FUNDAMENTALS OF SEQUENCE STRATIGRAPHY

Nivedita Chakraborty
Department of Geology
Kabi Jagadram Roy Government General Degree College

Introduction

Inception of sequence stratigraphy is the most recent and significant revolution in the field of sedimentology and stratigraphy. Since emergence, it gradually evolved as a process based working methodology in interdisciplinary research fields of geoscience. Sequence stratigraphy deals with genetically related strata in space and time, in a sense of absolute or relative. It is essentially based on analysis of cyclicity in the sedimentation record controlled by some fundamental natural parameters; such as sediment supply, tectonic subsidence, sedimentary processes etc. (Posamentier and Allen, 1999). Sequence stratigraphy marks the breaks in stratigraphic record through identification of stratigraphic units and their bounding surfaces; thereby providing a framework of stratal architecture. It helps to understand the origin of geomorphic elements within any particular depositional system through analysis of nature of sediments (autochthonous or allochthonous), facies relationships and their sequential organization in a three dimentional outline. In a way, sequence stratigraphy examines depositional trend within a basin in response to change in base level and rate of sedimentation in chronologic terms (Catuneanu et al., 2009). Application of sequence stratigraphy is therefore diverse: decoding the Earth's geological record in terms of genetic evolution of stratal package and, changes in paleogeography (on local, regional or global scale) and different sedimentary processes. This analytical tool has immense potential in basin analysis improving the predictive aspect of exploration for natural resources. Hence, it has gained attention as one of the most dynamic areas of research for both academic and industrial interest.

The term ‘‘sequence’’ was coined by Sloss et al. (1949) to designate a stratigraphic unit bounded by subaerial unconformities. However, sequence stratigraphy is generally regarded as stemming from the seismic stratigraphy of the 1970s (Vail et al. 1977). The introduction of ‘correlative conformity’ marked the initiation of modern seismic and sequence stratigraphy (Mitchum, 1977). Incorporation of outcrop and well data (Posamentier et al., 1988; Posamentier and Vail, 1988; Van Wagoner et al., 1990) and switch in emphasis from eustasy to relative sea-level (e.g., Hunt and Tucker, 1992; Posamentier and James, 1993; Posamentier and Allen, 1999; Catuneanu., 2006; Catuneanu et al.,2009) marked a major turnaround in sequence stratigraphy. Genetic stratigraphic approach proposed by Galloway (1989) was to sub-divide the stratigraphic succession at maximum flooding surfaces including the unconformity surface within the sequence. In contrast, the sequence stratigraphic approach employed by the Exxon research group (led by seismic stratigraphers) preferred unconformities and their correlative conformities to define sequences. Embry (1993, 1995) proposed another type of stratigraphic unit, named as transgressive–regressive (T–R) sequence. Sequence stratigraphy, in its present form and modern approach, integrates all sorts of data (sedimentological, chronostratigraphic, palaeontological, geomorphological, structural, geophysical and geochemical) available for a stratal package. It is now worldwide accepted as probably the best analytical tool applied to basin evolution.

Basic concepts

Base level and accommodation

Base level (of deposition or erosion) is generally regarded as a global reference surface to which continental denudation and marine aggradation tend to proceed (Catuneanu et al., 2002). It is a dynamic surface to which sediment accumulation fills up to or erodes down to and is related to continental erosion. For simplicity, base level is often approximated with the sea-level (Schumm, 1993). In reality, base level is usually below sea-level due to the erosional action of waves and marine currents. When base level is approximated as sea-level, the concept of 'base-level change' becomes equivalent with the concept of 'relative sea-level change' (Posamentier et al., 1988; Catuneanu et al., 2009). Base level fluctuations are independent of sedimentation, and reflect changes in response to a number of external (eustatic, tectonic, climatic), diagenetic (sediment compaction), and environmental (wave and current energy) controls. The concept of accommodation defines the space available for sediments to accumulate (Jervey, 1988), measured as the vertical distance between the sea surface and a reference plane, such as, a transgressive surface or an unconformity within already accumulated sediment pile or the basement. This space can be created or destroyed by fluctuations in base level, and is gradually consumed by sedimentation (Catuneanu, 2006).

Eustasy vs. relative sea-level (RSL)

Eustasy is a global phenomenon involving changes in the volume of water in the world's oceans. It is a function of sea-surface movement alone, measured between the sea surface and some fixed point usually the centre of the earth (Fig. 1). On the other hand, relative sea-level is a function of sea-surface movement in addition to sea-floor movement (Posamentier et al., 1988). The latter parameter may be controlled by tectonics, thermal cooling, sediment/water load, or compaction. Therefore, relative sea-level may vary from location to location keeping pace with variation in accommodation space (Fig. 1).

