Dolomite and Dolomitization Models

Lecture Outline

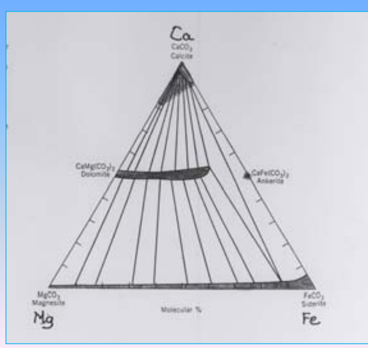
Chemistry, Dolomitization reaction, and Fabrics

- Direct precipitation
- Dolomite sediments
- Cements
- Replacement

Models of Dolomitization

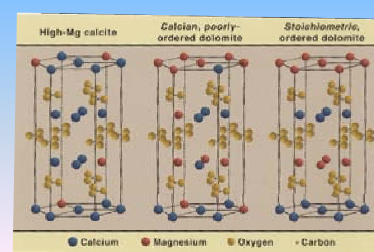
- Evaporative
- Seepage Reflux
- Mixing-zone
- Burial
- Seawater

Dolomite $CaMg(CO_3)_2$



Dolomite Crystal Structure

- Ordered crystal form requires a lot of time to crystallize and has not been synthesized in laboratory experiments.



Origins of Dolomite

1. Direct Precipitation
2. Replacement

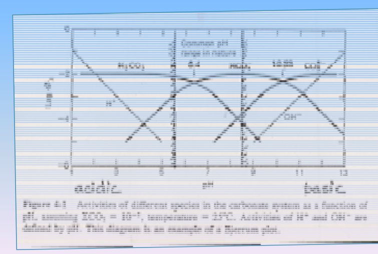
Direct Precipitation

- $Ca^{2+} + Mg^{2+} + 2(CO_3)^{2-} = CaMg(CO_3)_2$
- If the Mg/Ca ratio > .67 the reaction should go to the right and dolomite is precipitated
- Mg/Ca seawater = 5.2, Thus marine seawater is supersaturated with respect to dolomite (several orders of magnitude more), but dolomite does not precipitate readily from seawater. Why?

Dolomite doesn't precipitate from seawater because of kinematic factors such as:

1. Fast precipitation rates, Dolomite can't get ordered that fast.
2. Hydration of Mg_{2+} ions (associated with water molecule) Ca ions more readily absorbed into the crystal structure and calcite or aragonite is formed. Mg hydration is more easily overcome by higher temps- that's why burial dolomitization is popular way to dolomitize.
3. Low activity of CO_3^{2-}- Seawater contains mostly HCO_3 and H_2CO_3. Dolomite forms from the CO_3 ion and not the HCO_3 anion, therefore high alkalinity and high pH solutions favor dolomite.

- At any one time the solution will contain: H_2CO_3, HCO_3, CO_3, H, and OH.
- Which of these species is the dominant one depends on pH

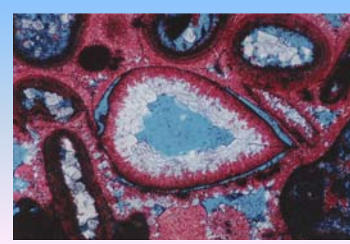


Dolomite micrite sediment

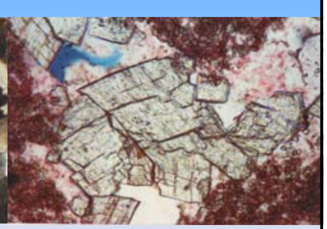
- In modern Sabhkas Mg/Ca = 6 are precipitating dolomite in very small amounts.
- Sulfate reduction found in decomposing algal mats leads to alkaline fluids, conducive to local dolomite precipitation.
- Produces protodolomite or primary dolomite - crystal structure poorly ordered.

