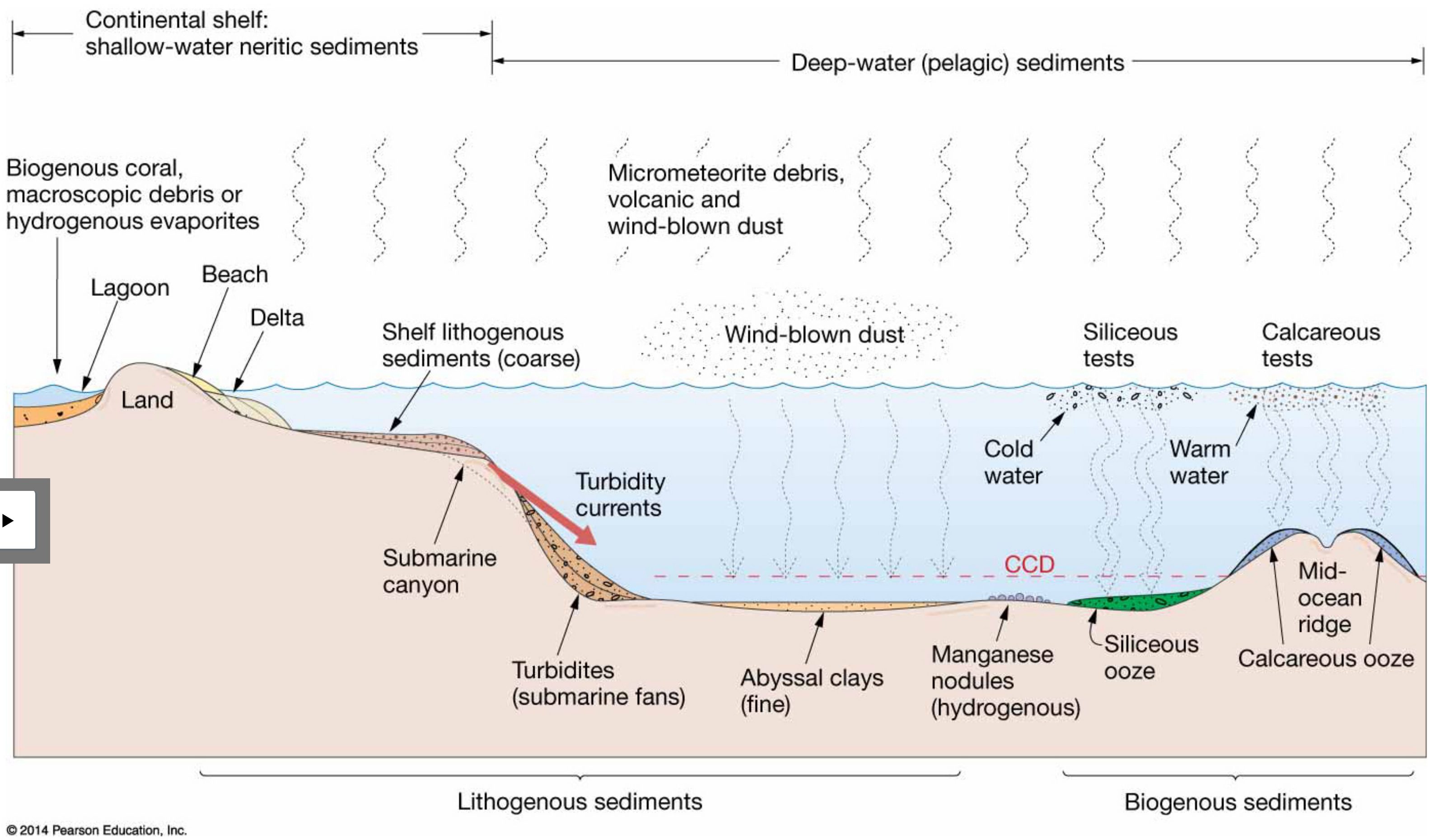
Lecture 8: Marine Sediments Part 2

Lecture 8 – Marine Sediments (ctd)

Let's take a moment to recap some of the concepts we learned about marine sediments during our last lecture. We discussed the types of materials that make up marine sediments, we discussed how marine sediments are transported into and to the ocean bottom (which includes how the sediments sort by size). We now know about the major controls of where and how biogenous sediments accumulate on the bottom (including how mechanisms like the CCD control where carbonate will end up), and how hydrogenous sediments serve as a record of the history of the ocean (paleoceanography). You can review the things we learned last lecture by looking carefully at the figure below – all of the processes and mechanisms we discussed are summarized here. If anything isn't familiar, go back to the previous lecture to review.

