The Sedimentary Record of Sea-Level Change - Figure captions

Figure 3.6 Cartoon showing the relationship between relative sea-level, water depth, eustatic sea-level, tectonics (uplift and subsidence), and accumulated sediment. Note that relative sea-level incorporates subsidence and/or uplift by referring to the position of sea-level with respect to the position of a datum at or near the sea-floor (e.g. basement rocks, top of previous sediment package) as well as eustasy. Eustasy (i.e. global sea-level) is the variation of sea-level with reference to a *fixed* datum, for example the centre of the Earth. *(Angela Coe, Open University).*

Figure 4.1 Sediment accommodation space and its relationship to eustatic sea-level and tectonic uplift and subsidence. Marine accommodation space created during a rise in relative sea-level has been partially filled with sediment (yellow and dark-grey), whereas the non-marine accommodation space created during the rise in relative sea-level has been totally filled with sediment (yellowish-green). *(Angela Coe, Open University).*

Figure 4.2 (a) The equilibrium profile of an alluvial system. In order to maintain the equilibrium profile, erosion or deposition of alluvial sediments will take place if there is a relative sea-level change and/or tectonic movement in the source area. (b) Erosion of sediments due to uplift of the source area. (c) Erosion and deposition of sediments along the alluvial profile due to subsidence of the source area. (d) Deposition of sediments due to a relative sea-level rise. (e) Erosion of sediments due to a relative sea-level fall. *(Angela Coe, Open University).*

Figure 4.4 (a) Cross-section showing progradation of a coastal succession due to the rate of increase in accommodation space being less than the rate of sediment supply. (b) A simplified graphic log of the resultant coarsening-upward succession termed a parasequence. *(Angela Coe, Open University).*

Figure 4.6 Cross-sections and graphic logs showing the effects of long-term changes over two parasequences of: (a) an increase in the rate of creation of accommodation space (note that parasequence 2 is thicker than parasequence 1 on the left-hand side); (b) no change in the rate of creation of accommodation space; (c) a decrease in the rate of creation of accommodation space (parasequences 1 and 2 are the same thickness on the left-hand side); (d) a decrease in the amount of accommodation space (parasequence 2 is thicker than parasequence 1 on the left-hand side). Note that, if the accommodation space continues to decrease, it is unlikely that alluvial and coastal plain sediments will accumulate. The rate of sediment supply is assumed to be constant in each case. *(Angela Coe, Open University).*

Figure 4.7 Stacking patterns of parasequences. (a) Retrogradational parasequence set resulting from an increase in the rate of creation of accommodation space for each parasequence that is greater than the constant sediment supply (as shown by the increase in distance between each sea-level). (b) An alternative retrogradational parasequence set resulting from a constant rate of increase in accommodation space (as shown by the equal distance between each rise in sea-level) between parasequences but a decrease in the rate of sediment supply. (c) Aggradational parasequence set resulting from the rate of sediment supply being matched by the rate of increase in accommodation space. (d) Progradational parasequence set resulting from the rate of creation of accommodation space between parasequences being less than the constant rate of sediment supply. (e)–(g) Alternative progradational parasequence sets. (e) Progradational parasequences resulting from a constant rate of increase in accommodation space and an increase in the rate of sediment supply. For (f), there is no long-term increase in accommodation space (i.e. a sea-level stillstand) but there is a continuous sediment supply. For (g), there is a long-term decrease in accommodation space (i.e. a relative sea-level fall) this will always lead to progradation no matter what the rate of sediment supply is. *(Angela Coe, Open University).*

