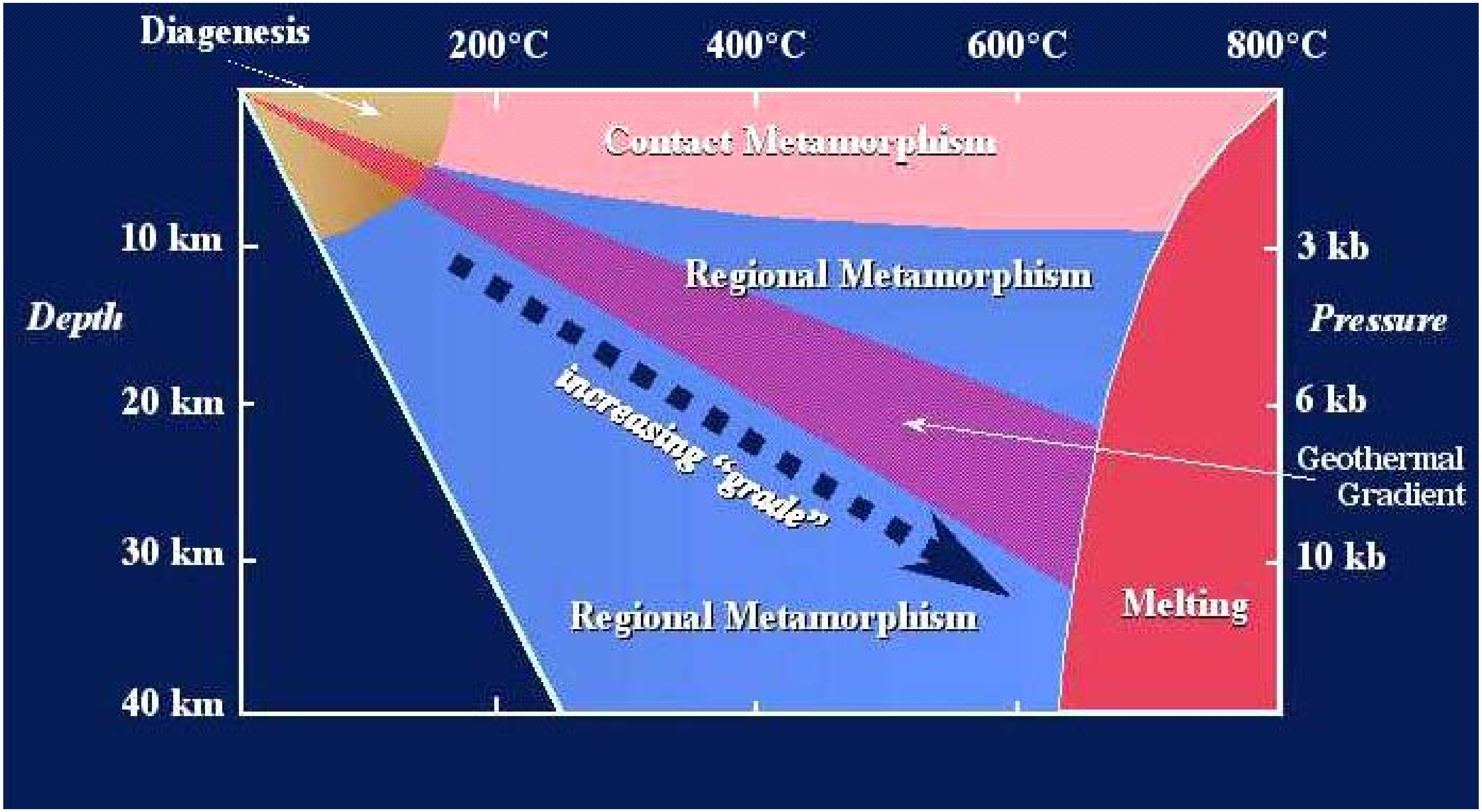
Siliciclastic sedimentary rocks

Diagenesis

Introduction

- **Diagenesis**: All the chemical, physical, and biologic changes undergone by a sediment after initial deposition, and during and after its lithification
  - Exclusive of weathering and metamorphism

