COURSE OUTLINE

OBTL status: completed

Course Title	**Earth Materials**		
Course Code	**ES2002**		
Offered	Study Year 2, Sem 2 | Study Year 3, Sem 2 | Study Year 4, Sem 2		
Course Coordinator	Caroline Bouvet de la Maisonneuve (Asst Prof)	CarolineBouvet@ntu.edu.sg	6592 7826
Pre-requisites	ES1003		
AU	4		
Contact hours	Lectures: 39, Laboratories: 39		
Approved for delivery from			
Last revised	11 Jun 2019, 16:21		

Course Aims

This course aims to introduce the principles of magmatic, sedimentary and metamorphic petrology and the use of the optical microscope in Geosciences. You will learn how to identify the different types of rocks and minerals under the microscope (and SEM) and make connections with the hand specimen. You will discover the main processes that lead to the formation of the different rock types and rock associations in different tectonic environments. You will gain hands on experience with the different analytical techniques used to study rocks (microscope and SEM) and make connections with the theoretical content. You will discover implications for the society and practical applications by discussing the importance of rocks and minerals for the industry, and problems related to human health and environmental pollution.

Intended Learning Outcomes

Upon successfully completing this course, you should be able to:

1. Identify magmatic, sedimentary, and metamorphic minerals and components under the optical microscope.
2. Recognize the geologic processes that produced a specific rock specimen.
3. Build connections between large scale tectonic processes, local scale chemical reactions and physical processes, and the characteristics of a rock.
4. Use phase diagrams and rock classifications to understand and infer rock formation processes.
5. Describe rocks, their constituents, texture, and geologic interpretation.

Course Content

Know the minerals and components that make magmatic, sedimentary and metamorphic rocks.

Know the environmental conditions of formation of magmatic, sedimentary and metamorphic rocks.

Know the physical and chemical processes that lead to the formation of these rocks and their expression in rocks.

Know how to use the optical microscope to study rocks and their origin.

Know how to use phase diagrams and rock classifications to study rocks and their origin.

Know how to describe rocks and communicate the related implications of your findings.

Assessment

Component	Course ILOs tested	ASE Graduate Attributes tested	Weighting	Team / Individual	Assessment Rubrics
Continuous Assessment					
Laboratories					
Short Answer Questions	1, 2, 3, 5	**1.** a **2.** a **3.** a, c **4.** a, b **5.** c **8.** a, b **9.** b, c **10.** a	25	individual	See Appendix for rubric
Lectures					
Final Theory Test 1	3, 4	**1.** a **2.** a **3.** a, c **4.** b **8.** a **9.** b	25	individual	See Appendix for rubric
Technology-enhanced Learning					
Activities	1, 2, 3, 4	**1.** a, b **2.** a **3.** a, c **4.** b **5.** c **8.** a, b **9.** b, c **10.** a	25	individual	See Appendix for rubric
Essay	1, 2, 3, 4, 5	**1.** a, b **2.** a **3.** a, c **4.** a, b **5.** c **8.** a, b **9.** b, c **10.** a	25	team	See Appendix for rubric
		Total	**100%**		

These are the relevant ASE Graduate Attributes.

1. Apply environmental knowledge, concepts and skills to make sound decisions

a. Interpret evidence to give sound environmental advice to stakeholders

b. Give advice to industry regarding existing environmental legislation

2. Demonstrate intellectual flexibility and critical thinking

a. Demonstrate intellectual flexibility to view environmental issues from multiple perspectives

3. Demonstrate passion and use advanced communication skills to share that passion

a. Effectively communicate environmental concepts in writing

c. Effectively communicate environmental concepts in various forms of media such as data visualisation, diagrams, animation, video, or podcasts

4. Formulate key scientific questions and develop hypotheses

a. Research and formulate questions involving environmental issues

b. Create and evaluate hypotheses to research such questions

5. Conduct research

c. Make first-hand observations in order to draw conclusions

8. Demonstrate the willingness and skills for lifelong learning

a. Demonstrate aptitude and enthusiasm to learn independently

b. Demonstrate good observation skills and a curiosity about the world

9. Demonstrate ethical values

b. Respect regulations involving plagiarism and copyright

c. Respect requirements regarding confidentiality, data protection, conflict of interest, and falsification of data

