UAF Core Curriculum in the Natural Sciences and its Assessment

1.0 Introduction

The UAF Core Curriculum for undergraduate bachelor’s study is described in the UAF Catalog [2009-2010, page 125] as being “characterized by a common set of learning experiences…” that “…provides students with a shared foundation of skills and knowledge that, when combined with specialized study in the major and other specific degree requirements, prepares student to better meet the demand of life in the 21st century.” The science objective for student achievement is “an intellectual comfort with the sciences – including the scientific method, frameworks that have nurtured scientific though, traditions of human inquiry and the impact of technology on the world’s ecosystem;…” This objective is satisfied by enrolling in Core-approved Natural Science courses.

Acceptance of a course into the Natural Science component of the UAF Core Curriculum (a course with an “X” designation) places certain requirements on the academic department and instructor responsible for the course, independent of the UAF campus location at which it is taught. First, it must be a four-credit course that includes a laboratory segment; typically three one-hour lectures and one three-hour lab per week. Additionally, and in brief summary (based in part on “Guidelines for Core Natural Science Designator, Faculty Senate Meeting 18, April 13, 1990” and Faculty Senate Form 8 – See Attachments A and B):

1.1 The course syllabus must include a list of the major scientific concepts that the course will convey and make it clear that the course is organized around these major concepts rather than their application;

1.2 Laboratory exercises are to be designed to familiarize students with methods for the acquisition and expansion of scientific knowledge, including: a) data collection and analysis, b) hypothesis building, and c) experimentation;

1.3 The course will consider relationships between science and society by exploring public science policy and its development; and

1.4 There will be a plan for evaluating the course’s effectiveness.

Leadership for the Natural Science component is delegated by the Provost to the Dean of the College of Natural Science and Mathematics, who in turn has for many years’ delegated leadership to an associate dean. There has been no committee structure since 2004. Recounting the long history of how the Natural Science component evolved over 20 years may be of interest, but we focus here simply on how the initial expectations are currently being carried out. The question of greatest interest here is probably “What do I need to do in order to satisfy requirements of the UAF Natural Science component of its Core Curriculum when I am the instructor?” The material herein should provide the answers.
2.0 Core Objectives When Teaching the Course

“The goal of the Natural Science component of the Core Curriculum is to prepare students for lifelong learning in the natural sciences ...” [Faculty Senate Guidelines, 1990]. The department and instructor must meet three objectives each time the course is taught, as discussed here, and once each five years the course will undergo a Core-required assessment process, for which the requirements will be discussed later. The three objectives to be met are as follows.

2.1 Communication through the course syllabus. Verify that your course syllabus satisfies Item 1.1, above, in addition to all the requirements of the Faculty Senate, as given elsewhere. You also need to outline for the students the expectations of the Core that are discussed below for Items 1.2 and 1.3, above, and how they will be carried out during the semester. When the course is to undergo fifth-year assessment, also outline for the students how the assessment activities will be incorporated into the course. A copy of each instructor’s course syllabus is to be submitted to the Dean’s Office each time the course is taught, marked for attention of the associate dean for core natural science assessment. The syllabus will be reviewed for conformity with Core expectations and assistance will be provided if needed.

2.2 Instruction in the scientific method and scientific experiments. Students are expected to become familiar with the scientific method and the concept of a scientific experiment (per Item 1.2 above), where an experiment is intended to answer a question in a quantitative manner. The question leads to some ideas and then to a specific hypothesis for which an experiment can be designed to make measurements that in principle will provide support for or disagreement with the hypothesis. This leads to all the issues of design, measurements, data collection, analysis, interpretation of the data, and finally a test of the original hypothesis. How do the students gain this familiarity? The chosen vehicle is the course’s laboratory section, which places much responsibility on your TAs while you and your department’s lab coordinator share leadership responsibility and provide TA mentoring. Instruction should be part of the normal laboratory experience and occur in at least three distinct labs (per Form 8). You should also look for opportunities to discuss the scientific method and experiments within the classroom lecture period, particularly if it can be done seamlessly in the context of your lecture materials. Note too that some instructors get hung up on the word “hypothesis,” saying that only biologists use this method. This is not true, but the dictionary provides alternative words, such as assertion, premise, conjecture, assumption, etc. This activity is intended to be a permanent part of the course each time it is taught, not just when it is assessed. Assessment will be discussed in Section 3.