Burial diagenesis



Stages of diagenesis

- Early (shallow) diagenesis (Eogenesis)
  - Near-surface environment (1 -100 m)
  - Under the conditions of the depositional env.
  - 0.1 – 1 Ma
- Deep burial diagenesis (Mesogenesis)
  - Increasing temp. and pressure
  - Changed pore-water chemistry
- Uplift diagenesis (Telogenesis)
  - Bring back the rocks into contact with meteoric waters

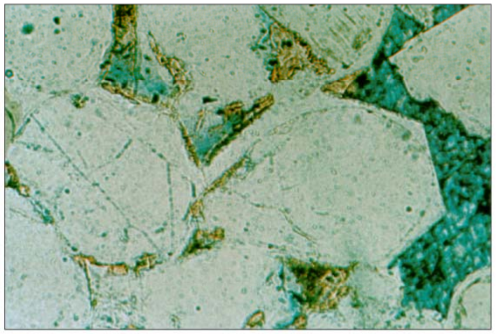
Controlling factors

- Initial controls:
  - The depositional environment
  - Climate
  - Composition and texture
- Pore-fluid chemistry and migrations
  - Salinity, pH, Eh, and hydraulic conductivity
- Burial history
  - Depth of burial
  - Timing of uplift

Near-surface (eogenetic) environment

- Marine
  - Begins when pore waters are modified
    - Organic matters: bacterial oxydation (dissolution)
    - Clay minerals, quartz and feldspar overgrowths
    - Carbonate cement
    - Pyrite cement (under reducing, low-oxygen, conditions)
    - Iron oxides in oxygenated pore waters (e.g. red clays on the deep ocean floor)
- Continental hot and humid
  - Pore waters are acidic (bacterial breakdown of organic matter)
    - Quartz overgrowths and kaolinite
    - Feldspar is dissolved
- Continental semi-arid/arid
  - Pore waters are often oxidizing and leaching is less important
    - Formation of red beds (from dissolution of mafic minerals) and calcretes
  - Gypsum cementation (desert roses)
  - Alteration of volcanic grains to zeolites

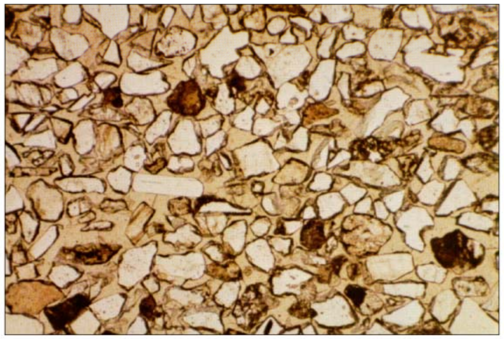
Silica cementation



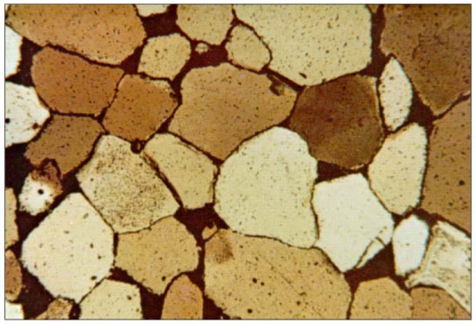
Quartz overgrowth

Origin of silica:

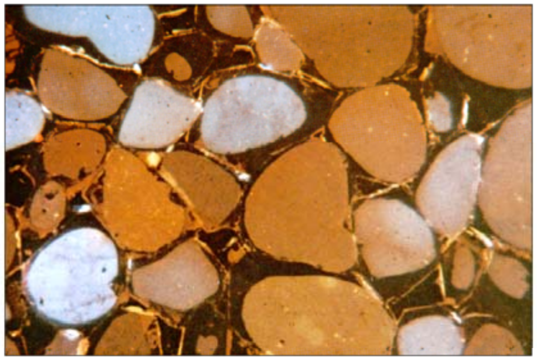
1) Pressure solution
2) Upward migration of SiO_2-rich solutions
3) Dissolution of silica dust, other silicates, biogenic silica
   - Siliciceous skeletons $\rightarrow$ higher solubility than Qtz
4) Groundwater



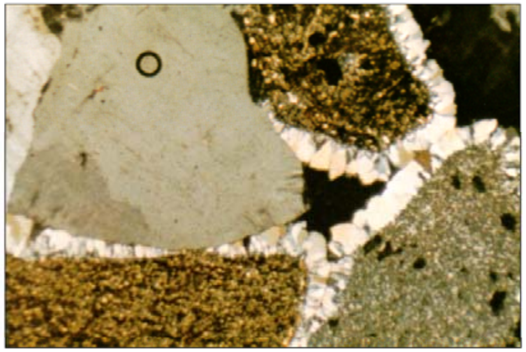
Opal-cemented sandstone



Under light microscope



Cathodoluminescence microscope

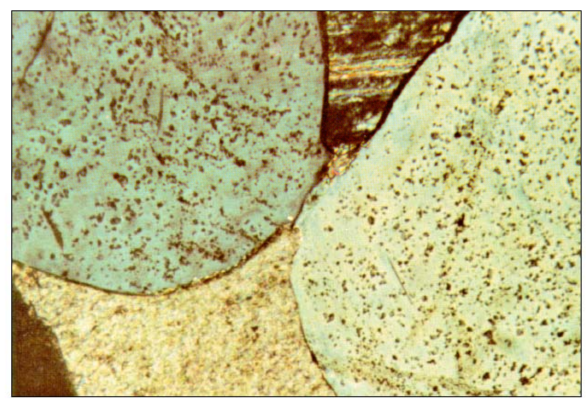


Megaquartz

Carbonate cementation

- Poikilotopic crystals (commonly the 1st cement)
  - Evaporation of vadose gw
- Sparry calcite cement
- Can postdate quartz overgrowths and authigenic kaolinite
  - As a result of increase pH and/or Temp.

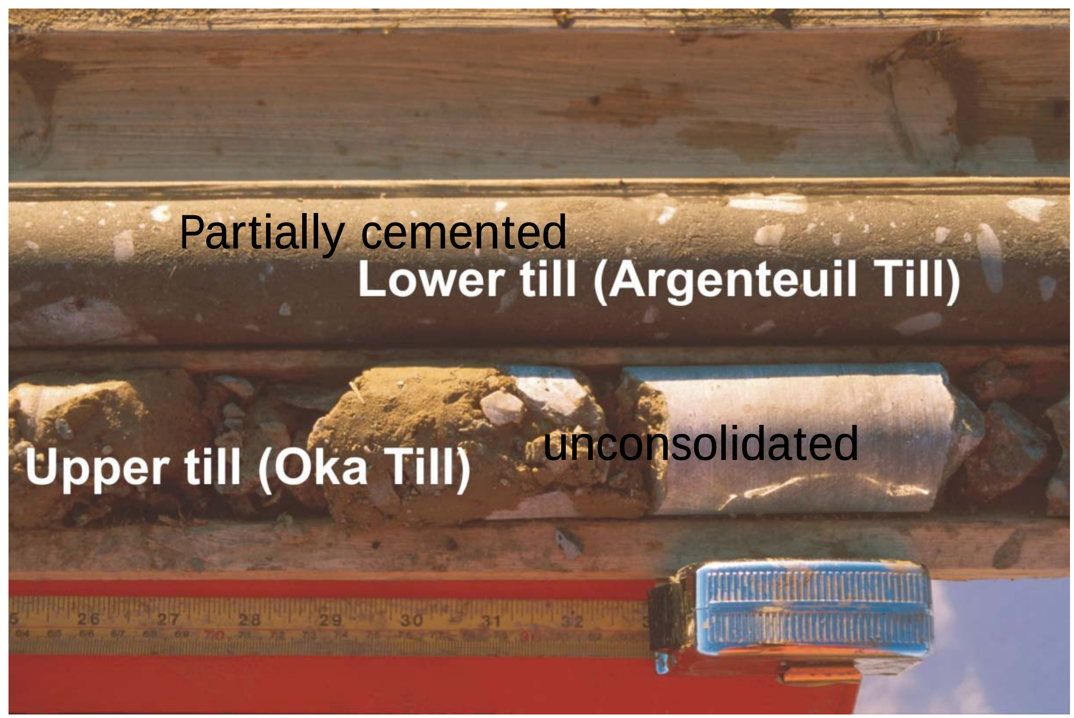
Poikilotopic calcite cement
Large crystals enclosing grains



