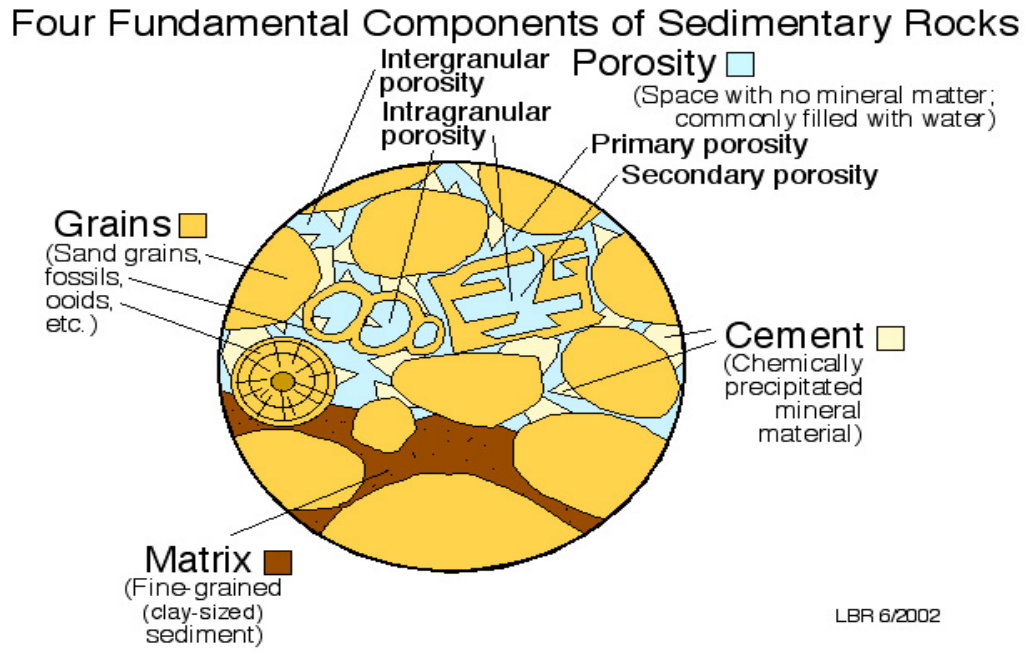
Reservoir Rock & Source Rock Types: Classification,

Properties & Symbols

Reservoir rock: A permeable subsurface rock that contains petroleum. Must be both porous and permeable.

Source rock: A sedimentary rock in which petroleum forms.

- Reservoir rocks are dominantly sedimentary (sandstones and carbonates); however, highly fractured igneous and metamorphic rocks have been known to produce hydrocarbons, albeit on a much smaller scale
- Source rocks are widely agreed to be sedimentary
- The three sedimentary rock types most frequently encountered in oil fields are shales, sandstones, and carbonates
- Each of these rock types has a characteristic composition and texture that is a direct result of depositional environment and post-depositional (diagenetic) processes (i.e., cementation, etc.)
- Understanding reservoir rock properties and their associated characteristics is crucial in developing a prospect