2.3 Disconnects between scientific knowledge and public policy and/or behavior in U.S. society (i.e., science and society). Students are asked here to explore the how scientific evidence and knowledge influences public policies (Item 1.3, above) and/or public perceptions. First, it is important for students to learn how to recognize that they can be entwined and then learn how to rationally detect and discuss the strengths and weaknesses of opposing views. Finally how do students take this information and construct their positions on the issue? Some instructors will take the unacceptable
position that there is so much material to cover in the course and this subject is not in the
textbook; hence they will not do it. This is not acceptable and raises the question of
continue participation in the Core’s Natural Science component. My ongoing observation
is that one can generally find an example per week or even every several days in a
newspaper or online that is worthy of discussion, even if only to frame the issues for the
students to consider on their own. Several of the more endearing and ongoing subjects are
global warming, nuclear energy, fossil fuels, mineral extraction in the head waters of a
fishery, AIDS and birth control, etc.

An example: The News Miner [18 August 2010] ran a story on the use of
individual septic systems at Cape Cod, Massachusetts because the local
government did not want to encourage an increased population by installing a
community sewer system. The increase occurred anyway and the delayed
consequence of the decision is enhanced nitrogen migration in the sandy soils and
large algae blooms in the local waters.

Another example: I was reading a biology assessment report about the same time
as schools in Mexico were closing due to the fast onset of the “Swine” flu several
years ago. This was then a timely example of a public policy being influenced by
rapidly developing, somewhat fragmentary knowledge and several early deaths.
There was not unanimous opinion amongst the students as to how the government
should have responded.

Some instructors have been known to occasionally engage in a discussion with the entire
class to broaden the range of opinions openly expressed. This can extend to the
laboratory sessions as well, while recognizing that there is great demand on everyone’s
time. The objective is to engage the students in issues for which scientific knowledge and
evidence are part of the debate on issues of public science policy that affects society.
Recognizing that public policy is carried out within political systems, one might equate
“society” with voters. Some instructors struggle with the difficulty in getting students to
challenge “authoritative” sources without question, which is contrary to one of the
objectives of a “college education” and the goal of live-long learning. This activity is
intended to be a permanent part of the course each time it is taught, not just when being
assessed. Assessment will be discussed in Section 3.

3.0 Assessment of the Core Natural Science Course

Each Natural Science course in the UAF Core Curriculum is scheduled for assessment
once every five years, as is summarized in Attachment C. Courses not responsive in the
scheduled year are encouraged to carry out the assessment as soon as possible and return
to the regular assessment schedule. Assessment of the syllabus is addressed each time the
course is taught, as previously discussed. There are three other assessment tools that
involve students and the follow-up work by the course instructor, as discussed here.

3.1 Assessment for instruction in the scientific method and scientific experiments.
Assessment of this learning experience once each five years is also done as part of the
laboratory by assigning an activity that can also be discussed and started within a lab session and possibly completed outside the lab period as a take-home assignment. It should be done later in the semester after you are confident that adequate instruction has taken place. The most frequent method by which the assessment is being carried out is through the instructor’s design of an experiment, construction of a data set, along with some “spurious” or “bogus” data, and some interpretations that contain errors. This experiment should be relevant to the particular course. The student’s task is to study the problem presented, consider a set of questions of your choosing (that are designed to assess the students understanding), and provide written answers of several sentences length. This has been known as the “brief” writing exercise and/or as the “Instructor-written exercise based on a (bad) example of scientific research design.” The original example devised in 2004 for a biology course is included in Attachment D and is repeated later along with a further example. There are numerous examples that can be provided by faculty members in your department who have been previous agents of this assessment activity (and who can possibly make recommendations on how it can be improved) or you can start from scratch and devise your own. Once the students have submitted their work, review it and arrive at your personal assessment of how they performed. Have they demonstrated an ability to detect “bogus” data, for example? Did they detect an extrapolation that then led to a dubious conclusion, etc. You will have to construct a method of scoring the work and selecting how much, if any, of a score will count towards the course grade. It is part of a lab period and take-home work, so too little credit can lead to reduced student participation. This new knowledge of the student outcomes will now be used to prepare your written assessment of the student learning outcomes, as discussed in Section 4.

