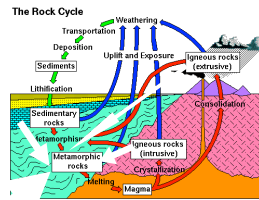

ANY QUESTIONS?

1



METAMORPHIC ROCKS

2



3

METAMORPHIC ROCKS

- ☛ Rocks that have been subjected to either enough heat or pressure to cause the minerals in that rock to undergo solid state chemical changes.
- ☛ Metamorphic rocks never melt - if they did they would become igneous magma. This is why we say that the changes are solid state.

4



Metamorphic Rocks are usually highly deformed because they have been subjected to high temperature and pressure!

5

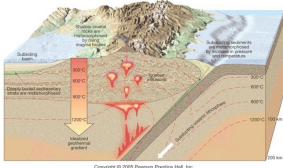
AGENTS OF METAMORPHISM

- Heat
- Pressure
- Chemical activity



6

HEAT



Heat is the most important agent of metamorphism. Normally a geothermal gradient increases in temperature with depth at about 30°C per kilometer. The gradient is much higher in some areas, for example at the edges of continents where one oceanic plate dives under another or where plutons have become embedded in the crust.

The first minerals that begin to change are clays, then others that are more stable begin to change as the temperature increases. It usually takes burial to 20KM or more for feldspars to begin to metamorphose.

7

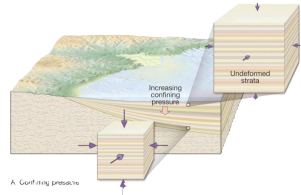
Pressure

Pressure increases with depth (as does heat) so that there is 1,000kg/cm² at 4 km depth. In general, shallow rocks will shear while deeper rocks will deform like plastic. Increased pressure may cause minerals to melt or may cause atoms to move into configurations that represent tighter packing. May cause rocks to develop shear planes.

- Confining (lithostatic) Pressure
- Differential Pressure (stress)
- Shear Stress

8

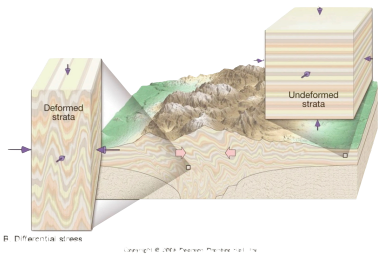
CONFINING (LITHOSTATIC) PRESSURE



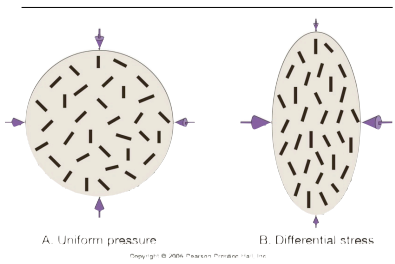
Equal pressure in all directions tends to cause objects to uniformly become smaller.

9

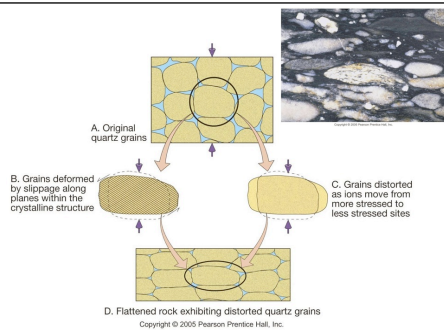
DIFFERENTIAL PRESSURE



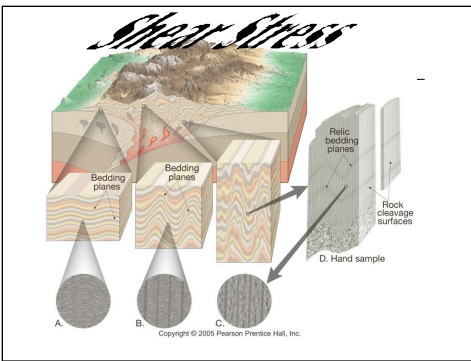
10



11



12



13

CHEMICAL ACTIVITY

As rocks are buried, water becomes heated and ions go into solution.