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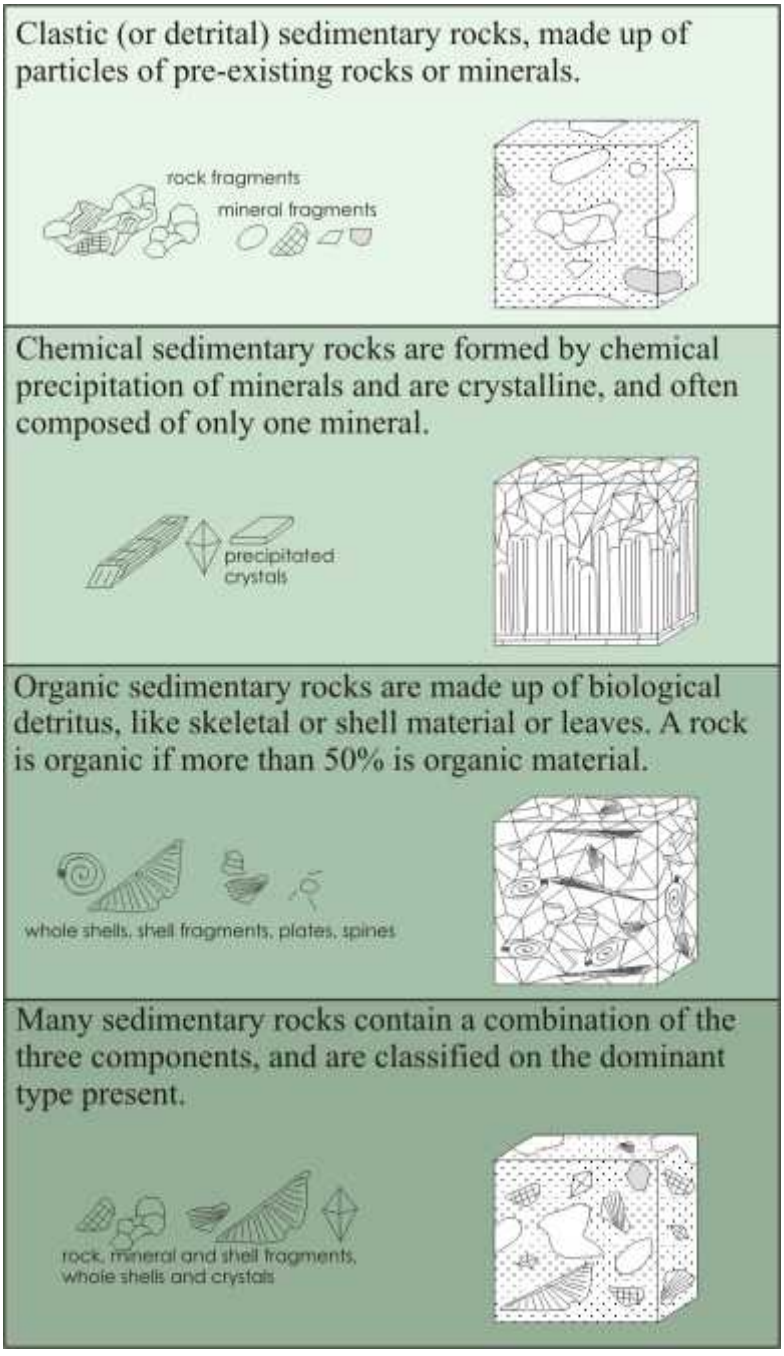
Different Forms of Sedimentary Rock:

- Sandstones
- Conglomerates

- Halite (rock salt)
- Gypsum
- Anydrite

- Limestone
- Chalk
- Coquina
- Coal



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Sediments and Corresponding Sedimentary Rocks

Sediment	*Sedimentary Rock*	*Where the sediment accumulates*
Gravel	Conglomerate	Alluvial fans, river channels, wave-swept coastlines
Sand	Sandstone	Desert dunes; river channels, shorelines, deltas, shallow seas
Mud	Shale	Lakes. river floodplains, tidal flats, distal deltas, deep sea
Shells and lime mud	Limestone	Warm shallow seas
$CaCO_3$ produced by marine plankton	Chalk	Deep sea
SiO_2 produced by marine plankton	Chert	Deep sea
Woody plant matter: Peat	Coal	Swamps
Salt	Rock salt	Lagoons or marginal seas in horse latitudes

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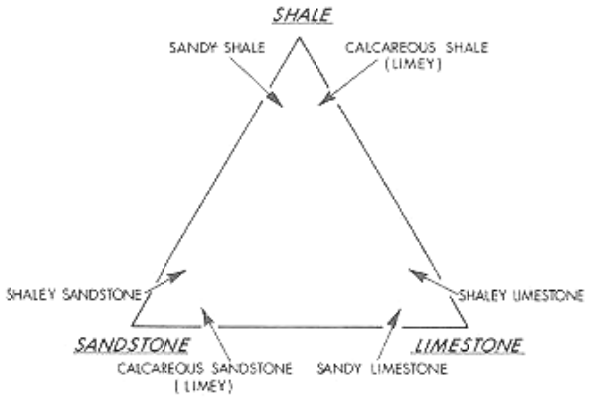

Figure 9-1 The three most common sedimentary rocks: shales, sandstones, and limestones.

Schematic illustrating the three distinctive sedimentary rocks, sandstone, shale, and limestone, and gradations of each.

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Shales -- Source Rocks and Seals:

Description:

- Distinctively dark-brown to black in color (occasionally a deep dark green), occasionally dark gray, with smooth lateral surfaces (normal to depositional direction) and irregular vertical surfaces (parallel to depositional direction)

Properties:

- Composed of clay and silt-sized particles (q.v., week 2 notes)
- Clay particles are platy and orient themselves normal to induced stress (overburden); this contributes to shale's characteristic permeability
- Behave as excellent seals
- Widely regarded to be the main source of hydrocarbons due to original composition being rich in organics
- A weak rock highly susceptible to weathering and erosion

History:

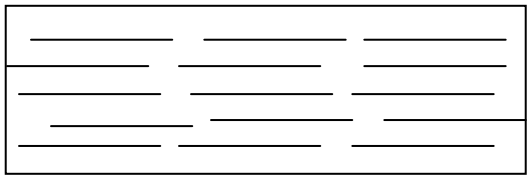
- Deposited on river floodplains, deep oceans, lakes, or lagoons

Occurrence:

- The most abundant sedimentary rock (about 42%)

Geologic Symbol:

- Horizontal, evenly-spaced dashed lines



Standard basic geologic symbol for shale. May be modified to illustrate further detail.