Transgression and regression vs. relative sea-level rise and fall

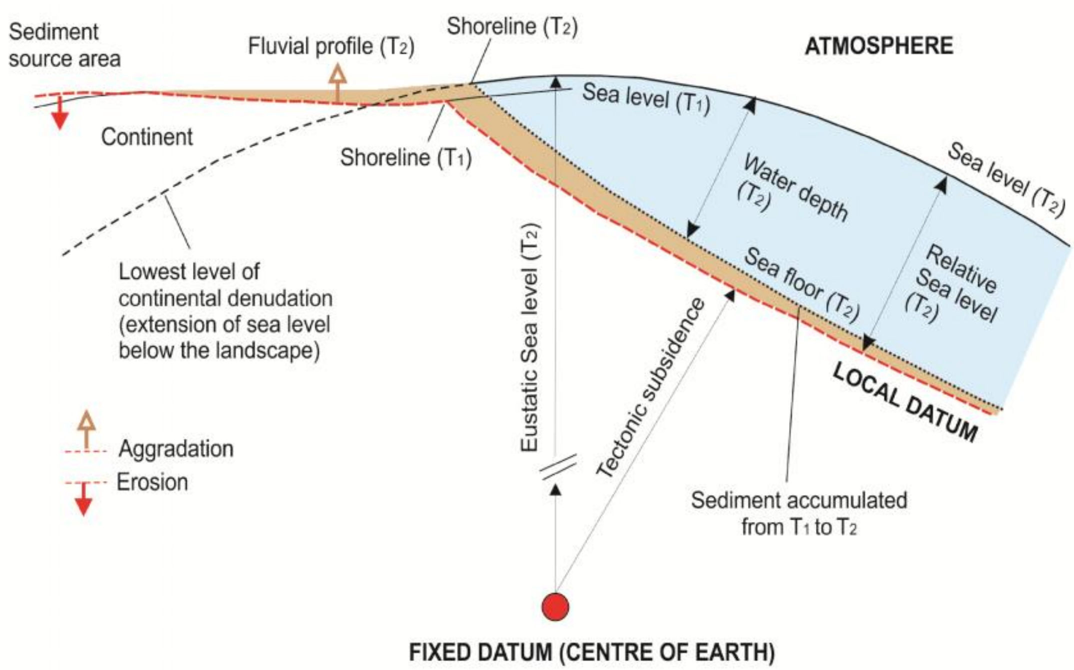
A transgression is an advance of the sea over land while a regression is a retreat of the sea from land. The direction of shoreline movement is a function of the balance between accommodation space and sediment supply. *Transgression* occurs when accommodation is created more rapidly than it is consumed by sedimentation, i.e. the rates of base level rise outpace the sedimentation rates at the shoreline (Fig. 2). Therefore, when relative sea-level is rising, areas with low sediment influx may be characterized by transgressive shorelines (Posamentier and James, 1993). A *normal* regression, induced by seaward movement of the shoreline, occurs in the early and late stages of base level rise when the sedimentation rates outpace the available accommodation on the shelf, thereby causing the shoreline to regress (Fig. 2). During normal regression, the coastal plain continues to be a depositional surface, alluvial accommodation increases, and fluvial aggradation takes place on the coastal plain as the shoreline regresses and the coastal plain expands (Catuneanu, 2002). A *forced regression*, on the other hand, takes place during stages of base level fall, when the shoreline is forced to regress by the base level fall irrespective of the sediment supply (Fig. 2). During forced regression, the coastal plain is not a site of sedimentation but rather a zone of sedimentary bypass/erosion forming an unconformity (in both the nonmarine and shallow marine settings) and accompanied by fluvial incision landward of the shoreline (Posamentier et al., 1992).

Retrogradation, aggradation and progradation

Retrogradation is the diagnostic depositional trend for transgressions, and is defined as the backward (landward) movement or retreat of a shoreline by wave erosion; it produces a steepening of the beach profile at the breaker line (Bates and Jackson, 1987). It is characterized by relative sea-level rise with low sediment flux (Fig. 3). Consequently, the increased accommodation is only partly filled and water depth increases, but less than the total relative sea-level rise and the magnitude of the increase varies with location. If there is a balance between sediment influx and the rate of increase of accommodation so that the position of the shoreline remains
stable and water depth at any given location remains constant, the sediments in all environments along the
profile will simply build up without any variation of character. This phenomenon is known as aggradation (Fig. 3). Progradation is the diagnostic depositional trend for regressions, and is defined as the building forward or outward toward the sea of a shoreline by nearshore deposition of river-borne sediments or by continuous accumulation of beach material thrown up by waves or moved by longshore drifting. It occurs at shorelines where there is an oversupply of sediments with respect to increasing accommodation; therefore a regressive section develops with upward-decreasing water depth (Fig. 3) (Bates and Jackson, 1987; Posamentier and Allen, 1999).

