the "forearc," which is between this arc of islands and the trench's edge.

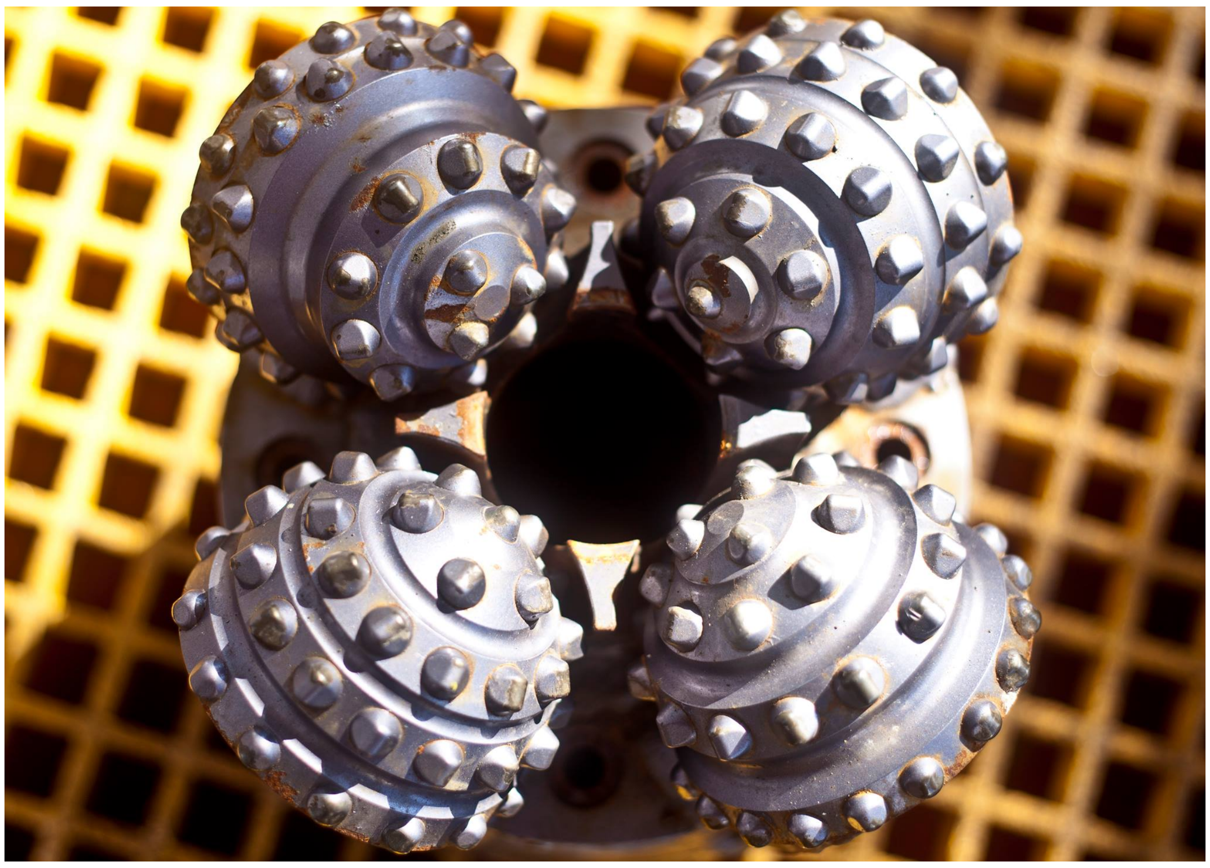
The scientific team also aims to show that chunks of forearc crust with names like "gabbro" and "dykes," are in the same configuration deep below as found, albeit slightly eroded, on nearby islands. The origin of these rocks is debated, though can be found in the Alps and Himalayas when continents come together.

“Geoscientists never prove anything. We just hope we are less wrong than the last people!” adds Stern.

Proposing a mission like this and finally stepping aboard the JR takes trench-deep patience and international collaboration. When scientists first got together eight years ago to propose drilling just four holes, it was unclear if four proposals led by eight scientists from around the world would make the cut; the process is very competitive, and approval was iffy. After eight years of waiting, 120 people will finally set sail on the *JOIDES Resolution* this August.

Five-foot sections of seafloor cores from worlwide expeditions stored in College Station, Texas at The Gulf Coast Repository. Photo by Amy West

Digging deep beneath the ocean floor can be fascinating, even to this marine *biologist*. Having the technology to section out an inanimate part of history that predates human origins or prehistoric animals like the giant penguins is mind-boggling. Conclusions won’t be drawn overnight, but just getting actual material in hand to analyze is more than half the battle. I’ll be there to document the “rock” and “roll” of the ship, and hopefully impart a “bit” of information on what makes this world go round.



The rotary core barrel– the drill bit that allows deep drilling into the ocean floor.
Photo courtesy of Adam Bogus/IODP

For more information check out the *JOIDES Resolution* website or follow on Facebook

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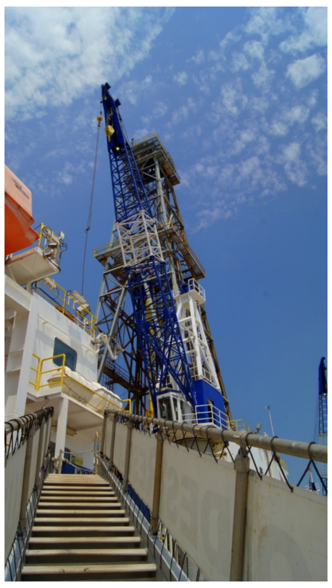
Archived: Seafloor Research Vessel Gets Underway

Rocking lazily in the gentle swell as our floating country of 113 people steams out to the first drill site offers me time to recollect what it takes to finally pull out of port. Stepping aboard this 471-foot ocean drill ship, which flies a Cyprus flag, are 30 scientists hailing from countries such as France,...