*For a complete version of the Standard Geologic Map Symbolization refer to
URL: http://ngmdb.usgs.gov/fgdc_gds/geolsymstd/download.php

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Sandstones and Sandstone Reservoirs:

Description:

- Composed of sand-sized particles (q.v., week 2 notes)
- Recall that sandstones may contain textural features indicative of the environment in which they were deposited: ripple marks (alluvial/fluvial), cross-bedding (alluvial/fluvial or eolian), graded-bedding (turbidity current)
- Typically light beige to tan in color; can also be dark brown to rusty red

Classification:

- Sandstones can be further classified according to the abundance of grains of a particular chemical composition (i.e., common source rock); for example, an ***arkosic sanstone*** (usually abbreviated: ark. s.s.) is a sandstone largely composed of feldspar (feldspathic) grains….Can you recall which continental rock contains feldspar as one of its mineral constituents???
- Sandstones composed of nearly all quartz grains are labeled ***quartz sandstones*** (usually abbreviated: qtz. s.s.)

Properties:

- Sandstone porosity is on the range of 10-30%
- Intergranular porosity is largely determined by sorting (primary porosity)
- Poorly indurated sandstones are referred to as *fissile* (easily disaggregated when scratched), whereas highly indurated sandstones can be very resistant to weathering and erosion

History:

- Sandstones are deposited in a number of different environments. These can include deserts (e.g., wind-blown sands, i.e., eolian), stream valleys (e.g., alluvial/fluvial), and coastal/transitional environments (e.g., beach sands, barrier islands, deltas, turbidites)

- Because of the wide variety of depositional environments in which sandstones can be found, care should be taken to observe textural features (i.e., grading, cross-bedding, etc.) within the reservoir that may provide evidence of its original diagenetic environment

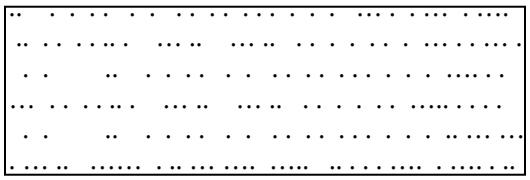
- Knowing the depositional environment of the s.s. reservoir is especially important in determining reservoir geometry and in anticipating potentially underpressured (commonly found in channel sandstones) and overpressured reservoir conditions

Occurrence:

- Are the second most abundant (about 37%) sedimentary rock type of the three (sanstones, shales, carbonates), the most common reservoir rock, and are the second highest producer (about 37%)

Geologic Symbol:

- Dots or small circles randomly distributed; to include textural features, dots or circles may be drawn to reflect the observation (for example, cross-bedding)



Standard geologic map symbol for sandstone. May be modified to illustrate further detail.

Case example:

- The Bartlesville Shoestring Sands are home to the Sallyards and Lamont Oil Field which is a classic Pennsylvanian shoreline sand reservoir (very similar, and in fact, difficult to distinguish from a stream valley reservoir). These ovular, lens shaped sands are situated in southern Kansas.

Bartlesville Shoestring Sands: Cross-section and Regional Map

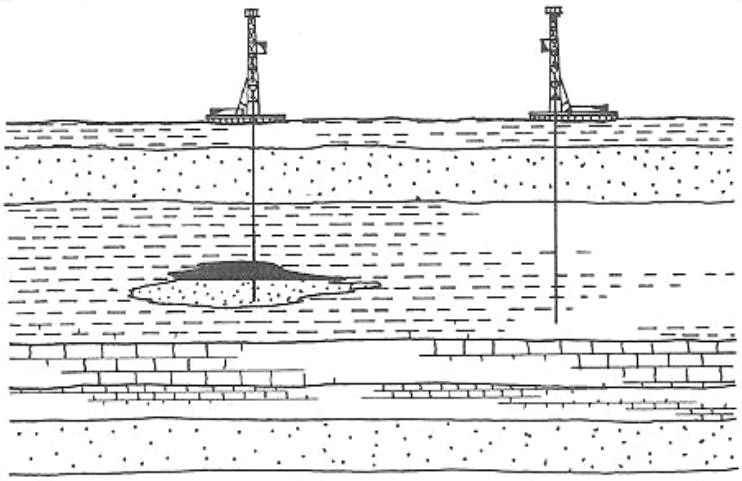


Figure 6-7 A cross section of the earth's crust showing a shoestring sandstone encased in a shale layer.