Figure 4.8 Sea-level curves used in Figures 4.10, 4.11, 4.12, 4.15, 4.16, 4.17 and 4.18: (a) relative sea-level curve derived from addition of a uniform subsidence rate and a sinusoidal change in eustatic sea-level; (b) complex curve (shown in purple) that results from combining the relative sea-level curve in (a) with shorter-term changes in accommodation space associated with the development of parasequences. Equal time divisions are shown by red lines numbered t_0, t_1, etc. In this case, each of these time units is assumed to be the time taken for the deposition of a parasequence. A and D = points in time when relative sea-level is neither rising or falling. A = maximum sea-level for period between t_0 and t_{21}, B = minimum sea-level for period between t_2 and t_{29}. B and D = maximum rate of relative sea-level fall and rise respectively (inflexion points). *(Angela Coe, Open University).*

Figure 4.10 Features of the highstand systems tract (HST). (a) Interval on the theoretical relative sea-level curve shown in Figure 4.8, during which the HST is deposited. (b) Detail of the relative sea-level curve (in blue) and the HST sediments deposited. The curve spans a phase of decreasing relative sea-level rise (i.e. a decrease in rate of creation of accommodation space). The relative sea-level curve is divided into equal time units (red lines t_1, t_2 etc.). Dashed horizontal black lines in the middle indicate the amount of accommodation space created during each time step in the relative sea-level rise. The right-hand part shows the sediments deposited for each of the equal time intervals, assuming a constant rate of sediment supply. Note how the decrease in accommodation space in the proximal areas results in an aggradational to progradational parasequence stacking pattern. Sediments deposited over the time interval between the maximum rate of sea-level rise and maximum sea-level form the HST. (c) Typical geometry and features of the HST along a margin with a shelf break. Note that in the example illustrated, the HST did not prograde as far as the shelf break. (d) Typical geometry and features of the highstand systems along a ramp margin. (c) and (d) not to scale. *(Angela Coe, Open University).*

Figure 4.11 Features of the sequence boundary (SB). (a) Interval (t_7–t_{16}) on the theoretical relative sea-level curve where the sequence boundary forms. t_7 = initiation of sequence boundary formation and time of formation of the correlative conformity. t_{16} = last point where fluvial incision can take place. (b) Geometry and features of the sequence boundary along a margin with a shelf break. (b) and (d) Sediments that may be deposited simultaneously with formation of the sequence boundary are not shown. (c) Chronostratigraphical diagram from t_0–t_{23} to show the time represented by the unconformity surface of the sequence boundary (shaded in pink) and its relationship in time to the correlative conformity surface. (d) Geometry and features of the sequence boundary along a ramp margin. (e) Chronostratigraphical diagram from t_0–t_{23} showing similar features to (c). Note that for simplicity the hemipelagic and pelagic sediments that will be deposited in the deeper part of the basin are now shown; the correlative conformity will pass through these. Deposits shown above the correlative conformity part of the sequence boundary (t_7) in (c) and (e) are illustrated in Figures 4.12, 4.15, 4.16 and 4.17. (b) and (d) are not to scale. *(Angela Coe, Open University).*

Figure 4.12 Features of the falling stage systems tract (FSST). (a) Interval on the theoretical relative sea-level curve shown in Figure 4.8 during which the FSST is deposited. (b) Detail of the relative sea-level curve (in blue) and the FSST sediments deposited. The curve spans a phase of increasing and then decreasing rate of relative sea-level fall (i.e. a slow, then rapid, and finally a slow decrease in the amount of accommodation space). The relative sea-level curve is divided into equal time units (red lines t_7, t_8 etc.). Dashed horizontal black lines in the middle indicate the amount of accommodation space lost during each time step in the relative sea-level fall and hence the potential depth down to which fluvial valleys might incise. The right-hand part shows sediments deposited for each of the equal time intervals assuming a constant rate of sediment supply, that sediment continues to be deposited, and that the depositional profile is gently sloping. The sediments deposited over the interval between maximum and minimum relative sea-levels form the FSST. The tops of the previously deposited parasequences in the FSST are eroded as relative sea-level continues to fall. (c) Geometry and features of the FSST along a margin with a shelf break. In this case, the first two parasequences of the FSST are deposited on the continental shelf as downstepping parasequences (t_7–t_8 and t_8–t_9). It is assumed that in this case after t_9 relative sea-level fell below the shelf break and therefore that all further sediment was transported down the steep continental slope into the deep sea where it was deposited as submarine fans on the basin floor. (d) Geometry and features of the FSST along a ramp margin showing the deposition of an attached FSST. (c) and (d) are not to scale and show a slightly greater relative sea-level fall than (a) and (b) in order to show all the features. *(Angela Coe, Open University).*

