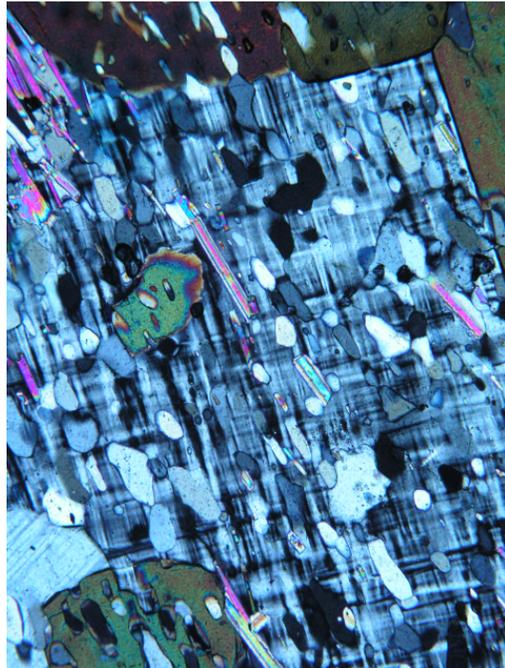


ERTH301 Mineralogy: Course Description and Syllabus

Welcome to Mineralogy! In this course you will learn about the structure and chemical makeup of Earth materials. We will investigate minerals over a range of scales, from macroscopic to microscopic. Since this is a geology course, we will investigate how geologic materials and processes influence mineral occurrence, stability, and composition. The course is divided into three modules. The first introduces key concepts in crystal chemistry and symmetry, the second presents the fundamentals of optics and X-ray diffraction as techniques central to the identification and characterization of minerals, and the third introduces us to major rock-forming minerals in a systematic progression, concluding with discussion of crystal nucleation and growth.

Learning Objectives

The Department of Earth Sciences defines five learning objectives for the undergraduate degree program related to the relevance of geology and geophysics, the acquisition of technical knowledge, implementation of the scientific method, developing oral and written skills, and understanding the basic principles of science. This course objectives encompass three levels of maturity in all five categories, by *introducing* computer applications relevant to mineral sciences; *developing* understanding of the impact of geology and geophysics to understanding Earth, articulating scientific problems, applying scientific ethics, exploring the basic tenets of geologic and geophysical sub-disciplines, and learning how these disciplines relate to other basic sciences; and gaining *proficiency* in the application of math, physics, chemistry, laboratory methods, critical analysis, problem-solving, and explaining complex phenomena. Specific learning objectives are listed at the end of this syllabus.



Essential Info

Credits: 4

Semester: Fall 2020

Lecture time and place: MWF 11:30 am- 12:20 pm POST 703

Lab: Tuesday 1:30 – 4:20 pm in POST 703

Instructors:

Dr. Julia Hammer

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phone: 956-5996

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office hours: scheduled upon request

TA: TBD

office: ____ email: ____

Course Prerequisites

ERTH200; CHEM 162 and CHEM 162L *or* CHEM 171 and CHEM 171L *or* CHEM 181A and CHEM 181L

Texts: Required: Nesse *Introduction to Mineralogy* any edition. Look for used copies of the 1st Ed. at Amazon.com. The bookstore should have the 3rd Ed.

Many students find these **optional** resources helpful: 1. Perkins *Mineralogy 2nd Ed.*, 2. Klein *Manual of Mineral Science 22nd Ed.*, 3. Deer, Howie, and Zussman, *An Introduction to the Rock Forming Minerals*, 4. Nesse *Optical Mineralogy, 2nd Ed.*

Other Required Materials

Students are required to purchase a **ERTH301 Workbook**, consisting of loose-leaf homework assignments and lab exercises that we will need this semester. The cost of this workbook is ~\$25 (exact amount TBD) and is available for purchase (cash only) from the Departmental Administrator in POST 701.

