The Six Surfaces of Sequence Stratigraphy

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Each different type of stratigraphy uses a specific property of sedimentary rocks to allow changes to be determined and correlated so as to generate stratigraphic boundaries and associated units. To understand what makes a given type of stratigraphy "tick" and how to best apply it, it is critical to understand what basic rock property change is used to delineate stratigraphic contacts for that discipline. Furthermore, it is also important to know what phenomena are responsible for generating these changes in the rock record in the first place. For example, when one considers biostratigraphy, it is clear that changes in fossil content are used to delineate the boundaries of biostratigraphic units. We also know that such changes in fossil content are mainly driven by a combination of evolution and shifting environments. With this knowledge we can go a long way in understanding the basic tenets of biostratigraphy.

In sequence stratigraphy we utilize various changes in depositional trend as boundaries. Examples of such changes in trend are the change from sedimentation to subaerial erosion and the change from transgressive sedimentation to regressive sedimentation. These changes, which are recognized as specific types of surfaces (e.g. subaerial unconformity for the change from sedimentation to subaerial erosion), are used as the boundaries of the units of sequence stratigraphy (e.g. sequence, systems tract). We know that such changes in depositional trend and associated recognizable surfaces are generated by the interplay between rates of sedimentation and the rates of creation or destruction of accommodation space. Such changes in accommodation space are due to tectonic movements, eustatic sea level change, compaction and climate change and the sum of all these changes is commonly referred to as stratigraphic base level change. This provides us with a working definition of sequence stratigraphy: **"Sequence stratigraphy consists of the recognition and correlation of changes in depositional trends in sedimentary rocks. Such changes, which were generated by the interplay of sedimentation and oscillating base level, are now determined by sedimentological criteria."**

There are two main types of change in depositional trend which result from base level movements. These are 1) a change from sedimentation and accumulation to erosion or greatly reduced sedimentation and vice-versa and 2) the change from a regressive trend to a transgressive one and vice-versa. During a cycle of base level rise and fall, seven important changes of depositional trend, which represent variations of the two main types, occur. Four occur during base level rise and three during fall. These changes happen over either a short or long time interval when compared to the duration of the complete cycle. These seven changes in depositional trend are:

Base level rise

1) expansion of deposition and accumulation of nonmarine strata in a landward direction across a subaerial erosion surface.
2) change from a regressive trend to a transgressive one in a marine succession.
3) cessation of sedimentation along the shoreline and the migration of shoreface erosion landward during transgression.
4) change from a transgressive trend to a regressive one in nonmarine and marine strata.

Base level fall

5) cessation of sedimentation on the basin edge and the gradual basinward expansion of subaerial erosion
6) development of sea floor erosion on the inner shelf and gradual basinward migration of this erosional area
7) cessation of deposition on large portions of a marine slope.

These seven significant changes produce six distinctive, recognizable horizons in the sedimentary record and these horizons are the ones that can be used for sequence stratigraphic analysis.

When base level starts to rise, new accommodation space begins to be created in areas formerly undergoing erosion. This results in the landward expansion of the basin margin and a progressive onlap of the underlying **subaerial unconformity** by nonmarine strata throughout the entire time of base level rise. With rising base level, less sediment is transported to the marine portion of a basin because of reduced fluvial gradients and increased sediment storage in the nonmarine area along the expanding basin margin. During the initial stage of rise, enough sediment still reaches the marine area to allow the shoreline to continue to advance basinward (regression) as it had during the previous time of sea level fall. However such advancement occurs at a declining rate until finally the rate of base level rise at the shoreline exceeds the rate of sediment supply. At this time the shoreline ceases its seaward movement and begins to shift landward (transgression). This change from regression to transgression results in two major changes in depositional trend. Along the shoreline, net erosion occurs and this zone of shoreface erosion moves landward during the transgression. The resulting erosion surface is known as a **shoreface ravinement** and it develops during the entire time transgression occurs. Also with the initiation of transgression, finer sediment starts to be deposited at any given shelf locality due to the increasing distance from the sediment source as well as the overall reduced supply to the marine area. This results in a significant change from a coarsening upward trend that characterized the preceding regression to a fining-upward one. The horizon that marks this significant change is termed a **maximum regressive surface**.

Eventually the rate of base level rise slows and sedimentation at the shoreline once again exceeds the rate of removal by waves. The development of the shoreface ravinement stops and the shoreline reverses direction and begins to move seaward (regression). This results in increased sedimentation to the marine basin and coarser sediment begins to prograde across the shelf. This produces a change from a fining-upward trend to a coarsening-upward one and the horizon that marks this change in trend is termed a **maximum flooding surface.** Thus three sedimentary horizons which represent changes in depositional trend are produced during base level rise. These are maximum regressive surface, shoreface ravinement and maximum flooding surface. Also during this time, the subaerial unconformity that developed during the preceding base level fall is progressively covered with sediment completing its development as a distinctive stratigraphic horizon. Notably, in many cases, most of the subaerial unconformity is eroded by the shoreface ravinement as it advances landward.

With the start of base level fall, sediment accommodation space begins to be reduced and sedimentation ceases on the basin margin. Subaerial erosion advances basinward during the entire time of fall and this produces a **subaerial unconformity** that reaches its maximum basinward extent at the end of base level fall. The seaward movement of the shoreline, which began in the waning stages of base level rise, continues throughout base level fall but at a faster pace. Also when base level starts to fall, the inner part of the marine shelf begins to be eroded. This is due to the regrading of the shelf as it attempts to equilibrate with falling base level. This inner shelf erosion surface migrates seaward during the entire interval of base level fall and is progressively covered by prograding shoreface deposits. This results in a highly diachronous horizon known as the **regressive surface of marine erosion**.

In some instances during the interval of base level fall, when the basin edge reaches, or is near to, the shelf edge, a profound sedimentation change occurs on the marine slope. In clastic environments almost all of the incoming sediment is commonly channeled down submarine canyons and much of the slope becomes an area of greatly reduced sedimentation or even erosion. This surface is eventually onlapped by laterally expanding submarine fans and slope aprons and is termed a **slope onlap surface**. In carbonate environments a slope onlap surface develops when the platform is exposed during base level fall and the carbonate factory shuts down. This results in the starvation of the slope that is eventually onlapped by younger sediments of varied origin.

In summary, six distinctive surfaces are formed during one oscillation of base level. Three surfaces are formed during base level rise: shoreface ravinement, maximum regressive surface and maximum flooding surface and three surfaces are formed during base level fall: subaerial unconformity, regressive surface of marine erosion and slope onlap surface.

Of these six surfaces, the subaerial unconformity, the shoreface ravinement that has eroded through a subaerial unconformity, the maximum regressive surface and the maximum flooding surface have significant utility in sequence stratigraphy. The subaerial unconformity, shoreface ravinement and maximum regressive surface are used to form the boundaries of a sequence and the maximum flooding surface is used to subdivide such a sequence into a transgressive systems tract below and a regressive systems tract above.