Academic Assessment Committee

CCSU

Central Connecticut State University

Full Assessment Report (assessment results from AY 2017-18):

Geological Sciences Department

- BS and BSED in Earth Science
- General Education

Compiled By Kristine Larsen, with assistance from Mark Evans and Jennifer Piatek

Degree or Program Summary

Department: Geological Sciences

Report Preparer: Kristine Larsen

Program Name and Level: BS and BSED in Earth Sciences

Program Assessment Question	Response
URL: Provide the URL where the Learning Outcomes (LO) can be viewed.	http://www.physics.ccsu.edu/piatek/tmp/gsci-outcomes.html
Assessment Instruments: Please list the source(s) of the data/evidence, other than GPA, that is/are used to assess the stated outcomes?	Individual assignments in courses at the 200-300 level. See Appendix A for details.
3) **Interpretation**: Who interprets the evidence?	Faculty in the department
4) **Results**: Using this year's Findings, list: a. The conclusion(s) drawn b. The changes that were or will be made as a result of those conclusion(s)	Currently GSCI 360 (Research Methods in the Geological Sciences), which has a pre-requisite of junior standing, serves as both an introduction to communicating the geological sciences (writing and presenting scientific reports) and as a preparation for completing independent research during the student's senior year (GSCI 460 – Senior Project - required for all geological sciences majors electing a geology specialization, and taken by students in other specializations as an elective). However, there is not sufficient instruction time in this 1-credit course to adequately prepare students for both communicating scientific topics and developing an appropriate senior-level research project. This is reflected in the perennially uneven performance of students on the GSCI 360 assignments that assess LO3a/3b and LO5 (see Appendices A and B). A new 1-credit prerequisite course will be developed during the 2018-9 academic year, GSCI 260 Communicating the Geological Sciences, focusing on communication (oral and written) which will free up time in a revised GSCI 360 to focus specifically on research skills.

5) **Strengths**: List ways in which your assessment process is working well.	Our process assesses a variety of important skills that our students are expected to achieve before graduation that will prepare them for both employment and graduate school.
6) **Improvements**: List ways in which your assessment process needs to improve based on student data (A brief summary of changes to assessment plan can be reported here).	We are still struggling with the assessment of BSED students since their number is so small. The department now has five different specializations. While there is a common core of courses, there are differences between the requirements, and care needs to be taken to ensure that our assessment process captures students in all specializations. For example, while GSCI 221 Mineralogy is a requirement of all five specializations, as of Fall 2018 GSCI 360 is not. Therefore the assessment process needs to be revisited to ensure that students are not falling through the cracks on LO3a/3b and 5. This will be taken into account during the development of GSCI 260.

<u>General Education Summary</u>:
Department: <u>Geological Sciences</u>

General Education LO Assessed: <u>5,6,10</u>

Report Preparer: <u>Kristine Larsen</u>

General Education Questions	Response
<u>1)</u> **<u>Courses</u>**: List course(s) and the CCSU General Education Learning Objective/Outcome with which the course is aligned.	AST 278 Observational Astronomy: 5. To strengthen writing and communication skills. Relevant outcomes include the ability to: develop a chosen topic, organize specifics to support a main idea, use proper grammar, address a particular audience, and revise and edit to produce focused and coherent texts. 6. To strengthen quantitative skills. Relevant outcomes include the ability to: apply mathematical and statistical techniques as a means of analysis within a variety of disciplines, and assess the strengths and weaknesses of these techniques of analysis. 10. To develop and encourage the practice of civic responsibility. Relevant outcomes include the ability to: involve oneself in campus, local, or other communities; take a public stance on a community issue (in either a classroom or public setting); understand and analyze public issues and public affairs from the perspective of the larger community
Participation in General Education Assessment Initiative (Multi-State Collaborative model)	
2) Our departmental faculty participated in the assessment of the GenEd Learning Objectives/Outcomes by contributing to the GenEd Assessment Initiative (Multi-State Collaborative model). *Please list the participating faculty and General Education Learning Objective/Outcome(s) for which faculty have provided student artifacts.*	Kristine Larsen, AST 278. Outcomes 5, 6, and 10. Larsen is a member of the committee of faculty developing a rubric for LO 3: 3.To develop scientific understanding of the natural and social worlds. Relevant outcomes include the ability to: explain how scientists think, work, and evaluate the natural and social world; use techniques such as controlled observation, experiment, mathematical analysis of data, and production and interpretation of graphical and tabular data presentation; and demonstrate knowledge and appreciation of the natural and social world. New lab exercises are being constructed for AST 209 Stellar and Galactic Astronomy, and artifacts will be submitted in 2018-9. The results will be used to improve these new lab exercises.

Preamble and Highlights

1) Brief description about degree or program

The Geological Sciences programs at CCSU provide a wide range of opportunities for students to explore the Earth and Earth processes, as well as the planets within our solar system and the stars beyond.

As of Fall 2018 the department has three Geology specializations appropriate for students intending on becoming a professional Geologist:

Earth Science: Geology Specialization BS:
The Geology Specialization is designed for students planning a career as a professional geologist with government agencies (e.g. geological surveys), and geotechnical, mining, and energy industries, as well as graduate school.

Earth Science: Environmental Geology Specialization BS:
The Environmental Geology Specialization is designed for students planning a career as a professional geologist with government agencies (e.g. environmental protection), and environmental industries, as well as graduate school.

Earth Science: Planetary Geology Specialization BS:
The Planetary Geology Specialization is designed for students planning a career as a professional geologist with government agencies (e.g. NASA) or the remote sensing industry, as well as graduate school.

In addition, there are two Earth Science specializations for students who want the Earth Science background but do not intend on being a professional Geologist:

Earth Science: Environmental Earth Science Specialization BS:
The Environmental Earth Science Specialization is designed for students who want to study geological sciences with an environmental focus, but who are not intending to work as professional geologists. This Specialization is appropriate for students planning a career in public policy relating to environmental issues, environmental education, resource management, business (environmental consulting), environmental hazards, environmental law, or environmental medicine.

Earth Science: General Earth Science Specialization BS:
The General Earth Science Specialization is designed for students who want to study geological sciences, but who are not intending to work as

professional geologists. This Specialization is appropriate for students planning a career in public policy relating to earth science issues, earth-science education, resource management, museum/observatory management, science journalism, library science, technical writing, or business.

The department also offers a BSED program for students preparing to teach Earth Sciences at the secondary level.

2) Most significant changes made to the degree or program, curricular or programmatic, based on results from assessment activities

The most significant change to the program is ongoing as of Fall 2018, the addition of a required (by all specializations) GSCI 260 Communicating the Geological Sciences and the revision of GSCI 360 Research Methods in the Geological Sciences (required by some specializations).

SECTION 1-LEARNING OUTCOMES (LO)

1) Provide a numbered list of LOs for program graduates.

Learning outcomes for all Earth Science Programs (BS and BSED):

By the time of graduation, students will demonstrate proficiency in the following areas:

1. Scientific literacy: Students will be able to identify, analyze, and apply earth science concepts, principles, laws, and theories.
2. Ability to do science: Students will be able to interpret, analyze, and apply the Scientific Method and other related inquiry skills, as well, as quantitative methods, in the earth science lab.
3. Communications: Students will be able to use oral and written communication to accurately and effectively convey earth science concepts.
4. Technology literacy: Students will be able to select and accurately use appropriate tools, equipment, and technologies in the earth science lab.
5. Research: Students will be able to locate, interpret, analyze, and/or conduct and present earth science research.

SECTION 2-FINDINGS

LO 1: Scientific literacy: Students will be able to identify, analyze, and apply earth science concepts, principles, laws, and theories.	
1) Describe how student learning was evaluated, what criteria were used, and who completed the evaluation.	Student learning was evaluated by the faculty member offering the course in which the assessment instrument was assigned. The detailed description included in the assignment (see Appendix C) provides the requirements for successful completion of the assignment (what the student will be evaluated on).

2) Append the instrument and/or rubric(s).	See Appendix C.	
3) Explain the link between the assessment method(s) and each LO measured.	The instrument was selected to assess the stated learning outcome because of its ability to directly measure at least a significant number of the listed skills. BS and BSED students: Successful completion of the GSCI 221 Mineralogy "Unknown mineral" assignment requires that students be able to apply a variety of earth science concepts, principles, laws, and theories.	
4) Summarize student performance.	BS: *N = 10* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*	BSED: *N = 1* *Exceeded: 100%* *Met: 0.0%* *Failed: 0.0%*
5) Trend up to five years of data.	As seen in Appendix B, while BSED students have always done very well on this assignment, it is only in the past two cycles that the BS students have unanimously mastered this LO. This improvement is heartening.	

LO 2a: Ability to do science: Students will be able to interpret, analyze, and apply the Scientific Method and other related inquiry skills in the earth science lab.	
1) Describe how student learning was evaluated, what criteria were used, and who completed the evaluation.	Student learning was evaluated by the faculty member offering the course in which the assessment instrument was assigned. The detailed description included in the assignment (see Appendix C) provides the requirements for successful completion of the assignment (what the student will be evaluated on).
2) Append the instrument and/or rubric(s).	See Appendix C.
3) Explain the link between the assessment method(s) and each LO measured.	The instrument was selected to assess the stated learning outcome because of its ability to directly measure at least a significant number of the listed skills.

	BS and BSED students: Successful completion of the GSCI 221 Mineralogy "Unknown mineral" assignment (specifically the portions dedicated to testing properties, taking a X-ray diffraction sample, and mineral identification) requires that students be able to interpret and analyze data as well as apply quantitative methods in the earth science lab.	
4) Summarize student performance.	BS: *N = 10* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*	BSED: *N = 1* *Exceeded: 100%* *Met: 0.0%* *Failed: 0.0%*
5) Trend up to five years of data.	As seen in Appendix B, the trend is similar to that of LO 1. While BSED students have always done very well on this assignment, it is only in the past two cycles that the BS students have unanimously mastered this LO. This improvement is heartening.	

LO 2b: Ability to do science: Students will be able to apply the quantitative methods in the earth science lab.	
1) Describe how student learning was evaluated, what criteria were used, and who completed the evaluation.	Student learning was evaluated by the faculty member offering the course in which the assessment instrument was assigned. The detailed description included in the assignment (see Appendix C) provides the requirements for successful completion of the assignment (what the student will be evaluated on).
2) Append the instrument and/or rubric(s).	See Appendix C.
3) Explain the link between the assessment method(s) and each LO measured.	The instrument was selected to assess the stated learning outcome because of its ability to directly measure at least a significant number of the listed skills. BS and BSED students: Successful completion of the GSCI 221 Mineralogy

	"Unknown mineral" assignment (specifically the portion dedicated to calculating the d-spacings of the crystal lattice) requires that students be able to apply quantitative methods in the earth science lab.	
4) Summarize student performance.	BS: *N = 10* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*	BSED: *N = 1* *Exceeded: 100%* *Met: 0.0%* *Failed: 0.0%*
5) Trend up to five years of data.	As seen in Appendix B, students have generally shown mastery of this LO across the board.	