You are required to obtain a **hand lens** for this course. You will use this tool frequently, not only in this class, but also in many of the upper division geology courses. (A geologist always has a hammer, notebook or tablet, and a hand lens when going into the field.) Look for a handheld lens that is 13-20 mm in diameter, providing 10x or 15x magnification. Order your lens from the web site Amateur Geologist (<http://www.amateurgeologist.com/>) or a similar vendor of geological supplies.

Learning Opportunities

Expectation for Lecture preparedness

Use of the **texts** and all supplemental reading is critical. Lecture will not be a forum where basic material from the text is reiterated. During lecture we will clarify parts of the reading that are not being understood, develop concepts from the text, and work together to solve problems. You are required, therefore, to read the assigned text *before* class. This will be reinforced using **questions to be answered before class** using the Laulima site for this course. We may also use a phone-ready **polling app**, Poll Everywhere, to assess participation and lecture preparedness. Bring a **calculator** to class each day. We will work problems out in real-time together. To every class and lab meeting, **bring colored pencils, pens, and a stapler**.

Lab

Lab is scheduled for 3 hours on Tuesday afternoons. Several of the labs explore lecture material by directing your observations of mineral specimens. We will also use calculations, computer programs, and physical models to learn concepts. Labs will be integrated with lecture material to the greatest possible extent, usually following what we have discussed in lecture. Therefore, lab material will be incorporated with lecture material for the exams.

All labs are designed to take 3-5 hours to complete. Students who arrive prepared, having read the lab assignment, read the associated text, and completed any pre-lab exercises, *may* finish the lab activity during the 3-hour session. You will be given access to POST 703 and POST 733 after hours, and you should anticipate spending additional time on many of the labs. **Labs should be handed in on time**. Unless there is a good excuse, late penalties (including zero credit) apply.

Homework

Concepts that are introduced in reading and lecture are developed in frequent (typically weekly) homework assignments. Sometimes, an assignment will be given with a due-date of the very next class meeting (48h later). These homework assignments are intended to give

you practice solving problems by developing specific skills. They are also a good indication of how exam questions are worded, and thus provide excellent study materials. Every attempt will be made to return graded homework assignments or their keys prior to exams.

Assessments

Grading (number of assessments and contribution of each to course grade)

Labs (15 @ 2% each)	30%
Midterm Exams (2 @ 10% each)	20%
Final Exam (1 @ 10%)	10%
Homework (usually 15 @ 1.33% each)	20%
Reading Questions answered on Laulima (usually 27 assignments @ 0.37% each)	10%
Lecture preparedness (tools variable)	10%

Title IX information

The University of Hawai'i is committed to providing a learning, working and living environment that promotes personal integrity, civility, and mutual respect and is free of all forms of sex discrimination and gender-based violence, including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence, and stalking.

If you or someone you know is experiencing any of these, the University has staff and resources on your campus to support and assist you. Staff can also direct you to resources that are in the community. Here are some of your options:

- As members of the University faculty, your instructors are required to immediately report any incident of potential sex discrimination or gender-based violence to the campus Title IX Coordinator. Although the Title IX Coordinator and your instructors cannot guarantee confidentiality, you will still have options about how your case will be handled. Our goal is to make sure you are aware of the range of options available to you and have access to the resources and support you need.

- If you wish to remain ANONYMOUS, speak with someone CONFIDENTIALLY, or would like to receive information and support in a CONFIDENTIAL setting, use the confidential resources available here:

<http://www.manoa.hawaii.edu/titleix/resources.html#confidential>

- If you wish to directly REPORT an incident of sex discrimination or gender-based violence including sexual assault, sexual harassment, gender-based harassment, domestic violence, dating violence or stalking as well as receive information and support, contact: Dee Uwono Title IX Coordinator (808) 956-2299 t9uhm@hawaii.edu.

