# MINERALOGY

## composition and structure of planetary materials

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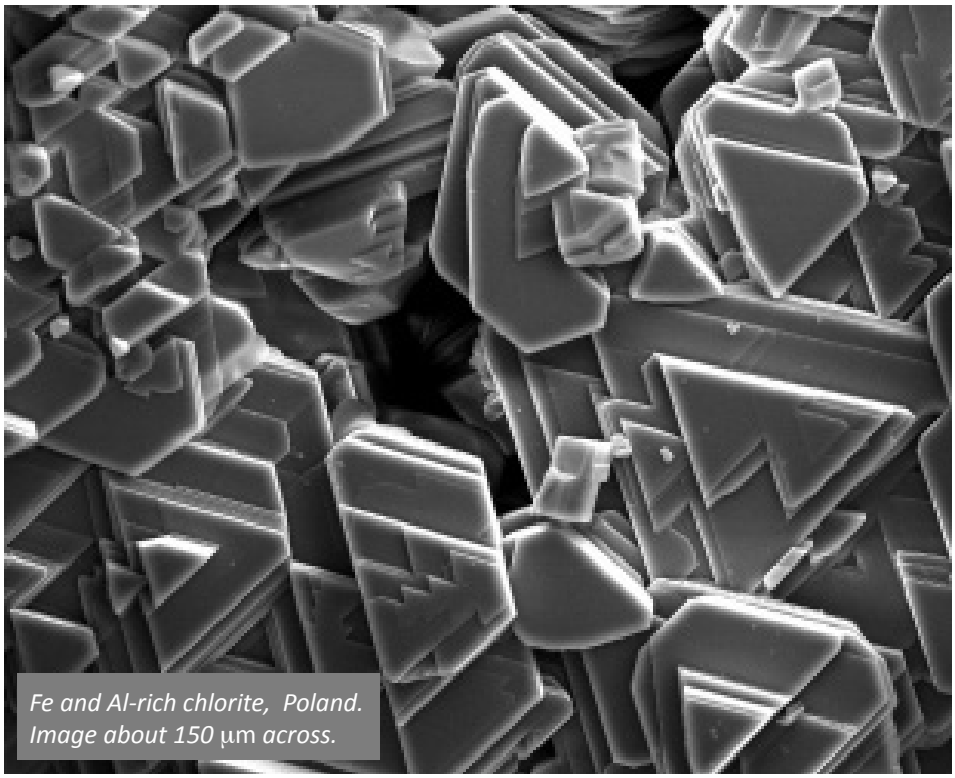
**Class Meetings**
OLRI-179
MWF 8:30-10:30 am

**GEOL-250-01**
http://moodle.macalester.edu



*Fe and Al-rich chlorite, Poland. Image about 150 μm across.*

## *Why Study Mineralogy?*

Welcome! You are about to embark on a fascinating tour of the building blocks of planets. Mineralogy, the first "majors" course in many geology programs, introduces students to the composition, structure, and significance of crystalline materials. Doing geology often involves the use of clues to solve problems or answer questions. These "clues" can come in many forms (e.g., maps, images, landforms), but commonly involve minerals. Once you know how to "read" the clues from minerals, you will have access to information that bears on a wide variety of geological questions, including: the origin and evolution of the Earth's crust and mantle, tectonic processes, diagenesis, fossilization, and water-rock systems. As an example, geologists are now studying the evolution of our solar system using evidence from dust-

## Essential Questions

- What clues do mineral composition and structure provide about the origin and evolution of earth?
- What roles do minerals play in global change, and how can we use minerals to study paleoclimate?
- What role did minerals have in emergence and evolution of life?
- How has life changed the mineral composition of the Earth?
- How can minerals be used to address environmental issues?

## What's In This Syllabus?

| | |
|---|---|
| Why Study Mineralogy | 1 |
| Course Description | 2 |
| Required Texts | 2 |
| Course Objectives | 2 |
| Teaching Philosophy | 3 |
| Course Format | 4 |
| Approaches to Learning | 5 |
| Evaluation of Learning | 6 |
| Course Etiquette | 7 |
| Academic Integrity | 8 |
| Strategies for Learning | 8 |
| Resources and Support | 8 |
| Course Schedule | 10 |
| Course Concept Map | 11 |

## Textbooks

*REQUIRED:*
Introduction to Mineralogy
Second Edition (2012)
William D. Nesse; Oxford University Press

*RECOMMENDED:*
An Introduction to the Rock-Forming Minerals
Third Edition (2013)
Deer, Howie, and Zussman; Mineralogical Society

size mineral grains recovered from a nearby comet. Evidence for some of the Earth's earliest continental crust comes from grains of detrital zircon, and these same grains provide evidence of the evolution of the Earth's oceans. More than 90% of the iron, an essential element for life, in the central Atlantic Ocean comes from wind-blown mineral dusts from the Sahara Dessert. Many geologists are currently exploring ways to address climate change problems by sequestering atmospheric $CO_2$ in crustal rocks. Other scientists are studying the implications of interactions between minerals and organisms and aqueous fluids. Key objectives of this course are for you to learn how to study minerals and "listen" to the clues they hold.

