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Sequence Stratigraphy Concepts and Applications: A Review

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Abstract

In this paper, a brief historical review on sequence stratigraphy from the renaissance, 1681 A.D., to the present day concepts and practices was attempted. Sequence stratigraphy integrates time and relative sea-level changes to track the migration of sedimentary facies. The strength of this technique lies in its potential to predict facies within a chronostratigraphically constrained framework of unconformity-bound depositional sequences. Sequence Stratigraphy can be used to study sedimentary rock relationships within a time-stratigraphic framework of repetitive, genetically related strata bounded by surfaces of erosion or non-deposition, or their correlative conformities. The application of sequence stratigraphy provides the potential for chronostratigraphic correlation within and among growth-faulted sub-basins, thus improving prediction of stratigraphic and areal distribution of deeply buried lowstand reservoirs. Sequence stratigraphy provides a guide to potential combination traps and the opening of a window on exploration for deep, unexpanded sub-fault reservoirs and traps, thereby enabling explorationists to properly place a given sub-basin into a petroleum system framework in a cost-effective manner.

Keywords: sequence stratigraphy, systems tract, sequence boundary, biostratigraphy

1. Introduction

Sequence stratigraphy integrates time and relative sea-level changes to track the migration of facies. Sequence stratigraphy is rooted mainly in seismic stratigraphic sequence analysis, and its strength lies in its potential to predict facies within a chronostratigraphically constrained framework of unconformity-bound depositional sequences. Sequence stratigraphy is done using outcrops, well logs or cores, and interpretations may depend on rather different sets of data. However, the basic geometrical criteria remain the same. Using the methodology developed for seismic sequences by Vail et al. (1977), interpreters analyze seismic reflections to describe stratal geometry and delineate the systematic patterns of lap-out and truncation of strata against chronostratigraphically constrained surfaces. In this manner, they establish the presence of unconformity-bound depositional sequences, deduce relative sea-level changes, and describe the depositional and erosional history of an area. Sequence stratigraphy can be used to study sedimentary rock relationships within a time-stratigraphic framework of repetitive, genetically related strata bounded by surfaces of erosion or non-deposition, or their correlative conformities (Posamentier et al., 1988; van Wagoner et al., 1988). Rock stratigraphic sections are divided into sequences, parasequences and or their associated system tracts.

2. Introduction

Holy sea level change

- ➢ (Noah, Anebi Nuhu in Holy Bible and Al-Koran)
- ➢ The Renaissance
    - ▪ 1681: Barnet "Sacred Theory of the Earth"
    - ▪ 1748: De Maillet "Telliamed"
        - Spawned the Neptunists

1788: Hutton and the concept of the unconformity

- ➢ Basalt, cross-cutting relationships and the sinking of the Neptunists

Early ideas for mechanisms of sea level fluctuation

- ➢ 1835: Lyell and raised beaches
- ➢ 1842: MacLaren and glacial advances and 1840: Agassiz
- ➢ 1864: Croll and orbital cycles

Early ideas on sea level and stratigraphic control

- 1898 and 1909: Chamberlain and world-wide “diastrophic control” on stratigraphy
- 1906: Suess and eustasy
- 1906: Grabau and concepts of lapping relationships

Relationship between sedimentation and time

- 1912 and 1917: Barrell

1935: Wanless and Shepard and Pennsylvanian “cyclotherms”
1949: Sloss, Krumbein and Dapple the interregional unconformity, and the “Sequence”
1958: Wheeler and the “Wheeler diagrams”
1963: “Sloss Sequences” from Larry Sloss
Late 1960’s and early 1970’s: seismic stratigraphy
1974: Frazier named a unit bounded by “marine starvation surface” which is today’s maximum flooding surface a complex sequence.
1975: Chang (1975) renamed Sloss et al. (1949)’s sequence as “synthem”.
1977: the research group at Exxon, Peter Vail and AAPG Memoir 26 (Payton, 1977; Vail et al., 1977).

