Course outline for Metamorphic Petrology (MetPet) • EPSC 445 (3 credits)

This document is in addition to information provided on the course website (https://eps.mcgill.ca/~hinsberg/Metamorphic_2013/Welcome.html). Where there is a discrepancy in the information provided, the information on the website is to be regarded as correct. Please note that this course does not use the MyCourses website.

Course prerequisites:

EPSC 210 (Introduction to Mineralogy)

EPSC 212 (Introduction to Petrology)

These two courses ensure that you have the necessary background in petrology and the identification of minerals in thin section and hand specimen

Course schedule:

Lectures: Mon and Wed, 11:30 – 12:30 in FDA 315

Labs: Tuesday from 14:30 to 17:30 in FDA 315

Instructors:

Vincent van Hinsberg	Email: Vincent.vanHinsberg@mcgill.ca. Office hours: Monday and Wednesday from 12:30 to 13:30 in office FDA 341. Others days or times by email appointment.
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Course overview:

How to read metamorphic rocks to reconstruct their history • Metamorphic rocks are the most common rock type on Earth, and their study allows us to put constraints on the pressure, stress and temperature conditions in the crust and mantle, and on the bulk composition in these environments. Metamorphism affects rocks in three ways; it changes their mineralogy, it changes their shape, and it can change their composition. In this course we look at the processes behind metamorphism, the description and classification of metamorphic rocks, and how to extract information from metamorphic rocks and minerals to determine the conditions under which they formed.

Required Course Materials:

We will use the same textbook as for EPSC 212 and you have the choice between **Winter (2010) An Introduction to Igneous and Metamorphic Petrology**, or **Philpotts and Ague (2009) Principles of Igneous and Metamorphic Petrology**. Both cover the same subject material and I will list the required and suggested reading during the course for both books. There is no need to purchase both. Philpotts and Ague (2009) is available from the McGill bookstore and both books can be purchased online, new or second-hand. Earlier editions of both books can be used. The course is set up with the expectation that you have either one of these books and assessment may include topics that are in the required reading in these books, but not covered in lectures or labs.

In addition, the following books are excellent supplementary reading:

- Bucher and Frey (2010) Petrogenesis of Metamorphic Rocks: nice textbook on metamorphic petrology with 4 chapters of general concepts followed by detailed descriptions of metamorphism in different rock compositions. This book is available as an eBook from the McGill library website*.

- Frank Spear (1994) Metamorphic Phase Equilibria and Pressure-Temperature-Time Paths. Comprehensive overview of all aspects of metamorphism. Both an excellent textbook and reference work. Can be bought from the Mineralogical Society of America.

Although no book is required for the lab section of the course, there are several helpful guides on recognizing minerals in thin section, which you will be allowed to use during the labs. These include:

- MacKenzie, Adams and Brodie (2017) Rocks and Minerals in Thin Section (A Colour Atlas): photographs of most common rock forming minerals in thinsection. This book is available as an eBook from the McGill library*.

- Yardley, MacKenzie and Guilford (1990) Atlas of Metamorphic Rocks and Their Textures: similar to previous, but dedicated to metamorphic rocks. Beautiful images.

- Perkins and Henke (2003) Minerals in Thin Section: a detailed guide to microscopy with lots of pictures and drawing of minerals and textures in thinsection.

- Philpotts (2003) Petrography of Igneous and Metamorphic Rocks: detailed guide to microscopy of igneous and metamorphic rocks with lots of figures and a CD with images.

- Barker (2014) A key for identification of rock-forming minerals in thin section: Nice guide to mineral identification using the petrographic microscope with lots of colour images. This book is available as an eBook from the McGill library*.

* Direct links to the eBooks can be found on the course website

Learning outcomes:

The aim of this course is to get familiar with metamorphic rocks, their minerals and textures, and the tools that have been developed to convert these observations into the P-T conditions under which these rocks formed and the path taken through the Earth. Specifically, upon successful completion of the course, you will be able to;

- Describe the processes that cause metamorphism and the mineralogical, textural and compositional changes that result;

- Classify and name metamorphic rocks in terms of protolith, P-T conditions and tectonic setting and assign metamorphic rocks to a metamorphic facies;

- Identify the common metamorphic rocks, minerals and textures in hand specimen and thin section, including reaction textures;

- Use thermodynamic, geochemical, petrological and radiogenic isotope tools to decipher the metamorphic history of rocks, and by extension that of the Earth's crust;

- Make observations, report these observations in sketches, written text and micrographs, and extract pertinent information from your observations;

- Run thermodynamic calculations to determine phase stability in P-T space, and to calculate derivative properties such as density and seismic velocities;

- Combine different, and, in some cases, apparently contradictory sources of information to derive a consistent, logical and integrated synthesis interpretation

The labs will moreover reinforce your **teamwork** skills, including distributing tasks, time management and discussion of findings, and **scientific report writing**, including adhering to the structure of a scientific report, correct reporting of observations, and argumentation of interpretations.

Instructional methods:

The course consists of 2 hours of lectures and 3 hours of labs a week. Lectures will focus on the background and theoretical aspects of metamorphism and metamorphic petrology, whereas this knowledge will be applied in the labs. Labs will involve description and interpretation of hand specimens and thin sections, and thermodynamic and geothermobarometric calculations to constrain metamorphic conditions. The observations made in the labs and the interpretations derived from these will be reported in lab reports.

