6.3 Beach and Barrier Island Systems

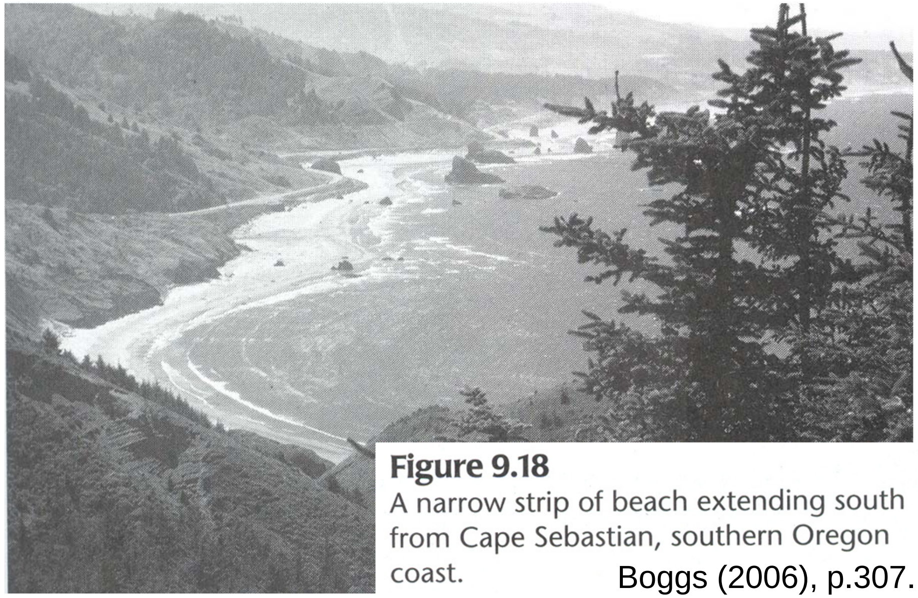


Figure 9.18
A narrow strip of beach extending south from Cape Sebastian, southern Oregon coast.
Boggs (2006), p.307.

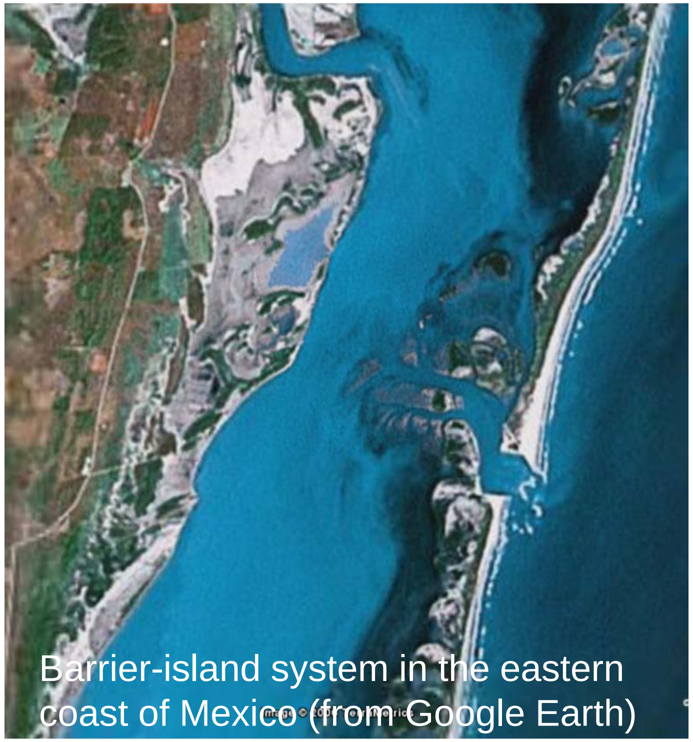
Mainland beaches: long, narrow accumulations of sand aligned parallel to the shoreline and attached to land.

Beach and barrier island occur in three types:

- A **single beach** attached to the mainland,

- A broader **beach-ridge system** that constitutes a strand plain, which consists of multiple parallel beach ridges and parallel swales, but which generally lacks well-developed lagoons or marshes; a type of strand plain consisting of sandy ridges elongated along the coast and separated by coastal mudflat deposits is called a chenier plain,

- A **barrier island** separated wholly or partly from the mainland by a lagoon or marsh.



Barrier-island system in the eastern coast of Mexico (from Google Earth)

Barrier island beaches: similar to mainland beaches but are separated from land by a shallow lagoon, estuary, or marsh. Barrier island beaches are often dissected by tidal channels or inlets.

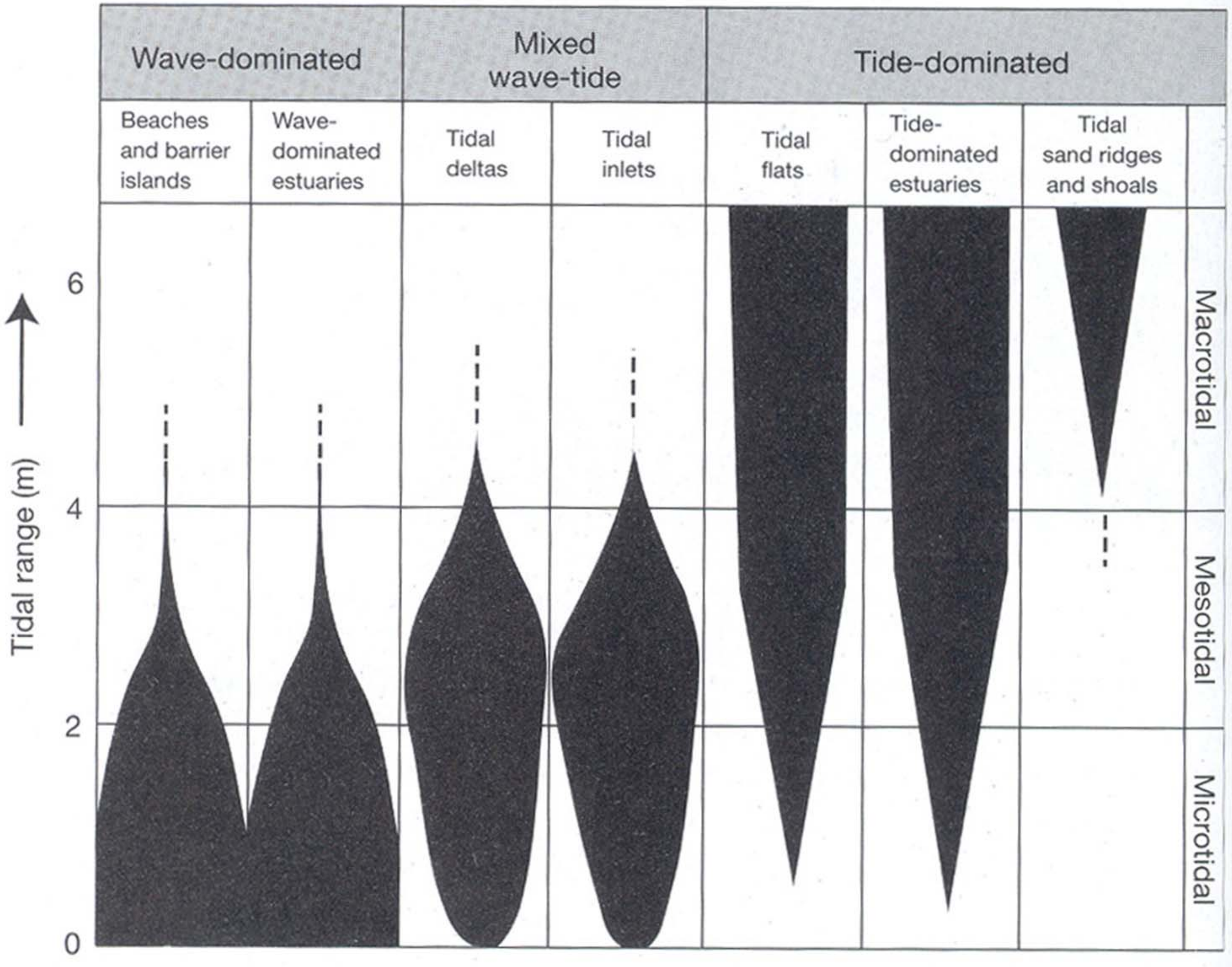
Dorset coast, UK

Coasts are classified on the basis of tidal range:

➢**Microtidal** (0-2 m tidal range, e.g. northwest, southwest and east Taiwan coast): Barrier-island and associated environments occur preferentially along microtidal coasts.

➢**Mesotidal** (2-4 m, e.g., westcentral Taiwan coast): If barriers are present, they are typically short or stunted, with tidal inlets common.

➢**Macrotidal** (> 4 m): Barriers are generally absent. The extreme tidal range causes wave energy to be dispersed and dissipated over too great a width of shore zone to effectively from barriers.



Boggs (2006), p.308.

Figure 9.20
Types of coastline with respect to tidal range, grouped into wave-dominated, tide-dominated, and mixed wave-tide types. [After Hayes, M. O.,1979, Barrier island morphology as a function of tidal and wave regime, *in* Leatherman, S. P. (ed.), Barrier islands from the Gulf of St. Lawrence to the Gulf of Mexico: Academic Press, New York, Fig. 2, p. 4, reproduced by permission.]

Depositional setting: beach (海灘) and shoreface (濱面)

Beach environments:

- **Backshore**: landward from the beach berm above high-tide level and commonly includes back-beach dune deposits;
- **Foreshore**: intertidal (littoral) zone between low-tide and high-tide level.

Shoreface (nearshore): from low-tide level to the fair-weather wave base (about 10-15 m).

Main depositional processes:
Fair-weather and storm **waves**, **wave swash and backwash** on beaches, **nearshore currents** (longshore and rip currents).

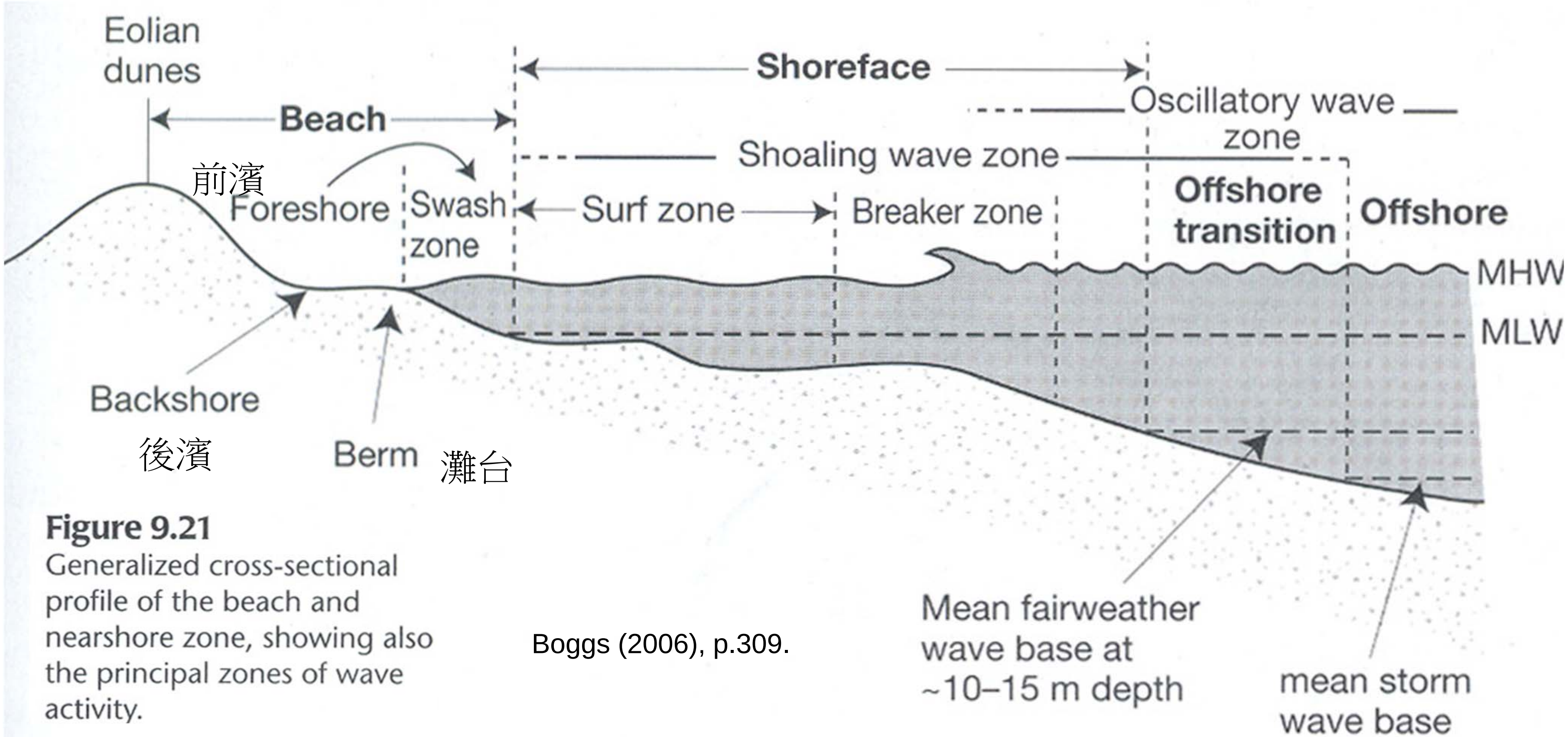


Figure 9.21
Generalized cross-sectional profile of the beach and nearshore zone, showing also the principal zones of wave activity.

