Building an Idealized Stratigraphic Sequence – Clastic Shoreline Example

William W. Little

Purpose:

The purpose of this exercise is to guide students through the process of constructing a stratigraphic sequence based on understanding relationships between the production of space and filling that space with sediment.

Objective:

The ultimate goal is that students can take the fundamental model and modify it to reflect changes in the relative abundance of these two factors (space and fill).

Methods:

In-class Discussion:

Students are asked leading questions to guide them through the steps of constructing a stratigraphic sequence from the lower boundary through each systems tract to the capping boundary. Questions are based heavily on space/fill relationships as related to changes in the direction and rate of base level. The discussion assumes a previous introduction to these concepts. Most formal terminology is saved for the end of the discussion to maintain focus on concepts, rather than words.

As this is an undergraduate course, I have attempted to simplify, but not falsify, concepts. A task I'm not sure I've always achieved.

Laboratory Exercises:

The exercises I used are described at the end of this document. Their purpose is again to help understand concepts, rather than just memorize terminology.

Position within Course:

Sequence stratigraphy is the concluding topic for my upper division course on sedimentology and stratigraphy.

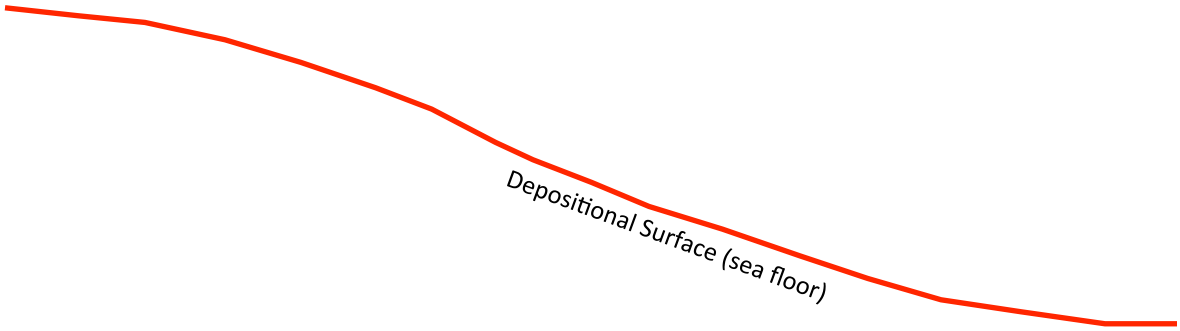
In-class Discussion

What is a sequence?

The stratigraphic record of base-level change from highstand to lowstand back to highstand.

What elements are needed to construct a stratigraphic sequence?

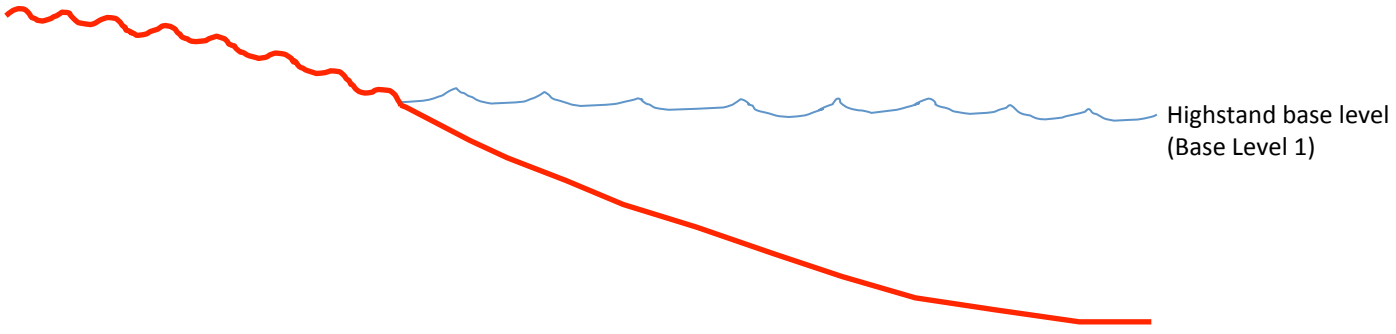
A basinward-sloping depositional surface



What is the significance this surface?

