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ENGINEERING GEOLOGY & GEOTECHNICAL MODELS

ENGINEERING GEOLOGY

Metamorphism

Metamorphism

- Metamorphism can be defined as the solid state recrystallisation of pre-existing rocks due to changes in heat and/or pressure and/or introduction of fluids i.e without melting. There will be mineralogical, chemical and crystallographic changes.

- Metamorphism produced with increasing pressure and temperature conditions is known as prograde metamorphism. Conversely, decreasing temperatures and pressure characterize retrograde metamorphism.

Limits of Metamorphism

- The temperature lower limit of metamorphism is considered to be between 100 - 150° C, to exclude diagenetic changes, due to compaction, which result in sedimentary rocks. There is no agreement as for a pressure lower limit. Some workers argue that changes in atmospheric pressures are not metamorphic, but some types of metamorphism can occur at extremely low pressures (see below).
- The upper boundary of metamorphic conditions is related to the onset of melting processes in the rock. The temperature interval is between 700 - 900° C, with pressures that depend on the composition of the rock. Migmatites are rocks formed on this borderline. They present both melting and solid-state features.

Regional Metamorphism

- Regional or Barrovian metamorphism covers large areas of continental crust typically associated with mountain ranges, particularly subduction zones or the roots of previously eroded mountains. Conditions producing widespread regionally metamorphosed rocks occur during an orogenic event.
- The collision of two continental plates or island arcs with continental plates produce the extreme compressional forces required for the metamorphic changes typical of regional metamorphism. These orogenic mountains are later eroded, exposing the intensely deformed rocks typical of their cores.
- The conditions within the subducting slab as it plunges toward the mantle in a subduction zone also produce regional metamorphic effects. The techniques of structural geology are used to unravel the collisional history and determine the forces involved. Regional metamorphism can be described and classified into metamorphic facies or zones of temperature/pressure conditions throughout the orogenic terrane.

Metamorphic Facies

- Metamorphic facies are recognizable terranes or zones with an equilibrium assemblage of key minerals that were in equilibrium under specific range of temperature and pressure during a metamorphic event. The facies are named after the metamorphic rock formed under those facies conditions from basalt. Facies relationships were first described by Eskola (1920).

- Facies:
  - Low T - low P : Zeolite
  - Mod - high T - low P : Prehnite-Pumpellyite
  - High-P low T : Blueschist
  - Mod P - Mod to high T: Greenschist - Amphibolite – Granulite
  - High P - Mod - high T : Eclogite

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Metamorphic Grades

In zones of progressive metamorphism in Scotland), metamorphic rades are also classified by mineral assemblage based on the appearance of key minerals in rocks of pelitic (shaly, aluminous) origin:

- Low grade ------------------- Intermediate --------------------- High grade
- Greenschist ---------------- Amphibolite ---------------------- Granulite
- Slate ------ Phyllite ------ Schist --------- Gneiss ----------------------- Migmatite(partial metling) >>>melt

- Chlorite zone
  - Biotite zone
    - Garnet zone
      - Staurolite zone
        - Kyanite zone
          - Sillimanite zone

Contact (Thermal) Metamorphism

Contact metamorphism occurs typically around intrusive igneous rocks as a result of the temperature increase caused intrusion of magma into cooler country rock.

The area surrounding the intrusion (called aureoles) where the contact metamorphism effects are present is called the metamorphic aureole. Contact metamorphic rocks are usually known as hornfels.

Rocks formed by contact metamorphism may not present signs of strong deformation and are often fine-grained.

Contact (Thermal) Metamorphism

Contact metamorphism is greater adjacent to the intrusion and dissipates with distance from the contact.

The size of the aureole depends on the heat of the intrusive, its size, and the temperature difference with the wall rocks.

Dykes generally have small aureoles with minimal metamorphism whereas large ultramafic intrusions can have significantly thick and well-developed contact metamorphism.

Contact (Thermal) Metamorphism

The metamorphic grade of an aureole is measured by the peak metamorphic mineral which forms in the aureole.

This is usually related to the metamorphic temperatures of pelitic or alumonisilicate rocks and the minerals they form.

The metamorphic grades of aureoles are andalusite hornfels, sillimanite hornfels, pyroxene hornfels.

Contact (Thermal) Metamorphism

Magmatic fluids coming from the intrusive rock may also take part in the metamorphic reactions. Extensive addition of magmatic fluids can significantly modify the chemistry of the affected rocks. In this case the metamorphism grades into metasomatism.

If the intruded rock is rich in carbonate the result is a skarn. Fluorine-rich magmatic waters which leave a cooling granite may often form greisens within and adjacent to the contact of the granite.