## Course Description

One of the most central concepts in mineralogy is that of "equilibrium." Ultimately, nearly every question and observation in mineralogy can be related to this important concept. As such, we will continually relate our understanding and questions back to the concept of equilibrium. As we learn about minerals, we will also develop several other important concepts, including: (1) mineral groups; (2) symmetry and form; (3) mineral chemistry; (4) mineral structures; and (5) mineral associations and environments. Our understanding of these concepts will be reinforced through use of various laboratory methods (e.g., physical properties, crystallography, spectroscopy, optical microscopy, scanning electron microscopy and energy dispersive spectroscopy, and x-ray diffraction) and through examination of specimens of common and important minerals. The course begins with basic mineral concepts and theories, and then focuses on the application of those concepts in the second half of the course. A final project on a rock, collected by you, provides an opportunity to "pull it all together" and to demonstrate your mastery of mineralogy.

## Course Objectives

Upon completing this course, you will have a new appreciation for minerals, rocks, and the world we live in. There are a number of essential concepts around which this course is developed, including: element abundances, chemical bonds, ionic radii, properties of matter, symmetry, light, x-rays, the effects of temperature and pressure, and mineral associations and environmental conditions. These powerful concepts offer new perspectives that only geology can give, and that will serve you throughout your work and personal life regardless of your career choice.

Other, more specific course learning outcomes are described in the table below. These not only provide a basis for the evaluation of student learning in the course, but are also designed to support the **Macalester College Student Learning Goals**.

## Interesting Mineral Facts

4,404,000,000
age in years of the oldest mineral on earth

10,000,000
years to grow a 2 cm garnet crystal by diffusion

32,980
number of pounds of iron each person consumes in their lifetime

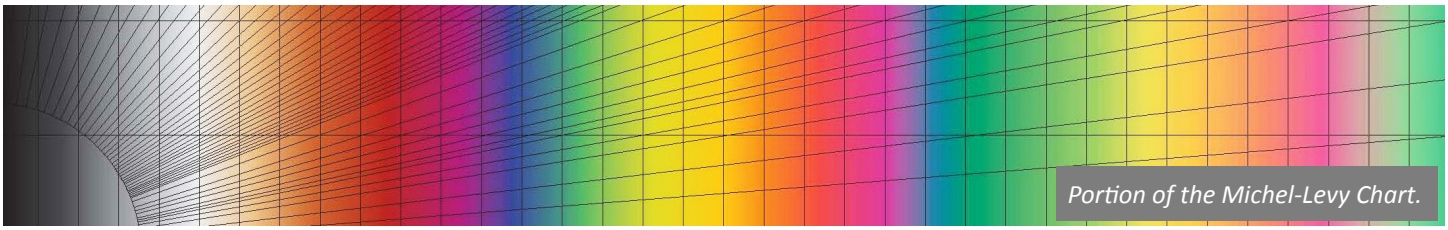
7,000
the absolute hardness of diamond compared with talc

4,830
the approximate number of known mineral species

1,600
the melting temperture of $SiO_2$ in degrees celsius

50
length in miles of wire made from one ounce of gold

9
the number of rare earth elements in an iPhone



Portion of the Michel-Levy Chart.

## Teaching Philosophy

My goal is that students will leave my courses not only more knowledgeable about geology, but also more intentional and self-directing about their learning. The AAC&U (2002) Greater Expectations: A New Vision for Learning as a Nation Goes to College report reminds us that in an increasingly complex and interconnected world, students need to be intentional learners who are purposeful and self-directing, empowered through intellectual and practical skills, informed by knowledge and ways of knowing, and responsible for personal actions and civic values. As self-directing learners, students need to develop skills and habits for diagnosing their learning needs, formulating learning goals, identifying resources for learning, selecting and implementing learning strategies, and evaluating learning outcomes (Savin-Baden and Major in Foundations of Problem-Based Learning, 2004).

The past few decades have seen a large body of research that informs our

| Course Learning Goals | Macalester Student Learning Goals | IDEA Center Learning Objectives |
|---|---|---|
| Be able to determine mineral properties for the purpose of identifying minerals | Demonstrate Intellectual Breadth and Depth | Objective 1: Gaining factual knowledge (terminology, classifications, methods, trends) |
| Understand the relationships between internal (composition and structure) and external properties of minerals | | Objective 2: Learning fundamental principles, generalizations, or theories |
| Understand the physical conditions that affect the occurrence, composition, and structure of minerals | | |
| Be able to employ data about mineral composition and structure to studies of their origin and evolution | | |
| Recognize common minerals and be able to identify others | | Objectve 3: Learning to apply course material (to improve thinking, problem solving, and decisions) |
| Be able to use the interaction of light with solid materials to study minerals | | |
| Be able to utilize the interaction of x-rays with crystalline materials to study minerals | | |
| Be able to use modern instrumentation (spectrograph, optical microscope, x-ray diffractometer, scanning electron microscope), methods, and literature to study minerals | | |
| Be able to determine elements of symmetry and apply 3D visualization of symmetry and structure in the study of minerals | | |
| Know how to apply research strategies to investigate minerals and rocks | Think Critically and Analyze Effectively | |

## What You Can Expect From Your Instructor

- provide learning opportunities that will help you meet course objectives
- provide constructive feedback on your performance
- be open to constructive feedback on the course and instruction
- be open-minded in responding to your ideas
- allow you to wrestle with ideas in order to develop your own understanding
- bring teaching experience and a passion for the Earth into the classroom

*Horizontal reflectance goniometer (~1900).*

understanding of learning, intellectual development, cognitive theory, and the physiology of the brain. In particular, several books have had a profound influence on my teaching and course design. D. Fink's book on Significant Learning emphasizes the importance of the educating the "whole student." Whereas I previously regarded my role as primarily a teacher of science, I now have a much more wholistic view of my role as an educator and this has resulted in careful consideration of what I teach and how it contributes to the development of students. How People Learn: Brain, Mind, Experience and School (Bransford et al., 2000) details the importance of building on prior knowledge, active learning, metacognition, transfer, and learning communities. I address these in my courses with a combination of knowledge surveys, problem-based learning, reflective journaling, and collaborative work. I use knowledge surveys to guide student learning and as formative assessment tools. Daily reading reflections provide students opportunities to self-assess their learning and understanding.

