SEDIMENTARY ROCKS – Tutorial Script

Sedimentary rocks are those formed by the **compaction** or **cementation** of surface debris – such as rock fragments, minerals, shells, bones, and more. They can also form through the precipitation of minerals directly from surface waters rich in dissolved ions. When we classify and identify sedimentary rocks, we review the textures and compositions, which are the clues we use to recognize the original surface formation setting.

By the end of this learning module, you should be able to list the most common sedimentary rocks, recognize their textures and compositions, and link them to their formation environment and history.

As you can see with this identification table, sedimentary rocks are broken up into two types – chemical and clastic. **CHEMICAL** is how we characterize rocks that are made from minerals that precipitated directly from surface fluids. **CLASTIC** is how we characterize rocks that are made from compacted or cemented debris. How do we tell the difference? This pile of rocks contains both. So the first thing we can do with this pile is separate it into two piles based on texture. When we can see, with our naked eye or with a hand lens, individual grains stuck together, we know it's clastic. When we can't see grains, it's harder. Mud-sized grains will not be visible through a hand lens. If handling the sample leaves mud-sized pieces on our hand afterwards, we know it's clastic, but if the mud-sized particles are densely compacted and don't come off in our hands, how can we distinguish between that and a micro-crystalline chemical rock? Luster and texture. The chemical precipitates display either interlocking crystals which clearly grew together or a smooth, reflective surface that looks a lot like plastic. The clastic clay particles display a rougher duller texture.

So based on these distinctions, we can separate this pile of rocks into these chemical textures and these clastic textures. Let's look more closely at the chemical textures.

What kinds of minerals precipitate out of cold, supersaturated fluids at or near earth's surface? Calcite and quartz. Add to that halite and gypsum which precipitate when saltwater evaporates – either in shallow coastal lagoons or ponds in warm, dry climates or when salty lakes evaporate in the desert. Calcite and quartz most commonly precipitate from solutions that are percolating through sediment just below the surface. As these waters dissolve minerals along their route, the water fills with increasingly greater amounts of dissolved ions, and when these ions reach saturation and then the water enters a new environment with a new temperature or pressure that drops calcite or quartz solubility, these minerals will precipitate. When they precipitate in between sediment grains, they cement those grains together. When calcite and quartz precipitate in layers as waters seep out and across the earth's surface or in larger cavities underground or when they replace organic matter, such as with petrified wood, they produce a rock made entirely of calcite or quartz. Sometimes the crystals can be big enough to see, but usually they are microscopic and they give the rock a luster that looks like plastic.

Another way to form this type of chemical sedimentary rock is when microscopic shells are compressed during burial, and they recrystallize. When a chemical sedimentary rock is composed entirely of calcium carbonate, it's called **LIMESTONE**. When it's composed entirely of quartz or silica, it's called **CHERT**. There are many special varieties of each, but that's the basic name used.

Here are some examples. All of these CHERTs are made of precipitated or recrystallized silica, but each is a different color and has a slightly different formation story. This red chert was originally made of mostly mud-sized silica shells from dead radiolaria, combined with minor amounts of a dark clay mineral – both of which settled down from the surface of the ocean to collect on the ocean floor. These were compressed, the silica recrystallized, and this example represents one chunk of many layers of chert found in San Francisco as part of a ribbon chert formation – interlayered clay minerals and silica shells folded during accretion to North America 100 million years ago. This black chert with the chalky rind is called **FLINT** and likely a recrystallized accumulation of diatom or radiolaria shells or sponge glass spicules or some other silica derivative of a dead lifeform, deposited contemporaneously with microscopic foraminifera or coccolithophore shells on the bottom of the ocean floor. The sediment was buried, and the calcareous shells loosely compacted together, while the silica-rich material clumped together and recrystallized to form nodules of chert surrounded by chalk.