Sparry calcite cement
Crystal >10 microns

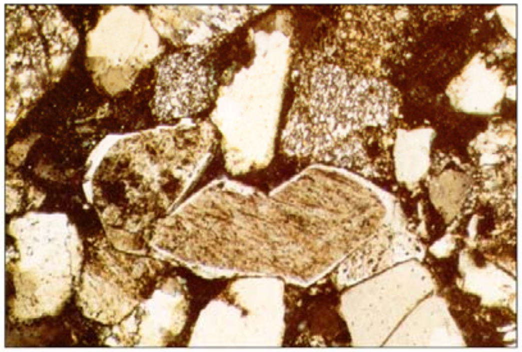
Partially cemented sediments

Glacial sediments (e.g. till, glacifluvial gravel)
In Canada locally show evidence of early diagenesis
(e.g. vadose zone carbonate cementation)

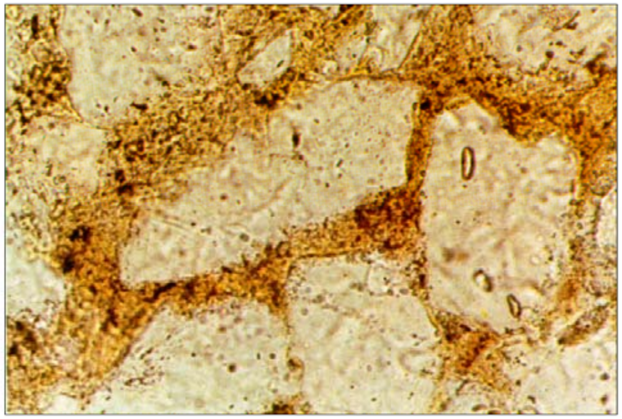


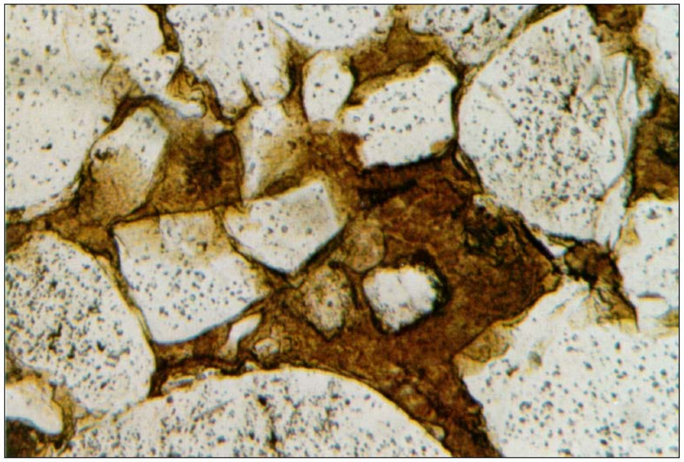
Feldspar authigenesis

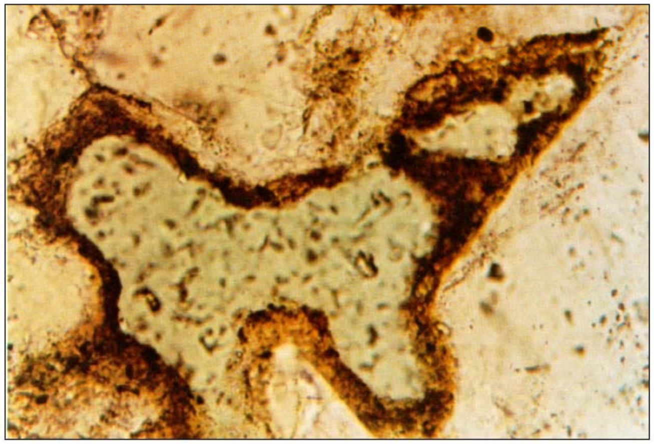
- Feldspar overgrowths
  - Alkaline pore waters rich in Na^+ or K^+, Al^{3+} and Si^{4+}
  - Shallow depths of burial



Clay mineral authigenesis

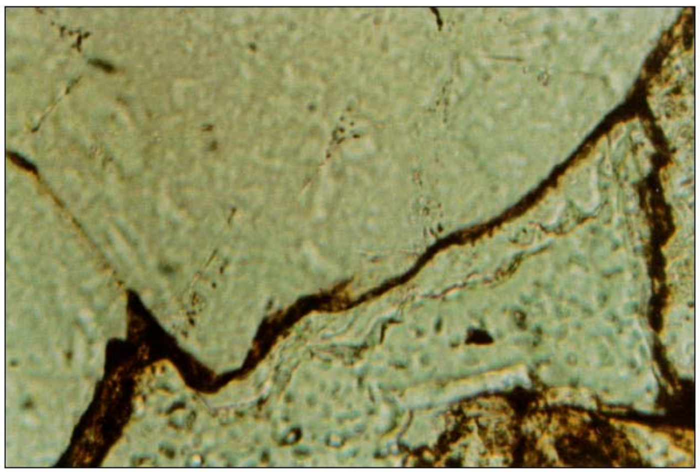


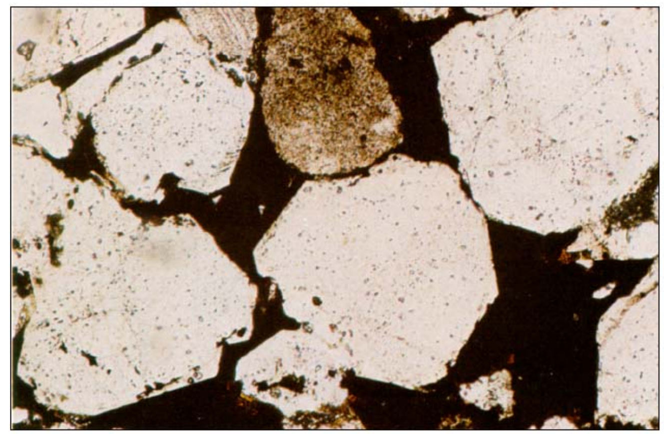




Kaolinite cemented sandstone

Hematite cementation (red beds)





Hydrated iron oxide which “ages” to hematite

Early pigmentation

0.1% of iron is sufficient

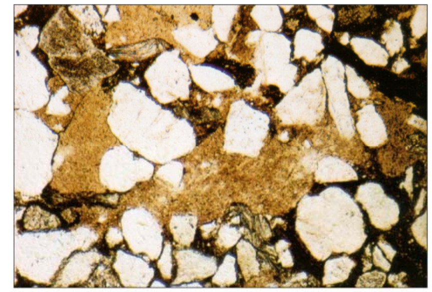
Red beds…

Îles-de-la-Madeleine

Mesogenetic environment

- Increasing pressure and temperature
  - Silicate minerals dissolve
  - Carbonates precipitate (if pH is not too low)
- Pore waters become more saline
  - High pore-fluid pressures
- Many grains become unstable
- Changes in clay mineralogy
  - Smectite $\rightarrow$ illite (55-200 $^\circ$ C) (shale dewatering)
- Pressure dissolution
- Mineral replacement
- Secondary porosity
  - Quartz and feldspars by carbonate minerals
  - Feldspars by clay minerals