- The “Slug Diagram” and the transgressive/regressive and chronostratigraphic framework
- The “Vail Curves” of absolute sea level

1984: AAPG Memoir 36, sequence stratigraphy ideas were expanded
1987: publication of Haq et al. (1988) Chart
1988: Jervey’s model used sea-level change, subsidence and constant sediment supply as input.
1988: Society of Economic Paleontologists and Mineralogists (SEPM) Special Publication 42 “Sea Level Changes: An Integrated Approach” (Wilgus et al., 1988)

- Spelled out detailed mechanisms of sequence stratigraphy
- New concepts such as parasequences and accommodation space were introduced.
- Opened sequence stratigraphy to non-industry scrutiny
  - 1991: Miall’s attacks on the Vail Curves
  - Modified for non-shelf setting, non seismic data sources and impractical assumptions

1990's: Many publications questioning certain aspects of sequence stratigraphy, or validity of inter-basinal correlations, or alternative models for the development of sequences

- High-resolution, sub-seismic scale sequence stratigraphy both in siliciclastic and carbonates. Milankovitch theory of orbital forcing was revived to explain the origin of high-frequency subsequence scale cycles
- Computer modeling packages developed to replicate and analyze the sedimentary fill of sedimentary basins (e.g., SEDPAK, Mr. Sediment…)

1994: Biddle et al. and Inverse seismic modeling based on physical properties.

3. Principles of Sequence Stratigraphy

Sequence stratigraphy is the study of genetically related facies within a framework of chronostratigraphically significant surfaces (van Wagoner et al., 1990). Sedimentary facies is defined as the sum total of the lithological and paleontological aspects of a stratigraphic unit in a particular place. The parameters of facies are geometry, lithology, paleontology (including ichnofossils), sedimentary structures and paleocurrent patterns (Reijers, 1996). Vertical facies analysis must be done within conformable strata packages to accurately interpret coeval, lateral facies relationships along a single depositional surface (Walther, 1894; Walker, 1984). Walther's (1894) Law states that a vertical succession of facies, a facies sequence, reflects a similar lateral succession of facies, facies belts, provided that the facies transitions are gradual (Reijers, 1996; Emery and Myers, 1997).

3.1 Accommodation Space

According to Holland (2008), accommodation space is the space available for sediments to accumulate at any point in time, and it is controlled by base level. Accommodation space can be filled with sediments or water. The distance between the sediment/water interface and the sea surface is known as water depth. The accommodation space not filled with water is filled with sediment (Fig.1).

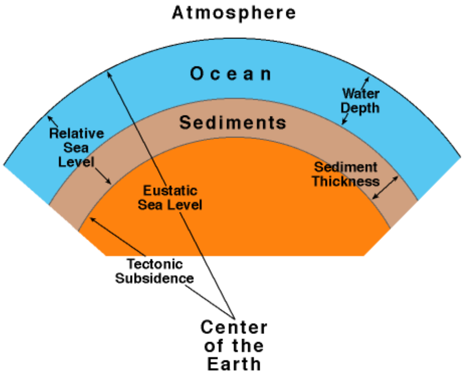

Fig.1. Diagrammatic representation of accommodation space (Source: Holland, 2008)

3.2 Geometric Analysis of a Depositional Sequence

3.2.1 Unconformities

Definition of unconformity:- An unconformity is a surface of erosion or non-deposition that separates younger strata from older rocks and represents a significant hiatus. Unconformities are classified on the basis of the structural relationships between the underlying and overlying rocks. They represent breaks in the stratigraphic sequence, that is, they record periods of time that are not represented in the stratigraphic column. Unconformities also record a fundamental change in the environment (from deposition to non-deposition and/or erosion) which generally represents an important tectonic event. The recognition and mapping of unconformities are the first steps in understanding the geological history of a basin or a geological province - whether recognized in seismic lines, outcrops or well data. Unconformities are used as boundaries of stratigraphic units. There are four types of unconformities, namely: nonconformity, angular unconformities, disconformity, and paraconformity.

3.2.2 Relationships of Strata to Sequence Boundaries

A **seismic sequence** is a depositional sequence identified on a seismic section (Obaje, 2013). It is a relatively conformable succession of reflections interpreted as genetically related strata. It is bounded at its top and base by surfaces of discontinuity marked by reflection terminations interpreted as unconformities or the correlative conformities. A seismic sequence consists of genetically related strata. Because it is determined by a single objective criterion such as the physical relationships of the strata themselves, the depositional sequence is useful in establishing a framework for stratigraphic analysis. The concept of sequence stratigraphy was initially developed in 1977 at Exxon by Vail and his colleagues and diffused with the publication of AAPG Memoir 27. The definition of depositional sequence was modified by Vail et al. (1984; 1977), Posamentier and Vail (1988) to include systems tracts. A system tract is associated with a segment of the eustatic curve and its timing in any given basin will depend on local subsidence and sediment supply.