Boggs (2006), p.309.

Wave processes

As waves progress shoreward into the shallow shoaling zone, forward velocity of the waves slows, wave length decreases, and wave height increases. The waves eventually steepen to the point where orbital velocity exceeds wave velocity and the wave breaks, creating the **breaker zone (**碎浪帶**)** . Breaking waves generate turbulence that throws sediment into suspension and also brings about a transformation of wave motion to create the **surf zone (**衝浪帶**) .** In this zone, a high-velocity translation wave (a wave translated by breaking into a current, or bore, is projected up the upper shoreface, causing landward transport of bedload sediment and generation of a short-duration “suspension cloud” of sediment. At the shoreline, the surf zone gives way to the **swash zone (**流濺帶**)** , in which a rapid, very shallow swash flow moves up the beach, carrying sediment in partial suspension, followed almost immediately by a backwash flow down the beach. The backwash begins at very low velocity but accelerates quickly. (If heavy minerals are present in the suspended sediment, they settle rapidly to generate a thin heavy-mineral lamina).

■ Normal waves of moderate to low energy tend to produce a net landward and alongshore transport of sediments thus building up beaches.

■ Storm waves cause erosion of the beach and a net displacement of sediments in a seaward direction.

■ Sediments tend to be well sorted, positively skewed deposits (better sorted coarser half than finer half).

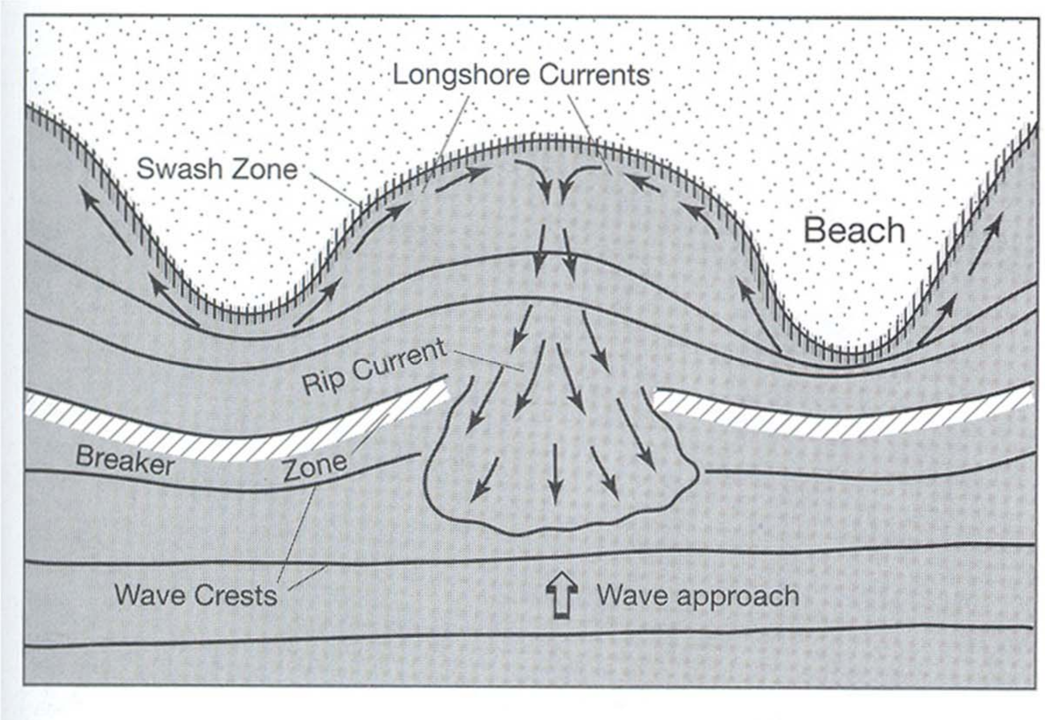
■ Heavy minerals tend to accumulated on swash zone due to the slow backwash flow.

Wave-induced currents

As breakers and winds pile water against the beach, they create not only wave but also two types of unidirectional currents:

◆ **Longshore currents**: When waves approach the shore at an angle. These currents move parallel to shore following longshore troughs, which are shallow troughs in the lower part of the surf zone. This system of parallel longshore troughs between shallow beach ridges is referred to as a ridge and runnel system. Together with swash zone processes, longshore currents are primary agents of alongshore sand movement.

◆ **Rip currents**: Where two opposite-directed longshore current meet and there is a topographic low between sand bars, the current moves seaward as a narrow, near-surface currents. These currents may entrain considerable sediments in suspension and carried out to sea by surface flow.



Boggs (2006), p.311.

Figure 9.22
Schematic representation of longshore currents that move locally in opposite directions, generated owing to bending (refraction) of wave crests as they move over an irregular seafloor, leading to the formation of rip currents that flow seaward through the breaker zone.

Depositional setting: Barrier-island system

Three environments: Recognition of ancient barrier-island complexes requires that this intimate association of the three environments be recognized.

- Sandy-barrier chain: subtidal to subaerial barrier-beach complex.
- Enclosed lagoon, estuary, or marsh: the back-barrier, subtidal-intertidal region,
- Tidal inlets, flood and ebb tidal deltas: Channels that cut through the barrier and connect the back-barrier lagoon to the open sea

Boggs (2006), p.312

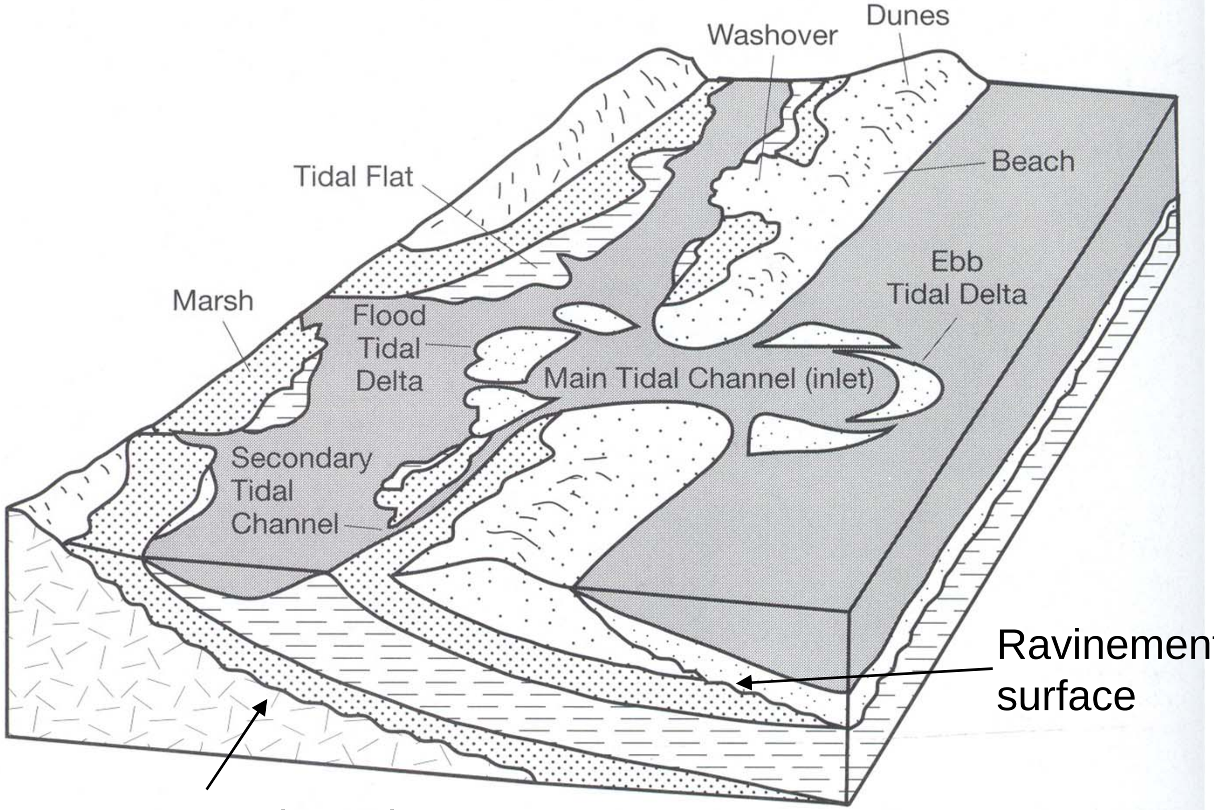
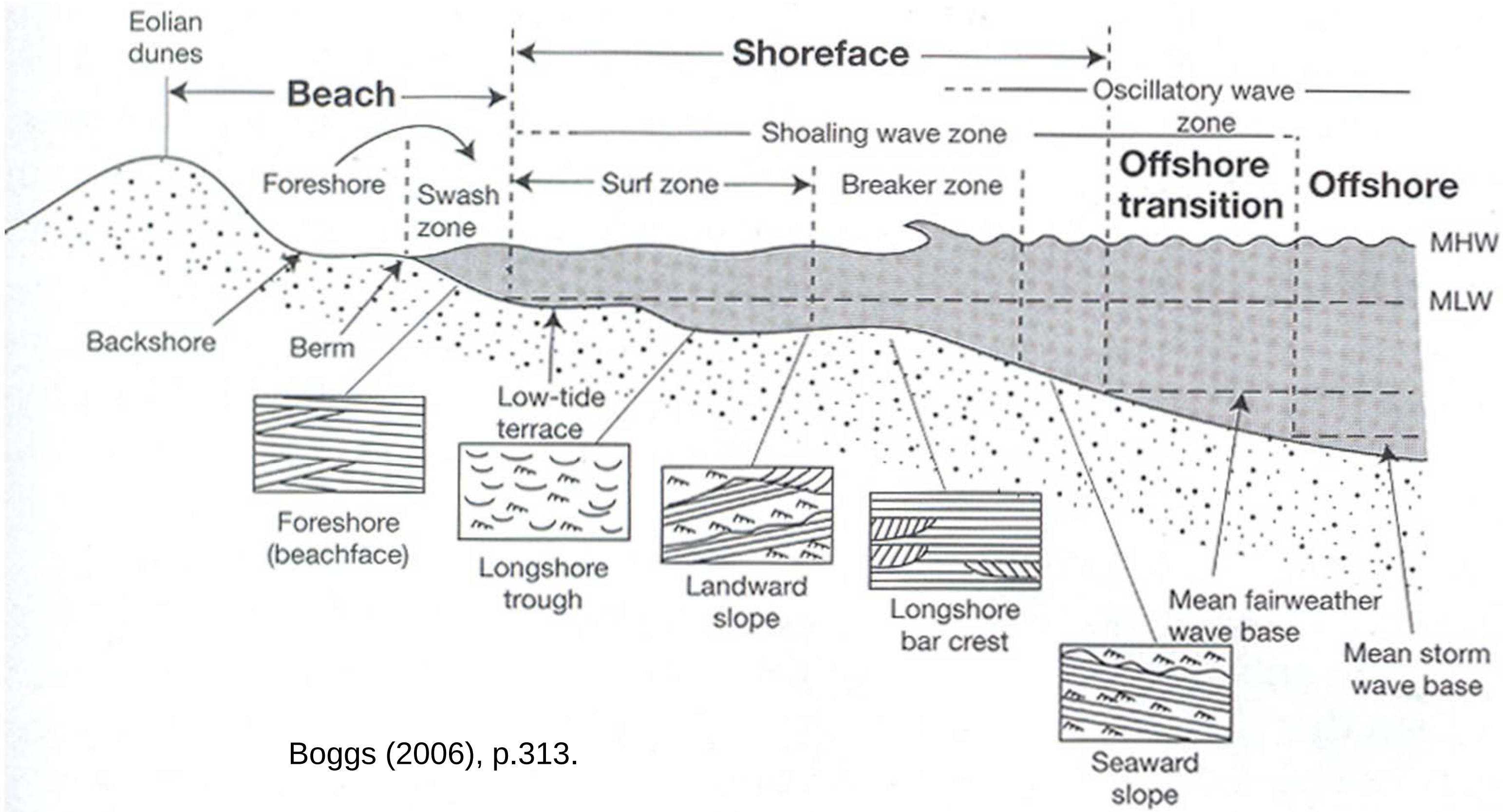


Figure 9.23
Generalized model illustrating the various subenvironments in a transgressing barrier-island system. [From Reinson, G. E., 1992, Transgressive barrier island and estuarine systems, *in* Walker, R. G., and N. P. James (eds.), Facies models, Fig. 3, p. 180, reproduced by permission of Geological Association of Canada.]

