GEOL 20120: Investigating Minerals

MODULE COORDINATOR: Associate Professor Julian Menuge

CREDITS: 5	**MODULE LEVEL**: 2	**SEMESTER**: I

PRE-REQUISITES/PRIOR LEARNING:

This module is suitable for students who have taken at least one elementary course in Geology. No prior use or knowledge of the petrological (polarizing) microscope is required.

OVERVIEW OF MODULE:

The module consists of linked lectures, online teaching and practical classes followed by a group research project.

The practical classes use the petrological (polarizing) microscope as a tool for the description and identification of minerals. They cover plane polarized light and crossed polarized light techniques and their use for the systematic description of common rock-forming minerals. The textural difference between and amongst igneous, sedimentary, metamorphic and hydrothermal rocks will be examined under the microscope and explained.

Lectures will outline the optical theory required to understand polarized light observations; introduce chemical concepts used in geochemistry including elements and ions, the Periodic Table, chemical bonding, balanced chemical reactions and partition coefficients; introduce concepts in crystallography and mineralogy including atomic structure, crystal symmetry, chemical substitution and solid solution, exsolution and polymorphism; outline how silicate minerals are classified; introduce the relationships between mineral atomic structure, chemical, optical and other physical properties; and examine the evidence for the average chemical composition of the Earth and of its crust, mantle and core.

The lectures will be supplemented by online material supported by self-assessment quizzes.

The group project will employ the petrological microscope and chemical analyses of minerals to determine the chemistry and mineralogy of a suite of rocks to better understand their origin and economic or environmental significance. Students will produce individual written reports and a group presentation to present their findings to the class.

LEARNING OUTCOMES:

On completion of this module students should be able to:

1. Use a petrological microscope to perform optical tests, describe and identify minerals and interpret textures;
2. Describe and interpret mineralogical and geochemical data presented in graphical form;
3. Demonstrate in writing a knowledge of mineralogy and mineral chemistry and how they relate to each other;
4. Write a scientific report describing and interpreting petrographic and geochemical data;
5. Participate in production and delivery of an oral presentation of group project findings.

ASSESSMENT:

Mid-semester exam: 60%
(Test of Theory and Practical work)

Group Project: 25%
(Written report on individual contribution)

Group Project: 15%
(Contribution to oral presentation)

LECTURES:

Lecture 1: Minerals, crystals and polarised light. *(Assoc. Prof. J.F. Menuge)*
Course outline; importance of minerals; the nature of ordinary and plane polarized light; optical properties under the petrological microscope in plane polarized light and between crossed polars; crystalline structure, symmetry and the seven crystal systems.

Lecture 2: Silicate minerals. *(Assoc. Prof. J.F. Menuge)*
Silicate composition of crust and mantle; The SiO_4 tetrahedron, silicate polymerization and silicate classification, with examples of each class; Goldschmidt's rules, chemical substitution and solid solution; examples of silicate solid solutions; relationships between silicate properties and silicate classification.

Lecture 3: Mineral stability and phase diagrams. *(Assoc. Prof. J.F. Menuge)*
Controls on mineral stability and its depiction on phase diagrams; crystal-liquid binary diagrams (anorthite-diopside and plagioclase); eutectic points; the Lever Rule in binary diagrams; polymorphism, the SiO_2 phase diagram and the geological occurrence of SiO_2 polymorphs; alkali feldspar solvus diagram and perthite textures.

Lecture 4: Mineral – melt partitioning of elements. *(Assoc. Prof. J.F. Menuge)*
Olivine – basalt liquid element partitioning; definition of partition coefficient and bulk partition coefficient; major and trace elements; compatible and incompatible elements; controls on element partitioning; trace element substitution; behaviour of the rare earth elements; partitioning during batch melting and fractional crystallization; economic importance of extreme fractional crystallization.

Lecture 5: Chemical composition of the Earth. *(Assoc. Prof. J.F. Menuge)*
Methods for estimating average chemical composition of the upper and lower crust – chemical analysis of rock samples, composites; mantle xenoliths and ophiolites as samples of the mantle; geophysical constraints; evidence from differentiated meteorites for composition of the core and mantle; evidence from chondritic meteorites for bulk earth composition; chondrite normalisation.

Lecture 6: Sandstone minerals and textures, and what they tell us. *(Assoc. Prof. J.F. Menuge)*
Outline of the various textural features of sandstones: detrital grains, detrital matrix, diagenetic overgrowths and cements; mineralogy; size, rounding and sorting of detrital grains; porosity and permeability. Deductions from textures and mineralogy about provenance, weathering environment, transport medium, depositional and diagenetic environments.

