Geology 284 - Mineralogy, Fall 2008
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Metamorphic Minerals

Metamorphism means Change

Rocks Change as Conditions Change

- When changes in conditions of Sedimentary Rocks are not too dramatic, we call changes in the rock **diagenesis** (up to about 200^{o}C)
- When new minerals, which are never observed to form at Earth's surface, form, we call the changes **metamorphism**

Metamorphism is: changes in a rock's mineralogy, texture or composition without melting (in the solid state)

Any kind of rock can become a Metamorphic Rock

- Meta-igneous rocks
- Originally igneous, have been changed
- Meta-sedimentary rocks
- Originally sedimentary, have been changed
- Poly-metamorphic rocks (meta-metamorphic rocks)
- Already metamorphic, changed again

What causes Metamorphism?

- Increase in temperature (T)
- T increases with depth in the Earth
- Increase in pressure (P)
- P increases with depth (from the load of overlying rock)
- Deformation (changes rock texture)
- Movement of fluids (like water vapor)

Two main types of Metamorphism

Contact Metamorphism

- Caused by heat from a nearby pluton
- Forms narrow "contact aureole"

Regional Metamorphism

- Over large regions
- Usually associated with mountain building

Metamorphic Minerals

The two most important factors controlling mineralogy of metamorphic rocks are the composition of the rock (ingredients available to make new minerals)

and the grade of metamorphism.

We account for rock composition by grouping rocks into general compositional classes

- Pelitic rocks clay-rich sediments, shales
- Psammites sandstones
- Mafic rocks basalts and gabbros
- Carbonates limestones
- Ultramafic mantle rocks, composed entirely of mafic minerals
- Granitic granites

We'll consider important minerals in each of these rock types separately

Psammites meta-sandstones

- start with Quartz and Feldspar
- metamorphic rock has Quartz and Feldspar
- coarser grain size
- rock may be foliated
- called Quartzite or Quartzofeldspathic Gneiss
- Not much change with metamorphism

Metamorphosed Granites

- Start with Quartz, Feldspar and Micas

- Metamorphic rock has Quartz, Feldspar, and Micas
- Rock may be foliated (gneissic layering)
- Metamorphic rocks called granitic gneiss
- Again not much change with metamorphism

Metamorphosed Shales, Pelitic Rocks

- Sedimentary protolith has Quartz silt and Clay minerals
- Clays contain K, Fe, Mg, Ca, and especially Al in addition to SiO_2
- These elements can make many new and interesting minerals
- Their mineralogy also changes dramatically with metamorphic grade or intensity

Some Minerals we already talked about occur in Pelitic Metamorphic Rocks

What silicate group does each belong to?

- Quartz
- Plagioclase
- K-feldspar
- Muscovite
- Biotite

What are the new and interesting minerals?

- Garnet $(Ca,Mg,Fe,Mn)_3Al_2Si_3O_{12}$
- Staurolite $Fe_2Al_9Si_4O_{23}(OH)$

- Andalusite Al_2SiO_5
- Sillimanite Al_2SiO_5
- Kyanite Al_2SiO_5
- Notice the essential Al, which comes from clays
- All of these minerals are isolated tetrahedral Silicates
- All are porphyroblastic (big, visible crystals!)

Garnet Structure

Garnet Properties

More Garnet Examples

Garnet Porphyroblasts in thin section

Staurolite

Twinned Prismatic Staurolite

Optical Properties of Staurolite

- High relief
- Low birefringence, max. 1st order yellow
- Clear, yellow or light brown color
- Pleochroic
- Commonly exhibits a sieve-like texture due to abundant quartz inclusions

Staurolite in a Thin Section

The Aluminosilicate Polymorphs, Al_2SiO_5

- Andalusite
- Sillimanite
- Kyanite

View Andalusite Movie

http://socrates.berkeley.edu/~eps2/wisc/geo360/andalusite.mov

The Al_2SiO_5 Phase Diagram - see handout

Kyanite Properties

- Blue, bladed crystals (can be clear or white)
- H=5 along blades, H=7 across blades
- SG = 3.60
- One perfect cleavage
- Luster vitreous, pearly

Kyanite Optical Properties

- Typically colorless in thin section, may be blue
- High relief, low birefringence, but higher birefringence than andalusite

- Monoclinic, inclined extinction
- Bladed shape and one perfect, one good cleavage characteristic

Kyanite in thin section

Andalusite Properties (Low pressure form of Al_2SiO_5)

- Luster vitreous
- Color pink or white
- H=7.5, SG=3.18
- Stubby, square prisms
- May show a crossed pattern of graphite inclusions, called Chiastolite
- Optically lower relief and lower birefringence than kyanite

Andalusite

The Al_2SiO_5 Phase Diagram - see handout

Sillimanite Properties (hi T polymorph)

- Acicular to thin prismatic
- Clear, colorless and vitreous
- May form mats of fine fibers, called fibrolite
- Optically, sillimanite has high relief, moderate birefringence, and parallel extinction
- Clear needles, thin prisms or fibers

Sillimanite in thin section

Sillimanite (Fibrolite)