Figure 4.15 Features of the lowstand systems tract (LST). (a) Interval on the theoretical relative sea-level curve shown in Figure 4.8, during which the LST is deposited. (b) Detail of the relative sea-level curve (in blue) and the LST sediments deposited. The curve is over a phase of slowly rising relative sea-level (i.e. an increase in the rate of creation of accommodation space). The relative sea-level curve is divided into equal time units (red lines t_{16}, t_{17} etc.). Dashed horizontal black lines in the middle indicate the amount of accommodation space created during each time step in the relative sea-level rise. The right-hand part shows sediments deposited for each of the equal time intervals assuming a constant rate of sediment supply and that the depositional profile is gently sloping. The sediments deposited over the time interval between the minimum relative sea-level and the more pronounced increase in sea-level form the LST. (c) Geometry and features of the LST along a margin with a shelf break. Initially, submarine slope fans may be deposited (shown as t_{16}–t_{18}) until the gradient is low enough and sea-level is high enough that the shoreline can prograde out into the basin (t_{18}–t_{21}) and coastline sediments can be deposited. (d) Geometry and features of the LST along a ramp margin. (c) and (d) are not to scale. *(Angela Coe, Open University).*

Figure 4.16 The geometry and features of the transgressive surface (TS). (a) Position on the theoretical relative sea-level curve where the transgressive surface starts to form. (b) Geometry and features of the transgressive surface along a shelf break margin. (c) Geometry and features of the transgressive surface along a ramp margin. (b) and (c) not to scale. *(Angela Coe, Open University).*

Figure 4.17 Features of the transgressive systems tract (TST). (a) Interval on the theoretical relative sea-level curve shown in Figure 4.8 during which the TST is deposited. (b) Detail of the relative sea-level curve (blue) and TST sediments deposited. The curve spans a phase where increase in the rate of relative sea-level rise is greater than the rate of sediment supply. The relative sea-level curve is divided into equal time units (red lines t_{20}, t_{21} etc.). Dashed horizontal black lines in the middle indicate the amount of accommodation space created during each time step in the relative sea-level rise. The right-hand part shows sediments deposited for each of the equal time intervals assuming a constant rate of sediment supply. These parasequences show a retrogradational pattern. Sediments deposited over the time interval between pronounced increase in the rate of creation of accommodation space and maximum rate of relative sea-level rise form the TST. (c) Geometry and features of the TST along a margin with a shelf break. (d) Geometry and features of the TST along a ramp margin. (c) and (d) not to scale. *(Angela Coe, Open University).*

Figure 4.18 Features of the maximum flooding surface (MFS). (a) Position (t_{23}) on the theoretical relative sea-level curve shown in Figure 4.8 where the maximum flooding surface forms in this case. The exact position of the MFS depends on the balance between the rate of relative sea-level rise and rate of sediment supply. (b) Geometry and features of the maximum flooding surface along a margin with a shelf break. (b) and (d) Sediments that may be deposited simultaneously with formation of the maximum flooding surface are not shown. (c) Chronostratigraphical diagram from t_0–t_{38} to show the time represented by the maximum flooding surface and condensed section (shaded pink). (d) Geometry and features of the maximum flooding surface along a ramp margin. (e) Chronostratigraphical diagram from t_0–t_{38} showing similar features to (c). Note that for simplicity the hemipelagic and pelagic sediments that will be deposited in the deeper part of the basin are not shown.(b) and (d) not to scale. *(Angela Coe, Open University).*

