GY 402: Sedimentary Petrology

Lecture 21:
Shelves

Instructor: Dr. Douglas W. Haywick
Last Time

Carbonate Petrography

- **Beasties** (know your enemy!)
  - Corals
  - Molluscs (gastropods and bivalves)
  - Echinoderms
  - Brachiopods
  - Foraminifera
  - Bryozoans
  - Barnacles
Skeletal Allochems

**Corals**: common constituents in tropical limestones (especially rudstones/floatstones). Rugose and Tabulate orders were calcitic. Scleractinian corals are aragonitic.
Skeletal Allochems

**Molluscs:** common constituents in all limestones. Come in many shapes and sizes. Snails are aragonitic. Bivalves come in aragonitic and calcitic forms. There is a wide variety of “skeletal fabrics” in this phylum.
**Skeletal Allochems**

**Echinoderms**: common constituents in all limestones (especially Paleozoic-aged). Consist of sea urchins, sea stars, sea bisquits, and especially crinoids. Composed of calcite or Mg-calcite.

![Crinoid](image)

PPL (unstained) 1 mm
**Skeletal Allochems**

**Brachiopods**: common constituents in Paleozoic limestones. Rare in Mesozoic/Cenozoic limestones. Composed of calcite in either fibrous or prismatic textures.

**Brachiopod (fibrous)**

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**Brachiopod (prismatic)**
Skeletal Allochems

Foraminifera: common constituents in all muddy limestones. Rarer in grainstones. Composed of calcite, look for planktonic and benthic forms.
Skeletal Allochems

Bryozoans: colonial beasties that are ubiquitous in Paleozoic limestones. Less common in Meso/Cenozoic limestones. Composed of calcite. First evolved during the Latest Cambrian or earliest Ordovician. They are your Gods.
Barnacles: annoying arthropods that stick to the bottom of your boat. Formed from plates of calcite, they are common carbonate constituents, but really only dominate sediment in cold water limestones.
Today’s Agenda

Shelves

• Definition and a bit of history
• Factors controlling shelf sedimentation
• Carbonate Shelves
Continental Shelves

By definition: shelves are: "oceanic environments characterized by moderate water depths (10m to 150/200m) in which a variety of shallow marine and moderate depth facies occur"

Continental Shelves

Or... the low gradient, shallow marine areas that flank continents.

Continental Shelves

Shelves come in many flavors. **Pericontinental** shelves surround continents. **Epicontinental** shelves are flooded continents.
Continental Shelves

- Shelves have been studied for well over 100 years through a variety of techniques.
Continental Shelves

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- Idea about their formation and the processes that operate on them have evolved over this time…
Continental Shelves

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- Idea about their formation and the processes that operate on them have evolved over this time…

e.g., Shepard (1932) postulated that shelves were “graded”
Continental Shelves

• But detailed sedimentological analysis and geophysical mapping suggests that most shelves are not graded. Consider Australia….
Continental Shelves

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Continental Shelves

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Continental Shelves

- Currently, 50% of the world’s pericontinental shelves are “relict” artifacts left over from the last sea level low stand (e.g., 6000 + years BP).
- They are currently sites of reworking (especially bioturbation) and colonization by various benthic beasties, but little to no active sedimentation.
Continental Shelves

We currently recognize 6 types of shelves (5 of which are “depositional”).

1. **Siliciclastic**/detrital (sand, silt, clay)
2. **Biogenic** (carbonate sediment, shells, etc.)
3. **Residual** (*in situ* weathering of rocky substrates)
4. **Volcanic** (recent volcanic rocks)
5. **Authigenic** (chemical precipitates like glauconite, phosphate, dolomite)
6. **Relict** (which we will now ignore)

Time does not allow us to examine all these types of shelves, so we will only consider the first 2.
Factors influencing shelf sedimentation
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Six factors are recognized as influencing shelf sedimentation. The last three are designated as “biggie” factors.

1) **Sea level fluctuations** (controls distribution of relict sediments, barrier reefs etc.)
2) **Animal-sediment interactions** (modifies the substrate)
3) **Chemistry** (produces authigenic minerals)
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4) Type and **rate of sedimentation**
5) **Climate**
6) Type and intensity of **shelf hydraulic regime** ("energy")

Biggies
Factors influencing shelf sedimentation

Type and rate of sedimentation

Surprisingly, direct sediment supply to and across shelves is pretty negligible except in areas adjacent to very large rivers and estuary systems. Most sediment is strung out parallel to shorelines due to long shore drift.
Factors influencing shelf sedimentation

Type and rate of sedimentation

Situation 1: “Normal” - a balance between sediment input and longshore drift resulting in a classic shoreline-hugging sediment wedge.
Factors influencing shelf sedimentation

Type and rate of sedimentation

Situation 2: “High-energy shoreline” – mud is transported from the nearshore across much of the shelf before being deposited.
Factors influencing shelf sedimentation

Type and rate of sedimentation

Situation 3: “very-high sedimentation” – sediment blankets the whole shelf. This only happens adjacent to 12 rivers in the world (including the Mississippi).