3.2 Assessment for disconnects between scientific knowledge and public policy and/or behavior in U.S. society (i.e., science and society). Assessment of this learning experience once every five years is carried out by means of a student essay that focuses on issues in which scientific evidence and/or knowledge are in conflict with public science and social policies. In general, the subject will have become a political issue, and seldom these days is it carried out in an overtly contemplative manner. The intention here is to be contemplative, gaining an understanding of all views. As an additional guide, there is this quote from the 2/9/04 memo from then Associate Dean John Aspnes to faculty of courses up for assessment;

“There are “disconnects” between scientific evidence and public policy or public behavior in U.S. society. Describe an example, including a synopsis of some relevant scientific evidence. Overall (not just with reference to this particular issue), to what extent do you think that science is divorced from public policy and societal problems? Is this good, bad, or simply unimportant?”

It is recommended that the science and public policy writing exercise be assigned sometime during the last quarter of the semester once you think students will have learned enough to meaningfully complete it. The subject area is expected to be related to the nature of the course; e.g., PHYS 213X would not be expecting an essay on mineral extraction in a fishery. Outside of that general guideline, instructors have provided the students great latitude, with some providing a list of acceptable topics, some asking for a
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title in advance, and some being more detached. The original design in 2004 asked for a “2-page essay (~500 words).” Some instructors increase the length, but that can increase the depth of consideration and you need to consider the range of abilities in the class, which presumably is largely populated by lower-division students. This is a more serious writing exercise and should be treated with more respect than it has been by some instructors. Other instructors have taken this assignment very seriously and are known to have it permanently integrated into their courses. Substitution as a final exam for the course is inconsistent with its intent. Once students have submitted their work, review it and provide an assessment. Do they display an ability to detect a conflict between established scientific knowledge (or evolving knowledge) and public policies. Are they able to articulate well the key ideas being presented and sort fact from fiction in claims. Are there any conflicts between the policy decisions and society; i.e., did the voters march in the streets and/or throw the “bums” out at the next election? Kansas suddenly comes to mind! Many instructors comment, even express joy or disappointment as to the writing skills of the students; e.g., does it improve with class rank? The methods of scoring vary, but significant focus should be on logical clarity in the discussion of the scientific evidence and the public policy and how the two are in conflict. There may be cases where a conflict is resolved and the two become in harmony in the U.S., so a thoughtful analysis of how the conflict was resolved might be nice for a change. Scoring should also take into account the use of references, writing, spelling, etc. A class of 100 will probably get treated differently than a class of 25 simply because of the relative workloads placed on the instructor. You have the choice as to how much, if any, of the score will count towards the course grade, but it can represent a significant piece of take-home work, so too little credit can lead to reduced student participation. There are numerous examples of essays on file in the Dean’ Office within the assessment archives.

3.3 Natural Science Core Questionnaire. At the end of the semester in which the five-year assessment takes place, have your students complete the standard “Natural Science Core Questionnaire” that has been in use since 2004 and return them to you. It is provided here as Attachment E. Many do this at the same time as the students complete the Instructional Assessment System (IAS) form designed to gather students’ opinions of instruction. Some instructors use part of this period to have an open discussion about the course with its students. You should assess the outcome of this exercise and any discussions with students.

4.0 Course Assessment Report.

Following completion of the course, you are required to prepare and submit an assessment report that summarizes the several assessment activities described above, along with recommendations for course improvements. There is pressure towards fully electronic submissions (versus hardcopy notebooks), and instructors are asked to do so in a continuous PDF format (assembled by you) as opposed to a disjointed collection of files on a CD that required work once submitted. Assistance can be provided, for scanning materials submitted in the course in non-electronic form. Anonymity is required for any student-submitted work, especially as the Provost’s Office is pushing for greater online access to assessment information. This is driven by Institutional Accreditation.
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The outline of a typical report nowadays provides the general headings discussed below, but do not feel constrained by this “typical” format. The first report that established the general spirit of the reports that have been submitted since then was submitted in 2004 by Profs. Paul Layer and Rainer Newberry for GEOS 101X (see Attachment F). An example of a recent report from 2006 is included in Attachment G, and note that this is an example where the author has admittedly gone well on and above the normal expectations.

A generic outline could, and often does, look something like the following, but with greatly varying internal contents.

4.1 Introduction. The introduction outlines your expectations for student learning and how student performance is assessed relative to those expectations. Grades are one obvious means of assessment. A few instructors give an exam on the first day and include the same questions as part of the final in order to assess increases in knowledge gained in the semester based on the “before” and “after” answers to the same questions. Nearly every report contains a nice introduction to the course, methods of teaching, an evaluation of the student composition in rank (freshmen, sophomore, junior, senior, non-degree, etc), and the breakdown of academic majors. Include initial and final total enrollment headcount. Some instructors are very good at discussing their personal philosophy of teaching and sometimes their novel ways of trying to understand how students learn. Include copies of all labs (not copies of students’ work) and identify those labs that are intended to fulfill of Item 1.2 of the Introduction. Typically included in the report are copies of all exams and quizzes (not copies of students’ work), and some instructors elect to include representative examples of students’ completed work (labs, quizzes, and exams) in order to support their discussion. In all cases it is imperative to blank out all information that can identify the students.