Dolomite Cements

- Describe using same terms utilized for calcite cements
- Clear, "limpid" or rhombic, drusy spar lining cavities.
- Typical of Mixing-Zone dolomite cements



Baroque Dolomite or Saddle-Dolomite" Cements

Baroque Dolomite

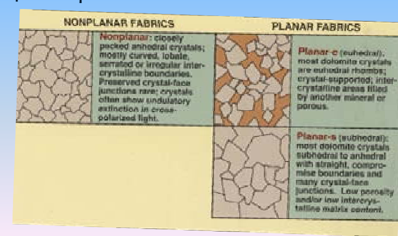
- May also form as a replacement dolomite
- Has warped crystal lattice causing the crystal faces and cleavage planes to be curved. Irregular crystal boundaries.
- Results in undulose extinction.
- Typically have cloudy appearance in thin section and a pearly luster in hand specimen due to fluid inclusions.
- Commonly has high Fe content.
- Forms in deep, burial connate environment.
- Commonly associated with hydrocarbons, so thought to form at low temperatures (60-150°C) in connection with SO_4 released by organics in the hydrocarbons

Dolomite Replacement of Calcite or Aragonite

- $2CaCO_3 + Mg^{2+} = CaMg(CO_3)_2 + Ca$
- or all Ca used:
- $CaCO_3 + Mg^{2+} + CO_3^{2-} = CaMg(CO_3)_2$

Dolomite Crystal Morphology

- 1. Pseudomorph after crystal replaced
- 2. Planar-e: euhedral
- 3. Planar-s: subhedral
- 4. Non-planar



Important factors controlling replacement fabric:

1. **Grain original mineralogy** - pseudomorphs common in high Mg calcite; low Mg calcite tends to resist dolomitization for example brachiopods often not replaced.
2. **Grain original crystal size**-pseudomorphs common in large original crystals (echinoderm overgrowths) and very fine grained material (lime muds) with many nucleation sites. Retains original sedimentary structures.
3. **Timing of dolomitization**-amount of cementation that has taken place or dissolution, basically what other diagenetic processes have occurred
4. **Nature of dolomitizing fluids** - saturation state and temperature

Nature of Dolomitizing Fluids

Saturation state:

- **supersaturated** - pervasive dolomitization that replaces everything
- **saturated** - selective replacement of most susceptable grains.

Temperature:

- **Low temperature** - planar, euhedral crystals
- **High temperature (50-100°C)** - irregular anhedral crystals and Baroque replacement dolomite

- Crystals often have cloudy centers from impurities in the crystals they're replacing and fluid inclusions.

Terms for describing replacement dolomite textures:

1. Dolomite crystal size: unimodal or polymodal
2. Dolomite crystal shape: planar, non-planar, pseudomorphic
3. Degree of preservation of original fabric: mimic(fabric preserving) or non-mimic (fabric destroying)
4. Whats been replaced and how much: grains, matrix, cement; partial or complete.

Models of Dolomitization

- **All models must explain:**

1. **Source of Mg^{2+}**
    - Generally seawater is assumed, meteoric waters have very low Mg concentrations (Low Mg calcite)
    - Transformation of smectite clays to illitic clays during burial releases Mg^{2+}
    - Formation water brines - highly variable mineralogy
2. **Method of pumping dolomitizing fluids through pore space**

5 General Models

1. Evaporative
2. Seepage Reflux-
3. Mixing-zone
4. Burial
5. Seawater

Evaporative Model

-Supratidal Sabhka ppt. from high Mg/Ca waters.

-Most modern forming dolomites of this type

Mg concentrated through evaporation

Water recharged through:

1. periodic flooding, sinks into sediment.
2. tidal pumping
3. intense evaporation of water in the capillary zone causes upward flow of groundwater "evaporative pumping".

Commonly get replacement of aragonite and associated gypsum ppt. which raises the Mg/Ca ratio.

Intense evaporation of small pools, lakes, lagoons forms high Mg/Ca brines that are very dense and sink or descend into the sediments and subsurface.

Proposed for Capitan Reef Complex - lagoonal seds dolomitized, reef not dolomitized.

Has been applied to many important carbonate reservoirs (Ex: Permian Zechstein ,Northern England; Cretaceous Edwards Fm, Texas)

Mixing-Zone Model

- Mixing of marine-meteoric waters
- Seawater supplies the Mg and mixing dilutes the water to overcome kinetic factors.
- Groundwater is the pumping system
- Produces coarse, rhombic clear spar with planar boundaries and commonly replaces aragonite.

Burial Model

- Expulsion of Mg^{2+} from shales during burial dewatering and from subsurface brines with elevated temps.
- Problem moving fluids through, most fluids move up not laterally during compaction.
- Baroque dolomite commonly ascribed to burial

Seawater Model

- Mg from sea water
- Pumped through seds by ocean current pumping system - convection cell due to differential temperatures of platforms (warm) versus open ocean waters (cold)