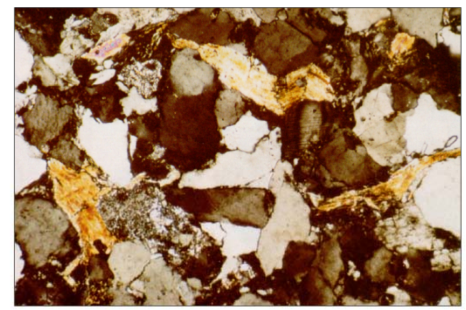
Compaction and pressure dissolution

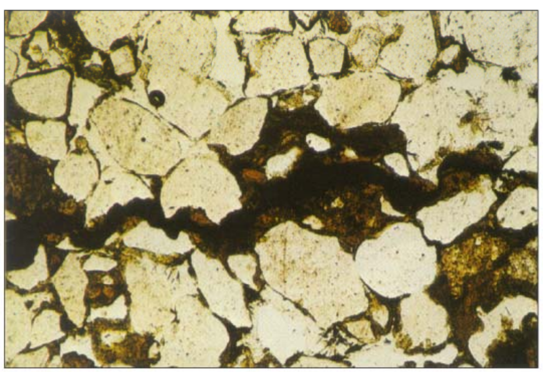


Deformed shale clasts

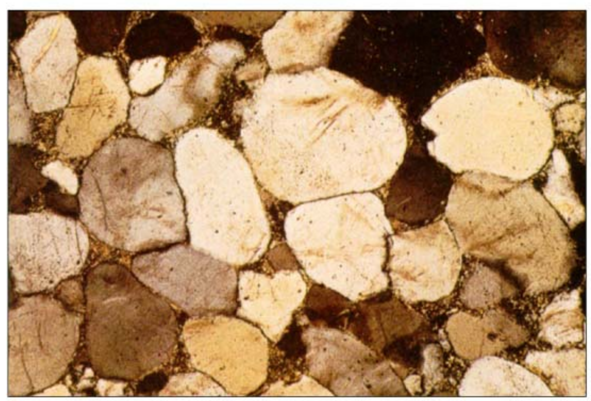
- Compaction
  - Dewatering
  - Closer packing of grains (↓ porosity)
  - Bending of weak grain + plastic deformation
  - Pressure dissolution at points of contact