10. Demonstrate collaboration and leadership skills

a. Learn collaboratively and be willing to share expertise with peers

Formative Feedback

Your weekly activities (thin section descriptions, quizzes, assignments) will be graded and handed back the following week, with feedback in the form of a grade and comments on how to improve. These activities will help you build knowledge and understanding for the final theory and practical tests, which will be in a similar form. The weekly activities and feedback relate to learning outcomes 1-5.

You will work on a project in pairs, and qualitative feedback will be provided on the report at the end of the semester (i.e. shortly after the report is due).

Learning and Teaching Approach

Lectures (39 hours)	There will be lectures at the beginning of each week covering the topics of all Learning Outcomes (LO 1-5). These will be done in an interactive way, involving your participation in the form of discussions and contributions to the whiteboard. These lectures will also be punctuated with demonstrations using the microscope and analog models of crystals. Short MCQs at the beginning of each lecture, on the topic of the previous lecture, will facilitate content assimilation and ensure that you can discuss about a topic and learn in an active way. Some assignments will also be given for hands on application of the content covered during lectures (LO 4).
Laboratories (39 hours)	During labs, you will individually have access to microscopes and be encouraged to share your findings and observations with your classmates in order to discover rocks in thin section and describe them adequately (LO 1-3, 5). You will also be doing exercises and asked questions that help you build connections between theoretical processes and their expression in rocks (LO 3-4). You will have the opportunity to go to the SEM and acquire data in pairs for a thin section of your choice (LO 2). This will be part of a 6-week long project aiming at going in depth on one sample to fully discover how to recognize the expression of specific phenomenon in rocks (LO2-3) and how to present this in a professional way (LO 5).

Reading and References

The textbook chosen for this class is:
Klein C., and Philpotts, A. (2012) Earth Materials Introduction to Mineralogy and Petrology. Cambridge University Press.

I encourage you to read it between lectures to help you discover more of the content, while shorter lectures and hands-on practice will be done in class.

Course Policies and Student Responsibilities

(1) General

You are expected to complete all assigned pre-class readings and activities, attend all lecture classes punctually and take all scheduled tests by due dates. You are expected to take responsibility to follow up with course notes and course related announcements for seminar sessions they have missed. You are expected to participate in all seminar discussions and activities.

(2) Missed Assessments

When you are absent from an assessment due to illness, you must submit a medical certificate within 7 working days. A student who is absent from assessment without valid Leave of Absence will be given zero mark for the missed assessment. Course lecturers may, however, use his/her own discretion for extenuating circumstances. Policy on medical leave for student may be found from http://www.ntu.edu.sg/Students/Undergraduate/AdminServices/Pages/Applyforshortleave.aspx.

(3) Special Accommodations

All courses will have some form of assessment and if you envision that you will have difficulty satisfying an assessment component due to your disability then you are advised to contact the Course Coordinator within the first 2 weeks of the course.

Students requiring assistance in the learning environment should contact and notify the Associate Chair (Academic) in their School within the first 2 weeks of their first semester so that you and School can work together to optimise your learning experience. Examples of services that may be provided or supported in individual courses include an editor service to help those with reading and writing difficulties, and access to a personal mentor within the School.

Please access the NTU Office of Academic Services' website http://www.ntu.edu.sg/sasd/oas/Pages/default.aspx for more information about the arrangements for candidates during examinations.