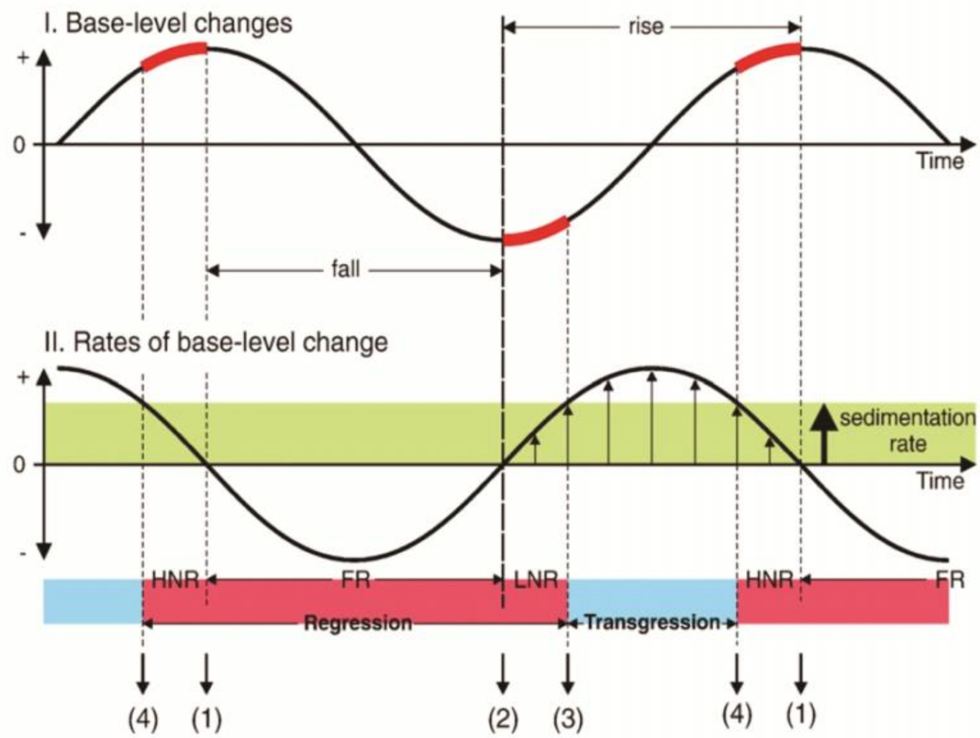
Stratal terminations

Stratal terminations refer to the geometric relationships between strata and the stratigraphic surfaces against which they terminate, and may be observed on continuous surface or subsurface (two dimensional seismic transects and well-logg cross-sections). Stratal terminations were originally defined by Mitchum et al. (1977) when interpreting seismic profiles; however they can also be observed in above or below a stratigraphic surface in large scale outcrops. Four stratal terminations can be used to identify sequence stratigraphic surfaces, two occurring above a surface (onlap and downlap), and two occurring below a surface (truncation and toplap). In addition, offlap is a key stratal stacking pattern diagnostic for forced regressions and the delineation of sub-aerial unconformities and their correlative conformities. Stratal terminations provide critical information regarding the direction and type of syn-depositional shoreline shift and therefore are useful for interpretation of depositional trends, and hence for the systems tracts. In some cases, the understanding of stratal terminations in terms of shoreline shifts is obvious. For example, *coastal onlap and offlap* indicates transgression and forced regression respectively. In other cases, stratal terminations may indicate alternative interpretations, as for example, *downlap* may form in relation to either normal or forced regressions. In such cases, additional criteria (as depositional trends; aggradational, erosional or progradational) have to be considered (Catuneanu, 2006).



Scenarios of relative sea level rise	Scenarios of relative sea level fall
Relative rise = subsidence + eustatic rise	Relative fall = tectonic uplift + eustatic fall
Relative rise = subsidence - eustatic rise (subsidence > eustatic fall)	Relative fall = tectonic uplift - eustatic rise (tectonic uplift > eustatic rise)
Relative rise = eustatic rise (no subsidence)	Relative fall= eustatic fall (no subsidence)
Relative rise = subsidence (no eustatic change)	Relative fall = tectonic uplift (no eustatic change)
Relative rise = eustatic rise - tectonic uplift (eustatic rise > tectonic uplift)	Relative fall = eustatic fall - subsidence (eustatic fall > subsidence)

Figure. 1: Eustasy, relative sea-level, water depth and sedimentation as a function of sea-level, sea-floor and local datum surface (after Posamentier et al., 1988 and Catuneanu, 2006). Scenarios of relative sea- level rise and fall in relation to eustasy and tectonics have been summarized in table.



	Events	Surfaces
(1)	Onset of forced regression	Correlative conformity; *sensu* Posamentier and Allen (1999)
(2)	End of forced regression	Correlative conformity; *sensu* Hunt and Tucker (1992) Subaerial unconformity Regressive surface of marine erosion
(3)	End of regression	Maximum regressive surface
(4)	End of transgression	Maximum flooding surface Transgressive ravinement surfaces

Figure. 2: Concepts of transgression, normal regression and forced regression, as interpreted by the interplay of base-level changes and sedimentation rate (adopted from Catuneanu, 2006).
Abbreviations: FR = Forced regression; LNR = Lowstand normal regression; HNR = Highstand normal regression. The four events of the base-level cycle are (1): onset of forced regression; (2): end of forced regression; (3): end of regression; (4): end of transgression. These four events and their corresponding type of stratigraphic surfaces have been summarized in tabular form (after Catuneanu 2002, 2006)

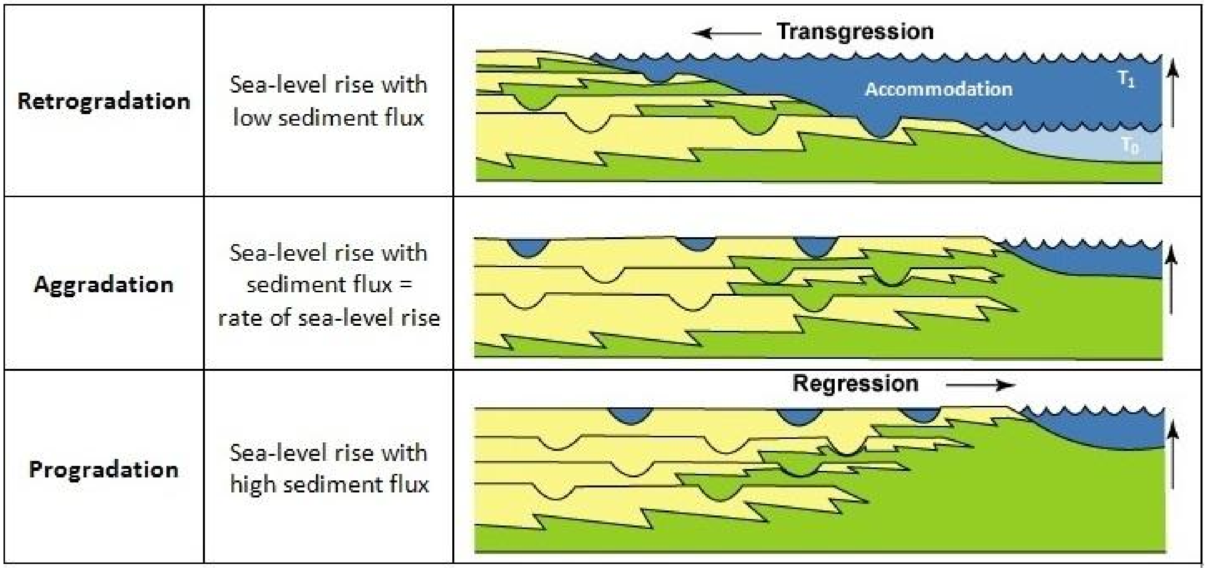


Figure. 3: Stratigraphic architecture of the succession during retrogradation, aggradation and progradation in accord to sea-level rise and sediment flux (after Posamentier and Allen, 1999)

