Mineralogy

Course of Mineralogy G102
Second Semester (February-June, 2014)
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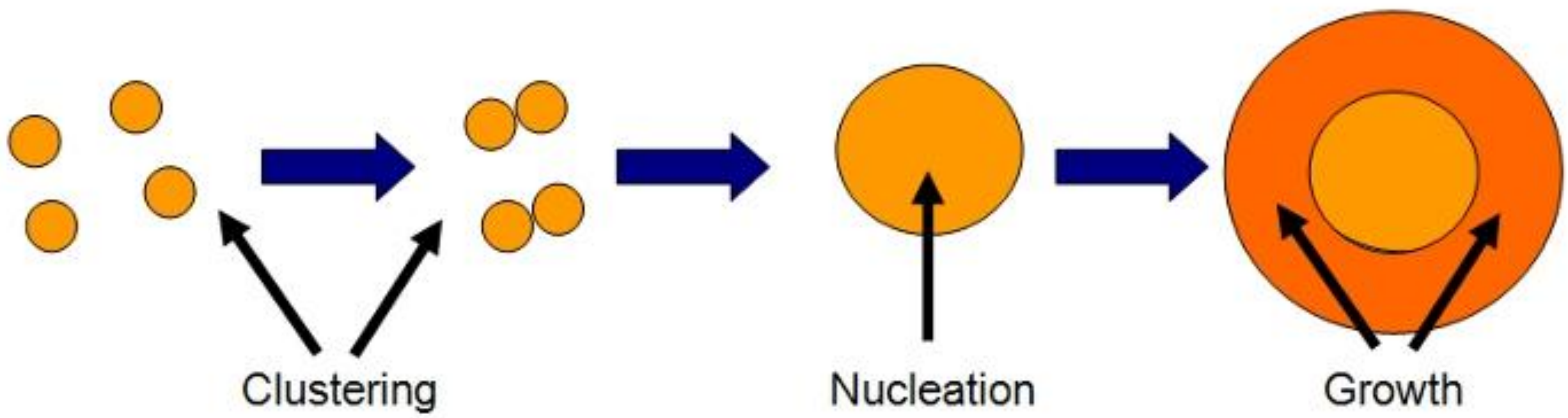
Lecture 4

Crystallization and Dissolution of Minerals

Part 2

Nucleation in fluids

Nucleation is clustering of several unit cells (seed crystal) together to form nucleus.
Nucleus represents the template of crystal growth in which repetition of crystal structure can develop.



Crystal growth in fluids:

- Reasons for crystal growth:

- **1- lowering of the temperature** of the fluid that has the chemical potential to precipitate minerals.
- *Note//*
- *1- all liquids have a liquidus equilibrium temperature below which nucleation and crystallization can take place and above which the liquid phase state is maintained.*
- *2- cooling of liquid that capable to totally crystallization at specific liquidus temperature is rare in geological environments expect for the production of ice from water.*