Without hot solutions even the great heat and pressure would not make some of the chemical reactions occur, these hot solutions greatly speed up the chemical reactions.

These hot solutions do much in the changing of minerals into unique metamorphic minerals. They are called hydrothermal solutions.

You have seen garnet in mineral lab, this is a mineral that forms only during metamorphism.



14

As rocks are subjected to great heat and pressure they begin to undergo several changes:

1. Changes in the minerals - The bulk chemistry may be the same but the minerals change with increasing degrees of metamorphism.
2. Folding and bending - As heat and pressure increase the rocks may be folded into a series of small scale folds as they begin to act like they are made out of silly putty or clay.

Important to remember that during metamorphism the rock stays solid, once it melts it is magma and therefore no longer a metamorphic rock.

All these chemical and structural changes occur in solid rock!

Metamorphism occurs under the surface at higher temperatures and pressures than exist at the surface.

15

DEGREE OF METAMORPHISM

☞ Texture

☞ Mineralogy

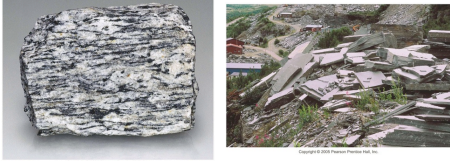
As metamorphism proceeds there is growth of new crystals, therefore many metamorphic rocks have visible crystals like coarse-grained igneous rocks.

The texture and mineralogy of a metamorphic rock are a key to how much it has been metamorphosed.

16

TEXTURE

If the minerals have a sheet-like structure, like the micas, then they will be squished flat into a particular orientation. This gives the rock a layered or banded appearance called foliation.



17

FOLIATED METAMORPHIC ROCKS

18

FOLIATION

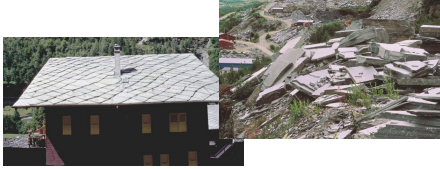
- Rock cleavage - when clays re-crystallize at fairly low degrees of metamorphism they form minute muscovite flakes which are aligned in the rock. The rock they are in can be easily split along the direction of alignment. SLATE exhibits good rock cleavage.
- Schistosity - as metamorphism increases the tiny mica flakes will grow into larger crystals about a cm in diameter. This gives the rock a 'scaly' or 'platy' appearance called schistosity. A rock with this texture is called a SCHIST. Schists usually represent rocks that were either rich in clay or also mafic igneous rocks.
- Gneissic - at higher metamorphism, ions will migrate and cause minerals to segregate. The result is a rock with alternate light and dark banding where light and dark minerals separate. Such a rock is called a GNEISS. Gneisses come from the metamorphism of GRANITE, DIORITE, GABBRO, SHALE or DIRTY SANDSTONES.

19

Rock Name	Texture	Grain Size	Comments	Parent Rock
Slate	Very fine	Very fine	Excellent rock cleavage, smooth dull surfaces	Shale, mudstone, or siltstone
Phyllite	Fine	Fine	Breaks along wavy surfaces, glossy sheen	Slate
Schist	Medium to Coarse	Medium to Coarse	Micaceous minerals dominate, scaly foliation	Phyllite
Gneiss	Medium to Coarse	Medium to Coarse	Compositional banding due to segregation of minerals	Schist, granite, or volcanic rocks

20

SLATE



Slate
I M F C
Very fine
Excellent rock cleavage, smooth dull surfaces
Shale, mudstone, or siltstone

21

PHYLLITE



Phyllite
C O T A B I A
Y
Fine
Breaks along wavy surfaces, glossy sheen
Slate

22

SCHIST



Schist
e a s i p
m o l e d
Medium to Coarse
Micaeous minerals dominate, scaly foliation
Phyllite

23


Gneiss



Gneiss
n i s
g i s
Medium to Coarse
Compositional banding due to segregation of minerals
Schist, granite, or volcanic rocks

24

NON-FOLIATED METAMORPHIC ROCKS

Marble	NON-FOLIATED		Medium to coarse	Interlocking calcite or dolomite grains	Limestone, dolostone
Quartzite			Medium to coarse	Fused quartz grains, massive, very hard	Quartz sandstone

25

MARBLE



Metamorphosed limestone or dolomite becomes marble.



