Goals: To provide a sound introduction to mineralogic concepts that are important for modern geoscientists with a wide range of intended fields of specialization, including environmental geology and space sciences. Topics of particular concern are crystal chemistry, basic symmetry and structure of crystals (minerals), basic X-ray diffraction of crystalline materials, fundamental information on the important mineral groups (definition of the groups; composition, structure, physical properties, occurrence, and usage of major mineral species), and optical microscopy. By the end of the course, the student should have a fundamental knowledge of the major mineral groups, the geologic and chemical relations among minerals, and the importance of earth materials to the broader fields of geoscience and environmental science.

Pre-requisites for course: prior completion of EPSc 201A and first-semester college chemistry.

Class time: 3 lectures (MWF 10-10:45am) and 1 two-hour lab (Mon 3:00 - 4:45pm or Tues 3:00 - 4:45pm) scheduled per week. Note: students will spend several additional hours per week “in the lab” or working remotely on lab materials/assignments.

Texts: One text is required, which – ideally – includes an accompanying CD-ROM:

Graduate Student Assistant to the Instructor (AI):

Ph.D. graduate student Greg Ledingham, Rudolph Hall, room 250; preferred contact is via e-mail: greg.ledingham@wustl.edu ; tel./texting: (303) 746-2513. Office hours: TBA.

Communication through Canvas
Posting of assignments, questions for lab reports, lecture notes, lecture slides, blank copies of slides for your own notes, etc. will be on Canvas. Class e-mails will come through Canvas.

Dates to remember: (Those with religious, sports, academic, or other personal obligations at any of the times listed below, please speak with Jill as soon as you realize the time conflict. Appropriate arrangements will be worked out. We will be as flexible as possible!)

Monday, Sept. 14: First day of class.
Friday, October 2: Homework #1 due.
Friday, October 9: Homework #2 due.
Wednesday, October 21: Homework #3 due.
Wednesday, October 28: First exam. Exactly when on that day, where, etc. TBA.
Monday, November 16: Homework #4 due.
Wednesday, November 25: Second exam. Morning? TBA.
Thursday-Friday, November 25-26: Thanksgiving holiday.

Continued...
Monday, November 30: **first draft of your term paper due.** Paper copy preferred; digital copy accepted.

Monday, Dec. 7: **Homework #5** due.

Friday, December 18: Last day of classes

**Monday, December 21: Final version of term paper due by 10:00am.**

**Wednesday, January 6: Final Exam, on-line, at 10:30am - 12:30pm.**

Requirements of the course:

- **Class attendance is required** in person or on-line (attendance will be taken).

- Other requirements: reading of assigned materials; 2 during-semester exams, final exam; several written homework assignments; participation in weekly labs, written materials checked & graded by AI/professor; one term paper with about 15 double-spaced pages of text (+ bibliography, figures, tables).

- Students are expected to respond to questions asked by the professor in class. Occasional pop quizzes may be given to alert students to the kinds of specific materials that they need to know and understand.** [**see next page**]

- Class and lab assignments must be handed in on the date due in order to receive full credit; **penalty for unexcused lateness is 5% per day.** Please coordinate (ahead of time, if possible) with the professor if a time conflict arises.

**Professor’s Office hours:**

I usually keep my office door open (Rudolph Hall, rm. 233) for questions as students see fit. I post notes on the door to tell people where they can find me. I definitely encourage students to come and talk to me about: questions relating to the class material, perceived difficulties in the course, suggestions for changes in the course, mineralogic topics of interest to them, etc. Tel. 314-935-5434; e-mail: pasteris@levee.wustl.edu Given the COVID situation, I will get input from the class about more ways to connect.

* Please do not use electronic devices (e.g., computer, tablet, cell phone) without professor’s permission while attending lecture in person. No electronic devices should be on or in view during a quiz or exam – without professor’s (forewarned) permission.* More than one study has shown that students retain lecture information better when they write their notes by hand compared to typing them in class. Electronic devices also are a distraction to others in the room.
Grading in the Course

My intention is to weight the "activities" of the course as follows**:

- 20% for homework
- 20% for during-semester exams (2 of these)
- 25% for labs (after dropping each student's lowest lab grade)
- 15% for the term paper
- 20% for the final exam

Special Accommodations for Test-Taking

If you have a “visa” from the WU Disability Resources Testing Team/Cornerstone/The Learning Center for special accommodations during test-taking, please let Jill know as soon as possible. We want to be sure to have in place the resources needed for your test-taking under the appropriate conditions.