August 12, 2014

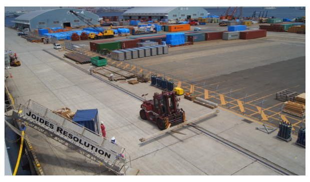
Rocking lazily in the gentle swell as our floating country of 113 people steams out to the first drill site offers me time to recollect what it takes to finally pull out of port.



Welcome aboard the JOIDES Resolution!

Stepping aboard this 471-foot ocean drill ship, which flies a Cyprus flag, are 30 scientists hailing from countries such as France, Japan, U.S, Germany, Russia, Australia, Austria, China, and Canada. Separate companies represent the other groups: 20 technicians, 15 catering staff, and the vessel crew. Amazingly, the 17 women on board are only among the scientists and technicians. The international collaboration keeps the boat and drill operations functioning, people comfortable and fed, and science successful.

Loading items for our two-month adventure took five days. Garbage and long tubes of core from the previous cruise had to be removed, multiple gas bottles exchanged, while four miles of drill pipe had to be stored on board along with long wooden boxes of a couple of miles of plastic liners that collect the core.



Moving drill pipe to load onto the ship.

It took a day and half to fill the gas tank, with a capacity of a million gallons. Though our transits are pretty short in comparison to other trips, this ship uses roughly 40 gallons to go one mile.

Photo by Amy West

Meals are an important component for a harmonious existence. Here's a peek into the $120,000 food bill that feeds our ship-bound group:

Photo By Amy West

2,200 pounds of potatoes

25 boxes of apples

660 pounds of carrots

2,640 pounds of flour

half ton of steak

400 pounds of farmed salmon

1,320 pounds of whole chicken

Some of the women scientists and technicians on board for our expedition. Photo by Mark Reagan/IODP

All the food is shipped from the U.S. and ordered nine weeks in advance, though it can take a month and a half to arrive. Fresh produce comes from the country where the boat docks, where some items can be cost-prohibitive. For instance, grapes cost about U.S. $40/pound.

While freshwater must be used conservatively on most boats, the ship's ability to convert saltwater into freshwater means water usage is essentially unlimited. That's ideal, since the ship uses about 10,000 gallons every day, which is equivalent to each person consuming nearly 4 gallons each hour. Cleaning our clothes takes about a hundred pounds of laundry soap every week.

The bane for most is the ship's Internet connection. Though it costs about $1,000/day, it's virtually back to the days of a dial-up modem, where everyone shares a 512 KB connection. "Googling it" is not really an option; it's likely quicker to ask someone on the ship for the answer. Aside from researching facts, dowloading papers, or communicating with work back on land, we now keep in touch with friends and family through websites like Facebook. As a bandwidth hog, social media takes on a truer meaning of time suck, so Internet usage is limited, especially during shift changes. Shedding cyberspace distractions may be welcomed, but nevertheless challenging when we're habituated to instantaneous knowledge and downloads.

Sedimentologists Alastair Robertson and Steffen Kutterolf taste the sediment from deep ocean cores to determine its graininess. Photo by Amy West

More notable, though, is the collaborative melding of the scientists on board, who are mostly meeting for the first time. Normally, researchers are focused on their own projects. On this expedition, scientists may have their own research interests, but it's more of a team effort to work together to collect and process samples communally.

Rather than collecting samples for each person, everyone shares what is collected, and the diverse expertise helps piece together the actual story of the cores. When you have nowhere to go, few distractions, and work as your only purpose, it makes for a very productive and intellectually stimulating setting.

Though some scientists wear different hats here at sea, petrologists, geochemists, structural geologists, paleontologists, and paleomagnetists are some of their titles. It's primarily a hard rock cruise, but a few sedimentologists are also present to comb through the first section of the seafloor for layers of ash from land-based volcanoes, which can inform us about the planet's eruptive history.

The excitement of this group is palpable, especially when anticipating the first core of deep-ocean sea floor to arrive on deck from 10,000 feet below. It's a time when theories will be put to the test as to how the sub seafloor is actually layered. It's a small, international group drawn together by deep-sea discovery, and united by rock, right down to the last grain of boninite.

Boninite, named after the Bonin Islands nearby, is a rock that can form in the early stages of subduction. Unlike most rocks boninite is high in magnesium and silica. Photo by Amy West