Figure 5.1 The influence of tectonic and climatic processes on the sedimentary record. *(Angela Coe, Open University).*

Figure 5.12 Cross-section through 12 sequences (1–12) with (a) systems tracts and (b) the grouping of these sequences into the longer term sequence sets marked. In this case, relative sea-level is assumed to have fallen below the shelf break and all the FSST and LST are deposited as submarine fans. The deposits above the LST in sequence 12 and below the TST in sequence 1 are not shown. *(Kevin Church, Open University.)*

Figure 7.9 Features of wave-dominated deltas (also sometimes called shoreface systems). These deltas occur when wave processes in the basin rework the sediment introduced by rivers. Shorelines are elongate in a coast-parallel direction. Deposits coarsen-upward and contain HCS and wave ripples produced by storms. Trough cross-stratification and low-angle planar cross-bedding are the product of shoaling and breaking waves in the shallow waters of the upper shoreface. This type of shoreline system is the most common in the Book Cliffs (a) 3-D block diagram; (b) typical graphic log of a wave-dominated delta succession (typically *c*. 20–30 m thick). Bio-index refers to the intensity of bioturbation: 1 = low, 6 = high. For the Book Cliffs succession, the tidal range was typically *c*. 2–4 m, FWWB *c*. 5–15 m, and SWB *c*. 15–40 m. *(John Howell, University of Bergen and Stephen Flint, University of Liverpool.)*

Figure 7.10 Examples of offshore transition zone, shoreface and foreshore facies from the Book Cliffs. Graphic log is *c*. 20–30 m long. (a) Upper shoreface trough cross-stratified sandstones and planar-stratified foreshore deposits from Bear Canyon (sandstone is *c*. 6 m thick). (b) Highly bioturbated middle shoreface facies from Gentile Wash. Note that this facies is not always present in the succession (pencil shows scale). (c) Offshore transition zone heterolithic deposits from Woodside Canyon (pole is 1.2 m long). (d) Low-angle dipping, planar-laminated foreshore facies from Woodside Canyon. *((a)–(e) John Howell, University of Bergen.)*

Figure 7.11 Block diagram and graphic log to show typical features of the coastal plain. On average, the thickness of deposits shown in the graphic log is *c*. 5 m. The deposits of the non-marine part of the Blackhawk Formation were laid down in the area behind the shorelines. They include meandering fluvial channels and associated overbank deposits. Peats accumulated during periods when siliciclastic sediment supply was low and the water table was very high; following burial, these became coals. *(John Howell, University of Bergen and Stephen Flint, University of Liverpool.)*

Figure 7.14 Features of estuarine facies associations. (a) 3-D facies model for the Book Cliffs estuarine deposits and mini-graphic logs (each of *c*. 10 m) showing typical vertical successions. (b) Erosive-based tidally influenced estuarine channel system cut into older shoreface deposits, Desert Member, Tusher Canyon. (c) Bayhead delta deposits, Soldier Creek (scale bar = 30 cm). (d) Large-scale tidal bedforms (inclined heterolithic stratification), Tusher Canyon (people for scale). (e) Interbedded tidal channel, tidal flat deposits and a thin coal, Woodside Canyon. (cliff *c*. 10 m high)). (f) Detail of mud-draped sandstones typical of tidal deposits within an estuarine environment, Straight Canyon (pencil for scale). (g) Aerial view of small, modern estuary; the Essequibo, Guyana, South America (image *c*. 60 km from top to bottom). *((a) and (b) Stephen Flint, University of Liverpool; (a), (c)–(f) John Howell, University of Bergen; (g) NASA.)*

Figure 8.1 Exposure photograph and graphic log of the third marine parasequence up from the base of the Sunnyside Member (denoted Sunnyside PS3 (or S3 in Figure 10.1) in Woodside Canyon. Note the sheet-like geometry, shallowing-upward trend and bounding flooding surfaces. See Figure 7.9 for key. *(John Howell, University of Liverpool.)*

