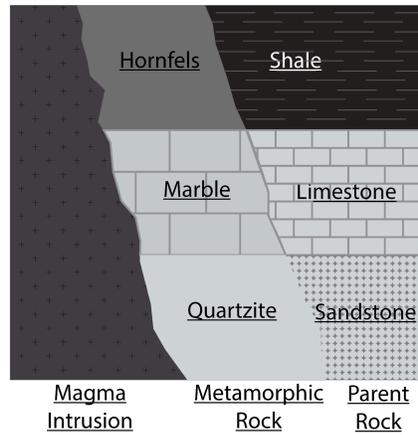


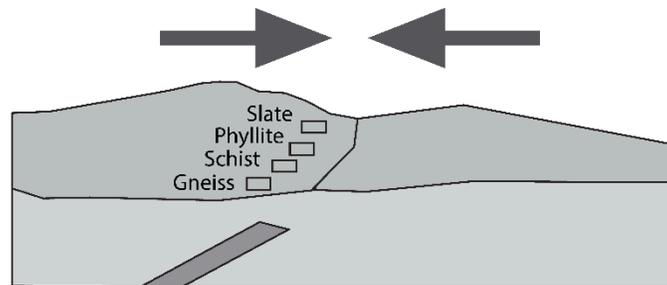
## First some review of Metamorphism Types and P-T paths:

### Contact Metamorphism



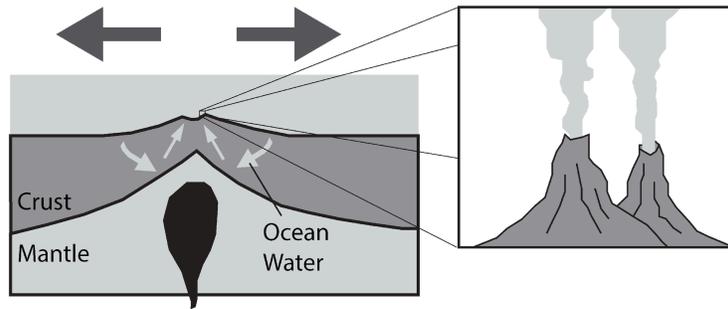
Contact metamorphism is associated with high temperatures around magmatic intrusions. Rocks in the metamorphic aureole (immediate surroundings) typically have grains welded together, and will also see an increase in grain size.

### Regional Metamorphism



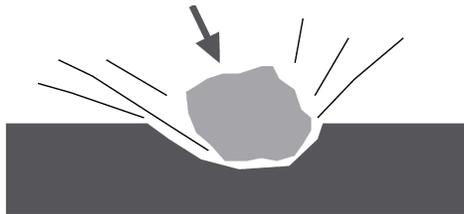
Rocks metamorphosed in mountain building environments (orogens) will have an increasing metamorphic grade according to depth of metamorphism. Slate rocks have foliation. Phyllites show a characteristic sheen from microscopic mica minerals. A schist is identified by having visible (to unaided eye) mica grains. Gneiss has characteristic banding of mafic mineral- and felsic mineral-rich layers.

## Hydrothermal Metamorphism



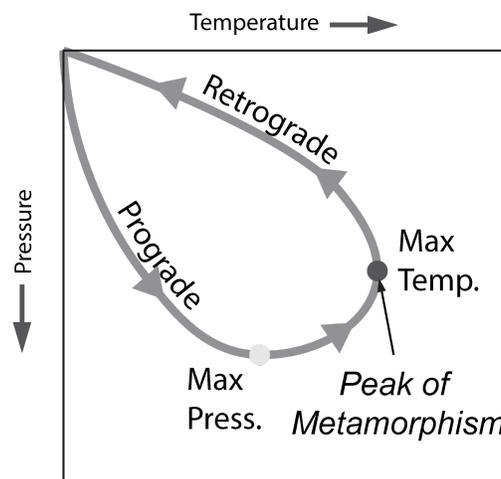
Ocean water circulated into the crust at mid-ocean ridge spreading centers will hydrate some minerals. Evidence for circulation of water is observed where the water vents back into the ocean.

## Shock Metamorphism



Although relatively uncommon, meteor impacts do occur on Earth. The intense pressure forms unique minerals, and alters the crystal structure of others. Some local melting occurs, and that material may be ejected from the impact site.

## P-T time paths



Rocks undergoing metamorphism will follow some sort of Pressure-Temperature (PT) time (or P-T-t) path. Increasing temperature during prograde causes changes in the rock. We often see the *peak of*

*metamorphism* (maximum temperature) recorded in the mineral assemblage of rocks. Most water has been driven off, and system is losing energy (heat loss), so not many reactions occur during retrograde.