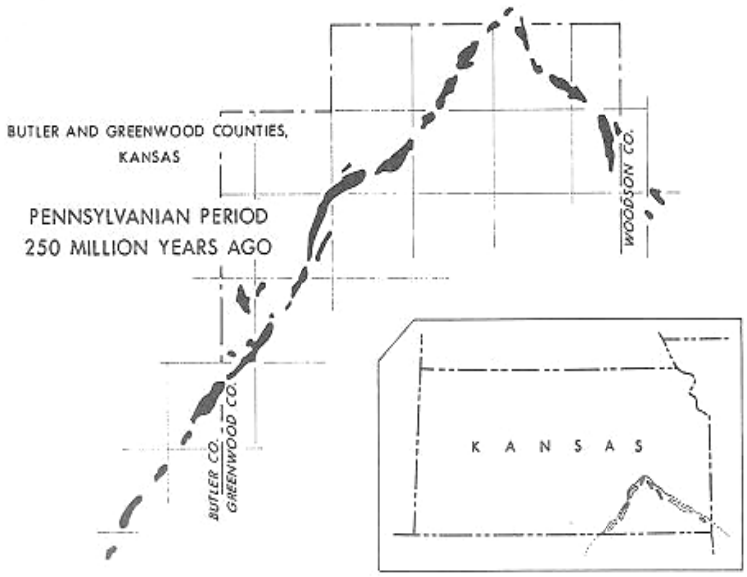


Figure 6-8 A map of the Sallyards and Lamont oil field trends in southeastern Kansas (each square is 6 miles on a side) and an insert showing how the sandstone reservoir rocks were deposited during the Pennsylvanian Period as shoreline sands when seas covered southeastern Kansas. *(From P. L. Hilpmax, 1958, Producing zones of Kansas oil and gas fields: Kansas Geological Survey Oil and Gas Investigation 16)*

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Carbonates and Carbonate Reservoirs:

Description:

- Grains (clasts) are largely the skeletal or shell remains of shallow marine dwelling organisms, varying in size and shape, that either lived on the ocean bottom (benthic) or floated in water column (neritic)
- Many of these clasts can be identified by skilled paleontologists and micropaleontologists and can be used for correlative purposes or age range dating; also beneficial in establishing ***index fossils*** for ***marker beds*** used in regional stratigraphic correlations
- Dolomites are a product of solution recrystallization of limestones
- Usually light or dark gray, abundant fossil molds and casts, vuggy (vugular) porosity

Classification:

- Divided into limestones (calcium carbonate -- $CaCO_3$) and dolomites (calcium magnesium carbonate – $CaMg(CO_3)_2$)
- Limestones can be divided further into Mudstones, Wackestones, Packstones, Grainstones, and Boundstones according to the limestones depositional texture; see Dunham classification scheme

Table 14
Depositional Texture of Carbonates

DEPOSITIONAL TEXTURE RECOGNIZABLE					DEPOSITIONAL TEXTURE NOT RECOGNIZABLE
Original Components Not Bound Together During Deposition				Original components were bound together during deposition ... as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavities that are roofed over by organic or questionably organic matter and are too large to be interstices.	*Crystalline Carbonate* (Subdivide according to classifications designed to bear on physical texture or diagenesis.)
Contains mud (particles of clay and fine silt size)			Lacks mud and is grain-supported		
Mud-supported		Grain-supported			
Less than 10 percent grains	More than 10 percent grains				
Mudstone	*Wackestone*	*Packstone*	*Grainstone*	*Boundstone*	

From Dunham, 1962. Permission to publish by AAPG.

Dunham classification scheme of limestones based on depositional textures.

Properties:

- Porosity is largely a result of dissolution and fracturing (secondary porosity)
- Carbonates such as coquina are nearly 100% fossil fragments (largely primary porosity)
- Are characteristically hard rocks, especially dolomite
- Susceptible to dissolution weathering

History:

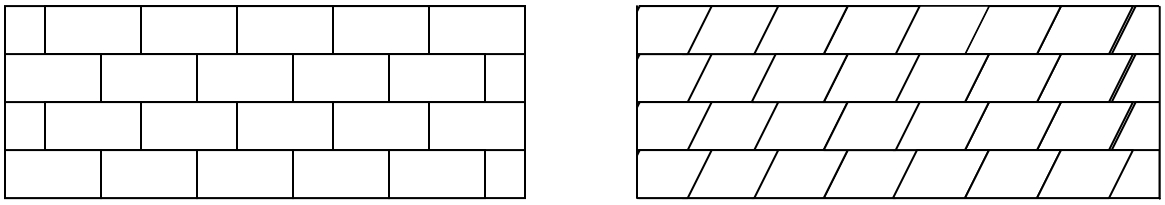
- Limestone reservoirs owe their origin exclusively to shallow marine depositional environments (lagoons, atolls, etc)
- Limestone formations slowly accumulate when the remains of calcareous shelly marine organisms (brachiopods, bivalves, foramaniferans) and coral and algae living in a shallow tropical environment settle to the ocean bottom
- Over large geologic time scales these accumulations can grow to hundreds of feet thick (El Capitan, a Permian reef complex, in West Texas is over 600 ft thick)