Characteristics of modern beach and barrier-island systems

Beach deposits: Backshore

- A zone dominated by intermittent storm-wave deposition and eolian sad transport and deposition.
- Faint, landward-dipping, nearly horizontal laminae, interrupted locally by crustacean burrows, record deposition by storm waves. These beds may be overlain by small- to medium-scale eolian trough cross-bed sets, which are commonly disturbed by root growths and burrows of land-dwelling organisms.



Boggs (2006), p.313.

Figure
Typical sedimentary structures formed in the beach and nearshore zone (same profile as shown in Fig. 9.21). [Sedimentary structures after Davidson-Arnott, R. G. D., and

Backshore deposits: Kenting National Park

Beach deposits: Foreshore

- Predominantly of fine to medium sand but may also include scattered pebbles and gravel lenses or layers.
- Sedimentary structures are mainly parallel laminae, which dip gently (2-3 degree) seaward.
- Thin, heavy mineral laminae are commonly present, alternating with layers of quartzose sand.
- Antidues maybe formed.
- High-angle cross bed dips landward caused by migration of foreshore ridges.

Shoreface deposits

Shoreface can be divided into upper, middle, and lower shorefaces, which correspond roughly to the surf, breaker, and outer shoaling zones.

- Upper shoreface (surf-zone) deposits: Form in an environment dominated by strong bidirectional translation waves and longshore currents. Multidiretional trough cross beds are common with trace fossils such as Skolithos.

- Middle shoreface (breaker zone): Form in high-energy conditions owing to breaking waves and associated longshore and rip currents. Sediments are mianly fine- to medium-grained sand, with minor amounts of silt and shell material, that may display both landward- and seaward-dipping trough cross-beds as well as subhorizontal plane laminations. Trace fossils consisting of vertical burrows (such as Skolithos and Ophiomorpha) are common.

- Lower shoreface (outer shoaling zone): Form under relatively low-energy conditions and grade seaward itno open-shelf deposits. They are composed dominatly of fine to very fine sand but may contain thin, intercalated layers of silt and mud. Sedimentary structures can include small-scale cross-stratification; planar, nearly horizontal laminated bedding; and hummocky cross-stratification. Trace fossils such as Thalassinoides may be common.

Back-barrier sediments

Washover fan: occur where storm-driven waves cut through and overtop barriers, washing lobes of sandy beach sediment into the back-barrier lagoon.
Sediment: consists dominantly of fine- to medium-scale landward-dipping foreset bedding.

Tidal-channel: occur where tidal currents cut through barriers into inner lagoons.
Sediments: dominantly of sand, commonly have an erosional base marked by coarse lag sands and gravels; bidirectional large- to small-scale planar and trough cross-beds that may display a general fining-upward textural trend.

Tidal-delta: form on both the lagoonal side of the barrier (flood-tidal delta) and the seaward side of the barrier (ebb-tidal delta). **Sediments**: dominantly of sands attaining a vertical thickness of tens of meters; highly varied succession of planar and trough cross beds that may dip in either a landward or a seaward direction.

Tidal-flat: form along the margins of the mainland coast and the back of the barrier.
Sediments: grade from fine- to medium-grained ripple-laminated sands in lower areas of the tidal flats through flaser- and lenticular-bedded fine sand and mud in midtidal flats to layered muds in higher parts of the flats.

Lagoonal and marsh: occur in low-energy back-barrier lagoon and grade laterally into higher energy, sandy deposits of tidal channels, deltas, and washover lobes. **Sediment**: dominantly of interbedded fine sands, silts, muds, and peat deposits that may be characterized by disseminated plant debris, brackish-water fossils such as oysters, and horizontal to subhorizontal layering.

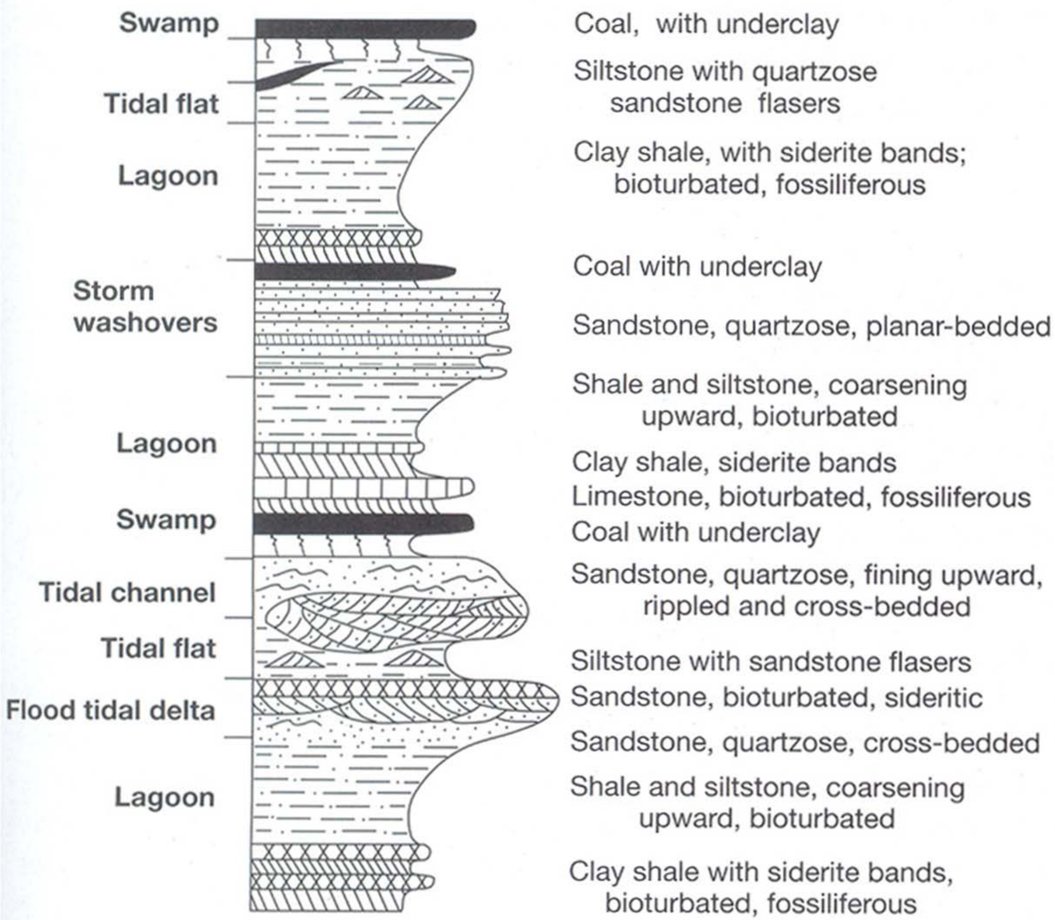
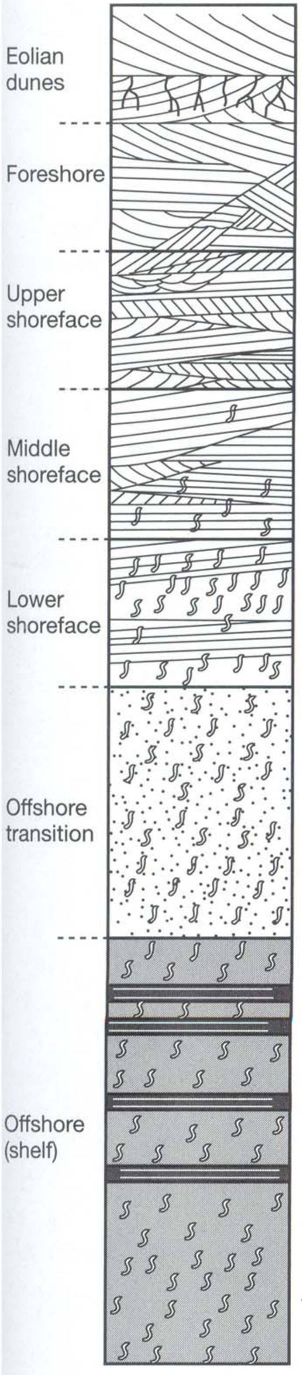


Figure 9.27
Generalized succession of facies deposited in a back-barrier environment, Carboniferous of eastern Kentucky and southern West Virginia. Such successions range from 7.5 to 24 m thick. [After Horne, J. C., J. C. Ferm, F. T. Caruccio, and B. P. Baganz, 1978, Depositional models in coal exploration and mine planning in Appalachian region: Am. Assoc. Petroleum Geologists Bull., v. 62, Fig. 4, p. 2385, reprinted by permission.]

Boggs (2006), p.317.

Ancient beach and barrier-island sediments

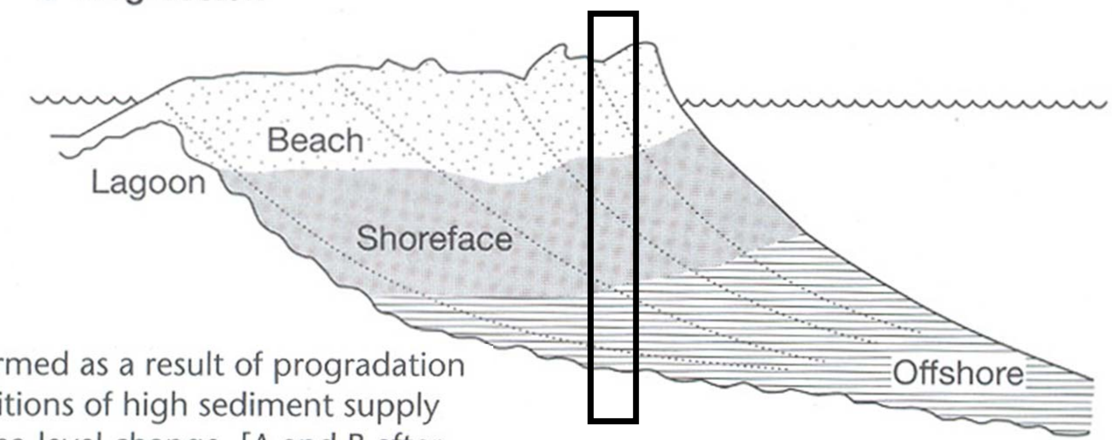


In response to the change of relative sea level and amount of sediment supply the shoreline may move in a landward direction (transgression) or in a seaward direction (regression).

Regression leads to deposition of back-barrier lagoonal and marsh deposits over sandy deposits of the barrier beach-beach complex.

Barriers tend to be transformed into strand plains, producing dominantly sandy facies in which beach deposits overlie shoreface deposits.

C Regression



C. Facies formed as a result of progradation under conditions of high sediment supply relative to sea-level change. [A and B after

Figure 9.25
Idealized succession of beach sediments on a low-energy, prograding, Holocene beach. [After Reineck, H. E., and I. B. Singh, 1980, Depositional sedimentary environments, 2nd ed., Fig. 534, p. 387, reprinted by permission of Springer-Verlag, Heidelberg.]

Boggs (2006), p.312

Transgression causes deposition of barrier-beach deposits on top of back-barrier lagoonal and marsh deposits.