## Now, test your knowledge:

Briefly define the following terms:

**metamorphic grade –**

**prograde -**

**retrograde -**

**foliated -**

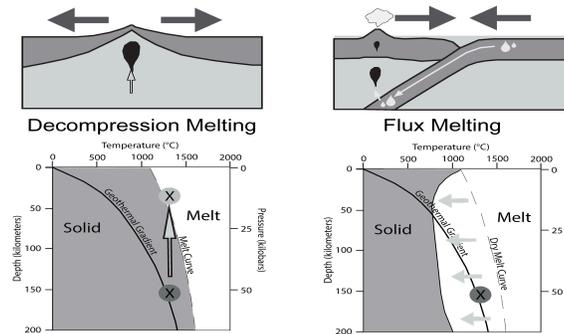
**non-foliated -**

Answer the following:

1. Match the parent rock type with the equivalent contact metamorphosed rock:
  - A. Limestone
  - B. Sandstone
  - C. Shale
  - D. Granite
  - E. Basalt
  - i. Marble: \_\_\_\_\_
  - ii. Hornfels: \_\_\_\_\_
  - iii. Quartzite: \_\_\_\_\_
2. In question 1, “Marble” is the:
  - A. Parent Rock
  - B. Metamorphosed Rock
3. True/False. During metamorphism, grain size tends to increase in rocks.
  - A. True
  - B. False
4. Which of the following tectonic settings would you expect regional metamorphism?
  - A. Mid-ocean ridge spreading center
  - B. Transform fault

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Metamorphism Types

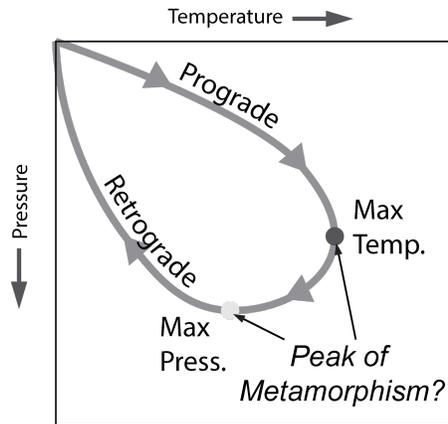
- C. Rift basin
  - D. Continent-Continent convergent zone
5. True/False. The rocks formed in regional metamorphism are foliated.
- A. True
  - B. False
6. Which of the following gives the correct order of increasing metamorphic grade?
- A. Schist, Phyllite, Gneiss, Schist
  - B. Slate, Phyllite, Gneiss, Schist
  - C. Slate, Phyllite, Schist, Gneiss
  - D. Phyllite, Schist, Gneiss, Slate
  - E. Gneiss, Schist, Slate, Phyllite
7. Which of the following minerals likely formed in a hydrothermal metamorphic setting at a mid-ocean ridge? (hint: circulating ocean water (H<sub>2</sub>O) was involved)
- A. Chlorite (Mg<sub>5</sub>Al)(AlSi<sub>3</sub>)O<sub>10</sub>(OH)<sub>8</sub>
  - B. Quartz SiO<sub>2</sub>
  - C. Pyroxene MgSiO<sub>3</sub>
  - D. Olivine (Mg,Fe)<sub>2</sub>SiO<sub>4</sub>



During hydrothermal metamorphism at mid-ocean ridges, the newly created ocean crust becomes hydrated, as new minerals form that contain water in their crystal structure. When ocean crust is subducted, those minerals become unstable at depth. They give off their water and become new phases.

8. Which of the following minerals likely formed in a subducting ocean crust slab, when pressures forced water out of the rocks?
- A. Pyroxene MgSiO<sub>3</sub>
  - B. Chlorite (Mg<sub>5</sub>Al)(AlSi<sub>3</sub>)O<sub>10</sub>(OH)<sub>8</sub>
  - C. Serpentine (Mg, Fe)<sub>3</sub>Si<sub>2</sub>O<sub>5</sub>(OH)<sub>4</sub>

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Metamorphism Types



9. In the above P-T time path figure, the prograde and retrograde paths travel in a clockwise direction (note pressure increases downward in the diagram). Which condition is considered to be the *peak of metamorphism*?
- A. Maximum Temperature
  - B. Maximum Pressure
  - C. Prograde
  - D. Retrograde

## Now, think deeper:

On your own:

10. List some specific places on Earth today where metamorphism is occurring.

11. What type of metamorphism is occurring at each one of the locations you listed above?

### Working in groups of 2 or 3

12. Take turns sharing your answers to questions 10 and 11. Discuss any different interpretations you might have with your partner's locations. Also, write down any changes your partner would make to your interpretations.