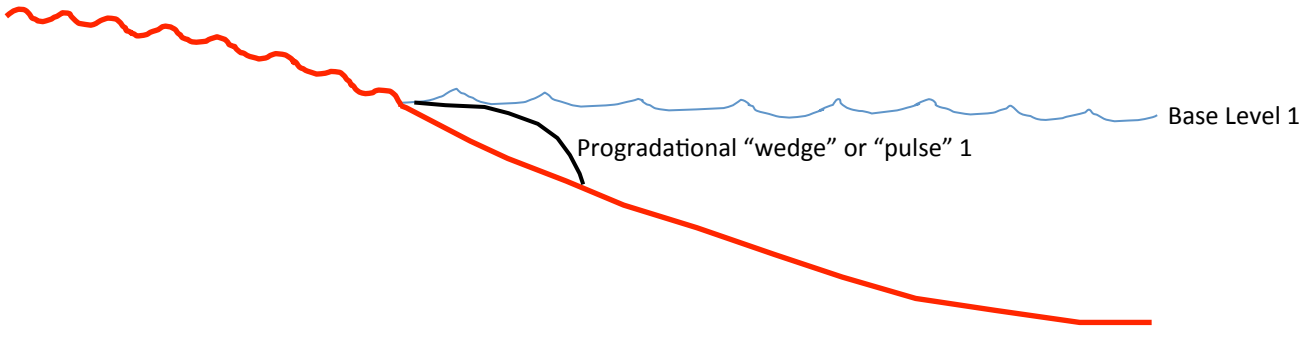
It is a platform over which sediment can accumulate, forms the base of a sedimentary deposit, and represents the boundary between depositional events.

An intersecting base-level surface



What is the significance this surface?

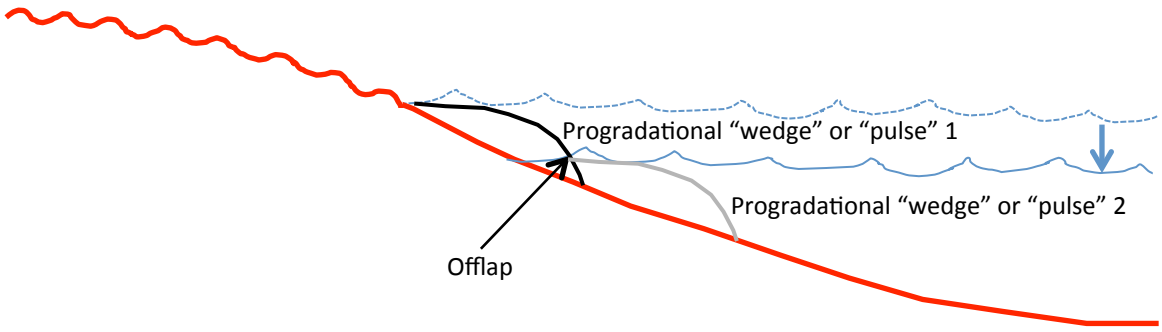
It limits the depth to which erosion can occur landward of the shoreline and the elevation to which sediment can accumulate basinward.