3.2.3 Sequences

Sequence - "a stratigraphic unit that is defined on the basis of bounding unconformities." An unconformity is a composite surface of erosion and/or non-deposition separating older from younger sediment or rock bodies. Two type of sequence are recognized, one descriptive (*stratal sequence*), and the other interpretive, involving bounding unconformities of specific character (*depositional sequence*). **Stratal sequence –** "a stratigraphic unit that is defined exclusively with reference to bounding unconformities without regard to their character." A stratal sequence is an unconformity-bounded unit equivalent to the synthem and approximately equivalent to the allostratigraphic unit of the North American Commission on Stratigraphic Nomenclature (NACSN) in 1983. An allostratigraphic unit is bounded by stratigraphic discontinuities that are commonly but not necessarily unconformities according to the way in which the term unconformity is conventionally used.

Depositional sequence – “a relatively conformable succession of strata bounded by unconformities of subaerial erosion/nondeposition or their submarine equivalents and by genetically correlative conformities.” The intent of this definition is to permit the extension of a depositional sequence beyond the point at which one or both boundaries cease to be unconformable. The interpretation of a depositional sequence does not require correlative conformities to be present within a particular area of study. A depositional sequence is an unconformity-related unit, and essentially the sequence upon which modern sequence stratigraphy is based (van Wagoner et al., 1990). According to Berggren et al. (2001), the sequence terminology dilemma was resolved by the NASCN Working Group’s recognition that the sequence of Sloss, the allostratigraphic units and the synthems are identical types of units, while on the other hand, the sequences of seismic and sequence stratigraphy differ from the others only in that they may be extended beyond the basinward termination of the bounding unconformities.

The NASCN Working Group has abandon the use of the terms “allostratigraphic units” and “synthem” and unified the terminology of unconformity-related units to the preferred single term “sequence” for all such units. A **sequence** is defined as "a relatively conformable succession of genetically related strata bounded at its top and base by unconformities and their correlative conformities. It is composed of a succession of systems tracts and it is interpreted to be deposited between eustatic fall inflection points".

Sequence bounding unconformities are initiated at times when the rate of sea level fall exceeds the rate of subsidence. As subsidence rates increase seaward on most platforms, the unconformities pass downdip into correlative conformities. Sequence stratigraphy may be applied at several scales, and in this sense it is fractal in nature (meaning that at any scale sequences have the same characteristics). Phanerozoic history is comprised of first-order eustatic sequences. First-order sequences are called megasequences by Haq et al. (in SEPM Special Publication 42) and are equivalent to the cratonic sequences of Sloss. Eras are comprised of second-order eustatic sequences (supersequences of Haq et al.). Seismic stratigraphy normally is concerned with third-order sequences (1 - 5 MY duration), and it is this level that is the subject of AAPG Memoir 26. Geologic studies of well log cross sections, outcrops, and cores deal with third, fourth (10^5 years duration) and fifth-order (10^4 years duration) sequences, and these are the subject of van Wagoner et al. (1988).

3.2.4 Parasequences

Parasequence are defined as a relatively conformable succession of genetically related beds or bedsets bounded by marine flooding surfaces and their correlative surfaces. In addition to these defining characteristics, most parasequences are asymmetrical shallowing-upward sedimentary cycles (Fig. 2). These parasequence cyclic stacking patterns are commonly identified on the basis of variations in grain size and when these fine upwards are indicated by triangles whose apex is up while those that coarsen upwards are indicated by inverted triangles whose apex is down. By genetically related, it is meant that all facies within a parasequence were deposited in lateral continuity to one another, that is, Walther's Law holds true within a parasequence. So, for a typical siliciclastic wave-dominated shoreline, a particular suite of facies should occur in a predictable order. In both clastics and carbonates the second and often co-incident step, in the interpretation of well logs and cores, is the use of parasequence stacking patterns (the vertical occurrence of repeated cycles of coarsening or fining upwards sediment). The parasequences are used to identify the systems tracts.

3.2.5 Lowstand Systems Tract

The LST is formed by sediments that accumulate after the onset of relative sea-level rise, during normal regression, on top of the FSST (Fig. 3) corresponding to an updip subaerial unconformity stacking patterns of clinoforms may forestep, and aggrade, particularly in siliciclastic systems, thicken downdip, with a topset of fluvial, coastal plain and/or delta plain deposits. LST sediments often fill or partially infill incised valleys that were cut into the underlying HST and other earlier deposits, during the forced regression. This systems tract has also been termed the late lowstand systems tract (Posamentier et al. 1988; Posamentier and Allen 1999) or the lowstand prograding wedge systems tract (Hunt and Tucker 1992). According to SEPM STRATA (2013), earlier papers recognized the ‘shelf margin systems tract’ as the lowermost systems tract associated with a 'type 2 ‘sequence boundary’ (Posamentier et al., 1988). The distinction between types 1 and 2 sequence boundaries has been dropped (Posamentier and Allen 1999; Catuneanu 2006), and the facies are now considered to be part of the LST. The LST is a time-based systems tract (Emery, 2009).

