Quadrant II – Transcript and Related Materials

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Module Name: Products of regional metamorphism- rocks and characteristic minerals in different facies in different kinds of rocks such as shales, limestones and basalts - 1

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Notes:

A shale is a fissile, terrigenous sedimentary rock in which particles are mostly of silt and clay size.

Mineralogically, they are made up of clay minerals, fine white micas, chlorite, quartz, minor feldspars (albite and K-feldspar), iron oxides and hydroxides, zeolites, carbonates, sulfides, and organic matter.

These are also referred to as pelites or pelitic rocks.

<u>Regional metamorphism of pelitic rocks</u>

Progressive metamorphism of pelitic rocks would vary depending on the geothermal gradients.

Regional metamorphism under low to medium P/T conditions include Barrovian and Buchan facies series.

The Buchan Facies Series form under pressures, which, in the middle grades of metamorphism, are lower than that of the aluminum silicate triple point.

Hence, the critical sequence of aluminum silicates is kaolinite → pyrophyllite → andalusite →sillimanite.

The Barrovian Facies Series, in contrast, develops where pressures in the middle grades of metamor phism are higher than that of the aluminum silicate triple point.

The resulting aluminum silicate mineral sequence is kaolinite →pyrophyllite → kyanite → sillimanite.

The presence in pelitic rocks of either andalusite or kyanite at the middle grades of metamorphism is one feature that distinguishes these facies series from one another.

The low-grade assemblages of Buchan are virtually identical to those of the Barrovian Facies Series.

Similarly, Greenschist Facies rocks are mineralogically similar to their equivalents in Barrovian Facies Series.

In the Amphibolite Facies, where andalusite and cordierite appear, that the Buchan Facies Series is distinguished from the higher-pressure Barrovian rocks.

Although garnet and staurolite may appear in addition to cordierite in the Buchan Facies Series, the relative order of appearance of these minerals differs.

High P/T metamorphism include Franciscan and Sanbagawa Facies Series.

The characteristic mineral assemblages in each of the facies series is discussed below.

- <u>Buchan Facies Series</u>

  - Zeolite Facies

    illite/smectite-kaolinite-chlorite/smectite-quartz-hematite

    kaolinite-illite-illite/smectite-chlorite-quartz-analcite

    Clay minerals

    Alkali feldspar, smectites, iron oxides, calcite, dolomite, Ca-zeolites, and organic carbon may also occur.

  - Prehnite - Pumpellyite Facies

    illite/smectite-chlorite-quartz-albite-hematite

    K-rich alkali feldspar, are absent

    new phases appear - "phengite" (greenish white mica), albite, and illite/ chlorite or illite/smectite/chlorite mixed-layer minerals.

    Smectites, K-rich alkali feldspar, kaolinite disappear

    smectite + K-rich alkali feldspar <==> illite + quartz ±chlorite

kaolinite + quartz + alkali feldspar + magnetite + calcite +Mg++ + (OH) <==> illite/montmorillonite/chlorite (mixed layer) + illite +CO_2 + H_2O.

- Greenschist Facies
  white mica-chlorite-quartz-albite-magnetite,

  white mica-chlorite-quartz-epidote-albite, and

  white mica-chlorite-biotite-albite-quartz-ilmenite.

  Stilpnomelane, alkali feldspar, pyrophyllite, chloritoid, sphene, and calcite may appear in this facies.

  The Greenschist – Amphibolite Facies boundary is a broad zone.

  The disappearance of albite marks the maximum upper limit of the Greenschist Facies.

- Amphibolite Facies
  muscovite biotite-quartz-andalusite-cordierite-staurolite-oligoclase-ilmenite

  Albite and pyrophyllite are absent

  cordierite and andalusite (at lower grades) and sillimanite (at higher grades) are found in alumina rich rocks.

  Additional phases include, chloritoid, alkali feldspar, tourmaline, apatite, and sphene

  Reactions forming andalusite and cordierite, combined with the disappearance of albite, mark the transition to the Amphibolite Facies (distinctive of Buchan Facies Series).