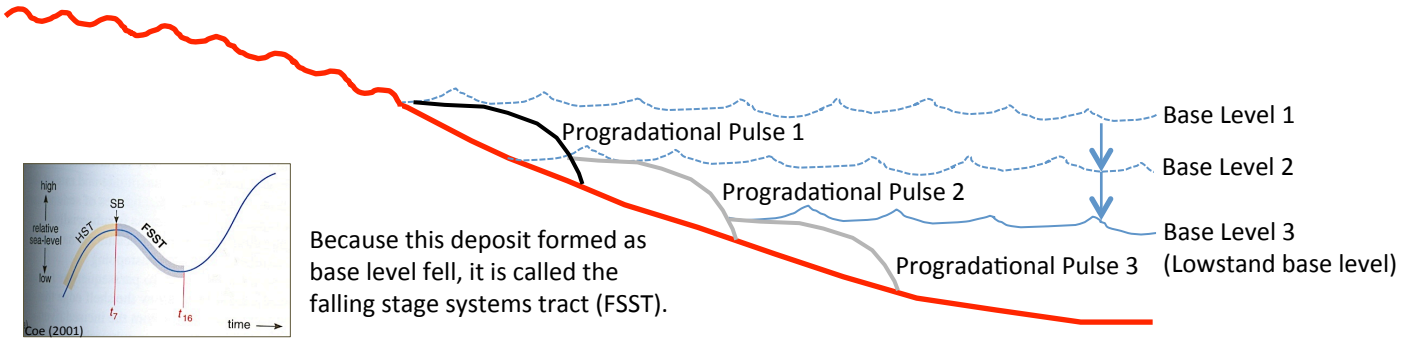


What happens when base level drops?

The zone of erosion extends basinward, down the previous depositional slope, and sediment is reworked basinward and downward due to a loss of accommodation space. New deposits offlap previous deposits as a downstepping set of progradational pulses (progradational parasequence set). This is referred to as a forced regression.

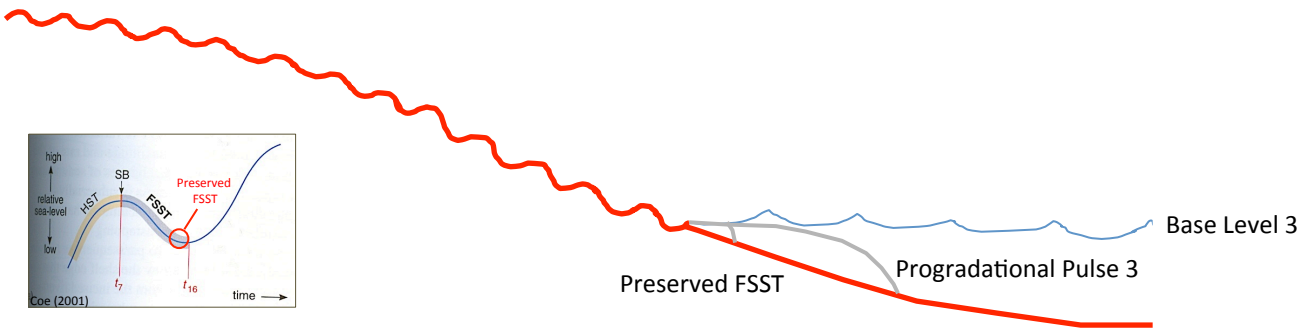
Diagram the sediment shift first to show the offlaping relationship.





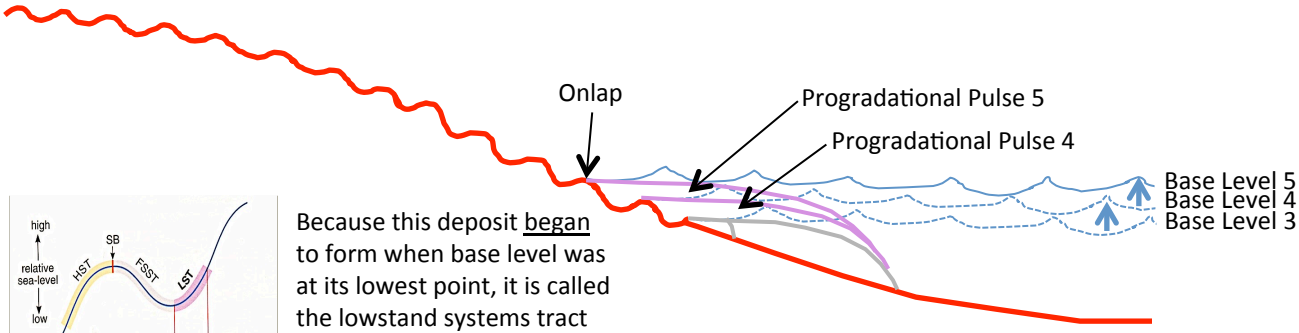
Because this deposit formed as base level fell, it is called the falling stage systems tract (FSST).

Add erosion to give a more realistic picture of the preserved deposit. Notice that Progradational Pulse 1 has been entirely "cannibalized" and Pulse 2 is mostly gone.



What happens when base-level begins to turn around and slowly rise?