LO 3a: Communications (Oral) : Students will be able to use oral communication to accurately and effectively convey earth science concepts.	
1) Describe how student learning was evaluated, what criteria were used, and who completed the evaluation.	Student learning was evaluated by the faculty member offering the course in which the assessment instrument was assigned. Evaluation criteria are provided in Appendix C.
2) Append the instrument and/or rubric(s).	See Appendix C.
3) Explain the link between the assessment method(s) and each LO measured.	The instruments were selected to assess the stated learning outcome because of their ability to directly measure at least a significant number of the listed skills. BS students: Successful completion of the GSCI 360 Research in Earth Sciences presentation of research grant proposal assignment requires that students use oral communication to accurately and effectively convey earth science concepts.

	BSED Students: Successful completion of the AST 278 Observational Astronomy Public Observing Capstone or GSCI 290 Field Methods soil catena presentation requires that students use oral communication to accurately and effectively convey earth science concepts.	
4) Summarize student performance.	BS: *N = 13* *Exceeds = 69%* *Meets= 23%* *Fails=8%*	BSED: *N = 2* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*
5) Trend up to five years of data.	As seen in Appendix B, some BS and (to a lesser degree) BSED students struggle with this requirement. The general trend is that students clearly need more help in preparing for successful oral communication of earth science concepts.	

LO 3b: Communications (Written) : Students will be able to use written communication to accurately and effectively convey earth science concepts.	
1) Describe how student learning was evaluated, what criteria were used, and who completed the evaluation.	Student learning was evaluated by the faculty member offering the course in which the assessment instrument was assigned. Evaluation criteria are provided in Appendix C.
2) Append the instrument and/or rubric(s).	See Appendix C.
3) Explain the link between the assessment method(s) and each LO measured.	The instruments were selected to assess the stated learning outcome because of their ability to directly measure at least a significant number of the listed skills. BS students: Successful completion of the GSCI 360 Research in Earth Sciences written research grant proposal requires that students use written communication to accurately and effectively convey earth science concepts.

	BSED students: Successful completion of AST 278 Observational Astronomy written research paper on a particular constellation or GSCI 221 Mineralogy written report on a particular mineral requires that students use written communication to accurately and effectively convey earth science concepts.	
4) Summarize student performance.	BS: *N=13* *Exceeds=61%* *Meets=39%* *Fails=0%*	BSED: *N = 2* *Exceeded: 100%* *Met: 0%* *Failed: 0%*
5) Trend up to five years of data.	As seen in Appendix B, as in the case of LO3a, a significant number of BS students struggle with mastery of this LO. BSED students appear to have a much higher rate of success, although the sample size is very small (7 students over 5 years).	

LO 4: Technology literacy: Students will be able to select and accurately use appropriate tools, equipment, and technologies in the earth science lab.	
1) Describe how student learning was evaluated, what criteria were used, and who completed the evaluation.	Student learning was evaluated by the faculty member offering the course in which the assessment instrument was assigned. The detailed description included in the assignment (see Appendix C) provides the requirements for successful completion of the assignment (what the student will be evaluated on).
2) Append the instrument and/or rubric(s).	See Appendix C.
3) Explain the link between the assessment method(s) and each LO measured.	The instrument was selected to assess the stated learning outcome because of its ability to directly measure at least a significant number of the listed skills. BS and BSED students: Success completion of the GSCI 221 Mineralogy

	"Unknown mineral" assignment (specifically the portions dedicated to testing properties, taking a X-ray diffraction sample, and mineral identification) requires that students be able to select and accurately use appropriate tools, equipment, and technologies in the earth science lab.	
4) Summarize student performance.	BS: *N = 10* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*	BSED: *N = 1* *Exceeded: 100.0%* *Met: .0%* *Failed: 0.0%*
5) Trend up to five years of data	As seen in Appendix B, with the exception of AY 2-15-6, both BS and BSED students have been able to master the technology utilized in the Mineralogy laboratory.	

LO 5: Research: Students will be able to locate, interpret, analyze, and/or conduct and present earth science research.	
1) Describe how student learning was evaluated, what criteria were used, and who completed the evaluation	Student learning was evaluated by the faculty member offering the course in which the assessment instrument was assigned. The detailed description included in the assignment (see Appendix C) provides the requirements for successful completion of the assignment (what the student will be evaluated on).
2) Append the instrument and/or rubric(s).	See Appendix C.
3) Explain the link between the assessment method(s) and each LO measured.	The instrument was selected to assess the stated learning outcome because of its ability to directly measure at least a significant number of the listed skills. BS Students: Successful completion of the GSCI 360 Research in Earth Sciences written research grant proposal requires that students be able to locate, interpret, and analyze earth science research. BSED students: Successful completion of the GSCI 221 Mineralogy final report on a particular mineral requires that students be able to locate, interpret, and analyze earth science research.

4) Summarize student performance.	BS: *N=13* *Exceeds=61%* *Meets=39%* *Fails=0%*	BSED: *N = 1* *Exceeded: 100.0%* *Met: .0%* *Failed: 0.0%*
5) Trend up to five years of data	As seen in Appendix B, while the small number of BSED students (7 in 5 years) were able to master this LO, BS students struggled with the GSCI 360 assignment. The general trend is that students clearly need more help in locating, interpreting, and analyzing earth science research.	

SECTION 3 – ANALYSIS

For each outcome:

1) Within the context of data from past years, describe what these current results mean, including an identification of patterns of students' **strengths and weaknesses** across the program
2) Describe how the results have changed over time.

LO	1) Within the context of data from past years, describe what these current results mean, including an identification of patterns of students' **strengths and weaknesses** across the program	2) Describe how the results have changed over time.
1 Scientific literacy	As seen in the data in Appendix B, in recent years students have demonstrated a mastery of this LO. This would be considered a strength of our students.	As seen in the data in Appendix B, the current mastery of this LO by department students has improved over the past two cycles from very good to excellent.
2a Ability to do science (Scientific Method)	As seen in the data in Appendix B, in recent years students have demonstrated a mastery of this LO. This would be considered a strength of our students.	As seen in the data in Appendix B, the current mastery of this LO by department students has improved over the past two cycles from very good to excellent.
2a Ability to do science (Quantitative methods)	As seen in the data in Appendix B, students have generally demonstrated a mastery of this LO. This would be considered a strength of our students.	As seen in the data in Appendix B, there has been very little change over time with respect to this LO.
3a Communications (Oral)	As seen in the data in Appendix B, some students continue to struggle with this LO. This would be a weakness across the	As seen in the data in Appendix B, some students continue to struggle with this LO.

	program that will be addressed with the curricular changes described within this report.	
3b Communications (Written)	As seen in the data in Appendix B, some students continue to struggle with this LO. This would be a weakness across the program that will be addressed with the curricular changes described within this report.	As seen in the data in Appendix B, some students continue to struggle with this LO.
4 Technology literacy	As seen in the data in Appendix B, students have generally demonstrated a mastery of this LO. This would be considered a strength of our students.	As seen in the data in Appendix B, there has been very little change over time with respect to this LO.
5 Research	As seen in the data in Appendix B, some students continue to struggle with this LO. This would be a weakness across the program that will be addressed with the curricular changes described within this report.	As seen in the data in Appendix B, some students continue to struggle with this LO.

<u>SECTION 4 –USE OF RESULTS</u>

For <u>each</u> outcome:

1) Describe how these results have been used to make curricular or programmatic adjustments over the last five years.
2) Clearly articulate the relationship between the result and the curricular/programmatic adjustment.

LO	1) Describe how these results have been used to make curricular or programmatic adjustments over the last five years.	2) Clearly articulate the relationship between the result and the curricular/programmatic adjustment.
1 Scientific literacy	None have been made.	Students continue to demonstrate mastery of this LO.
2a Ability to do science (Scientific method)	None have been made.	Students continue to demonstrate mastery of this LO.
2a Ability to do science (Quantitative methods)	None have been made.	Students continue to demonstrate mastery of this LO.
3a Communications (Oral)	A draft of a new course, GSCI 260, as well as revisions to GSCI 360 are in process in order to directly address the students' continued struggles in this area.	Separating the introduction to oral and written communications in the earth sciences from the research component, and exposing students to these

		skills before they take their research methods course, is being done as a direct result of the demonstrated difficulties some students have in mastering LO 3a/b and LO 5
3b Communications (Written)	A draft of a new course, GSCI 260, as well as revisions to GSCI 360 are in process in order to directly address the students' continued struggles in this area.	Separating the introduction to oral and written communications in the earth sciences from the research component, and exposing students to these skills before they take their research methods course, is being done as a direct result of the demonstrated difficulties some students have in mastering LO 3a/b and LO 5
4 Technology literacy	None have been made.	Students continue to demonstrate mastery of this LO.
5 Research	A draft of a new course, GSCI 260, as well as revisions to GSCI 360 are in process in order to directly address the students' continued struggles in this area.	Separating the introduction to oral and written communications in the earth sciences from the research component, and exposing students to these skills before they take their research methods course, is being done as a direct result of the demonstrated difficulties some students have in mastering LO 3a/b and LO 5

<u>SECTION 5- DEPARTMENTAL PROGRAM ASSESSMENT PLAN</u>

1) Identify where improvements are needed, referencing the evidence indicating this need.

i) Assessment for LO 3a/3b and LO 5 is required for students in the new Environmental and General Earth Science Specializations, which do not require GSCI 360. The former will be taken care of by the development of assignments for (and their first offering in) the new GSCI 260 course during the 2018-9 and 2019-2020 academic years. (See Appendix B)

ii) Revisions in GSCI 360 are also required to address the difficulties some students have in achieving a desired level of proficiency in LO 5. (See Appendix B)

iii) With the implementation of five specializations, some of which do not require GSCI 360, care needs to be taken to ensure that all students, regardless of specialization, are assessed in each LO.

2) Propose strategy on implementing improvements:

The current assessment plan will be revisited and new assessment instruments created in order to assure that students in all specializations will be assessed. This will be done in concert with the creation of the new course GSCI 260 and the revisions to GSCI 360. The assessment of LO 5 for those specializations that do not require GSCI 360 will parallel that for the BSED students, the use of the GSCI 221 Mineralogy final report on their individual mineral. This will afford the interesting opportunity to directly compare a subset of BS students with the BSED students.