Modified from McCave (1972)
Continental Shelves

Climate

Controls shelf sedimentation by its effects on the surrounding land mass (siliciclastic source area).

- Wet and hot (tropical) = intense chemical weathering and clay production
- Cold and dry (temperate) = physical weathering and sand/gravel production

Modified from Hayes (1967)
Continental Shelves

Hydraulic regime

Three dominant processes are responsible for transporting, reworking and sorting sediment on shelves (including relict areas).

1) Tide-dominated shelves (17% of pericontinental shelf areas)
2) Ocean current-dominated shelves (3% of pericontinental shelves)
3) Storm-dominated shelves (80% of pericontinental shelf areas)

We will only consider tide- and storm-dominated shelves
Tide-dominated Shelves

An excellent example of tide-dominated shelves is the English Channel

From Reading (1975)
Tide-dominated Shelves

- Macrotidal environment (+/- 4m tides)

From Reading (1975)
Tide-dominated Shelves

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Ancient sedimentary sections deposited on tidally-influenced shelves are characterized by herring bone cross-bedding

From Reading (1975)
Storm-dominated Shelves

Along our shelf, we can expect a tropical storm every year, a category 1/2 hurricane every couple of years and a category 3/4 hurricane every 10 or so years. A category 5 storm might occur every 25-50 years.
Storm-dominated Shelves

A tropical cyclone can cause more change in a coastline (and on the shelf) in one day than fair-weather processes did in 10 years…

… but what about the really big storms?
Storm-dominated Shelves

e.g., 100 year, 500 year, 1000 year or 10,000 year storms?

Although incredibly rare, they would make major impacts on shelf sediments that might be preserved in the rock record.

http://apod.nasa.gov/apod/image/redspot_gal.gif
Storm-dominated Shelves

Storm-dominated Shelves

HCS (hummocky cross-stratification)

From: Harms et al. (1975)

From Walker and James (1992)

Remember HCS?

http://course1.winona.edu/csumma/images/sedstrux/hcs8a.jpg
Carbonate Shelves

Unlike their siliciclastic analogs, biogenic (carbonate) shelves are largely the products of *in situ* sedimentation. Moreover, carbonate shelves tend to be more complex for 2 reasons:

1) They are made up of diverse biological communities (and some are temperature-limited)

2) Evolution has changed those beasties over time.

Temperate vs Tropical Carbonate Shelves
Temperate vs Tropical Carbonate Shelves

Carbonate Shelves

No discussion on shelves would be complete without the Bahamas; a classic tropical biogenic (carbonate) shelf.

http://www.nationsonline.org/gallery/Bahamas/bahamas360.jpg
Carbonate Shelves

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http://www.nationsonline.org/gallery/Bahamas/bahamas360.jpg

From Bathurst (1975)
Carbonate Shelves

- Area: 700 x 300 km
- Depth: 0 m to 200m (mostly < 3 m)
- Tongue of Ocean: 3500m deep
- Mesotidal (2 to 4 m tidal range)
- Also storm-dominated
- 3.5 to 4 m of Recent sediment
- Sedimentation rate ≈1000mm/1000yrs

From Bathurst (1975)
Carbonate Shelves

The Grand Bahama Bank can be divided up into a series of facies. The type depends on your discipline.

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• Geologists: Lithofacies (i.e., sediments)

• Biologists: Biofacies (i.e., beasties)
Carbonate Shelves

The Grand Bahama Bank can be divided up into a series of facies. The type depends on your discipline.

• Geologists: Lithofacies (i.e., sediments)

  Habitat/substrate (i.e., reef, rocky, sediment...)

• Biologists: Biofacies (i.e., beasties)

http://www.fishchannel.com/images/article-images/reef-habitat2-500px.jpg
The Grand Bahama Bank can be divided up into a series of facies. The type depends on your discipline.

Lithofacies

1) reef (reef + coralgal)
2) oolitic (oolite + grapestone)
3) mobile oolite
4) mud
Tropical Carbonate Shelves

The Grand Bahama Bank can be divided up into a series of facies. The type depends on your discipline.

1) reef (skeletal rudstone/floatstone)

From Bathurst (1975)
Tropical Carbonate Shelves

The Grand Bahama Bank can be divided up into a series of facies. The type depends on your discipline.

2, 3) oolitic (grainstone/packstone)
Tropical Carbonate Shelves

The Grand Bahama Bank can be divided up into a series of facies. The type depends on your discipline.

4) mud (mudstone)

http://strata.geol.sc.edu/Bahamas/pages/
Upcoming Stuff

Homework
1) Write 6 (ML lit review) due Thursday by 5 PM

Lab this Week
Non skeletal Limestones

Online:
Nothing; online lectures are done for the semester

Thursday
1) Reefs (Lecture 26)
Friday 4:00 PM depart to Moscow Landing