- Granulite Facies
  Absence of white mica, presence of alkali feldspar + sillimanite or orthopyroxene, occurrence of the assemblage cordierite + orthopyroxene

  muscovite + quartz <==> sillimanite + orthoclase + H_2O

  biotite + quartz <==>hypersthene + almandine+ K-rich alkali feldspar + H_2O

- Barrovian Facies Series

  - **Zeolite Facies**
    kaolinite-illite-illite/smectite-chlorite-quartz-analcite

    illite-illite/smectite-kaolinite-chlorite

    illite-chlorite-kaolinite-K-rich alkali feldspar

    Assemblages are characterized by clay minerals

    smectites, iron oxides, calcite, and dolomite, Ca-zeolites may occur

    Organic carbon is also generally present

  - **Prehnite-Pumpellyite Facies**
    kaolinite and K-rich alkali feldspar, are absent from rocks of certain bulk compositions.

    Appearance of albite, phengitic white mica, and illite/chlorite or illite/smectite/chlorite mixed-layer minerals.

    K-rich alkali feldspar and smectite are among the first minerals to disappear from aluminous rocks.

  - **Greenschist Facies**
    white mica (muscovite and paragonite)-chlorite-quartz-albite-magnetite

    white mica-chlorite-biotite-quartz-albite-magnetite,

    white mica-chlorite-chloritoid-epidote-magnetite-hematite

    white mica-chlorite-garnet-biotite-quartz-albite-oligoclase-magnetite

    As in Buchan Facies series, the Greenschist – Amphibolite Facies boundary is a broad zone.

    The disappearance of albite marks the maximum upper limit of the Greenschist Facies.

  - **Amphibolite Facies**
    Albite and pyrophyllite are absent

    Staurolite is formed (chloritoid appears in Buchan facies series)

    Kyanite (at lower grades) and sillimanite (at higher grades) are found in alumina rich rocks.

    white mica-biotite-quartz-plagioclase (oligoclase) garnet-magnetite,

white mica-biotite-chlorite-quartz-oligoclase-garnet-staurolite-ilmenite,

white mica-biotite-quartz-oligoclase-garnet-kyanite-ilmenite,

white mica-biotite-quartz-oligoclase-garnet-sillimanite ilmenite.

- **Granulite Facies**

The upper part of the Amphibolite Facies and the Granulite Facies are characterized locally by zones of lit-par-lit gneisses.

They consist of a light-colored, quartz-feldspar-rich leucosome, produced by partial melting and/or the local injection and crystallization of a lower temperature melt between layers or foliation planes, and a melanosome, a dark-colored, ferromagnesian mineral-rich, refractory rock.

Leucosomes - granitoid mineral assemblages, melanosomes - biotite or amphibole-rich assemblages.

Absence of white mica, the presence of orthopyroxene in pelitic rocks, and occurrence of the assemblage cordierite + orthopyroxene.

biotite-garnet-sillimanite-K-rich alkali feldspar-andesine-quartz-magnetite-ilmeno-hematite

biotite-K-rich alkali feldspar-andesine-quartz-cordierite-garnet-iron oxides

garnet-andesine-quartz-rutile-ilmenite-orthopyroxene-sillimanite-zircon

The alkali feldspar is typically perthitic.

Additional phases include apatite, spinel, and graphite.

- Sanbagawa Facies Series
  - **Zeolite Facies**

    illite/smectite-kaolinite-chlorite/smectite-quartz-hematite

  - **Prehnite Pumpellyite Facies**
    white mica-chlorite-stilpnomelane-quartz-albite-Na amphibole-sphene

  - **Blueschist Facies**
    white mica-chlorite-chloritoid-quartz-Na-amphibole-sphene-hematite

  - **Greenschist Facies**

white mica-chlorite-quartz-albite-garnet-graphite

- **Amphibolite Facies**
  white mica-biotite-chlorite-quartz-garnet-oligoclase-epidote-graphite

- Franciscan Facies Series
  - **Zeolite Facies**
    illite/smectite-kaolinite-chlorite/smectite-quartz-hematite
  - **Prehnite-Pumpellyite Facies**
    white mica-chlorite/smectite-stilpnomelane-quartz-albite-sphene
  - **Blueschist Facies**
    white mica-quartz-lawsonite-Na amphibole-garnet-hematite
  - **Eclogite Facies**
    quartz-sodic pyroxene-garnet-white mica-kyanite

Products

The metamorphic rocks produced include slates, phyllites, schists, gneisses and migmatites.

The Schists vary in mineral composition depending on the grade of metamorphism- Chlorite schist, biotite schist, Glaucophane schist etc.

At upper amphibolite- Granulite facies condition, partial melting may occur giving rise to migmatites.