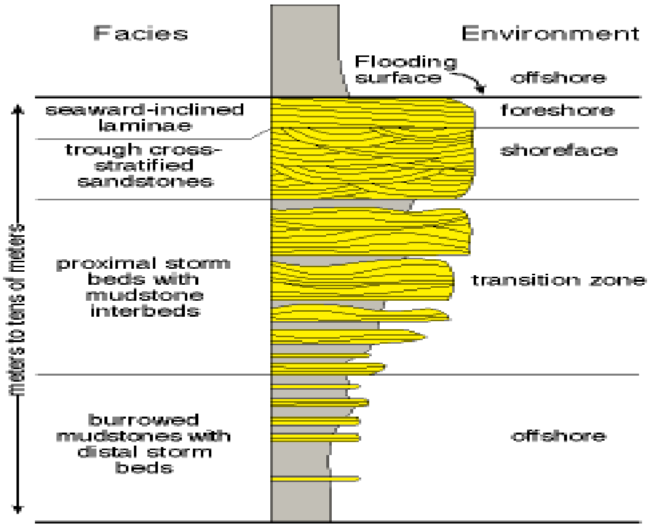

Fig. 2. Parasequence (Source: Holland, 2008)

3.2.6 Transgressive Systems Tract

The TST is formed by sediments that accumulated from the onset of transgression until the time of maximum transgression of the coast, just prior to the renewed regression of the HST. The TST lies directly on the maximum regression surface formed at the end of regression (also termed a transgression surface) (Fig. 3). A transgressive systems tract is overlain by the maximum flooding surface (MFS) formed when marine sediments reach their most landward position. The stacking patterns show backstepping, onlapping, retrogradational clinoforms that, particularly in siliciclastic systems, thicken landward. In cases where there is a high sediment supply the parasequences may be aggradational (SEPM STRATA, 2013). Emery (2009) defined the TST as material-based systems tract, and it was originally defined by van Wagoner et al. (1988).

3.2.7 Highstand Systems Tract

The HST includes the progradational deposits that form when sediment accumulation rates exceed the rate of increase in accomodation during the late stages of relative sea-level rise (SEPM STRATA (2013)). The HST lies directly on the MFS formed when marine sediments reached their most landward position. This systems tract is capped by the subaerial unconformity and its correlative conformity *sensu* Posamentier and Allen (1999). The stacking patterns show prograding and aggrading clinoforms that commonly thin downdip, capped by a topset of fluvial, coastal plain and/or delta plain deposits. Emery (2009) defined the highstand systems tract (HST) as a component unit of a sequence defined by a maximum flooding surface and its correlative surfaces as the lower boundary and a basal surface of forced regression (BSFR) and its correlative surfaces as the upper boundary (Fig. 3). The HST is a time-based systems tract.

3.2.8 Falling Stage Systems Tract (FSST)

Forced regressive (falling stage) systems tract (FRST, or FSST) is a unit of a sequence defined by a basal surface of forced regression (BSFR) and its correlative surfaces as the lower boundary and a correlative conformity (CC) and its correlative surfaces as the upper boundary (Fig. 3). The FSST is a time-based systems tract (Emery, 2009). According to SEPM STRATA (2013), the FSST is formed by forced regressive deposits that accumulated after the onset of a relative sea-level fall and before the start of the next relative sea-level rise. The FSST lies directly on the sequence boundary *sensu* Posamentier and Allen (1999) and is capped by the overlying lowstand systems tract (LST) sediments.

3.2.9 Sequence Models

There are four main types of sequence models in sequence stratigraphy in practice. These are Exxon/van Wagoner et al. (1988), Embry (1993), Hunt & Tucker (1992), modified by Helland-Hansen and Gjelberg (1994) and Posamentier & Allen (1999) sequence model, respectively. The schematic of the different sequence models is shown in Fig. 4, wherein red color is used for the sequence boundaries, while blue color is used to depict the internal systems tract boundaries.