Occurrence:

- Are the least geologically abundant (about 21%) of the three (shales, sandstones, carbonates), but the highest producer (about 61.5%)

Geologic Symbol:

- Limestone – layers of uniform rectangles, each layer offset from that above it.
- Dolomite – layers of uniform rhomboids, each layer offset from that above it.

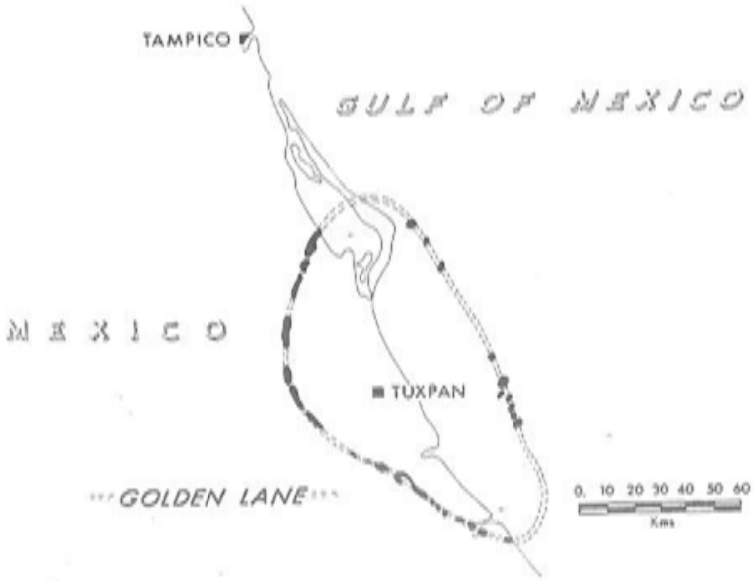


Standard geologic map symbols for limestone (left) and dolomite (right). May be modified to illustrate further detail.

Case example:

- The Golden Lane oil field is a prime example of a very large carbonate reservoir that has enjoyed a very productive life. It is an ancient (Cretaceous) atoll karst limestone encircling the Mexican city Tuxpan, both on and off shore.

Golden Lane Oil Field: Regional Map and Sequential Cross-sections



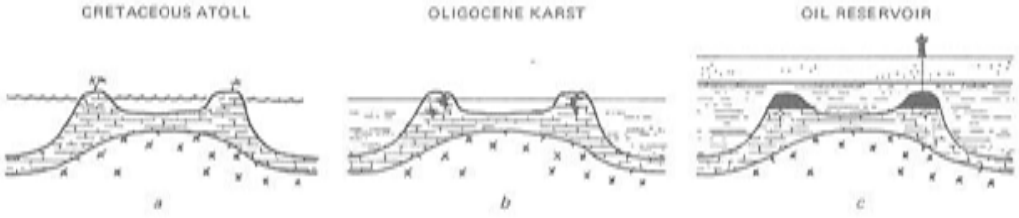


Figure 8-16 Cross sections showing the formation of the Golden Lane oil fields. (*a*) Deposition of a large, Cretaceous atoll of limestone that is then buried in the subsurface; (*b*) erosion of the overlying sediments during the Oligocene to expose the atoll and dissolve it; (*c*) the Golden Lane oil fields with the oil in the karst limestone.

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Transgressions and Regressions in the Sedimentary Column

Transgression: The advancement of seas onto the land.

Regression: The Sea's retreat from the land.

- The transgression/regression cycle is preserved in the rock record by a repeating sequence of sandstones, shales, and limestones (a pattern common in the stratigraphic column)