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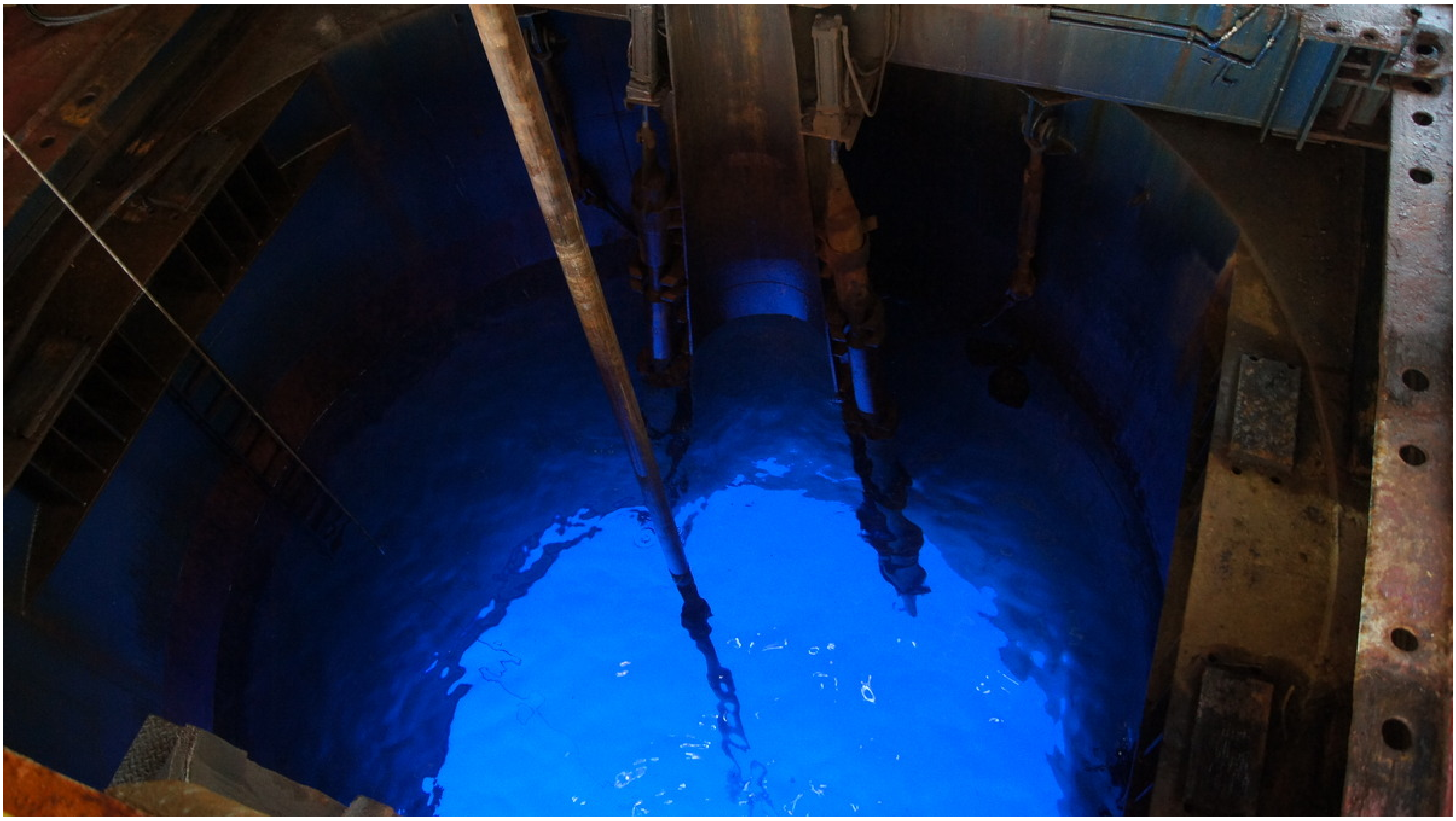
Archived: Breaking Down Rocks in the Deep Ocean

EVENTS

When I witness adults cooing over Eocene-era rocks, or tasting 15 million-year-old ocean sediments, I instantly wonder what their childhood was like. Were they kids that didn't want to leave the sandbox after recess? Were they shy and looked at the ground more than they looked at the sky? Why curiosity for inanimate objects over,...



August 28, 2014

When I witness adults cooing over Eocene-era rocks, or tasting 15 million-year-old ocean sediments, I instantly wonder what their childhood was like. Were they kids that didn't want to leave the sandbox after recess? Were they shy and looked at the ground more than they looked at the sky? Why curiosity for inanimate objects over, say, plants or something with eyes and a heart?

A sample "party" gathers to determine what parts of the rock will be sampled. Photo by Amy West

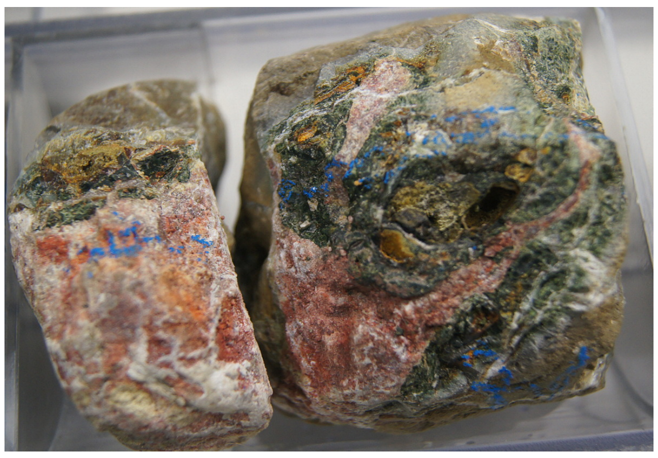
How the earth is layered beneath the seafloor infiltrates daily activities on board; it can lead to rewritten lyrics for Ring of Fire to fit our current exploration in the actual Ring of Fire. At dinner, the slice of carrot cake, with different dots of color

resemble "ophiolites" (rare rocks formed around the start of subduction) to co-chief scientist Julian Pearce. As he cuts into the slice of chocolate cake and its graham cracker crust, it reminds Pearce of our difficult attempt that day of coring past soft, mushy sediment and into hardened sediment and altered rock. As Pearce and sedimentologist Alastair Robertson reminisce when they first met each other more than four decades ago, they can recall what geological feature they were standing on at the time. They see the details of our world through a hand lens.

Handing over the first part of the core, " the core catcher", which keeps the rest of the core inside the long core barrel as it's pulled to the ship. Photo by Amy West

Which can be pretty neat when you get into the nitty gritty of what transpires to create our continents. Conversing with these rock and sediment lovers is like entering a rabbit hole though. Once you start down the path of igneous rocks (formed from lava), it divides into several kinds of igneous rocks, such as basalt or andesite. Yet, those two lavas can be composed differently depending on where they form in tectonic settings (e.g. a subduction zone or mid-ocean ridge). Within those settings lavas can cool faster than others enabling them to form different-sized crystals, or form glass. Those crystals (minerals) will have different names like olivine or feldspar depending on their elemental makeup. Stripping a rock down to its bare elements, like titanium or chromium, helps to resolve a rock's origin, or what melted in the first place to create it. However, if any fluids came into contact with it, that rock may now be "altered", which takes you down a winding path of secondary minerals such as calcite or zeolite.

