CARBONATE PLATFORM DEPOSITIONAL SYSTEMS

I. Distribution: "carbonate sediments are born, not made"; virtually all carbonates are formed within their depositional environments, or at least close to them; "platform" refers to shallow water carbonate systems.

A. Present carbonate platform systems: when we look at modern carbonate systems, we are reminded once again that the present is not always a good key to the past.

1. Global distribution: present shallow water carbonate systems are found in low latitudes, generally between 30° north and 30° south of the equator; there are some special carbonate sediments made entirely of shell fragments in some temperate areas (like the North Sea), but these are relatively insignificant.

2. "Subtidal carbonate factory": most carbonate material is generated in shallow subtidal marine waters; some of it is transported shoreward and some basinward.

3. Low terrigenous influx: carbonate systems develop where there is little (like Florida) or no (like the Bahamas) significant influx of terrigenous sediments, which would stifle the growth of carbonate producing organisms.

B. Ancient carbonate platform systems:

1. Global distribution: ancient carbonates are found almost everywhere; limestones are among the most common sedimentary rocks.

2. Distribution in time: limestones are found in every system, but huge deposits were formed in the Ordovician, Devonian, Mississippian and Cretaceous; developed in extensive carbonate seas spread widely across the continents.

II. Sedimentation processes: carbonates are like siliciclastics, but different.

A. Usual physical processes: all the previously discussed physical processes, such as gravity, waves, tides, currents, bioturbation, and so forth interact with carbonate sediments as they do terrigenous siliciclastics; the generation of bedforms and cross-stratification parallels that of the siliciclastics.

B. Special factors: carbonate sediments, though, are different in some ways that go beyond just grain density and mode of formation.

1. Intensity of storms: storms are strong in the low latitudes, where carbonate sediments are most prominent; carbonate sediments are thus usually more affected by storms than their terrigenous counterparts.

2. Cohesion of fine particles: all clay-size sedimentary particles adhere (remember Hjulstrom's Diagram?), but it is an especially prominent process in calcareous muds.

3. Early cementation: carbonate sediments can be cemented quickly within the depositional environment, even before significant burial; this will have an important effect on carbonate sedimentary systems.

4. Biological production of grains: organisms are constructing grains in situ, so grain size does not often directly reflect environmental energy levels.

5. **Light penetration:** since biological production is a primary carbonate-producing process, the amount and type of light which penetrates the water will be a primary control; blue light penetrates farther than red light; some organisms require particular wavelengths for photosynthesis.

III. Organic framework reefs: one of the most important carbonate systems.

A. *Reef* definition: a wave-resistant framework built by organisms.

B. Carbonate accumulations: sediments accumulate in the reef environment in a variety of ways.

1. **Framework:** most modern reefs have an interlocking framework of corals and algae; ancient reefs have been built of brachiopods, sponges, clams and other organisms; resists wave action.

2. **Biogenic debris:** sediment, from shells to fine muds, accumulates in the protected spaces in a framework; there are some very low energy environments in even the highest energy reef.

C. Reef types: the classic system developed by Charles Darwin.

1. **Fringing:** attached to the land (island or continent).

2. **Barrier:** a lagoon between the reef and the land.

3. **Atoll:** barrier reef around a volcanic island, which has subsided, leaving just the reef, which continued to grow upward (to stay in the photic zone).

D. Reef facies and sediments: reef-related sediments are relatively easy to distinguish between environments in the reef system.

1. **Reef front:** sometimes called the windward reef; exposed to the open ocean; coarse reef talus develops on this seaward side.

2. **Framework:** interlocking organisms providing the structure of the reef; much sediment accumulates between the branches.

3. **Lagoon:** protected, relatively low energy waters; usually lots of well bioturbated carbonate muds; half the sediment may be pelletal.

E. Ancient reefs: many examples in the fossil record.

1. **Silurian of the Michigan Basin:** barrier reefs surrounding evaporative basins; mostly tabulate corals.

2. **Devonian of western Canada:** important to the oil industry; petroleum generated in the slope and basinal organic-rich sediments, which have buried the reefs in a general transgression; petroleum migrates up dip and is trapped in the porous reef (diagram); mostly tabulate corals.

3. **Permian of west Texas:** made predominantly of brachiopods and calcareous algae; formed around basins and along shelf edges.

4. **Pleistocene of the Bahamas:** juxtaposed with modern reefs; records of recent sea level changes.

IV. **Supratidal (sabkhas):** common on broad, low-relief carbonate coasts.

A. **Supratidal processes:** above the highest usual tide line.

1. **Storm waters:** bring water into the system, dumping it into lakes or ponds.

2. **Evaporation:** the seawater evaporates, becoming richer in solutes.

a. **Evaporative minerals:** mineral sequence precipitates out in an order we will discuss later.

b. **Dolomitization:** with increased evaporation, magnesium levels increase; dolomite can either form directly or replace calcite or aragonite; we will talk about this later.

V. **Tidal flats:**

A. **Like siliciclastic counterparts:** sediments deposited between the low and high tidal levels.

B. **Exceptions:** carbonate sediments will be different from siliciclastics.

1. **Cohesion of lime muds:** like clay minerals, lime mud particles easily cohere to each other.

2. **Early cementation of carbonate sediments:** carbonate sediments often cement up quickly just after deposition; an example would be beachrock.

C. **Stromatolites:** form when mats of bacteria bind layers of sediment. [Covered earlier.]

VI. **Eolianites:** wind-blown carbonate sediments; always formed in association with carbonate beaches.

A. **Coastal dunes:** the carbonate sediment is derived from the beaches and shallow subtidal, then moved by the wind.

B. **Bedforms:** very common in eolianite deposits.

1. **Ripples and dunes:** identical to their siliciclastic counterparts.

2. **Root casts and molds:** much more common in eolianites because the sediment often cements around the roots.

C. **Ancient eolianites:** Pleistocene and Holocene of the Bahamas.

VII. **Shallow ramp:** the nearshore part of an extended, gradually deepening platform extending to the sea.

VIII. **Ooid shoals:** formed above wavebase on carbonate ramps and platforms under the right chemical, biological and hydrodynamic conditions.

A. **Agitation:** essential for unearthing and burying the developing ooids.

B. **Bedforms:** ooid shoals are usually dominated by waves and tidal currents.

1. **Ripples and dunes:** often show results of bidirectional processes; cross-stratification is prominent, partly because there are few infaunal organisms to cause extensive bioturbation.

C. **Oncoids:** algally-bound balls of sediment; like stromatolites, only they roll around.

D. **Ancient ooid shoals:** Mississippian of Ohio River Valley.

IX. **Deep ramp:** typically below wavebase, but still in the photic zone.

X. **Slope and Basin:** below the photic zone, so the sediment is most typically derived from above, either in the water column (as pelagic shells) or swept off the shallower shelf and ramp.

XI. **Organic banks (including *mud mounds*):** usually found on the shelf/slope break.

A. **Mostly Paleozoic:** it is always curious when a sedimentological phenomenon is restricted by age.

B. **Stromatactis:** isopachous veins of carbonate cement through what is usually micrite.

C. **Origin hypotheses:** mud mounds may be constructed by the baffling properties of organisms like sponges and corals; another idea is that they are associated with methane vents ("cold seeps"), which we'll talk about later.