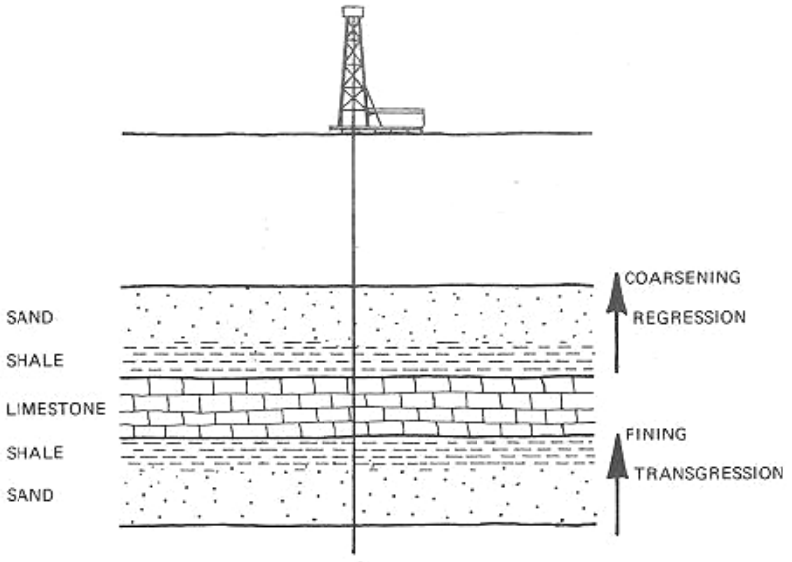

Figure 9-27 Cross section showing a fining upward vertical sequence deposited during a transgression and a coarsening upward vertical sequence deposited during a regression.

- Indicative of Coastal (transitional)/ Marine depositional environment
- Sands are deposited near shore; muds along continental shelf; and marine organisms on deep ocean bottom
- This depositional trend of sediments grading outward moving away from the shoreline and toward the deep ocean is called a **facies change**

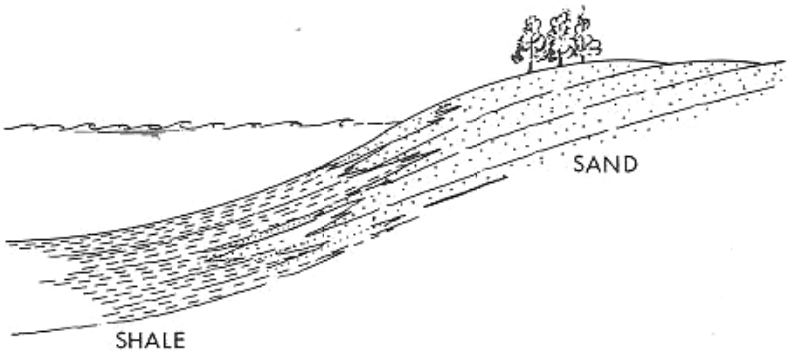

Figure 9-25 Cross section from the deep ocean onto a beach, showing the deposition of a rock layer with a sandstone (beach) and a shale (deep-water) facies.

A schematic of facies changes in near-shore off-shore depositional environments.

- As the sea level advances and retreats a succession of facies changes are deposited atop one another but are offset according to the relative movement of the water level at the time of deposition
- This succession of deposition will result in a vertical sequence of rock similar to the lateral gradation in a facies change
- A sequence of sedimentary rock fining upward would indicate a transgression (i.e., sandstone overlain with shale overlain with limestone)
- A sequence of sedimentary rock coarsening upward would indicate a regression (i.e., limestone overlain with shale overlain with sandstone)
- Pinch-outs and interfingering of facies can potentially provide stratigraphic traps for hydrocarbons (and frequently do)

