High-grade metamorphic rocks
EPSC 240, Geology in the Field
Oct 15, 2018

Key concepts for Week 7:

Map symbols for rock unit age and name: On geologic maps, rocks are given symbols consisting of an uppercase letter denoting the age, followed by lower case letters specifying the rock unit. In the Phanerozoic (Cambrian to today) the first letter is usually the first letter of the period (e.g. O for Ordovician, J for Jurassic). Prior to the Phanerozoic, no periods are defined and other letters are used. The rocks of the Grenville Orogen are Proterozoic in age, and are marked with X, Y, Z for Paleoproterozoic, Mesoproterozoic, and Neoproterozoic, respectively. On the Grenville geologic map, a superscript sometimes follows the first letter where precise dates are available.

Brittle deformation: Rocks deform by breaking along sharp surfaces, including fracturing, jointing, crushing and grinding (cataclasis). Brittle deformation is preferred at low temperature and fast deformation rate.

Ductile deformation: Rocks deform by flow within or between mineral crystals, such as in glacier flow. Ductile deformation is dominant at high temperatures and slow deformation rates.

Felsic: Light-coloured igneous rocks mostly made of quartz and feldspar (*fel-* for feldspar, and *-si* for silica), e.g., granite. Usually >65% silica.

Mafic: Dark-coloured rocks containing olivine, pyroxene, or amphibole (*ma-* from magnesium, *-fi* for ferric/ferrous iron), e.g., basalt or gabbros. The silica content is 45-52%.

Metamorphism: Rocks are transformed by increased heat and pressure, which accelerate chemical diffusion through the rock. As conditions change, some of the original minerals become unstable and are replaced by different minerals which are more stable at the new conditions. This term is used when the bulk chemistry of the rock remains essentially the same, but the components are re-arranged to form new minerals (we call this a closed system).

Metasomatism: At elevated temperature, fluids may react with rocks to change their composition and mineralogy. This is particularly common around cooling magmatic intrusions, which give up water with high concentrations of dissolved minerals. This term is used when the bulk chemistry of the rock has been substantially changed during recrystallization, by introduction or removal of some elements due to fluid flow (open system).

Metamorphism and metasomatism are usually accompanied by changes in rock fabric.

Rock fabric: Characteristics of the mineral arrangement and alignment in the rock. Usually these characteristics are pervasive in three dimensions through the rock volume, like the grain in wood.

Foliation: Layering formed by the arrangement of minerals in surfaces within the rock.

Cleavage: Similar to mineral cleavage, these are planes where a rock will break in a preferred direction, often caused by foliation.

Gneissic banding: Minerals are aligned in colour bands (e.g., by separation of feldspar and biotite into light- and dark- coloured bands in an orthogneiss), but the rock usually has no cleavage.

Slaty cleavage or schistosity: Strong foliation of platy minerals (clays and/or micas) which give the rock a strong cleavage. Characteristic of slates (low grade metamorphic) and schists (mid- to high-grade metamorphic).

Massive: used to describe a rock with no foliation (minerals are randomly aligned and/or arrangement of minerals is 'isotropic' – the same in all directions).

There are several types of more isolated structural features which deform the rocks:

Joints: Sets of *s*harp fractures formed by only opening (rocks still line up on either side of fracture). Form due to expansion of rock, often during uplift and erosion, or due to frost cracking near the surface.

Faults: Sharp fractures along which rock has slipped (so rock on one side is displaced from rock on the other side). Often filled with broken and weathered rock (fault rock) and/or mineral veins such as quartz, calcite, and chlorite. Direction of motion may be determined by striations on the fault surface, by matching features across the fault, or by drag folds (see below).

Shear zones: Tabular zones in the rock which have flowed in a ductile way to accommodate the relative offset (e.g., the ductile equivalent of a fault). Usually develop a flow foliation within the zone, parallel to the direction of flow. Direction of slip can be determined from this foliation, and from bends or folds in the rocks around the shear zone.

Folds: Bends or curves in features of the rock which were originally straight, such as bedding or foliation. Usually formed by ductile deformation. Folds near faults or shear zones can be formed due to drag from the relative motion, and record the direction of slip.

Metamorphism, metasomatism, and structural deformation are intimately related. For example, metasomatism is enhanced along faults and shear zones, because these provide permeable pathways for reactive fluids to move into the rock. Crystal growth caused by increases in heat or pressure can affect the strength of the rock and assist deformation, and the development of foliation sometimes reflects this. Therefore, it is important to understand the mineralogy (and changes in mineralogy) as well as the fabrics and structural features to interpret the history of a rock.

Protolith	**Typical fabric**	**High-grade metamorphosed**	**Typical fabric**
granite	equigranular, isotropic	granitic orthogneiss	foliated, banded
basalt	isotropic, aphanitic or porphyritic	amphibolite	coarser grained, massive or foliated
limestone	usually fine-grained, bedded	marble	massive to foliated, may be banded
shale	fine grained, bedded	schist	coarser grained, foliated

Examples of metasomatic rocks:

Skarn: A rock containing carbonate and silicate minerals, usually formed when hydrous fluids from granitic magmas interact with limestones. The fluids may bring in precious metals, e.g., a gold or copper skarn. May be foliated or massive, and can be relatively coarse-grained.

Pegmatite: Felsic igneous rocks with a high concentration of water derived from the parent intrusion, which may endow the rock with rare minerals (e.g., gemstones). Can be massive or zoned, and sometimes grows extremely large crystals.