September 27, 2021

News and notes

Before going on to a discussion of metamorphic rocks, here are a few news items I found interesting:

Volcanoes

- Volcanic eruptions continue at many places in the world, including La Palma, Canary Islands, Spain, Suwanose-jima volcano, Japan, and Popocatepetl, Mexico.

- Interesting recently published research on magma differentiation in volcanoes: Volcanic plumbing filters on ocean-island basalt geochemistry. A more accessible discussion of this research is shown here.

- Also on volcanoes, opportunities for copper mining: What are dormant volcanoes good for? Copper mining.

Earthquakes

- Notable earthquakes this past week: Magnitude 5.9 earthquake in Melbourne, Australia September 22; Magnitude 6.5 Earthquake Off the Coast of Nicaragua, also on September 22; Magnitude 5.7 Earthquake in the Philippines on September 26; and a Magnitude 6.0 Earthquake Beneath Crete, on September 27.

- An interesting discussion on earthquake prediction in Phys.org, here.

- Earthquakes resulting from oil & gas extraction are a business concern, from Forbes Magazine: Not Again! Are Earthquakes In Delaware Basin Headed For An Oklahoma-Like Disaster?.

Energy

- The U.S. exported slightly more petroleum than it imported in the first half of 2021. Most, if not all, the increase in American petroleum production over the past few years has come from the use of formation fracturing technology, so called "fracking". The trade-offs come in environmental impacts, including earthquakes. Also, if interest rates go up, oil & gas extraction by formation fracturing may not be financially viable.

- Daily energy news from the U.S. Energy Information Administration is found here

September 27, 2021

Metamorphic Rocks - Part 1

Figure 1 - Metamorphic Rock, Georgian Bay ON
Credit: P199, Creative Commons Attribution-Share Alike 4.0 International license

Now that we are finished looking at sedimentary environments and rocks, let's go on to examine metamorphic rocks. First, we'll look at the rock cycle and the environments that create metamorphic rocks, then, we'll introduce the concept of metamorphic facies.

The Rock Cycle

Like many things in nature, the creation, destruction and re-creation of rocks follows a definite cycle often the called the Rock Cycle, as illustrated in Figure 2.

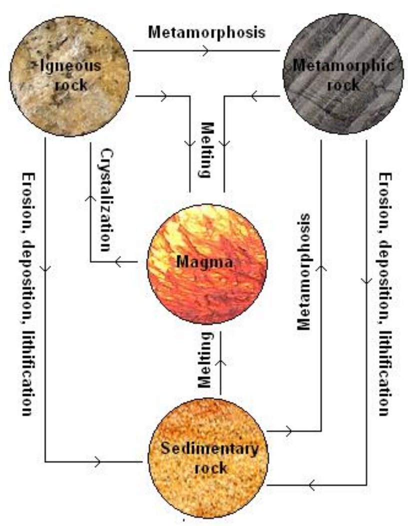

Figure 2 - Rock Cycle
Credit: Actualist, Creative Commons Attribution-Share Alike 3.0 Unported license

So, how does the Rock Cycle work?

We begin with molten magma, which is extruded onto or near the Earth's surface, and which then crystallizes into igneous rocks (see my previous posts on igneous rocks, June 14, June 21, June 28 and July 5). The next step is weathering and erosion (discussed in my posting of May 17, 2021) followed by deposition of the eroded material in various sedimentary environments (see my previous posts on July 12, July 19, July 26, August 2, August 9, August 16, August 23, September 13 and September 20.)

After deposition, there is burial. Both sedimentary rocks and un-eroded igneous rock can become buried deeper and deeper. As, the pressures and temperatures increase, minerals alter and metamorphic rocks are formed. Erosion can expose these new metamorphic rocks, and they can be eroded. Alternatively, if the burial is deep enough, the rock will be melted into magma again.

Metamorphic Environments

A number of environments can lead to the formation of rock. Here are the main metamorphic environments:

Burial Metamorphism

Burial metamorphism occurs when sediments are buried just deep enough to cause minerals to begin to recrystallize under heat and pressure. Consequently, new minerals will grow, but the overall appearance of the rock may not change. Burial metamorphism takes place at temperatures below~300 °C and pressures associated with hundreds of metres of depth.

Regional Metamorphism

Regional metamorphism refers to the large-scale metamorphism that happens during the collision of tectonic plates. These are massive events where the rocks are folded, broken, and stacked on each other. The forces involved include the squeezing force from the tectonic plate collision and from the weight of stacked rocks. The deeper the rocks are buried, the higher the pressures and temperatures.

Examples of areas with regional metamorphism include the mountains along the western coast of North America, the Himalaya mountains of Asia, and the Appalachian/Caledonian complex formed by the closure of the Iapetus Ocean during the Paleozoic Era. Figure 3 illustrates the mechanism of regional metamorphism.