Type 1 vs. Type 2 unconformities

Concept of Type 1 vs. Type 2 unconformities in sequence stratigraphy was defined by Vail and Todd (1981) and improvised by Posamentier and Vail (1988). Type 1 unconformity forms by drastic fall in relative sea-level (forced regression) and consecutive abrupt basinward shift of coastal onlap, sometimes associated to fluvial incision. On the other hand, Type 2 unconformity develops in response to decelerating followed by accelerating rise in relative sea-level (related to normal regression). This unconformity is characterized by an abrupt basinward shift of coastal onlap too, but without forced regression and significant fluvial incisions. Type 1 unconformities are readily identifiable in outcrop (Van Wagoner et al., 1990); however Type 2 unconformities are hard, may even be impossible, to recognize. Presently, idea of Type 2 unconformity is not accepted anymore and has been dropped. The term unconformity in sequence stratigraphy has been confined to those surfaces only those are exposed by rapid fall in RSL i.e Type 1 unconformity.

Sequence stratigraphic surfaces

One of the key aspects of sequence stratigraphy has been the identification of key stratigraphic surfaces that can be used to subdivide geological sections into sequences and their component sub-units. Sequence stratigraphic surfaces may correspond to ‘conceptual’ horizons (i. e., without a lithologic contrast) or physical surfaces, depending on their outcrop expression (e. g., Carter et al. 1998) marking changes in stratal stacking pattern.

Subaerial unconformity

The subaerial unconformity (Sloss et al. 1949), also known as 'lowstand unconformity' (Schlager 1992) or 'regressive surface of fluvial erosion' (Plint and Nummedal 2000) or 'fluvial entrenchment/incision surface' (Galloway 2004), forms under subaerial conditions during forced regression, transgression, during periods of negative fluvial accommodation or during relative sea-level fall as a result of fluvial erosion or bypass, pedogenesis, wind degradation, or dissolution and karstification (Posamentier et al. 1988; Leckie 1994; Blum 1994).

Correlative conformities

After forced regression, the unconformity that has developed on the coastal and alluvial plain merges into a conformable surface, i.e., a correlative conformity, seaward of the coastline. It most instances, because the coeval surface seaward of the coast is below water, i.e., is overlain by shelf, some sediment accumulation occurs, and therefore it does not record a sedimentary hiatus or unconformity (Posamentier and Allen, 1999). However, controversies sustain regarding its timing and physical attributes in most outcrop sections. According to Mitchum (1977), the correlative conformity is a surface which is time equivalent to a sequence boundary marking the onset of a sea-level fall. Posamentier et al. (1988) considered it as the paleo-seafloor at the onset of forced regression while Hunt and Tucker (1992) placed it at the end of forced regression.

Maximum flooding surface

It refers to the surface of deposition at the time the shoreline is at its maximum landward position (i.e. the time of maximum transgression). In other words, it is the paleo-seafloor at the peak of transgression, and its correlative surface within the non-marine setting. Maximum flooding surface (MFS) marks a change in stratal stacking patterns from transgression to highstand normal regression (Fig.4). MFS can be a potential stratigraphic marker for regional correlation (Galloway, 1989).

Maximum regressive surface

The maximum regressive surface (Helland-Hansen and Martinsen 1996) is a stratigraphic surface that marks a change in stratal stacking patterns from lowstand normal regression to transgression. It is the paleo-seafloor at the end of lowstand normal regression, and its correlative surface within the non-marine setting.

Transgressive ravinement surface

The transgressive ravinement surface (Nummedal and Swift 1987) or 'transgressive surface of erosion' (Posamentier and Vail 1988) are diachronous erosional surfaces that form by means of wave scouring or tidal scouring during transgression in coastal to shallow-water environments. It's basinward termination merges into the maximum regressive surface while it's landward termination merges into the maximum flooding surface.

Sequence stratigraphic units

Sequence:

Mitchum (1977) defined sequence as a relatively conformable succession of genetically related strata bounded by unconformities or their correlative conformities. Two types of sequences have been classified, viz. Type 1 and Type 2. Type 1 sequence is generated where the fall in RSL is significant while Type 2 sequences generated where the RSL fall is not sufficient. Within a basin, a succession may be constituted by multiple such sequences. A stack of multiple sequences bounded by basin-wide unconformities may be addressed as a Megasequence.

Systems tract:

A systems tract is “a linkage of contemporaneous depositional systems, forming the subdivision of a sequence” (Brown and Fisher 1977) and represents ‘a specific sedimentary response to the interaction between sediment flux, physiography, environmental energy, and changes in accommodation’ (Posamentier and Allen, 1999). The definition of a systems tract is independent of spatial and temporal scales. Systems tracts are interpreted on the basis of strata stacking patterns, position within the sequence, and types of bounding surface (Van Wagoner et al. 1987, 1988, 1990; Posamentier et al. 1988; Van Wagoner 1995; Posamentier and Allen 1999).

<u>Falling-Stage Systems Tract (FSST)</u>

The FSST is the product of a forced regression including all the regressive deposits that accumulate after the onset of a relative sea-level fall and before the start of the next relative sea-level rise (Fig.4). The fall in relative sea-level is evidenced by the erosion of the subaerially exposed sediment surface updip of the coastline at the end of forced regression, and the formation of a diachronous subaerial unconformity that caps the Highstand Systems Tract (HST). The subaerial unconformity may be onlapped by fluvial deposits that belong to the lowstand or the transgressive systems tracts. The subaerial unconformity may also be reworked by a time-transgressive marine ravinement surface overlain by a sediment lag (Catuneanu et al., 2011).

<u>Lowstand Systems Tract (LST)</u>

The LST includes deposits that accumulate after the onset of relative sea-level rise, during normal regression, on top of the FSST and the corresponding updip subaerial unconformity. LST sediments often fill or partially infill incised valleys that were cut into the HST, and other earlier deposits, during forced regression (Fig.4, 5).