The focus of my courses is on mastery. As such, there are many opportunities for revision. Grading in the course is criterion based, rather than norm-based, to minimize competition among students while they work on collaborative activities. Regular journal activities throughout the semester provide students opportunities to reflect on their learning, how it is working, and how it might be improved. Many of these activities are accomplished using Moodle, a learning management system that not only serves as a dynamic syllabus and schedule throughout the course, but also helps guide student learning and build community.

In general, whenever possible we will try to learn by "doing" rather than by more traditional lecture. Therefore, it is essential that students come to class prepared to learn. Many of our activities will benefit from collaborative work, and you will be encouraged to work closely with others.

### *Course Format*

The course utilizes a studio format. In other words, lecture and laboratory are not separate. The class meets in three two-hour blocks each week to provide maximum flexibility for moving between hands-on, group activities, and lecture. In general, whenever possible we will try to learn by "doing" rather than by more traditional lecture. Therefore, it is essential that you come prepared to class. This means that you must do the assigned readings before class in order to benefit from, and effectively contribute to, the classroom activities. Participants are expected to arrive on time and attend the full class period. Many of our activities will benefit from teamwork, and you are encouraged to work closely with others in the course throughout the semester. However, it is important that you make sure each team member has full ownership and

Be curious.

Question.

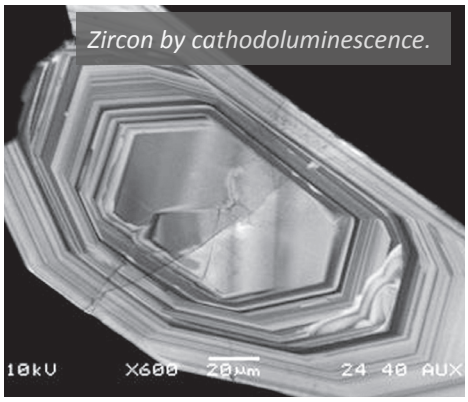
Seek.

Collaborate.

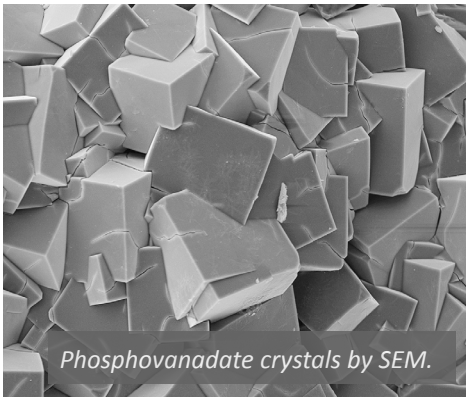
Reflect.

Learn.

Grow.



Zircon by cathodoluminescence.


Phosphovanadate crystals by SEM.


Falls of St Anthony (Lewis, 1847)

Fluorite (D. Green).

understanding of the course materials. A team-based approach is also more similar to the way that real scientists work. Academic integrity is expected from all students. Participants with special needs are strongly encouraged to speak with the instructor at the beginning of the course to gain maximum benefit from course activities and information.

## *Approaches to Learning*

Different courses require different methods of study. There is a generous amount of work in this course, but research has shown that the best way to learn is to "learn by doing," and doing takes time. But, you will remember it better and understand it better as a result. As with many science disciplines, there is a lot of terminology and information to learn in this course, but these are not the final goal of our learning. I am most interested that you develop a deep understanding of the important concepts and skills related to mineralogy. Every element of the course is designed to encourage this kind of learning, so please allow me to help you make this happen. Attend class regularly; do all the assigned readings before class; take notes and ask questions in class; complete all of the activities; re-read your notes and the assignments after class; and seek assistance whenever you have questions. Working together closely with your colleagues and the instructor will facilitate deeper learning.

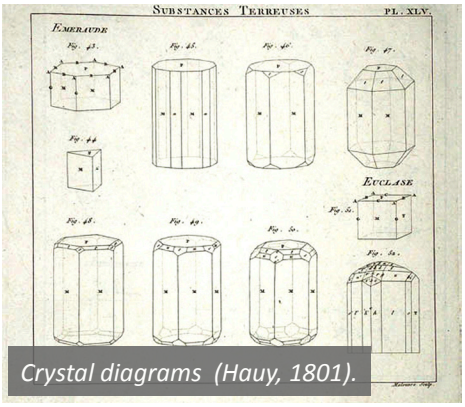
To help you learn I have prepared a knowledge survey for this course. This survey consists of 10-15 items from each chapter in the textbook. Other items are written to address the project and skills in the course. Each survey item identifies an important learning objective and describes a desired cognitive processes (Bloom level) needed for mastery. You will complete the knowledge surveys several times throughout the course (beginning, before each exam, and end of course). Your responses will not be graded, but they will provide information for students and faculty to understand and improve learning in the course. The knowledge surveys should also be reviewed before reading (to identify the learning goals), and after reading (to see if you have met those goals). Similarly, the knowledge surveys serve as a study guide before exams. Several questions on each of the exams will come directly from the knowledge survey.

