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. You will receive training in best practices of scientific writing. You'll engage with the material through laboratory exercises, which will be submitted as reports and evaluated as articles of scientific writing. 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.

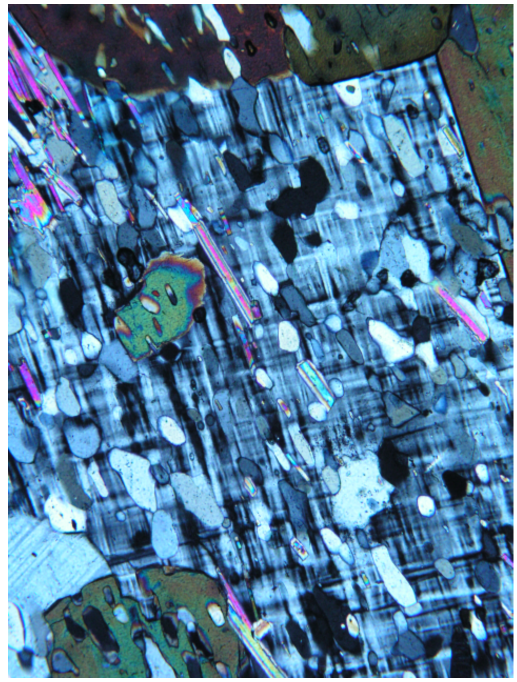
Learning Objectives

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 communication skills, and understanding basic geologic principles. 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 and articulating scientific data and interpretations in a written format, 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 for each of the three major modules at the end of this syllabus.

In satisfaction of the **Writing Intensive** (W) focus designation, the course has additional learning objectives. These are articulated below, along with the vehicle we will use in this course to achieve them.

Writing Learning Objective (WLO)	Technique
WLO1. Adapt writing to a clearly identified purpose and audience, according to disciplinary conventions and genres	The Lab Reports will be tailored for an audience of subject matter experts with no prior familiarity with the specimens on which you are working.
WLO2. Develop and organize appropriate and relevant content	You will receive training (through reading assignments and in-class reinforcement) on the best-practices of formal scientific writing, which is highly structured. A properly organized Lab Report is structured like an argumentative essay, with separate sections for presenting objective observations, subjective interpretations, and analytic conclusions.
WLO3. Evaluate and integrate supporting materials from appropriate sources, and credit them appropriately according to the genre and discourse requirements of the field	Mineral description and identification tasks require you to consult multiple sources (textbooks, journal articles, class notes, and accredited website such as Mindat.org), and to cite them appropriately.
WLO4. Control style and mechanics to communicate effectively	Clarity of expression is prioritized in all scoring rubrics. This includes (but is not limited to) deploying conventional grammar, minimizing jargon and verbosity, and establishing coherence at the paragraph level.

Essential Info



Credits: 4. Enrollment cap: 20
Lecture time and place: MWF 11:30 am- 12:20 pm on Zoom or as indicated
Lab: Tuesday 1:30 – 4:20 pm on Zoom (or in POST 703, if it is safe to meet in-person)

Instructors:
Dr. Julia Hammer
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phone: 808-389-8753
email: jhammer@hawaii.edu
office hours: scheduled upon request

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

Texts: **Required:** Nesse, William D. *Introduction to Mineralogy* any Edition.
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

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 of 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 class 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* meeting. This will be reinforced using **questions to be answered** using the Laulima site for this course. Bring a **calculator** to class each day. We will work problems out in real-time together. To every class and lab meeting, **have 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.

Your lab activities include a written component (averaging 250 words in prose format) constituting ~30% of each lab grade. In many cases, the written component is your opportunity to objectively describe a specimen using appropriate terminology— including its physical properties: morphology and habit, luster, density, and hardness; optical properties: relief, pleochroism, birefringence, optic sign, 2V angle; and associations with other minerals in the rock—and to integrate these observations with lecture-based and reading-based knowledge to identify the mineral. Adopting this 'forensic' approach to formulate argumentative essays, students build reasoning and communication skills along with technical skills.