- **2-Adiabitic undercooling:** effective undercooling happens as a consequences of changing the concentrations of solutions. (i.e supersaturation by evaporation of water colvent).
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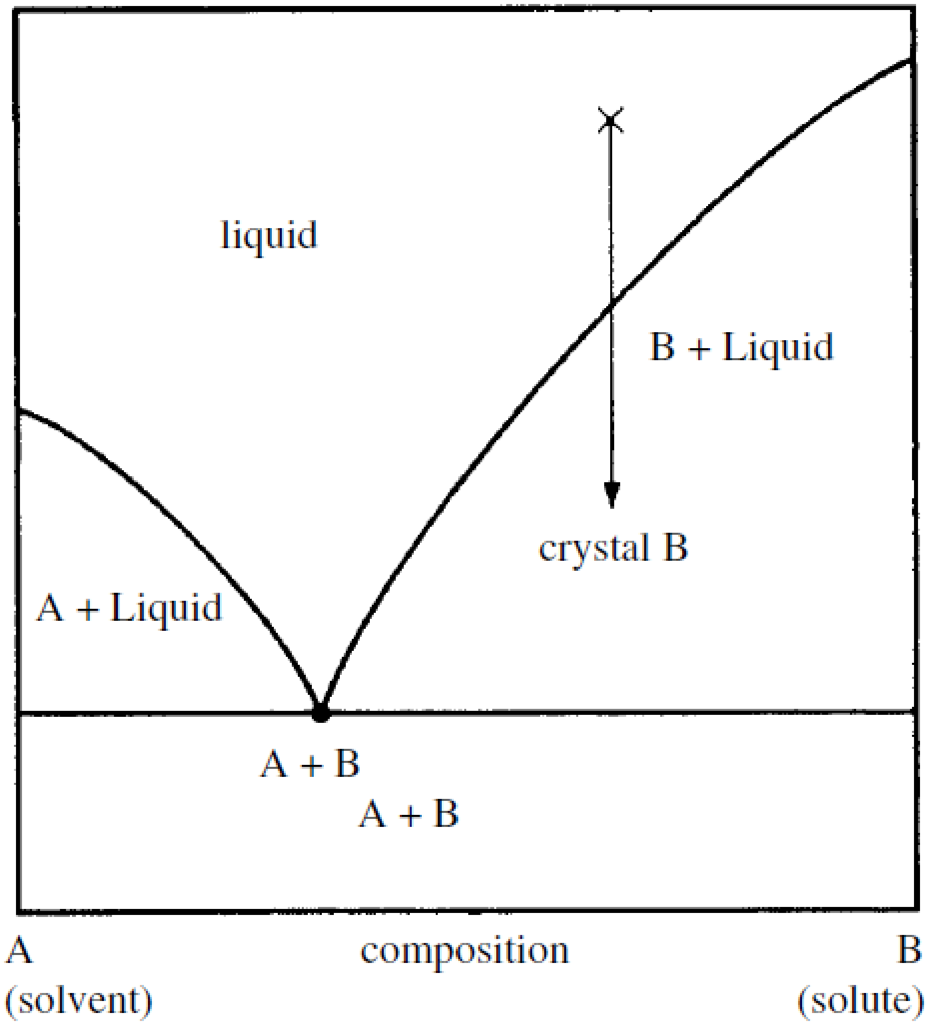
- Adiabitic undercooling can also be achieved by changing the composition of fluids. In this process there is exchange or redistribution of heat.
- Ex: mixing of salt water with meteoric groundwater along continental margins may lead to supersaturation and crystallization of calcite or quartz as the ionic strengths of solutions are changed.

- **3- Escape of volatiles from a liquid solution:** crystallization can also occur in response to escape of volatiles from a liquid solution, which is another example of composition change generation a effective undercooling.

- Ex: most silicate magmas contain dissolved H_2O, which has the effect of depolymerizing silicate molecules. When this H_2O separates out as a separation phase, as it does if the magmatic system intrudes to shallow (low pressure) regions or to the surface as a lava flow, linkage of silicate polymers is favored, being one step closer to the formation of stable nuclei and the crystalline structure of minerals such as quartz and feldspar.

Heat Transfer



An imaginary phase diagram of a solution with solvent component A and solute component B.

Due to the solute–solvent interaction energy, the melting point of the solution is lowered from that of the pure solute and solvent components to the eutectic point.

This phase diagram shows that a crystal may be grown at a much lower temperature than in melt phase growth by preparing a solution, and that the resulting crystal is determined not by which component has the higher melting point, but by the composition of the solution. These are the essential characteristics of solution growth (Sunagawa, 2005).

Controls of crystallization

- There are four factors control crystallization:
  - 1- the attachment kinetics in the transfer of solutes to crystal structures at the crystal-liquid interface must be favorable.
  -
  - 2- there must be a viable mechanism, such as diffusion or convection, to supply growth components to the growth surfaces from the fluid environment.

Controls of crystallization

- 3- there must be a viable mechanism of removal of unwanted chemical components in the fluid at the interface, also by diffusion or convection.

