Earth Sciences 3313A: IGNEOUS PETROLOGY - Fall 2019

Arenal Volcano, Costa Rica

Ultramafic flow, spinifex texture, fresh and altered

Instructor: Robert Linnen

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Meeting hours: There are no fixed office hours, please set up an appointment when you need to meet

Teaching Assistant: to be determined

Pre-requisites: ES 2206a/b - Mineral Systems, Crystallography and Optics

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Schedule

Lectures: Tuesdays & Thursdays: 12:30-13:20, Room: NCB-295.

Labs: Thursday 2:30-5:20 and, depending on enrolment, 6:00-9:00 – Room: B&GS-1065

Important Dates

Tuesday, October 17th: Midterm exam in class

Fall Reading Week November 4-8 no classes

Thursday, November 28: Lab exam in BGS 1065

December 8 – 19: Examination period. Final exam, date and location TBA.

CALENDAR DESCRIPTION OF EARTH SCIENCES 3313A

"IGNEOUS PETROLOGY"

Study of igneous processes using rock and thin section descriptions (petrography). Discussion of how different compositions and conditions influence the phases present in a rock (phase equilibria). Association of different rock types with plate tectonic setting.

WHAT ARE THE PRINCIPLE OBJECTIVES OF THIS COURSE?

To outline the physical and chemical properties of magma, to introduce the techniques that are used to interpret the origin and evolution of different series of magmas and to examine in more detail magma evolution in specific igneous/tectonic environments.

The laboratory is an integral part of the course and students will learn to identify common igneous rocks and textures in hand specimen and in thin section using a petrographic microscope.

In class, we will discuss:

- The origin and conditions for producing melts

- How different compositions and conditions influence the phases present in a rock (phase equilibria)

- The association of different rock types with plate tectonic settings

- The major and trace element behavior in igneous systems which is used to understand the formation and evolution of the crust-mantle system on Earth and other planets

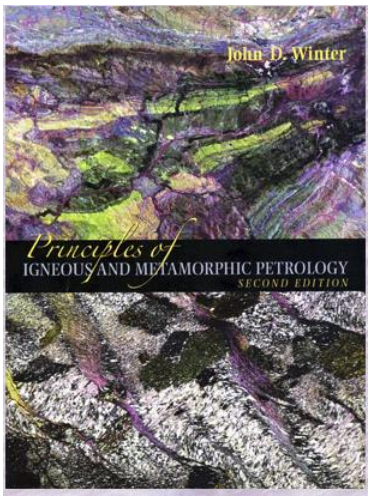
During the labs: Igneous processes are documented and interpreted using rock hand sample and thin section descriptions (petrography).

WHY STUDY IGNEOUS PETROLOGY?

Volcanoes are one of the main natural hazards to mankind and volcanic emissions are linked to past climate change. It is therefore important to understand the mechanisms and processes controlling volcanic eruptions. It is also clear that the materials which constitute the Earth's atmosphere, oceans, and crust ultimately originated from the Earth's interior and were brought to the Earth's surface via igneous processes. Consequently igneous petrology is a key component to understanding how the Earth works as a system and how that system has changed over time. Igneous rocks are also the source of metals in many types of ore deposits, thus understanding the behavior of metals in igneous processes is fundamental to mineral exploration.

LEARNING RESOURCES

The **required text** for this course is **Igneous and Metamorphic Petrology (2010) 2nd Edition, by John Winter**, The cost is somewhat high, ~$160, but this textbook is also used in the course Earth 3315B – Metamorphic Petrology. You may also be able to purchase it on used book websites (make a web search), or as electronic version.



You are required to read the book chapters associated with the corresponding lectures prior to class to get familiarized with the contents and technical vocabulary (see tentative schedule below and announcements made during classes).