3.3 Surfaces

3.3.1 Sequence Boundary

The sequence boundary is a subaerial unconformity (SU) up-dip and a correlative conformity (CC) down-dip. Where it is an unconformity, it is a surface of subaerial exposure and erosion; however, the expression of those features in an individual outcrop may or may not be obvious. In places, an unconformity may be marked by obvious erosion, such as a major incised channel or a beveling of structurally tilted underlying strata. Regionally, unconformities may display up to tens or sometimes hundreds of meters of relief. In siliciclastic systems, this relief is generated principally by down-cutting rivers. In the undissected regions between rivers, called interfluves, paleosols may mark an unconformity, and their presence may be indicated by caliche nodules or rooted horizons. Down-dip at its correlative conformity, a sequence boundary is commonly marked by an abrupt basinward shift in facies. This abrupt shift is called a forced regression by some workers to distinguish it from a normal regression in which a shoreline moves seaward simply due to sedimentation. An abrupt basinward shift of facies is manifested in an outcrop by an abrupt shallowing, such as shoreface sediments directly overlying offshore sediments or mid-fan turbidites directly overlying basinal shales. As facies above and below such a basinward shift in facies commonly represent non-adjacent environments, this surface is abrupt and Walther's Law cannot be applied across it. Minor submarine erosion may be associated with this abrupt basinward shift of facies. Farther downdip, the correlative conformity may display no obvious facies contrast or other unusual features; the position of the sequence boundary in these cases can only be approximated (Fig. 3). Sequence boundaries are generated by a relative fall in sea level. As this is a relative fall in sea level, it may be produced by changes in the rate of tectonic subsidence or by changes in the rate of eustatic rise, as long as those changes result in a net loss of accommodation space. Early models of sequence boundary formation argued that the sequence boundary formed at the time of maximum rate of fall, but subsequent models suggest that the age of the sequence boundary can range in age from the time of maximum rate of fall to the time of eustatic lowstand.

3.3.2 Basal Surface of Forced Regression (BSFR)

The Basal surface of forced regression (BSFR) was first defined by Hunt and Tucker (1992) as the surface that underlines the marine sedimentary wedge that builds seaward during a forced regression of the shoreline. According to Catuneanu (2006), BSFR of the FSST of Helland-Hansen and Gjelberg (1994) is also called the early lowstand systems tract of Posamentier and Allen (1999) (Figs. 3 and 4).

3.3.3 Regressive Surface of Marine Erosion (RSME)

Regressive surface of marine erosion (RSME) is usually formed during a time of base-level fall when the inner part of the marine shelf in front of the steeper shoreface is sometimes eroded. This area of inner RSME may be a few tens of kilometres wide, migrates basinward and it is a highly diachronous surface. RSME can potentially be quite widespread both along strike and down dip. Erosion beneath the RSME is minor and localized and thus it is almost always a diastem and not an unconformity (Emery, 2006).

