GY 111 Lecture Note Series
Sedimentary Environments 5: Deep Marine Environments

Lecture Goals
A) Deep versus shallow marine environments (submarine fans)
B) turbidites and greywacke
C) chalk

Reference: Press et al., 2004, Chapter 7; Grotzinger et al., 2007, Chapter 5;
GY 111 Lab manual Chapter 3

A) Deep versus shallow marine environments
Last time we outlined deposition on continental shelves (or shelves for short). Recall that the sediment deposited on shelves is highly variable. Near shorelines, it is usually siliciclastic in composition because of the proximity to beaches, deltas and rivers. Further offshore, you might run into bioclastic sediment that is the product of biologically-influenced chemical sedimentation. If the calcite and aragonite that comprises these sedimentary deposits are largely the result of “beasties” (i.e., shells, skeletons etc), those rocks are called bioclastic. If the sediment is sand-sized and if it is in the form of ooids (a product of tropical sedimentation), that rock is called an oolitic limestone.

So now we turn our attention to deeper water environments. Recall this diagram:

Deep water depositional environments are those where sediment accumulated in water deeper than about 200 m (e.g., off the edge of the shelf). Some sediment is deposited on the slope as underwater landslides originating from the shelf break (usually as a mixed sandstone-boulder breccia), but most of the action takes place at the bottom of the slope on the abyssal plain:
The previous sketch should look vaguely familiar to you (I hope it does, you saw something like it in a lecture not that long ago). Sedimentation at the base of the slope tends to be concentrated into fan-like deposits at the mouths of **submarine canyons** that were carved into the shelf during times of low sea level (e.g., 18,000 years ago). Like alluvial fans, these deposits are fan-shaped and can be enormous (100's of km$^2$ in area). They are known as **submarine fans** and they are noteworthy for being one of the few modern depositional environments that geologists have not directly visited. How can we; they are in water 1000's of metres deep. At best, we can use high tech research submarines like the **USS Alvin**, but given the size of the fans (**Big!**) and the size of the subs (**tiny**), it would take a long, long, long time to get sufficient data to make any decent conclusions about anything (see image of the Alvin to the right from [http://www.oeb.harvard.edu/faculty/cavanaugh/images/alvin.jpg](http://www.oeb.harvard.edu/faculty/cavanaugh/images/alvin.jpg)).

Most of what we know about submarine fans has been learned through a combination of studying outcrops on land and through remote sensing, specifically 3D sonar technology. Submarine fans look like alluvial fans and have similar divisions (see cartoon on the bottom of the past page). They have incised channels (some even with meanders and levees!), and are prone to underwater landslides just like alluvial fans. But there is one big difference that makes submarine fans unique. In order to fully appreciate what that difference is, we have to travel back in time to 1929 and try to make a phone call from New York to London, England.

B) Turbidites and Greywacke

Back in the good old days, telephone calls were made from devices that were physically connected to one another via copper wires (does anyone even remember a day before cell phones?). There were a lot of telephone companies in those days and even more transatlantic cables laid from New York to London. One day in 1929, an earthquake occurred on the Grand Banks near Newfoundland. Soon after, those telephone cables began to break. Geologists believe that the earthquake generated an underwater landslide that took out the cables one after another.

<table>
<thead>
<tr>
<th>Cable Number</th>
<th>Time of break (minutes after earthquake)</th>
<th>Current Velocity (km/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>183</td>
<td>73</td>
</tr>
<tr>
<td>2</td>
<td>541</td>
<td>56</td>
</tr>
<tr>
<td>3</td>
<td>618</td>
<td>52</td>
</tr>
<tr>
<td>4 (300 miles from epicenter!)</td>
<td>797</td>
<td>41 (could move 3 cm grains)</td>
</tr>
</tbody>
</table>

As the table above shows, the "landslide" was really moving. Clearly, it was no ordinary landslide or at least, no ordinary alluvial fan-type landslide. On land, a landslide moves down hill because of gravity and high water content, but it soon runs out of "oomph". Consequently, they never get
that far down. But underwater, a landslide incorporates more water into the mass the further it flows. The more fluid the landslide, the faster it goes. Ultimately, the landslide turns into a "muddy" underwater current that hugs the seafloor as it flows down the submarine fan. These currents are called **density currents** and as the Grand Banks earthquake showed, they can be very fast and rip up anything on the seafloor in their path. The density current generated by the Grand Banks earthquake was still breaking cables 13 hours after the earthquake and traveled hundreds of kms across the abyssal plain at high speed.

Eventually, density currents slow down (they "wane") and as they do so, they start to deposit the sediment that they had been transporting. The deposit that is produced is unique and is called a **turbidites**. Turbidites are **graded beds** which means that the grain size of the bed fines upwards frequently from gravel at the base to mud at the top:

Turbidites range in thickness from a meter or more to only a few cm (see image to right of bedded turbidites in Canada, from http://www.gggl.ulaval.ca). Thicker turbidites are usually deposited at the base of submarine fans. The thinner ones can extend 100's of km across abyssal plains. The really impressive thing is that the outcrops that I told you that geologists studied to understand submarine fans consist of **thousands** of individual turbidites (see adjacent picture). Each turbidite is a relatively short duration event (hours?), but each turbidite is separated by potentially hundreds of years of non-turbidite deposition (represented by mud, the normal abyssal plain sediment). The outcrops represent millions of years of time, most of which was boring as far as sedimentation was concerned.

There is one other siliciclastic rock that needs to be introduced at this time; **greywacke** (see image to left). This is a type of "dirty" sandstone (one containing a lot of mud matrix between sand grains) that forms in a lot of different environments. However, in GY 111, we will conclude that it is a deep marine deposit (submarine fans, trenches).
C) Chalk
Siliciclastic sediment is not the only deep water deposit on the seafloor. You also get a very fine-grained biochemical sedimentary rock called **chalk** (see image to right from the White Cliffs of Dover in England, from www.subbrit.org). This is an incredibly fossiliferous type of limestone, but the fossils are all but invisible to the eye. Chalks are composed of **nannofossils**, like eckolithoporoids (see image to left from www.ucl.ac.uk), each measuring no more than 0.001 mm across (1/1000th of a millimeter!). A 1 cm³ piece of chalk (about the size of a sugar cube) contains 40 billion separate nannofossils.

It is all the more impressive when you realize that there are chalks around the world that are 100's of meters thick implying that they contain trillions upon trillions of nannofossils. Wow. We have a pretty good chalk here in Alabama worth mentioning before we finish today's lecture. The **Selma Chalk** was deposited around the time of the dinosaurs and now underlies a good chunk of central Alabama including, as you must suspect, the Selma area. Curiously, the Selma Chalk appears to have been deposited in relatively shallow water (e.g., on the shelf) implying that conditions were different in the past. Today, chalk only is deposited in deep water.

Summary deep water environments cartoon

**Important terms/concepts from today’s lecture**

(Google any terms that you are not familiar with)

- abyssal plain
- submarine fans
- submarine canyons
- density currents
- graded beds
- turbidites
- chalk
- nannofossils
- Selma Chalk