(4) Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

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Course Instructors

Instructor	Office Location	Phone	Email
Caroline Bouvet de la Maisonneuve (Asst Prof)	N2-01B-27	6592 7826	CarolineBouvet@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course ILO	Readings/ Activities
1	Introduction to Earth Materials.	3	Introduction to crystal structures and mineral classification.
2	Introduction to the optical microscope.	1, 3	Mineral identification criteria in plain and cross polarized light.
3	Magmatic Rocks 1 - Classification of magmatic rocks	1, 2, 3, 4, 5	Components of magmatic rocks.
4	Magmatic Rocks 2 - Magma generation	1, 2, 3, 4, 5	Mafic plutonic and volcanic rocks.
5	Magmatic Rocks 3 - Magma differentiation	1, 2, 3, 4, 5	Felsic plutonic and volcanic rocks.
6	Sedimentary Rocks 1 - Components of sedimentary rocks	1, 2, 3, 4, 5	Components of sedimentary rocks.
7	Sedimentary Rocks 2 - Sedimentary processes	1, 2, 3, 4, 5	Sedimentary processes.
8	Metamorphic Rocks 1 - Classification of metamorphic rocks	1, 2, 3, 4, 5	Components of metamorphic rocks.
9	Metamorphic Rocks 2 - Metamorphic processes	1, 2, 3, 4, 5	Regional metamorphism
10	Analytical Techniques - SEM	1, 2, 3, 4, 5	Thin Section project
11	Course review - Magmatic, sedimentary and metamorphic rocks	1, 2, 3, 4, 5	Magmatic, sedimentary and metamorphic rock descriptions
12	Mineral Resources and Human Health	1, 2, 3, 4, 5	Mineral Resources - Opaque minerals
13	Final practical and theory tests	1, 2, 3, 4, 5	Final practical and theory tests

Appendix 1: Assessment Rubrics

Rubric for Laboratories: Short Answer Questions (25%)

Thin section descriptions during weekly Laboratories and during a final, 2h, practical test conducted during the last week of classes.

SECTION	UNSATISFACTORY	MARGINAL	GOOD	EXCELLENT	Pts.
Schematic drawing:	· No, incomplete, or fictive drawing · No legend or scale	· Unclear/dirty drawing · Minimalistic legend · No component abundances · No scale	· Good drawing · Most components are labelled · Component abundances are lacking or incomplete · Scale mentioned	· Clear and complete drawing · All components are labelled · The abundances of all components are listed in vol% · Scale mentioned	3
Components:	· Components are identified but are not described · Schematic drawings are not included · A textural description (size, shape,…) is not included for the components	· Less than half of the components are described in PPL and XPL · A schematic drawing is included for some components only · Only a few components are identified correctly based on their description · Limited textural description (size, shape,…)	· Most components are described in PPL and XPL · A schematic drawing is included for most components · Most components are identified correctly based on their description · A textural description (size, shape,…) is included for most components	· All components are described in PPL and XPL · A schematic drawing is included for all components · All components are identified correctly based on their description · A textural description (size, shape,…) is included for all components	4
Rock identification:	· No rock identification · A rock name is given with no justification or explanation	· The general (macroscopic and) microscopic rock texture is partially described · The nature of the rock is correctly identified but with little justification and no correlation with the previously listed observations	· The general (macroscopic and) microscopic rock texture is described · The implications of some observations is presented · The nature of the rock is correctly identified but partially justified based on the points above	· The general (macroscopic and) microscopic rock texture is described · A good summary of all observations is provided (components present, their abundance and texture) · The implications of these observations is presented · The nature of the rock is correctly identified and justified based on the points above · Any possible additional information about formation, environmental, depositional or emplacement processes and age is suggested	3

Rubric for Lectures: Final Theory Test 1 (25%)

A 2h, short answer test during the last week of classes assessing all the knowledge covered during lectures.