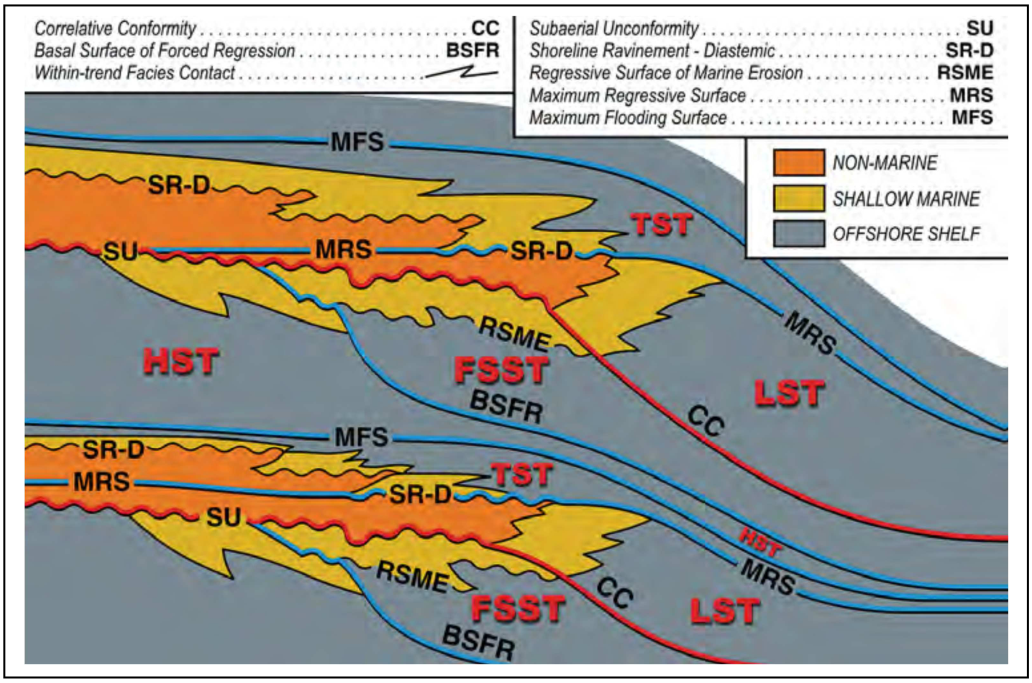

Fig. 3. Four systems tracts based on Hunt and Tucker (1992) model (Source: Emery, 2009)

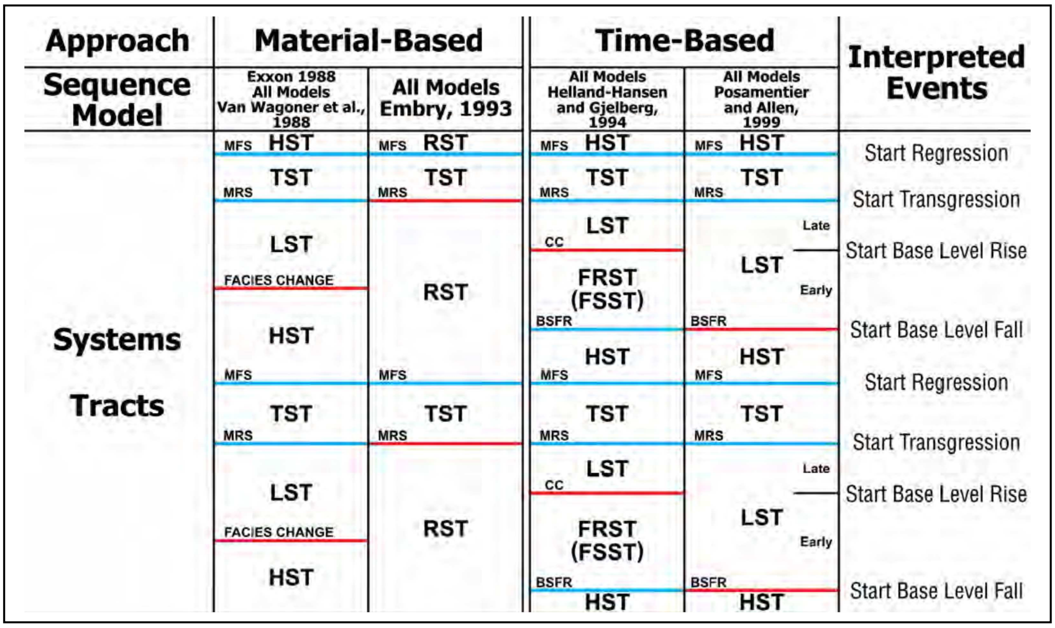

Fig. 4. Schematic of different sequence models (after Emery, 2006; Catuneanu, 2006)

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3.3.4 Maximum Regressive Surface (MRS)

The main characteristic for identification of an MRS in marine clastic strata is it is a conformable horizon or diastemic surface which marks a change in trend from coarsening-upward to fining-upward. The MRS is never an unconformity. Over most of its extent, the MRS also coincides with a change from shallowing-upwards to deepening-upward and this criterion is very helpful, especially in shallow water facies (Fig. 3). In deeper water, high subsidence areas, the change from of shallowing to deepening may not coincide with the MRS as defined by grain size criteria. In nonmarine siliciclastic strata, the change from coarsening to fining is also applicable for objectively identifying an MRS. In carbonate strata the change from shallowing upward to deepening upward is usually the most reliable and readily applicable criterion for identifying an MRS. Maximum regressive surface (MRS) is shown in Figs. 3 and 4.