The course activities that we do during, and outside, class are designed to help you develop a deeper understanding of important concepts through application to real-world problems. If you work together and ask lots of questions of each other, and the instructor, there is no reason not to receive full credit for these activities. In other words, these "low-stakes" activities provide an opportunity to develop the knowledge and practice the skills you will need for the exams and final project. Throughout the semester, we will also be identifying mineral unknowns. These give us a chance to apply the concepts learned in the course, to use modern instrumentation, to become familiar with the common rock-forming

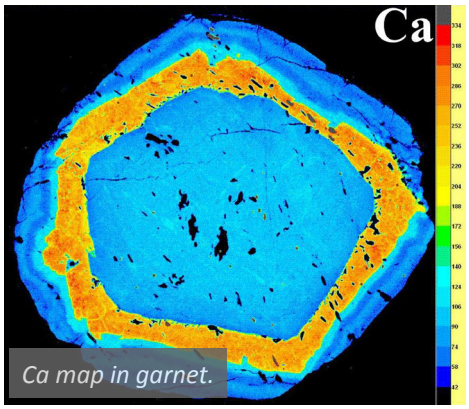
> We Don't Learn from Experience; We Learn from Reflecting on Experience.
>
> John Dewey (1933)


Polarizing microscope (1878).


Tremolite asbestos.



Crystal diagrams (Hauy, 1801).



Ca map in garnet.

minerals, and develop research strategies. It is important that you complete the activities and mineral unknowns on schedule because our work in the course continually builds on previous knowledge and understanding. Occasional journal reflections provide opportunities to reflect on your learning goals, strategies for learning, and ways to improve. The final project provides an opportunity to apply all of the knowledge and skills that you develop toward understanding a real-world problem. As always, you also have the option of ignoring all of the above and going for the "Squash Challenge" (challenge me to a match on the squash court). However, you should be warned that no one has ever attempted this option before!

Your first encounter with course material should be in the reading. I will use lecture sparingly in this course to address material that is not well in the explained in the text, when concepts are particularly complex, or when students indicate the need for additional explanation. If you have questions after reading and reflecting on the text, it is very important that you make any questions that you might have known to your classmates or me. Because we will spend much of our time in the classroom working on applying our knowledge and learning new skills, it is essential that you do the reading assignments each day before you come to class. If you do not, you will not be prepared to help your team or participate in classroom activities. To help you stay on task with the readings, I will frequently post a reading reflection that covers the reading assignment for that day. The questions will be posted to the course page on Moodle. You answer the questions and submit them electronically using Moodle. Late submissions (after the class meeting) will not receive full credit. You can miss up to two reading reflections without penalty. Your reflection will not be graded, but you will receive credit for each submission that demonstrates significant reflection on the assigned reading.

## *Exams*

There will be three exams in the course, and each will cover approximately one-third of the course material. There will not be a comprehensive final exam. The format of the exams will vary, but each will consist of a variety of questions, including terms, diagrams, short answer, and essay. Your knowledge of minerals and your skills for working with them will be evaluated by oral examination at the end of the semester. The purpose of this format is to provide a focus on mineral thinking and skills.

## *Evaluation of Learning*

Your learning in the course will be assessed using a variety of different formative and summative activities and performance tasks. Grading in this course is criterion-based. That is, assigned grades reflect student levels of mastery of knowledge and skills. Grading rubrics that clearly identify the content and skill dimensions, and the desired levels of mastery, will be used for the project and oral exams, and these will be available to students

### Reading Reflections

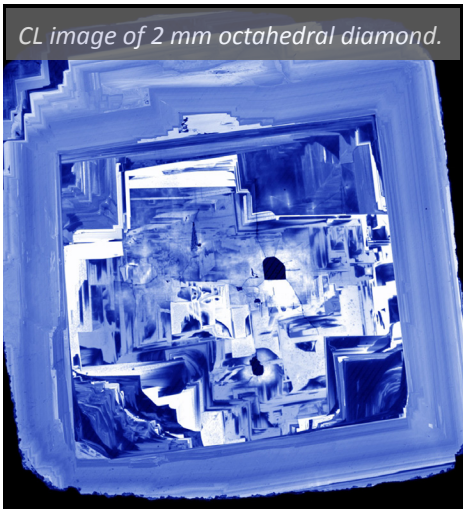
After completing each reading assignment, write brief responses (i.e., at least several sentences) to 2 out of 3 questions below. Submit responses thru Moodle page.

- **What is the main point of this reading?**
- **What information did you find surprising? Why?**
- **What did you find confusing? Why?**

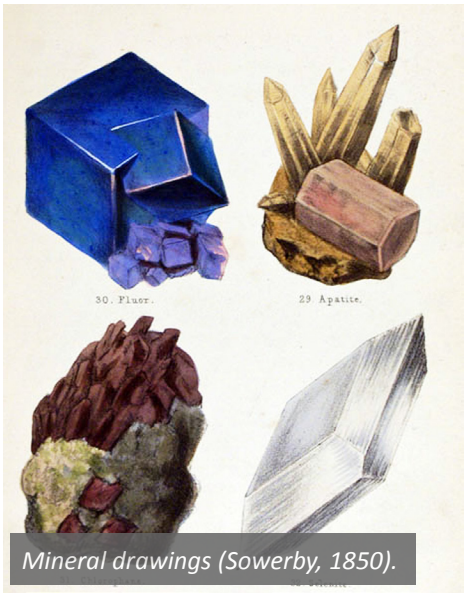
Though short and simple, these questions are based on metacognitive research and have been shown to improve learning. Reading reflections are not graded, but you will receive credit for submissions that indicate thoughtful reflection.