Positive points

**I think that class participation is important. Therefore, I use it as a “positive increment” factor. A student’s grade can be elevated by as much as one grade increment (e.g., from B+ to A-) by consistent participation in class discussions and questions, handing in voluntary assignments (announced in class), and by doing well on pop quizzes (the latter two of which will be awarded “positive points”). For your information, in past years, I have had as many as 3 out of 20 students raise their grades one notch by availing themselves of these positive-point opportunities.

COVID Accommodations

All students are required to wear masks, practice social distancing, and obey room-specific safety instructions when in Rudolph Hall. If you have any indication that you are ill, please do NOT come to class/lab. Please let us know that you are staying home, so that we do not worry about you.

Class lectures and labs will be video-recorded in case you are unable to attend in person. However, with a hands-on course like Earth Materials, you will get more out of attending in person than on-line – if that is feasible. The handling of class presentations and the expectations for students will be adjusted to meet the circumstances of both students present in person and students attending remotely. Please let us know if class presentations or interactions are not working well for you. We will work hard to see if we can improve the situation for you.

Some details of the operation of the course are still being worked out. We are remaining flexible and want to discuss options with all of you when practical.
Some Suggestions for Topics for the Term Paper on Earth Materials

First written draft due Nov. 30th; final version due December 21st. The following are just suggestions; you are welcome to choose other topics. Please discuss your topic with Jill – even if you choose it from this list -- before beginning any major research.

Topics in “Classical” Mineralogy and Inorganic Solids

--Mineralogy and formation of opal, graphite, or other mineral

--Formation of "salt" (evaporite) deposits, bauxite (Al) deposits, or analogous deposits

--Natural and synthetic forms of silica

--Some aspect of crystallization of solids from melt or aqueous fluid

--Some selected aspect(s) of the cause of color in minerals, only if you have a good physics background (conduction-band theory)

--Detailed discussion of the smelting process of some type of ore, e.g., iron oxides or copper sulfides

--Formation of soil (need to focus on some aspect or types)

--A chemical/structural analysis technique for minerals or rocks, e.g., X-ray fluorescence, transmission electron microscopy, electron microprobe analysis, infrared spectroscopy, Raman spectroscopy. Need to illustrate applications of this technique.

--Formation of dolomite

--Some aspect of deformation or recrystallization in metamorphic rocks

--Metamictization (radiation damage) in a mineral(s)

--High-pressure phase(s) assumed to exist in the earth’s mantle

--Chemical diffusion in minerals

--Aerogels

--Graphene

--Vapor-deposited diamond films

--Formation of nanocrystals
--Causes of compositional (or other type of) zoning in minerals

--Formation of sulfide “chimneys” at ocean-ridge spreading centers (challenging topic)

--Industrial process of converting rock (“ore”) into usable metal (Cu or Fe or Al, etc.)

**Topics in Biological and Environmental Mineralogy**

--Biomineralization, i.e., production of “minerals” by living organisms; will need to focus more

--Natural mineral composites, e.g., bone, tooth, carbonate shells

--Formation of minerals in the body – what, where, why, how analyzed; e.g., kidney stones

--Processing of natural phosphates into fertilizer and the environmental impacts of this process

--Remediation use of apatite (Ca phosphate) to collect and sequester heavy metals

--Development of rock-like materials to contain nuclear waste (e.g., SYNROC)

--Some aspect(s) of the health effects of asbestos or some other mineral (e.g., quartz and silicosis) – from a mineralogical viewpoint

--Clay minerals and cation exchange in environmental processes

--Zeolites (natural and synthetic) and their use in environmental clean-up

--Sulfide minerals and acid mine drainage

--Microbe-mineral interactions

--Environmental regulations for small (<10 and <2.5 µm) particles: mineral phases, particle analysis, health problems

--Clathrate hydrates, e.g., as a means of storing (sequestering) greenhouse gases, formation and effects on climate, destabilization as a cause of underwater landslides and sudden release of CO₂ and CH₄

--(New) types of solar cells: solid-state physics, environmental requirements

– Rare-earth elements: chemistry, mineralogy, modern applications in “green materials”
Overview of EPSc 352 Earth Materials

**Minerals**
- hand-sample I.D.
- material properties
- environmental issues
- compo. groups
- structural groups
- geologic occurrence
- industrial uses

**Crystal-Chemistry**
- chemistry
- bonding
- structure(-composition)
- infer genesis from composition
- phase diagrams
- compositional analysis, e.g., electron microprobe

**Crystallography**
- axial systems of crystals
- details of atomic structure of minerals
- symmetry: atomic to hand scales
- structural analysis, e.g., X-ray diffraction