- 4- there must be a means by which the heat of crystallization can be dissipated.

- *Note//1- if any one of these factors fails, crystallization is slowed or even arrested.*
- *2- the overall rate of crystallization cannot exceed the rate of the slowest step in the system affecting the growth rate.*

Mechanisms of crystal growth

- There are three mechanisms of crystal growth on crystal surface of minerals, these are:
- **1- Continuous growth:** attachments take place all over the surface more-or-less at the same time.
- **2- Layer spreading growth:** a single growth layer forms by attachments along a one-molecule (or one unit cell) thickness step before start of another layer.
- **3- Spiral growth:** growth occurs from screw dislocations by attachments along the sloping steps of continuous spiral.

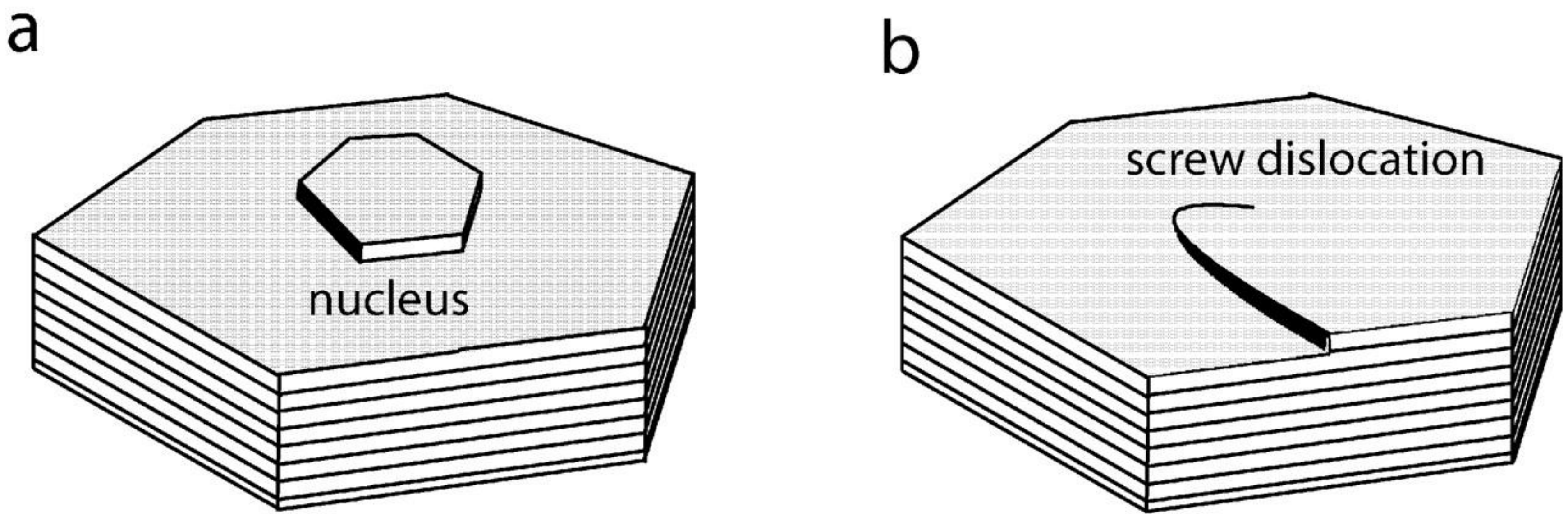


Photo from: claymin.geoscienceworld.org

Substrate Growth

- Substrate Growth is a growing of crystal suspended in fluid or from a site of nucleation on a preexisting solid.
  - The substrate may be a rock surface such as a faces of a fracture; the muddy floor f a water body basin; the roof, walls. And floor if a magma chamber; or simply a preexisting crystal that has an exposed surface.
  - The surface may be flat or curved.

Types of Substrate Growth

1. **Perpendicular substrate growth**: is characteristic of aplite-pegmatite dikes in which feldspars grow from an initial layer of granular aplite toward what becomes the medial plane of the dike.