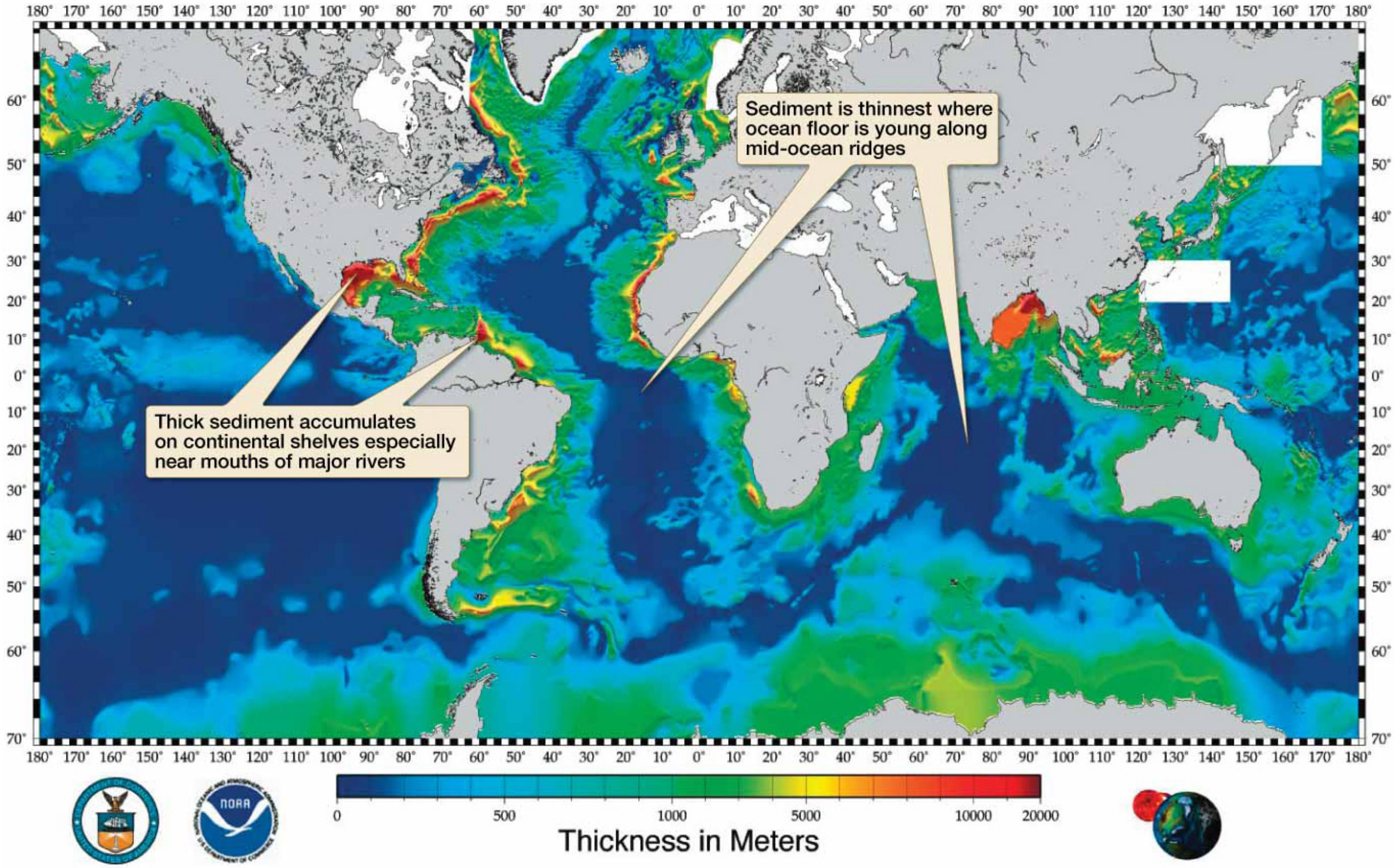


And here is a handy table summarizing sediment types, their composition, sources, and where they tend to be found in the ocean.