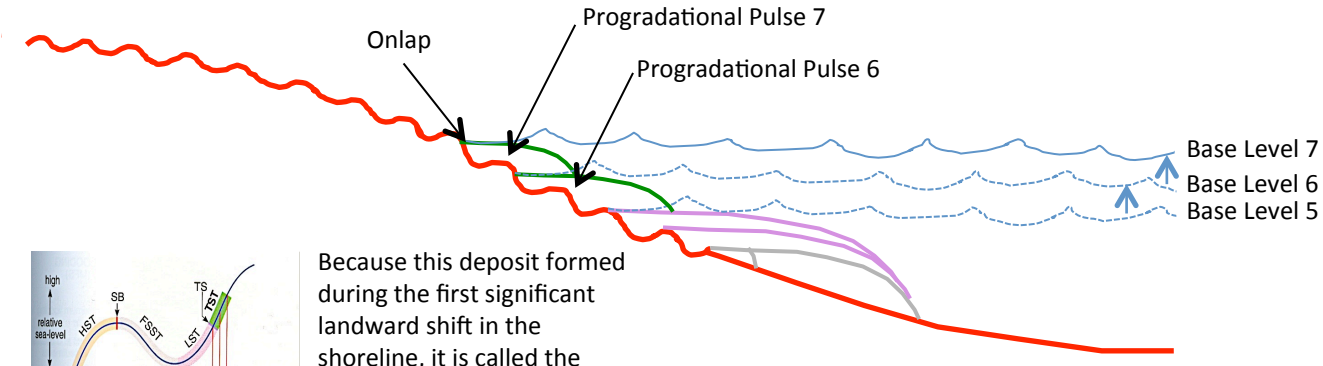
The erosional surface ceases its basinward extenstion, and sediment begins to accumulate vertically as new accommodation space is produced. The new deposits onlap the most basinward portion of the erosional surface as a set of vertically-stacked progradational pulses (aggradational parasequence set).



Because this deposit began to form when base level was at its lowest point, it is called the lowstand systems tract (LST).

What happens when base-level rises rapidly?

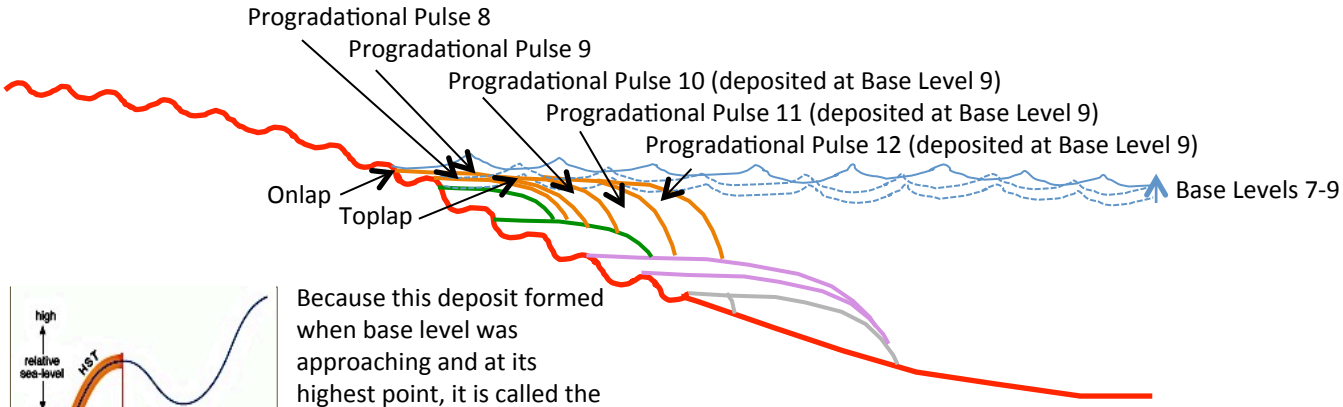
Deposition shifts landward as new accommodation space is produced more rapidly than it can be filled, forming a strong onlap pattern over the erosional surface and sediment starvation basinward, resulting in a retrogradational set of progradational pulses (retrogradational parasequence set). I realize my wording in the last sentence is a bit awkward; however, one concept I've found I need to continually emphasize is that sediment always moves basinward, even when the shoreline is retreating; therefore, I repeat the word "progradation" on every step.