EDUCATION IS WHAT SURVIVES WHEN WHAT HAS BEEN LEARNED HAS BEEN FORGOTTEN.

B.F. SKINNER


CL image of 2 mm octahedral diamond.


Snowflake (snowcrystals.com).



Mineral drawings (Sowerby, 1850).

beforehand. With this method, it is entirely possible for everyone in the class to earn a letter grade of "A."

Laboratory activities are due on the assigned date. In general, you will often find that I am quite understanding if you have a schedule conflict, or have a legitimate reason for turning in late work, but you must talk to me before the fact. Unexcused late assignments will receive a lower grade.

Incompletes are granted only under unusual circumstances. If you experience extraordinary circumstances during the semester, please consult with the instructor before semester end.

## *Academic Badges*

In the Mineralogy course, students have an opportunity to earn "academic badges" that recognize their mastery of new professional skills. Because academic badges are based on criteria and evidence, they also serve as independent evidence of certification of training and accomplishment. Badges will be awarded through Moodle and can be stored in a personal "backpack" for later documentation during ones professional career.

## *Course Etiquette*

Behaviour in the course is guided by two concepts: **respect** and **responsibility**. These are not only your right, but they are also your obligation. If you honor these, both toward others and yourself, everything else will fall into place.

It is vital that everyone in the course respect the time, space, values, and ideas of each member of the learning community. Come to class and group meetings on time; remain in the room for the duration of the meeting; and be prepared, engaged, and respectful. This also includes refraining from distracting activities during class (e.g., talking, reading non-course materials, leaving the classroom).

When communicating with me, I prefer face-to-face conversation, especially when important decisions or complicated topics need to be discussed. My online Google calendar is typically up-to-date, so you can check it to find out if I am likely to be available for a meeting. Always feel free to stop by my office – the door is always open (and the chocolate jar is usually full!). All of us are busy, and from time to time, face-to-face conversation may not be convenient, so please feel free to contact me by phone, email, or chat. Last-minute e-mails, texts, and chat messages are not generally acceptable forms of communication when dialogue is appropriate and needed (e.g., to re-schedule an exam).

Cell phones and other mobile devices will be silenced and stowed (not on your lap) during class.

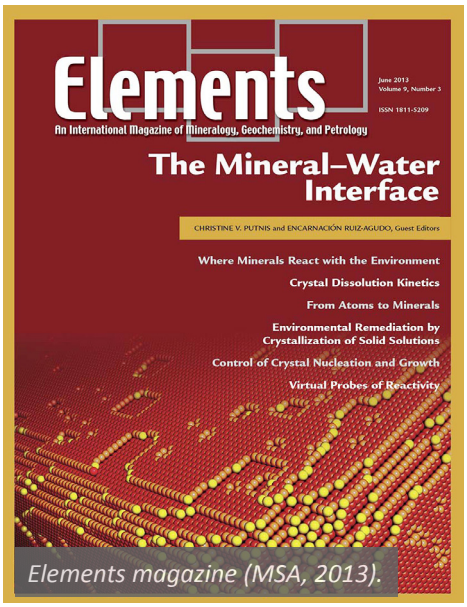
Laptop computers may be used for taking notes. There will also be times when laptops will be useful while working on projects. However, in-class laptops also present temptations that

### To Succeed in This Course

- Check the Moodle page frequently
- Meet assignment deadlines and requirements
- Communicate with me and the learning assistant
- Take responsibility for your learning
- Discover the joy of learning about the Earth

### Academic Badges

- Optical Mineralogy
- X-Ray Diffraction: Mineral ID and Characterization
- SEM-EDS: Mineral ID and Characterization
- Mineral Research Methods and Strategies



*Elements magazine (MSA, 2013).*


*Apatite crystals (D. Green).*

## What Letter Grades Mean

A = outstanding achievement

B = achievement that is above required, but not yet outstanding

C = course requirements met in every respect

D = worthy of credit, but not yet meeting requirements

NC= level of achievement not yet worthy of credit

many students find irresistible. Recent research demonstrates that the use of laptops in class reduces learning up to 20 percent, even for those near an open laptop in the classroom; please respect others in the class by not offering this distraction. You should not use a laptop during class in any way that will distract you, your classmates, or me from reaching our learning goals.