3) Specify goal of assessment activity, describing why the change should lead to specific improvement in corresponding LO.

i) The goal is to make sure that all students are assessed in all LOs, regardless of their specialization.

ii) Revisions to GSCI 360 and the creation of GSCI 260 will be done using the past 5 years' assessment data, and will stress the specific skills related to LO 3a/3b and LO 5 that some students have had difficulty attaining proficiency in.

4) Identify semester and year assessment activities are scheduled:

i) Curriculum changes will be made during the Spring 2019 semester, for implementation in Spring 2020.

ii) New assessment instruments will be created in the Spring 2019 semester in concert with the curriculum changes and further refined before their first offering in Spring 2020. After the results from that semester have been analyzed, further revisions to the courses curriculum and assessments will be made..

5) Identify the target group:

Juniors in all five Earth Science specializations (the approximate year that they will take GSCI 260)

6) Identify data to be collected:

Assignments that will be developed in concert with the curriculum changes will provide student artifacts for assessment.

7) State when data will be analyzed:

An initial analysis will be made the same semester that the artifacts are collected (Spring 2020 for the trial run). Deeper analysis will be done over the Summer.

8) Build into your timeline, any approvals or other procedural guidelines that need to be followed prior to implementing improvements.

   This plan is contingent on the university Curriculum Committee and Senate approving the new course GSCI 260 and revision to GSCI 360.

9) Anticipated year and semester expected improvements will be implemented in classroom.

   GSCI 260 will be offered for the first time in Fall 2020; revisions to GSCI 360 will be implemented in stages, first in Spring 2020 and then Spring 2021.

SECTION 6 GENERAL EDUCATION LEARNING OBJECTIVES/OUTCOMES ASSESSMENT

A. General Education Reporting Guidelines for General Education Assessment Initiative (Multi-State Collaborative Model) Participating Departments
Our departmental faculty participated in the assessment of the Gen Ed Learning Objectives/Outcomes by contributing to the Gen Ed Assessment Initiative (MSC-model).

1) ***List the participating faculty and CCSU General Education Learning Objective/Outcome(s) for which faculty have provided student artifacts to OIRA (Critical Thinking-LO#4; Written Communication-LO#5; Quantitative Reasoning-LO#6; Information Literacy-LO#7; and/or Civic Engagement-LO#10.)***

   Kristine Larsen has submitted artifacts for several years for LO 5 (constellation research paper for AST 278 Observational Astronomy) and LO 6 (Variable Star assignment for AST 278 Observational Astronomy). In Fall 2017 artifacts for the reflection assignment developed in 2016 for the community engagement capstone for AST 278 Observational Astronomy were submitted for LO 10 of the GE Assessment Initiative for the second year in a row. Kristine Larsen is part of the initiative to develop/adapt a rubric for LO 3 Scientific Inquiry. That rubric is anticipated to be completed during the 2018-9 cycle, after which it will be applied to department courses. In addition, a completely new series of lab exercises have been developed for AST 209 Stellar and Galactic Astronomy. Those exercises will be piloted in the Spring 2019 semester and artifacts submitted as part of the GE Assessment Initiative. Results will be used to improve those new assignments as needed.

2) ***List the course(s) where these student work/artifacts were collected.***

   AST 278 Observational Astronomy

Appendix A: 2017-8 Department Program Assessment Data

	BS	BSED
Scientific literacy	GSCI 221 Mineralogy “Unknown mineral” assignment [Process and reading scientific literature] *N = 10* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*	GSCI 221 Mineralogy “Unknown mineral” assignment [Process and reading scientific literature] *N = 1* *Exceeded: 100%* *Met: 0.0%* *Failed: 0.0%*
Ability to do science: Scientific Method	GSCI 221 Mineralogy “Unknown mineral” assignment: [Testing properties; X-ray diffraction sample; mineral identification] *N = 10* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*	GSCI 221 Mineralogy “Unknown mineral” assignment: [Testing properties; X-ray diffraction sample; mineral identification] *N = 1* *Exceeded: 100%* *Met: 0.0%* *Failed: 0.0%*
Ability to do science: Quantitative methods	GSCI 221 Mineralogy “Unknown mineral” assignment: [calculate d-spacings of the crystal lattice] *N = 10* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*	GSCI 221 Mineralogy “Unknown mineral” assignment: [calculate d-spacings of the crystal lattice] *N = 1* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*

Oral communication	GSCI 360 Research in Earth Sciences: Presentation of research grant proposal *N = 13* *Exceeds = 69%* *Meets= 23%* *Fails=8%*	AST 278 Observational Astronomy: Demonstrated ability to communicate astronomical knowledge clearly and factually correctly to the general public during capstone public observing sessions. OR GSCI 290 Field Methods: Demonstrated ability to communicate the results of a soil catena research project clearly and factually. *N = 2* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*
Written communication	GSCI 360 Research in Earth Sciences: Written research grant proposal *N=13* *Exceeds=61%* *Meets=39%* *Fails=0%*	AST 278 Observational Astronomy: Written research paper on a particular constellation. OR GSCI 221: Students will research their mineral using reference books and journal articles to make sure they have the correct identification. They will then write a 2-3 page final report on their mineral. *N = 2* *Exceeded: 100%* *Met: 0%* *Failed: 0%*

Technology literacy (tools both electronic and manual)	GSCI 221 Mineralogy “Unknown mineral” assignment: [Testing properties; X-ray diffraction sample; mineral identification] *N = 10* *Exceeded: 100.0%* *Met: 0.0%* *Failed: 0.0%*	GSCI 221 Mineralogy “Unknown mineral” assignment: [Testing properties; X-ray diffraction sample; mineral identification] *N = 1* *Exceeded: 100.0%* *Met: .0%* *Failed: 0.0%*
Research	GSCI 360 Research in Earth Sciences: Written research grant proposal *N=13* *Exceeds=61%* *Meets=39%* *Fails=0%*	GSCI 221: Students will research their mineral using reference books and journal articles to make sure they have the correct identification. They will then write a 2-3 page final report on their mineral. *N = 1* *Exceeded: 100%* *Met: 0%* *Failed: 0%*

Appendix B: 5 Year Comparison Data

Outcome MAJORS (BS and BSED)	2017-8	2016-7	2015-6	2014-5	2013-4*
Scientific literacy GSCI 221 Mineralogy “Unknown mineral” assignment [Process and reading scientific literature]	*BS: N=10* *Exceeds=100%* *Meets=0* *Fails=0* *BSED: N=1* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=10* *Exceeds=100%* *Meets=0* *Fails=0* *BSED: N=1* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=12* *Exceeds=83.3%* *Meets=0* *Fails=16.7%* *BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=7* *Exceeds=85.7%* *Meets=14.3%* *Fails=0* *BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=19* *Exceeds=73.6%* *Meets=21.1%* *Fails=5.3%* *BSED: N=5* *Exceeds=100%* *Meets=0* *Fails=0*
Ability to do science: Scientific Method GSCI 221 Mineralogy “Unknown mineral” assignment [Testing properties; X-ray diffraction sample; mineral identification]	*BS: N=10* *Exceeds=100%* *Meets=0* *Fails=0* *BSED: N=1* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=10* *Exceeds=100%* *Meets=0* *Fails=0* *BSED: N=1* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=12* *Exceeds=83%* *Meets=0* *Fails=16.7%* *BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=7* *Exceeds=85.7%* *Meets=14.3%* *Fails=0* *BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=19* *Exceeds=73.6%* *Meets=21.1%* *Fails=5.3%* *BSED: N=5* *Exceeds=100%* *Meets=0* *Fails=0*
Ability to do science: Quantitative methods GSCI 221 Mineralogy “Unknown mineral” assignment:	*BS: N=10* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=10* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=12* *Exceeds=91.7%* *Meets=8.3%* *Fails=0*	*BS: N=7* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=19* *Exceeds=94.7%* *Meets=5.3%* *Fails=0*

[calculate d-spacings of the crystal lattice]	*BSED: N=1* *Exceeds=100%* *Meets=0* *Fails=0*	*BSED: N=1* *Exceeds=100%* *Meets=0* *Fails=0*	*BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BSED: N=5* *Exceeds=100%* *Meets=0* *Fails=0*
Oral communication BS: GSCI 360 Research in Earth Sciences: Presentation of research grant proposal BSED: AST 278 Observational Astronomy: communicate astronomical knowledge clearly and factually correctly to the general public during capstone public observing sessions. OR GSCI 290 Field Methods: communicate the results of a soil catena research	*BS: N=13* *Exceeds=69%* *Meets=23%* *Fails=8%* *BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=7* *Exceeds=28.5%* *Meets=71.5%* *Fails=0* *BSED: N=2* *Exceeds=50%* *Meets=50%* *Fails=0*	*BS: N=13* *Exceeds=69%* *Meets=23%* *Fails=8%* *BSED: N=0*	*BS: N=11* *Exceeds=27%* *Meets=55%* *Fails=18%* *BSED: N=0*	*BS: N=8* *Exceeds=12.5%* *Meets=87.5%* *Fails=0* *BSED: N=2* *Exceeds=50%* *Meets=50%* *Fails=0*

project clearly and factually.					
Written communication BS: GSCI 360 Research in Earth Sciences: Written research grant proposal BSED: AST 278 Observational Astronomy: Written research paper on a particular constellation. OR GSCI 221: 2-3 page final report on their mineral.	*BS: N=13* *Exceeds=61%* *Meets=39%* *Fails=0* *BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=7* *Exceeds=28.5%* *Meets=43%* *Fails=28.5%* *BSED: N=1* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=13* *Exceeds=61%* *Meets=39%* *Fails=0* *BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=11* *Exceeds=18%* *Meets=55%* *Fails=27%* *BSED: N=0*	*BS: N=8* *Exceeds=50%* *Meets=50%* *Fails=0* *BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*
Technology literacy (tools both electronic and manual) GSCI 221 Mineralogy “Unknown mineral” assignment: [Testing properties; X-ray diffraction sample;	*BS: N=10* *Exceeds=100%* *Meets=0* *Fails=0* *BSED: N=1* *Exceeds=100%*	*BS: N=10* *Exceeds=100%* *Meets=0* *Fails=0* *BSED: N=1* *Exceeds=100%*	*BS: N=12* *Exceeds=83%* *Meets=0* *Fails=16.7%* *BSED: N=2* *Exceeds=100%*	*BS: N=7* *Exceeds=100%* *Meets=0* *Fails=0* *BSED: N=2* *Exceeds=100%*	[Assessment instrument not comparable]

mineral identification]	*Meets=0* *Fails=0*	*Meets=0* *Fails=0*	*Meets=0* *Fails=0*	*Meets=0* *Fails=0*	
Research BS: GSCI 360 Research in Earth Sciences: Written research grant proposal BSED: GSCI 221: 2-3 page final report on their mineral.	*BS: N=13* *Exceeds=61%* *Meets=39%* *Fails=0* *BSED: N=1* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=7* *Exceeds=28.5%* *Meets=43%* *Fails=28.5%* *BSED: N=1* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=13* *Exceeds=61%* *Meets=39%* *Fails=0* *BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=11* *Exceeds=18%* *Meets=55%* *Fails=27%* *BSED: N=2* *Exceeds=100%* *Meets=0* *Fails=0*	*BS: N=8* *Exceeds=50* *Meets=50* *Fails=0* *BSED: N=5* *Exceeds=100%* *Meets=0* *Fails=0*

* A different assessment plan was in effect. Data is only included for instruments that are the same as those used from 2014-15 on.

