Ocean Sediments – Tutorial Script

In this video, we will look closely at the sediment that makes the top layer of ocean crust. Where does it come from? What does it look like? Feel like?

Let's start with the vocabulary used to describe sediment size. Though there are many terms used to describe sediments of all sizes, we'll simplify them for this class into three categories: **muds, sands, and gravels**. Technically, gravels are sediment grains larger than 2 mm in diameter. Muds are less than 1/16 mm. Sands are everything in between.

Where is each of these grain sizes found in the ocean? The largest grains, the heaviest, settle quickly in still water and require high-energy water to be picked up and carried. The smallest grains require perfectly still, unmoving water to settle out. Ocean environments are separated into two major geographic zones – **neritic**, over the continental shelf – and **oceanic** over the slope, rise, abyssal plains, mid ocean ridges and trenches. Neritic waters tend to have faster-moving currents interacting with surface waters and the shallow bottom. These waters can pick up and shift around larger sediment grains. Rivers that enter here will retain mud-sized sediments in suspension and can carry them quite a distance offshore. Gravels tend to stick close to shore. Fine sands collect in medium-energy coves and can be carried out to the edge of the shelf. Muds settle out only in closed-off no-energy lagoons. Oceanic waters are deep with no currents that touch the bottom. Gravels and sands cannot be transported out here by anything other than floating icebergs, so the sediment that falls here is only the suspended muds. Where do these muds come from that get out to the oceanic zone? Nearby rivers that have a lot of suspended sediment. Airborne dust and ash that settles on the surface. And the shells and debris of organisms that live in the surface waters and settle to the seafloor when those organisms die.

The oceanic zone represents 4/5 of the world's ocean environments. However, the sediment that collects in the margin environment is the thickest in the world – up to 9 km thick, compared with the oceanic sediment thickness, which increases from 0 at the ridges to 0.6 km at the thickest oldest edges of the abyssal plains. Even though the sediment that collects in the margin environment represents only 1/5 the ocean's surface, its sediment volume represents almost 90% of the total ocean sediment. Why? Sediment collects here much faster – at rates from 0.5 to 800 m per 1000 years. For comparison, in the oceanic zones, sediment collects, at its fastest, 1 cm per 1000 years.

Pause now.

What makes up all these sediments? There are four major sources of sediment to the ocean, and of course each gets its own name. We call sediment that originated from rock weathering on land **lithogenous or terrigenous** sediment. What is it made of? Bits of rocks and minerals. When next to a weathering cliff, like along an eroding coastline, the material is made of bits of the rock in the cliff, and gravity carries them towards the oceans. When dropped by glaciers, these sediments can be quite large and come, relatively preserved, from the backcountry far inland. We call both of these types of sediments **immature**, because they haven't been modified much by travel. They can be angular and poorly sorted, consisting of grains of all compositions, shapes, and sizes -- mostly gravels.

When lithogenous sediment is carried by rivers, on the other hand, it becomes **mature**. Grains decrease in size to fine sands and muds. Why? During transit, the grains are knocked around and hit each other. They physically break down into smaller pieces. They also break down chemically. Most of the material dissolves or is turned into clays and rust. The most resistant materials, predominantly quartz grains, which don't dissolve or turn into clay or rust, remain. Clay minerals are mud sized and are the most common byproducts of rock weathering on earth's surface. Some of these clay minerals make it out to the oceanic zones, either by being held in suspension near large river deltas, or by being carried by winds off desert and mountain areas. We call those clays abyssal clays (as they are found in abyssal plains). We'll return to them shortly.

As lithogenous sediment dominates the coastal margins and accumulates at the fastest rates of all sediments there, and also reaches out in its mud-sized form to the deeper parts of the oceans predominantly as abyssal clay, lithogenous sediments make up the largest percentage by volume of marine sediments. However, because most of this volume stays close to the margins and piles up there thickly, they represent only 45% of the total seafloor surface coverage. The sediment that covers most of the seafloor surface is **biogenous**, which consists of shells of dead organisms and dominates the oceanic zones. The most important contributors to biogenous sediment are the single-celled autotrophic and heterotrophic plankton that live in the surface waters. Billions of these organisms live and die with lifetimes of days to weeks. Their shells collect on the bottom of the seafloor and contribute to siliceous and calcareous oozes, depending upon whether the shells are made of silica (siliceous oozes) or calcium carbonate (calcareous oozes). The term **ooze** tells us a lot about the consistency of these sediments. They are all mud sized – a very fine flour-like material. Larger, gravel-sized shells contribute to neritic nearshore sediments where there are large reefs – either tropical coral reefs or colder-water reefs made of mollusks, like mussels and limpets. We'll return to the oceanic oozes shortly to describe them in more detail.

Another type of sediment, called **hydrogenous**, represents minerals that are produced from from ions that were originally dissolved in water. We call that process **precipitation**. Seawater has many dissolved ions in it, and in numerous locations, those ions reach a concentration that is higher than can be dissolved by the water anymore, either because of evaporation of water or because of an influx of dissolved ions. We call that state **supersaturated**, and you can learn more about this in the seawater chemistry video tutorials. For now, we'll focus on where to find these precipitated hydrogenous sediments. At shallow inland seas, where rains are limited and evaporation rates are high, minerals can precipitate in high amounts. These minerals consist of halite (table salt), gypsum (dry wall material), and calcite. In some deep areas of the abyssal plains, dissolved phosphates and manganese become supersaturated and precipitate as nodules that grow bigger over time as new material precipitates atop the older material.