## *Academic Integrity*

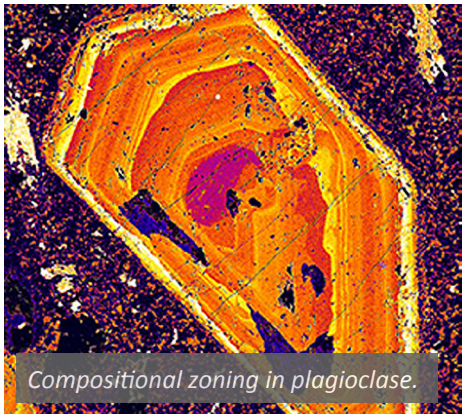
The focus of this course is on helping you to learn how to think and learn. I cannot help you learn if the work you submit is not your own. Furthermore, presenting the work of others without proper attribution is a very serious offense. Macalester "students are expected to maintain the highest standards of honesty in their college work. Forgery, cheating and plagiarism are serious offenses and students found guilty of any form of academic dishonesty are subject to disciplinary action" (consult the Academic Integrity at Macalester College website (http://www.macalester.edu/studentaffairs/studenthandbook/03academicpolicies/03-05academicintegrity.html)

## *Strategies for Learning*

As a student, you have a central role in the learning process. My role is to design opportunities that promote learning, and to provide guidance when necessary. Ultimately, it is your responsibility to set learning goals, plan your work, implement strategies for learning, and assess your progress toward your learning goals. The reflective journal assignments in this course provide opportunities to be more intentional in your thinking about becoming a self-directing learner.

## *Resources and Support*

I am committed to providing assistance to help you be successful in this course. If you encounter challenges in the course, whether they are content or skill related, or logistical in nature, I strongly encourage you to meet with me to discuss how to improve your learning. I maintain a detailed calendar outside my office door (and on Google Calendar) and welcome unscheduled visits whenever I am not in a class or a meeting. In particular, I encourage you to communicate with me if you anticipate any challenges in this course.


*Compositional zoning in plagioclase.*

## Evaluation of Learning

Final course grades will be assigned on the following percentage basis:

| | |
|---|---|
| Activities | 25 |
| Reading Reflections | 10 |
| Course Participation | 10 |
| Project Presentation & Report | 15 |
| Oral Exam | 10 |
| Mid-Term Exams | 30 |
| **TOTAL** | **100%** |

## Letter Grades

| Pts | 0 | 60 | 63 | 67 | 70 | 73 | 77 | 80 | 83 | 87 | 91 | 94 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | NC | D- | D | D+ | C- | C | C+ | B- | B | B+ | A- | A | |

## Additional Resources:

| | | |
|---|---|---|
| Allègre | (1992) | *From Stone to Star* |
| Blackburn and Dennen | (1988) | *Principles of Mineralogy* |
| Bloss | (1961) | *An Introduction to the Methods of Optical Crystallography* |
| Bloss | (1971) | *Crystallography and Crystal Chemistr* |
| Carmichael | (1989) | CRC Practical Handbook of *Physical Properties of Rocks and Minerals* |
| Cox | (1989) | *The Elements* |
| Cullity | (1978) | *Elements of X-Ray Diffraction* |
| Dyar, Gunter, and Tasa | (2008) | *Mineralogy and Optical Mineralogy* (Mineralogical Society) |
| Ehlers | (1987) | *Optical Mineralogy - V. I. Theory and Technique* |
| Frye | (1974) | *Modern Mineralogy* |
| Greenwood and Earnshaw | (1984) | *Chemistry of the Elements* |
| Griffen | (1992) | *Silicate Crystal Chemistry* |
| Klein | (1989) | *Minerals and Rocks - Exercises in Crystallography, Mineralogy, and Hand Specimen Petrology* |
| Klein | (2002) | *Mineral Science* - After James D. Dana (22nd edition) |
| Klein and Philpotts | (2013) | Earth Materials: Introduction to Mineralogy and Petrology |
| MacKenzie and Guilford | (1980) | *Atlas of Rock-Forming Minerals in Thin Section* |
| Mason and Berry | (1968) | *Elements of Mineralogy* |
| Nesse | (2004) | *Introduction to Optical Mineralogy (3rd edition)* |
| Perkins | (2011) | *Mineralogy* |
| Phillips and Griffen | (1981) | *Optical Mineralogy - The Nonopaque Minerals* Mineralogical Society |
| Stoiber and Morse | (1972) | *Microscopic Identification of Crystals* |
| Wenk and Bulakh | (2004) | *Minerals: Their Constitution and Origin* |
| Wood | (1977) | *Crystals and Light - An Introduction to Optical Crystallography* |
| Zoltai and Stout | (1984) | *Mineralogy: Concepts and Principles* |

## Recommended Supplies:

Hand lens (10x)
Colored pencils (red, blue, and yellow)

### Reading

- read with a purpose, for information, concepts, and application
- scan the text for the overall structure and organization
- preview before reading for the general idea (introduction, figures, tables, diagrams, photos, conclusion)
- annotate (avoid highlighting entire lines or paragraphs; underlining does very little to help you learn, but the process of deciding what to underline can promote learning)
- ask questions after reading (e.g., change each heading or title into a question; see if you can answer these after reading)
- re-read to check for understanding (summarize/paraphrase in your own words, connect with other things you already know, explain to others)

### Accommodations for Learning

I am committed to ensuring access to course content for students. Reasonable accommodations are available for students with documented disabilities. Contact the Office of Student Affairs, 651-696-6220 to schedule an appointment and discuss your individual circumstances. It is important to meet early in the semester; this will ensure that your accommodations can an implemented early on. The Assistant Dean of Students, Robin Hart Ruthenbeck, coordinates services for first, second and third year students, as well as seniors new to accommodations. The Associate Dean of Students, Lisa Landreman, coordinates students for seniors.