Figure 8.5 Shoreface parasequence close to fluvial input point from the Spring Canyon Member behind the town of Kenilworth. (a) Photograph of the Kenilworth face showing the low-angle clinoform surfaces in the mouth bar of the Spring Canyon

4 parasequence. Cliff is *c.* 100 m high. (b) Line drawing of (a) to show interpretation based on the work of Diane Kamola. (c) Detailed photograph of current ripples (as opposed to HCS) in mouth bar parasequence at Kenilworth. *((a)–(c) John Howell, University of Liverpool; (b) Stephen Flint, University of Liverpool.)*

Figure 8.8 Example graphic logs and photographs of non-marine parasequences in the Kenilworth Member. (a) Graphic log at Coal Creek showing Kenilworth parasequences 2, 3 and 4 in their non-marine facies. Kenilworth PS1 is still marine at this locality. The parasequence boundaries are coals, related to water table rise, landward of marine flooding. Note the increase in sandstone content upward in each parasequence. (b) Detail of the Kenilworth non-marine parasequences further landward at Willow Creek. This section was deposited on the landward side of coastal peat mires. Here, there is an upwards increase in the proportion of channel deposits within each parasequence, and parasequence boundaries are represented by the sudden increase in proportion of fine-grained overbank deposits. The photograph shows detail of the upward increase in sandstone in a coal seam-bounded non-marine parasequence. *((a) and (b) John Howell, University of Liverpool.)*

Figure 8.9 (a) View of Sunnyside PS3 and the adjacent parasequences. The photograph shows where Sunnyside PS3 is represented by a coal overlain by a marine shoreface (thin, pale-coloured band) that thickens seaward (to the right), forming a split in the Sunnyside coal. (Cliff is *c.* 50 m high.) (b) Interpreted formation of the split. (i) Relative sea-level rise results in transgression into a margin of raised mire and deposition of a shoreface sandbody. (ii) The top of the new parasequence is colonized by coal-forming plants, producing a thick peat. (iii) Early burial-related compaction is much greater for the peat than the sand, resulting in backward rotation of the shoreface sandstone body into the peat. The peat then becomes coal during later burial. *(John Howell, University of Bergen.*)

Figure 8.10 (a)–(e) Parasequence formation takes place in several stages, controlled by the balance between the rate of generation of accommodation space (through relative sea-level change) and rate of sediment supply. Arrows mark the migration directions of facies belts. *(John Howell, University of Bergen and Stephen Flint, University of Liverpool.)*

Figure 8.11 Schematic representation of volumetric partitioning in space and time for the Book Cliff parasequences. It illustrates the spatial change in the volumes of sediment being deposited in the non-marine, lagoonal, shoreface and offshore facies of a single parasequence as illustrated in Figure 8.10. (a) Relative sea-level rise causes the barrier island to move landward; sediment is deposited in the lagoon created behind the barrier and on the coastal plain. (b) During landward migration of the barrier island in a period of relative sea-level rise, all the sand is stored in the coastal plain. (c) As the shoreface starts to prograde again, sediment supply fills the available accommodation space, and the coastal plain again becomes a by-pass area and the main sand volume is partitioned into the coastal zone; hence a change in volumetric partitioning or ‘mass-balance’. (d) The same relationships expressed in a chronostratigraphical diagram. Note that the time during which the majority of non-marine strata are deposited in the parasequence corresponds to the thin layer of offshore marine shale at the base of the shoreface. The majority of the shoreface sand is slightly younger than the non-marine component of the parasequence. (e) Graphic logs showing idealized parasequences from a coastal plain, shallow and marginal marine setting and their relationship to (d). For (d) and (e), the numbered red lines are the time lines. *(John Howell, University of Bergen and Stephen Flint, University of Liverpool.)*