Zeolite?



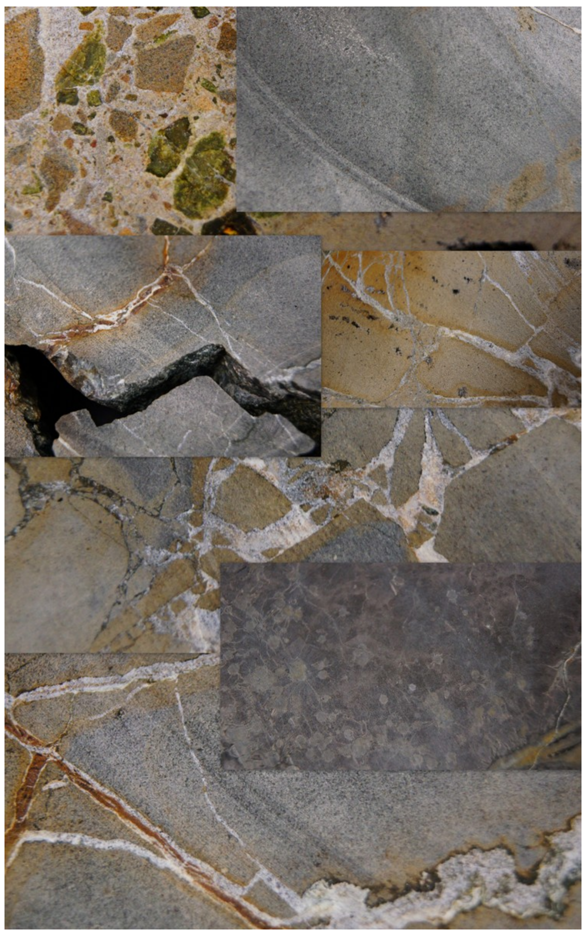
Rock core that has been altered by fluids. Photo by Amy West

A rock showing where fluids sat in the rock for a long time. Photo by Amy West

We'll stop at that intersection in the rabbit hole, but it's important to note that zeolites and other alteration minerals actually trap water when they form, and turn into a different mineral if they lose the water. So ultimately what this expedition really boils down to is tracing that trapped water. Water changes *everything*. It's what makes volcanoes near subduction zones so explosive, it alters a rock's chemistry, and provides a challenge to studying the ins and outs of subduction.

In a nutshell: when new seafloor forms from volcanic activity, minerals and fluids remain in the rocks until that seafloor eventually sinks into a trench millions of years later. As the sinking slab of rock gets warmer and softer, minerals and fluids escape and head straight up, hitting the overlying rock layers. That rush of fluids actually lowers the temperature at which the earth's dry interior melts, thus helping to create some of the lava that will eventually bubble up to form new ocean crust in the "forearc"—where we are now. Taking cores of these deep rocks in the forearc can tell us how much water came from the subducting plate, thus taking us further, quite literally, down the rabbit/borehole.

NATIONAL GEOGRAPHIC



Different faces of many rocks collected near the edge of the Bonin Trench at depths from 200-1200 ft below the seafloor. Photo by Amy West

One science meeting here can turn into pages of new vocabulary— a crash course in petrology, geophysics, geochemistry and sedimentology.

The overall picture is that this team of scientists can first look at a lava and tell how it cooled and what it eventually became. From there, they focus more narrowly on the rock's details (e.g. type and shape of minerals) to explain how the rock began its life. Unravelling the ocean story is more complicated than land-based geology, simply because of the extremely challenging process to acquire these rocks (a future post).

But to form any theory about subduction, several experts must work together to organize the few pieces they have of a 1000-piece puzzle.

Structural and alteration geologists can look at tiny cracks or veins in the rock to explain what stresses and alterations the rocks have faced.

Petrologists group the rock according to its size, shape and abundance of minerals, looking for clear delineations between different rock types.

Geochemists can "digest" rock and get the chemical composition by measuring the abundance of elements in a rock.

Paleomagnetists can determine the direction of the Earth's magnetic field when the rocks formed to help assign ages to the rocks.

Physical property specialists can highlight a rock's physical traits like density or naturally occurring radiation and how each changes with depth.

Barely visible fracture lines highlighted below the crack in this sediment core can tell structural geologists the direction of stresses. Photo by Amy West

In the end, childhood fascinations with the ground beneath us drove many scientists, such as co-chief scientist Mark Reagan into the careers they have today. If it weren't for, perhaps, that hand lens and rock hammer he had as a kid, he might not have cracked open a world harboring endless geological mysteries. It reminds us to always stay curious.

Co-chief scientist Mark Reagan pointing out interesting features to petrologist, Tim Chapman. Photo by Amy West

Follow Amy and the JOIDES Resolution on Twitter. Past blogs about this expedition are here.

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Archived: Time Warps With Seagoing Discoveries

It is sadly possible to be in the middle of the ocean with no land in sight and not see the ocean, or know when day turns to night. With 24-hour operations aboard the JOIDES Resolution, and most of us splitting each day by working a 12-12 shift, the natural cutoff to a day is...

September 4, 2014

The vast seascape off the Bonin Trench. Photo by Amy West

It is sadly possible to be in the middle of the ocean with no land in sight and not see the ocean, or know when day turns to night. With 24-hour operations aboard the *JOIDES Resolution*, and most of us splitting each day by working a 12-12 shift, the natural cutoff to a day is missing. The gym doesn't have windows, most cabins don't have windows, and some stations in the lab are without natural light. It sounds silly, but one almost needs an alarm or a friend to signal a trip out of the air-conditioning into the hot, sticky air to witness glorious sunsets and sunrises. The ritual Sunday boat drill at least tells us we have come to the end of the week. As much time as drilling into the ocean floor requires, I am still amazed what I can miss if I don't monitor the camera feed. Time slips away so quickly, but somehow twists back on itself to make it simultaneously feel we have all the time in the world. This intense focus and lack of distractions must somehow wobble time.