Materials from other sources will be also discussed in class. Additional figures will be uploaded to the OWL website

For additional information and power point copies of the figures, see *http://www.whitman.edu/geology/winter/* (the website also has a list of errata to fix in your own book)

There are several other excellent textbooks of Volcanology, Igneous Petrology and related subjects in the library. These include:

Philpotts, A.R. (2009), Principles of Igneous and Metamorphic Petrology,

Best, M.G., and Christiansen, E.H. (2001) Igneous Petrology

Frost, B.R and Frost, C.D. (2014) Essentials of igneous and metamorphic petrology

Rollinson, H. (1993) Using Geochemical Data: Evaluation, Presentation, Interpretation

LABORATORIES

The laboratory is required. Material will be uploaded to the OWL website before the lab. Students are responsible for printing out each assignment. All labs are due at the end of the lab period.

An **optical mineralogy text is <u>required</u>**, suggested books are

Nesse (2003) Introduction to Optical Mineralogy.

Deer, Howie and Zussman, (1992) An Introduction to Rock-Forming Minerals.
Philpotts (1989) Petrography of igneous and metamorphic rocks.

Other Required Materials:

- 10x or better hand lens
- a pencil magnet

MARKING SCHEME

Problem Sets **10%**

Three assignments, due one week after assigned. Penalty: 10% off for each late day (only exceptions are if you have special SSD arrangement, or exceptional reason approved by counseling), maximum 3 days late for credits, due in class. Assignments are normally marked and returned one week after they are due. Each student is required to complete assignments individually (see academic integrity below).

Lab Assignments **25%**

All labs are mandatory and are due at the end of the lab. 10% off for each late day, (only exceptions are if you have special SSD arrangement, or exceptional reason approved by counseling), **3 days late maximum for credits**. Each assignment will be posted on OWL on Monday of each week, **you are responsible for printing and reading lab hand outs prior to the lab session on Thursday.** Each student is required to complete labs individually (see academic integrity below).

Lab Exam **20%**

Thursday **November 28th**. Open book, and 1-page limited hand written notes (figures, notes or previous lab assignments specific to the studied lab materials will not be accepted),

Mid Term **15%**
Thursday **October 17th** during class time

Final Exam **30%**

Date and location to be announced.

Note: for both the mid term and final exam students should bring a calculator and a ruler. Both will consist of a mixture of multiple choice, short answer questions and a problem.

Students are responsible for all material that is presented during lectures. Note that, although there is a course text and most of the material comes from this text, material from other sources is also discussed during lectures. Also note that all additional material will be posted on the OWL site for the course.

SYLLABUS

Some topics may not be covered or at a different week.

Take notes of announcements in class or on OWL for updates on your reading assignments.

Introduction – Chapter 1

- magmatic environments/tectonic setting
- structure of the Earth

Classification of Igneous Rocks – Chapters 2 & 3

- based on minerals
- based on chemistry
- based on CIPW norms

Field Relations of volcanoes and intrusions – Chapter 4

- forms of volcanoes
- volatile contents of volcanic glasses
- temperatures of volcanic rocks
- forms of intrusions

Physical Properties of Magma – supplementary material

- cooling mechanisms of flows
- melt density, viscosity, diffusion
- melt structure

Phase Equilibria – Chapters 5 & 6

- binary diagrams, ternary diagrams
- fractional/equilibrium crystallization/melting

Major Element Geochemistry – Chapters 8 & 11

- characteristic normative minerals
- Harker diagrams
- Pearce Element Ratios
- fractional crystallization
- magma series and tectonic settings

Trace Element Geochemistry – Chapter 9

- major and trace element substitution in crystals
- partition coefficients
- thermodynamics – Henry's law behaviour
- batch melting and fractional crystallization
- partitioning of REE's
- tectonic applications

Basalts – Chapter 10

- evaluation of source, primary versus evolved
- melting of peridotite: effects of H_2O, degrees of partial melting, P-T

- origin of alkaline and tholeiitic basalts

MORB and OIB – Chapters 13, 14 & 15

- major element, trace element and isotopic composition of MORB
- petrogenesis of MORB
- major element, trace element and isotopic composition of OIB
- petrogenesis of OIB