Before labs, you will receive instruction about the specific style and format requirements, adhering to scientific best practices. In particular, we will study and adhere to the guidance set forth by Gopen and Swan (Gopen and Swan, 1990) and the Duke Scientific Writing Resource (School, n.d.) (https://sites.duke.edu/scientificwriting/). You will receive feedback from the instructor on a significant fraction of submitted materials. Lab reports will be scored using rubrics that evaluate the quality of three components in each written piece: grammar, style, and content.

All lab activities (not counting write-ups) are designed to take 3 hours to complete. Students who arrive prepared, having read the lab assignment, read the associated text, and completed any pre-lab exercises, usually finish the lab activity during the 3-hour session. As safety permits, 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). The 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.

Zoom etiquette

If class needs to be held over synchronous zoom, please participate with your camera and microphone both **on**. If there is any extraneous noise in your environment, you may turn your microphone off.

Assessments

Lab Reports	40%
Midterm Exams (2 @ 8% each)	16%
Final Exam (1 @ 8%)	8%
Homework (~15)	20%
Reading Questions	10%
Preparedness and Engagement	6%

letter	score
A+	≥96.7%
A	93.3%
A-	90.0%
B+	86.7%
B	83.3%
B-	80.0%
C+	76.7%
C	73.3%
C-	70.0%
D+	66.7%
D	63.3%
D-	60.0%
F	<60.0%

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 Liliʻuokalani Center for Student Services. If you need disability-related accommodations, please notify the KOKUA Program (808) 956-7511 or email: kokua@hawai.edu.

References Cited

Gopen, G.D., Swan, J.A., 1990. The Science of Scientific Writing. Am. Sci. 78, 550–558.

Duke University Graduate School. Scientific Writing Resource in Three Lessons. https://sites.duke.edu/scientificwriting/ accessed 02-02-2022.

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 and engagement instruments

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

Student Learning Objectives (10 selected)

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. Demonstrate understanding the importance of anionic groups by explaining why minerals sharing the same anionic group have similar physical and optical properties.
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. Define a lattice plane using Miller index notation, or conversely, use the Miller index to identify a set of parallel lattice planes.
9. Explain to a non-specialist, in writing, why planes having low-Miller index values dominate crystal shapes.
10. Identify forms by name on wooden blocks and from perspective drawings of blocks/crystals.

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 and engagement instruments

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

Student Learning Objectives (10 selected)

11. Demonstrate understanding of the distinctions between light velocity, vibration direction, propagation direction, and wavelength.
12. Perform the Becke line test to determine which of two materials has a greater index of refraction.
13. Manipulate Snell's law, e.g., to compute angles of incidence and refraction given RI of materials separated by an interface.
14. Manipulate the birefringence equation to solve for retardation, thickness or birefringence.
15. Use the Michel-Levy chart to determine the birefringence of a mineral of given thickness and interference color when viewed under crossed polarizers.
16. Categorize a mineral's optical character as isotropic, uniaxial, or biaxial, given only its crystal system.
17. Use the petrographic microscope to determine a mineral's sign of elongation, birefringence, optic sign, pleochroic scheme, extinction angle, and relief.
18. Develop and articulate in writing a time-conservative and systematic approach for identification of an unknown mineral using optical characteristics.
19. Develop understanding of crystallographic information describing mineral structures and know how it relates to physical properties.
20. 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 and engagement instruments

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 and reports.
4. Homework exercises.

Student Learning Objectives (10 selected)

21. Explain geologic formation environments of silica polymorphs using a diagram of the phase relationships in pressure-temperature space.
22. Form and defend a hypothesis about the structure of a silicate mineral using only the knowledge of its chemical formula.
23. Articulate in writing the process of compositional unmixing that typifies feldspar group minerals, including a discussion of cation ordering.
24. Relate the structural features of zeolites to their widespread utilization and synthesis in industrial applications.
25. 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.
26. Explain how occurrence of aluminum silicate minerals in a metamorphic rock preserves the tectonic history of a terrane.
27. Discuss, in writing, 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.
28. Explain why slow-growing faces inevitably dominate crystal shape and discuss theories explaining why some faces grow more slowly than others.
29. 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.
30. 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.