### Support from the MAX Center

The Macalester Academic Excellence (MAX) Center (x6121; Kagin Commons) is here to help you do your best at Macalester in meeting your own goals and highest standards. Through academic enrichment and support services, ranging from workshops to individual assistance, the MAX Center can help you excel in your academics. Professional counselors and peer tutors in writing, mathematics, science, and study skills provide personal assistance in:

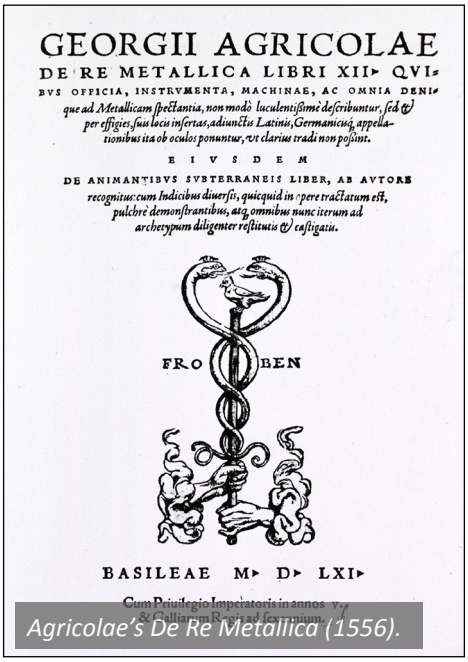
- Writing for any college course,
- Content areas such as calculus, organic chemistry, or cell biology
- Sharpening study and time management skills

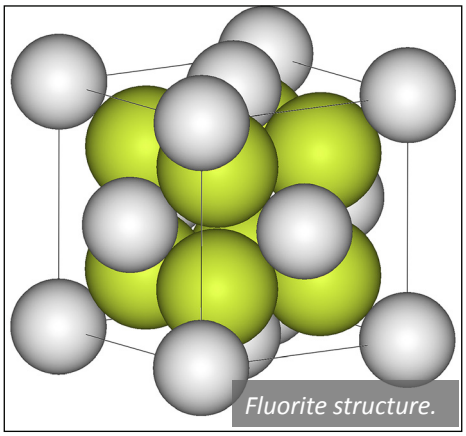
General hours are 9:00 A.M. – 4:30 P.M., M-F and 7 P.M. – 10 P.M., S-Th. Peer tutors are usually available in all areas during the evening. The MAX Center also provides testing accommodations. Students must verify the need for accommodations through the Dean of Students Office.

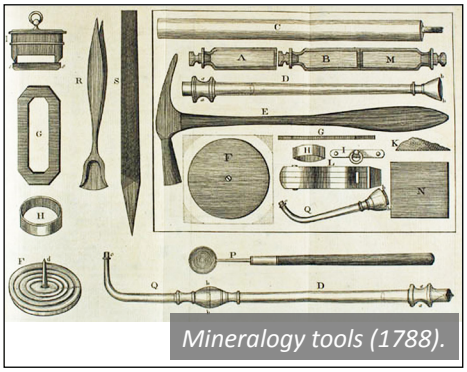
## Course Schedule

A detailed schedule of the course will be maintained on the Moodle course page. Below is a general outline of the topics and activities in the course.