The sheltered lowstand packages at a slope break, escaped from the erosion, are generally fan shaped and progradational in nature. They are designated as lowstand wedge. These wedges or fans (alluvial fan, fan delta, shelf fan, slope fan or deep submarine fan), resting on an unconformity surface get buried under deep water mud during the following transgression. Being enclosed by finer sediments, these fans often acts as highly potential oil reservoirs or prospective placer deposits.

Transgressive Systems Tract (TST)

The TST comprises the deposits that accumulated from the onset of transgression until the time of maximum transgression of the coast and just prior to the renewed regression of the HST. The TST lies directly on the maximum regressive surface formed at the end of regression and is overlain by the maximum flooding surface (MFS) formed when marine sediments reach their most landward position (Fig.4).

Sometimes the switch in depositional trend from retrogradation (transgression) to progradation (regression) is marked by a zone of (commonly condensed) deep-water facies rather than a unique surface in the rock succession (Carter et al. 1998). It is designated as condensed zone, formed in response to extremely slow rate of sedimentation and characterized by finest sediment with high organic carbon content, pyrite, glauconite or phosphate enrichment, or volcanic ash fall deposits. Fossils, generally intact, of a wide age range are likely to be concentrated within this zone.

Highstand Systems Tract (HST)

The HST includes the progradational deposits that form when sediment accumulation rates exceed the rate of increase in accommodation during the late stages of relative sea-level rise. The HST lies directly on the MFS formed when marine sediments reached their most landward position (Fig.4). This systems tract is capped by the subaerial unconformity and its correlative conformity (Posamentier and Allen, 1999).

Parasequence:

A parasequence, basic building blocks of a succession, in its original definition (Van Wagoner et al. 1988, 1990) is an upward-shallowing succession of facies bounded by marine flooding surfaces. However, it may be expanded to include all regional meter-scale cycles, whether or not they are bounded by flooding surfaces (Spence and Tucker 2007; Tucker and Garland 2010). In siliciclastic settings (coastal to shallow-water) parasequences characterize individual prograding sedimentary bodies. In case of carbonate setting, parasequence corresponds to a facies succession commonly containing a lag deposit or thin deepening interval followed by a thicker shallowing-upward part (Catuneanu et al., 2011).

All meter-scale shallowing upward stratal packages may not be individually related to RSL but result of any internal mechanism of the depositional system (for ex. channel filling). Besides, there may be strata packages of intermediate scale too. These are designated as Parasequence Sets.

Stacking patterns

Deposits defined by specific stratal stacking patterns form the basic constituents of any sequence stratigraphic unit (sequence, systems tract or parasequence). These units may include both shoreline-related and shoreline-independent deposits and associated stacking patterns. However, all stratal stacking patterns reflect the interplay of the two fundamental variables, accommodation and sediment supply. Shoreline-related stacking patterns are defined by combinations of depositional trends: forced regression (forestepping and downstepping at the shoreline, interpreted as the result of negative accommodation); normal regression (forestepping and upstepping at the shoreline, interpreted as the result of positive and overfilled accommodation); and transgression (backstepping at the shoreline, interpreted as the result of positive and underfilled accommodation) (Catuneanu 2006; Catuneanu et al., 2011 and references therein). On the other hand, Shoreline-independent stacking patterns may build up in areas far away from contemporaneous shorelines where sedimentation processes are unaffected by shoreline shifts. For example, in upstream-controlled fluvial settings, degree of amalgamation of channel deposits may reflect syn-depositional conditions of available fluvial accommodation. In deep-water settings, depositional styles may be defined by the degree of channel confinement, which may reflect changes in accommodation on the shelf and/or variations in sediment supply in the staging area (Catuneanu et al., 2011 and references therein).

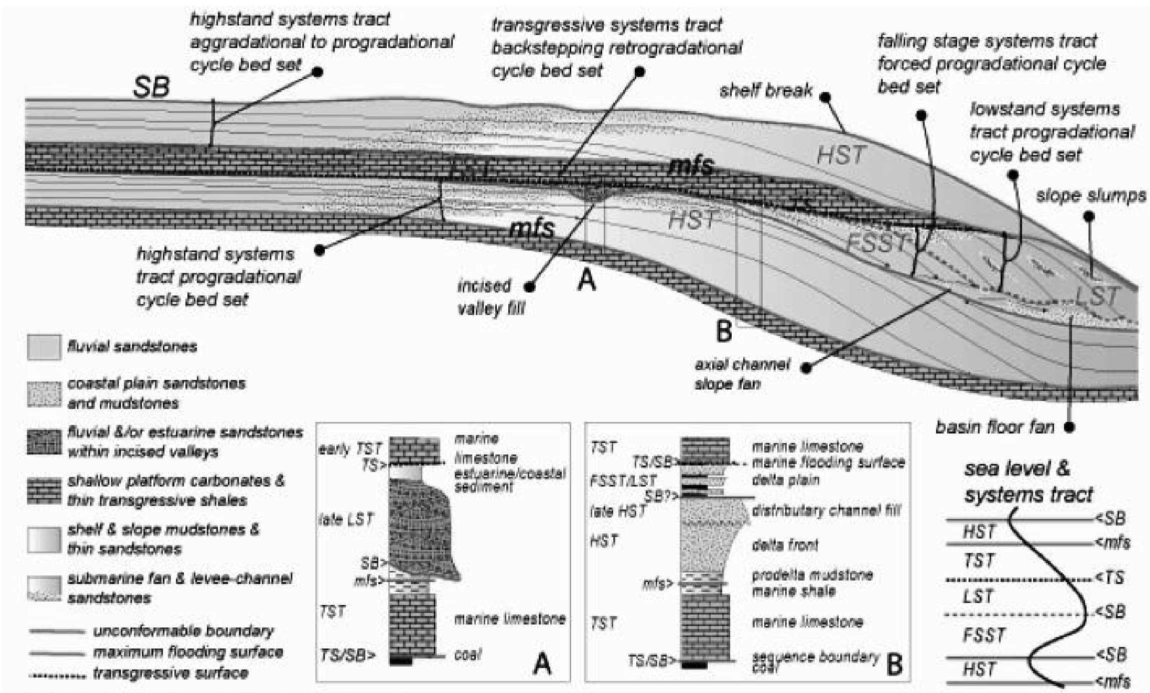


Figure 4. Depositional sequences and systems tracts (after Kendall and Tucker, 2010).
Abbreviations: HST = Highstand systems tract; TST = Transgressive systems tract; LST = Lowstand systems tract

