Sedimentary Rocks and Sedimentary Basins

Reading
• Stanley, S.M., 2015, Sedimentary Environments, – Ch. 5. Earth Systems History
• On Ecampus

Sedimentary Rocks
• Intro
• Origin of sedimentary rocks
  – Clastic Rocks
  – Carbonate Sedimentary Rocks
• Interpreting Sedimentary Rocks
  – Environment of deposition
• Implications for the Petroleum System

What is a Sedimentary Basin?
– A thick accumulation of sediment
– Necessary conditions:
  1. A depression (subsidence)
  2. Sediment Supply

What are the Sedimentary Basins?

World Map of Sedimentary Basins
Our Peculiar Planet: Liquid Water and Plate Tectonics

The Rock Cycle

SEDIMENT

- Unconsolidated products of Weathering & Erosion
  - Loose sand, gravel, silt, mud, etc.
  - Transported by rivers, wind, glaciers, currents, etc.
- Sedimentary Rock:
  - Consolidated sediment
  - Lithified sediment

3 Basic Types of Sedimentary Rocks

- Detrital (= Clastic)
  - Made of Rock Fragments
- Biochemical
  - Formed by Organisms
- Chemical
  - Precipitated from Chemical Solution

Formation of a Sedimentary Rock

1. Weathering
   - Mechanical & Chemical
2. Transport
   - By river, wind, glacier, ocean, etc.
3. Deposition
   - In a point bar, moraine, beach, ocean basin, etc.
4. Lithification
   - Loose sediment turns to solid rock
**Processes during Transport**

1. Sorting
   - Grain size is related to energy of transport
   - Boulders ⇒ high energy environment
   - Mud ⇒ low energy

**Significance for Petroleum System?**

- **Shales:** Fine grain, clay rich?, very low energy environ., low permeability, high organic content?
  → Source rocks, Seals, Permeability barriers

- **Sandstones:** Coarse grain, quartz-rich, high energy env., low organic content, high porosity?
  → Reservoirs, Migration pathways

**Processes during Transport: 2. Rounding**

- Abrasion is progressive
  - Angular grains ⇒ near source
  - Rounded grains ⇒ long transport

**Petroleum System Implications**

- **Well rounded**
  - Good Reservoir!
  - Well sorted
  - Quartz sandstone
  - High porosity and Permeability

- **Bimodal rounding**
  - Poorly sorted
  - Lithic sandstone
  - Low porosity and Permeability
  - Poor Reservoir!

Many depositional environments with particular characteristics:
**Lithification**

- **Compaction**
  - Decrease in pore space
  - Due to increasing lithostatic pressure with burial
- **Cementation**
  - Pores filled
  - Quartz or calcite cements
- **Recrystallization**
  - New mineral growth
  - Beginning of metamorphism
  - Can kill porosity

![Compaction: Shale Porosity vs. Depth Curve](image)

\[ \Phi = 41.73 e^{-z/8197 \text{ ft}} \]
\[ \Phi = 41.73 e^{-z/2498 \text{ m}} \]

Schmoker and Halley, 1982

**Lithification of Sand Grains**

- **Quartz**
- **Feldspar**
- **Pore space**
- **Cement**

A. After deposition
B. Compaction
C. Cementation

**Lithification of Shale**

Dewatering of shale
- Overpressure?
- Expulsion of hydrocarbons?

![SEM-CL image- Frontier Fm. -Lithic Sandstone](image)

Rock Fragment
- Cement
- *qtz*

SEM-CL image- Frontier Fm. -Lithic Sandstone

Reed, UT Austin

**Petroleum System Implications**

- Determines the nature of the reservoir
- Critical for economic viability
- Highly variable
- Hard to predict ahead of the drill
Classification of Clastic Sediments

- Based on Particle size
  - Gravel (more than 2 mm)
    - Pebbles (small) (Driveway gravel)
    - Cobble (medium) (Plum to melon size)
    - Boulders (large) (Melon to bus size)
  - Sand (2 mm - 1/16 mm)
  - Silt (1/16 - 1/256 mm)
  - Clay (< 1/256 mm)

Detrital Rock Names

- Conglomerate
- Shale

Biochemical Sedimentary Rocks

- Carbonate Rocks
  - Limestone \( \Rightarrow \) calcite \( \text{CaCO}_3 \)
  - Dolostone \( \Rightarrow \) dolomite \( \text{Ca,Mg (CO}_3 \text{)}_2 \)
- Coal
- Organic-rich shales have large biochemical component

Carbonate Sedimentary Rocks

- Made of Calcium Carbonate or Mg -Ca Carbonate
- Precipitated from seawater
  - Mostly by organisms (biochemical)
    - algae, shells, corals
  - In some cases chemically (inorganic)
    - Do not confuse with organic Carbon-rich rocks

Chalk - Microscopic algae

Coralline Algae on Sea Floor
Sedimentary Environments

- Type and geometry of sedimentary rocks
- Key to paleogeography
- Prediction of distribution of source rocks and reservoirs
- Use the modern to interpret the ancient

Coral Reef Carbonates

- Paleokarstity
- reef core
- back-reef lagoon
- m (m)

Limestone Formation in Reef

Carbonate Bank-Bahamas

Coral Reef

Sedimentary Environments of Deposition

- Glacier
- Delta
- Beach
- Continental slope
- Organic rich

Chalk

Fields in the North Sea produce from fractured chalk

White Cliffs of Dover, UK
Non-Marine Environments

- Glacial
- Deserts
- Alluvial Fans
- Lakes
- Swamps
- Braided Streams
- Meandering Streams

How do we recognize them?

- Rock Types
- Sedimentary Structures
- Fossils
- Geometry

Deserts

- Very good sorting
- Great reservoirs
- Rarely preserved

Jurassic Dunes (160 million years old)
Utah

Types of River

- Mountain
- Braided
- Delta
- Meandering
- Ocean

Alluvial Fans

- Conglomerates
- Poorly sorted
- Not so great!
Fluvial Environments (Rivers)

- Braided Stream
- Meandering Stream

Meandering Stream

Channel and Floodplain

National Geographic Photo

Development of Meanders

Time

Channel Sandstone

Sandstone

Mudstone

Conglomerate
**Vertical sequence of rocks left by a meandering river**

- Mud
- Shale
- Ripple-marked fine-grained sand
- Medium to fine sand, cross-bedded point bar
- Coarse, poorly channel sands

**Well log Response**

Peoria Field, CO

**Log signature of Sedimentary Rocks**

- River Point Bar: fine to coarse
- Delta-marine: coarse to fine
- Harrier Island: coarse to fine
- Transgressive sand: fine

**Fluvio Deltaic Reservoir - Prudhoe Bay**

Atkinson et al., 1988

**Take home Points**

- Sedimentary Environments produce recognizable rock sequences
- Useful for predicting the lateral rock changes in the subsurface
- Control reservoir properties
- Non-Marine Environments
  - Deserts
  - Rivers
- Electrical logs produce patterns for different environments are distinctive