Appendix C: Descriptions of Assignments and Rubrics

AST 278 Observational Astronomy Constellation Project

This project, if properly completed, will make you an "expert" on one of the major constellations. The project consists of two parts: a written report, typed double-spaced, with bibliography and proper citations, and a map of the constellation.

The project is due at *7:20 PM on October 24*. Late projects will receive reduced credit.

Suggested resources include:

Books on mythology
Star catalogs and books
Magazines (*Astronomy* and *Sky and Telescope*)
Websites (Wikipedia is not an acceptable source!)

The written portion of the project should contain the following:

1) The mythology of the constellation in at least two different cultures;

2) The names and mythology behind the brightest/famous stars;

3) The best time of the year to view the constellation from Connecticut;

4) Information on at least one meteor shower which radiates from the constellation;

5) Information on easily visible double and variable stars. A table is acceptable, but make sure you describe a couple of important examples;

6) Information on easily visible/famous deep sky objects (clusters, galaxies, nebulae). All Messier objects contained in your constellation should be described.

The map (which can be hand drawn or adapted from a book or computer program) should contain the following:

1) RA and Dec grid;

2) Bright stars plotted and named;

3) Positions of objects mentioned in your report marked on map;

4) Boundaries of constellations and positions of neighboring constellations.

Scoring Rubric for Constellation project ____________________

Astronomical content of paper:

Task	Completely fulfilled the objective. Superior effort shown	Fulfilled most of the objective. Good effort shown	Fulfilled some basic level of the objective but clearly incomplete	Unacceptable for this level – superficial work	Missing or completely wrong
Mythology	17	14.5	11.5	8.5	0
Bright stars	16	14	11	8	0
Viewing time	4	3	2	1	0
Meteor showers	6	5	4	3	0
Double and variable stars	16	14	11	8	0
Deep sky objects	17	14.5	11.5	8.5	0

Map

	Completely fulfilled the objective.	Fulfilled most of the objective.	Fulfilled some basic level of the objective but clearly incomplete	Missing or completely wrong
Map grid	3	2	1	0
Stars plotted	3	2	1	0
Deep sky objects plotted	3	2	1	0
Boundaries	3	2	1	0

Paper style (including grammar, spelling, proper citations)

	Nearly flawless	Few mistakes	Many mistakes
Grammar and spelling	8	4	0
Citations	4	2	0

Bonus points for something extraordinary: ____________________

AST 278 Observational Astronomy Public Observing Session Grading Rubric

Name ____

					Score (out of 16)	Comments
Proficiency using instrument	Can operate instrument in a basic way no difficulty (4 pts)	Can operate instrument in a basic way with only minor difficulty (3 pts)	Needs significant help with basic operations (2 pts)	Cannot operate instrument at all (0 pts)		
Proficiency finding object	Can find object with no help (4 pts)	Can find object with some minor aid (3 pts)	Can find object only with great difficulty (2 pts)	Unable to find object even with significant aid (0 pts)		
Knowledge about object and instrument	Demonstrated correct knowledge of object and instrument (4 pts)	Demonstrated mostly correct knowledge of object and instrument with minor errors (3 pts)	Significant errors even after being corrected (2 pts)	Demonstrated no knowledge of object and instrument (0 pts)		
Ability to work with public in a respectful manner	Demonstrated great respect and patience with public (4 pts)	Demonstrated reasonable respect, but lacked patience on occasion (3 pts)	Demonstrated a lack of respect and patience; was impatient or slightly disrespectful (2 pts)	Did not represent the university in a positive manner (0 pts)		

GSCI 360 Project Proposal Grading Rubrics (Written and Oral presentations)

Grading criteria

(As given on the project description handed out on the first day.)

In general, "Excellent" - A, "Expected" - B, "Acceptable" - C, "Incomplete" - D, "Unacceptable" - F

Content - Background: does the proposal contain sufficient background information?	Excellent ***25 points***	Expected ***21 points***	Acceptable ***18 points***	Incomplete ***15 points***	Unacceptable ***0 points***
Content - Method: is the method well-described and scientifically sound?	Excellent ***25 points***	Expected ***21 points***	Acceptable ***18 points***	Incomplete ***15 points***	Unacceptable ***0 points***
Content - Objectives: does the proposed project represent original research,, and are the proposed outcomes consistent with the proposed method?	Excellent ***25 points***	Expected ***21 points***	Acceptable ***18 points***	Incomplete ***15 points***	Unacceptable ***0 points***
Format, Budget, & Style: is the proposed timeline and budget appropriate, is the proposal clearly written, contain proper citations, and submitted in the requested format?	Excellent ***25 points***	Expected ***21 points***	Acceptable ***18 points***	Incomplete ***15 points***	Unacceptable ***0 points***

Grading criteria	As given on the project description handed out the first day of class. Generally speaking, "Excellent" - A, "Expected" - B, "Acceptable" - C, "Incomplete" - D, "Unacceptable" - F

Content: does the presentation present the objectives, background, method, and outcomes?	Excellent *30 points*	Expected *25 points*	Acceptable *22 points*	Incomplete *20 points*	Unacceptable *0 points*
Presenter Style: is the presenter clear and engaging, including when answering questions?	Excellent *30 points*	Expected *25 points*	Acceptable *22 points*	Incomplete *20 points*	Unacceptable *0 points*
Slide Style: are the slides used clear and well-designed to show information?	Excellent *20 points*	Expected *17 points*	Acceptable *15 points*	Incomplete *12 points*	Unacceptable *0 points*
Organization: is the presentation logically organized?	Excellent *20 points*	Expected *17 points*	Acceptable *15 points*	Incomplete *12 points*	Unacceptable *0 points*

GSCI 290: Soil Catena Exercise

In the Field (day 1):

What You Need

1. Hand auger
2. PVC trays for the soil samples
3. saran wrap for the core samples
4. Trowel, shovel, or other digging device
5. Pencil or pen or other method of recording data
6. Marking pen
7. Meter stick or tape measure
8. Camera

- The class will split into three groups
- Each person in the group should participate in ALL aspects of data collection:
- Each person in each group will record all important characteristics about the sample location
  - UTM coordinates

General surroundings (vegetation, slope dip, slope dip direction, whether slope is concave outward or inward.

  - At least one person in each group should photograph each site in which the cores are taken.
- Coring
  - Locate the site to be cored and record the data assigned by your instructor: use your field book.
  - Use the hand auger to drill a soil core. You will need to auger down only about 30 cm at a time.
  - Bring the soil core to the surface and carefully place in the PVC tube. Make sure the top of the core is in the correct position.
    - Measure and record the length of the core retrieved AND measure and record the depth of the hole. They WILL be different dude to core expansion.
    - Try to get a much of the core out as possible in chunks. Repeat as deep as you can go with the auger (or at the most about 1.0 to 1.5 m)
- Once coring is completed,
  - Do a preliminary identification of the soil layers in the core and measure their lengths
  - Measure and record the total depth of the core hole with the meter stick.
  - Photograph the core with a scale
  - Cover the core with the second half of the PCV and wrap the core in Saran wrap.
- Move on to the next site as assigned.

In the Lab (Day 2):

What You Need

1. Spray mist bottle full of water
2. Acid bottle filled with 10% HCl
3. Soil Characterization Data Sheet
4. Pencil or pen or other method of recording data
5. Soil color book
6. Paper towels
7. Marking pen
8. Meter stick or tape measure
9. Camera
10. Hammer, or other utensil for crushing peds and separating particles
11. pH meter
12. Beakers

Core will be laid out and unwrapped on a lab bench in 536NC
Each of the aforementioned groups will do a full soil analysis as described in the handout to be given that day.

Identifying and Measuring Horizons

1. Make sure the sun shines on the profile if possible.
2. Determine whether the soil profile is moist, wet, or dry by lightly placing your hands on the Soil face. If the soil profile is dry, moisten it with the spray mist bottle.
3. Start at the top of the profile and observe the characteristics of the soil moving towards the bottom of the profile.
4. Feel carefully at the soil profile for distinguishing characteristics such as texture, shapes, roots, rocks, small dark nodules, worms, small animals, insects, and worm channels. These observations will help to define the horizons.
5. Working in a straight vertical line, place a marker (such as a golf tee or nail) at the top and bottom of each horizon to clearly identify it. Be sure there is a consensus from all of the students regarding the depths of the soil horizons.
6. Measure the top and bottom depth of each horizon beginning at the top (surface) of the profile. Start with the meter stick or tape measure at 0 cm at the top of the profile. Note the depths at which each horizon starts and ends.
7. Record the top and bottom depth of each horizon in your field book.

Measuring Structure

1. Lay out the core. Keep it in its half-tube. Lay a meter stick beside it and have someone stand above it to photograph it, with the meter stick in place. Later stitch the photos together in powerpoint
2. Use a trowel or other digging device to remove a sample of soil from the horizon being studied.
3. Hold the sample gently in your hand and look closely at the soil to examine its structure.

4. Come to a consensus with other students in the group on the type of soil structure of the horizon. Possible choices of soil structure are:

- **Granular**: Resembles cookie crumbs and is usually less than 0.5 cm in diameter. Commonly found in surface horizons where roots have been growing.
- **Blocky**: Irregular blocks that are usually 1.5 - 5.0 cm in diameter.
- **Prismatic**: Vertical columns of soil that might be a number of cm long. Usually found in lower horizons.
- **Columnar**: Vertical columns of soil that have a white, rounded salt "cap" at the top. Found in soils of arid climates.
- **Platy**: Thin, flat plates of soil that lie horizontally. Usually found in compacted soil.

IN certain cases, soil samples may have no structure. These would be classified as either:

- **Single Grained**: Soil is broken into individual particles that do not stick together. Always accompanies a loose consistence. Commonly found in sandy soils.
- **Massive**: Soil has no visible structure, is hard to break apart and appears in very large clods.