TABLE 4.1 CLASSIFICATION OF MARINE SEDIMENTS

Type	Composition		Sources		Main locations found
Lithogenous	*Continental margin*	Rock fragments Quartz sand Quartz silt Clay	Rivers; coastal erosion; landslides		Continental shelf
			Glaciers		Continental shelf in high latitudes
			Turbidity currents		Continental slope and rise; ocean basin margins
	Oceanic	Quartz silt Clay	Wind-blown dust; rivers		Abyssal plains and other regions of the deep-ocean basins
		Volcanic ash	Volcanic eruptions		
Biogenous	*Calcium carbonate ($CaCO_3$)*	Calcareous ooze (microscopic)	*Warm surface waters*	Coccolithophores (algae) Foraminifers (protozoans)	Low-latitude regions; sea floor above CCD; along mid-ocean ridges and the tops of volcanic peaks
		Shells and coral fragments (macroscopic)		Macroscopic shell-producing organisms	Continental shelf; beaches
				Coral reefs	Shallow low-latitude regions
	Silica ($SiO_2 \cdot nH_2O$)	Siliceous ooze	*Cold surface waters*	Diatoms (algae) Radiolarians (protozoans)	High-latitude regions; sea floor below CCD; upwelling areas where cold, deep water rises to the surface, especially that caused by surface current divergence near the equator
Hydrogenous	Manganese nodules (manganese, iron, copper, nickel, cobalt)		Precipitation of dissolved materials directly from seawater due to chemical reactions		Abyssal plain
	Phosphorite (phosphorous)				Continental shelf
	Oolites ($CaCO_3$)				Shallow shelf in low-latitude regions
	Metal sulfides (iron, nickel, copper, zinc, silver)				Hydrothermal vents at mid-ocean ridges
	Evaporites (gypsum, halite, other salts)				Shallow restricted basins where evaporation is high in low-latitude regions
Cosmogenous	Iron–nickel spherules Tektites (silica glass)		Space dust		In very small proportions mixed with all types of sediment and in all marine environments
	Iron–nickel meteorites		Meteors		Localized near meteor impact structures

Now, I invite you to think about what we have learned about plate tectonics (a previous lecture) and what we now know about marine sediments, and put those together to consider what parts of the ocean might have the thickest sediments, and where might have the thinnest. The thickest sediments tend to accumulate along the shallow continental shelves where major rivers empty into the ocean because those rivers are a source of terrigenous sediment material. What about thin sediments? We find the thinnest sediment accumulation in places where the bottom of the ocean is ‘young’ and there hasn’t been as much time for sediments to accumulate – as you well know that ‘young’ ocean bottom is found along the mid-ocean ridges.



Marine sediments are not just cool and interesting recorders of ocean history, they are also important resources that humans rely on. The sea floor is a super valuable source of mineral and organic resources, however, because they are on the bottom of the ocean, they can be very costly and difficult to access.

One of the highly valuable resources that humans extract from the bottom of the ocean are energy resources – petroleum and gas hydrates. Petroleum (oil and natural gas deposits), are by far the most valuable of those energy resources. The petroleum comes from microscopic organisms that get buried in marine sediments before they have a chance to be broken down and decomposed. The high pressure and temperature during burial converts the organic matter that gets buried into petroleum (hydrocarbons) over the course of millions of years. The world has become increasingly more reliant on oil from marine sources – in the 1930s, marine sourced oil made up only a tiny fraction of all of the world's oil, but today, over 30% of the world's oil comes from the ocean. As humans explore deeper into the ocean to find sources of petroleum and offshore drilling technology allows humans to drill in the deeper parts of the ocean (>1000 m depth), new sources are being found, but these come at an increased risk of disasters (some of you might recall
the Deepwater Horizon (https://www.youtube.com/watch?v=T37AiTqo-Ag)