Because this deposit formed during the first significant landward shift in the shoreline, it is called the transgressive systems tract (TST).

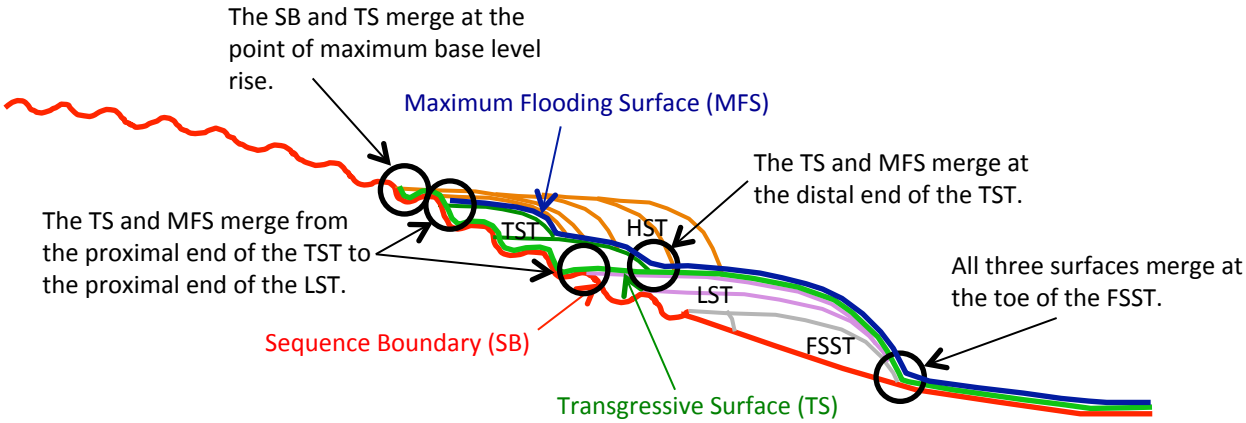
What happens as base level rise slows and finally stalls?

Deposition is able to keep pace with, then overwhelm space production, transitioning from onlap to toplap, as depositoinal patterns change from aggradational to progradational sets of progradational pulses (aggradational to progradational parasequence sets).



Because this deposit formed when base level was approaching and at its highest point, it is called the highstand systems tract (HST).

Add the remaining named sequence stratigraphic surfaces.



Why do these surfaces merge at the four locations circled on the above cross section? Number them 1 through 5 from left to right.

1 & 3) The sequence boundary along this stretch is erosional and formed as base level fell; therefore, during a subsequent rise in base level sediment will, by necessity, lap onto this surface.

2) The transgressive surface forms as long as the rate of base-level rise outpaces the rate of sedimentation and is found along the base of sediment deposited during this rise. At the point in time where the sedimentation rate out paces the rate of base level rise, new deposits prograde over the top of those that accumulated during the "rapid rise." The boundary between deposits of these two events is the maximum flooding surface and represents the "turn around" in the direction of shoreline movement.

4 & 5) These are areas of sediment "starvation" during invervals of rapid rise to highstand. In reality, there is likely to be a thin interval of sediment representing these boundaries, possibly dominated by thin carbonate deposits.

Summarize the characteristics of each sequence stratigraphic element, beginning at the base. These are factors that I work in as questions during the previous presentation.

Sequence Boundary:

- A surface
- Forms either during a lowering of base level (type 1) or a during a significant slowing of base level rise (type 2)
- Erosional landward of the shoreline and non-depositional to conformable basinward
- Recognized either by truncation of underlying strata or by abrupt juxtaposition of more proximal facies over more distal facies

Falling Stage Systems Tract:

- Progradational parasequence set
- Forms during same time frame as the SB and represents a forced regression
- Can often be recognized as proximal deposits abruptly overlying significantly more distal deposits
- Possibly identified by offlaping the sequence boundary
- Can be physically detached from the rest of the sequence
- Poor preservation potential
- Often not identified or combined with the LST

Lowstand Systems Tract:

- Aggradational parasequence set
- In proximal portion, often overlies an erosional contact that represents sediment bypass
- Forms during the initial rise of base level, as sediment begins to accumulate in the earlier bypass channel
- Recognized as more proximal deposits over more distal deposits
- Onlaps the sequence boundary

Transgressive Surface:

- A surface
- Forms as the rate of base level rise begins to out pace the rate of deposition
- Represents sediment starvation
- Can often be recognized by more distal facies abruptly overlying more proximal facies
- Can be erosional due to wave reworking

Transgressive Systems Tract:

- Retrogradational parasequence set
- Deposited during interval when the rate of base level rise is greater than the rate of deposition
- Recognized by position between the TST below and MFS above
- Tends to be absent in more basinal sections, thin in coastal regions, and thickest in fluvial-dominated proximal regions

Maximum Flooding Surface:

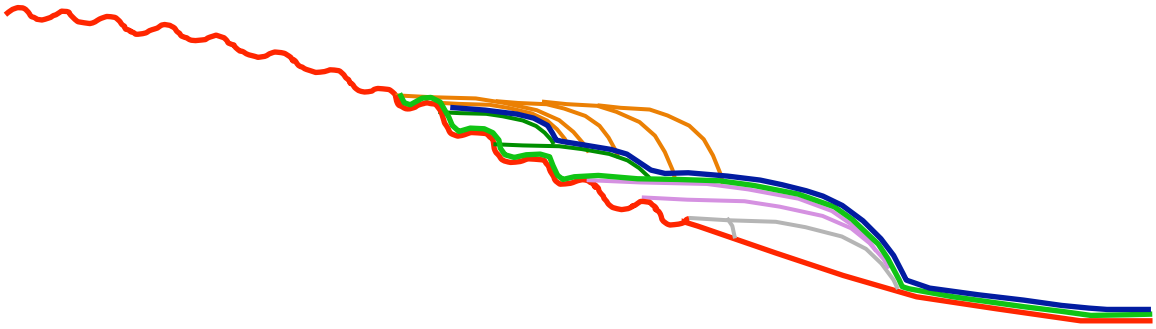
- A surface (may be more of a graded interval)
- Represents the turnaround from coastal transgression to regression
- Recognized by transition from more distal deposits below to more proximal deposits above

Highstand Systems Tract:

- Aggradational (at base) to progradational (toward top) parasequence sets
- Forms as the rate of base level rise slows, representing a normal regression
- Can produce a thick wedge of sediment that progrades over any of the other systems tracts
- Capped by the next sequence boundary

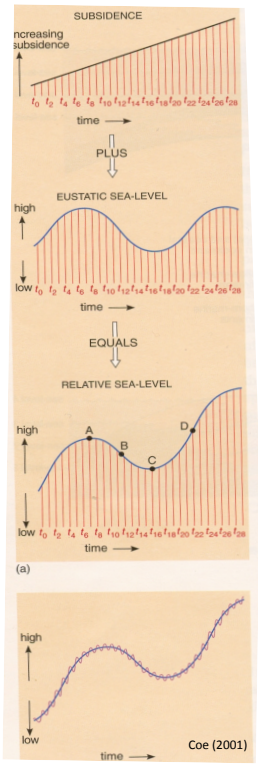
Lab Exercises

As a lab exercise, I have them take the diagram they created during the lecture and add a second sequence boundary and sequence. I have found this can be a significant challenge, but once they succeed, they firmly understand the concepts.



This can be drawn in a variety of ways. Choose somewhere to cut through the previous sequence, and build a new one above the new boundary.

Another lab assignment is to take the the base level chart from their textbook (below) and modify the model based on a much steeper and much flatter subsidence rate, as they stack three sequences. The idea is to get them thinking about preservation potential, as well as Type 1 vs. Type 2 sequence boundaries. The results are interesting. Unfortunately, I haven't saved any of the papers. I'll do so when I teach the course this fall and, afterward, update the exercise on this site.



To relate sequence stratigraphy to real rock successions, I use the Book Cliffs exercises on the SEPM Strata site: http://www.sepmstrata.org/page.aspx?pageid=53, supplemented with my own photographs and figures.