4. Record the structure type in your field book.

Measuring Main Color and Second Color

1. Take a ped from the horizon being studied and note whether it is moist, dry, or wet. If it is dry, moisten it slightly with water from your water bottle.
2. Break the ped and hold it next to the color chart.
3. Stand with the sun over your shoulder so that sunlight shines on the color chart and the soil sample you are examining.
4. Find the color on the color chart that most closely matches the color of the inside surface of the ped. Be sure that all students agree on the choice of color.
5. Record in your field book the symbol of the color on the chart that most closely matches the soil color that covers the largest area of the ped (dominant or main color). Sometimes, a soil sample may have more than one color. Record a maximum of two colors if necessary, and indicate (1) the dominant (main) color, and (2) the sub-dominant (second) color.

Measuring Soil Consistency

1. Take a ped from the soil horizon being studied. If the soil is very dry, moisten the face of the profile by squirting water on it, and then remove a ped for determining consistence.
2. Holding the ped between your thumb and forefinger, gently squeeze it until it pops or falls apart.
3. Record one of the following categories of soil ped consistence on the Soil Characterization Data Sheet.

- **Loose**: You have trouble picking out a single ped and the structure falls apart before you handle it. Note: Soils with single grained structure always have loose consistence .
- **Friable**: The ped breaks with a small amount of pressure.
- **Firm**: The ped breaks when you apply a good amount of pressure and the ped dents your fingers before it breaks.
- **Extremely Firm**: The ped can't be crushed with your fingers (you need a hammer!)

Measuring Soil Texture

Step 1

- Place some soil from a horizon (about the size of a small egg) in your hand and use the spray mist bottle to moisten the soil. Let the water soak into the soil and then work it between your fingers until it is thoroughly moist. Once the soil is moist, try to form a ball.
- If the soil forms a ball, go on to Step 2. If the soil does not form a ball, call it a sand . Soil texture is complete. Record the texture in your field book.

Step 2

- Place the ball of soil between your thumb and index finger and gently push and squeeze it into a ribbon. If you can make a ribbon that is longer than 2.5 cm, go to Step 3. If the ribbon breaks apart before it reaches 2.5 cm, call it a loamy sand. Soil texture is complete. Record the texture in your field book.

Step 3

- If the soil:
- Is very sticky
- Hard to squeeze
- Stains your hands
- Has a shine when rubbed
- Forms a long ribbon (5+ cm) without breaking,
- Call it a clay and go to Step 4.
- Otherwise, If the soil:
- Is somewhat sticky
- Is somewhat hard to squeeze
- Forms a medium ribbon (between 2-5 cm)
- Call it a clay loam and go to Step 4.
- Otherwise, If the soil is:
- Smooth
- Easy to squeeze,
- At most slightly sticky,
- Forms a short ribbon (less than 2 cm)
- Call it a loam and go to Step 4.

Step 4

- Wet a small pinch of the soil in your palm and rub it with a forefinger. If the soil:
  - Feels very gritty every time you squeeze the soil, go to A.
  - Feels very smooth, with no gritty feeling, go to B.
  - Feels only a little gritty, go to C.

A. Add the word sandy to the initial classification.

- Soil texture is either:
  - sandy clay,
  - sandy clay loam, or

- sandy loam
  - Soil Texture is complete. Record the texture in your field book.

B. Add the word silt or silty to the initial classification.

- Soil texture is either:
  - silty clay,
  - silty clay loam, or
  - silt loam
- Soil Texture is complete. Record the texture in your field book.

C. Leave the original classification.

- Soil texture is either:
  - clay, clay loam, or loam
- Soil Texture is complete. Record the texture in your field book.

Measuring Rocks

1. Place your hands on the surface of the profile and feel for the presence of rocks along the face of the profile that you are studying. Observe and record if there are **none**, **few**, or **many** rocks or rock fragments in the horizon. A rock or rock fragment is defined as being larger than 2 mm in size.
2. Record your observation in your field book.

Measuring Roots

1. Place your hands on the surface of the profile and feel for the presence of roots along the face of the profile that you are studying. Observe if there are **none**, **few**, or **many** roots in each horizon.
2. Record your observation in your field book.

Photographing the Soil Profile

1. Place a tape measure or meter stick starting with 0cm from the top of the soil profile next to where the horizons have been marked.
2. With the sun at your back, photograph the soil profile so that the horizons and depths can be seen clearly.
3. Take another photograph of the landscape around the soil profile.

Ph

Follow the procedure to measure soil Ph that is provided by Dr. Oyweumi.

Soil Density

Follow the procedure to measure soil density that is provided by Dr. Oyweumi.

After Lab:

The groups will then combine all of their data

<u>Each person</u> will then write up a soil Catena report. It will include:

- A topographic profile of the study area (to be made later outside of lab) showing the locations of the cores.

- An annotated topographic map showing the locations of the cores (also done outside of lab). This should be done in ArcMap (a georeferenced topographic map will be posted on BBL)

- Three well documented soil profiles (one per page, carefully colored if you want) with:

- Depth
- Full descriptions of the soil horizons
- pH and other analytical data

- A two-three page write-up describing the catena.

A GROUP POWERPOINT presentation will be done by each group on the findings of their soil catena. The presentation should be no more than 10 minutes. Everyone should have a speaking part.

The Assignment is Due December 14th for a presentation in class during Finals Week.

X-Ray Powder Diffraction

This handout provides background on the use and theory of X-ray powder diffraction. Examples of applications of this method to geologic studies are provided.

X-Ray Analytical Methods

X-rays were discovered by W.C. Röentgen in 1895, and led to three major uses:
• X-ray radiography is used for creating images of light-opaque materials. It relies on the relationship between density of materials and absorption of x-rays. Applications include a variety of medical and industrial applications.
• X-ray crystallography relies on the dual wave/particle nature of x-rays to discover information about the structure of crystalline materials.
• X-ray fluorescence spectrometry relies on characteristic secondary radiation emitted by materials when excited by a high-energy x-ray source and is used primarily to determine amounts of particular elements in materials.

Introduction

Rocks, sediments, and precipitates are examples of geologic materials that are composed of minerals. Numerous analytical techniques are used to characterize these materials. One of these methods, X-ray powder diffraction (XRD), is an instrumental technique that is used to identify minerals, as well as other crystalline materials. In many geologic investigations, XRD complements other mineralogical methods, including optical light microscopy, electron microprobe microscopy, and scanning electron microscopy. XRD provides the researcher with a fast and reliable tool for routine mineral identification. XRD is particularly useful for identifying fine-grained minerals and mixtures or intergrowths of minerals, which may not lend themselves to analysis by other techniques. XRD can provide additional information beyond basic identification. If the sample is a mixture, XRD data can be analyzed to determine the proportion of the different minerals present. Other information obtained can include the degree of crystallinity of the mineral(s) present, possible deviations of the minerals from their ideal compositions (presence of element substitutions and solid solutions), the structural state of the minerals (which can be used to deduce temperatures and (or) pressures of formation), and the degree of hydration for minerals that contain water in their structure. Some mineralogical samples analyzed by XRD are too fine grained to be identified by optical light microscopy. XRD does not, however, provide the quantitative compositional data obtained by the electron microprobe or the textural and qualitative compositional data obtained by the scanning electron microscope.

Theory and Methodology

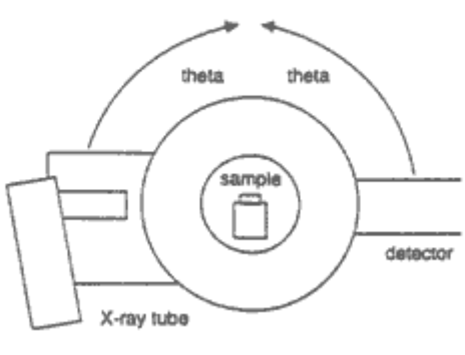


Figure 1. Simplified sketch of one possible configuration of the X-ray source (X-ray tube), the X-ray detector, and the sample during an X-ray scan. In this configuration, the X-ray tube and the detector both move through the angle theta (θ), and the sample remains stationary.

The three-dimensional structure of nonamorphous materials, such as minerals, is defined by regular, repeating planes of atoms that form a crystal lattice. When a focused X-ray beam interacts with these planes of atoms, part of the beam is transmitted, part is absorbed by the sample, part is refracted and scattered, and part is diffracted. Diffraction of an X-ray beam by a crystalline solid is analogous to diffraction of light by droplets of water, producing the familiar rainbow. X-rays are diffracted by each mineral differently, depending on what atoms make up the crystal lattice and how these atoms are arranged.

In X-ray powder diffractometry, X-rays are generated within a sealed tube that is under vacuum. A current is applied that heats a filament within the tube; the higher the current the greater the number of electrons emitted from the filament. This generation of electrons is analogous to the production of electrons in a television picture tube. A high voltage, typically 15-60 kilovolts, is applied within the tube. This high voltage accelerates the electrons, which then hit a target, commonly made of copper. When these electrons hit the target, X-rays are produced. The wavelength of these X-rays is characteristic of that target. These X-rays are collimated and directed onto the sample, which has been ground to a fine powder (typically to produce particle sizes of less than 10 microns). A detector detects the X-ray signal; the signal is then processed either by a microprocessor or electronically, converting the signal to a count rate. Changing the angle between the X-ray source, the sample, and the detector at a controlled rate between preset limits is an X-ray scan (figs. 1 and 2).