These limestones are similar in color but show a wide range of textures. This one is called crystalline limestone, because the crystals are all big enough to see. You also can see those crystals form in layers. It formed through slow evaporation from salty brines. This limestone has no visible crystals and a microcrystalline plasticky luster. That means it precipitated quickly in small amounts probably in underground caves or cavities. This limestone, shows a mixture of chemical and clastic textures. We see sand-sized clasts, cemented together, but when we look more closely at those clasts through a microscope, we see a chemical texture for perfectly spherical beads. This OOLITIC LIMESTONE is made when calcite crystals precipitate around small mud-sized particles in the surf zone and then collect more precipitate in spherical shells over the last one (like pearl formation, but without the oyster – it's the ocean laying down the calcite, because the water is supersaturated, and the waves are an active environment in which conditions change continually. The rolling back and forth during precipitation produces and maintains the spherical shape.

Now let's look more closely at the clastic texture rocks. We can separate these into two piles based on the clast composition – if the clasts are mostly shells, it's organic clastic, and typically that gives the rock a white or light-colored hue. If the clasts are mostly rock and mineral fragments, that means it's detrital, and the color of the rock comes from the color of the minerals or rock clasts. Especially when clasts are mud-sized, it is hard to tell from a hand sample what the grains are made of. For this particular lab class, mud-sized shells will always be white. If you see a rock made of mud-sized particles that are NOT white, they must be detrital.

Let's look more closely at the clastic rocks made mostly of shells. First step is to order them by grain size, with largest at the top and smallest at the bottom. Gravels, sands, and muds. Aligning the samples with the table, we see that any rocks made of gravel-sized shells must be calcium carbonate in composition and are called **COQUINA**. Sand-sized, **CALCARENITE**. If a rock is made of mud-sized shells, those shells could be made of calcium carbonate OR silica. How do we tell the difference? The acid test should make the calcium carbonate shells bubble. So this rock, which reacts to acid, is **CHALK**, and this one, which doesn't, is **DIATOMITE**. Chalk is made of the shells of microscopic organisms known as foraminifera or coccolithophores. Diatomite is made of the shells of microscopic organisms known as diatoms or radiolaria. Both samples form where waters are still or low energy, so that usually means outer continental shelf, slope, rise, abyssal plain, or mid-ocean ridge. Calcareous-shelled organisms tend to dominate where there are some (not too many) nutrients in the surface waters, and those waters are warm. Silica-shelled organisms tend to dominate where deep water upwells bringing with it cold waters and high nutrient contents. Note: where nutrients are absent in the surface waters, marine organisms are absent in the surface waters, and land-derived clay minerals are all that settle out. Those clay minerals can be red, green, brown, or even white. When white, they are easily confused with diatomite and chalk. These white clay minerals, called kaolinite, are usually distinguished in such circumstances by their behavior of getting sticky when wet (instead of water soaking into the sample quickly and easily, which it does for diatomite).

Sand-sized and gravel-sized shell clasts settle out when waters are higher energy, so they tend to be found in warm coastal waters along the inner shelf where biological reef activity is high. (That also means that rivers must be absent, as they would dump high amounts of clay minerals which would destroy the reefs.)

Note: Clastic rocks made of carbonate shells are often loosely named limestone. Good to know that that term is often used to describe any and all sedimentary rocks made primarily of carbonate minerals. The same is true for silica shells and the rock being called chert. For purposes of this lab class, be sure to give the rock the more detailed unique name.

And now on to the rocks made of primarily rock and mineral clasts. **Detrital**. Again, we can order these by grain size as shown here, with gravels at the top, and muds at the bottom. Looking more closely at the gravel-sized clasts, we see that this rock contains clasts that are mostly rounded, while this one has clasts that are angular. We call a rock made of angular gravel-sized rock and/or mineral clasts a **BRECCIA**. One made of rounded gravel-sized rock and/or mineral clasts is called **CONGLOMERATE**. Note that both of these rocks usually have clasts of ALL grain sizes, displaying very poor sorting. But gravel-sized clasts dominate. Each rock gets a different name – breccia or conglomerate – because the environment in which angular clasts collect and are buried and eventually cemented into a breccia is very different than the environment in which rounded ones do. Rounded grains require water to move over and around the grains over a long period of time – either during transport, or while the rock is breaking down. So deposits leading to conglomerates could be found along the center or banks of a river bed high up in the mountains (where parent source material is nearby) or along a rocky coastline with high wave activity. Angular clasts mean that no running water was involved. Gravel-sized angular clasts in a deposit indicate catastrophic rock avalanche events, rock slides, or landslides, or deposits left behind by glaciers.