3.3.5 Maximun Flooding Surface (MFS)

In marine siliciclastic strata, the MFS marks the change in trend from a fining upward trend below to a coarsening upward trend above (Embry, 2009). In nearshore areas, this change in trend coincides with a change from deepening to shallowing. Farther offshore, this relationship does not hold and the deepest water horizon sometimes can lie above the MFS. In terms of stacking pattern, the MFS is underlain by a retrogradational pattern which displays an overall fining upward and is overlain by a prograding one which records an overall coarsening upward (van Wagoner et al., 1990). In carbonate strata, the MFS also marks a change in trend from fining to coarsening. Notably, in a shallow-water carbonate-bank setting, the MFS will mark the horizon of change between deepening upward to shallowing upward and this criterion, which employs facies analysis, can often be more reliable than grain-size variation for its delineation in such a setting. In deeper water, carbonate ramp settings, the MFS marks a change from decreasing and / or finer carbonate material to increasing and/or coarser carbonate material. The MFSs have been placed at the change in gamma log trend from increasing gamma ray to decreasing gamma ray. This change in gamma ray trend is interpreted to reflect a change from fining and deepening-upward (increasing clay content) to coarsening and shallowing-upward (decreasing clay content). The MFS overlies the SU/SR-U/MRS surfaces (Figs. 3 and 4) and, as shown, represents the change in trend from fining to coarsening. The surface develops close to the time of onset of regression when the shoreline begins to move seaward and coarser sediment arrives at a given locality on the shelf. In distal areas, the MFS can be an unconformity due to starvation and episodic scouring and it is downlapped by prograding sediment. On seismic data the MFS is represented by a reflector often referred to as a “downlap surface” (Emery, 2009). MFS is marked by the change from fining upward to coarsening-upward. Thus, the MFS is interpreted to be generated very near the time of start of regression.

3.3.6 Transgressive Surface

The lowstand systems tract is commonly capped by a prominent flooding surface called the transgressive surface. The transgressive surface represents the first major flooding surface to follow the sequence boundary and is usually distinct from the relatively minor flooding surfaces that separate parasequences in the lowstand systems tract. The transgressive surface may be accompanied by significant stratigraphic condensation, particularly in nearshore settings, which may be starved of sediment because of sediment storage in newly formed estuaries. Typical features indicating condensation are discussed in more detail below. Following the relatively low rates of accommodation during the lowstand systems tracts, relative sea level begins to rise at an increasing rate. When this long-term rise is coupled with the short-term rise that forms a parasequence boundary, a major flooding surface is formed. The first of the series of these flooding surfaces is called the transgressive surface. In updip areas characterized by subaerial exposure and erosion during the lowstand systems tract, the transgressive surface and sequence boundary are merged into a single surface. Such situations are common in slowly subsiding regions such as in cratonic regions and the landward areas of passive margins.

3.4 Seismic Stratigraphy

According to Catuneanu et al. (2009), in seismic stratigraphy, there are four stratal terminations that can be used to identify sequence stratigraphic surfaces. There are two occurring above a surface known as onlap and downlap, while the remaining two occur below a surface are called truncation and toplap (Fig. 5). In addition, offlap is a key stratal stacking pattern that affords the recognition of forced regressions and the delineation of subaerial unconformities and their correlative conformities. Such lapouts are useful to the interpretation of depositional trends, and hence systems tracts. Stratal geometries, together with stratal terminations, can be used to define surfaces and systems tracts, and also to infer accommodation conditions at the time of deposition (Catuneanu et al., 2009).

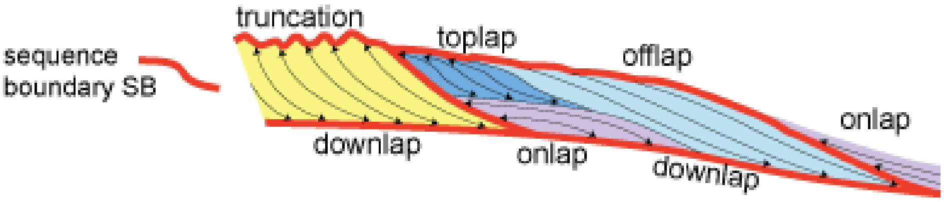

Fig. 5. Seismic stratal terminations (After Catuneanu, 2002 quoted in SEPM STRATA, 2013)

3.5 Biostratigraphy

Biostratigraphy is the study of rock strata using fossils (Giwa, et. al, 2006). The best sequence stratigraphic models of the sedimentary fill of basins are provided by a combination of seismic data, well logs and cores and outcrop studies in conjunction with biostratigraphy. The cores and well logs and outcrop studies provide access to a detailed vertical resolution of sedimentary sections while seismic and outcrop studies provide the lateral continuity to the sequence stratigraphic framework and the biostratigraphy provides the time constraints. All these different sequence stratigraphic techniques can be used independently of each other to produce accurate interpretations of the depositional histories of the sedimentary fill of a basin but the best models come from a mix of all three. Sequence stratigraphy is best determined when well logs are tied to biostratigraphic markers. Subsurface rock samples are usually obtained from ditch cuttings, sidewall or core samples. Mega-fossils are usually grounded; however, microfossils are preserved in their natural state. In biostratigraphic studies, the three basic disciplines studied are micropaleontology, nannopaleontology and palynology. Biostratigraphy has proven itself to be a major tool in developing an understanding of reservoir architecture and continuity, and in developing strategies to maximize petroleum production. At the same time, the high resolution biozonation schemes that are developed are useful for wellsite work, especially if the wells are being drilled horizontally to maximize recovery of hydrocarbons. Such a well is said to be "biosteered" using high resolution biozonation schemes. (Shipp & Marshall, 1995).

