Name:

Section:

Deep-Sea Sediments Unit (3 pts)

Kinds of Sediments

Sediments are particles (broken pieces, bits of stuff) that cover the ocean floor. Ocean sediments are typically “broken” into 4 categories: rocks carried off the land (lithogenous sediments), shells and other remains of dead organisms (biogenous sediments), chemicals that solidify out of ocean water (hydrogenous sediments), and dust and other particles that fall from outer space (cosmogenous sediments).

By far the two most common kinds of sediments are lithogenous sediments (bits of rock) and biogenous sediments (typically shells, mucous, and fecal matter). In special places, hydrogenous sediments are common on the ocean floor, like the sulfides that solidify out of ocean water at hydrothermal vents or salts that solidify and coat the bottom of warm-water lagoons as water evaporates away. (When chemicals join together to form solids in a liquid, we say that they “precipitate,” similar to how water molecules join together in air to produce liquid rain water – i.e., “precipitation.”)

These categories are somewhat arbitrary, because all sediments are really a mixture of all 4 kinds of sediments. We typically classify a sediment sample according whichever kind of sediment is “dominant” (i.e., whichever kind of sediment is the most abundant). In fact, we call a sediment “biogenous” if at least 30%+ of it is composed of the remains of ocean life. Thus, a sediment could contain nearly 70% rocks, and still be called “biological.” The reason for this is that rocks are the most common kind of sea-floor sediment, and if we did not lower the standard for biogenous sediments, then almost all ocean sediments would be classified as lithogenous, even when they contain unusually substantial amounts of biological material.

1. What are lithogenous sediments?

2. What are biogenous sediments?

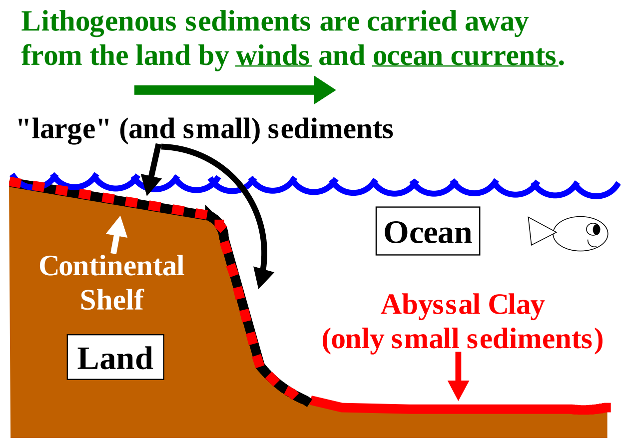
3. What are hydrogenous sediments?

4. Which kinds of sediments are the most abundant on the ocean floor?

5. True or false? “Ocean sediments are rarely pure. They are almost always mixtures of the different kinds of sediments.”

Key Things to Know About Lithogenous Sediments

Lithogenous sediments are carried to the coast by rainwater runoff, rivers, and winds, then currents and winds carry them out into the ocean. However, larger sediments are left up in the mountains or along beaches (e.g., sand), because they are heavier and sink quickly to the bottom, so after they have reached the shoreline, winds and currents cannot carry them far into the ocean before they settle to the bottom.



Thus, the important rules to remember for lithogenous sediments are:

- Large, heavy lithogenous sediments sink faster, so they settle on land or next to the land.
- Most small, light lithogenous sediments settle close to the land, because they come from the land and sink. However, since they sink very slowly, a few of them occasionally get carried out into the middle of the ocean by currents and winds.

The small lithogenous sediments that travel far from land and reach the deep-ocean floor are called ***red clay*** or ***abyssal clay***. ("Abyss" means "bottomless" or "deep.")

Ocean currents, rivers, waves, and wind are not the only things that can transport sediments – they are typically just the ones that push around the most sediments. For example, glaciers push sediments from the land into nearby coastal waters. In addition, sediments get stuck in glaciers that flow into the ocean and break off as icebergs. When the icebergs melt, the sediments fall to the ocean floor. This is a way in which large sediments can be carried to the deep-ocean floor.