Grade / Numerical Score	Criteria
A to A+ (80-100)	- Answers all questions correctly and thoughtfully, - Concise, complete, and articulate short answers, - Submits clean, well presented, carefully laid out documents, - Adequately and appropriately uses scientific vocabulary, - Demonstrates an in-depth and interdisciplinary understanding of the concepts under evaluation, - Completes the assignment within the identified time frame.
A- (75-79)	- Answers most questions correctly, - Concise and complete short answers, - Submits clean, well presented documents, - Appropriately uses scientific vocabulary, - Demonstrates an interdisciplinary understanding of the concepts under evaluation, - Completes the assignment within the identified time frame.
B to B+ (65-74)	- Answers sufficient questions correctly, - Mostly complete short answers, - Submits rather clean, well presented documents, - Often uses the appropriate scientific vocabulary, - Demonstrates an understanding of the concepts under evaluation, - Mostly completes the assignment within the identified time frame.
B- to C+ (55-64)	- Answers some questions correctly, - Answers are often incomplete, - Rarely submits clean, well presented documents, - Rarely uses the appropriate scientific vocabulary, - Demonstrates a limited understanding of the concepts under evaluation, - Mostly completes the assignment within the identified time frame.
C to D (45-54)	- Answers few questions correctly, - Answers are incomplete, - Does not submit clean, well presented documents, - Rarely uses the appropriate scientific vocabulary, - Demonstrates an insufficient understanding of the concepts under evaluation, - Does not fully complete the assignment within the identified time frame.
F (0-44)	Failure to complete assignments

Rubric for Technology-enhanced Learning: Activities (25%)

Continuous assessment in the form of occasional assignments.

Grade / Numerical Score	Criteria
A to A+ (80-100)	- Answers all questions correctly and thoughtfully, - Concise, complete, articulate, and personal short answers, - Submits clean, well presented, carefully laid out documents, - Adequately and appropriately uses scientific vocabulary, - Demonstrates an in-depth and interdisciplinary understanding of the concepts under evaluation, - Completes all assignments within the identified time frame.
A- (75-79)	- Answers most questions correctly, - Complete and personal short answers, - Submits clean, well presented documents, - Appropriately uses scientific vocabulary, - Demonstrates an interdisciplinary understanding of the concepts under evaluation, - Completes all assignments within the identified time frame.
B to B+ (65-74)	- Answers sufficient questions correctly, - Mostly complete and personal short answers, - Submits rather clean, well presented documents, - Often uses the appropriate scientific vocabulary, - Demonstrates an understanding of the concepts under evaluation, - Completes most assignments within the identified time frame.
B- to C+ (55-64)	- Answers some questions correctly, - Answers are often incomplete or impersonal (excessively paraphrased from peers), - Rarely submits clean, well presented documents, - Rarely uses the appropriate scientific vocabulary, - Demonstrates a limited understanding of the concepts under evaluation, - Completes some of the assignments within the identified time frame.
C to D (45-54)	- Answers few questions correctly, - Answers are incomplete or impersonal (excessively paraphrased from peers), - Does not submit clean, well presented documents, - Rarely uses the appropriate scientific vocabulary, - Demonstrates an insufficient understanding of the concepts under evaluation, - Completes few assignments within the identified time frame.
F (0-44)	Failure to complete assignments

Rubric for Technology-enhanced Learning: Essay (25%)

Thin section project and final report (conducted in pairs):

• To use an optical microscope to identify all the components of a rock, describe its texture and thereby identify the rock

• To familiarize with any additional, process-related (or age related) interpretations that can be made from thin section observation and correlate with general knowledge about plate tectonics and geologic processes