Course Topics:

1. *Causes of metamorphism*: effects of temperature, pressure and strain; contact, regional and subduction style metamorphism; heating from pluton intrusion
2. *Effects of metamorphism*: development of fabric and texture; changes in mineral assemblage; metasomatism and devolatilisation; overgrowths and relicts
3. *Metamorphic facies*: characteristic mineral assemblages for different P-T domains and P-T-t paths; low to high grade rocks; prograde and retrograde paths
4. *Mineral stability*: phase diagrams; terminal and sliding reactions; effect of bulk composition; solvi and exsolution; pseudo-section calculations
5. *Geothermobarometry*: constraining P-T conditions from mineral equilibria and assemblages; garnet-biotite thermometer; GASP barometer; solubility thermometers
6. *Metamorphism of selected protoliths*: characteristics of metamorphism of pelites, mafic rocks, carbonates and calc-silicates, and granites

Means of Assessment:

Title	Weight	Description	Due Date	Considerations and Late Penalties
Final Exam	1/3	Formal, closed-book, written exam that focusses on theory and concepts of metamorphic petrology. Consists of longer and multi-step questions and short calculations.	To be scheduled during the final exam period.	Missed final exams are handled by Service Point.
Lab report 1 (3 weeks)	2/9	Detailed study of a suite of metamorphic rocks with a mafic protolith in thin section, hand specimen and through (thermodynamic) calculations.	Before Friday, Oct 4 at 9:00	No late reports will be accepted**
Lab report 2 (3 weeks)	2/9	Detailed study of a suite of metamorphic rocks with a pelitic protolith in thin section, hand specimen and through (thermodynamic) calculations.	Before Friday, Nov 1 at 9:00	No late reports will be accepted**
Lab report 3 (3 weeks)	2/9	Detailed study of a suite of subduction-zone metamorphic rocks in thin section, hand specimen and through (thermodynamic) calculations.	Before Friday, Nov 22 at 9:00	No late reports will be accepted**

Lab reports are prepared in groups of 2 or 3 with one report handed in per group (petrographic descriptions within the report are graded individually). Lab reports present three components of work: Detailed petrography of a suite of metamorphic samples as obtained from thin section and hand specimen examination; Thermodynamic mineral stability assessment and positioning of the sample suite in P-T space using the pseudosection approach; Supplementary calculations including geothermobarometry, compositional projections and physical property modelling. For more details on the labs, please see the course website.

**The structure of the course does not allow for late submission of lab reports, because feedback needs to be available before the start of the next lab. Lab reports are prepared over a 3-week period and careful planning of work is highly recommended to accommodate any unexpected absences or delays of group members.

Assessment rubrics: This course uses the Faculty of Science assessment rubric, copied below.

Score	**Identification of relevant concepts** (Choice of correct model, theory, equation, etc.);	**Correct application of concepts** (Correct combination and application of models, theories, equations, etc.)	**Efficiency of approach** (No extra steps or extraneous information given)	**Quality of presentation** (Clarity, language, nomenclature, citing specific sources or examples where appropriate)
0	Concepts identified are completely irrelevant, or no concepts identified at all.	Concepts are applied completely incorrectly, or no attempt has been made to apply concepts.	The entirety of the work presented is unnecessary or irrelevant, or no approach has been taken at all.	Work is unclear and fails to use appropriate nomenclature. Citations (where required) are absent.
1	Some identified concepts are at least partly correct. Important concepts are missing and/or incorrect concepts are identified	Some concepts have been combined or applied in a partially appropriate manner. Important steps or syntheses are missing and/or incorrect steps are taken.	Much of the work presented is unnecessary or irrelevant.	Work is largely unclear and only occasionally uses appropriate nomenclature. Citations (where required) are substandard.
2	The identified concepts are largely correct and partly complete.	The application of concepts is somewhat appropriate with multiple minor, or a few major errors.	Some unnecessary steps are taken and/or unnecessary information is given.	Work is partly clear and uses some appropriate nomenclature. Citations (where required) are substandard.
3	The identified concepts are largely correct and mostly complete.	The application of concepts is largely appropriate with no major errors and few minor ones.	Few unnecessary steps are taken and/or unnecessary information is given.	Work is generally clear and uses appropriate nomenclature. Citations (where required) are appropriate.
4	All of the relevant concepts are identified, and no incorrect concepts are chosen.	The application of concepts is entirely correct and error-free.	No unnecessary steps are taken and no unnecessary information is given.	Work is at the highest level of clarity, using entirely appropriate nomenclature. Citations (where required) are comprehensive.

General McGill policy statements;

Instructor generated course materials (e.g., handouts, notes, summaries, exam questions, etc.) are protected by law and may not be copied or distributed in any form or in any medium without explicit permission of the instructor. Note that infringements of copyright can be subject to follow up by the University under the Code of Student Conduct and Disciplinary Procedures

Assessments in this course are governed by the Policy on Assessment of Student Learning (PASL), which provides a set of common principles to guide the assessment of students' learning. Also see Faculty of Science-specific rules on the implementation of PASL.

Legally mandated academic accommodations are handled by Student Accessibility and Achievement. For more information see https://www.mcgill.ca/access-achieve/

In accord with McGill University's Charter of Students' Rights, students in this course have the right to submit in English or in French written work that is to be graded. This does not apply to courses in which acquiring proficiency in a language is one of the objectives." (Approved by Senate on 21 January 2009)

Conformément à la Charte des droits de l'étudiant de l'Université McGill, chaque étudiant a le droit de soumettre en français ou en anglais tout travail écrit devant être noté, sauf dans le cas des cours dont l'un des objets est la maîtrise d'une langue. (Énoncé approuvé par le Sénat le 21 janvier 2009)

McGill University values academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offences under the Code of Student Conduct and Disciplinary Procedures" (Approved by Senate on 29 January 2003) (See McGill's guide to academic honesty for more information).

In the event of extraordinary circumstances beyond the University's control, the content and/or assessment tasks in this course are subject to change and students will be advised of the change.