Marine Transgression/Regression Sequence

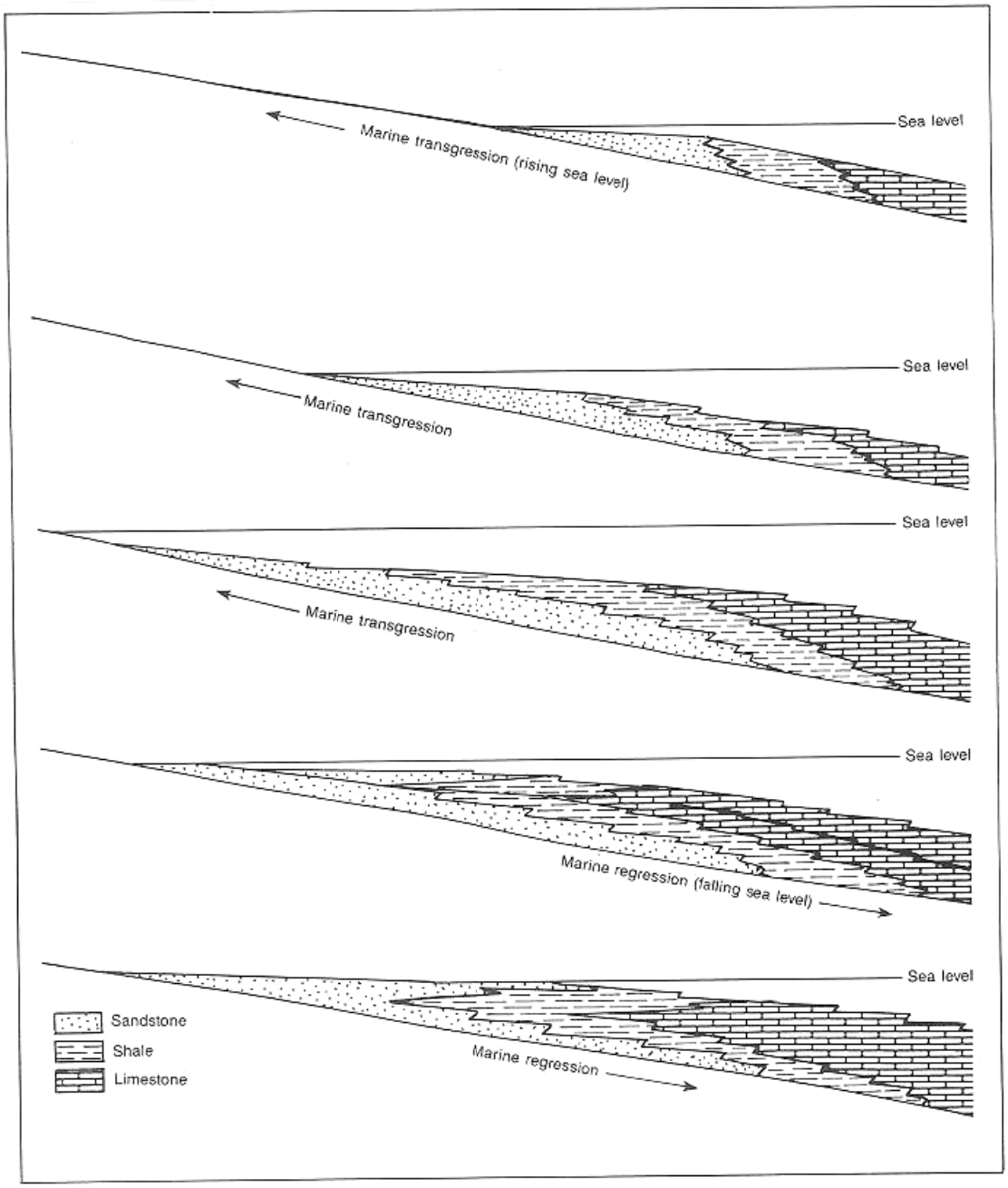

Fig. 69. Sediment deposition and marine transgression and regression.

Case Example:

- The following figure is a classic Tertiary transgression/regression cycle on the Gulf Coast of Texas. Many like it are observed around the world.

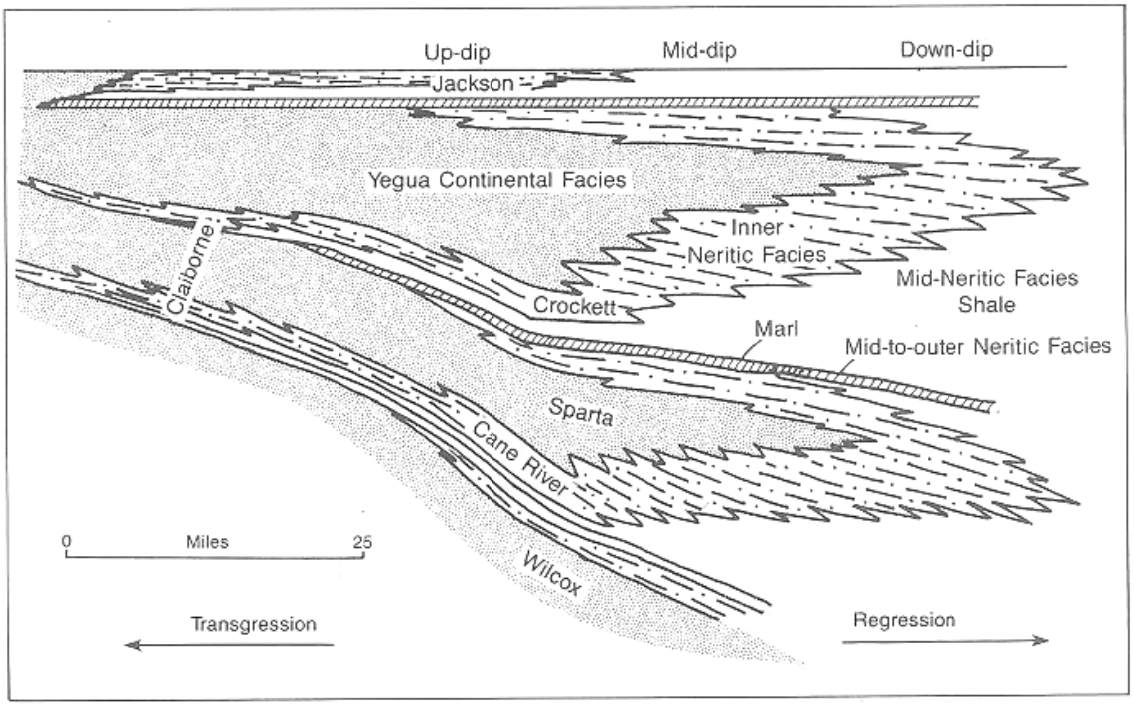

Fig. 43. Tertiary transgression and regression of the Gulf Coast of Texas. From Kay and Colbert, 1965. Permission to publish by John Wiley and Sons.