SECTION	UNSATISFACTORY	MARGINAL	GOOD	EXCELLENT	Pts.
Purpose:	· No purpose given	· Brief/unclear/incorrect purpose	· Purpose is stated	· Purpose is clearly, concisely, and completely stated	5
Introduction:	· No general description of the hand sample and thin section · No sample number / ref is provided	· Poor description of the hand sample and/or thin section · No sample number / ref is provided	· General description of the hand sample and thin section · Sample number / ref is provided	· Contains an excellent general description for the hand sample and thin section · Sample number / ref is provided	5
Data & Observations:	· Incomplete descriptions and list of components with no abundances · Identification criteria are listed according to theory only · Poor / No textural descriptions · SEM results are not, or partially presented	· Incomplete descriptions and/or incomplete list of components and their abundances · Most identification criteria are listed, mostly according to theory · Poor textural descriptions · SEM results are presented	· Description of all components and their abundances · Most identification criteria are listed, generally according to what is visible (not just theory) · Textural descriptions with appropriate vocabulary · SEM results are presented in a meaningful way	· Complete description of all components and their abundances · All identification criteria are listed and are according to what is visible (not just theory) · Thoughtful and complete textural descriptions with appropriate vocabulary · SEM results are fully integrated in a meaningful way with the rest of the text	30
Sample interpretation:	· Poorly organized or no analysis of data. · An irrelevant rock type is proposed. · Poorly discusses the age of the rock, the depositional environment, or the formation conditions. · Does not discuss the chronological order (sequence) of events. · Erroneously integrates knowledge from thin section observations, plate tectonics and geological processes. · No discussion of data reliability for SEM analyses.	· Rather well organized analysis of data. · A relevant rock type is proposed. · Partly discusses the age of the rock, the depositional environment, or the formation conditions based on the components and their assemblage. · Partly discusses the chronological order (sequence) of events. · Erroneously integrates knowledge from thin section observations, plate tectonics and geological processes. · Poor discussion of data reliability for SEM analyses.	· Well organized, and appropriate analysis of data. · A relevant rock type is proposed. · Partly discusses the age of the rock, the depositional environment, the formation conditions, and any other possible insights based on the components and their assemblage. · Partly discusses the chronological order (sequence) of events. · Somewhat integrates knowledge from thin section observations, plate tectonics and geological processes. · Discussion of data reliability for SEM analyses.	· Insightful, well organized, and appropriate analysis of data. · A relevant and correct rock type is proposed. · Discusses the age of the rock, the depositional environment, the formation conditions, and any other possible insights based on the components and their assemblage. · Discusses the chronological order (sequence) of events. · Integrates knowledge from thin section observations, plate tectonics, and geological processes in an articulate discussion. · Appropriate and complete discussion of SEM data reliability.	20
Conclusion:	· No Conclusions are drawn · No responses to the purpose · No proposal of future directions of study.	· Conclusions are drawn · Poorly supported responses to the purpose · No proposal of future directions of study.	· Conclusions are drawn and supported by data/analysis/research · Well supported responses to the purpose · Contains a proposal of future directions of study.	· Conclusions are drawn and well supported by data/analysis/research · Well supported, thoughtful responses to the purpose · Contains a proposal of future directions of study.	10
Supporting	· Contains few to no	· Contains scientific	· Contains scientific	· Contains relevant	10

information:	scientific sketches or photos · Scale is not provided · Mineral chemical data is not mentioned · Images and plots are not titled, labeled, or scaled	sketches or photos · Scale is not provided for most images · Mineral chemical data is mentioned in the text · Images and plots are often titled, labeled, and scaled	sketches and photos · Scale is provided for most images · Mineral chemical data is mentioned in the text · Images and plots are titled, labeled, and properly scaled	and insightful scientific sketches and photos · Scale is provided for all images · Mineral chemical data is plotted · Images and plots are titled, labeled, properly scaled, and data appropriate	
Mechanics:	· Messy, rushed job, illegible · Sections are not separated · Grammar needs editing · No raw data provided in appendix · Too long	· Could be cleaner / neater · Sections not labeled · Many typos, grammar mistakes · No/incomplete raw data provided in appendix · Too long	· Presented neatly · Labeled sections · A few typos, grammar mistakes · Raw data provided in appendix · Page limit respected	· Presented perfectly · Sections carefully laid out · No typos, grammar mistakes · All raw data provided in appendix · Page limit respected	10
Individual contribution:	· Team member poorly contributed to the project with limited data acquisition and report writing, and rare in-class participation	· Team member contributed to the project by completing a share of the data acquisition and report writing, and occasional in-class participation	· Team member actively contributed to the project through completing a fair share of the data acquisition and report writing, and in-class participation	· Team member actively and creatively contributed to the project through individual researching, completing a fair share of the data acquisition and report writing, and in-class participation	10

Appendix 2: Intended Affective Outcomes

As a result of this course, it is expected you will develop the following "big picture" attributes:

Show self-reliance when working independently yet also cooperate in group activities (display teamwork).

Question new ideals, concepts, models, etc. in order to fully understand them.

Prioritize time effectively to meet the needs of the learning trajectory.

Know the geologic conventions of rock examination and description and practice them