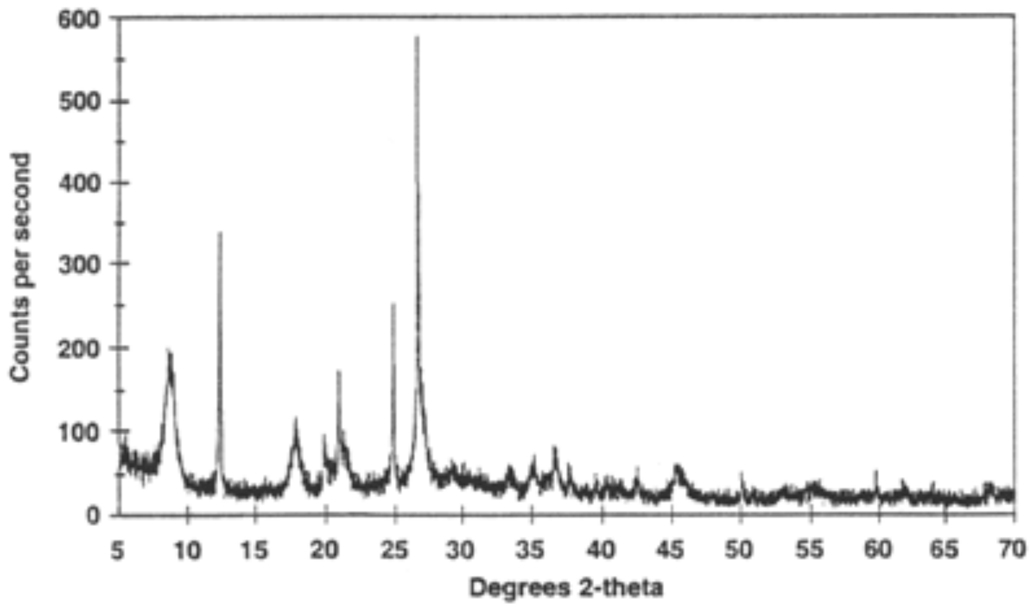
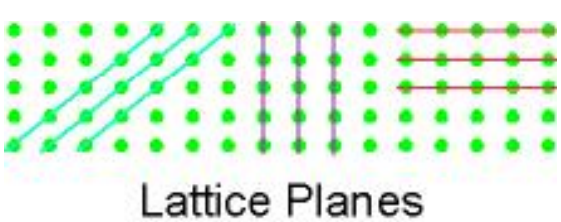


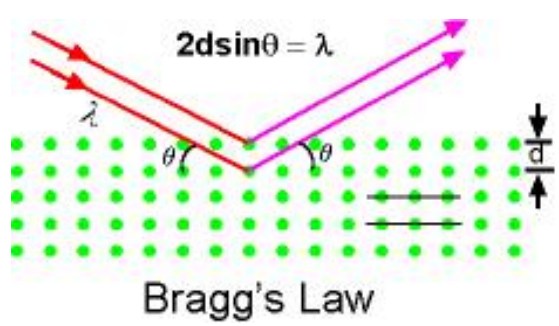
Figure 2. Example of an X-ray powder diffractogram produced during an X-ray scan. The peaks represent positions where the X-ray beam has been diffracted by the crystal lattice. The set of d-spacings (the distance between adjacent planes of atoms), which represent the unique "fingerprint" of the mineral, can easily be calculated from the 2-theta (2 θ) values shown. The use of degrees 2-theta in depicting X-ray powder diffraction scans is a matter of convention, and can easily be related back to the geometry of the instrument, shown in figure 1. The angle and the *d*-spacings are related by Bragg's Law, as described in the text.

When an X-ray beam hits a sample and is diffracted, we can measure the distances between the planes of the atoms that constitute the sample by applying Bragg's Law. Bragg's Law is:

$$n\lambda = 2d\sin\theta$$

where the integer *n* is the order of the diffracted beam, λ is the wavelength of the incident X-ray beam, *d* is the distance between adjacent planes of atoms (the *d*-spacings), and θ is the angle of incidence of the X-ray beam. Since we know λ (1.54 for Cu) and we can measure θ, we can calculate the *d*-spacings. The geometry of an XRD unit is designed to accommodate this measurement (fig. 1). The characteristic set of d-spacings generated in a typical X-ray scan provides a unique "fingerprint" of the mineral or minerals present in the sample. When properly interpreted, by comparison with standard reference patterns and measurements, this "fingerprint" allows for identification of the material.



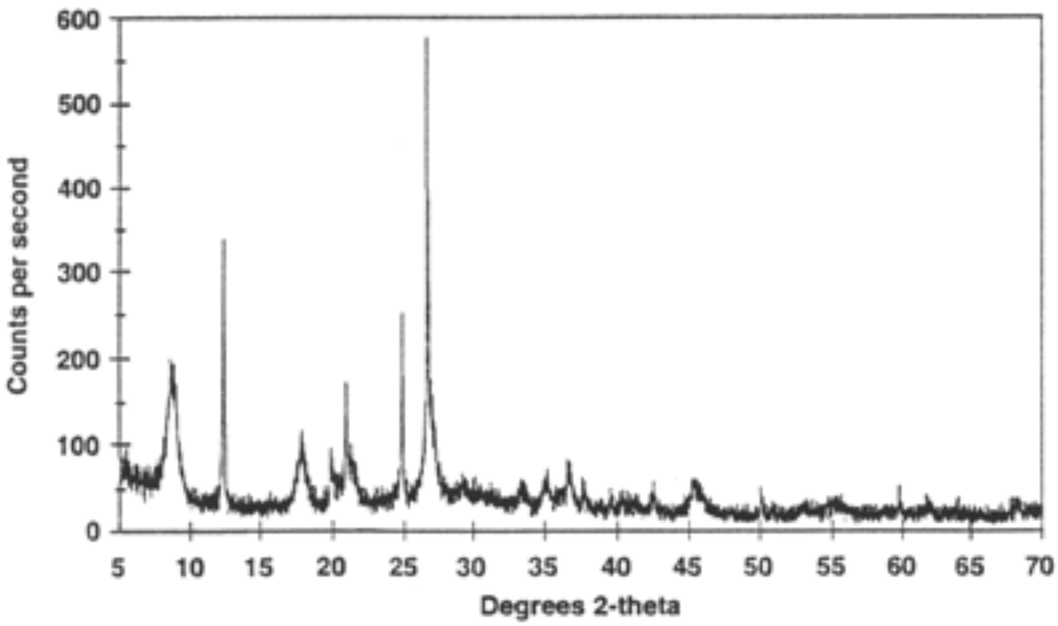


Diffraction Patterns

A diffraction pattern records the X-ray intensity as a function of 2-theta angle. All the diffraction patterns you'll see on this web site were prepared as step-scans. To run a step-scan we mount a specimen, set the tube voltage and current, and enter the following parameters:

--A starting 2-theta angle.
--A step-size (typically 0.005 degrees).
--A count time per step (typically 0.05-1 second).
--An ending 2-theta angle.

Once started, the goniometer moves through its range, stopping at each step for the allotted time. The X-ray counts at each step are saved to a file on the computer. Once finished, the data are smoothed with a weighted moving average and a diffractogram like the one below is printed or displayed.



Sample preparation

The Ideal Specimen is a statistically infinite amount of randomly oriented powder with crystallite size less than 10 µm, mounted in a manner in which there is no preferred crystallite orientation. Dr. Evans will explain the sample preparation procedure.

You will then prepare your unknown mineral samples and Dr. Evans will show you how to run them on the XRD and how to process the data

Applications of XRD

XRD has a wide range of applications in geology, material science, environmental science, chemistry, forensic science, and the pharmaceutical industry, among others. At the U.S. Geological Survey, researchers use XRD to characterize geologic materials from a wide variety of settings; below are just a few examples.

Mineral-Environmental Studies

In studies of areas affected by acid mine drainage, the identification of secondary minerals and fine-grained precipitates is a critical element. Acid is generated when iron sulfide minerals, such as pyrite, weather. Elements derived from the alteration of the sulfide minerals can form secondary minerals or go into solution. Elements that go into solution may form mineral precipitates as conditions (temperature, acidity, solution composition) change. Accurate mineralogical characterization of the precipitates and secondary minerals, together with hydrogeochemical data, help us to better understand the solubility, transport, and storage of metals.

Ore Genesis Studies

Minerals form under specific ranges of temperature and pressure. Mineralogical identification of ore minerals and associated minerals, including fine-grained hydrothermal alteration minerals, provides evidence used to deduce the conditions under which ore deposits formed and the conditions under which, in many cases, they were subsequently altered.

Predictive Stratigraphic Analysis

Mineralogical characteristics of paleosols (ancient buried soil horizons) and underclays (the fine-grained detrital material lying immediately beneath a coal bed) have been instrumental in correlating coal zones from the Appalachian basin into the Western Interior basin. They have been the key to quantifying the paleolatitudinal climate gradient in North America during the late Middle Pennsylvanian.

Remote-Sensing Studies

Mineralogical analysis by XRD is used in conjunction with remotely sensed data in several research investigations. XRD is used to identify the minerals composing clay-rich, hydrothermally altered rocks that occur on several Cascade volcanoes. Such rocks are believed to play an important role in the generation of large landslides and mudflows. XRD is used to analyze saline minerals, including borates. Many saline hydrate minerals produce diagnostic spectral bands, and spectral data provide a basis for mineral exploration using remote-sensing data. Analysis of airborne imaging spectrometer data can directly map mineral occurrences by detecting diagnostic spectral absorption bands, the shape and position of which are determined by individual mineral structures. A detailed knowledge of sample mineralogy, provided at least in part by XRD, is required to understand the observed spectral absorption features.

Genesis of Coal Beds

XRD is one of the primary tools used to evaluate the lateral and vertical variations in mineral matter and major, minor, and trace elements in coal beds. These data are used to help determine the impact of geologic and geochemical processes on coal bed formation in order to understand and predict both inorganic and organic variability within and among minable coal beds.

Mineral-Resource Assessments

Mineralogical characterization provides part of the data required to determine the particular kind of mineral deposits encountered in mineral-resource assessment studies. XRD allows us to identify fine-grained mixtures of minerals found in associated gangue and alteration assemblages, which cannot be resolved by other methods.

The following assignment is from the currently out-of-print MINERALS AND ROCKS: EXERCISES IN CRYSTALLOGRAPHY, MINERALOGY, AND HAND SPECIMEN PETROLOGY. By Cornelis Klein. John Wiley and Sons, New York, 1989

EXERCISE 15

IDENTIFICATION OF AN UNKNOWN BY X–RAY POWDER DIFFRACTOMETER TRACING

PURPOSE OF EXERCISE

To understand the steps involved in the identification of an unknown mineral using the diffractometer tracing of its powder diffraction effects. As in exercise 14, you will need to refer to the Powder Diffraction File of the JCPDS.

BACKGROUND INFORMATION: If you have completed exercise 14 before beginning this assignment, you will find that identification of unknown crystalline materials is a great deal faster by diffractometer technique than it is by film. This is so because a diffractometer tracing provides you with a graphical display of each peak position relative to a direct reading 2θ scale, as well as to a reasonably quantitative, direct reading relative intensity scale.