First, some perspective on drilling operations at the edge of the Izu-Bonin-Mariana Trench: Picture the tallest building in the U.S.: the One World Trade Center in New York, reaching just under a third of a mile. Stack eight more of them on top of each other and chop off, say, 300 feet –the height of the Statue of Liberty. Once you reach the top, which is equivalent to climbing a little over halfway up Mt. Everest, you will be aiming for one of those safety nets back on the ground that firemen use, and ultimately the small manhole centered beneath the net. To make it harder, let's fill up that entire space – from the ground to the tiptop of those stacked buildings – with water. Jump onto a boat and tell the captain to stay right above the net that you can no longer see. *Note: there will be strong currents, swells, and wind knocking you around in New York's new ocean.

Drill Timelapse

Start connecting 100 feet of pipe together (we'll use PVC pipe the diameter of a small plate for this exercise), and slowly lower it into the water. Do that process 150 more times. Right before you connect that last 50 feet of pipe, though, connect a fiber optic cable to a GoPro that can miraculously withstand nearly 7000 pounds of crushing pressure all around it. Slide the camera down the outside of the pipe almost to its end. The camera feed comes through a monitor so your boat driver can carefully nudge the boat to where the firemen's net is – hoping to spot the darned thing. You are watching the same scenario on another monitor at the opposite end of the boat, and in charge of lowering that last 50 feet of pipe once the net comes into view. When it does, you must push that wobbly mess of pipe straight into the open hole that is below the middle of the net.

FlexingSteel

Congratulations! This represents a successful reentry into the hole we had *already* drilled on the bottom of the seafloor.

That is just one operation on the *JOIDES Resolution*, which takes about half a day. Placing the net (i.e. reentry cone) and opening the manhole (i.e. borehole) in the first place, can take a week. In our case, we tried to save five days by lowering the reentry cone and casing (pipe to reinforce the top of the hole) and drilled it in all at once. It worked!

Here's a timeline when drilling in water depths of at least 15,000 ft:

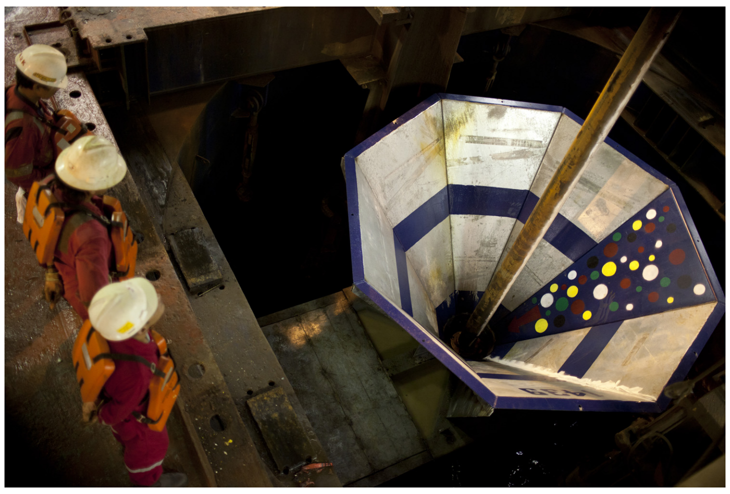
Sending the camera down and back- three hours

Navigating pipe back into the hole- five minutes to an hour

Changing drill bit every 40 hours of drilling (must bring 15,000 ft of pipe to the surface, then send it back down)- 20 hours

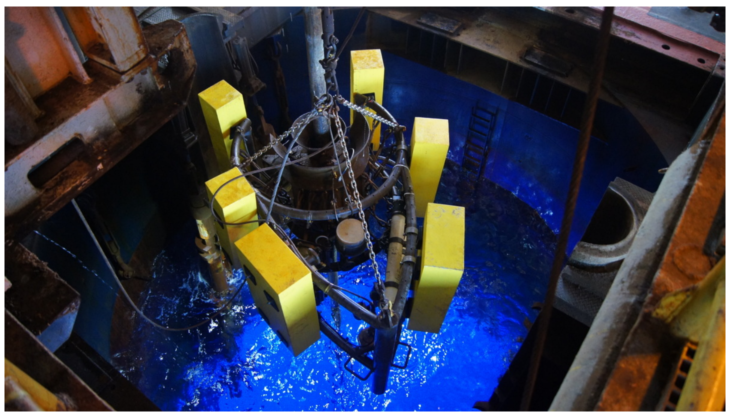
Sending instrument to retrieve the cored rocks- an hour

Cleaning out the hole- three hours to a full day



Preparing to lower the reentry cone (the "firemen's net"). Photo by Mark Reagan

Of course, those timeframes represent operations running smoothly, which they rarely do. Invariably equipment fails, weather rears up, or something like a medical evacuation can stop operations. Our color camera fiber optic cable recently failed, but the crew's ingenuity meant that although we have a less than spectacular black and white image, the expedition could proceed and we now save several hours deploying the camera.

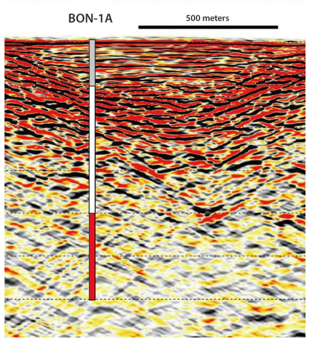


Lowering the camera through the ship's moonpool. Photo by Amy West

Cores of sediment can come up every 45 minutes. But hard rock can take three to four hours. Once on board, rocks have to be arranged, imaged, measured, and then cut. A day later the scientists gather together to decide what should be sampled for certain tests, and three to four days later, the chemistry results tell us something about the origin of the rocks.