Rocks of sand-sized rock and mineral fragments, regardless of clast shape, are called **SANDSTONES**. There are three types of sandstone here, which are distinguished from one another by the primary composition of their clasts. A QUARTZ SANDSTONE has primarily quartz clasts – an ARKOSE SANDSTONE, potassium feldspar clasts, and a GREYWACKE SANDSTONE is made primarily of clasts that are fragments of rocks, as opposed to minerals. Sands collect in areas of moderate water energy – usually between rocky headlands in coves or downcurrent of rivers along a straight coastline. Sands can also be picked up by winds and transported and collected in sand dunes, either behind a coastal beach or downwind of an alluvial fan in the desert. Sand dunes usually collect only a particular grain composition – of a particular density, so they tend to be homogenous. More mixed piles of sand, like found in a greywacke sandstone, come from more immature piles of sand, nearby the parent source– like river banks upriver nearer to the mountains, or beaches formed primarily from erosion of the local headlands and cliffs.

A rock made of mud-sized mineral grains is called a **MUDSTONE**. Usually the grains are clay minerals – minerals that require a high-powered microscope to study, as they are found in the tiniest of grains (and thus we didn't study them during our minerals identification lab). Clays collect in low-energy water environments, such as lakes and lagoons or the outer continental shelf and deep abyssal plains. They are especially abundant in the oceans where large river deltas dump their loads or where surface waters are devoid of nutrients and hence marine plankton. As you can see here, there are two rocks with mud-sized particles – one is so densely packed that the clay minerals, which are sheet silicates similar to micas, have all aligned themselves atop one another, giving the rock a layered look with planar or semi-planar cracks. We call this rock **shale**. If we were to continue to put this rock under increasing burial and pressure, the clay minerals would line up even more perfectly, and gradually start to transform chemically from clays into micas. That would take us out of the sedimentary realm and into the metamorphic realm, producing a rock known as SLATE. We'll talk more about slate in the next video on Metamorphic Rocks.

There is one more type of clue that can help us learn more about a sedimentary rock's formation history. A good detective will also look carefully for **fossils** -- either fossilized life forms or fossilized structures. For example, this rock is filled with the fossils of shells of bivalves and snails. This one, sand dollars. Not only do the sand-sized mineral grains tell us the rock is a cemented old pile of sand, but the fossils tell us these sands were just offshore of an ocean beach. In fact, by studying sand dollars alive today, we can get a much better idea of where this old pile of sand was in the past. Furthermore, the species of sand dollar can take us one step further and tell us how old the rock is.

What about this rock? The fossil in this rock is not of an old organism but of an old surface process -- **ripple marks**. Again we can see where these form today and based on that learn that originally this mudstone sat beneath currents that moved in and out of a shallow water area creating symmetrical ripple marks in the underlying muds or sands.

And what about these? What are they? **Fossilized mud cracks**. Here we can see a recent example from Death Valley. So these muds used to be part of a dried up river or lake bed, in a dry climate.

This image of ancient sand dunes exposed in rocks in a cliff face demonstrate another structure: **cross beds**. We see cross beds in the formation of sand dunes today, as sands deposit on the lee side of a dune, in a uniquely tilted layer arrangement. When we see these same structures later in a rock, we know the sands in that rock used to be part of a Dune complex.

Clues like these combined with sediment grain size, shape, and composition, help us build a story of what Earth's surface looked like at various times in its past. And that's the story told by sedimentary rocks.

Pause now.

For more information and more detail, continue on to the next video in this series.

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