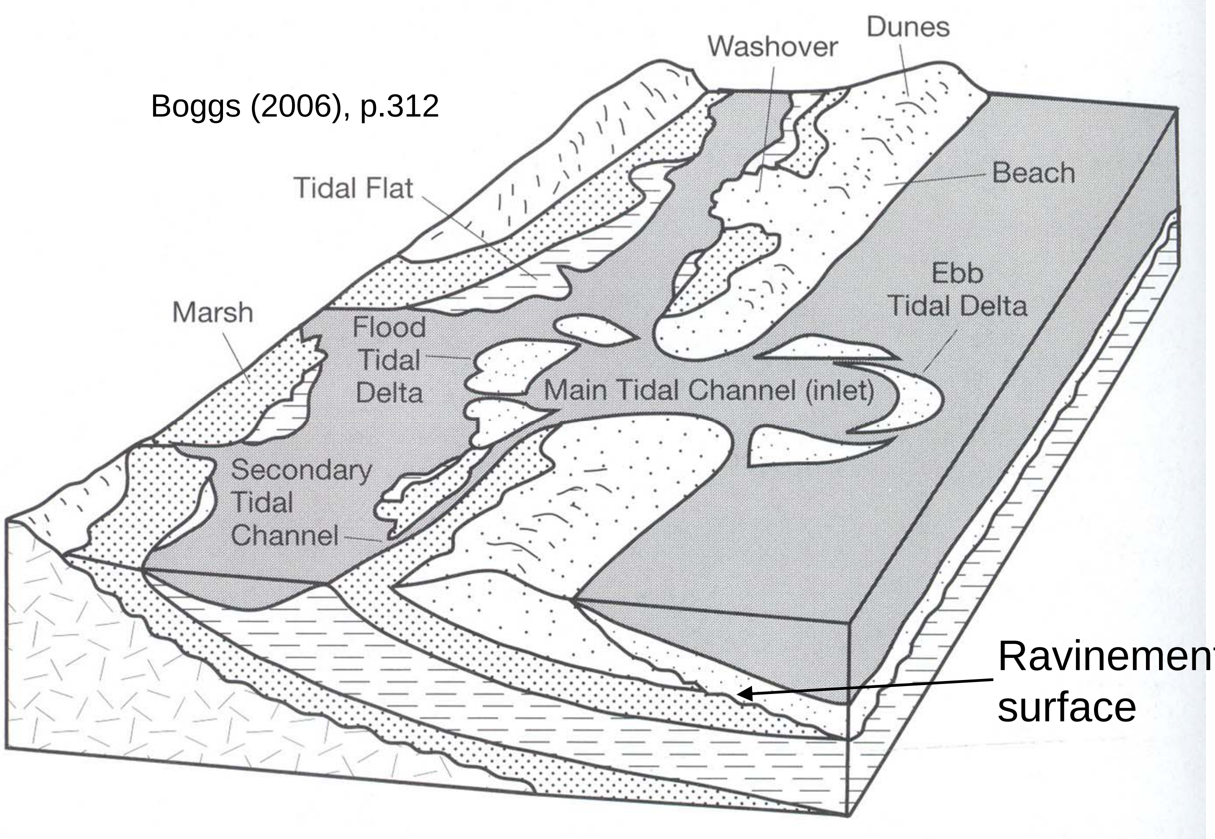


Figure 9.23
Generalized model illustrating the various subenvironments in a transgressing barrier-island system. [From

Ravinement surface: A surface generated by marine reworking and erosion during shoreline transgression. Beach and upper shoreface deposits are presumably eroded and transported to the lower shoreface, or offshore as storm beds, or to the lagoon as washover deposits.

Transgression through erosional shoreface retreat

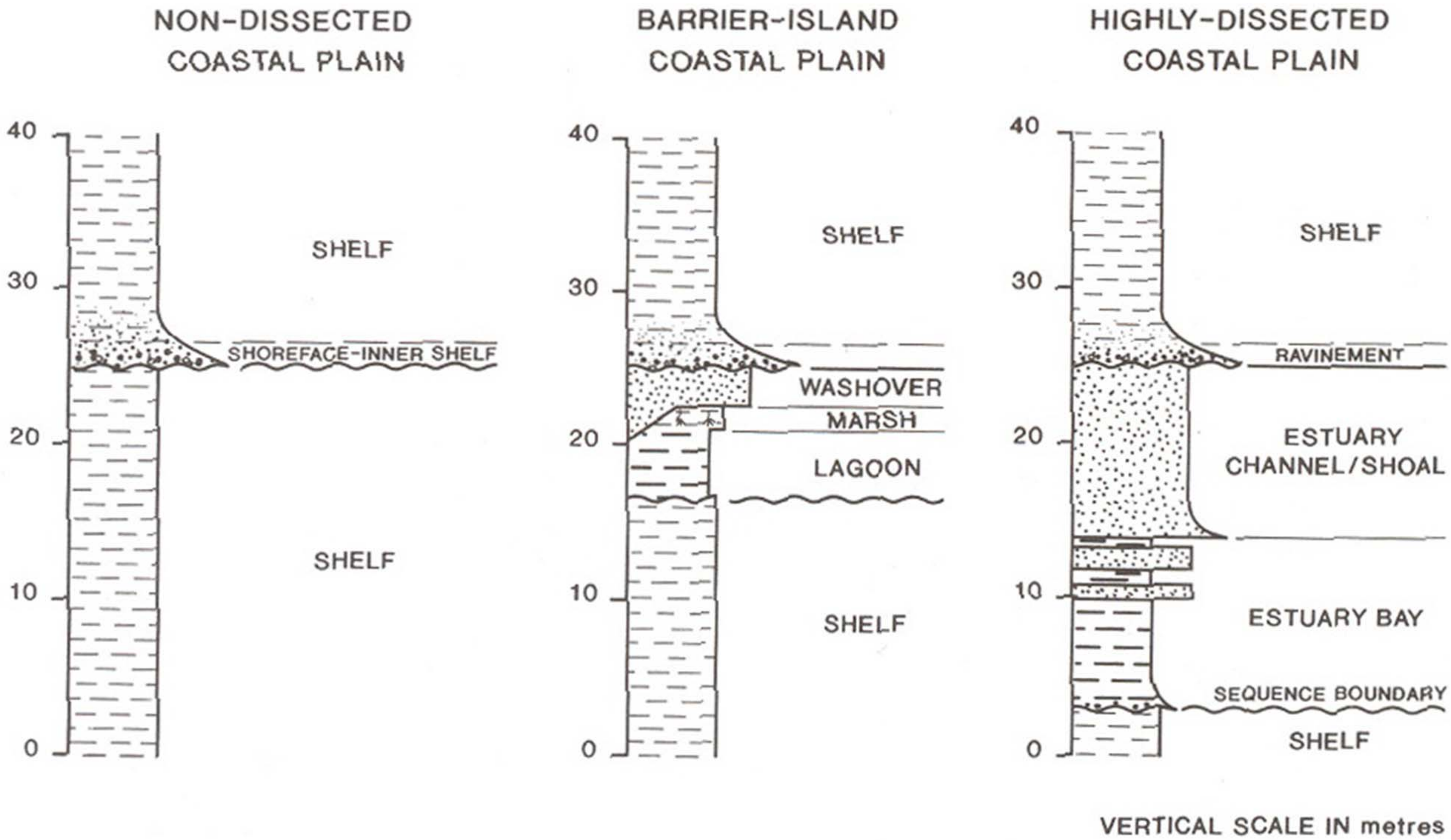


Figure 17 Generalized "end-member" transgressive facies successions for nondissected, barrier-island, and highly dissected coastal plain settings.

Reinson (1992)

Transgressive beach and barrier-island deposits may be generated by two mechanisms

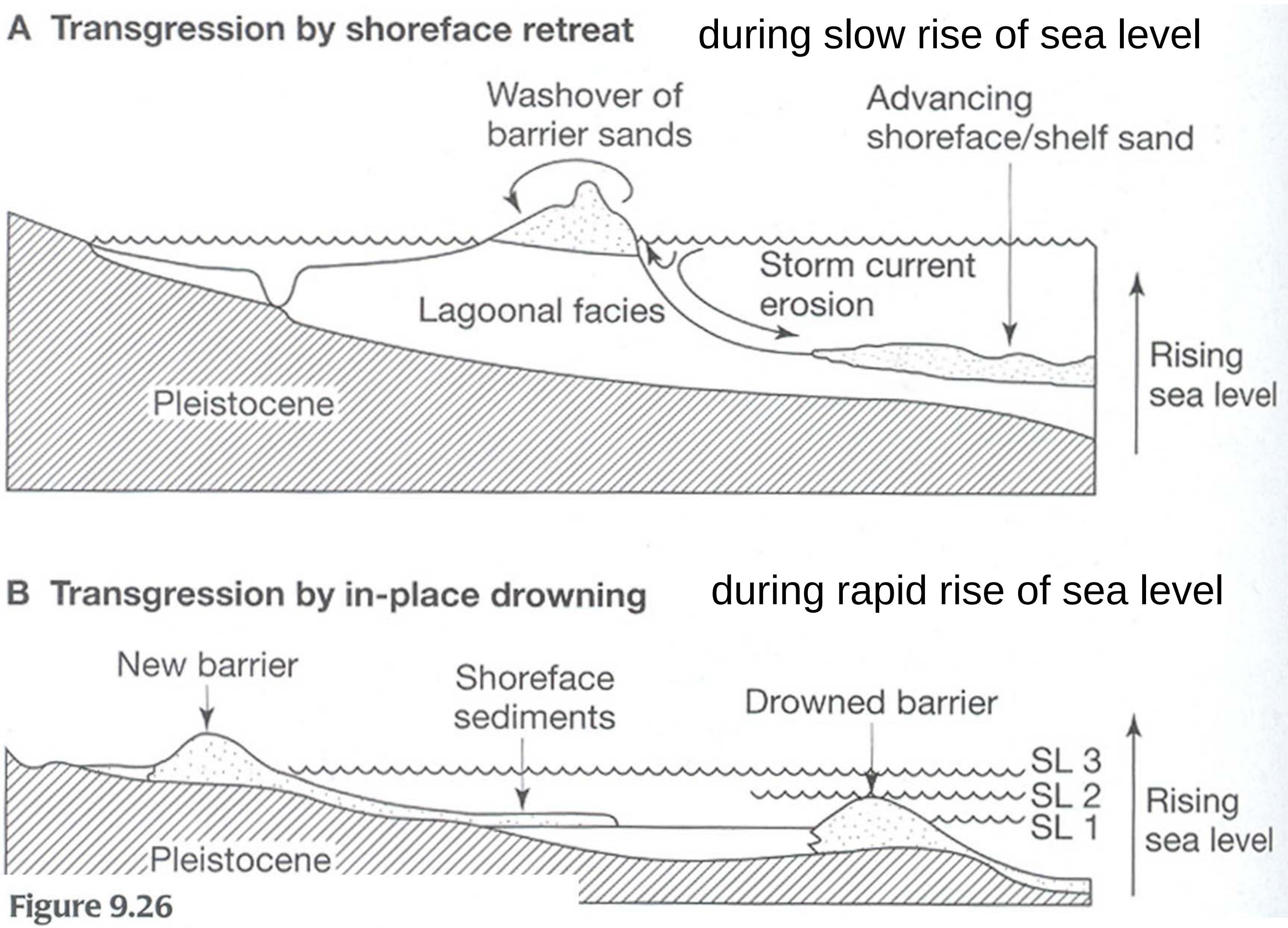


Figure 9.26
Barrier-island facies generated by transgression and regression. A. Transgression owing to shoreface retreat during gradual sea-level rise. B. Effects of rapid sea-level rise, producing in-place drowning (SL = sea level).

Boggs (2006), p.316

6.4 Estuarine Systems

Estuary: The seaward portion of a drowned valley system which receives sediments from both fluvial and marine sources and which contain facies influenced by tide, wave, and fluvial processes. Estuary tends to develop during transgression. Regression (progradation) tends to fill and destroy estuaries, causing them to change into deltas.

Boggs (2006), p.317

Figure 9.28
Wave-dominated estuary of the Klamath River, northern California coast. Note the large, northward-projecting (toward bottom of photograph) spit that partially blocks the mouth of the estuary.

Physiographic, Hydrologic, and Sediment Characteristics of Estuaries

7 types of estuary based on physiographic characteristics of relative relief and degree of channel mouth blocking.