Bended micas and concavo-convex contacts

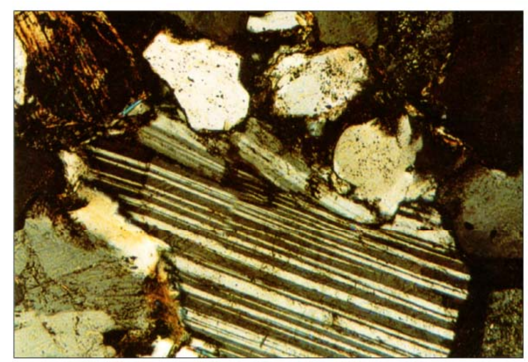




Stylolite in a sandstone

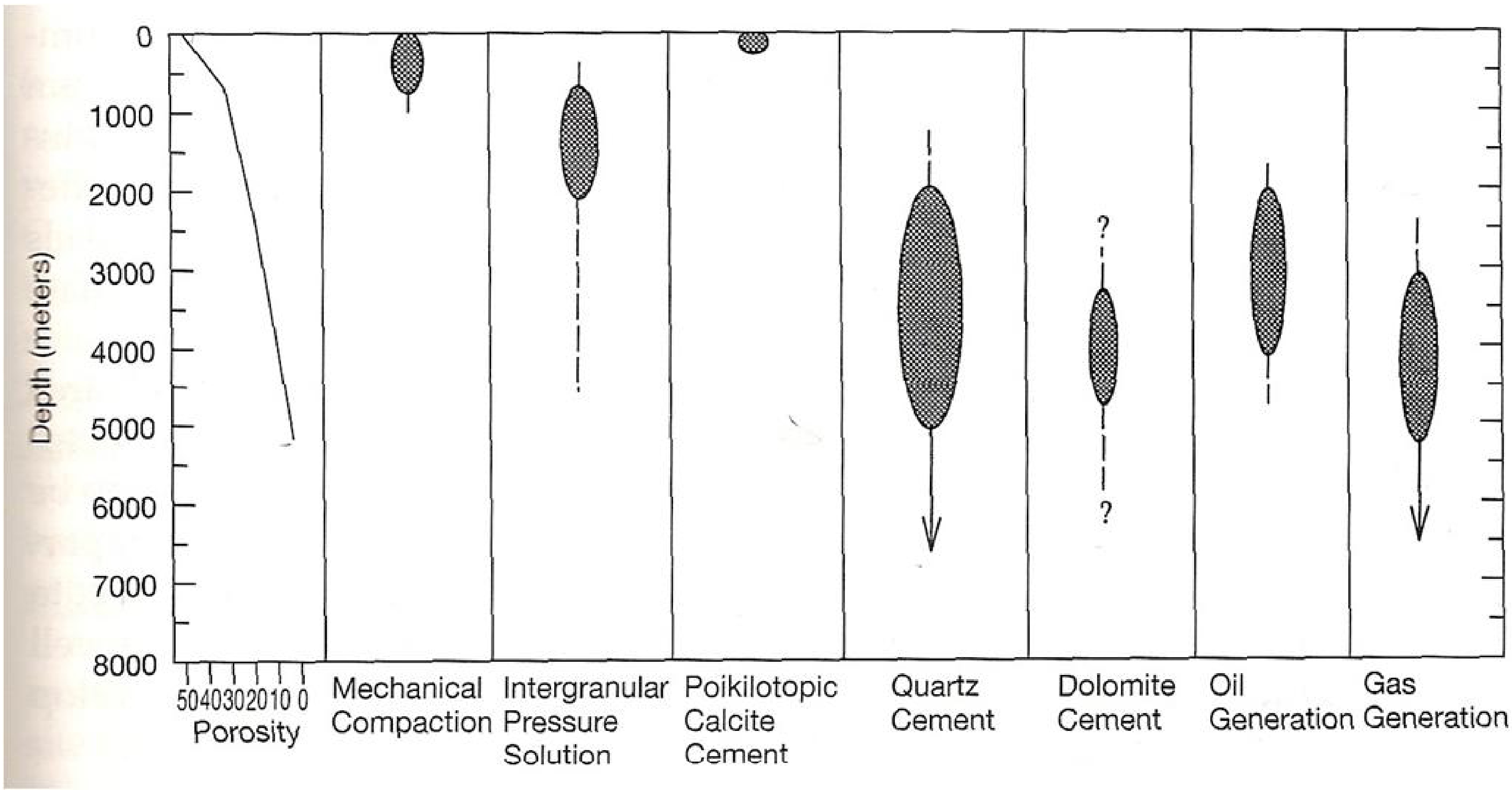


Compaction,
Pressure-solution texture



Fractures due to compaction

Burial compaction and cementation



Telogenetic environment

- Climate is again important
  - Semi-arid $\rightarrow$ oxydation of sulphides and iron carbonates (lead to goethite-limonite)
  - More humid $\rightarrow$ leaching of feldspars, carbonates and heavy minerals
- Porosity $\uparrow$