Diagenesis of Sandstones

All changes, physical, chemical, and biological, that occur in a sediment after deposition and before metamorphism (<150-200^oC)

These changes happen at sediment-water interface and after burial

Two important processes

- Compaction - decrease in volume, largely by squeezing out of water
- Cementation - introduction of chemical precipitates between grains
- Together these result in lithification = the change from a loose sediment into a cohesive rock

Compaction

- Spaces between grains of sediment are usually filled with water
- Porosity = void volume / total rock volume
- Permeability = ability of a rock to transmit a fluid (water, oil, gas), requires connected porosity

Compaction of Muds

- Modern muds contain > 60% water, which can be squeezed out by exerting little pressure
- Muds can be compacted because grains are ductile (flexible) and can pack easily

Compaction of Sands

- Sands are not easily compacted because they are supported by grain-to-grain contacts
- Quartz and feldspar are not ductile at diagenetic P and T
- Modern sands 45±5% porosity
- Compacted quartz sandstone ~30% porosity
- Ductile lithic fragments can be squeezed into pore spaces, so lithic sandstones can be compacted more

Can compaction alone convert sand into sandstone? Sometimes

- Quartz ± Feldspar + water squeezed to the limit of sedimentary conditions, still loose grains
- 80% Quartz + 20% schist or mudstone fragments yields multigrain aggregates
- 100% Mud yields mudrock
- Compaction alone can produce a rock from a sediment with high content of ductile lithic fragments or mud

Cementation

- Growth of new authigenic minerals from pore fluids
- Authigenic = grown in the sediment after deposition (as opposed to detrital)
- Cements precipitate in pores: usually coat grains, increase areas of grain-grain contact, decrease pore space (porosity)

Most common Cements are:

- Quartz - SiO_2
- Calcite - $CaCO_3$
- Hematite - Fe_2O_3
- Clay - kaolinite, illite, montmorillonite, chlorite (not really a clay mineral)

Quartz (SiO_2) Cement

- Quartz cement commonly nucleates on quartz grains, is optically and crystallographically continuous with detrital grain
- Quartz cement is most common where quartz grains are abundant
- SiO_2 must come from pore waters that move through the sandstone
- Quartz cemented quartz arenites (Tuscarora Ss.) are very resistant to weathering

Dust rings may show detrital grain boundaries

Calcite ($CaCO_3$) Cement

- Very common
- Reacts with acid
- Requires permeability for $CaCO_3$ saturated waters (with $[Ca^{++}]$ x $[CO_3^{2-}]$ above a certain value)
- Calcite is orders of magnitude more soluble than Quartz, may form and later dissolve
- Often discontinuous

- May form concretions = locally cemented areas in friable Ss, typically around fossils

Calcite-cemented Sandstone

Calcite (and dolomite) Cement, stained

Hematite (Fe_2O_3) Cement

- Forms in oxidizing environment
- Makes red beds red
- only about 1% Fe_2O_3 required to make red color
- Fe^{2+} dissolved from ferromagnesian minerals during diagenesis gets oxidized to Fe^{3+} and precipitated as hematite cement

Hematite Cement

Clay Cement

- Some clay in sandstones is detrital
- Some clay is authigenic
- Clay cement coats sand grains
- Clay plates grow perpendicular to surface and form honeycomb texture
- Clay coatings can prevent quartz cement from growing and preserve porosity

Clay Coatings

Authigenic clay is perpendicular to grain boundaries

Diagenesis is complex

- Compaction depends on mud content, sorting, % ductile fragments, angularity of grains, depth of burial (pressure)
- Cementation depends on chemistry and amount of pore fluid