Sequence stratigraphy emphasizes changes in stratal stacking patterns involving geometries and facies relationships in response to relative sea-level rise or fall. A transgression is defined as the landward migration of the shoreline. This migration triggers a corresponding landward shift of facies, as well as a deepening of the marine water in the vicinity of the shoreline. Transgressions result in a fining-upward sequence and retrogradational (or backstepping) stacking patters, denoted as Transgressive systems Tract (TST), e.g. marine facies shifting towards and overlying non-marine facies (Fig. 5) (Catuneanu 2002). Base of the TST would be sculpted by a basal, erosional unconformity (transgressive ravinement surface). This surface may be demarcated by a transgressive lag, generally granular or pebbly in nature, may gradually pinches out towards the basin interior.

Though, in case of high erosion rate all the way through the transgressive phase not allowing the TST to form, the record of transgression may remain locked up to the transgressive lag only.

Relative sea-level (RSL) fluctuates with time. When RSL falls, regression i.e seaward migration of the shoreline invariably occurs. This migration is accompanied by corresponding shallowing of the marine water in the vicinity of the shoreline as well as seaward shift of facies, e.g. non-marine facies shifting towards and overlying marine facies. A regressive facies pattern is characterized by an overall coarsening-upward sequence, progradational stacking patterns developed over the TST, and bounded by an erosional unconformity at the top. This progradational sequence is designated as Highstand System Tract (HST). Stacking patterns exhibit forestepping. Maximum Flooding Surface occurs at the top of TST or at the immediate base of HST (Fig. 4, 5). As a result of rapid fall in RSL, HST progradation may expose a vast area of depositional shelf or even slope. Under such circumstances, rivers will be rejuvenated, encroach onto the newly exposed marine depositional surface and may incise deep channels bearing extra-basinal conglomerates (Falling Stage systems Tract or FSST). The submarine sediment surface of previous regime would appear with emergence features. A subaerial unconformity would develop due to the forced regression caping the HST, which in turn may be onlapped by LST fluvials or by TST (Fig. 4). When a rise in RSL set off, at the beginning the rate of rise is low which would be surpassed by rate of sedimentation. Hence, another progradational succession would result (Lowstand System Tract or LST) following prograding HST. Stacking patterns exhibit forestepping, aggrading clinoforms (in siliciclastic systems) that thicken downdip, and a topset of fluvial, coastal plain and/or delta plain deposits. A LST is prone to be aggradational at its top part keeping pace with the gradually rising RSL (Catuneanu 2006; Catuneanu et al., 2009, 2010 and references therein).

Stratal stacking patterns describing normal regressions, transgressions or forced regressions can succeed each other in any order, as a function of syn-depositional conditions and/or post-depositional preservation (Catuneanu et al., 2011). Sequences may consist of any combination of these types of deposit may or may not including all of them. Recurrence of TST and HST within a succession comprises cyclic variation in stacking patterns; may get punctuated by unconformities at certain stratigraphic levels in response to sudden change in RSL. Hence, both TST and HST may be internally characterized by shorter cycles (i.e shorter packages known as parasequences) following smaller fluctuations in RSL within an overall retrogradational (transgressive) or progradational (regressive) sequence. From rock record it is apparent that, sequences may develop over a wide range of temporal and spatial scales, from a scale comparable to that of a parasequence or less (Krapez, 1996; Strasser et al., 1999).

Conclusion

Sequence stratigraphiy is a modern approach analyzing the sedimentary rock record within a time framework. Sequence stratigraphic methodology is a useful tool for understanding the major factors controlling sequential pattern (eustatic sea-level change, basin subsidence and sedimentation rate), enhance power of anticipation of lithologies, recognition of facies, palaeogeographic interpretation and basin-wide correlation. This analytical method emphasizes the identification of genetic types of deposits and sequence stratigraphic surfaces subdividing the stratigraphic section into component sequence and systems tracts in response to changes in the two fundamental parameters: accommodation and sediment supply. However, there are multiple combinations of what a sequence may preserve in terms of component systems tracts. No single template can provide a solution for every situation. Careful analysis and a thorough understanding of all controls on sedimentation are thus required when doing sequence stratigraphic interpretations.

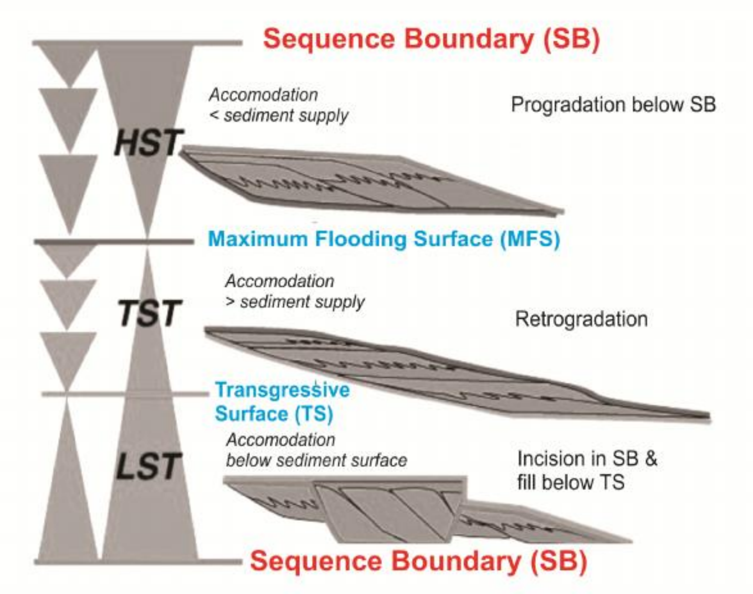


Figure 5. Stratal stacking patterns showing its basic constituents (after Kendall, 2003). Abbreviations:
HST = Highstand systems tract;
TST = Transgressive systems tract;
LST = Lowstand systems tract

References

Bates, R.L., Jackson, J.A., 1987. Glossary of geology: Alexandria, Virginia, American geological institute, 143pp.