26

QUARTZITE



Metamorphosed sandstone becomes Quartzite.



27

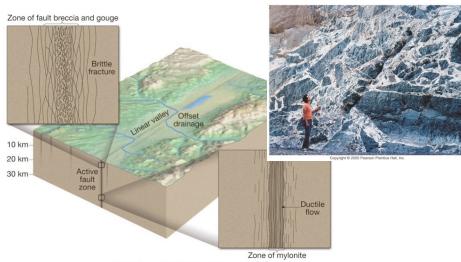
TYPES OF METAMORPHISM

28

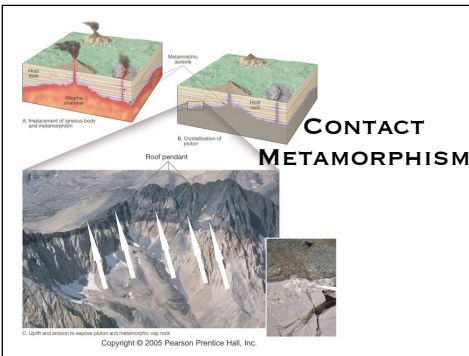
- 📍 **Fault Zone** - At surface rocks broken into fragmental fault breccias. At depth minor metamorphism, but only right along fault. Insignificant compared to other types.
- 📍 **Contact** - If rock is in contact or close to magma then the heat bakes the nearby rock just around the magma.
- 📍 **Regional**- large scale metamorphism that occurs during mountain building. Vast amounts of rock are subjected to high stresses and temperatures and may result in thousands of square miles of metamorphic rock.

29

FAULT ZONE METAMORPHISM



30



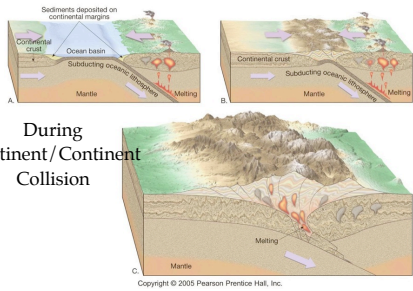
31

CONTACT METAMORPHISM



32

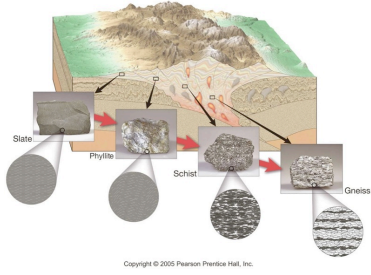
REGIONAL METAMORPHISM



During
Continent/Continent
Collision

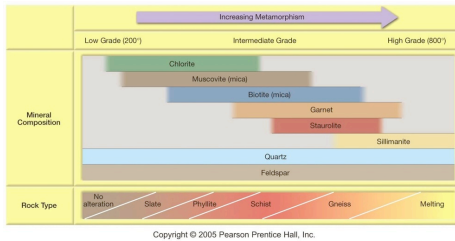
33

REGIONAL METAMORPHISM: METAMORPHIC ZONES



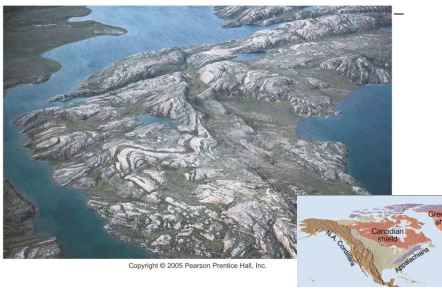
34

Metamorphic Zones



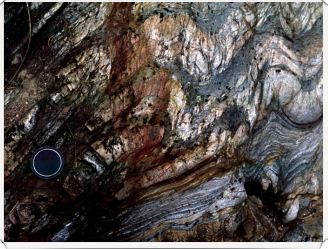
35

CANADIAN SHIELD



36

TAOS, NEW MEXICO



Folds in Schist

37

TAOS, NEW MEXICO



Folds in Schist

38

**MONDAY
EXAM #1**

39