THE ENDLESS VOYAGE

"The Ocean's Memory" Episode 106

It's important that we understand the past history of the ocean, a past history of climate, because we're in a period of climate change. We want to understand whether that's happened before. And sediments are really the diary of the Earth.

I really like that notion about the sediments being a historical record of what has happened on the globe. And it is a unique kind of thing. And that's one of the things, one of the rationales behind keeping collections like this going. Because we basically have a library of sediments here.

Marine sediments are enormously important economically. There are certain kinds of deposits that have been found in ocean sediments that are useful today. Sand and gravel, for example, has been mined. Diamonds have been mined from marine deposits and that's relatively unimportant. What's most important is that two of our major energy resources are generated from marine sediments and usually are trapped in marine sediments. And that's oil and natural gas.

NARRATOR:
THESE TUBE-LIKE VESSELS CONTAIN CORES, SEDIMENT SAMPLES BROUGHT UP FROM THE FLOOR OF THE OCEAN. MARINE SEDIMENT BLANKETS THE SEAFLOOR, CONTAINING WITHIN IT LONG HELD SECRETS THAT CAN LIE BURIED FOR MILLIONS OF YEARS—SECRETS ABOUT EARTH'S ANCIENT CLIMATE, OCEAN CHEMISTRY AND CIRCULATION. EVEN EARTH'S SHIFTING MAGNETIC POLARITY LEAVES ITS SIGNATURE DEEP WITH THE SEDIMENT OF THE SEAFLOOR. AND SO, IN A VERY REAL SENSE, SEDIMENT IS INDEED THE OCEAN'S MEMORY.

DONN GORSLINE, Ph.D., University of Southern California:
Sediment is the debris that accumulates on the surface of the Earth as the result of chemical, physical, biological processes that work on materials. And when they're exposed to the Earth's atmosphere, water, biological factors, they break down. The rocks disintegrate, if you want to put it in those terms, producing particular matter and material that goes into solution. And it's the particulate matter—the debris that forms as a result of those processes—that we call sediment.

ROSS HEATH, Ph.D., University of Washington:
Most of the sediments come from land. They're what we call terrigenous sediments. They form when rain falls on soil, washes it into the rivers, and the rivers go into the ocean and they carry the sediment with them.

JAY YETT, Ph.D., Orange Coast College:
If you're looking at terrigenous sediments, you're usually looking at materials that have been eroded from the mountains and deposited along the coastlines, for example.

In addition, there are some volcanoes. We've seen some evidence of that around here. And that certainly adds sediment to the system. If you're done a lot of coastlines, you see that the cliffs are eroding. That material falls into the ocean. It becomes sediments also. So, all these different processes form near shore terrigenous sediments, which are the dominant type. But there are some other processes that can carry sediments from the land into the deep ocean as well. One that you would certainly notice if you lived in the Sahara Desert or in China is the wind. Huge dust storms form over areas that are very arid, like deserts, and those sediments are carried out into the ocean where they settle and, again, arrive at the seafloor. Finally, one that I think most people don't think much about is ice. As glaciers move across the landscape, they erode huge chunks of geology from the bottom—rocks, clays, sands, whatever you want to find there—and then, as they break off and form icebergs in the ocean, they drift out to sea, they carry this material with them, and when they melt, they drop into the seafloor. So you can actually find huge boulders hundreds and hundreds of miles from land that have been carried by ice. So, all those are processes that form what we call terrigenous sediments.

NARRATOR:
WHILE TERRIGENOUS SEDIMENTS ARE THE MOST ABUNDANT, THEY ARE NOT THE ONLY SEDIMENTS FOUND IN THE MARINE ENVIRONMENT.

If you're looking at more marine types of sediments that you would find in the deep oceans, or at least, the deeper oceans, then there are sediments produced by organisms, biogenous sediments.

A number of different species of organisms form skeletons or shells. These are mostly made out of calcium carbonate, limestone, which we're all familiar with, I think. When these animals die or they're eaten, the shells or skeletons fall to the seafloor. And they form distinctive sediments called biogenic deposits.

There are sediments that are produced by just chemical reactions within the ocean working on sediments. Some manganese deposits, manganese nodules and those sorts of things—hydrogenous sediments. And then, of course, there is this little input, but it can be sometimes significant input, from outer space, cosmogenous sediments.