- Feldspar crystals tend to enlarge laterally as they grow, resulting in a coarsening of grain size in the medial zone. The same phenomenon is common for quartz crystals that line geode surfaces.

mark-schneider-quartz-geode-opened

Examples

Chalcedony growth	Chalcedony growth

www.rocksforkids.com

Types of Substrate Growth

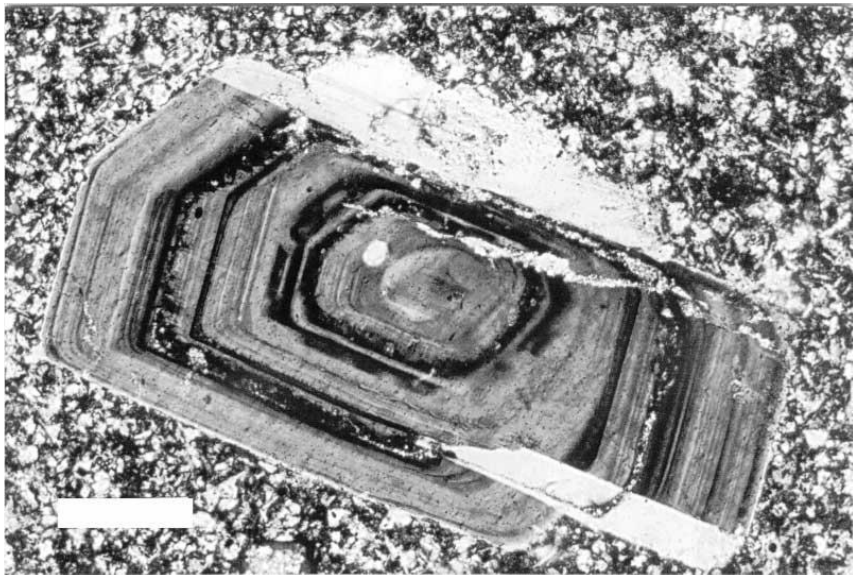
2. **Fibers substrate growth:** is characteristically without enlargement, such as those of satin spar gypsum.

satin spar (from: academic.emporia.edu)

Growth Zoning

- **Compositional zoning:** means that change in composition of the crystal occurs as it grows. This happen in the absence of thoroughgoing fluids, and resupply of new growth components.
- The changing composition is a reflection of lowering temperatures in the "closed" system.
- Ex: zoning of plagioclase from higher temperature, more calcic composition, to lower temperature, more sodic compositions at rims.

Oscillatory Zoning in a Plagioclase Mineral



Photomicrograph in polarized light. Banding corresponds to variations of concentration of sodium and calcium in the crystal. (http://theselforganizingplanet.com)

Recrystallization in Solids

- Recrystallization in solids is a mechanisms by which new crystals form from old crystalline and amorphous materials.
- In solid-state system, or parts of systems that elsewhere have an intergranular fluid film, three textural aspects of crystalline solids are pertinent:
- 1- parent crystal
- 2- subgrain
- 3- new grains (neoblasts)