High relief estuary

➢ **Fjord**: high-relief estuaries with a U-shaped valley profile formed by drowning of glacially eroded valleys during Holocene sea-level rise.
➢ **Fjard**: related to fjords but have lower relief.
➢ **Ria**: Estuaries developed in winding valleys with moderate relief.

Boggs (2006), p.318

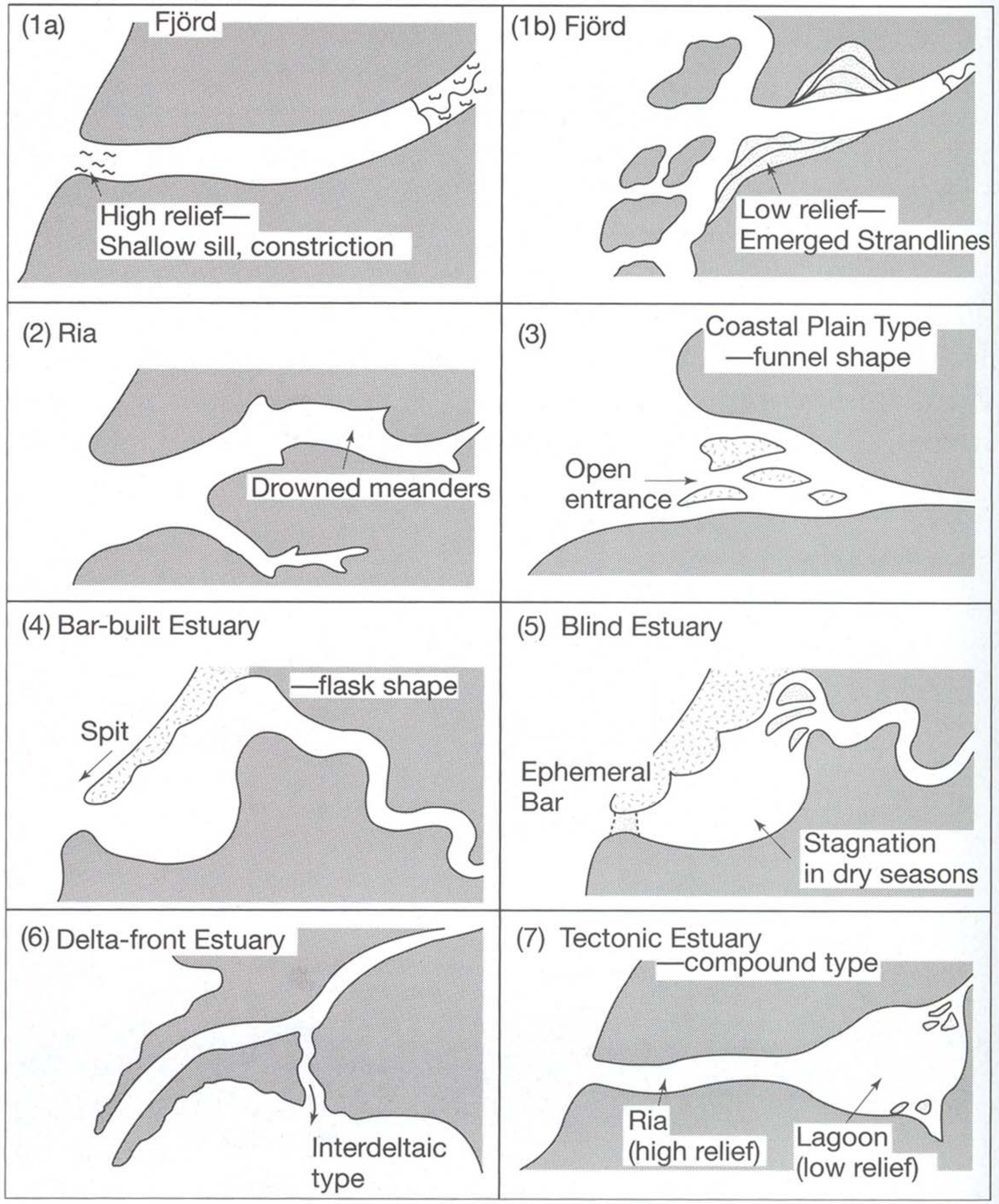


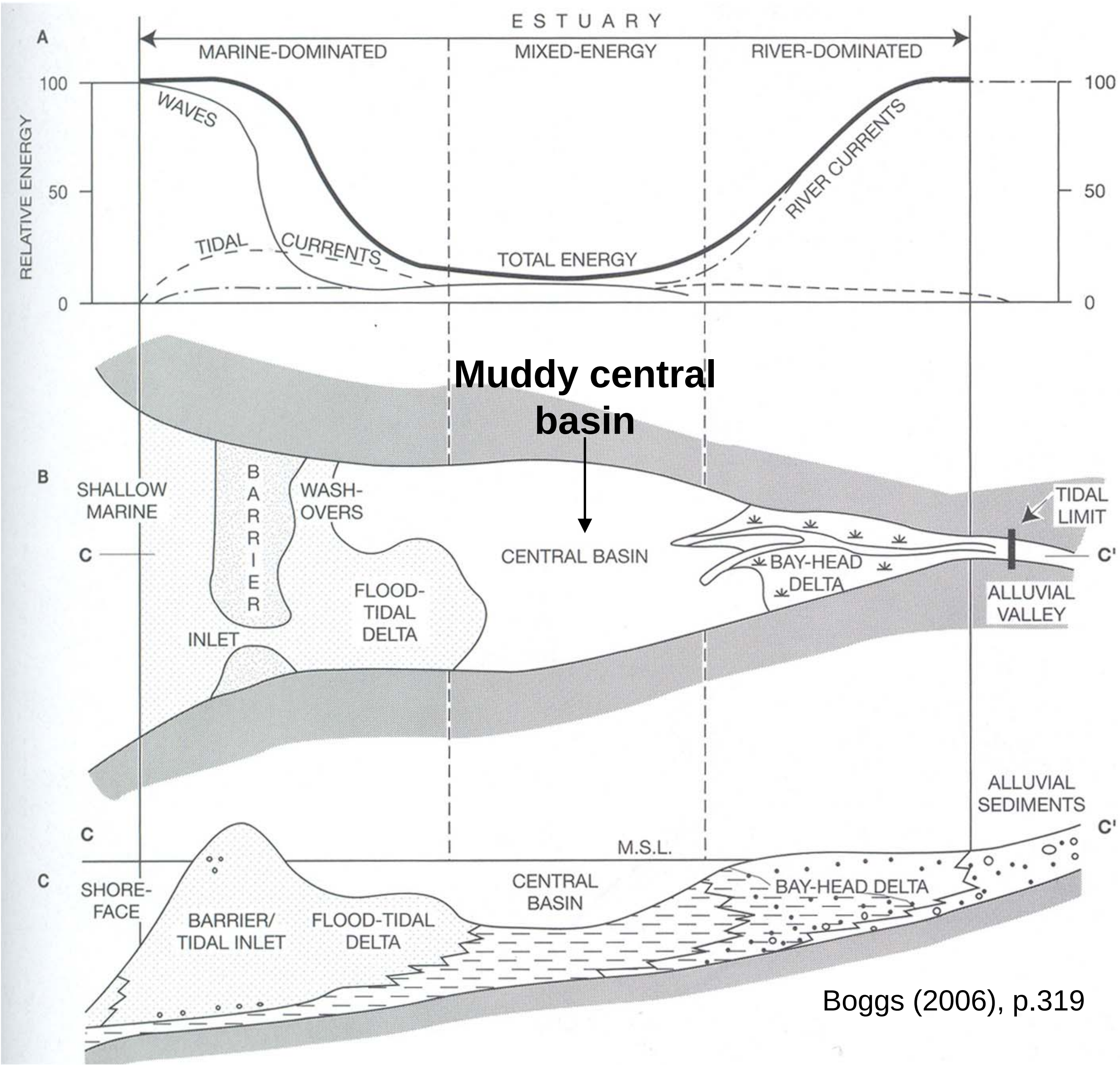
Figure 9.29
Principal types of estuaries based on physiographic characteristics. [From Fairbridge, R. W., The estuary: Its definition and geodynamic cycle, *in* Olausson, E., and I. Cato (eds.), 1980, Chemistry and biochemistry of estuaries, Fig. 2, p. 9, John Wiley and Sons, New York, reprinted by permission.]

Low relief estuary

- **Coastal-plain estuary**: Low-relief, funnel-shaped in plan view, open to the sea.
- **Bar-built estuary**: Low-relief,, L-shaped in plan view, lower courses paralel to the coast. Similar to lagoon.
- **Blind estuary**: similar to bar-built estuary but are seasonally blocked by longshore drift or dune migration. Similar to lagoon.
- **Deltaic estuary**: occur on delta fronts as ephemeral distributaries.
- **Tectonic estuary** (compound estuary): Flask-shaped, high-relief rias backed by a low-relief plain created by tectonic activity.

Three types of estuary based on hydrologic and sedimentary characteristics: Wave-dominated, tide-dominated, and mixed wave and tide dominated.

Wave-dominated estuary



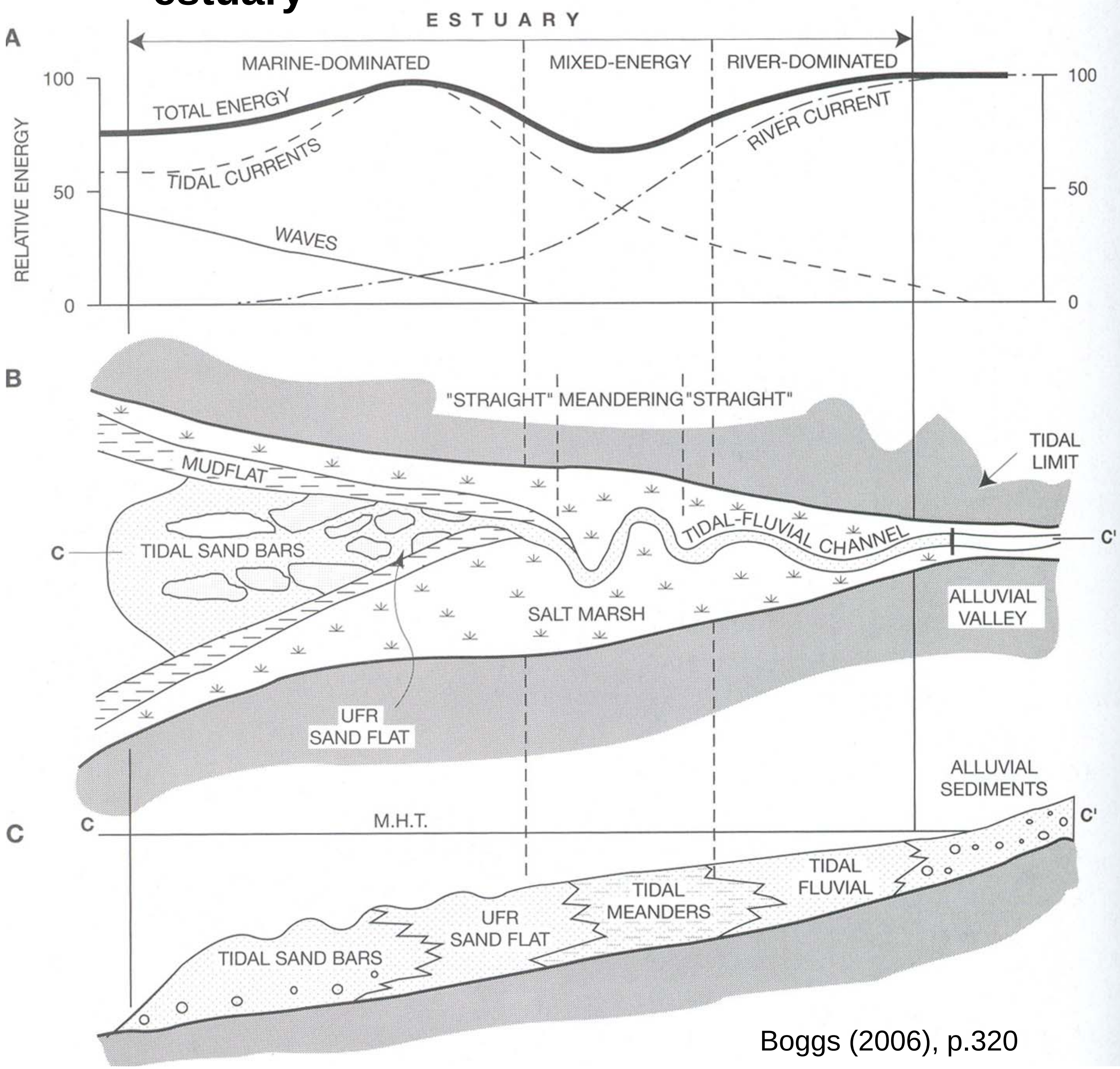
Boggs (2006), p.319

Estuary mouth experiences high-wave energy. Sediments tend to move alongshore and onshore into the mouth of the estuary, where a subaerial barrier/spit or submerged bar develops.

