9.7: Sedimentary Facies

Environments and Facies

Scott Creek Beach, CA
Antidunes are common in creeks flowing across beaches. Here, they can be identified by the waves on the surface of the water. They were migrating upriver. When the eroding sand bank collapsed, the antidunes were disrupted and took 50 ft of seconds to reform. Faint beach stratification can be seen in the bank.

Look at the photo of Scott Creek Beach above. Note that the antidunes are forming in one part of a creek. The middle of the creek has upper planar lamination flow speeds, and the closest part is very shallow and has some antidunes again. (I know some of this from being there more than from looking at the photo.) Note that there is a faint lamination present in
the eroding bench on the far side of the creek. This lamination mimics the beach surface. It is lamination from the waves swashing and transporting sediment on the beach. If all sediment transport stopped immediately, one would see a suite of sedimentary structures: Antidunes and upper planar laminae next to each other in the creek, an erosional surface overlying planar stratification that undulates like a beach. The association of these features would tell you that the sediment was deposited in an environment with a variety of flow conditions.

The suite of structures forms a **facies**. A facies (Latin for aspect or appearance) is a body of rock (i.e. a sequence of beds) or sediment marked by a particular combination of compositional, physical and biological structures that distinguish it from bodies of rock/sediment above, below and adjacent to it. A sedimentary facies has a characteristic set of properties that makes it distinctive, which the geologist defines. Usually facies are defined based on a suite of characteristics in rocks/sediment.

**Facies vs Environments** - By grouping characteristics of the rocks into facies, the depositional environments can be more easily compared and interpreted. It is important to remember that the sedimentary environment is the combination of physical, chemical and biological processes that influence sediment deposition, whereas sedimentary facies are the characteristics of the rocks/sediments after deposition. It is the difference between a water flow speed of 20 cm/sec and high angle cross stratification; the stratification is the result of high flow speed, but they are not the same.

### Example Facies

Facies are groupings of rock types based on similar features. We use these groupings to generalize individual properties into useful, genetically related categories. Some examples include:

#### Facies based on grain size:

- Coarse-grained sandstone with 1-5% pebbles (suggests high flow speeds)
- Fine-grained, well-sorted sandstone (suggests low flow speeds with either only one size sediment source or a consistent flow speed)
- Mudstone (suggests standing water)

#### Facies based on sedimentary structures:

- Fine-grained sandstone with current ripple cross lamination
- Fine-grained sandstone with upper planar lamination
- Fine-grained sandstone lacking cross stratification, but with abundant burrows

#### Facies based on grain composition:

- Coarse-grained sandstone with 25% lithic fragments, 25% feldspar, and 50% quartz
- Coarse-grained sandstone with 80% quartz, 10% mica, and 10% feldspar
Coarse-grained sandstone with 99% quartz and trace gold flakes

**Beach Facies**

What features do we see in the photo of the beach? How should we divide those into facies? We can compare them to what we would see in the rock record. Take a look at photos of Scott Creek Beach stratification again: mygeologypage.ucdavis.edu/sumer/gel109/sedstructures/Beach.html. Describe some of the facies.

**Turbidites - Success of a Facies Model**

Turbidites provide a good summary of the ideas we have been talking about, e.g. facies and sedimentary structures related to flows. Turbidites are deposited from slurries of sediment and water in any standing body of water (lakes, oceans). (photos of turbidites)

1. Turbidity flows start with slope failure in soft sediment. Slopes become oversteepened where sedimentation rates are very high, such at the mouths of rivers. Because flow speeds are very low in standing water, the sediment does not get washed downslope. Rather, it builds up until there is a subaqueous slope failure. Earthquakes can trigger these slides, too.

2. Sediment and water mix creating a “fluid” that is denser than the surrounding water because of the entrained sediment. Thus, it flows downhill even if the slope is very low (1°).

3. The base of the flow is commonly erosional on steep slopes, so more sediment is entrained in the flow.

4. Enough sediment is entrained that erosion stops. Deposition begins as the slope gets shallower or the flow starts to slow down. Initially, the coarsest grains are deposited (remember the Hjulstrom diagram) and then finer grains, so the sediment is “graded”. However, the sediment is usually poorly sorted because the flow is a slurry of water and sediment so hydraulic sorting is reduced. (Facies = Bouma a)

5. Sediment concentration decreases with deposition, so one gets more hydraulic sorting. The flow is very fast so the sediment has upper planar lamination. (Facies = Bouma b)

6. As the flow slows more, grain size decreases and ripples start to form. Dunes do not usually form for two reasons: a) often only fine sand and finer grains are left in the flow by this point; and b) dunes do not have time to develop. (Facies = Bouma c)

7. Eventually, the flow slows to the point that bedload transport stops and deposition is mostly settling of silt and then clay. The progressive settling of coarser and then finer grains produces a faint lamination, but it is not as strong as the planar laminations in Bouma b. (Facies = Bouma d)

8. Mud settles out producing shale. This can look identical to background settling of clays brought into the lake/ocean as suspended sediment. (Facies = Bouma e)

Bouma divisions a-d can take hours or a day or so to be deposited. However, division e, which is usually the thinnest, commonly accumulates over months or longer (e.g. hundreds of years) depending on how frequent turbidites are in the area.