A powder X-ray diffractometer is a great deal more complex and expensive than a powder camera mounted on an X-ray generator. A diffractometer, in conjunction with an X-ray generator, consists of a goniometer (a device that measures the angular location in terms of 2θ for a diffraction peak), an X-ray counting device (such as a Geiger, a scintillation, or a proportional counter for measurement of peak intensity), and an electronic readout system (see Fig. 15.1). On nonautomated powder diffractometers the graphical result is a diffractometer chart obtained over a 2θ region of about 6° to 80°, during a time period of about 45 minutes. On an automated diffractometer the same results are printed out on an 8 2 x 11-inch page in about 15 minutes. In either case, the final diagram shows peak locations with respect to a horizontal 2θ scale, as well as relative intensities of the peaks in terms of a vertical scale. To search the JCPDS file for identification of the unknown, an investigator needs at the minimum to convert the 2θ values of the three most intense peaks on the graph to *d* values [using the *X-ray Diffraction Tables* of Fang and Bloss (1966), or, if these are not available, by using Table 14.1, or by solving the Bragg equation as outlined in section 2 of assignment 14]. It is strongly suggested, however, that to be certain the identification is completely unambiguous, the investigator should compare the *d*s of another ten or so peaks in the pattern with the published pattern on which the identification is based. Even though the identification of an unknown is based on matching of the three most intense X-ray diffraction lines, all other lines in the unknown pattern and those of the selected matching reference pattern should show good agreement in *d* values and intensity.

MATERIALS

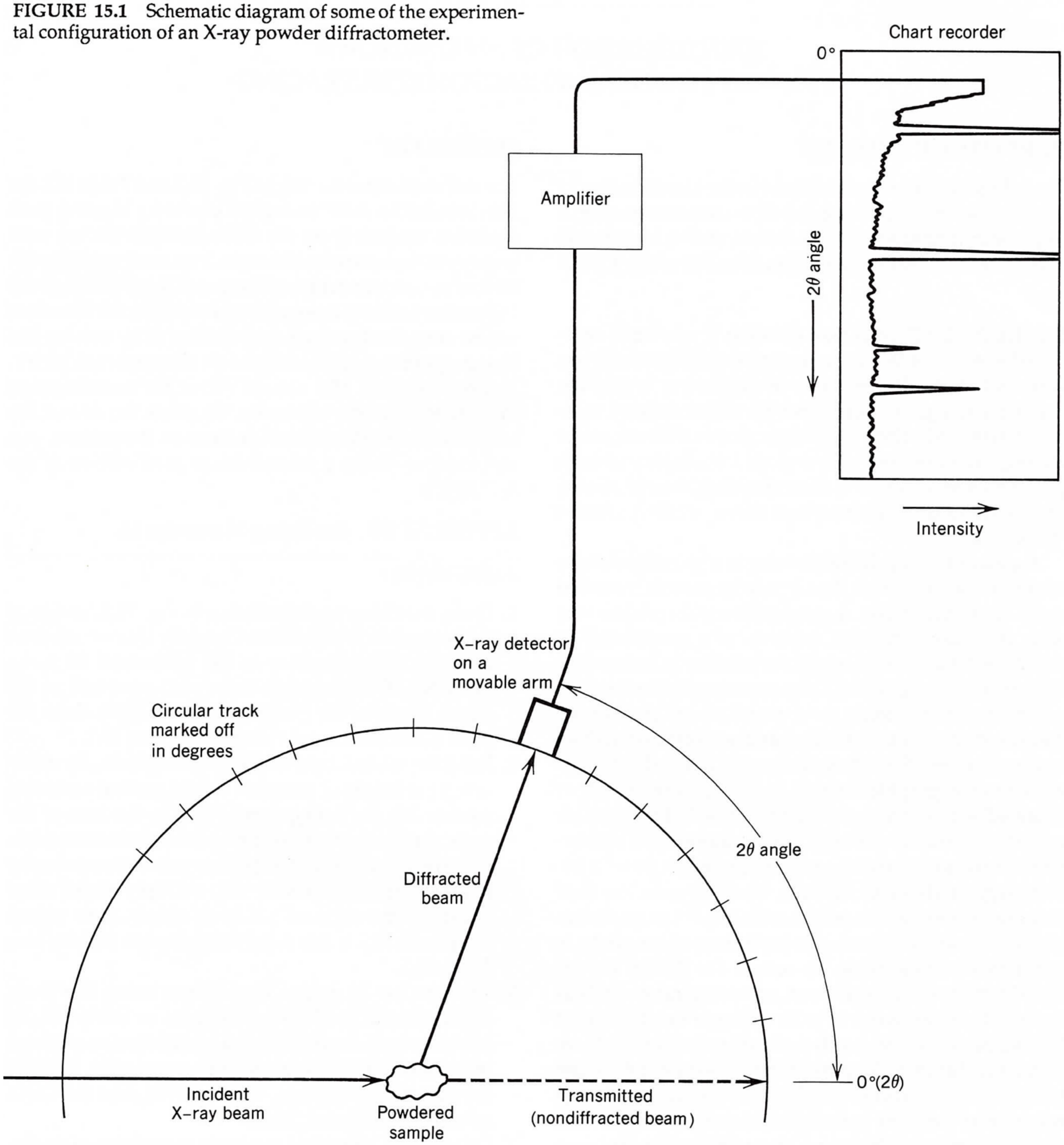
The diffractometer tracing in Fig. 15.2 and Table 15.1 for data tabulation. A 90° triangle is useful for locating peak positions accurately on the diffractometer tracing with respect to the horizontal 2θ scale. You need access to the 2θ-to-*d* conversion tables of Fang and Bloss (1966), *X-ray Diffraction Tables*. If these are not available, the 2θ values can be converted to their appropriate *d*s by solving the Bragg equation with the help of an electronic calculator. Figures 15.3 and 15.4 should allow for unambiguous identification of the unknown. To check the *d*s and the intensities of all the diffraction lines on the pattern, you will need access to a microfiche or card edition of the JCPDS file.

REFERENCES See listing in exercise 14.

ASSIGNMENT

1. Using the diffractometer tracing in Fig. 15.2, assign 2θ values to each of the peaks. Carefully locate each peak position with reference to the horizontal 2θ scale. Write the 2θ appropriate to the peak next to it on the figure. Number the peaks from left to right. Enter the peak numbers and 2θ values into Table 15.1.
2. Read the relative intensities of all the peaks, by measuring the height of the peak on the vertical scale and subtracting the background value in the area of the peak. Assign the value of 100 to the most intense peak. If the height of the tallest peak is *y* divisions (where *y* is some number less that 100), multiply all the other peaks by the ratio of 100/*y* to obtain their values relative to 100. Enter these relative peak heights into Table 15.1.
3. Convert the 2θ angles to *d* values using the *X-ray Diffraction Tables* of Fang and Bloss, or Table 14.1, or calculate each *d*, using the Bragg equation as outlined in section 2 of the assignment in exercise 14. Because the pattern shows no $\alpha_1 - \alpha_2$ doublets , use the CuKa column in Fang and Bloss.
4. Using the *d* values of the three most intense peaks, identify the substance with Fig. 15.3 or 15.4.
5. After identification, make sure the additional five *d* values listed in Fig. 15.3 or 15.4 show good agreement with the data from your pattern.
6. If a JCPDS file is available, locate the complete reference card on the substance and make sure *all* peaks and their intensities of both the "unknown" and the substance you identified it to be show good correspondence.

FIGURE 15.1 Schematic diagram of some of the experimental configuration of an X-ray powder diffractometer.



EXERCISE 15

Student Name

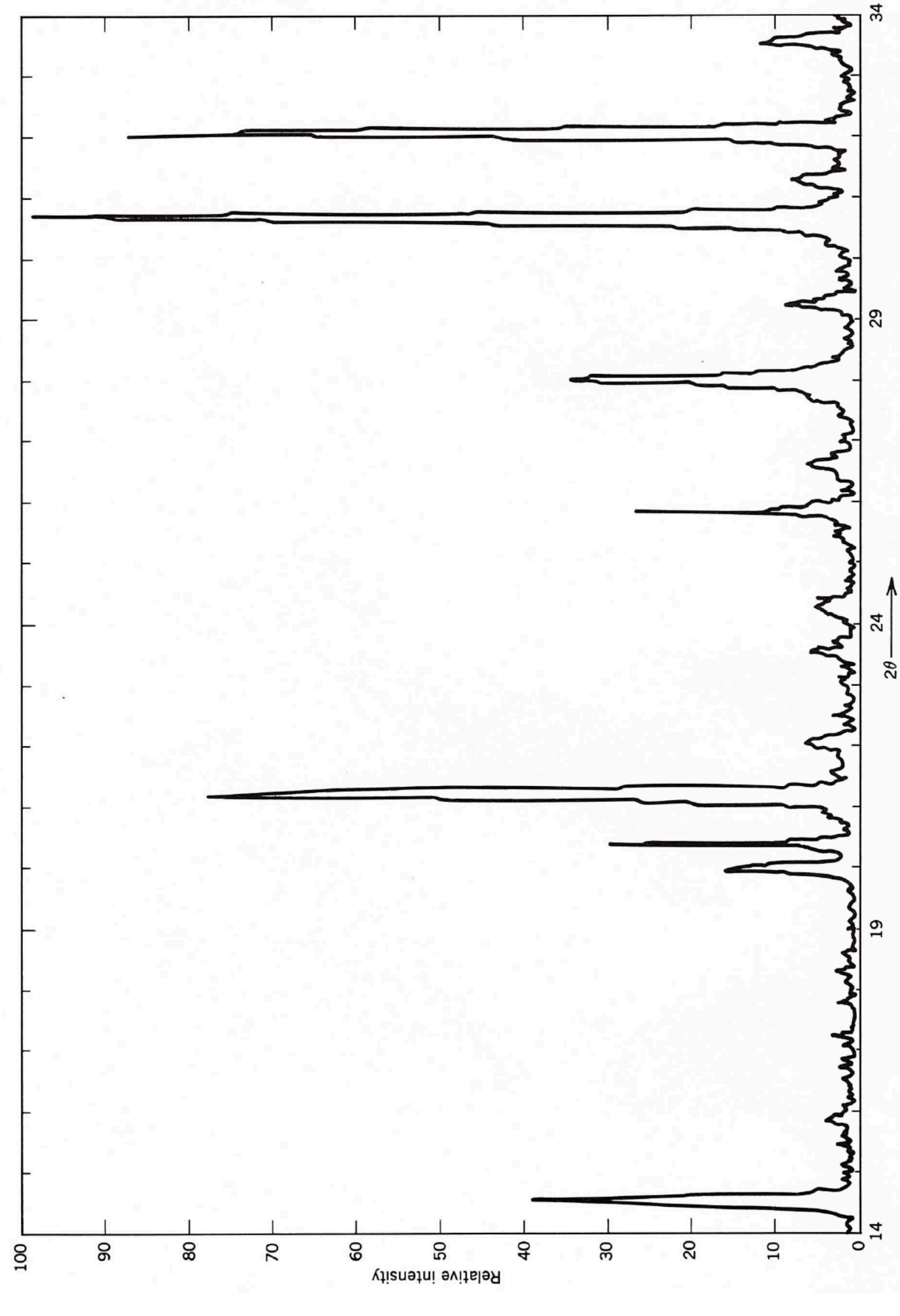


FIGURE 15.2 Diffractometer tracing for the unknown that is to be identified in this exercise. The X-ray radiation was produced by a Cu target X-ray tube. The 2θ-angle scale is horizontal. The relative intensity scale is vertical.