Figure 9.30
Distribution of (A) energy types, (B) morphological components in plan view, and (C) sedimentary facies in longitudinal section within an idealized wave-dominated estuary. The shape of the estuary is schematic. The barrier/sand plug is shown as headland attached; however, on low-gradient coasts, it may be separated from the mainland by a lagoon. The section in Part C represents the onset of estuary filling following a period of transgression. [From Dalrymple,

Tide-dominated estuary

- Elongate tidal sand bars develop parallel to the length of estuary.
- Sandy tidal channels flanked by marshes
- Muddy sediments are characterized by nearly planar alternations of silt, clay, very fine sand, and carbonaceous (plant) debris.
- Bioturbation by burrowing and feeding organisms may locally mix and homogenize these layers.
- Typically contain a brackish-water fauna that may include oysters, mussels etc.



Boggs (2006), p.320

Figure 9.31
Distribution of (A) energy types, (B) morphological components in plan view, and (C) sedimentary facies in longitudinal section within an idealized tide-dominated estuary. UFR = upper-flow regime; M.H.T. = mean high tide. The section in Part C is taken along the axis of the channel and does not show the marginal mudflat and salt-marsh facies; it illustrates the onset of progradation following transgression. [From Dal-

Many estuaries are subjected in time to transgression.

Transgression brings about a landward shifting of environments, resulting in vertical stacking of estuary-mouth sands on top of middle-estuary muds and/or fluvial-tidal channel sands. Regression causes filling and destruction of estuary and seaward progradation, changing it into a delta.

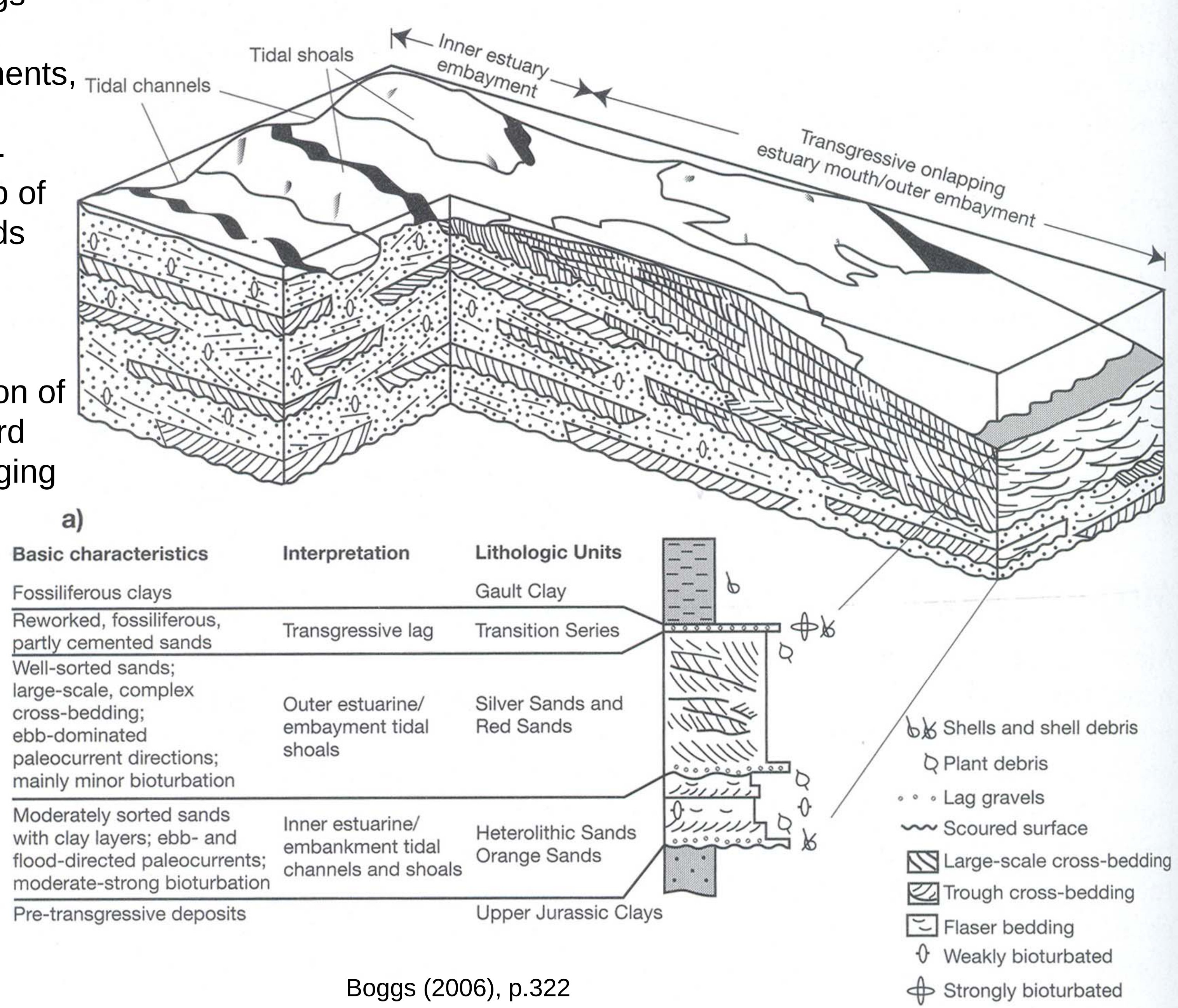


Figure 9.32
Model for a tide-dominated, transgressive estuarine-embayment depositional system based on the Woburn Sands (Lower Cretaceous), southern England. (a) Idealized vertical section showing facies in the more seaward part of the estuary. (b) Block diagram showing sand body characteristics of the inner and outer estuarine embayments. [After Johnson,

Boggs (2006), p.322

6.5 Lagoonal Systems

A coastal lagoon is defined as a shallow stretch of seawater – such as a sound, channel, bay, or saltwater lake – near or communicating with the sea and partly or completely separated from it by a low, narrow elongate strip of land, such as a reef, barrier island, sandbank, or spit. Lagoons commonly extend parallel to the coast, in contrast to estuaries, which are oriented approximately perpendicular to the coast. Many lagoons have no significant freshwater runoff. Lagoons may occur in close association with river deltas, barrier islands, and tidal flats.

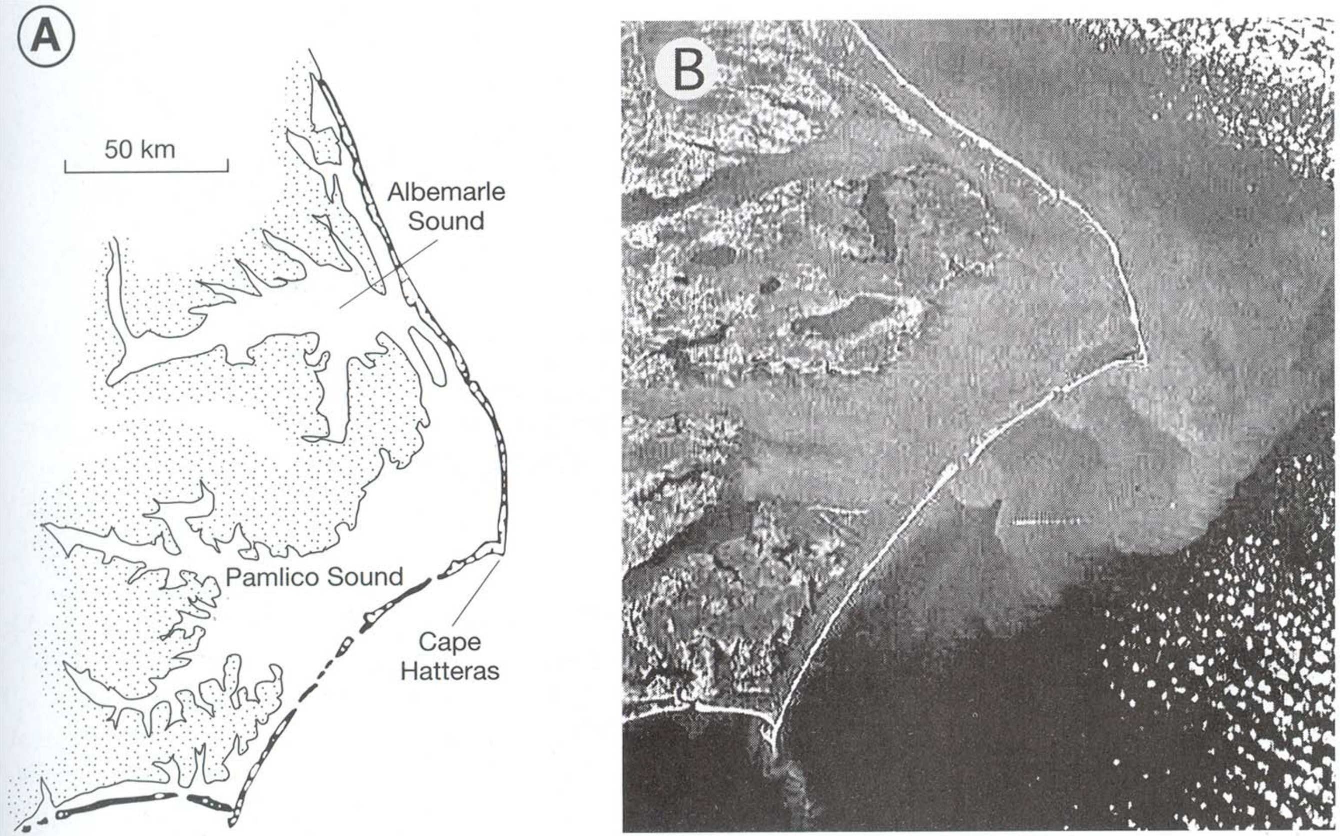


Figure 9.33
Cape Hatteras, South Carolina; a lagoonal system enclosed by a barrier-island chain. A. Diagrammatic sketch of the barrier chain and lagoon. B. Cape Hatteras as seen from Apollo 9; Pamlico Sound is partly obscured by clouds. [A. From Barnes, R. S. K., 1980, Coastal la-

Boggs (2006), p.323

Tidal currents and wind-forced waves are dominant sedimentary agents in lagoons. Other agents may include freshwater runoff and episodic storms.

Except within tidal channels that extend into the lagoon, lagoons are predominantly areas of low water energy. Sedimentation in lagoons is dominated by deposition of silt and mud, although occasional high wave activity during storms can cause washover of sediment from the barriers.

In areas where little siliciclastic sediments is available and climatic conditions are favorable, sedimentation in lagoons is dominated by chemical and biochemical deposition. Under very arid conditions, lagoonal sedimentation may be characterized by deposition of evaporites (mainly gypsum, some halite and minor dolomite). Under less hypersaline conditions, carbonate deposition (e.g., carbonate muds and associated skeletal debris, ooids in more agitated environments) prevails particularly behind barrier reefs. Algal mats, commonly developed in the supratidal and shallow intertidal zone, may trap fine carbonate or siliciclastic mud to form stromatolites.

Criteria distinguishing ancient lagoonal deposits from estuarine and other deposits:

Evidence for restricted circulation: (a) presence of evaporites or anoxic facies, e.g., black shale; (b) lack of strong tidal influence; (c) slow rates of terrigenous sediment influx; (d) dominantly fine-grained sediments; (e) low faunal diversity; (f) extensive bioturbation.