HEATH:
Tiny micrometeorites that occur in areas where other kinds of sediments are very rare, you can actually separate them out of the sediments. They, of course, are falling all over the Earth, but in most places we can't see them because they're completely masked by the other sediments. But in a few places in the ocean, they're relatively easy to find.

NARRATOR:
WHILE SEDIMENTS OF ALL VARIETIES CAN BE FOUND ALMOST ANYWHERE IN THE MARINE ENVIRONMENT, THERE ARE SOME VERY DISTINCT DISTRIBUTION PATTERNS.

HEATH:
A good example would be to go off the Mississippi and the Gulf of Mexico. There you have virtually pure terrigenous sediments. The Mississippi is pouring out so much stuff that everything else is completely masked, you never see it. On the other hand, if you to the equatorial Pacific, you're a long way away from any terrigenous sources. There are no rivers there. There are no winds blowing off deserts. And so what you find there is almost pure biogenic sediments. Likewise, if you go to the middle of the South Pacific, you can find chemical sediments, because there's not much biology there.

NARRATOR:
REGARDLESS OF WHERE A GIVEN SEDIMENT ORIGINATES, SEDIMENT IS A UNIQUELY VALUABLE COMMODITY WITHIN THE MARINE ENVIRONMENT.

YETT:
When you look at energy resources, the vast majority of oil and natural gas deposits were formed from marine sediments and trapped in marine sediments. Organic material that's been buried within that sediment is then broken down as the sediment is buried deeper and deeper. As that sediment gets deeper, it heats up, the organic molecules are broken down into smaller and smaller molecules and, at some point, that material becomes oil. And that oil then accumulates and can migrate out of the original rock. It can accumulate in another kind of sediment or rock. If that organic material continues to heat up…that oil is broken down into natural gas. And then the natural gas can be trapped.

The oil and gas, which is almost all obtained from sediments, is worth billions and billions of dollars. Coal is associated with sediments—it's another very valuable commodity. And one that most people don't think about is construction material. As environmental concerns eliminate the possibility of making quarries on land, more and more gravel and sand are obtained from the ocean and used in construction. In addition, there are some exotic sediments that are also very valuable. Diamonds, I think most people would be very interested to find there are substantial offshore diamond deposits off Africa. There are things like tin and titanium, which are also found in sediments in the ocean, particularly. And also things like phosphate fertilizer comes from sediments.

Probably the most famous potential deep sea deposit are the manganese nodules. And the manganese nodules are precipitates. They're hydrogenous sediment. They're precipitated from the ocean water very slowly, and the manganese nodules are manganese dioxide that contain large amounts of copper, nickel, cobalt, a number of industrial, useful minerals. There has been continued interest in the manganese deposits. At the present time, they are not economically significant because the cost of retrieval and the cost of producing the metal exceeds that of current terrestrial deposits. But in the future, those are a potential major source of those important minerals.

NARRATOR:
THE PROCESS OF EXTRACTING ECONOMICALLY VALUABLE RESOURCES FROM MARINE SEDIMENTS IS AN ONGOING CHALLENGE.

JAY YETT, Ph.D., Orange Coast College:
Most oil and gas is extracted using technology that developed back in the 20s and 30s and even earlier, which is just drilling into the rocks—in this case, the marine rocks—and having that oil and gas migrate from the sediment—the sedimentary rock—into the well and then pumping it out. What's been found over the years is that that extracts a good part of the oil, but not a high percentage, I suppose. And the estimates are in an oil field, after the pumping is done under normal techniques, that you may still have 40, 50, 60% of the oil still in the field. And the reason for it is the oil has stuck to the grains, basically, of the sand in which you'd find that oil. So the idea has been, is there any other way that you can extract that remaining 50 or 60%? And techniques that have been used are to use injection wells nearby, inject either hot water, hot steam or chemicals into those reservoirs that will force or clean off that oil and force it into the producing well. And that's been very successful.

NARRATOR:
AS IMPORTANT AS MARINE SEDIMENTS HAVE PROVEN TO BE ECONOMICALLY, THEIR SCIENTIFIC VALUE MAY ULTIMATELY PROVE TO BE EVEN MORE CRITICAL.