EXERCISE 15

Student Name

TABLE 15.1 Record of Measurements Obtained from the Diffractogram in Fig. 15.2.
Refer to the diffractogram in Fig. 15.2.

Line Number[a]	*2θ angle*	*d*	*I*

Published 2θ values for the three most intense lines in the pattern of Fig. 15.2.

2θ	I
30.62	100
31.97	90
21.06	75

[a] Line numbers go consecutively from left to right.

Mineral identified as: ____________________

JCPDS file no.: ____________________

GSCI 221 Mineralogy: The Unknown Mineral Term Paper

Welcome to mineralogy!
You are given a mineral sample that is an unknown, in some cases even to Dr. Evans. The following assignments will allow you to definitively identify your specimen and then become an expert on it. The total paper is worth 100 points.

ASSIGNMENT #1:
PHYSICAL DESCRIPTION OF SPECIMEN
(<u>DUE OCTOBER 4</u>) (10 points)

The first step to a definitive mineral identification is typically a physical description of the specimen using the properties listed below. Describe the following for your unknown. If you have difficulty with any of these (e.g., hardness/tenacity of a very small specimen) ask me to give you some hints.

Color:
Luster:
Streak:
Cleavage/Fracture (if apparent):
Hardness:
Tenacity:
Density:
Magnetism:
Fluorescence:
Acid reaction:

SPECIMEN IDENTITY: _______________
(If you don't have enough information as yet, state that, and give your best guess.)

ASSIGNMENT #2:
X-RAY DIFFRACTION
(<u>DUE NOVEMBER 9</u>) (20 points)

One of the most definitive tests of an unknown mineral's identity is to make a measurement of the mineral's powder X-ray diffractogram. The "XRD powder pattern" provides a unique fingerprint of the mineral – every mineral will have a different and definitive diffractogram. In fact, crystal structures are still largely derived from high resolution measurements of the diffraction resulting from excellent single crystal specimens. In your XRD laboratory, you will be given the opportunity to prepare and run an unknown sample. This will be practice for your sample. Be sure you understand this lab before you attempt to identify your specimen using XRD.

Guess regarding Identity: _____________
In Assignment #1, you were asked to make a guess of your mineral specimen's identity. This assignment will allow you to unequivocally decide if your guess was on target or not. To find out, you will need to do the following:
(1) Look up the XRD pattern for the mineral you believe your specimen to be. Photocopy that XRD pattern and attach it to this sheet.
(2) Use your guess mineral pattern to decide what 2theta range will be best for identifying your specimen. In other words, in what angle range are the largest (most intense) peaks located?
(3) Make an XRD slide of your mineral and sign up for a time to analyze it.
(4) Make a figure showing the measured intensity vs the 2theta values measured for your specimen. Attach it to this assignment.
(5) Is your unknown the mineral that you guessed in Assignment #1? If not, what mineral is it?

ASSIGNMENT #3:
LIBRARY RESEARCH & OUTLINE
(DUE NOVEMBER 15) (20 points)

Congratulations! By now you know the identity of your mineral: you have a physical description and an XRD pattern. Now it's time to do a little more reading on your mineral specimen. Find the following information for your mineral:

I. CRYSTALLOGRAPHY.
a. Crystal System
b. Point Group
c. Unit Cell Parameters
II. CHEMISTRY.
a. Mineral Composition
b. Mineral Structure (site types, coordination, etc.)
c. Related Minerals: Solid Solutions
d. Related Minerals: Polymorphs
III. LOCALES & GENESIS.
a. Famous locales
b. Occurrence/Petrogenesis (how is it formed?)
IV. USES/ECONOMICS.
V. CURRENT RESEARCH (info from at least TWO technical articles)

If you can find it, you might also include sections dealing with the mineral history
Turn in an outline with the information that you find. Next to each piece of information, include the SOURCE of the information. Turn in a references list with your outline. Here is an example of what it should look like. The more detailed yours is, the better!

MINERAL CONNECTICUTITE
I. CRYSTALLOGRAPHY
a. Crystal System: Isometric (Mineralogist X and Mineralogist Y, 1999)
b. Point Group: 4/m 3 2/m (Mineralogist X and Mineralogist Y, 1999)
c. Unit Cell Parameters: a = 2Å (Mineralogist XX, 2001)

II. CHEMISTRY
a. Mineral Composition: K_8O_4 (Mineralogist XX, 2001)
b. Mineral Structure
i. K is in 8-fold coordination with respect to O (Mineralogist Y, 1978)
ii. K-O bonds are 5Å long (Mineralogist Y, 1978)

And so forth… then add a bibliography of the form **(Use the GSA reference format. If you are not familiar with it, see Dr. Evans):**
Mineralogist X and Mineralogist Y (1999) A new mineral: Connecticutite. Journal of Minerals v. 23, p. 28-32.
Mineralogist XX (2001). The Mineral Connecticutite. Mineral Publishing, New York, 232 pp.

FINAL PAPER
(<u>DUE DECEMBER 13</u>) (50 points)

LATE PAPERS WILL LOSE 10 POINTS FOR EACH DAY THAT THEY ARE LATE

FINAL PAPER FORMAT
1. **Title Page:** a title, your name, and (optional) anything else you deem useful (your email address, the course name, my name, an illustration, whatever)

2. **Text:** ~4-5 pages of double-spaced text (12 pt type)
USE SECTION HEADINGS such as:
Introduction
Mineral Chemistry
Mineral Crystallography
Etc.

3. **References: ≥ 5 references** from sources that may include books, journals, government publications, or web sites. However, web sites should be referenced **ONLY** if they are the **PRIMARY** source of information, and **no more than2** will count toward your overall 6 reference minimum (Check with Dr. Evans FIRST). **DO NOT FORGET THAT YOU MUST INCLUDE TWO PEER-REVIEWED JOURNAL PAPERS!!! Reference format should be as in *Geological Society of America Bulletin*.**

Some Recommended Mineralogy Literature **<u>Do a GeoscienceWorld search!!!</u>**
Mineralogy Journals
- American Mineralogist
- Canadian Mineralogist
- Acta Crystallographica
- Contributions to Mineralogy and Petrology
- Mineralogical Magazine
- Mineralogical Record (mostly for hobbyists, rather than professional scientists)

Other Journals
- Nature
- Science
- Earth and Planetary Science Letters
- Geochimica et Cosmochimica Acta
- Chemical Geology
- Journal of Sedimentary Petrology
- Journal of Geophysical Research
- Journal of the American Chemical Society

Books (some of these are in 536NC or ask Dr. Evans, please do not remove from room except to copy)
- Dana's System of Mineralogy by Dana
- Rock-Forming Minerals by Deer, Howie and Zussman
- Manual of Mineralogy by Klein & Hurlbut
- Introduction to Mineral Sciences by Putnis
- Reviews in Mineralogy Series published by Mineralogical Society of America
- And many more.

4. **Tables (optional):** See articles for examples

5**. Figures** with *Figure Captions***: 2 minimum**, figure caption may be on same page or separate and should explain the figure, define any relevant symbols (e.g., for plots), and reference source material if appropriate
****Make sure that you make a reference your figures in your text.

GSCI 360: Research Methods **Research Proposal Project**

The final project in this course is a proposal describing a research project that *could* be completed as your Senior Project (required for all geology specializations). Your proposal must include a description of the project as well as information about the cost and work required to complete the work.

- Your proposed project should require a year to complete: one full-time summer followed by 2 semesters during the school year (2-3 hours of work per week, equivalent to taking GSCI 460).
- It *is strongly recommended* that you propose work you are interested in pursuing for your senior project, but this is not required.
- Proposals must involve new potential work: you cannot propose to "redo" a project from another course or work you completed as independent research. You can propose an extension to a previous project, if you describe previous results and how new work would be an improvement.

Proposal Format: The final proposal must be submitted as a single PDF file that strictly follows the template given online. Use this list (also in the template) to make sure your proposal is complete.

- ☐ ***Cover page***: Includes proposal title, the name of the principal investigator, the name of your potential project advisor, and a project summary (not to exceed 300 words).
- ☐ ***Proposal narrative***: Includes a review of previous work and describes the project objectives, method, and expected outcomes. Must include appropriate in-line citations.
  - ☐ Your narrative must have at least 5 pages of text (not including figures/tables)
  - ☐ The narrative should not exceed 10 pages *including* figures/tables.
  - ☐ Text must be in a 12-point font, single or double spaced, with one-inch margins
- ☐ ***Project timeline:*** a table of major milestones and expected completion dates for project objectives.
- ☐ ***Reference list:*** full sources for all citations, alphabetized and in GSA format.
- ☐ ***Proposal budget***: 1 page, including a table of expenses and.a text justification explaining why each expense is necessary for the project. *The online template has an example with proper formatting..*
- ☐ ***Facilities and equipment***: describes which facilities and equipment *relevant to the proposal method* are available for this project at CCSU or elsewhere (maximum 1 page in length).
- ☐ ***Biographical sketch:*** Resume for the principal investigator, including information about *relevant* education, employment, presentations, and activities (maximum 1 page).

Oral Presentations: Each proposer must give an 5-7 minute conference-style talk summarizing your project, followed by questions from the audience, during the last class period (***May 10, 10:50 AM***): PowerPoint slides must be turned in via Moodle **no later than 11:59 PM on May 9.** Grades will based on the following criteria:

- ***Content (30%)***: does the presentation content include objectives, background, method, and outcomes?
- ***Presenter Style (30%)***: is the presenter clear, engaging, able to answer questions, and within the time limit?
- ***Slide Style (20%)***: are the slides used clear and well-designed (including figures), and turned in on time?
- ***Organization (20%)***: is the presentation logically organized and clearly presented?

Written Proposals: Final proposals must be submitted to Moodle in a <u>single PDF file</u> by **11:59 pm EDT on May 17.** <u>Proposals will not be accepted late, nor via any other submission method:</u> any questions about submitting proposals should be addressed before the due date. Grades will be based on the following criteria:

- ***Background (25%)***: does the proposal contain detailed background information from a range of sources?
- ***Method (25%)***: is the method well-described and scientifically sound, and likely to achieve the objectives?
- ***Objectives (25%)***: does the proposed project include achievable goals that represent original research, and are the proposed outcomes consistent with the proposed method?
- ***Format, Budget, & Style (25%)***: is the proposed timeline and budget appropriate, is the proposal clearly written with proper citations, and submitted in the requested format (see template)?