Glossary:

Anhydrite: An evaporate mineral of calcium sulfate.

Arenite: Consolidated, clastic rock of sand sized particles: arkose, sandstone, etc.

Argillaceous: Shaly, or containing clayey constituents.

Arkose: Coarse-grained, feldspathic, variably sorted sandstone containing angular grains, representing rapid deposition and limited grain transport.

Boundstone: Sedimentary carbonate rock the original components of which were bound together in place during deposition: most algal bank and reef deposits.

Calcarenite: A clastic limestone comprising over 50 percent sand-size calcium carbonate particles cemented as a calcareous sandstone.

Calcareous: Rock or other material containing up to 50 percent calcium carbonate.

Carbonate: Rock-forming minerals containing the carbonate ion which include calcite and dolomite.

Carbonate mud: Usually precipitated lime mud: calcium carbonate mud without reservoir or source potential.

Carbonate platform: A substantial limestone or dolomite substrate upon which a reef might be built.

Chalk: Fine-textured marine limestone formed by shallow water accumulation of calcareous remains of floating micro-organisms and algae.

Clast: A grain or fragment.

Coral: Warm water, sessile, commonly calcareous, bottom-dwelling marine invertebrate animal. Colonial corals build coral reefs and banks.

Coralline limestone: Limestone composed of coral constituents.

Dolomite: Calcium magnesium carbonate: $CaMg(CO_3)_2$

Dolomitization: A volume-reducing recrystallization process which adds the magnesium ion to calcium carbonate to form dolomite: can occur contemporaneously with deposition or diagenetically.

Evaporite: A rock or mineral deposited by precipitation during evaporation.

Facies: Rock type: lithology.

Facies change: Change of one rock type to another time-correlative rock type.

Formation: A discrete rock unit with characteristics suitable for distinctive study and mapping.

Grainstone: A grain-supported carbonate rock with less than one percent intergranular mud.

Group: A rock unit ronking above formation and comprising several formations.

Gypsum: Hydrous calcium sulfate.

Halite: Rock salt which consists of sodium chloride.

Index fossil: A fossil that is diagnostic of a specific geologic age or range.

Induration: Transformation of sediment to rock: lithification, diagenesis.

Intergranular: Between the grains of a rock.

Laminae: Thin layers of fine-grained sediment.

Layer: A thickness of rock. A stratum.

Limestone: Lithified calcium carbonate $CaCO_3$

Matrix (sedimentary): Fine-grained silt or clay material infilling intergranular sedimentary pore space between coarse grains.

Member: A time-rock stratigraphic unit of which several can comprise a formation.

Mud (sediment): A mixture of silt and /or clay particles and water. Diagenetically transformed into siltstone and/or shale.

Oolite: A sedimentary rock comprising concentrically precipitated calcium carbonate ooliths approximately one mm in diameter.

Oolitic limestone: A limestone, comprising calcareous ooliths, often having good reservoir potential.

Packstone: Granular carbonate rock, the grains of which occur in a self-supportine framework surrounded by some calcareous matrix.

Petroleum source rock: A sedimentary rock suitable for the generation of petroleum.

Quartz: Silicon dioxide.

Reef: A bank, ridge or mound constructed by calcareous animals and plants.

Reservoir rock: A permeable subsurface rock unit which contains petroleum.

Rock sequence: A progression of layered rocks often illustrative of specific stratigraphic characteristics.

Salt dome: A circular or elliptical, positive salt-cored structure which vertically penetrates or deforms the surrounding sediments.

Sandstone: A clastic sedimentary rock of sand-size particles.

Shale: A fine-grained, usually laminated, clastic rock of compacted clay or mud particles.

Silica: Silicon dioxide, quartz.

Siltstone: A rock made of silt.

Source rock: A sedimentary rock in which petroleum forms.

Turbidite: A turbidity current-deposited , graded clastic sequence.

Vug: A small void in a rock (typically carbonates) that is a result of the dissolution of fossil components or grains.

Wackestone: Mud-supported carbonate rock with more than 10% grains larger than 20 microns in diameter: calcarenite.