Types of recysatllization

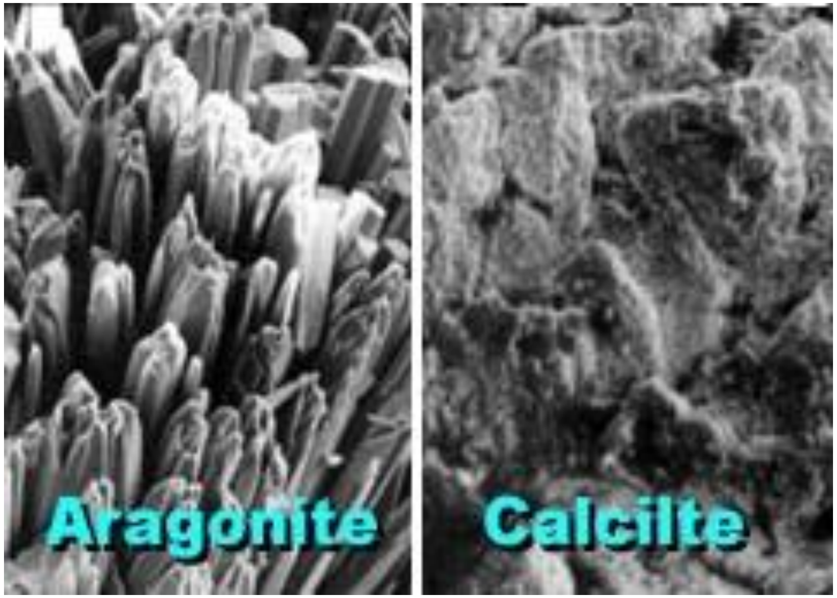
- Recrystallization: is a formation of new grains.
- Types of recrystallization:
  - there may be no change in mineral phase

(quartz crystals ⟶ new quartz crystals;
calcite ⟶ new calcite crystals).

  - there may be transformation or reaction generation new mineral phases (quartz ⟶ coesite; aragonite ⟶ calcite).

Recystallization

Recrystallization of aragonite to calcite	Recrystallization of quartz



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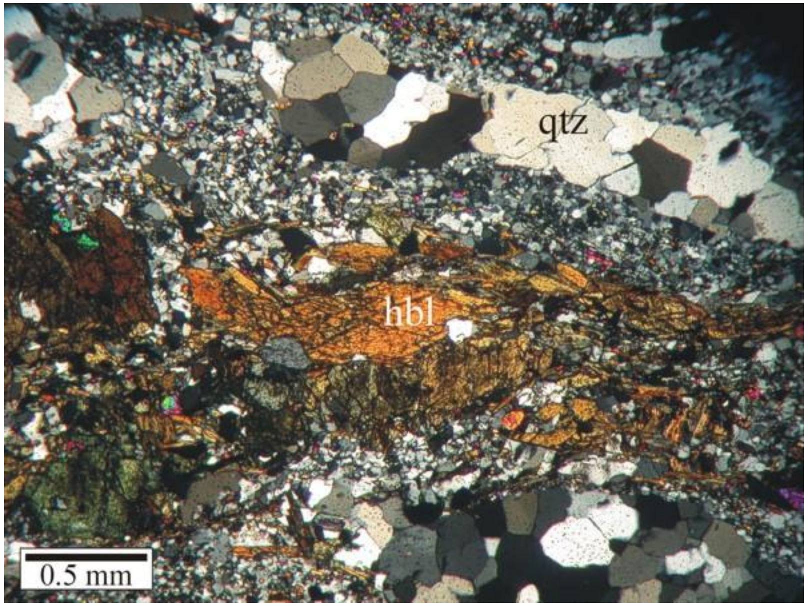

pubs.usgs.gov

- The driving force for recrystallization is either the lower energy configuration representes by:
- 1- relatively underformed crystals that have deformed from deformed crystals, *or* 2- grain-size enlargement in which the ration of crystal-surface energy to crystal volume is reduced.

- For a given mineral or mineral grain aggregate, there is a threshold temperature that sets the recrystallization process in motion.

- The recrystallization process may begin with an amorphous or poorly crystalline material and end with fully structurally lattices.
- Ex: protodolomite is a poorly structurally ordered carbonate mineral that is likely to recyrstallize to ordered and stable dolomite.

Crystal dissolution

- Crystal dissolve (solvate) into liquids or vaporize into gases because the conditions favoring growth are reversed.
- The crystal that is in the process of growing in liquid (noncarbonate-bearing) because of an appropriate level of supersaturating, will stop growing and perhaps start to dissolve if:
- 1- the solution is heated
- 2- the supersaturating is reduced or eliminated by dilution
- 3- there is adiabatic decrease in pressure, effectively lowering the liquids, leaving the crystal out of equilibrium with adjacent liquid.