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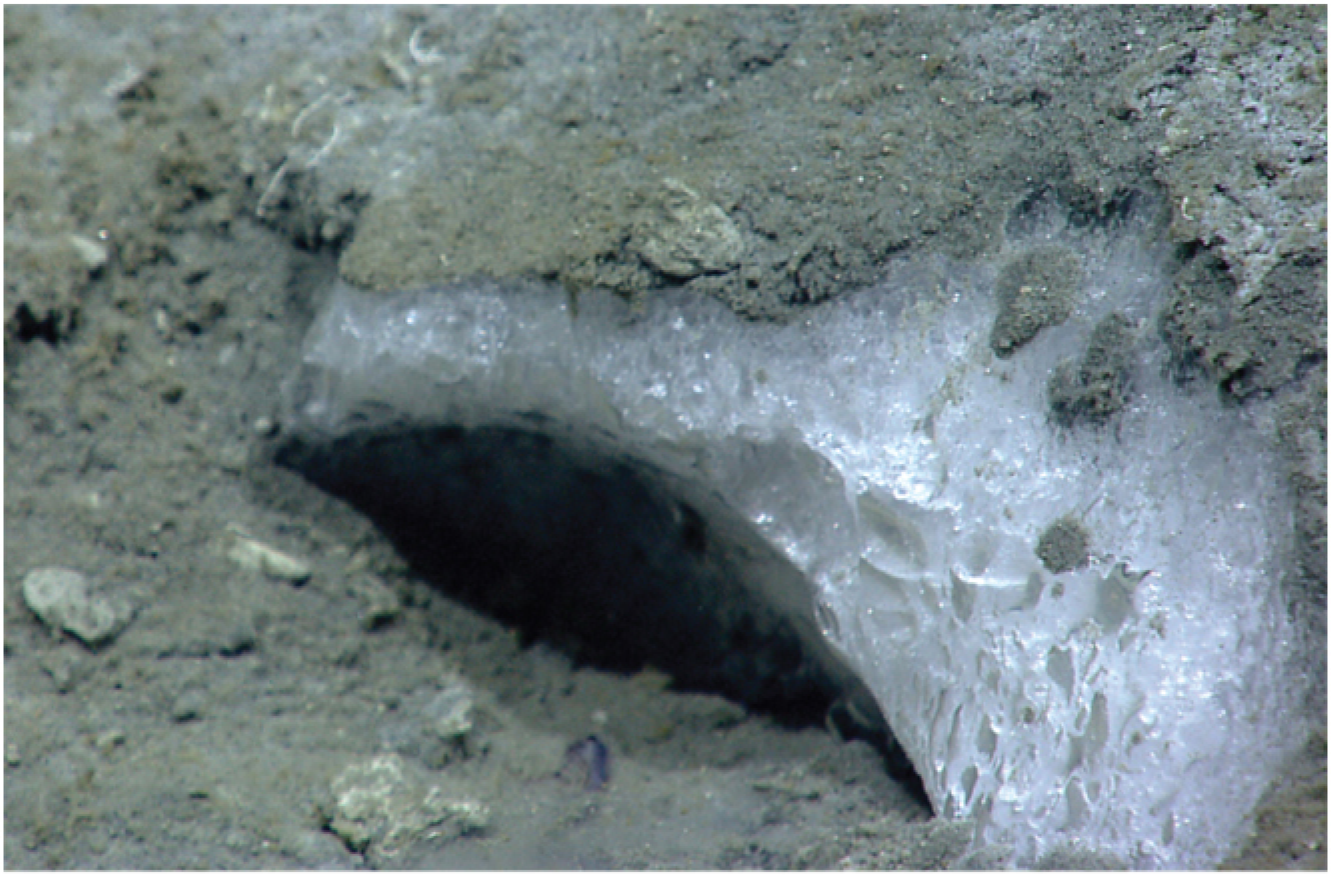
crisis in 2010, when a deep ocean oil well exploded). The land-based petroleum resources are all known and there is no chance of finding new oil resources on land, so exploration of the ocean in search of new sources of

oil will continue.