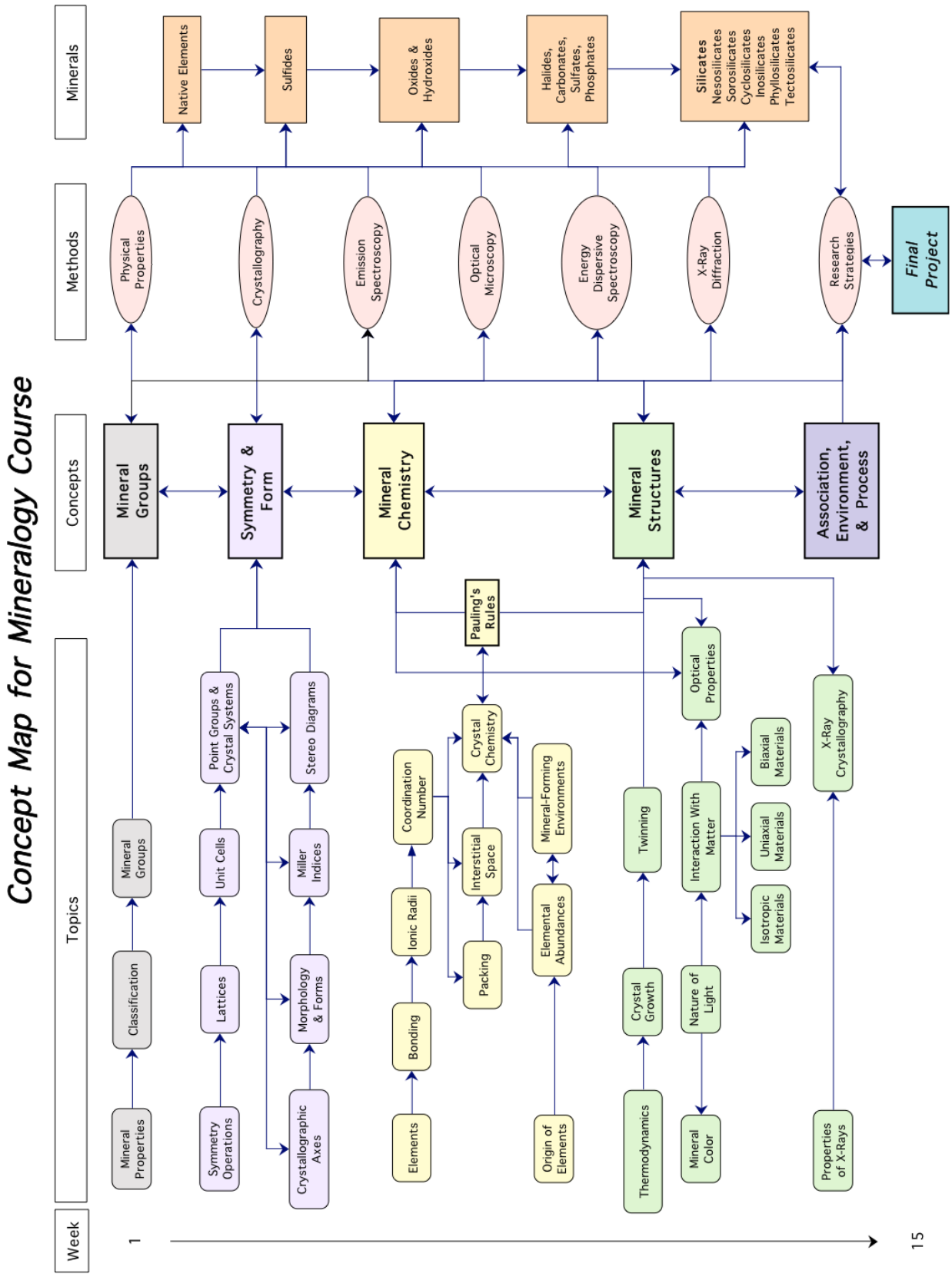
| Week | Date | Topics |
|---|---|---|
| Week 01 | 31 Aug | Introduction to mineralogy, mineral properties, classification, and groups |
| Week 02 | 07Sept | Atomic Structure and crystal symmetry |
| Week 03 | 14 Sept | Packing, interstitial space, and projection |
| Week 04 | 21Sept | Coordination and composition |
| Week 05 | 28 Sept | Growth, twinning, and interactions with light<br>Mid-Term Exam I<br>Mineralogy Fieldtrip (04 October) |
| Week 06 | 05 Oct | Isotropic minerals – Malted Milk Balls? |
| Week 07 | 12 Oct | Uniaxial minerals – Plain or Peanut? |
| Week 08 | 19 Oct | Optics Continued<br>Mid-Semester Break |
| Week 09 | 26 Oct | Biaxial minerals – Baking Potatoes Anyone? |
| Week 10 | 02 Nov | Imaging atoms with X-rays |
| Week 11 | 09Nov | Orthosilicates and project<br>Mid-Term Exam II |
| Week 12 | 16 Nov | Sorosilicates, cyclosilicates, inosilicates, and project |
| Week 13 | 23 Nov | Inosilicates, phyllosilicates, and project<br>Thanksgiving Break |
| Week 14 | 30 Nov | Tectosilicates and project |
| Week 15 | 07 Dec | Mineral Conference (8:00-10:00 on 11 Dec). |
| Week 16 | 14 Dec | Mid-term Exam III<br>Oral exams (scheduled during finals week) |


GEORGII AGRICOLAE
DE RE METALLICA LIBRI XII▸ QVI▸
BVS OFFICIA, INSTRVMENTA, MACHINAE, AC OMNIA DENI▸
que ad Metallicam spectantia, non modò luculentissimè describuntur, sed &
per effigies, suis locis insertas, adiunctis Latinis, Germanicisq; appella-
tionibus ita ob oculos ponuntur, vt clarius tradi non possint.
EIVSDEM
DE ANIMANTIBVS SVBTERRANEIS LIBER, AB AVTORE
recognitus: cum Indicibus diuersis, quicquid in opere tractatum est,
pulchrè demonstrantibus, atq; omnibus nunc iterum ad
archetypum diligenter restitutis & castigatis.
FROBEN
BASILEAE M▸ D▸ LXI▸
Cum Priuilegio Imperatoris in annos VV
& Galliarum Regis ad sexennium.
*Agricolae's De Re Metallica (1556).*


*Fluorite structure.*


*Mineralogy tools (1788).*


*Wooden crystal models (1880).*


Concept Map for Mineralogy Course
Week
Topics
Concepts
Methods
Minerals
1
15
Mineral Properties
Classification
Mineral Groups
Symmetry Operations
Lattices
Unit Cells
Crystallographic Axes
Morphology & Forms
Miller Indices
Point Groups & Crystal Systems
Stereo Diagrams
Elements
Bonding
Ionic Radii
Coordination Number
Packing
Interstitial Space
Crystal Chemistry
Origin of Elements
Elemental Abundances
Mineral-Forming Environments
Paulling's Rules
Thermodynamics
Crystal Growth
Twinning
Mineral Color
Nature of Light
Interaction With Matter
Isotropic Materials
Uniaxial Materials
Biaxial Materials
Optical Properties
Properties of X-Rays
X-Ray Crystallography
Mineral Groups
Symmetry & Form
Mineral Chemistry
Mineral Structures
Association, Environment, & Process
Physical Properties
Crystallography
Emission Spectroscopy
Optical Microscopy
Energy Dispersive Spectroscopy
X-Ray Diffraction
Research Strategies
Final Project
Native Elements
Sulfides
Oxides & Hydroxides
Halides, Carbonates, Sulfates, Phosphates
Silicates
Nesosilicates
Sorosilicates
Cyclosilicates
Inosilicates
Phyllosilicates
Tectosilicates