If you have a **disability** and related access needs, the Department will make every effort to assist and support you. For confidential services students are encouraged to contact the Office for Students with Disabilities (known as Kōkua) located on the ground floor (Room 013) of the Queen Lili'uokalani Center for Student Services. If you need disability-related accommodations, please notify the KOKUA Program (808) 956-7511 or email: kokua@hawaii.edu.

ERTH301 Mineralogy: learning objectives

Specific examples of the course learning objectives are described below for each of three modules.

1. Crystal Chemistry and Symmetry

Topics: Crystal chemistry (parts of the atom, abundance of elements, chemical bonding, sizes of atoms and ions, coordination), crystal structure (relationship between structure and bond types, application of Pauling's rules, polymorphism, mineral classification, compositional variation, formulas, graphical representation in binary and ternary diagrams). Symmetry includes translational symmetry, point symmetry, laws governing formation of crystal faces, Miller indices, definition of crystal forms, crystal habit.

Contact time: Ten lectures and four labs

Learning resources:

1. Reading in Nesse: CH 2, 3, 4.
2. Demonstrations using specimens and interactive visualizations.
3. Homework assignments.
4. Guided laboratory exercises.

Student Learning Objectives

During this module you will:

1. Describe periodicity in the chemical characteristics of elements listed in order of increasing atomic number or mass.
2. Predict element substitutions in minerals using chemical characteristics (electronegativity, ionic size, valence, etc.), and define element substitutions in common solid solution series as simple, coupled, omission, or interstitial.
3. Hypothesize which minerals have similar characteristics (physical and optical properties) on the basis of their chemical formulas, thereby demonstrating understanding the importance of anionic groups.
4. Solve chemical word problems, demonstrating the ability to manipulate units and convert moles to mass and vice versa.
5. Demonstrate understanding of phase diagrams for any one-component system: anticipate reactions that occur due to a change in temperature or pressure, describe difference between displacive and reconstructive polymorphs, discuss element ordering on atomic sites in the formation of polymorphs.
6. Apply Pauling's rules to commonly occurring anionic groups to predict which groups form polymers.
7. Repeat a motif by applying symmetry operators in 2D and 3D and recognize symmetry operators in 2D patterns and 3D blocks.
8. Use symmetry content of 2D and 3D structures to identify the appropriate plane group or point group.
9. Define a lattice plane using Miller index notation, or conversely, use the Miller index to identify a set of parallel lattice planes.
10. Explain why planes having low-Miller index values dominate crystal shapes.
11. Identify primitive and non-primitive unit cells.
12. Identify by name common forms in isometric and non-isometric crystal systems.
13. Identify forms by name on wooden blocks and from perspective drawings of blocks/crystals.
14. Plot a mineral's composition in a ternary classification diagram.

2. Optical Mineralogy and X-ray diffraction

Topics: properties of polarized light, interaction of light with matter, petrographic microscope parts and purposes, isotropic and anisotropic materials, birefringence, the uniaxial and biaxial optical indicatrices, color and pleochroism, extinction angle and sign of elongation, optic sign, index of refraction.

Contact time: Eleven lectures and five labs.

Learning resources:

1. Reading: Nesse CH7 and 8.
2. Reading: RIMG vol. 78
3. Demonstrations of Becke line test, relief, and refractive index determination.
4. Optical properties demonstrations using plagioclase feldspar and tourmaline.
5. Guided laboratory exercises.
6. Homework exercises.

Student Learning Objectives

15. Demonstrate understanding of the distinctions between light velocity, vibration direction, propagation direction, and wavelength.
16. Perform the Becke line test to determine which of two materials has a greater index of refraction.
17. Manipulate Snell's law, e.g., to compute angles of incidence and refraction given RI of materials separated by an interface.
18. Manipulate the birefringence equation to solve for retardation, thickness or birefringence.
19. Use the Michel-Levy chart to determine the birefringence of a mineral of given thickness and interference color when viewed under crossed polarizers.
20. Categorize a mineral's optical character as isotropic, uniaxial, or biaxial, given only its crystal system.
21. Demonstrate understanding of the uniaxial and biaxial indicatrices.
22. Use the petrographic microscope to determine a mineral's sign of elongation, birefringence, optic sign, pleochroic scheme, extinction angle, and relief.
23. Put into practice a time-conservative approach for identification of an unknown mineral using optical characteristics.
24. Develop understanding of crystallographic information describing mineral structures and know how it relates to physical properties.
25. Use crystallographic software to visualize crystal structures and analyze bonding and coordination.
26. Understand basic principles of X-ray diffraction experiment, learn to use software for evaluation of diffraction data, and be able to apply this knowledge to simple phase identification.