Figure 9.1 Schematic diagram, showing the effects of a relative sea-level fall in a basin with a continental shelf of varying width and depth. Cliff running across near the left-hand edge of the Figure shows the position of the former highstand shoreline. (a) In areas with a narrow, relatively shallow shelf, relative sea-level can fall to the shelf edge, subaerially exposing the entire shelf, rivers incise valleys out to the shelf edge and supply sediment to either shelf edge deltas or the heads of existing canyons. Gravitational processes take over and most of the sediment is remobilized within turbidity currents and deposited as basin floor fans. The sequence boundary is expressed by the erosional base of the incised valleys, the coeval interfluve surface on which a palaeosol will develop and the base of the submarine fan. (b) Effects of the same relative sea-level fall when, due to the shape of the basin, the shelf edge is not subaerially exposed. The result is a FSST and LST delta on the mid- or outer shelf (this is the case for most of the sequence boundaries in the Book Cliffs where the basin had a ramp-style topography). FSST and LST deltas may remain attached or become detached from the preceding HST, depending on the rate of sea-level fall and amount of sediment supplied. In case (c), the very low gradient of the shelf prevents the rivers carrying sediments to the new shoreline and the relative sea-level fall results in attached terminal fluvial deposits. In this case, no FSST or LST shorelines exist. This model was proposed by John Van Wagoner for the Castlegate Sandstone in the Book Cliffs. *(John Howell, University of Bergen and Stephen Flint, University of Liverpool.)*

Figure 9.6 The Woodside Canyon incised-valley complex. (a) Correlation of Sunnyside Member measured sections shows clear truncation of Sunnyside shoreface paraequence 3 by the sequence boundary and the variety in the estuarine fill of the incised valley. Note the incision on the sequence boundary; the fluvial deposits at the base of the valley fill; the predominance of tidal deposits within the valley and planar nature of the overlying flooding surface (PSB). (b) Map showing location of the correlation line in (a) and position of the incised valley with respect to the present-day Woodside Canyon. (c) Sequence boundary and margin of incised valley in Woodside Canyon. The white and pale-brown coloured shoreface deposits of Sunnyside PS3 on the right-hand side have been removed by the sequence boundary and replaced by later, poorly exposed, heterolithic tidal deposits (cliff is *c*. 40 m high). (d) Inclined heterolithic strata, deposited by lateral accretion on the point bars of meandering tidal channels within the estuarine complex. (e) Heterolithic tidal flat deposits deposited in areas away from the main tidal channels within the estuary (pole = 1.2 m). (f) Coarse-grained, trough cross-stratified sandstones (lens cap for scale). These fluvial deposits occur at the base of the estuary and were deposited in isolated pads as relative sea-level was falling. (g) Coarsening-upward succession of rippled and trough cross-stratified sandstones interpreted as a small delta deposited within the estuary (cliff is *c*. 20 m high). Palaeocurrent indicators imply flow towards the west (landward) and consequently the unit is interpreted as a flood tidal delta. *((a) and (b) Stephen Flint, University of Liverpool; (a)–(c), (e)–(g) John Howell, University of Bergen; (d) Chris Wilson, Open University.)*

Figure 9.7 3-D visualization of the drainage network produced by erosion on the Sunnyside Sequence Boundary. The main valley axis is at the base of the map and two tributary valleys from the west and north-west drain into it. The line of cross-section A–A' refers to the cross-section in Figure 9.6. *(John Howell, University of Bergen and Stephen Flint, University of Liverpool.)*

Figure 9.8 Detail of the incised valley complex overlying the Lower Sunnyside Sequence Boundary: an incised valley complex in a non-marine setting. (a) Map showing the distribution of incised valleys above the Lower Sunnyside Sequence Boundary in the northern part of Book Cliffs. Position of previous highstand shoreline shown in blue. (b) Cross-section along the axis of one of the incised valleys, showing the predominance of sandy tidal deposits. *(John Howell, University of Bergen and Stephen Flint, University of Liverpool.)*