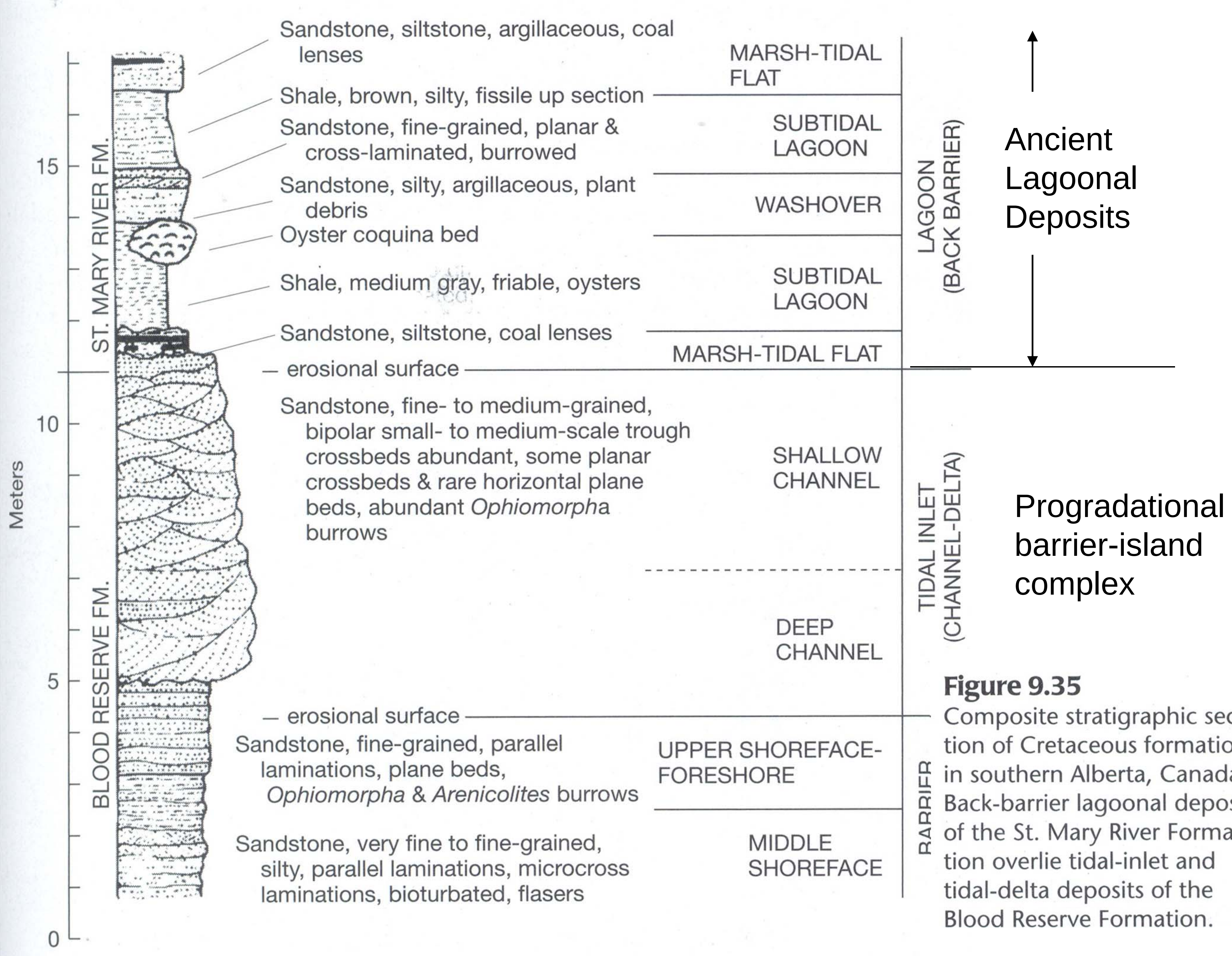
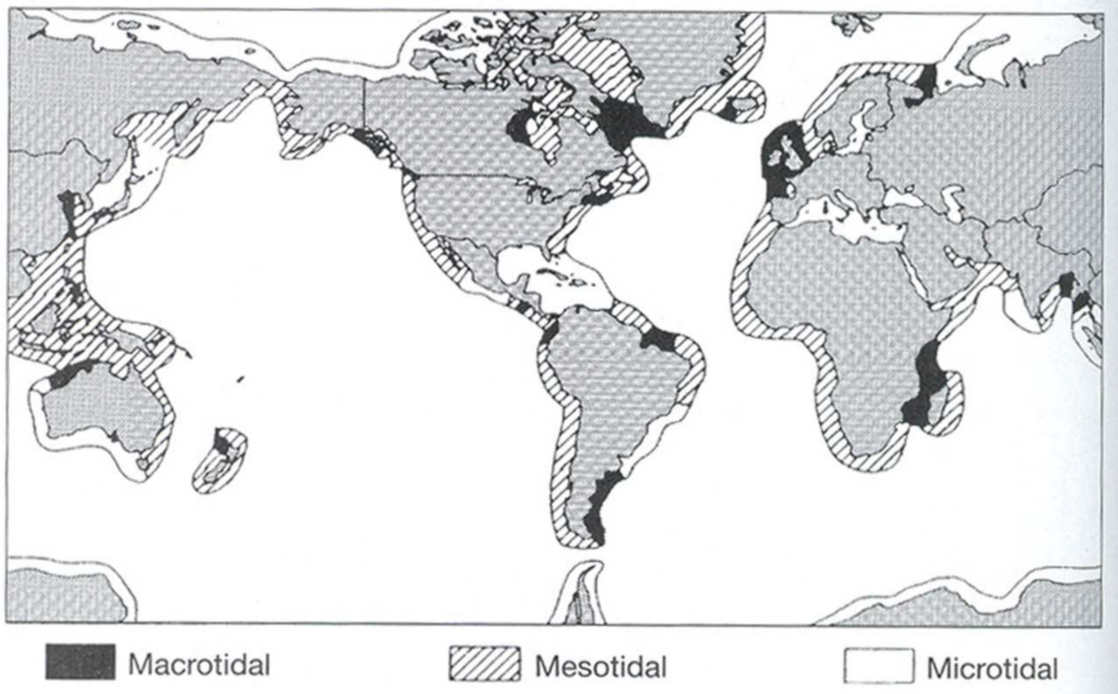


Figure 9.35
Composite stratigraphic section of Cretaceous formations in southern Alberta, Canada. Back-barrier lagoonal deposits of the St. Mary River Formation overlie tidal-inlet and tidal-delta deposits of the Blood Reserve Formation.

6.6 Tidal-flat Systems

Tidal flats form primarily on mesotidal and macrotidal coasts where strong wave activity is absent. They occur within estuaries, bays, the backshores of barrier-island complexes, and deltas, as well as along open coasts.

Figure 9.36
Global classification of coastlines by tidal range (microtidal 0–2 m; mesotidal 2–4 m; macrotidal >4 m). [From Klein, G. deV., 1985, Intertidal flats and intertidal sand bodies, *in* Davis, R. A. Jr. (ed.), Coastal sedimentary environments, 2nd ed.: Springer-Verlag, New York, Fig. 3.1, p. 189, Redrawn from Davies, J. L., 1964, Zeitschrift für Geomorphologie, v. 8, Fig. 4, p. 136.]

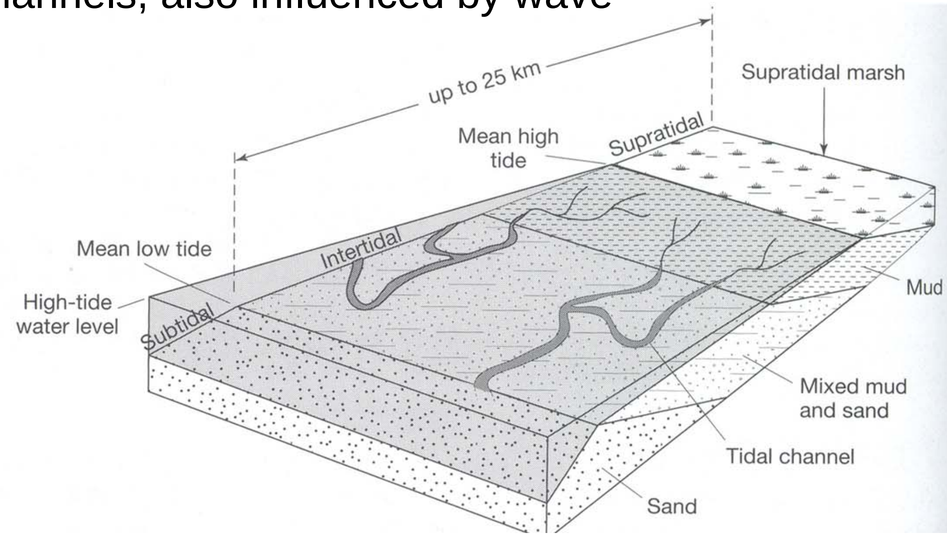


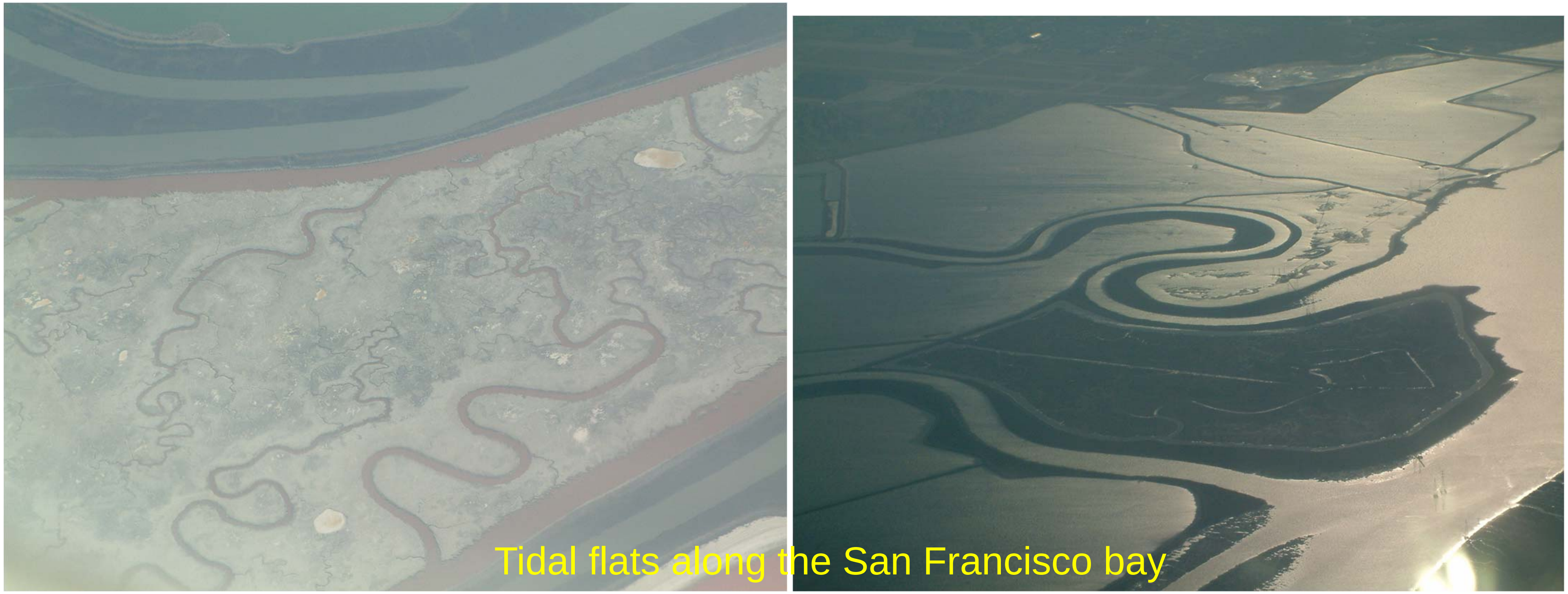
Tidal flats are marshy and muddy to sandy areas dissected by a network of tidal channels and creeks that are largely exposed ruing low tide. As tide level rises, flood-tide waters move into the channels until at high tide the channels are overtopped and water spreads over and inundates the adjacent shallow flats.

Figure 9.37
Tidal flat in the Ashe Island area, about 70 km (45 mi) south of Charleston, South Carolina, exposed at low tide. Note tidal channels and areas covered by shallow water (dark patches) on the flats. National Oceanographic and Atmospheric Administration (NOAA) photograph. Downloaded from the Internet 4/23/04.

Tidal flat is divided into three zones: subtidal, intertidal and supratidal.
Subtidal zone (lying below mean low tide level): subjected to the highest tidal-current velocities especially in the tidal channels, also influenced by wave proecesses.

Figure 9.38
Schematic diagram showing the relationship of subtidal, intertidal, and supratidal zones in the tidal-flat environment. Note that mud is the dominant deposit in the upper part of the intertidal zone, mixed mud and sand predominate in the lower intertidal zone, and sand is deposited in the subtidal zone and in tidal channels. Muddy marsh deposits characterize the supratidal zone.