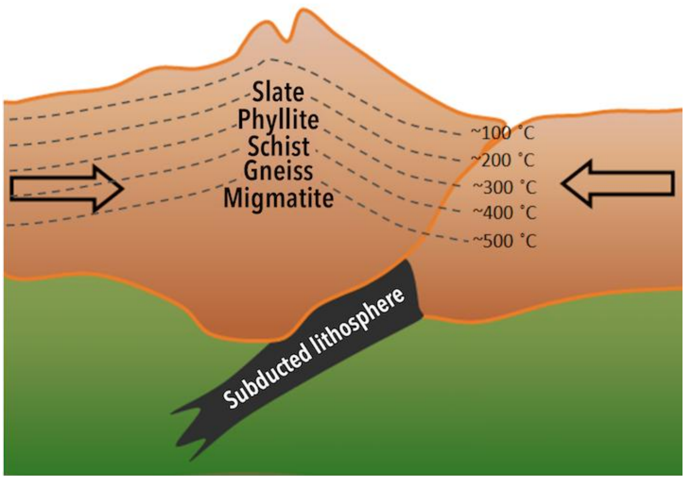

Figure 3 - Regional Metamorphism
Credit: Karla Panchuk

Seafloor (Hydrothermal) Metamorphism

Seafloor (hydrothermal) metamorphism occurs at zones of seafloor spreading where recently formed rocks are slowing moving away from the plate boundary, as in Figure 4.

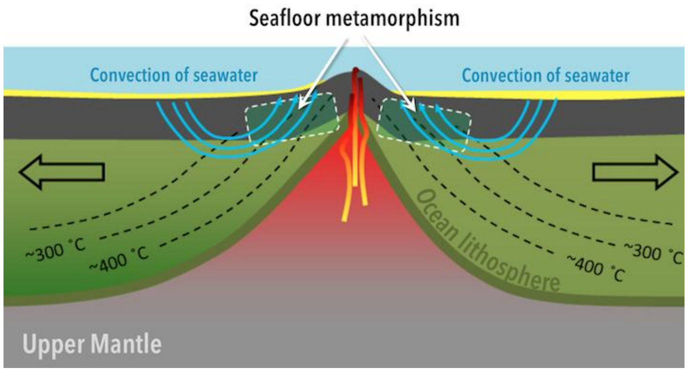

Figure 4 - Seafloor (Hydrothermal) Metamorphism
Credit: Karla Panchuk

Seafloor (hydrothermal) metamorphism happens at relatively low temperatures and pressures. Groundwater flowing through the basalts and gabbros modify the olivine and pyroxene minerals in the rock to form chlorite and serpentine. The result are greenstone, a non-foliated metamorphic rock.

Subduction Zone Metamorphism

Where tectonic plates converge and one plate is forced under another, subduction zone metamorphism occurs. Figure 5 shows the mechanism.

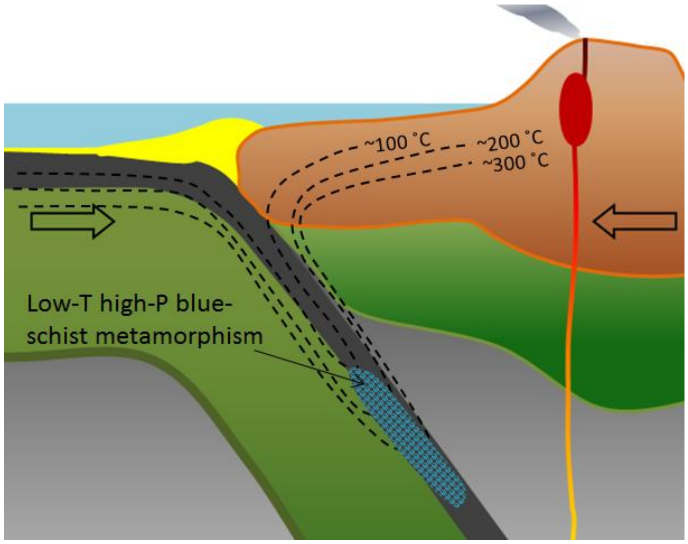

Figure 5 - Subduction Zone
Credit: Steven Earle

This kind of metamorphism occurs at relatively low pressures and high pressures. The high pressures are the result of the collision between the tectonic plates. The relatively low temperatures are the result of the slow heating of the subducted plate as it is buried. Under these conditions, glaucophane, the diagnostic mineral of blueschist rocks, is formed.

Contact Metamorphism

Contact Metamorphism occurs where magma comes in contact with colder rock. Figure 6 illustrates the process.