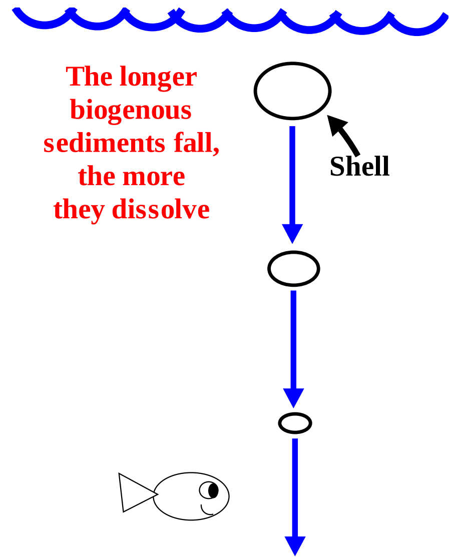
6. Is it the large lithogenous sediments or the small ones which tend to reach the middle of the ocean and the deep-ocean floor?

7. What is the name of the tiny lithogenous sediment that is found on the deep-ocean floor?

8. What carry this kind of sediment <u>from farther inland to the coast</u>?

9. What carry this kind of sediment a<u>way from land and out into the ocean</u>?

Key Things to Know About Biogenous Sediments



Biological sediments are referred to as oozes. There are 2 kinds of ooze, ***calcareous ooze*** and ***siliceous ooze***. Calcareous ooze consists primarily of calcium carbonate shells, and siliceous ooze consists primarily of silica shells.

Most dead, decaying bodies and fecal matter are dissolved by ocean water, decomposed by bacteria, or consumed by animals as they slowly sink towards the bottom of the ocean. Only a small amount reaches the bottom, often no more than 1%. Thus, the important rule to remember for biogenous sediments is:

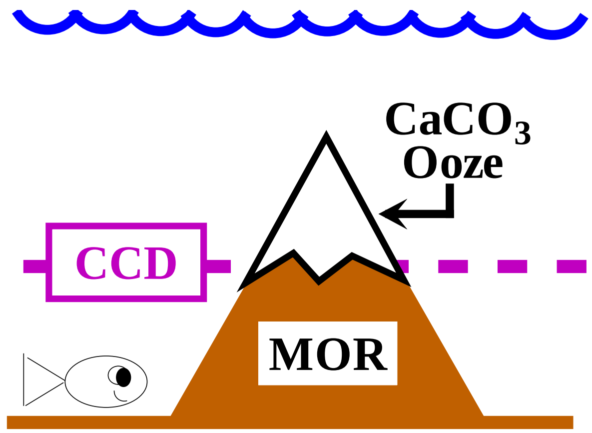
- Most biogenous sediments dissolve before reaching the bottom.
- The longer it takes them to fall, the more they will dissolve before reaching the bottom. If the ocean is too deep, they will dissolve away completely before reaching the bottom.

Most biological sediments consist primarily of calcium carbonate or silica, substances that some phytoplankton and zooplankton make their shells out of. The other parts of the organisms tend to get decomposed by bacteria.

Silica is most common on the ocean floor beneath cold surface water, because silica dissolves rapidly in warm water. It dissolves in cold water too, just more slowly.

Calcium carbonate is most common on the ocean floor beneath warm surface water in places that are not too deep. Calcium carbonate dissolves rapidly in cold, carbon-dioxide-rich ocean water under high pressure, precisely the conditions that are common in the deep ocean. Thus, it does not sink too deeply before is dissolves into the ocean water. Cold water can hold more carbon dioxide than warm water, so it is more acidic, and therefore dissolves the calcium carbonate faster. Unlike silica, though, calcium carbonate does not dissolve at all in warm water. In fact, calcium carbonate dissolved in ocean water will solidify ("precipitate") in very warm ocean water. It forms small chunks on the ocean floor called oolites which roll around in the waves, smoothing them. Some corals make little homes for themselves (little "shells" or "exoskeletons") out of calcium carbonate. It is easier for them to solidify calcium carbonate in warm water; this is one reason that coral reefs grow in warm, tropical places.