Gas hydrates are a mix of methane gas and water, that forms an ice-like solid under high pressure and low temperature. Gas hydrates were only recently discovered (in 1976), and can contain a variety of gasses (for example carbon dioxide, hydrogen sulfide, ethane, propane), but the most common are methane hydrates. These methane hydrates are a huge source of methane. Gas hydrates are highly unstable, and only remain solid under the high pressure and low temperature conditions that create them. If temperature increases, or pressure decreases around them - like if they are brought to the surface or exposed during an underwater landslide – they vaporize quickly and release the gases that were trapped in the solid. The gases that are released as they decompose can be lit on fire. These gas hydrates have important links to global climate history – when they are released on large scales, they can belch huge amounts of methane (a greenhouse gas) into the atmosphere altering the global climate. They also are an important potential source of energy but their instability causes a problem with exploiting them for energy. These gas hydrates are also relatively dispersed on the sea floor which makes collecting them uneconomical.



(a) Photo of ice-like gas hydrate created from a methane seep on the continental margin, depth = 1055 meters (3500 feet); width of photo is about 1 meter (3.3 feet).

(b) Gas hydrates decompose when exposed to surface conditions and release natural gas, which can be ignited.

Marine sediments are also a valuable source of building materials. Sand and gravel (both terrigenous materials) are mined for use in concrete, as fill material, and to replenish some beaches. Gypsum from evaporites is used in making drywall, and limestone (a biogenic sediment) is used for building blocks and tiles.

We already discussed manganese nodules – these represent sources of manganese, iron, copper, nickel and cobalt. Of these minerals, cobalt is among the most valued because it is used in making strong metal alloys used in making magnets, power tools and jet engine parts. Manganese nodules are difficult to collect (mine), and because of how super slowly they form, are a non-renewable resource that once used would not replenish for many tens of thousands of years.

Evaporites are an important source of salt. Some of those salts are important for building materials (gypsum - see above), but table salt (halite) also comes from evaporites (think about the vast ways that salt is used! Cooking, curing, de-icing roads, agriculture – it goes on and on). Halite is also used to produce other important chemicals that are used in making soaps, disinfectants, PVC pipes, acids, herbicides, fireworks… you name it! What would we do without marine sediments!

How do we study the process of marine sediment formation? One of the ways we do this is by collecting the material that is sinking from the surface to the bottom and study it. The tool we use to capture these sinking particles is called a sediment trap, and the particles collected, and the rate they are collected at tells us a lot about how the sediments form, what makes the sediments, and how the ocean surface is connected to the bottom (we call this benthic-pelagic coupling). These traps can be positioned at various depths and locations to collect sediments in different places and over different amounts of time – these samples can allow us to know decomposition rates, or dissolution rates.

We can also sample sediment by taking a core of the bottom. A core is basically a vertical slide of the bottom. There are a number of ways that a core can be collected – from simply pushing a tube into the bottom and picking it up, to more specialized tools like piston cores or drill rigs. We would sample to different depths into the bottom to look at various things. You would sample deeper into the bottom to sample older and older sediments. Ocean drilling rigs allow us to sample some of the deepest sediments. An example of one of those is the ocean drilling project on board the drilling ship JOIDES Resolution (check out **this cool video (https://youtu.be/0nydKlpZdlU)**