3.5 Carbonate Sequence Stratigraphy

According to Catuneanu et al. (2009), the concepts of sequence stratigraphy apply to carbonate systems in much the same way as they do to siliciclastic or other terrigenous (e.g., detrital calcareous clastic) systems. In other words, carnonate stratigraphic sections share similar bounding surfaces such as subaerial unconformities, correlative conformities maximum flooding surfaces, flooding surfaces, maximum regressive surfaces, regressive surfaces of marine erosion, and transgressive ravinement surfaces. However, the difference lies in the physical character of these surfaces and the sediments they subdivide (Catuneanu et al., 2009). The following factors predicate the observed difference: "(1) in carbonate settings sediments are primarily sourced locally in response to the productivity of carbonate-producing organisms, forming the 'carbonate factory'; (2) most carbonate production is related to photosynthesis and so water depth, either directly (in the case of autotrophs, which use inorganic material to synthesize living matter) or indirectly (in the case of heterotrophs, which include filter feeders that are light-independent, and, consequently not controlled by water depth); (3) carbonate production is also related to the salinity, temperature and nutrient content of the seawater; (4) the dispersal of carbonate sediment is influenced by biological processes that include binding, baffling, encrusting, and framework-building; (5) carbonates are prone to cementation penecontemporaneous with accumulation, which stabilizes the sea bottom and thus restricts sediment mobility; and (6) carbonates are prone to physical and chemical erosion in both submarine and subaerial settings. Interpreting key surfaces in a sequence stratigraphic context can be particularly problematical because deposits may be erased and critical events may go unrecorded. It is important to remember that the influence of all these factors is related to the evolutionary and ecological history of the various organism groups involved, be they microbial, faunal or floral" (Catuneanu et al., 2009).

4. Applications of Sequence Stratigraphy

Sequence stratigraphy interpreted from well logs tied to biostratigraphy is used to correlate and analyze sedimentary rocks from the perspective of geologic time. Well logs lend themselves to the detailed reconstructions of paleogeography and the generation of high frequency stratigraphic models that predict the distribution of sedimentary facies, particularly those associated with aquifers, sediment bound ore bodies, and hydrocarbon reservoirs, their source rocks and seals. Sequence-stratigraphic analysis is an appropriate method for identifying subtle variations exhibited in a stratigraphic succession (Brown, et al, 2004). According to Brown et al. (2004), application of sequence stratigraphy provides the potential for chronostratigraphic correlation within and among growth-faulted sub-basins, thus improving prediction of stratigraphic and areal distribution of deeply buried lowstand reservoirs; providing a guide to potential combination traps; opening a window on exploration for deep, unexpanded sub-fault reservoirs and traps; placing the sub-basin into a petroleum system framework; and focusing on improper correlation of genetically similar wire-line log patterns of temporally lithostratigraphic units.

It has been established that the maximum flooding surfaces (MFS) within the marker shales are the boundaries of the sequences (Galloway, 1989). The sequence surfaces can be traced from seismic profiles using the approach of Vail (1987) and derivation from wire-line logs after Durand (1995) and using biostratigraphic data, they can be easily confirmed. According to Obaje (2004), sand percentages can be derived from wire-line logs of which the vertical sand stacking pattern is an inversion (mirror image). Thick shales separating reservoir sands are candidates for MFS, the thin ones are usually interbedded in shoreface deposits and contain lower-order flooding surfaces (Reijers, 1996). The sequence boundaries can be identified from the wire-line logs and checked against the maximum depth (from seismic profiles) and biofacies abundances and diversities.

5. Conclusion

Sequence stratigraphy has come of age, and it is a tool every explorationist must master. It is essential for regional and local exploration studies, for seismic evaluation, and for reservoir evaluation. It is a very useful tool for the identification of 3rd Order depositional sequences and systems tracts that are associated with potential hydrocarbon reservoirs, source rocks and seals in sedimentary basins

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