The falling material often ends up clumping together, so you can actually see it with your own eyes. It glistens when deep-sea explorers shine their lights on it, so it goes by the nickname "marine snow." Calcium carbonate sediments often end up coating the top of underwater



mountains like the mid-ocean ridge, but not their sides, because the sides are too deep: the calcium-carbonate sediments completely dissolve away before reaching the bottom. We call the depth at which the shells have completely dissolved the "calcium compensation depth" or CCD. Once the shells reach the top of the underwater mountain, though, they get buried by other sediments and will not dissolve anymore, because they are no longer surrounded by the ocean water. Something similar can happen to silica shells, though they are often found deeper than calcium carbonate shells: since it dissolves slower in cold water, it can travel farther down before completely dissolving away.

Oozes (biological sediments) on the ocean floor are decomposed by bacteria and dissolved by ocean water, but if there is less water around them, then they dissolve slower. In addition, the water closer to the bottom can become supersaturated with dissolved chemicals, which keeps the biological sediments from dissolving anymore.

10. Which kind of sediment is made primarily of calcium-carbonate shells?

11. Which kind of sediment is made primarily of silica shells?

12. Which kind of sediment dissolves quickly in warm ocean water and slowly in cold water?

13. Which kind of sediment dissolves in cold ocean water, but does not dissolve in warm water?

Coastal Ocean Sediments

The continental shelves (shallow, flat areas close to the coast) are really part of the continents. When sea level is lower (e.g., during an ice age), they are weathered and eroded like any other place on land, so the sediments on them and that spill over their edge onto the deep-ocean floor can resemble sediments from the land. Huge, underwater avalanches called “turbidity currents,” can carve out canyons along the edge of continental shelf. These sediments are often called relic sediments because they are leftover from when sea level was lower.

These relic sediments on continental shelves can be quite large (e.g., gravel, sand) compared to most deep-ocean sediments which are small (e.g., mud). Once sea level rises again, other sediments like mud and plankton shells pile up as well and mix with them over time. We will call this mixture of sediments “continental material.”

14. True or false? “Gravel and sand are commonly found o<u>n continental shelves</u>.”

15. True or false? “Gravel and sand are commonly found <u>on the deep-ocean floor, far from land</u>.”

Distribution of Deep-Ocean Sediments

To understand where each kind of sediment is the most abundant kind of sediment on the deep-ocean floor, we need to apply the following information:

- Red clay does not dissolve.
- Calcareous ooze does not dissolve in warm water, but dissolves rapidly in cold water.
- Siliceous ooze dissolves slowly in cold water and rapidly in warm water.
- The deeper the ocean is, the more time oozes spend in contact with ocean water, which can dissolve them and thus prevent them from reaching and building up on the ocean floor.
- There is a lot more calcareous ooze or siliceous ooze in surface water than red clay, because oozes are primarily made of the shells of the animals and algae that live out in the ocean, far from land. Red clay has to travel hundreds or thousands miles from land out into the ocean, so very little red clay gets this far out into the ocean; most sinks closer to land.

Calcareous ooze (calcium-carbonate sediments) is the dominant sediment beneath the warm surface water of the mid- and low latitudes where the ocean floor is not too deep, like on top of the mid-ocean ridge, seamounts (underwater mountains), and the outer edges and slopes of wide continental shelves. Recall that calcium carbonate dissolves rapidly in cold water (it is more acidic from excess carbon dioxide) while silica dissolves rapidly in warm water. Thus, calcareous ooze is the most abundant sediment in places where the surface water is warm at the surface and not too deep, because most of the silica shells dissolve at the surface. The calcium carbonate shells do not begin dissolving until they reach the colder water beneath the surface, and the shells do not dissolve much on the way down, because the ocean floor is not too deep, so they do not have much time to dissolve before reaching the bottom. Once buried, they are no longer in contact with the ocean water that dissolves them. Very little red clay reaches the middle of the ocean, so there is much more calcareous ooze than red clay sinking towards the bottom.