HEATH:
Day by day, sediments get laid down, they carry a record of what kind of environment they formed in and so we can read that record.

DONN GORSLINE, Ph.D., University of Southern California:
Some of the elements that are present in sediments give us records, for example of ancient water temperatures, tells us something about the salinity of the ocean. It gives us some information about changes in the production of biological life with time. And that right now, I think, is the topic that's most interesting to most of us who work with sediments. I presume because that has the biggest impact on things that involve short-term climate changes and things of that nature.

ROSS HEATH, Ph.D., University of Washington:
The sedimentary record is our best indicator, I think, of what past climate has been. The evidence we get on land is very patchy. It's gappy, so we might miss warm events or cold events. Whereas in the ocean, there are quite a few places where we have a continuous record, in some cases, going back tens of millions of years. And what we find when we look at this is that there are major changes in the past—there are warm periods like today, there are cold periods, ice ages, that are related, by and large, to changes in the way that the Earth circulates around the sun. When we look back at these past, say, warm periods, we find that none of them are as warm as we are today. If we go back to the middle of the last century, fine. We were right where we ought to be for an inter-glacial or warm period. But in the last few decades, the temperature has moved into a set of values we've never seen before.

There apparently are critical combinations of climatic and oceanographic factors that trigger very rapid changes in the Earth's climate. And by rapid, perhaps changes that take place in a few decades. And that gives one pause, because you wonder if—as changes are created in our climate system as a result of mankind—one that's well known is the change in carbon dioxide content of the atmosphere as a result of industrialization, the burning of fossil fuels. And the worry I think of is, are we approaching one of those criticals, at which time, in the space of a couple decades there'll be major changes in the Earth's climate?

NARRATOR:
AS OCEANOGRAPHERS AND OTHER SCIENTISTS ATTEMPT TO PREDICT FUTURE CLIMATE BY RECONSTRUCTING THE PAST, THEY INCREASINGLY RELY ON SEDIMENTS TO PROVIDE CRITICAL INFORMATION.

One of the ways that paleoceanographers have approached this problem of trying to interpret past climate is to look at the organisms that have been found within the sediment.

WOLFGANG BERGER, Ph.D., Scripps Institution of Oceanography, UCSD:
As long as they're biogenous materials within the terrigenous records around the continents, which there always are, we can read the history of the ocean quite well.

All organisms are controlled in their distribution by environmental factors. So there are essentially no organisms that are cosmopolitan in a real sense that they exist everywhere. So, when you look at the sediments and the animals that are found within the sediments, if you have representatives still living today of the same kinds of animals, you can make some inferences about what those environmental conditions were in the past that would allow that organism to live in that particular area.

HEATH:
Certain kinds of microscopic plants and animals like warm water, other ones like cool water. And by counting the proportions of the different types, we can actually measure the temperature of the water to within a couple degrees Centigrade. There are also chemical ways of doing it. For example, a lot of the shells are made of calcium carbonate. They include a tiny amount of magnesium. The amount of magnesium depends directly on the temperature of the water that the shells formed in. So, just by measuring magnesium and calcium in the shells, we can get back a temperature.

The second is a little bit more sophisticated which is to use the isotopes—oxygen isotopes found in the shells of those organisms, particularly the calcium carbonate types. And the isotope ratios are related to water temperature, so that if you do an analysis of the shells, you can theoretically get a temperature of the water at the time that organism lived.

GORSLINE:
What it really represents is a response to the organism to a particular temperature, the ease with which it can build its calcium carbonate, so on and so forth.

And that's been used extensively to try to map past climates. And the interesting thing about looking at sediments is that you can have a very long record. It could be millions of years, so we can get an idea of what past climates might have been, give us a much longer time interval to look at climatic changes, which is important when you start to look at issues about global warming, et cetera. The longer record that you have, the better your interpretations will be.

NARRATOR:
THE INSIGHTS INTO PAST CLIMATE THAT SEDIMENT PROVIDES ARE OF EXTRAORDINARY IMPORTANCE. BUT WHAT MAY BE EQUALLY USEFUL IS THE INFORMATION SEDIMENT YIELDS ABOUT EARTH'S MAGNETIC FIELD.