**Optical Mineralogy**
- physics of light-solid interactions
- how light propagates through anisotropic minerals
- use of petrographic microscope
- identification of minerals using polarized light
- relations of optical properties and symmetry
### 2020 Tentative Schedule: Updates Provided in Class

<table>
<thead>
<tr>
<th>Week of:</th>
<th>Mineralogic Topics</th>
<th>Reading Assignment</th>
<th>CD Module</th>
<th>Lab Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept. 14</td>
<td>Define mineral, earth’s chemistry, element partitioning</td>
<td>KD 1, 3</td>
<td></td>
<td>Finish course intro. Start: defining a mineral; earth’s chemistry. No lab report. Come to room 204.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Do not come to lab room</strong></td>
</tr>
<tr>
<td>Sept. 28</td>
<td>Closest packing, coordination polyhedra, Pauling’s rules. Mineral composition, solid solution. <strong>Homework #1 due Friday, 10/2.</strong></td>
<td>KD 5</td>
<td>I</td>
<td>2. Bonding &amp; Structure</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Come to lab room 202.</td>
</tr>
<tr>
<td>Oct. 5</td>
<td>Binary phase diagrams. <strong>Homework #2 due Friday, 10/9.</strong></td>
<td>KD 2; Ehlers ch. 1,2</td>
<td>3</td>
<td>3. Minerals 1: non-silicates</td>
</tr>
<tr>
<td>Oct. 12</td>
<td>Binary phase diagrams (cont.); fractionation; zoning.</td>
<td>KD 2; Ehlers ch. 1,2</td>
<td>4</td>
<td>4. Minerals 2: silicates</td>
</tr>
<tr>
<td>Oct. 19</td>
<td>Crystal growth; morphological crystallography. <strong>Homework #3 due Wednesday, 10/21.</strong></td>
<td>KD 10 (pp. 217-234), KD 12 (pp. 266-281)</td>
<td>II</td>
<td>5. Crystal Growth</td>
</tr>
<tr>
<td>Oct. 26</td>
<td><strong>EXAM #1 on Wednesday, 10/28; timing that day TBA.</strong> Crystal systems. Internal symmetry.</td>
<td>KD 6 (to p. 131)</td>
<td>II, III</td>
<td>6. Symmetry</td>
</tr>
<tr>
<td>Nov. 2</td>
<td>Lattices, unit cells, Miller indices. Lines, forms, zones.</td>
<td>KD 6 (pp. 131-137), KD 7</td>
<td>II, III</td>
<td>7. Symmetry</td>
</tr>
<tr>
<td>Nov. 9</td>
<td>Physical properties of minerals. X-ray diffraction (XRD).</td>
<td>KD 14, selection of term-paper topic</td>
<td>8</td>
<td>8. Miller Indexing; databases and library resources</td>
</tr>
<tr>
<td>Nov. 30</td>
<td><strong>Monday, 11/30 first draft of term paper due.</strong> Finish non-silicates. Begin silicate minerals.</td>
<td>KD 15, 16 (some), Optics TBA</td>
<td>IV</td>
<td>11. Begin optical microscopy</td>
</tr>
<tr>
<td>Dec. 7</td>
<td>Silicate minerals. <strong>Homework #5 due Monday, 12/7.</strong></td>
<td>KD 17 (some)</td>
<td>12</td>
<td>12. Optical microscopy II</td>
</tr>
</tbody>
</table>
### EPSc352 Earth Materials: General Information

<table>
<thead>
<tr>
<th>Week of</th>
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<th>Reading Assignment</th>
<th>CD Module</th>
<th>Lab Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 14</td>
<td>Finish silicate minerals. Some environmental mineralogy. <strong>Last day of classes Friday, 12/18.</strong></td>
<td>KD 17 (some), KD 18 (some), KD 19</td>
<td>IV</td>
<td>13. Optical microscopy III</td>
</tr>
<tr>
<td>Dec. 21</td>
<td><strong>Final version of Term Paper due by 10am.</strong> Electronic version acceptable.</td>
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<tr>
<td>Jan. 6</td>
<td><strong>Final Exam, on line, on Wednesday, Jan. 6th at 10:30am - 12:30pm.</strong></td>
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</tbody>
</table>

KD = your text by Klein and Dutrow; numbers refer to chapter numbers unless otherwise stated.

Ehlers= book on phase diagrams; book is on reserve in EPSc library. Ask the librarian for it. Required chapters will be e-mailed to you as PDFs.