Figure 9.9 Photographs of the incised valley complex overlying the Lower Sunnyside Sequence Boundary in a non-marine setting. (a) The Sunnyside Sandstone in Straight Canyon; note the two distinct sandbodies and the recessively weathered, heterolithic unit in the centre (cliff *c*. 20 m high). (b) Coarsening-upward succession of tidally influenced deltaic deposits at the top of the valley fill succession in Soldier Creek (Figure 7.1) (person shows scale). (c) Large-scale cross-bedding with organic carbon-rich drapes. Cross-bedding of this magnitude provides evidence for meso- to lower macrotidal conditions and represents amplification of the tidal wave within an estuary (cliff *c*. 6 m high). (d) Smaller-scale, heterolithic tidal cross-stratification (image is *c*. 1 m top to bottom). *((a)–(d) John Howell, University of Bergen.)*

Figure 10.1 (a) Sequence stratigraphy of the Blackhawk Formation. Lithostratigraphical members are bounded by tongues of marine shale that usually equate to the maximum flooding surfaces within sequences. Consequently, in a number of cases, individual sequences cross member boundaries. There is also an overall increase in the degree of progradation upward. The parasequences are numbered within each member, e.g. SC4, SC5 are parasequences 4 and 5 in the Spring Canyon Member. Note that whilst the number of marine parasequences in each sequence is typically correct, at least seven parasequences exist in the Spring Canyon Member and up to 30 may exist within the Desert Member. In both cases, the exact number is not known due to incomplete exposure or erosion by subsequence sequence boundaries and they are therefore not all shown. Note that parasequence A2 is composed of shoreface facies; it is picked out in red because it is interpreted as a FSST. *(John Howell, University of Bergen and Stephen Flint, University of Liverpool.)*

Figure 10.2 Summary of progradation of the Blackhawk Formation siliciclastic wedge through time. The graph shows the position of the up-dip terminations of the upper shoreface facies within each parasequence. The lithostratigraphy and sequence stratigraphy are superimposed. Note the overall change through time from the broadly aggradational parasequences of the Spring Canyon and Aberdeen sequences to the strongly progradational stacking patterns in the Grassy. This graph is a simplification of the high resolution pattern which also shows more pronounced progradational parasequences in the Desert Member. *(John Howell, University of Bergen and Stephen Flint, University of Liverpool.)*

Figure 10.7 Schematic summary diagram to indicate the controls on sequence development in the Book Cliffs. Note that there are complex feedback relationships between several of the variables, thus making it difficult to isolate the effect of a single variable. However, the rate of change of accommodation space is the fundamental control on both the volume and type of sediment preserved in the rock record and on the partitioning of time between rocks and surfaces. . *(John Howell, University of Bergen and Stephen Flint, University of Liverpool.)*

Figure 11.2 A comparison of the rates of accumulation for pelagic, shallow cool-water and shallow warm-water carbonates, and the rate at which accommodation space may be created by glacio-eustasy, basin subsidence, and fault-related subsidence. *(Dan Bosence, Royal Holloway University of London.)*

Figure 11.10 Surface and underwater photographs of carbonate producers and sediments from Florida Bay and Reef Tract. (a) Excavated bed of seagrass (*Thalassia*) illustrating dense growth of shoots (1 cm diameter), roots and leaves that trap and bind carbonate mud, much of which is produced from organisms living on the grass blades. (b) Muddy bottom of Florida Bay with population of calcified green algae (10–15 cm high). *Udotea* is a fan-shaped alga (centre foreground) and *Penicillus* is a bush-shaped alga (centre back); other algae are non-calcified forms. (c) Florida Bay shoreline showing accumulation of molluscan shell gravel and king crab (crab *c.* 154 cm across). (d) Low altitude aerial view of Florida Bay illustrating shallow-water mud mounds that preferentially accumulate carbonate sediments through the trapping of sediment in seagrass beds. (e) Box core of intertidal microbial mat with horizontal microbial/sediment laminations and vertical desiccation cracks (scale bar = 10 cm). (f) Mud pebble conglomerate formed from erosion and redeposition of intertidal microbial facies (scale bar = 10 cm). (f) Mud pebble conglomerate formed from erosion and redeposition of intertidal microbial facies (scale bar = 10 cm). (g) Current-washed skeletal sand in back-reef area with colony of coral *Acropora* (*c.* 30 cm across). (h) Coral (*Diploria c.* 1 m across) overturned by a recent storm to reveal bioeroded (by echinoids and parrot fish) undersurface to colony. (i) *Halimeda*, a calcareous green alga (*c.* 10 cm high). *((a)–(h) Dan Bosence, Royal Holloway University of London; (i) Chris Wilson, Open University.)*