Any other place in the ocean where sediment precipitates from solution? Something we discussed in the plate tectonics and earth formation video tutorials? Hydrothermal vents! Hot waters rich in dissolved ions leached from the ocean crust enter the colder seawater. As that hot water cools, it becomes supersaturated with dissolved ions (cold water can dissolve less than warm water; that's why when cooking, we heat up our water when we want to dissolve things like sugar or salt in it!). Hydrogenous sediments are found in many places across the oceans, but they represent less than 1% of the surface area, as they are largely scattered.

The most uncommon sediment found in the ocean, but still found in abundances greater than on land, is **cosmogenous** sediment – meteorites that fall from space – and **tektites**, which are bits of Earth's crust that have been ejected into space after a meteorite impact excavates a crater. This ejected excavated crustal material melts as it exits the atmosphere and solidifies as it falls back down – producing a spherical, tear-drop-shaped glass nodule, with eroded pits created by its journey back down through the atmosphere. Why are these found in the oceans in more abundance than on land? Simply because of the slow sedimentation rate of the oceans. Where sediment collects at rates as low as 1 cm per 1000 years, it's easier to find the tektites and meteorites that fall among them.

Pause now.

Now let's return to the oceanic zone and look more closely at the mud-sized abyssal clays and siliceous and calcareous oozes that form there. Are all three found in the same location? In most cases, one is the dominant. Why? Abyssal clays, remember, are lithogenous or terrigenous will dominate near high-volume rivers with large deltas. Without rivers nearby, abyssal clays come from the settling of airborne dust and ash that's been blown from the land. If there are nearby deserts with high wind activity, the rates of abyssal clay settling can be comparable to that of calcareous or siliceous shells. So the settling rate of abyssal clays in the deep oceans can be anywhere from 1 mm to 1 cm per 1,000 years.

We call the organisms that live in the surface waters **plankton** (free-floating, can't swim faster than currents). If they are autotrophic (make their own food), they are the bottom of the food chain, and are referred to as **phytoplankton**. Heterotrophic plankton are referred to as **zooplankton**. **Diatoms** are phytoplankton with silica shells (SiO_2). **Coccolithophores** are phytoplankton with calcium carbonate shells ($CaCO_3$). **Radiolaria** are the most common zooplankton with SiO_2 or silica shells. **Foraminifera** are the most common with $CaCO_3$ shells. These four organisms play very important roles in the world's oceans, and it's valuable to memorize these names and shell types now, as they will appear many times throughout future video tutorials. We'll review one more time, then you'll take a quiz. Autotrophs: Diatoms and Coccolithophores. Heterotrophs: Radiolaria and Foraminifera. Silica shells: Diatoms and Radiolaria. Calcareous shells: Coccolithophores and Foraminifera.

Pause now.

So where do these organisms thrive and hence their shells dominate the oceanic muds on the seafloor? Calcareous-shelled creatures are the most abundant organisms in the world's oceans, so theoretically, their shells should dominate all deep–sea muds. That would be true, except for two things. First, in areas where deep water rises to the surface, a process called **upwelling**, silica-shelled organisms thrive. These waters are cold and filled with **nutrients**. Nutrients are dissolved ions that autotrophs pull from the water to use for building cells and shell material. All autotrophs require that the water have nutrients. Heterotrophs get their cell-building and shell-building nutrients from their food. Since autotrophs make their own food, they need to get their nutrients from the surrounding water. Silica-shelled autotrophs are adapted to cold nutrient-rich water, while calcareous-shelled autotrophs tend to prefer warmer waters and don't require as high a nutrient content. So siliceous oozes dominate under areas of upwelling. Though some calcareous shells might also be found in these oozes, along with abyssal clays, the silica shells dominate. Where are these areas? Upwelling can occur anywhere at any time, but it is typically found year round in the waters surrounding Antarctica, and along the eastern edges of the ocean basins along the equator. We'll learn more about why that's true in the video tutorials that deal with ocean currents.

So everywhere else there should be calcareous oozes? Not quite. There is one remaining issue to take into account. Calcareous shells will dissolve in acidic waters. And as water gets deep, cold temperatures and high pressure mean more carbon dioxide is dissolved. More carbon dioxide means more acidic. For more information, refer to the video tutorial on Carbonated Oceans. For now, we focus on the result – though calcareous creatures might exist in the surface waters, their shells will dissolve en route to the seafloor, if the seafloor is deeper than the **calcium carbonate compensation depth** otherwise known as the CCD. The CCD is the depth at which the acidity of the seawater is high enough to dissolve these shells in their normal abundance, and thus no calcareous shells accumulate below this depth unless they collect faster than they can dissolve. For our purposes, that means they should be absent. This depth varies in the oceans, but is, on average, around 4500 meters. That means the deep abyssal plains will not have calcareous shells accumulating. Only siliceous oozes or abyssal clays can collect at these depths. So let's use this information now to describe the distribution of oceanic muds across the world's oceans. With what seafloor feature do these calcareous oozes correspond? Mid-ocean ridges, the shallowest parts of the oceanic zone. Siliceous oozes dominate at the eastern equatorial zones and in polar regions as previously discussed. The rest of the oceans is dominated by abyssal clays.

Pause now.

Ocean Sediments
Produced by Katryn Wiese
City College of San Francisco

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**Marine Sediment Distribution -- Map showing distribution of marine sediments. Gray: land. White: Sediments of the continental margin. Blue: glacial sediments. Orange: land-formed sediments. Brown: pelagic clay. Green: siliceous sediments. Yellow: calcareous sediments.*