ONLINE EXERCISES:

Week 1: Mineral hand specimens.
An introduction to simple properties that can be used to describe and identify hand specimens of minerals: colour, transparency, streak, lustre, hardness, cleavage and fracture, specific gravity, crystal habit, magnetism, reaction with HCl.

Week 2: The Periodic Table – elements, ions, bonding and chemical compounds.
Information and self-assessment related to the Periodic Table – elements, chemical symbols, atoms, ions, ionic charge and radius, co-ordination numbers, chemical bonds and chemical formulae.

Week 3: Silicate minerals – atomic structure and chemical composition.
Information and self-assessment on: silicate polymerization and atomic structures; classification of silicate minerals; the behaviour of aluminium in silicate minerals; element substitution, solid solution chemistry and its graphical representation; optical determination of plagioclase composition.

Week 4: Mineral stability and phase diagrams.
Information and self-assessment on: plotting, calculations and interpretations related to phase diagrams, including binary crystal-liquid (anorthite-diopside, plagioclase), solvus (alkali feldspar) and polymorphic pressure - temperature (SiO_2, Al_2SiO_5) examples.

Week 5: Mineral – melt partitioning.
Information and self-assessment on: interpretation of plagioclase phenocryst zoning and reverse zoning; interpretation of major and trace zoning in phenocryst olivine; effects of extreme fractional crystallisation on incompatible element concentrations.

Weeks 6 and 7: Constructing a mineral identification key.
Instructions and advice on how to construct an efficient mineral identification key from lab notebook and other sources of information for use in the GEOL20120 mid-semester exam.

PRACTICAL CLASSES: *(3 hours)*

Practical 1: Introduction to the petrological microscope; quartz, microcline, plagioclase, biotite and muscovite in granite.
Issue of petrological microscopes to students and explanation of how the various part of the microscope work. Systematic description of the optical properties of minerals in granite in thin section and hand specimen. Use of the Michel-Levy chart. Recognition of zoned and twinned crystals.

Practical 2: Description of augite, hypersthene, hornblende, olivine, serpentine and magnetite.
Systematic description in hand specimen and thin section of augite, hypersthene, hornblende and olivine in igneous rocks, and of olivine, serpentine and magnetite in a metamorphic rock; igneous textures and their use to understand igneous processes.

Practical 3: The Becke line test; description of orthoclase and sanidine; plagioclase composition
Positive and negative relief; using the Becke line test to determine sign of optical relief in muscovite, orthoclase, sanidine and quartz. Systematic description of orthoclase and sanidine; introduction to plagioclase composition determination.

Practical 4: Visit to thin section laboratory; description of andalusite, sillimanite, kyanite, garnet and epidote.
Explanation of how thin sections are made including visit to thin section laboratory. Systematic description in hand specimen and thin section of andalusite, sillimanite, kyanite, garnet and epidote in metamorphic rocks; metamorphic textures and mineralogy and their use to understand metamorphic processes.

Practical 5: Sandstone and limestone petrography.
Description in thin section of two aeolian sandstones and deductions concerning sediment provenance, weathering, sediment transport, burial and diagenetic history. Description in thin section of an oolitic limestone and deductions concerning depositional environment.

Practical 6: Sandstone petrography.
Description in thin section of fluvial and marine sandstones and deductions concerning sediment provenance, weathering, sediment transport, burial and diagenetic history. (*2 hours*)

GROUP PROJECT LAB SESSIONS: *(supervised for 3 hours)*

Students work in groups on a research project in these sessions and as necessary at other times of their choosing. The details of what is done in each session will vary from group to group; some themes and topics likely to be in common to all groups are indicated below.

Group Project Session 1.
Distribution to groups of thin sections and hand specimens; description of textures and identification of minerals in thin sections.

Group Project Session 2.
Introduce Excel spreadsheet calculations to test microscope mineral identifications using geochemical data; continue descriptions of hand specimens and thin sections.

Group Project Session 3.
Complete hand specimen and thin section descriptions and submit sketches for scanning; consider industrial value and / or environmental implications of the rocks plan and begin to construct group PowerPoint presentations.

Group Project Session 4.
Advice on report writing. Group PowerPoint presentations (approximately 20 minutes plus questions) given in front of the class, graded by the module coordinator and postgraduate demonstrators.