Geology Field Trip to the Phoenix Mountains (Squaw Peak area)

Introduction

The Phoenix Mountains, including Squaw Peak, contain a wonderful assortment of different metamorphic rock types. These rocks were originally deposited at about 1.7 billion years ago as sediments, volcanic flows, pyroclastic deposits, and some igneous intrusions emplaced at shallow levels (beneath the surface, but not very deep). Because the region was on the edge of a continent, these rocks became buried, very strongly deformed (mostly squeezed from the side), and metamorphosed (subjected to high temperatures and pressures at depths of ~10 km). This deformation caused the layers to fold, tilt, and commonly be nearly on end. Deformation, in conjunction with the metamorphism, caused minerals to align themselves into new planes and layers that cut through the old layers, forming a **cleavage** or **foliation** (cleavage is more like discrete fracturelike surfaces, whereas foliation is defined by planes of newly grown minerals).

This area, therefore, represents an excellent opportunity to observe metamorphic rocks derived from various pre-existing rock types. Aspects to observe include the type of layering and its orientation, the kinds of minerals, and small-scale features like folds and deformed objects, like pebbles. Once you have observed and described the metamorphic rock that you see, you can try to interpret what kind of rock it was before metamorphism (this interpreted pre-existing rock is called the "protolith"; the protolith of a quartzite is usually a sandstone). The rock we observe today reflects the protolith, how strongly the rock was deformed, and the metamorphic conditions (temperature and pressure).

Interpreting the Protolith

To interpret the protolith of a metamorphic rock we observe in the field, we need to note the following key aspects:

Homogeneity: Is the rock homogeneous (all the same) or does it instead show layering or other variations in the abundance of different minerals (mostly mica in some layers and quartz in others). If a metamorphic rock is homogeneous over tens of meters, it means that the protolith was also that way, which in turns generally implies an igneous protolith (sediments usually show layering).

Grain Size: For metamorphism at relatively low temperatures (less than 400°C), the grain size of the metamorphic rock largely reflects the grain size of the protolith. Mudrocks, like shales, turn into fine-grained slates, whereas coarse-grained igneous rocks may retain many of their large crystals. Deformation can reduce the grain size and cause grains to be smeared out into lenses or to be fractured. In contrast, metamorphism at higher temperatures can cause metamorphic minerals to grow, and such minerals may have crystal-like shapes, especially if the minerals grew after deformation

Grain Distribution: If you can see individual sand-size or larger grains/crystals, are the grains concentrated in layers or are they scattered randomly throughout the rock. Again, sedimentary processes tend to sort grains into layers (except in debris flows), whereas igneous rocks tend to have their crystals (like phenocrysts) be more randomly oriented.

Minerals: The minerals that can form during metamorphism depend on what minerals the rock started with (you can't make a rock with lots of dark metamorphic minerals if the protolith only contained quartz). So a metamorphic rock composed of mostly quartz probably started out as a quartz-rich sandstone, a quartz vein, or perhaps a volcanic rock that was altered by hot, silica-rich fluids. A schist or slate, which contains lots of mica, must have originally contained lots of clay minerals; likely protoliths include mud rocks (shales, mudstones, siltstones, soils) or volcanic rocks that were converted into clay-rich rocks by weathering or by hot, naturally acidic waters (like in a hot spring). A metamorphic rock with lots of black and dark green minerals probably began with a basaltic composition (fine-grained basalt flows or coarser grained intrusions). Some greenish rocks began as intermediate-composition igneous rocks, like andesites.

Original Preserved Features: In spite of being deformed and cooked up, many original features of the protolith may be preserved. These include pillows in old pillow basalts, clasts in conglomerate protoliths, cross beds (in stream, delta, and wind deposits), and graded beds (in sediments formed by floods or deep-water turbidity currents). In addition to helping you interpret the protolith, such features may help you infer the environment of deposition of the protolith (stream vs. deep-water turbidite) or they may help you determine which way was originally up in rock types that have been tipped on end or even turned upside down.

The Mission - see page 1 for our mission

Traverse the small ridges EAST of the road, observing what you see, making good notes, and trying your hand at interpreting protoliths. Note the orientation of the rock units and how the units track across the landscape. Note, measure, and plot on your map the orientation of cleavage and how cleavage relates to bedding or other lithologic layering. This will help you determine where the big folds in the area are located (see sketch below). You may also be able to determine which way the beds face (that is, which way was originally up). Look for evidence that the rocks have been strained (stretched pebbles, etc.). Try to draw little sketches, cross sections, and maps in your notebook depicting what you see.