Blum, M.D., 1994. Genesis and architecture of incised valley fill sequences: a Late Quaternary example from the Colorado River, Gulf Coastal Plain of Texas. In: Weimer, P., Posamentier, H.W. (Eds.), Siliciclastic sequence stratigraphy: recent developments and applications. Memoir 58. American Association of Petroleum Geologists, pp. 259–283.

Brown Jr., L.F., Fisher, W.L., 1977. Seismic stratigraphic interpretation of depositional systems: examples from Brazilian rift and pull apart basins. In: Payton, C.E. (Ed.), Seismic Stratigraphy — Applications to Hydrocarbon Exploration. Memoir 26. American Association of Petroleum Geologists, pp. 213–248.

Carter, R. M., Fulthorpe, C. S., Naish, T. R., 1998. Sequence concepts at seismic and outcrop scale: the distinction between physical and conceptual stratigraphic surfaces. Sedimentary Geology 122, 165–179.

Catuneanu,O., 2002, Sequence Stratigraphy of clastic systems: concepts, merits, and pitfalls, Journal of African Earth Sciences 35 (1), 1-43.

Catuneanu, O., 2006. Principles of Sequence Stratigraphy. Elsevier, Amsterdam, 375 pp.

Catuneanu, O., Abreu, V., Bhattacharya, J.P., Blum, M. D., Dalrymple, R.W., Eriksson, P. G., Fielding, C. R., Fisher, W. L., Galloway, W. E., Gibling, M. R., Giles, K. A., Holbrook, J. M., Jordan, R., Kendall, C. G. St. C., Macurda, B., Martinsen, O. J., Miall, A. D., Neal, J. E., Nummedal, D., Pomar, L., Posamentier, H.W., Pratt, B. R., Sarg, J.F., Shanley, K.W., Steel, R. J., Strasser, A., Tucker, M. E., Winker, C., 2009. Towards the standardization of sequence stratigraphy. Earth-Science Reviews 92, 1–33.

Catuneanu, O., Bhattacharya, J. P., Blum, M. D., Dalrymple, R.W., Eriksson, P. G., Fielding, C. R., Fisher, W. L., Galloway, W. E., Gianolla, P., Gibling, M. R., Giles, K. A., Holbrook, J. M., Jordan, R., Kendall, C. G. St.

C., Macurda, B., Martinsen, O. J., Miall, A. D., Nummedal, D., Posamentier, H.W., Pratt, B. R., Shanley, K.W., Steel, R. J., Strasser, A., Tucker, M. E., 2010. Sequence stratigraphy: common ground after three decades of development. First Break 28, 21–34.

Catuneanu, O., Galloway, W. E., Kendall, C. G. St. C., Miall, A. D., Posamentier, H. W., Strasser, A.,Tucker, M. E., 2011. Sequence stratigraphy**:** Methodology and Nomenclature**,** Newsletters on Stratigraphy, Stuttgart 44/3, 173–245.

Embry, A. F., 1993. Transgressive-regressive (T–R) sequence analysis of the Jurassic succession of the Sverdrup Basin, Canadian Arctic Archipelago. Canadian Journal of Earth Sciences 30, 301–320.

Embry, A.F., 1995. Sequence boundaries and sequence hierarchies: problems and proposals. In: Steel, R.J., Felt, V.L., Johannessen, E.P., Mathieu, C. (Eds.), Sequence stratigraphy on the Northwest European Margin. Special Publication 5, Norwegian Petroleum Society, 1–11.

Galloway, W.E., 1989. Genetic stratigraphic sequences in basin analysis, I. Architecture and genesis of flooding-surface bounded depositional units. American Association of Petroleum Geologists Bulletin 73, 125–142.

Helland-Hansen, W., Martinsen, O.J., 1996. Shoreline trajectories and sequences: description of variable depositional-dip scenarios. Journal of Sedimentary Research 66 (4), 670–688.

Hunt, D., Tucker, M.E., 1992, Stranded Parasequences and the forced regressive wedge Systems Tract*:* deposition during base-level fall. Sedimentary Geology 81, 1–9.

Jervey, M. T., 1988. Quantitative geological modeling of siliciclastic rock sequences and their seismic expression. In: Wilgus, C.K., Hastings, B.S., Kendall, C.G.St.C., Posamentier, H.W., Ross, C.A., Van Wagoner, J.C. (Eds.), Sea Level Changes — An Integrated Approach. . Special Publication, 42. Society of Economic Paleontologists and Mineralogists (SEPM), 47–69.

Kendall, C. G. St. C., 2003. Sequence stratigraphy, SEPM strata, SEPM stratigraphy web.

Kendall, C. G. St. C., Tucker, M., 2010. Sequence stratigraphy, SEPM strata, SEPM stratigraphy web.

Krapez, B., 1996. Sequence-stratigraphic concepts applied to the identification of basin-filling rhythms in Precambrian successions. Australian Journal of Earth Sciences, 43, 355-380.

Leckie, D.A., 1994. Canterbury Plains, NewZealand—implications for sequence stratigraphic models. American Association of Petroleum Geologists Bulletin 78, 1240–1256.