Siliceous ooze (silica sediments) is the dominant sediment beneath cold surface water and where the ocean floor is not too deep, like on top of the mid-ocean ridge and seamounts (underwater mountains). Recall that silica shells dissolve slowly in cold water while calcium carbonate shells dissolve rapidly in cold water. Therefore, silica shells are much more likely to reach to the bottom in places with cold surface water, since they do not dissolve as much as calcium carbonate shells on the way to the bottom. Nonetheless, silica shells do dissolve on their way to bottom, so if the water is very deep, the silica shells may dissolve away before reaching the bottom. If the silica shells reach the bottom without completely dissolving away, they can be buried and thus are no longer in contact with the ocean water that dissolves them. Very little red clay reaches the middle of the ocean, so there is much more siliceous ooze than red clay sinking towards the bottom.

Beneath upwelling zones, a lot of shells are sinking and thus the water may become supersaturated with silica, allowing the shells to reach the bottom even if the water is fairly deep. (In supersaturated water, all the water molecules are bonded with silica or other atoms and molecules, so they are unable to bond with and dissolve any more silica shells.) Thus, siliceous ooze if found on the ocean floor beneath upwelling zones like the Equator and next to west coasts (the east sides of oceans), not just on the ocean floor of the Polar Oceans.

The deeper parts of the ocean floor like the abyssal plains and trenches are dominated by abyssal clay, also called red clay. Red clay consists of very, very small sediments which are carried away from land by currents and winds. Most clay settles close to land on the continental shelves and slopes. However, clay sinks very slowly, which allows a little clay to drift beyond the continental shelves and out into the middle of the ocean. Even though red clay piles up very slowly on the ocean floor, red clay is the dominant sediment on the deeper parts of the deep ocean floor because calcareous ooze and siliceous ooze dissolve away before reaching the bottom: since the bottom is so far away from the surface, the shells spend a lot of time in contact with ocean water, which dissolves them. Red clay does not dissolve in water, and therefore it is the only sediment that can reach the deeper parts of the deep ocean floor without dissolving away. As noted before, there is one major exception: in places where there are a lot of shells sinking to the bottom (e.g., beneath an upwelling zone), siliceous ooze can become the dominant sediment on fairly deep parts of the ocean floor since the water can become supersaturated with silica.

16. What are the 3 major kinds of deep-sea sediments?

17. Which kind of sediment does ***not*** dissolve in ocean water?

18. (i) Under what conditions does calcareous ooze become the most abundant kind of sediment on the deep-ocean floor?

    (ii) Why is calcareous ooze more abundant than siliceous ooze under these conditions?

    (iii) Why is calcareous ooze more abundant than abyssal clay (red clay) under these conditions?

19. (i) Under what conditions does siliceous ooze become the most abundant kind of sediment on the deep-ocean floor?

    (ii) Why is siliceous ooze more abundant than calcareous ooze under these conditions?

    (iii) Why is siliceous ooze more abundant than abyssal clay (red clay) under these conditions?

20. (i) Under what conditions does abyssal clay (red clay) become the most abundant kind of sediment on the deep-ocean floor?

    (ii) Why is abyssal clay (red clay) more abundant than siliceous ooze and calcareous ooze under these conditions?

Why Study Ocean Sediments?