3. Systematic Mineralogy

Topics: framework silicate minerals (silica group, feldspar group, zeolite group), sheet silicates (classification of layer silicates, clay minerals), chain silicates (pyroxene group, amphibole group), disilicates and ring silicates (zoisite group, beryl, cordierite, tourmaline), orthosilicates (olivine group, garnet group, aluminum silicates), carbonates, sulfates, oxides, hydroxides, halides, sulfides, native elements). We will also discuss mineral stability,

kinetic theory, crystal nucleation, effects of rate on crystal morphology and zoning, defects, subsolidus processes (ordering, twinning, recrystallization, exsolution, pseudomorphism)

Contact time: Seventeen lectures and six labs

Learning resources:

1. Reading in Nesse: CH 5, 6, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20 (selected pages)
2. Supplemental discussions of pyroelectricity, magnetism, mineral breakdown reactions, color, economic ore bodies, and geochronology, focusing on fluorite, Fe-Ti oxides, hornblende, azurite, malachite, zircon, water ice and clathrates.
3. Guided laboratory exercises.
4. Homework exercises.

Student Learning Objectives

27. Demonstrate understanding of crystal aggregate types in classifying microcrystalline silica minerals.
28. Explain geologic formation environments of silica polymorphs using a P-T diagram.
29. Use a silicate mineral's formula to form a hypothesis about its structure.
30. Explain, with the aid of a phase diagram, the process of compositional unmixing that typifies feldspar group minerals, including a discussion of cation ordering.
31. Identify types of mineral twins in feldspar thin sections, and use twin properties to estimate composition.
32. Relate the structural features of zeolites to their widespread utilization and synthesis in industrial applications.
33. Relate the microscopic structures of single and double chain silicates to their (macroscopic) diagnostic cleavage.
34. Utilize appropriate charts to infer compositional constraints on olivines, pyroxenes, and amphiboles from their optical properties.
35. Organize information regarding optical properties, physical properties, and chemical formulae into a table to be used for identification of unknown minerals. Augment the table with personal observations.
36. Determine whether a layer silicate is dioctahedral or trioctahedral in structure by inspection of mineral formula.
37. Explain how anisotropy of seismic wave propagation in olivine can be used to study mantle flow.
38. Explain how occurrence of aluminum silicate minerals in a metamorphic rock preserves the tectonic history of a terrane.
39. Give one example of how the distribution of valence electrons in different energy levels is related to mineral color.
40. Summarize the carbonate mineral group in terms of (a) geologic occurrences, (b) compositional classification and common substitutions, (c) shared physical and optical properties, and (c) polymorphism.
41. Determine the rate-limiting step in crystal growth by inspecting crystal morphology.
42. Explain why slow-growing faces inevitably dominate crystal shape, and discuss theories explaining why some faces grow more slowly than others.
43. Utilize a liquidus binary T-X phase diagram to describe evolution in crystal and liquid composition during cooling, considering two cases: equilibrium and fractional crystallization.

44. Distinguish between different types of crystal defects (point, line, planar, and surface) and discuss their roles in chemical substitutions, rock deformation, and physical properties of rocks.
45. Describe the process of compositional unmixing by drawing a subsolidus binary T-X diagram and tracing the fate of an initially homogeneous pyroxene during cooling. Explain how such a diagram can be used to constrain thermal history of a volcanic rock.