The first step that truly counts with time, though, is the seismic imagery on which we base our drilling decisions. Interpreting the data can be subjective (I heard one scientist liken it to a "witchy, voodoo process"). Data can be inaccurate, particularly when surveying in complex environments that show topography on or beneath the seafloor. The measurements that help create these images come from knowing the density of particular rocks, and how fast sound travels once bounced off them.

After a sample "party", scientists vie for parts of a rock to do certain analyses. Photo by Amy West



Example of a seismic image used to "read" what's beneath the

If drilling into new rocks the images are harder to interpret. Furthermore, what may appear as dark layers of hard rock could have sediment in between or actually be cement-like sediment. While drilling requires sediment to "spud in" or begin drilling, this group wants an expeditious route to the rocks. If our interpretation is wrong, we lose a lot of time (though keep the sedimentologists happy). With this operation costing $120,000 a day, we can't afford to miss our mark. Thanks to our seismic wizards, we've been spot on.

Scientific ocean drilling requires numerous steps, repeatedly connecting and disconnecting the same gear, and a complex choreography of teamwork. I suppose time passes normally, but it's that we've been too busy to track it. What's been collected thus far (a future post) has delighted the science team, so perhaps time won't feel regular again until they return home to the arduous task of analyzing the samples and writing up the results. Then they'll probably wish they were back at sea waiting for new rocks to arrive.

seafloor. Courtesy of IODP/TAMU

NATIONAL GEOGRAPHIC

The very end and most important part of the drill pipe: the drill bit. Photo by Amy West

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Archived: Pulling Secrets from Deep-sea, Drillbit-Eating Rocks

When trying to keep up with conversations that throw around words like 'hyaloclastites', 'orthopyroxenes', or 'slickensides' it feels as if I've tripped and tumbled into a language course without a study guide. Though definitions may be at my fingertips, tracking them down can quickly turn into a 'Deeper Definition Dilemma'. I call it my 3D...

EVENTS

September 17, 2014

Beautiful flat deep-blue waters near the Bonin Trench. Photo by Amy West

When trying to keep up with conversations that throw around words like 'hyaloclastites', 'orthopyroxenes', or 'slickensides' it feels as if I've tripped and tumbled into a language course without a study guide. Though definitions may be at my fingertips, tracking them down can quickly turn into a 'Deeper Definition Dilemma'. I call it my 3D world.

To elucidate: my outreach partner described her track when delving into the meaning of boninite– a significant rock we have collected hundreds of feet beneath the seafloor. Its definition is an *andesite high in magnesium*. Andesite is thus defined as *an extrusive in between a basalt and rhyolite*. My previous blog described basalt, yet rhyolite is the *volcanic equivalent of granite*. Granite's definition says it's *felsic intrusive of igneous rock*.

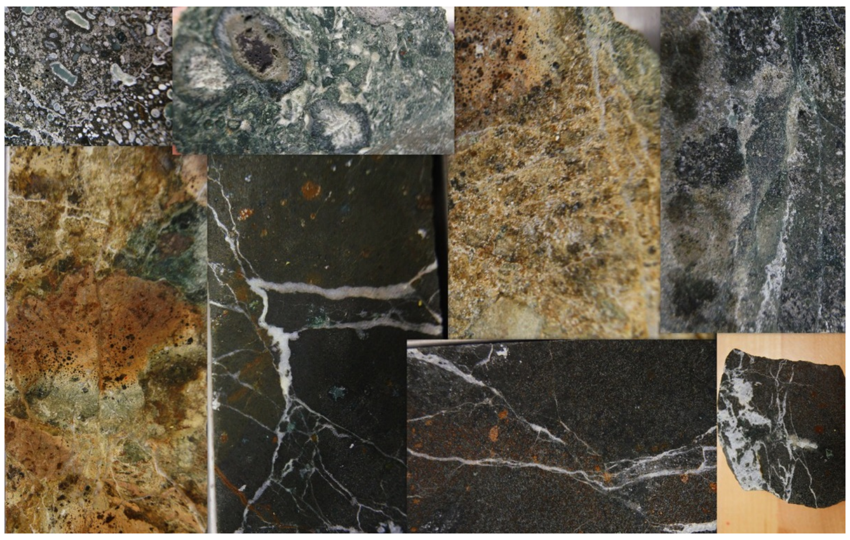
Deep-sea rocks that form from the first stages of subduction. Subduction makes the world go 'round. Photo by Amy West

When I introduced this expedition, I explained how rocks make this world go round. So, here we go:

Most rock names come from the regions where they were first discovered: gabbros in Gabbro, Italy; harzburgite from the Harz mountains in Germany; and andesite from the Andes. Boninite is no different; it's named after the Bonin Islands just a few miles southwest of us. When George Bush returned to those islands 50 years after being shot down over Chichi-jima in WWII, he likely had no idea he walked on some very special rocks.

Boninite is a rare rock that appears to signal the beginning stages of subduction in an arc island region. So when boninites show up on land, as they do in mountain belts like the Appalachians and Himalayas, it's a clue that two tectonic plates probably collided there at some point in history.

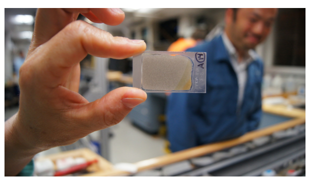
Where boninites form nowadays is known in only one region- underwater exploding volcanoes a kilometer deep near Tonga. A submersible captured footage back in 2009 of this spectacular show spewing bits of boninite. Our team of scientists surmised this modern day spectacle is similar to what happened 50 million years ago where we're drilling now.



