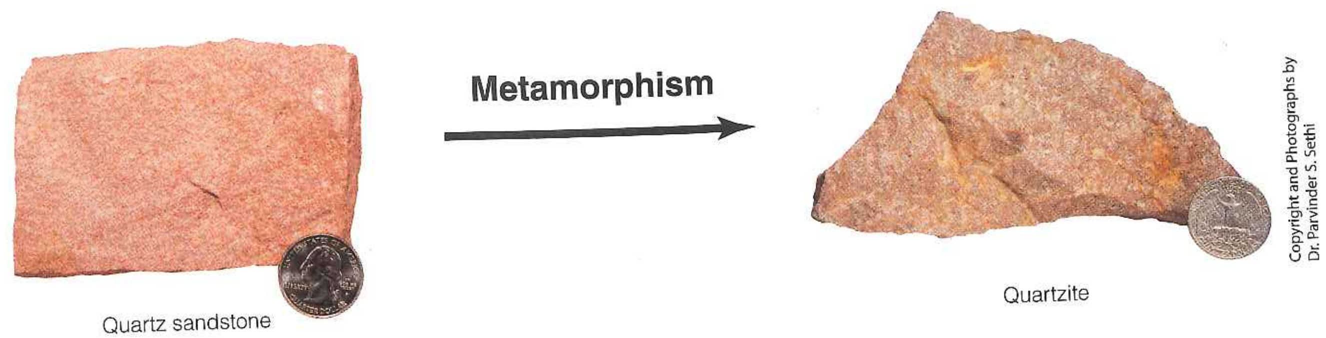

Figure 7.16 Quartzite
Metamorphism of the sedimentary rock quartz sandstone yields quartzite.

metamorphic zone The region between lines of equal metamorphic intensity known as isograds.

metamorphic facies A group of metamorphic rocks characterized by particular minerals that formed under the same broad temperature and pressure conditions.

or an *isograd*. The region between two adjacent isograds makes up a single **metamorphic zone**—a belt of rocks displaying the same general degree of metamorphism. By mapping adjoining metamorphic zones, geologists can reconstruct metamorphic conditions throughout an entire area (Figure 7.17).

Not long after Barrow and his coworkers completed their work, geologists in Norway and Finland came up with a different method of mapping metamorphism that was more useful than the metamorphic zone approach. A **metamorphic facies** is defined as a group of metamorphic rocks characterized by particular mineral assemblages formed under broadly similar temperature and pressure conditions (Figure 7.18). Each facies is named after its most characteristic rock or mineral. For example, the green metamorphic mineral chlorite, which forms under relatively low temperatures and pressures, yields rocks belonging to the *greenschist facies*. Under increasingly higher temperatures and pressures, mineral assemblages indicative of the *amphibolite* and *granulite facies* develop.

Although usually applied to areas where the original rocks were clay-rich, the concept of metamorphic facies can be used with modification in other situations. It cannot, however, be used in areas where the original rocks were pure quartz sandstones or pure limestones or dolostones. Such rocks, regardless of the imposed temperature and pressure conditions, will yield only quartzites and marbles, respectively. In such cases, all one can say is that "metamorphism happened."

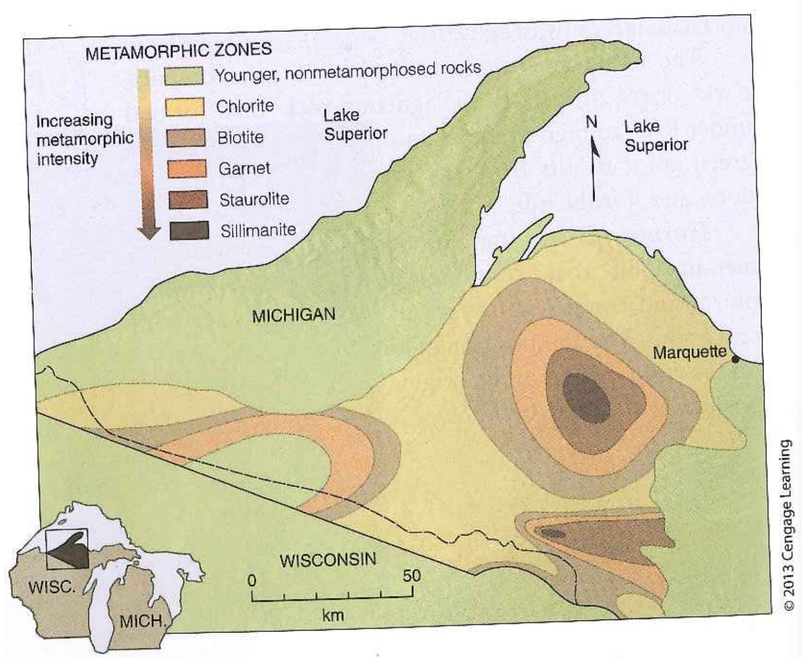

Figure 7.17 Metamorphic Zones in the Upper Peninsula of Michigan
The zones in this region are based on the presence of distinctive silicate mineral assemblages resulting from the metamorphism of sedimentary rocks during an interval of mountain building and minor granitic intrusion that occurred during the Proterozoic Eon, approximately 1.5 billion years ago. The lines separating the different metamorphic zones are isograds.