LISA TAUXE, Ph.D., Scripps Institution of Oceanography, UCSD:
Sediments get magnetized by the fact that there are tiny magnetic particles in almost everything. There's this stuff called magnetite that is everywhere as a trace quantity. It's in dust. It's on your skin. It's everywhere in very small amounts. These tiny magnetic particles get attached to clay particles, or they tend to attach themselves electrostatically to clays or whatever, and they're in most marine sediments. So the marine sediments have trace amounts of these permanent magnets in them. And they act as compasses and just align themselves with the field. Not perfectly, but enough to retain a record of the Earth's magnetic field when they are deposited.

NARRATOR:
AS WITH CLIMATE CHANGES, THERE HAVE BEEN SOME UNEXPLAINED ABERRATIONS IN EARTH'S MAGNETIC FIELD DURING THE RECENT PAST.

The magnetic field over the last 2000 years has dropped by half, and it's dropping very, very rapidly. If it keeps dropping at this rate, it will be zero in 500 years. So, what happens if we have no magnetic field? I'm not saying that's going to happen. In fact, I don't think it's going to happen. But, it's an interesting thought experiment. What would happen to us if there were no magnetic field? What does the magnetic field do for us? It shields cosmic rays. One of the major dangers to space exploration is the bombardment of solar and cosmic rays. The magnetic field shields us to a large extent from those cosmic rays. What we use sediments for is to get us a record of the polarity history through time, tie that to the climatic record, for example, or the record of evolution.

NARRATOR:
WHILE MANY SEDIMENTS CAN PROVIDE A WINDOW TO THE PAST, THE VIEW THEY OFFER DOES NOT EXTEND BACK INDEFINITELY.

HEATH:
They can last as long as the seafloor. Eventually, of course, the seafloor is subducted underneath the continents and the record disappears. And that's one of the sad things. We get beautiful history in the ocean, but we only have it going back about 200 million years, whereas the history of the Earth is 4.5 billion years. So most of the record's gone. It's been washed under the continents and turned back into volcanoes.

NARRATOR:
DESPITE ITS TEMPORARY NATURE, SEDIMENT REMAINS UNIQUELY VALUABLE. AS A RESULT, OCEANOGRAPHERS HAVE WORKED HARD TO REFINE THE PROCESS OF OBTAINING AND ANALYZING SEDIMENT SAMPLES.

The very first sediments were collected by sounding weights that were used when people measured the depth of the ocean with a big lead weight on the end of a wire or rope.

BERGER:
Initially, when people first recovered sediment from the seafloor, they were restricted to retrieving sediment directly from the upper-most seafloor. And by dredging or by putting down basically some sort of a can or a pot and then just scraping the seafloor for a while and then bringing something up. Or putting a little bit of grease on a lid and then see what sticks from it. Then from this, they concluded what is down there.

Which wasn't much good for looking at history, but it would allow you to determine what the sediment was made of. Then they began to use pipes, essentially just pipes that had a heavy weight on one end, were dropped on the end of a wire and allowed to fall into the bottom and pulled back up.

GORSLINE:
And those so-called gravity corers—because gravity is the driving force—can collect—smaller gravity cores may collect only a meter of sediment. Larger, heavier instruments collect longer and longer cores. A typical large gravity corer these day, used on research vessels can probably recover a core that's from 5 to 10 meters long. Quite a significant record. To get longer records, we have to use larger ships, have to use heavier equipment, and we can use something called a piston corer. And the piston corer is a tube with a piston at the bottom of the tube, with a wire passing up the tube to a trigger and then from there to the ship. The biggest piston corers that are used in the deep ocean today can recover cores up to 40 meters in length, over 120, 150 feet long. From there we moved into really major scale equipment and we began to talk about drilling ships and the deep sea drilling program where we use oil well drilling techniques to drill holes that are hundreds of meters in length. Most of the good, long records of deep ocean history come from the deep sea drilling program.

NARRATOR:
WHEN THE DEEP SEA DRILLING PROJECT WAS INITIATED IN THE LATE 1960s, ITS GOAL WAS QUITE LIMITED.

JERRY BODE, Texas A&M University, Scripps Institution of Oceanography, UCSD:
The original program was simply an 18-month program to prove or disprove the idea of seafloor spreading and plate tectonics. Because we had never recovered deep ocean

sediments before other than what was the top 10, 20 meters. No one knew what the seafloor held in terms of information.