Metasomatic altered aureoles can localize the deposition of metallic ore minerals and thus are of economic interest

Hydrothermal Metamorphism

Hydrothermal metamorphism is the result of the interaction of a rock with a high-temperature fluid of variable composition. The difference in composition between existing rock and the invading fluid triggers a set of metamorphic and metasomatic reactions.

The hydrothermal fluid may be magmatic (originate in an intruding magma), circulating groundwater, or ocean water. Convective circulation of water in the ocean floor basalts produces extensive hydrothermal metamorphism adjacent to spreading centers and other submarine volcanic areas. The patterns of this hydrothermal alteration is used as a guide in the search for deposits of valuable metal ores.

Prograde and Retrograde Metamorphism

Metamorphism is further divided into prograde and retrograde metamorphism. Prograde metamorphism involves the change of mineral assemblages (paragenesis) with increasing temperature and (usually) pressure conditions. These are solid state dehydration reactions, and involve the loss of volatiles such as water or carbon dioxide.

Prograde metamorphism results in a rock representing the maximum pressure and temperature experienced. These rocks often return to the surface without undergoing retrograde metamorphism , where the mineral assemblages would become more stable under lower pressures and temperatures.

Prograde and Retrograde Metamorphism

Retrograde metamorphism involves the reconstitution of a rock under decreasing temperatures (and usually pressures) where revolatisation occurs; allowing the mineral assemblages formed in prograde metamorphism to return to more stable minerals at the lower pressures.

This is a relatively uncommon processes, because volatiles must be present for retrograde metamorphism to occur.

Most metamorphic rocks return to the surface as a representation of the maximum pressures and temperatures they have undergone.

Foliation

The layering within metamorphic rocks is called foliation (derived from the Latin word folia, meaning "leaves"), and it occurs when a strong compressive force is applied from one direction to a recrystallizing rock.

This causes the platy or elongated crystals of minerals, such as mica and chlorite, to grow with their long axes perpendicular to the direction of the force.

This results in a banded, or foliated, rock, with the bands showing the colors of the minerals that formed them.

Metamorphic Rock Textures

The five basic metamorphic textures with typical rock types are:

- Slaty: slate and phyllite; the foliation is called 'slaty cleavage'
- Schistose: schist; the foliation is called 'schistocity'
- Gneissose: gneiss; the foliation is called 'gneisocity'
- Granoblastic: granulite, some marbles and quartzite
- Hornfelsic: hornfels and skarn