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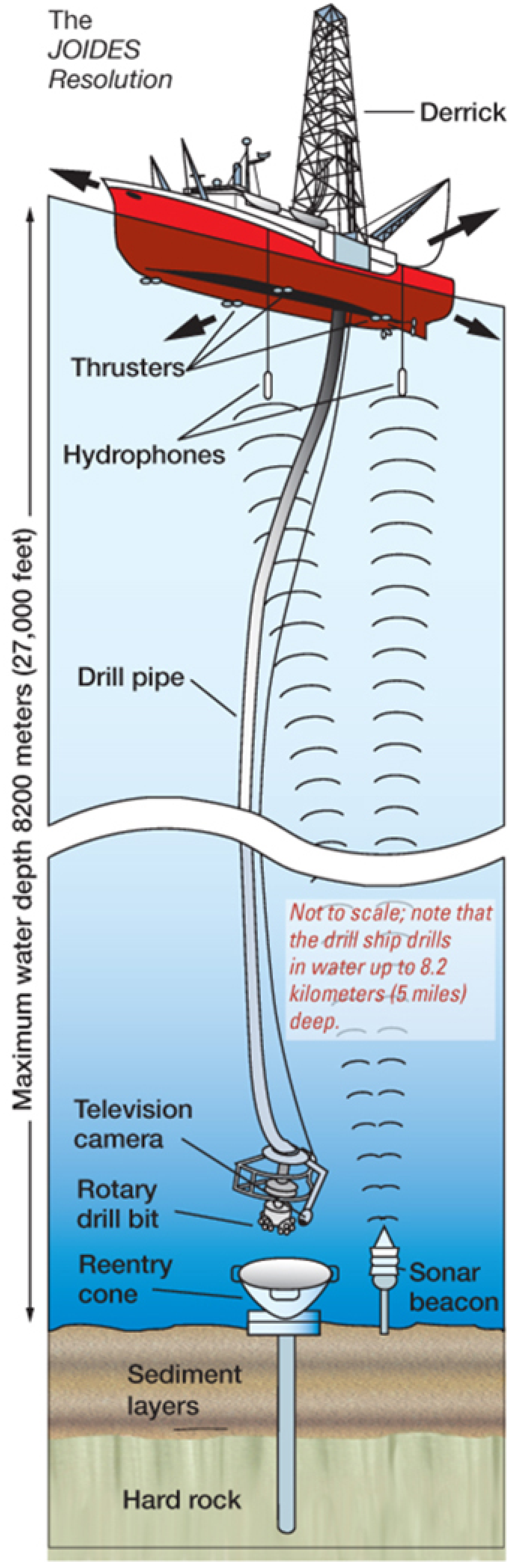
for a sneak peek into the JOIDES Resolution and other research tools for sea floor discovery). That project is an international marine research program that uses cores of ocean sediments to explore the Earth and ocean history. It has made more than 120 expeditions to collect over 220 km of ocean sediment cores, and has allowed the study of Earth climate history over 100 million years into the past, has given us a better understanding of plate tectonics, has confirmed the impact of a meteorite 65 million years ago that killed the dinosaurs, and many other amazing science discoveries. The deepest water depth it has recovered cores from is 5,980 m deep – pretty amazing just to be able to collect a core at that depth. The image below shows how the JOIDES makes the cores – it is highly technical and complicated with drill pipes, sonars, hydrophoes, anchors, and cameras all having to work in concert to connect and insert the cores.


The
JOIDES
Resolution
Derrick
Thrusters
Hydrophones
Drill pipe
Maximum water depth 8200 meters (27,000 feet)
Not to scale; note that the drill ship drills in water up to 8.2 kilometers (5 miles) deep.
Television camera
Rotary drill bit
Reentry cone
Sonar beacon
Sediment layers
Hard rock

Each sediment layer represents a unique event in Earth's history.

When the cores come up to the surface on the ship, each core is split longitudinally, which allows you to see the various layers. The sections of the core are marked to identify areas that you might want to sample more closely. These areas of interest can be analyzed in a number of ways including radiocarbon dating, analysis of biogenic organisms, chemical analyses, and many more analyses to discover the age, composition, and nature of each layer to learn about the history of that place in the ocean. These 220 km of cores are archived in warehouses to be studied for years to come. Photos of those core repositories are shown below. These storage lockers sometimes need to be kept cold to help preserve their integrity, and these lockers (or core libraries) are maintained by a number of institutions all over the world. The cores stored there are available to scientists around the world to continue making discoveries about the history of the Earth and ocean, and to learn about how the ocean works! Pretty amazing!