The various faces of boninite. Photos by Amy West

Scientists believe boninites take a special set of circumstances to form the rock. The recipe calls for water and extremely hot mantle that has previously melted, and essentially melts again at shallower depths at temperatures around 1300-1400°C (~2370-2550°F). Though counterintuitive, this happens because water trapped on the sinking ocean plate infuses into hot mantle rocks on the overriding plate, thus lowering the mantle's melting point, much like adding salt water to ice to lower the ice's melting temperature.

Why does this magma from the melted mantle rise up? It fills a "gap" that occurs at the junction between two oceanic plates when they collide and one bends down. This twice-melted mantle already robbed of many elements, bubbles up into the space. Its distinctive chemical signature is reflected in boninitic rock—rich in silica and magnesium and low in titanium unlike other ocean rocks. Water transforms the mineral makeup in the magma by breaking chemical bonds. Boninites don't appear where new seafloor originates because water is not in the recipe there- it's just melted mantle.



This thin section of rock allows geoscientists to look at the shapes of individual minerals. Photo by Amy West

Finding boninites here in the forearc helps confirm that very hot parts of the mantle were indeed shallow. Though this expedition would like to know why one plate subducted in the first place, this research may offer stronger evidence that supports certain theories- (e.g. the plate sank due to its length and density, or the entire Western Pacific subducted all at once). What the expedition can determine, however, is what happens after the tectonic area fails.

I can't introduce boninites without spotlighting the layers of rocks lying beneath them. This 'family' of rocks also tells historic tales of subduction, and this team wants to drill a complete column of them in the ocean, though these rocks can be seen on land in several places where they are uplifted when continental plates collide (scientists like to toss around the term, "tectonically transported".) On land, this chunk of ocean floor, known as an ophiolite*, has shifted, twisted, and weathered away over time. If we can pinpoint how these rock layers occur on the seafloor, it can help scientists understand what happened historically on land. Ophiolites occur worldwide, for instance in Oman, Cyprus, California, Chile, and provide a great source of the metals we use in fabrication, such as copper, zinc, gold, and chromium.

Students walking on parts of an ophiolite- glass overlaid by pillow lavas, cut by vertical dikes- in the

The debate stems from how ophiolites form and what they represent. Common wisdom was that ophiolites represent all ocean floor, explains Eric Ferré, a structural geologist on this expedition. He argues that drilling into ophiolites on land doesn't provide a fundamental understanding of the oceanic activities that placed them there.

“If you want to understand how the ocean exchanges heat with the earth, you have to understand the ocean floor.” says Ferré.

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Photo by Julian Pearce

Geochemist Maria Kirchenbaur points out features of the boninites to co-chief scientist, Mark Reagan, and petrologist Tim Chapman. Photo by Amy West

Expedition 352 could show that ophiolites are not representative of all ocean floor ever formed; they may just be confined to the beginning stages of subduction. The world’s leading experts on ophiolites and boninites are on board this ship, and from the holes we’ve drilled thus far, they are still not entirely sure whether the rock layers lie in layers on top of each other as suspected, or lay like a tilted stack of books along the seafloor. To baffle researchers further, many ophiolites have been found with boninites, indicating a particular subduction process happened many times throughout the world.

Confirming this sequence of rocks may advance our knowledge on how subduction leads to continental crust. But drilling through an entire column of deep seafloor rocks is easier said than done. We are on our 4th site now, though only had two planned. We’ve brought up unexpected rocks, which can lead to more theories. Some of the rocks at the bottom have nearly trapped us, broken our bit, or refused to provide us any samples.

It may be they are not ready to divulge their secrets just yet.

You can follow our expedition on Twitter

* Ophiolites sequence that scientists generally agree on: volcanic rocks formed underwater. Then **dikes**, which are the pipes that feed the magma. Then **gabbros**, which are the frozen remains of a magma chamber, and below that is the top bit of mantle called **peridodites**.

A ‘healthy’ drill bit: the rotary cone barrel (RCB) used for drilling into hard rock . Photo by Amy West

The bottom of the damaged drill bit that is missing all of its drill cones. Photo by Amy West

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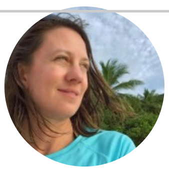

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Archived: As Expedition Ends, Scientists Feel The Pressure

EVENTS

The wind whipping around from Tropical Storm Fung-Wong makes it challenging to write outdoors. I know–what kind of complaint is that? But after severely reduced physical activity for eight weeks on this ship, sitting in front of a computer sends the sit bones into spasms. Plus the wind puts the constantly whirring thrusters into...

September 26, 2014

Drilling through fault rock results in many fractured pieces. Photo by Amy West

The wind whipping around from Tropical Storm Fung-Wong makes it challenging to write outdoors. I know–what kind of complaint is that? But after severely reduced physical activity for eight weeks on this ship, sitting in front of a computer sends the sit bones into spasms. Plus the wind puts the constantly whirring thrusters into overdrive, which keep us on station. That would be fine and all, but I share a cabin with a buzzing bow thruster, so it's "Sleepless at Sea" for me.

Sunset watch. Photo by Amy West

Sunset watch now seems to be busier on "steel beach" (top deck with great views and deck chairs), and finding a place to get away from it all can be harder near the end of an expedition. I'm writing in the wind because a chief scientist nabbed my comfortable writing spot. The shift in energy gears for everyone is most noticeable—people are more edgy. A whiteboard listed names of those on the nightshift who began cracking. It's challenging to sustain the energy levels exuded at the beginning, since writing reports, analyses, and daily seminars eventually looks like a conveyor belt of never-ending goods. Turns out we all need variety in our day-to-day living; even scientists who love the idea of doing JUST research.

