Clicker
• The transformation of one rock into another by solid-state recrystallization is known as
  – a) Sedimentation
  – b) Metamorphism
  – c) Melting
  – d) Metasomatism
  – e) Hydrothermal alteration

Metamorphism
• Metamorphism is the solid-state transformation of pre-existing rock into texturally or mineralogically distinct new rock as the result of high temperature, high pressure, or both.

Metamorphism
• The mineralogy of a metamorphic rock changes with temperature and pressure.

  • In general, the highest temperature mineral assemblage is preserved.
  • It is possible to infer the highest P-T conditions from the mineralogy.

Diamond is Metamorphic
**Metamorphic Environments**

- Regional metamorphism involves the burial and metamorphism of entire regions (hundreds of km²)
- Contact metamorphism results from local heating adjacent to igneous intrusions. (several meters)

**Regional Metamorphism**

- Because the tectonic forces required to bury, metamorphose, and re-exhume entire regions are slow,
- most regionally metamorphosed terranes are old (> 500 MY), and
- most Precambrian (> 500 MY) terranes are metamorphosed.

**Regional Metamorphism**

- Regional metamorphism is typically isochemical (composition of rock does not change), although water may be lost.
- Metasomatism is a term for non-isochemical metamorphism.
- Contact metamorphism is typically metasomatic.
### Conditions of Metamorphism

- Changing the mineralogy of a sediment requires temperature > 300°C and pressures > 2000 atmospheres (~6 km deep).
- Temperature increases downward at ~20°C/km in crust.
- Pressure increases downward at ~1000 atm (1kbar) per 3 km (~330 bar/km).

### Effect of Increasing Temperature

- Increases the atomic vibrations
- Decreases the density (thermal expansion)
- Increases the speed of reactions

### Effect of Increasing Pressure

- Increases the density (compression)
- Pressure can be hydrostatic (equal in all directions), or
- Pressure can be directed as a shear which can cause
  - Foliation (alignment of platy minerals)
  - Lineation (alignment of needle-like minerals).

### Temperature and Pressure

- Continental temperatures increases by ~30°C / km (90°C = 3 km).
- Pressure increases by 330 atm / km (1kbar = 3km).
**Metamorphosed Sediments**

- Conglomerate  Metaconglomerate
- Sandstone    Quartzite
- Shale        Phyllite / Slate
- Shale        Schist
- Shale        Gneiss
- Limestone    Marble
- Gypsum       (Anhydrite)

**Schist: Metamorphosed Shale**

**Blueschist**

**Marble & Blueschist:**

Metamorphosed Shale + Limestone

**Marble**

**Metamorphosed Igneous Rock**

- Granite       Gneiss
- Diorite       Gneiss
- Basalt/Gabbro Eclogite
- All are high-grade
- Partial melting Migmatite
Garnet in Schist

Gneiss

Migmatite (Partial Melting)

Migmatite (Partial Melting)

Inner Gorge, Grand Canyon

Garnet Amphibolite Gneiss
Garnet Amphibolite Gneiss

Garnet Chlorite Schist

Blueschist
Aosta Valley, Italy

Diamond in Eclogite

Black Canyon of the Gunnison

Metamorphism Terms
- Regional Metamorphism
- Contact Metamorphism
- Isochemical
- Metasomatism
- Hydrostatic
- Foliation
- Lineation
- Terrane
- Quartzite
- Phyllite
- Slate
- Schist
- Gneiss
- Marble
- Eclogite
- Granulite
- Migmatite
Clicker Question
• Which is a term for metamorphism that involves significant chemical change?
  – A. Regional metamorphism
  – B. Contact metamorphism
  – C. Metasomatism
  – D. Diapirism
  – E. Lithification

Clicker Question
• Which is a term for metamorphism that involves significant chemical change?
  – A. Regional metamorphism
  – B. Contact metamorphism
  – C. Metasomatism
  – D. Diapirism
  – E. Lithification

Clicker Question
• The high grade metamorphic equivalent of limestone is?
  – A. Eclogite
  – B. Quartzite
  – C. Marble
  – D. Slate
  – E. Gneiss

Clicker Question
• The high grade metamorphic equivalent of limestone is?
  – A. Eclogite
  – B. Quartzite
  – C. Marble
  – D. Slate
  – E. Gneiss

Clicker Question
• A shale caught in a subduction zone and carried to high pressures at low temperatures would be a?
  – A. Blueschist
  – B. Quartzite
  – C. Marble
  – D. Slate
  – E. Anhydrite

Clicker Question
• A shale caught in a subduction zone and carried to high pressures at low temperatures would be a?
  – A. Blueschist
  – B. Quartzite
  – C. Marble
  – D. Slate
  – E. Anhydrite