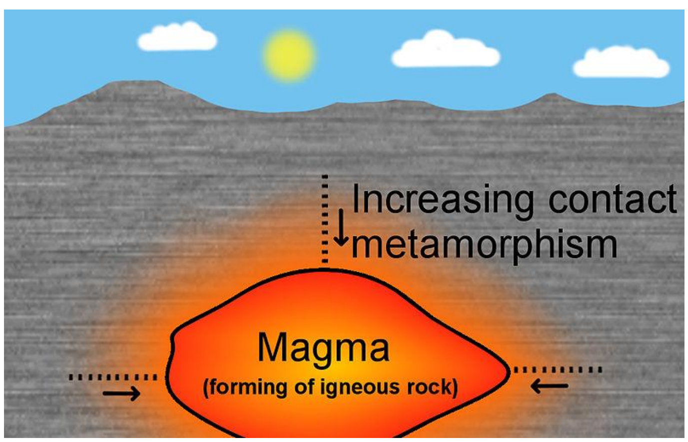

Figure 6 - Contact Metamorphism
Credit: Jasmin Ros, Creative Commons Attribution-Share Alike 3.0 Unported license

Contact metamorphism is common around volcanoes and volcanic zones.

Shock Metamorphism

Shock Metamorphism is associated with the impact of an extraterrestrial object, such as a meteor or asteroid. Features that are diagnostic of shock metamorphism are shocked quartz, and shatter cones; Figures 7 and 8 show examples of these features.

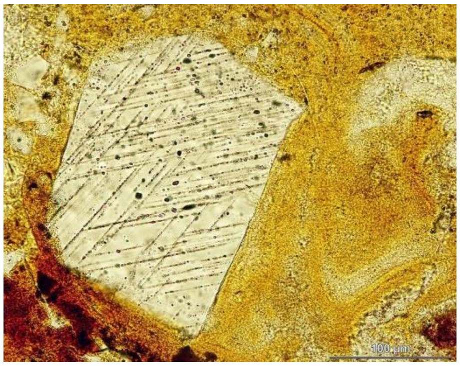

Figure 7 - Shocked Quartz
Credit: Martin Schmieder, Creative Commons Attribution-Share Alike 3.0 Unported license

Figure 8 - Shatter Cone Structure
Credit: Johannes Baier, Creative Commons, Attribution-Share Alike 4.0 International license

Dynamic Metamorphism

Dynamic metamorphism occurs within fault zones as the result of the high shear stress of the faulting. A diagnostic feature of dynamic metamorphism is fault breccia, as in Figure 9. Dynamic metamorphism occurs at relatively low temperatures, but very high pressures. As well, it tends to be confined to narrow zone within the fault and the neighbouring rocks are generally unaffected. Where faults occur within a zone already under high temperatures and pressures, the minerals will alter and deform, creating a mylonite, as in Figure 10.

Figure 9 - Fault Breccia
Credit: James St. John, Creative Commons Attribution 2.0 Generic license

Figure 10 - Mylonite
Credit: Toolguy8, Creative Commons Attribution-Share Alike 4.0 International license

Metamorphic Facies

The different temperature and pressure regimes under which metamorphic rocks are formed are called metamorphic facies. The kinds of minerals and structures that define each metamorphic facies will be determined by the temperature and pressure under which those minerals form. In future postings, we'll look at the kinds of rocks found within these different facies. Figure 11 illustrates metamorphic facies with the accompanying temperatures, pressures and likely depth below surface.

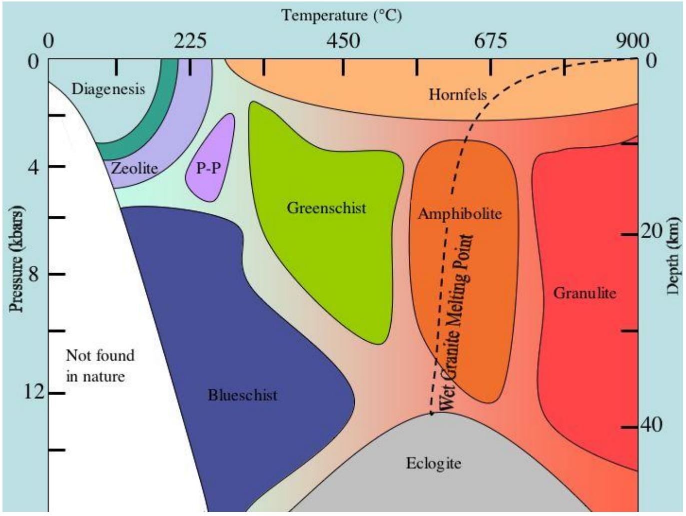

Figure 11 - Metamorphic Facies
Credit: David Magrass, public domain

Standard Caveat

The purpose of my weblog postings is to spark people's curiosity in geology. Don't entirely believe me until you've done your own research and checked the evidence. If I have sparked your curiosity in the subject of this posting, follow up with some of the links provided here. If you want to, go out into the field and examine some rocks on your own with the help of a good field guide. Follow the evidence and make up your own mind.

In science, the only authority is the evidence.