Mitchum Jr., R.M., 1977, Seismic Stratigraphy and global changes of sea level. Part 11: glossary of terms used in seismic Stratigraphy. In: Payton, C.E. (Ed.), Seismic Stratigraphy—Applications to Hydrocarbon Exploration, vol. 26. A.A.P.G. Memoir, pp. 205–212.

Nummedal, D., Swift, D.J.P., 1987. Transgressive stratigraphy at sequence-bounding unconformities: some principles derived from Holocene and Cretaceous examples. In: Nummedal, D., Pilkey, O.H., Howard, J.D. (Eds.), Sea-level fluctuation and coastal evolution. Special Publication 41. Society of Economic Paleontologists and Mineralogists (SEPM), pp. 241–260.

Plint, A.G., Nummedal, D., 2000. The falling stage Systems Tract: recognition and importance in Sequence stratigraphic analysis. In: Hunt, D., Gawthorpe, R.L. (Eds.), Sedimentary Response to Forced Regression, 172. Geological Society London Special Publication, pp. 1–17.

Posamentier, H.W., Allen, G.P., 1999. Siliciclastic Sequence Stratigraphy*:* concepts and applications. SEPM Concepts in Sedimentology and Paleontology 7, 210 pp.

Posamentier, H.W., and James, D.P., 1993. An overview of sequence-stratigraphic concepts: uses and abuses. In: Posamentier, H. W., Summerhayes, C. P., Haq, B. U. and Allen, G. P. (Eds.), Sequence Stratigraphy and Facies Associations, Spec. Publs Int. Ass. Sediment. 18, 3-18.

Posamentier, H.W., Allen, G.P., James, D.P., Tesson, M., 1992. Forced regressions in a sequence stratigraphic framework: concepts, examples, and exploration significance. American Association of Petroleum Geologists Bulletin 76, 1687–1709.

Posamentier, H.W., Vail, P.R., 1988. Eustatic controls on clastic deposition II — sequence and systems tract models. In: Wilgus, C.K., Hastings, B.S., Kendall, C.G.St.C., Posamentier, H.W., Ross, C.A., Van Wagoner, J.C. (Eds.), Sea Level Changes — An Integrated Approach. Special Publication 42. Society of Economic Paleontologists and Mineralogists (SEPM), pp. 125–154.

Posamentier, H.W., Jervey, M.T., Vail, P.R., 1988. Eustatic controls on clastic deposition I — conceptual framework. In: Wilgus, C.K., Hastings, B.S., Kendall, C.G.St.C., Posamentier, H.W., Ross, C.A., Van Wagoner, J.C. (Eds.), Sea Level Changes — An Integrated Approach. Special Publication 42. Society of Economic Paleontologists and Mineralogists (SEPM), pp. 110–124.

Schlager, W., 1992. Sedimentology and sequence stratigraphy of reefs and carbonate platforms. Continuing Education Course Note Series 34. American Association of Petroleum Geologists, 71 pp.

Schumm, S.A., 1993. River response to baselevel change: implications for sequence stratigraphy. Journal of Geology 101, 279–294.

Sloss, L.L., Krumbein, W.C., Dapples, E.C., 1949. Integrated facies analysis. In: Longwell, C.R. (Ed.), Sedimentary Facies in Geologic History. Memoir 39, Geological Society of America, pp. 91–124.

Spence, G.H., Tucker, M.E., 2007. A proposed integrated multi-signature model for peritidal cycles in carbonates. Journal of Sedimentary Research 77, 797–808.

Strasser, A., Pittet, B., Hillgartner, H. and Pasquier, J.-B., 1999. Depositional sequences in shallow carbonate-dominated sedimentary systems: concepts for a high-resolution analysis. Sedimentary Geology 128, 201-221.

Tucker, M. E., Garland, J., 2010. High-frequency cycles and their sequence stratigraphic context: orbital forcing and tectonic controls on Devonian cyclicity, Belgium. Geologica Belgica 13/3, 213–240.

Vail, P.R., Mitchum Jr., R.M., Thompson III, S., 1977. Seismic stratigraphy and global changes of sea level, part 3: relative changes of sea level from coastal onlap. In: Payton, C.E. (Ed.), Seismic Stratigraphy — Applications to Hydrocarbon Exploration. Memoir, 26. American Association of Petroleum Geologists, pp. 63–81.

Van Wagoner, J.C., 1995. Overview of sequence stratigraphy of foreland basin deposits: terminology, summary of papers, and glossary of sequence stratigraphy. In: Van Wagoner, J.C., Bertram, G.T. (Eds.), Sequence Stratigraphy of Foreland Basin Deposits: Outcrop and Subsurface Examples from the Cretaceous of North America. Memoir 64, American Association of Petroleum Geologists, pp. ix–xxi.

Van Wagoner, J.C., Mitchum, R.M., Posamentier, H.W., Vail, P.R., 1987. An overview of sequence stratigraphy and key definitions. In: Bally, A.W. (Ed.), Atlas of Seismic Stratigraphy, 1. Studies in Geology, 27. American Association of Petroleum Geologists, pp. 11–14.

Van Wagoner, J.C., Posamentier, H.W., Mitchum, R.M., Vail, P.R., Sarg, J.F., Loutit, T.S., Hardenbol, J., 1988. An overview of sequence stratigraphy and key definitions. In: Wilgus, C.K., Hastings, B.S., Kendall, C.G.St.C., Posamentier, H.W., Ross, C.A., Van Wagoner, J.C. (Eds.), Sea Level Changes – An Integrated Approach. Special Publication, vol. 42. Society of Economic Paleontologists and Mineralogists (SEPM), pp. 39–45.

VanWagoner, J.C., Mitchum Jr., R.M., Campion, K.M., Rahmanian, V.D., 1990. Siliciclastic sequence stratigraphy in well logs, core, and outcrops: concepts for high-resolution correlation of time and facies. American Association of Petroleum Geologists Methods in Exploration Series 7, 55 pp.