Tidal flats along the San Francisco bay

Sedimentary Processes and Sediment Characteristics of Tidal-flats

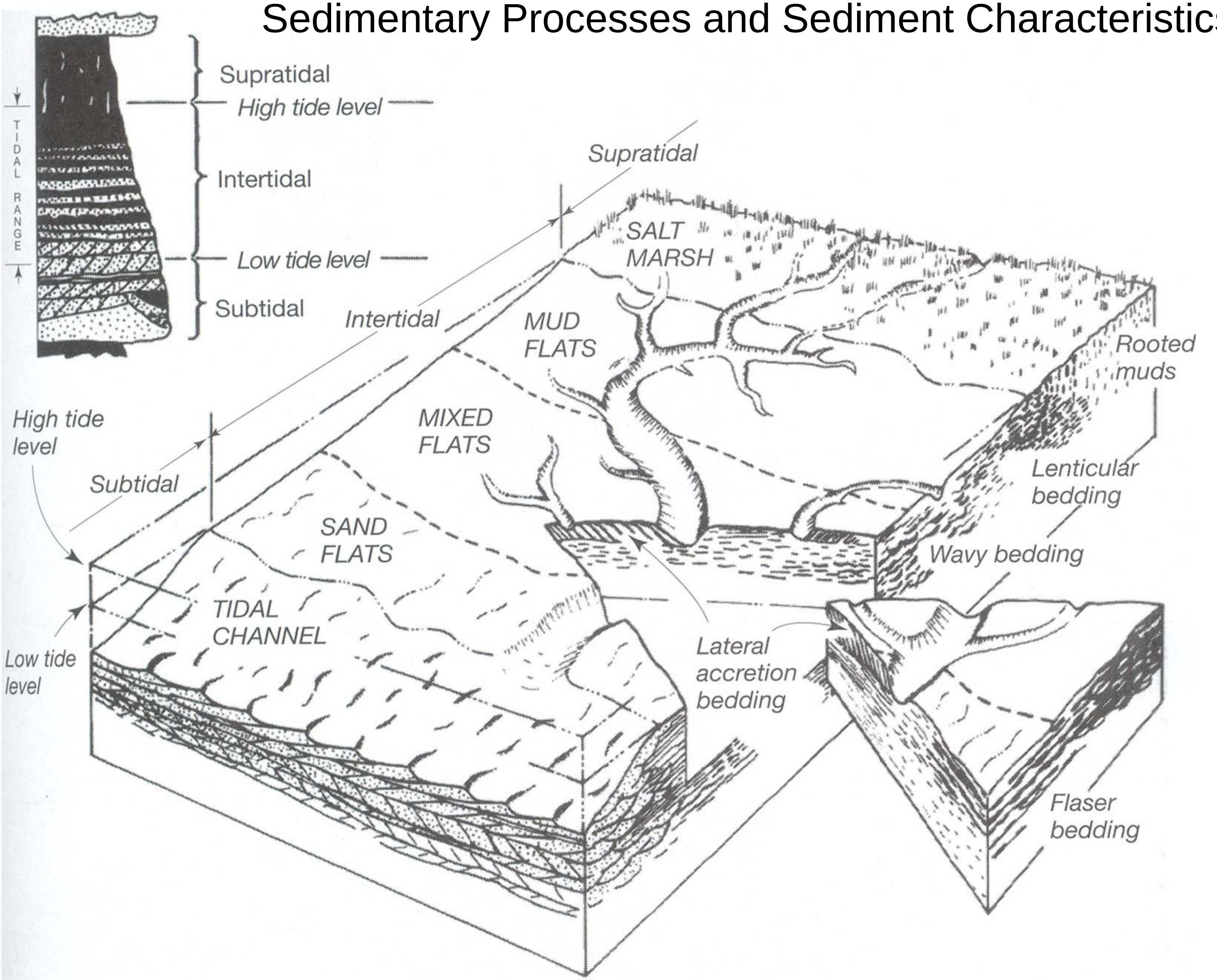


Figure 9.39
Schematic diagram of a typical siliciclastic tidal flat. The tidal flat fines toward the high-tide level, passing gradationally from sandflats, though mixed flats, to mudflats and salt marshes. An example of the upward-fining succession produced by tidal-flat progradation is shown in the upper-left cor-

Ancient Tidal flat sediments

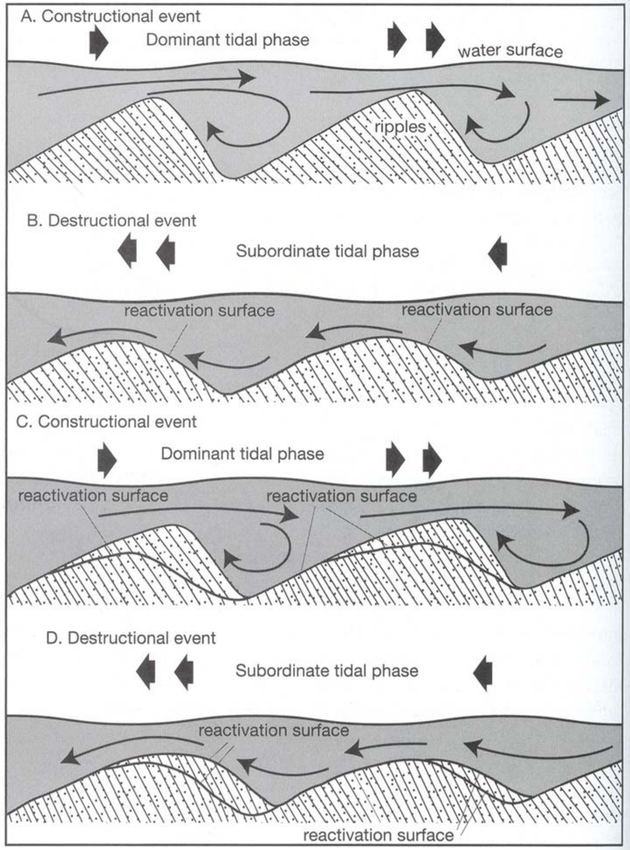


Figure 9.41
Schematic representation of reactivation surface developed owing to alternation of a dominant tidal phase (constructional event) with a subordinate phase (destructional event). [After Klein, G. deV., 1970, Depositional and dispersal dynamics of intertidal sand bars: Jour. Sed. Petrology, v. 40, Fig. 28, p. 1118, reproduced by permission of SEPM (Society for Sedimentary Geology), Tulsa, Okla.]

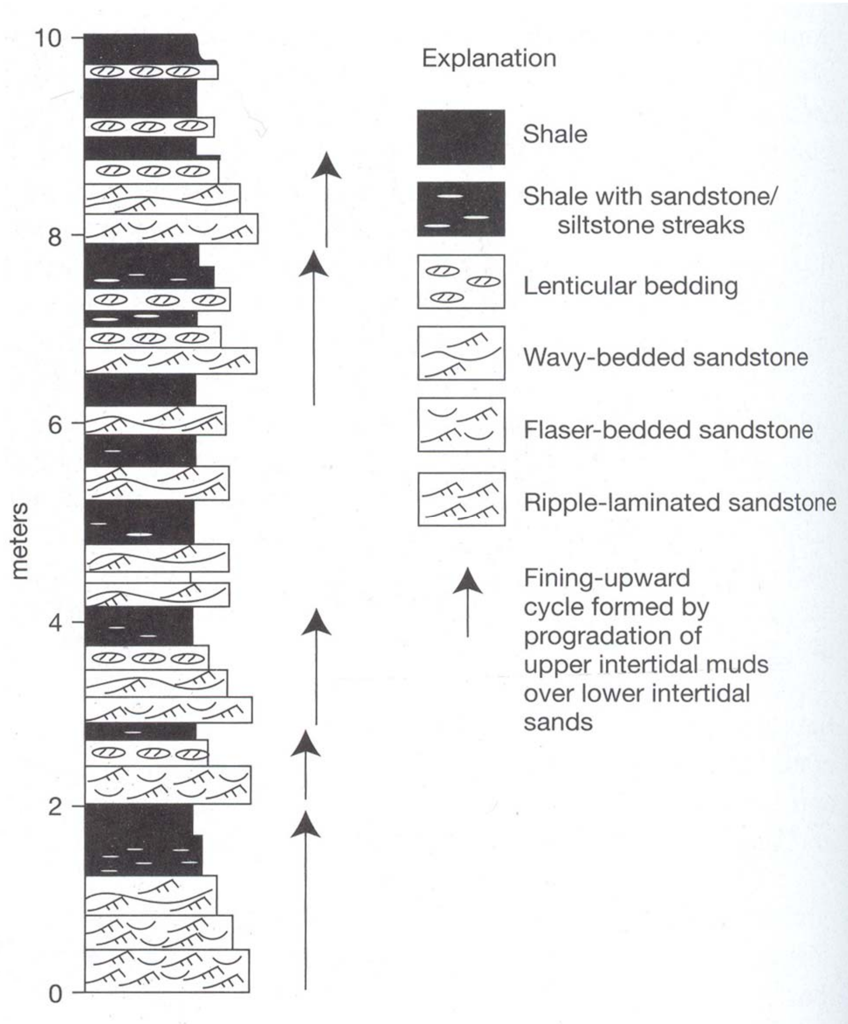


Figure 9.42
Representative lithostratigraphic column of the upper member of the Baraichari Shale Formation (late Miocene-Pliocene), Bengal Basin, Bangladesh, interpreted as a cyclic succession of progradational tidal-flat deposits. [After Alam, M. M., 1995, Tide-


扇形鹽田
青鯤鯓
頂潭
後港
西寮
頂山
西寮67民宿
台灣鹽博物館
七股鹽山
鹽埕
沙崙寮
觀海樓
藍色招潮蟹
龍山宮
龍山村
七股瀉湖
七股
溪南
六孔仔碼頭
水產試驗所海水繁養殖研究中心
海寮
溪南春休閒渡假漁村
七股寮
南灣碼頭
九股
三股
青萍別館
五塊寮
永吉
九塊厝
台南縣
台南市
黑面琵鷺保育管理及研究中心
海埔新生地
溪埔
黑面琵鷺保護區
青草崙
沙崙腳
土城仔
鄭成功紀念公園
十一戶子
台南科技工業區
南海寮
媽祖宮
鹿耳門天后宮
城西焚化廠附設夢幻水城
曾文溪口
南寮
四草大眾廟
鄭成功登陸紀念碑
抹香鯨陳列館
四草砲台
四草湖
鹿耳門溪口
61
176
173
17

海岸變遷．滄海桑田

台江內海於西元1823年前，其西側由一至七鯤鯓、安平島、北汕尾島、隙子嶼、海翁汕、南鯤鯓汕及北門嶼環繞，東側海岸線深入到現在的台南市柴頭港里、台南縣永康市的大橋、洲仔尾及新市鄉以西、安定鄉竿寮港、加弄港(今安定)、西港仔港(今西港)、含西港(今佳里鎮蚶西港)、卓加港(今七股篤加村)到將軍下山仔腳（今玉山村）。面積約有一萬五千公頃，大概是今潟湖的十倍大。

為何台江內海會變成今日的七股潟湖？與曾文溪四次改道有密切的關係。當時曾文溪的上游名為灣裡溪，該溪流至蘇厝甲(今安定鄉蘇厝北方)後，向北北西方向流經西港羨仔林，經佳里興與漚汪社之間向北轉西注入海，因此曾文溪的下游昔稱漚汪溪。

曾文溪第一次改道：道光三年(西元1823年)七月，因颱風及連下七天七夜的豪雨，來自上游之雨水挾著滾滾土石氾濫成災，曾文溪在安定蘇厝甲附近直沖入海進入台江。

曾文溪第二次改道：清同治十年(西元1871年)，曾文溪主流經改由原北分支流經公地尾轉南歷土城東邊由舊口入海，下游稱鹿耳門溪。

曾文溪第三次改道：發生於光緒三十年(西元1904年)，下游自公地尾轉由三股仔經國姓港入海，下游稱為三股溪，入台江內海處是今龍雄二號橋邊。

曾文溪第四次改道：發生於民前一年(西元1911年)，下游改道自公地尾向西經十分塭青草崙入海，即今台南縣七股鄉十份村五塊寮與台南市安南區土城青草崙之間入海。

明朝鄭成功時期古地圖