Island Arc Magmas – Chapter 16

- major and trace elements of island arcs
- petrogenesis of island arcs

Continental Arc Magmas – Chapter 17 & 18

- major and trace elements of continental arcs
- petrogenesis of continental arcs
- granitoid geochemistry

Learning Outcomes:
Upon successful completion of this course, students will be able to:
• explain magmatic processes and igneous rock formation within the Earth's crust and mantle using elemental geochemistry, phase diagrams, and petrography.
• describe the geochemical and physical processes responsible for producing magmas and the diversity of igneous rock types by using real and theoretical examples.
• classify igneous rocks based on their petrography or geochemistry and associate these characteristics with plate tectonic settings.
• observe and identify key minerals, and important features of igneous rocks in thin section and hand specimen, and apply their observations to rock forming processes.
• use numerical, graphical, and synthesizing techniques to solve igneous petrological problems.

General Information

General information is available at http://www.registrar.uwo.ca/. For scholastic offenses, University of Western Ontario policies are listed http://www.uwo.ca/univsec/academic_policies/. Scholastic offences are taken seriously and graduate students are directed to read the policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf

Information for accommodation for religious holidays can be found at

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf

The link to learning skills services at the Student Development Centre is http://www.sdc.uwo.ca/ and services provided by the University Students' Council is http://westernusc.ca/services/

Accommodation

If you are unable to meet a course requirement due to illness or other serious circumstances, you

must provide valid medical or supporting documentation to the Academic Counselling Office of your home faculty as soon as possible. Any student looking to book an appointment with a physician, a counsellor, psychologist, psychiatrist, in search of group care options, or any other service provided through Student Health Services and Psychological Services must book an initial appointment in Student Health Services, UCC 11 (Lower Level of the University Community Centre).

For further information, please consult the university's medical illness policy at http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf

For non-medical absences, where the student has received academic accommodation the student should contact the course instructor and the nature of the accommodation will the discussed and agreed upon, depending on the nature of the absence.

Accessibility

Please contact the course instructor if you require material in an alternate format or if you require any other arrangements to make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 661-2111 x.82147 for any specific question regarding an accommodation. Students are not required to sit for more than one hour at a time. For additional information please see www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_disabilities.pdf

Academic Policies

The website for Registrarial Services is http://www.registrar.uwo.ca.

In accordance with policy, http://www.uwo.ca/its/identity/activatenonstudent.html, the centrally administered e-mail account provided to students will be considered the individual's official university e-mail address. It is the responsibility of the account holder to ensure that e-mail received from the University at his/her official university address is attended to in a timely manner.

Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, at the following Web site: http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf.

The term paper may be subject to submission for textual similarity review to the commercial plagiarism detection software under license to the University for the detection of plagiarism. All papers submitted for such checking will be included as source documents in the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between The University of Western Ontario and Turnitin.com (http://www.turnitin.com).

Support Services

Please contact the course instructor if you require lecture or printed material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Student Accessibility Services (SAS) at 661-2147 if you have any questions regarding accommodations.

The policy on Accommodation for Students with Disabilities can be found here: http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_disabilities.pdf

The policy on Accommodation for Religious Holidays can be found here:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf

Learning-skills counsellors at the Student Development Centre (http://www.sdc.uwo.ca) are ready to help you improve your learning skills. They offer presentations on strategies for improving time management, multiple-choice exam preparation/writing, textbook reading, and more. Individual support is offered throughout the Fall/Winter terms in the drop-in Learning Help Centre, and year-round through individual counselling.

Mental Wellbeing

Crisis supports will continue to be offered in both Student Health Services (UCC 11) and Psychological Services (WSSB 4100) during operating hours. Please call 911 if your safety, or the safety of others is a concern. Additional crisis supports can be found at www.uwo.ca/health/crisis.html.

Students can book an appointment with Student Health Services or Psychological Services in-person in UCC 11 (Monday-Friday 9:00a.m.-4:00p.m.), or by telephone at 519-661-3030.

If you require any further clarification, please email health@uwo.ca

Additional student-run support services are offered by the USC, http://westernusc.ca/services.