NARRATOR:
AS IT TURNED OUT, THE INFORMATION THAT WAS AVAILABLE WENT WELL BEYOND THE SCOPE OF THE INITIAL PROJECT. ONCE SEAFLOOR SPREADING WAS CONFIRMED, OCEANOGRAPHERS QUICKLY REALIZED THEY COULD DERIVE MORE BENEFIT FROM THE SEDIMENT OF THE DEEP OCEAN THAN HAD EVER BEEN IMAGINED. SOON, THE GOALS OF THE INVESTIGATION BEGAN TO EXPAND, WHICH MEANT THE CAPABILITIES OF THE DEEP SEA DRILLING PROJECT NEEDED TO DO THE SAME THING. AND EVENTUALLY, THAT PROJECT GAVE WAY TO SOMETHING EVEN MORE ADVANCED: THE OCEAN DRILLING PROGRAM.

BODE:
One of the problems that we had in the Deep Sea Drilling Project toward the end of it, is that the ship was too small—is that the science had progressed so much that we couldn't do much at sea. With the new ship, we had much more space and all of the scientific equipment—we enhanced it, we even put a scanning electron microscope on board, we had a cryogenic magnetometer, paleo-mag unit on it which allowed them to look at the magnetics tied up in—even the slightest magnetics tied up in the sediments. And it turned out to be quite good. But the big advantage was everything was together. We didn't have to move the cores.

WARREN SMITH, Scripps Institution of Oceanography, UCSD:
One of the intriguing things is that certain apparatus have not changed at all. You basically have a hollow tube, and you have to have some kind of a devise to keep the sediment in after it's collected as you bring it back up through the water column. Those are the little core catchers. And the technological approaches of analyzing the sediment have just absolutely expanded exponentially. That's where the technology has really driven us into the modern age, as opposed to the days when we first began. But we're actually still doing dredging and we're still doing the gravity coring basically like they were doing clear back in the 1800s in some of the original British expedition that went out on the H.M.S. Challenger. They were doing dredging and coring very similar, but the technical stuff that we've added to it basically falls into the electronic realm, because we now have sensors where we can do things in situ, right along as you drop the core in and you can actually measure temperatures. You can measure currents right while you're on the bottom with a sampling devise.

ROSS HEATH, Ph.D., University of Washington:
The field of paleoceanography was virtually created by the Deep Sea Drilling Project and its successors. During the early days of the drilling, the sediments were very stirred up and so the record wasn't very good, but it was way better than we'd ever had before, so the big picture began to emerge. Then, as the technology improved, they began to push a pipe ahead of the drill string, got really good samples that you could examine down to the millimeter scale, and suddenly you could look at ancient sediments in as much detail as

you can look at modern ones. The key developments were also helped by the fact that people began to understand what the fossils were telling us. They recognized that different kinds of animals and plants lived in different conditions and, therefore, you could use them to backtrack and figure out what happened in the past. Another important key to the use of the Deep Sea Drilling Project cores was the discovery that oxygen isotopes represented the amount of ice in the major ice caps. And so, as the glaciers waxed and waned during the past, they were recorded in the oxygen isotopes of the sediment, so they could be used to date sediments from all over the world.

JAY YETT, Ph.D., Orange Coast College:
Dating of the sediment is primarily to tell us the sequence of events—what happened first, what happened next, what happened next. So, if we can determine not only the kinds of sediments, the environments in which they were deposited, then we can also determine their ages, and we can compile that from a whole series of different areas, and we can piece together the history of the ocean and the ocean floor.

WOLFGANG BERGER, Ph.D., Scripps Institution of Oceanography, UCSD:
Now, they won't come with a label saying how many million years, but they will tell you where you are in time. It's a little bit like looking at a church in Europe and knowing that it's Gothic. It doesn't tell you the precise time, but you know that it's going to be built somewhere, you know, maybe in the 13th or 14th century.

So, we began to get a global chronology or timeframe to set all these sediments in. We now have a very good history of the oceans for the last…roughly 50 million years. So, we're beginning to understand the ways in which the ocean behaves under very different conditions from the present ones. And that's important when we start to look at what might happen as the global climate warms.