LO5 PLATE TECTONICS AND METAMORPHISM

Although metamorphism is associated with all three types of plate boundaries, it is most common along convergent plate margins. Metamorphic rocks form at convergent plate boundaries because temperature and pressure increase there as a result of plate collisions.

Figure 7.19 illustrates the various metamorphic facies produced along a typical oceanic–continental convergent plate boundary. When an oceanic plate collides with a continental plate, tremendous pressure is generated as the oceanic plate is subducted. Because rock is a poor heat conductor, the cold descending oceanic plate heats slowly, and metamorphism is caused mostly by increasing pressure with depth. Metamorphism in such an environment produces rocks typical of the blueschist facies (low temperature, high pressure). Geologists use the presence of blueschist facies rocks as evidence of ancient subduction zones.

As subduction along the oceanic–continental convergent plate boundary continues, both temperature and pressure increase with depth and yield high-grade metamorphic rocks.

Eventually, the descending plate begins to melt and generate magma that moves upward. This rising magma may alter the surrounding rock by contact metamorphism, producing migmatites in the deeper portions of the crust and hornfels at shallower depths. High temperatures and low to medium pressures characterize such an environment.

Although metamorphism is most common along convergent plate margins, many divergent plate boundaries are characterized by contact metamorphism. Rising magma at mid-oceanic ridges heats the adjacent

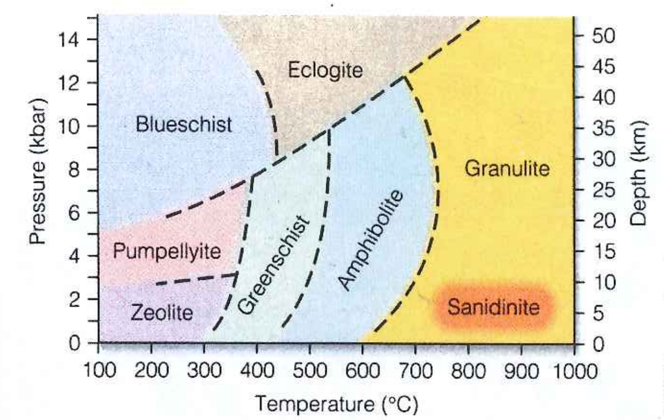

Figure 7.18 Metamorphic Facies and Their Associated Temperature–Pressure Conditions.
A temperature–pressure diagram showing under what conditions various metamorphic facies occur. A metamorphic facies is characterized by a particular mineral assemblage that formed under the same broad temperature–pressure conditions. Each facies is named after its most characteristic rock or mineral.

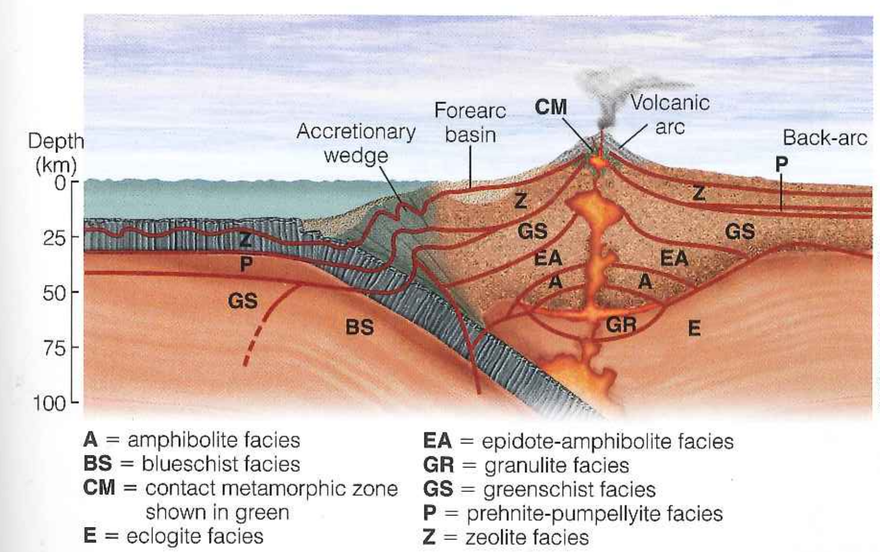

Figure 7.19 Relationship of Facies to Major Tectonic Features at an Oceanic–Continental Convergent Plate Boundary

Remember that metamorphic zones are identified by the appearance of a single index mineral within rocks of the same general composition that occur throughout an area. However, rocks of greatly different composition within an area can belong to the same metamorphic facies, because each facies has its own characteristic assemblage of minerals whose presence indicates metamorphism with the same broad temperature–pressure range unique to that facies.