**Changes in Character Downslope**

The parts of turbidites that are deposited change downslope and usually only a few of the subdivisions are preserved. In the
most proximal (upslope) environments, divisions a and b are most common. In the more distal areas, all of the coarser sediment has already been deposited upstream, so divisions d and e are most common. Generally, there are also channels which fan out producing variations in rock types that change in space and through time.

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**Turbidite Facies Models**

Over the decades, sedimentologists have described and interpreted sedimentary rocks and defined generalized facies and facies associations that are characteristic of different depositional environments. These generalized facies and associations are called Facies Models. Each depositional environment or system has its own facies model. This is a VERY powerful tool for interpreting ancient environments. See my video summary: [http://www.youtube.com/watch?v=G05juwK2OTI](http://www.youtube.com/watch?v=G05juwK2OTI)


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**History of Turbidites and Their Interpretation**

Turbidite facies analysis and the resulting facies model led to the discovery of a new process. Sedimentologists had characterized turbidites all over the world. They all had the same flow characteristics consisting of a very strong erosive flow, deposition of a normally graded bed which was massive, followed by upper plane bedding, rippled finer sands, coarsely laminated silts, then shales. Comparisons with known flows showed that this sequence of deposits must come from a fast
initial flow that slowed through time to still water. And this repeated again and again. The associated facies and the succession of different facies in these sequences suggested that the deposits had to be in deep water. For example, the fossils were all characteristic of deep water, shales were abundant and are characteristic of still water (shallow or deep), and they were sometimes associated with deep water storm deposits. Thus, the sedimentologists proposed slope failure and turbid currents flowing down slope and called them turbidity currents. A process like this had not been observed in modern depositional environments, so the idea was controversial. Many geologists did not believe that you could generate strong enough currents underwater to get those flow characteristics. Eventually in 1964, two geologists Heezen and Drake realized that an event in 1929 provided strong evidence for turbidity currents. In 1929, which is long before there were satellites, under water telegraph cables were strung from Newfoundland to Europe. In November, about 30 cables broke in order from farthest north and shallowest to farther south and deeper water. At the time, people did not know why they broke, but Heezen and Drake suggested that a turbidity current was triggered by an earthquake and the cables broke as the turbidity current passed over them (they are strong flows!). Because they were continuously used for communication, the time each cable broke was precisely known. Heezen and Drake calculated that the front of the flow traveled at 250 km/h (36,000 cm/s) when the turbidite first formed and then slowed to around 20 km/h (7000 cm/s) by the time the last cables broke 500 km from the source. This was a fast, strong flow and may be typical of turbidites. These flow speeds are very erosive. It is only after the turbidite slows down even more that you get deposition. The characteristics of the flow seen by the breaking cables fit the flow characteristics proposed by the sedimentologists, and now turbidity currents and the facies model developed for turbidites are widely accepted and often treated as a good example of rocks that closely reflect flow characteristics. Turbidites and their interpretation are almost an ideal example of a good Facies Model.

**Extra on Dense Sediment Flows**

Sometimes with slope failures on land or under water, much more sediment can be put into motion than the flow would normally erode. Depending on the amount of water mixed with the sediment, the flow characteristics are different. When abundant water is present, the sediment can form a thick slurry with a higher density ($\rho$) than sediment-free water, commonly leading to a higher $Re$ and more turbulent flow:

$$Re = \frac{u \times l \times \rho}{\mu}$$

Also, collisions between grains become extremely important. Both of these tend to keep the sediment moving. Grain-to-grain collisions also make sorting much less efficient, and the sediment that gets deposited tends to consist of whichever grains make it to the base of the flow and are not kicked back up again. Usually, the largest grains are part of this first deposit because they weigh more, but small grains are also present. As the amount of sediment decreases, the flow becomes more like typical water flows. Turbidites are subaqueous flows that start out with a very high sediment load and decrease in time to more normal flows. They have characteristic sedimentary structures associated with them that reflect these changes.

If there is very little water associated with a clay-rich sediment flow, the flow can be very viscous due to the charge attraction among clay particles. The high viscosity reduces $Re$ (Equation $\ref{Re}$). Debris flows with lots of cohesive mud can even be laminar. In laminar flows, there is no mixing of the water or grains (or ice) and there is no sorting of grain sizes. Thus, the sediment remains mixed up with large grains, sometimes boulders, “floating” in mud. They flow down slopes pulled by gravity until the flow seizes up and stops. This can be due to too low a slope or loss of water. Underwater debris flows can
also be diluted by water that gets incorporated at the edges of the flow and become less viscous and more turbulent through time.

There also are dry sediment flows in which air is present between grains. For example, rock avalanches and some pyroclastic flows from volcanoes lack water. For these to move significant distances, large amounts of energy from either gravity or explosions are necessary to keep the sediment in motion.