The galley crew goes all out for a sushi night– a great morale booster toward the end of the cruise. Photo by Amy West

The one constant during these two months is the drilling operations; it never sleeps, and sometimes, it seems, neither do the crew. The complexity of the operations seems like IODP [International Ocean Discovery Program] would rarely encounter success, but with the troubleshooting expertise and finely tuned fashion of collecting data, the program has garnered phenomenal success. Research from IODP and its previous namesakes provided evidence for plate tectonics, ocean temperatures during the Ice Age, microbes that live in the seafloor, and a major meteor that rammed Earth 65 million years ago. These missions can be a lot of "bang for the buck." Not only does one research cruise provide physical specimens for ANY geoscientist to sample a year after the cruise ends and decades beyond, but it also can spawn many scientific papers, since it requires a herd of scientists to tell this story.

During the cruise, each science faction will present preliminary data about the site we are currently drilling, and then do it again when we leave that hole. Facts, thus, arrive in pieces, much like the fractured rocks we bring up. There's hardly time to step back, connect the pieces across scientific fields, and discuss the bigger picture because of the continuous flow of rocks that need classification, or mashed into powder for chemical analyses, or heated to 600° C to demagnetize. Each group submits reports each week, each month, and for each site. A

year following the cruise only scientists involved in this mission can analyze the material. If they publish anything, ALL the scientists must be listed as author. After a year the moratorium is lifted, and the rest of the rock science world has access to the samples. The original group then meets one to two years later to discuss their findings. And this time they won't be on a boat.

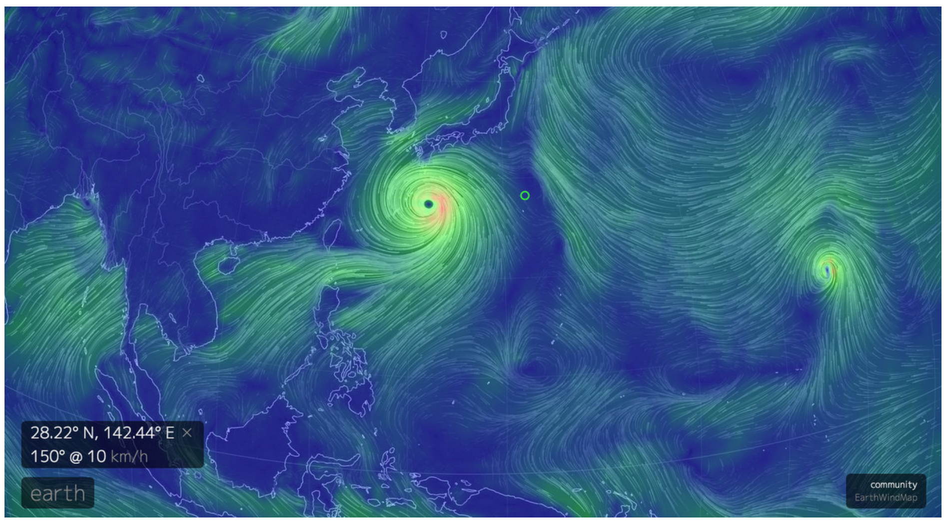
Rock samples from one site for each scientist to take back to labs. Photo by Amy West

Bosun Leo Yaun stores the core barrels back on board once we finished drilling. Photo by Amy West

Though two months feels like oodles of time, in the end it feels like we need more time and data to formulate the cohesive picture of what the rocks say about the origins of subduction; after all we drilled just four sites that averaged 20 percent in rock recovery. Combining results from all three 2014 cruises to the Izu-Bonin-Mariana region will take years. In some cases, an expedition can bring up samples that debunk a geoscientist's entire life's work. Each scientist on board will probe in more detail back on land in labs that aren't bobbing up and down and have more instruments. The staff scientist for this cruise, Katerina Petronotis, and chief scientists Julian Pearce and Mark Reagan, who are the stewards of the entire expedition and ensure each person follows through on their obligations, has an official role on this mission until 2018.

Our group decided to pile on one more writing assignment: submit a scientific paper to a high-level journal within the next two months. Since the National Science Foundation funds this research, preliminary results are released to the public two months after the mission ends. However, if a paper is accepted within this two-month moratorium (which has happened only a few times prior), that public release will be put on hold.

Getting to make such a discovery comes back to having so many things go right. Weather is one of them. We had unbelievably calm weather despite sailing in the heart of typhoon season, whereas Expedition 351 ceased operations to move for weather. Anything beyond 14- to 15-foot heave on the drill string can compromise drilling as it's hard to keep the bit on the bottom. We were also lucky to escape using explosives to free ourselves from fault material that had buried us; 190,000 pounds of pulling force did the trick so we could retrieve thousands of feet of drill pipe.



When first beginning this expedition, we (green dot) were safely tucked in between two typhoons. Wind image generated on earth.nullschool.net. Data from GFS / NCEP / US National Weather Service

Ironically, Tropical Storm Kammuri inches toward the site we just left. As we now head for port in Taiwan, the mood has changed again. Images of beer appear on the walls and in presentations. There's conversation about walking more than 30 meters without having to climb stairs. No matter how tired we are at the end of the day, or the trip, the opportunity to be on board this drill ship as a scientist, technician or educator is remarkable. The data collected on this trip about subduction zone origins will likely generate new models, and show that our planet is more complicated than previously thought. We'll have to remember this when returning to the stresses of our normal lives.

Grass is always greener, even when sailing on the blue, blue ocean.

You can follow the expedition prior to this here.

Some rocks from beneath the seafloor had amazing greens and patterns and cracks, and were also under a lot of pressure. Photo by Amy West

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