Metamorphic Rock - Slate

Metamorphic Rock - Slate

Metamorphic Rock - Phyllite

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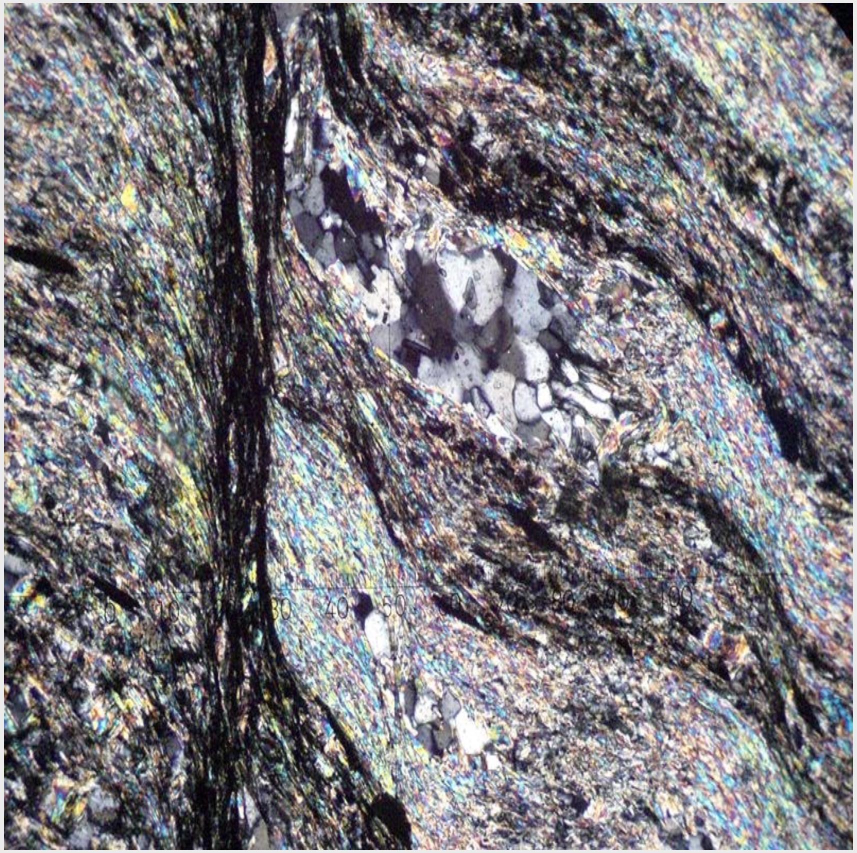
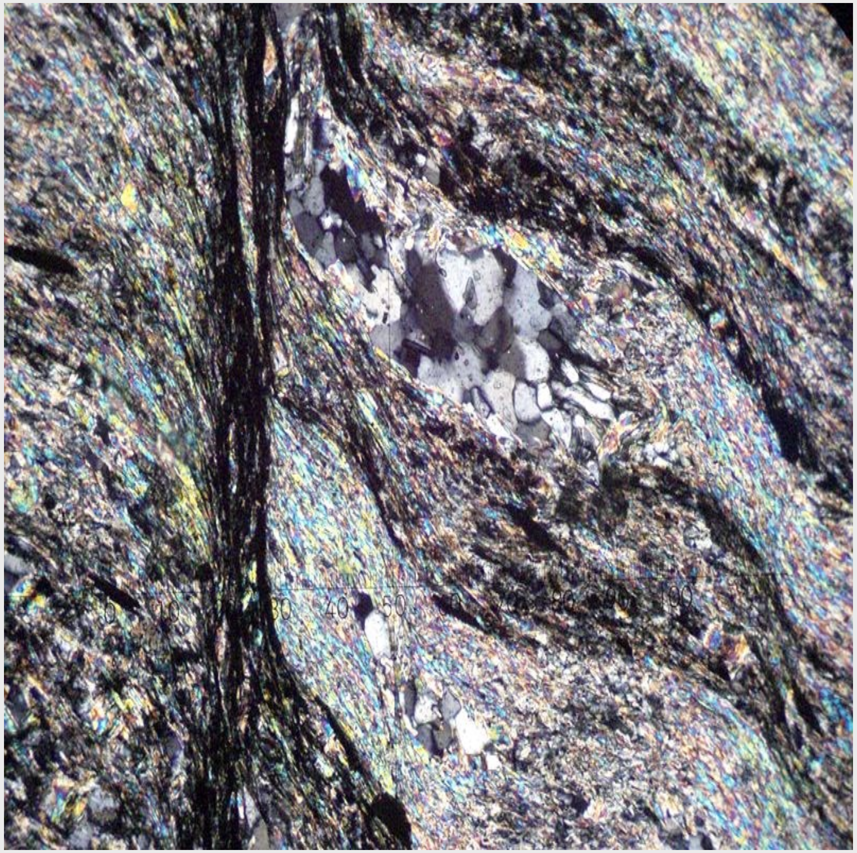
Metamorphic Rock - Phyllite



Metamorphic Rock - Phyllite

Phyllite is a type of foliated metamorphic rock primarily composed of quartz, sericite mica, and chlorite; the rock represents a gradation in the degree of metamorphism between slate and mica schist. Minute crystals of graphite, sericite, or chlorite impart a silky, sometimes golden sheen to the surfaces of cleavage (or schistosity).



Metamorphic Rock - Schist

The schists form a group of medium-grade metamorphic rocks, chiefly notable for the preponderance of lamellar minerals such as micas, chlorite, talc, hornblende, graphite, and others. Quartz often occurs in drawn-out grains to such an extent that a particular form called quartz schist is produced. By definition, schist contains more than 50% platy and elongated minerals, often finely interleaved with quartz and feldspar.

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Metamorphic Rock - Gneiss

Gneissic rocks are usually medium to coarse foliated and largely recrystallized but do not carry large quantities of micas, chlorite or other platy minerals. Gneisses that are metamorphosed igneous rocks or their equivalent are termed granite gneisses, diorite gneisses, etc..

Metamorphic Rock - Granulite

Granulites are metamorphic rocks that have experienced high temperatures of metamorphism. They typically have a granular (granoblastic) texture -- that is, a texture comprised of similarly sized and shaped grains -- and hence the name granulite.

Metamorphic Rock - Marble

Marble is a metamorphic rock resulting from the metamorphism of limestone, composed mostly of calcite (a crystalline form of calcium carbonate, $CaCO_3$).

Metamorphic Rock - Quartzite

Quartzite is a hard, metamorphic rock which was originally sandstone.[1] Sandstone is converted into quartzite through heating and pressure usually related to tectonic compression within orogenic belts. Pure quartzite is usually white to grey. Quartzites often occur in various shades of pink and red due to varying amounts of iron oxide

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