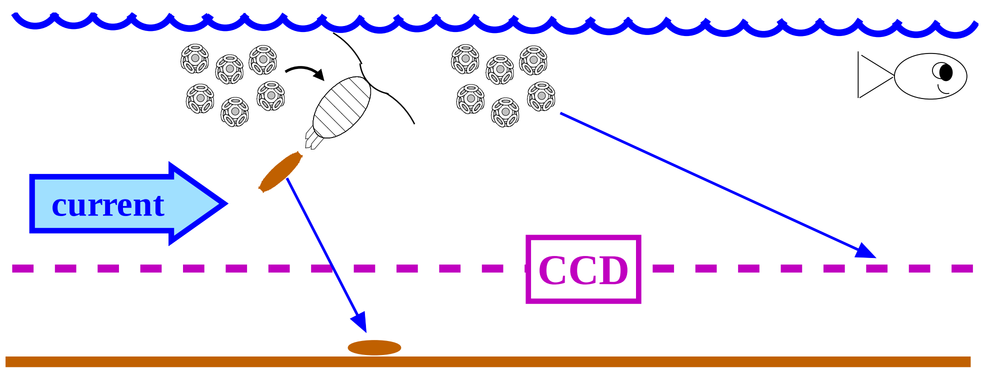
Scientists spend a lot of time and money investigating ocean sediments, the muck on the bottom of the ocean, and I imagine that most people's first reaction is "Why bother?" Ocean sediments provide clues about what was happening in the past at the location where the sediments are found. As we dig down deeper into the sediments, we are going back in time, learning how things were different in the past. Probably the most important reason to study ocean sediments is that they give us clues to where oil and natural gas deposits can be found in the ocean. In addition, the biological remains in the sediments tell us how phytoplankton and animal populations naturally fluctuate up and down with time, helping us better manage our fisheries (e.g., avoid overfishing). Many deep-sea animals live on or in the sediments and they are extraordinarily diverse (i.e., there are many different, unique species) so they are a source of new, unique chemical compounds that might be useful (e.g., medicines and "green" biofuels, read about "bioprospecting" in topic 13A). Sediments also contain pollution, and can be used to track down its sources. Climate change is an important area of research that uses ocean sediments, because changes in water temperature affect the kind of biological sediments that we find on the ocean floor. Thus, ocean sediments allow us to reconstruct how the Earth's climate has changed over millions of years, giving us insight into whether the present warming is "normal" or "unusually fast." (The answer is "unusually fast.")

21. Why do we study deep-sea sediments? What are the practical benefits?

The Noble Copepod and the Preservation of Biological Sediments

Unfortunately for oceanographers who study seafloor sediments, the small bodies of phytoplankton sink very, very slowly. In fact, it could easily take 10 years for them to reach the bottom of the ocean, plenty of time for the bodies to dissolve completely away. In addition, if by some miracle they reached the bottom of the ocean, they would be far away from where they lived at the surface: even a small ocean current (say, 1 cm/sec) could push the falling bodies thousands of miles in 10 years. Thus, it should be very hard to use ocean sediments to learn about life in the ocean in the past, past climates, oil and natural gas deposits, etc.

The copepod, a small crustacean, and its digestive system come to our rescue, though. Copepods are one of the most abundant kinds of zooplankton in the ocean, so they eat a lot of phytoplankton. (I like to call them the "cows of the sea.") Their digestive tract extracts much of the good stuff (e.g., carbohydrates) from the phytoplankton bodies, but it does not digest the phytoplankton shells (in the same way that we eat the meat of a chicken or cow, not its bones). Instead, these get crushed together in its fecal pellets. (99% of particles that reach the deep-ocean floor are fecal pellets!) Since the fecal pellets consist of dense calcium carbonate and silica shells "smushed" closely together, they are very dense and sink rapidly to the bottom of the ocean (in about 10 days). Because the fecal pellets spend little time falling, they do not dissolve very much on the way down and don't get pushed very far from where the phytoplankton and copepods lived. Thus, they provide an accurate record of the kind of life that lived above the spot where we dig up the sediments. Thanks, copepods!



22. How do copepods contribute to the sediments on the ocean floor?

23. Why are there more sediments on the ocean floor because of copepods?