Figure 12.1 Relationships between carbonate platform morphology, sea-level and carbonate sediment supply. The gradients shown on the cross-sections are vertically exaggerated. The graphs on the right show vertical changes in carbonate production (in metres of vertical thickness per 1000 years) with depth (in metres below sea-level). Production reaches a maximum between 10 and 30 m water depth and then decreases with increasing water depth. (a) During periods of relatively low sea-level, the limited horizontal extent of the carbonate platform results in small total amounts of carbonate being generated because of the small area of high productivity. (b) Flooding over the platform top significantly increases the horizontal extent of the productive area, and sediment production will rapidly fill all the newly created accommodation space. *(Dan Bosence, Royal Holloway University of London.)*

Figure 12.10 Diagrams illustrating variations in the sequence stratigraphy of carbonate ramps: (a) distally steepened ramp; (b) arid climate (evaporitic) ramp. *(Dan Bosence, Royal Holloway University of London.)*

Figure 12.11 Computer-generated profiles of carbonate platforms from Sedtec 2000 showing the stratigraphy resulting from different types of sea-level change. All sediment surfaces are plotted on the same initial surface and run for the same arbitrary time period of 2 to 1.75 Ma. This 0.25 Ma period has been arbitrarily subdivided into 13 equal blocks of time thus the black chronostratigraphical lines (flooding surfaces) on (a) to (h) are every 19.23 ka. Simulations (a)–(d) show sediment deposited with respect to depth of deposition. (a) Sea-level at stillstand throughout run with average values set for production, erosion and sediment deposited with respect to depth of deposition. (b) Sea-level rise of 0.1 m/ka and other values as for (a). (d) Cyclic sea-level change (10 m amplitude with 100 ka frequency and 5 m amplitude with 20 ka frequency) superimposed on linear rise, other values as in run (a). The sea-level curve used for (d) and (h) is shown in the bottom right-hand corner of each panel. The red time lines are plotted every 19.23 ka and correspond to the black chronostratigraphical lines on (d) and (h). (e)–(h) as for (a)–(d) except that stratigraphy is displayed with respect to depositional processes (see key). No siliciclastics were introduced in these runs. Note that in (e)–(h) reworked platform interior carbonate (green) retains its colour when redeposited downslope from the platform. *(Dan Bosence and Dave Waltham, Royal Holloway University of London.)*

Sequence stratigraphy cartoons Idealized illustrations of key features of the sequence stratigraphy model. (a) Relative sea-level curve for (b)–(e) showing the position of the systems tracts and key surfaces. In this example, parasequences are assumed to have equal duration as indicated by the equal time units (t_0, t_1, etc.). (b) and (d) Cross-sections through a HST and the overlying depositional sequence (FSST, LST, TST and HST) for a continental margin with a shelf break (b) and ramp type continental margin (d). (c) and (e) Chronostratigraphical representation of (b) and (d) respectively. Hemipelagic and pelagic sediments are now shown. *(Angela Coe, Open University.)*

Phanerozoic geological time-scale From: Gradstein, F. M. & Ogg, J. G. (1996) A Phanerozoic timescale, *Episodes*, **19**, 1–2; with amendments from J.G. Ogg (personal communication) 2002. Conventional British spelling used on this version.