4.2 Instruction in the scientific method and scientific experiments; i.e., instructor-prepared first writing exercise. As noted above, the sample exercise is intended to test recognition of poor sample design for an experiment within your discipline. What did you deduce about the students’ performance when looking at the students’ class rank and academic major? You will need to include in your assessment report a copy of the written exercise (the instructions given to the students) and the results (scoring rubric and score distribution). It is not necessary to include copies of all student results, but examples can be included to support points made in your assessment. You must remove all student identification information after you have completed your assessment.

4.3 Disconnects between scientific knowledge and public policy and/or behavior in U.S. society (i.e., science and society); i.e., student-prepared second writing exercise. Review the students’ work and provide an assessment, where you consider things discussed above. You need to include in your assessment report a copy of your scoring rubric, score distribution, and number of essays submitted. It is not necessary to include copies of all student essays, but examples can be included to support points made in your assessment. Many instructors provide examples of excellent, average, and poor essays, for example.
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Again, you must remove all student identification information once your assessment is completed.

4.4 Student assessment questionnaire. Compile and discuss the data from the completed survey forms, all of which should be included in the report, but after you have removed all student identification information. You will want to maintain knowledge of the students’ names initially if you are comparing student’s perceived outcomes in the questionnaire with their final grades, as some have done. Include such things as how many students submitted the completed questionnaire and the distribution of scores for each of the six questions. I tabulate percentages for the “strongly agree” and “agree” in tabular for all courses, to preserve a long-term summary. Provide your interpretation of how the students assessed the course. Does the outcome lead you to suggest changes in the course? Some instructors use part of the time to discuss the course with the students on this last day and have been known to alter elements of the course as a result; e.g., TAs return homework in a more timely manner.

4.5 Self Assessment, Conclusions (lessons learned; strengths and weaknesses; planned improvements). And finally, what have you learned from the students and from yourself about the success or failure of the students’ outcomes? Final grades remain the most visible and quantitative signatures of the students’ performance, while the two writing exercises and the questionnaire provide alternative instruments through which one can gain different insights into the students’ learning. How did the assessment process contribute to this newfound knowledge? What are your plans for improvements to the student outcomes?

5.0 Assessment of the Natural Science Component for the Academic Year

Your report will be read by the associate dean, who will assemble his notes into an informal review or comments that summarizes what was learned in reading your report. A copy of the review will be sent to you, the department chair, and the CNSM dean. You will be invited to provide comments, should you so desire. Your report, the associate dean’s review, and any reply will be filed together in the Dean’s Office for 10 years, and is available to anyone interested in assessment of the Natural Science Core Curriculum. My comments made while reading the assessment report of Attachment G are provided in Attachment H.

Finally, the associate dean will examine all instructor-prepared assessment reports collected each academic year (typically 6-8) and will assess whether or not the Natural Science Core Curriculum goals are being achieved; e.g., what deficiencies may be present and are in need of correction and any recommendations for change to the curriculum, if needed. This annual report is submitted to the CNSM dean and the UAF provost in the fall semester following the academic year covered in the report.

John D. Craven
CNSM Associate Dean
August 2010
GUIDELINES FOR CORE NATURAL SCIENCE DESIGNATOR:

The Natural Science requirement in the Core Curriculum shall be two 4-credit hour courses, each with a laboratory (8 credit hours total). Both courses must be selected from those available in one of the two options defined below.

The goal of the Natural Science component of the Core Curriculum is to prepare students for lifelong learning in the natural sciences (biology, chemistry, earth science, physics). In order to achieve this goal, three objectives will be met:

1. Students will become familiar with the methods used for acquisition and expansion of scientific knowledge through laboratory/field exercises which deal with
   a. data collection and analysis,
   b. hypothesis building, and
   c. experimentation.
2. Students will learn and use major concepts of natural science either by exploring in depth a single discipline or the conceptual relationship between at least two of the natural sciences. Although there are no well-defined criteria for identifying a "major concept" of natural science, the following are generally accepted examples: momentum and energy, electricity and magnetism, the atomic and nuclear nature of matter, equilibrium, the cellular basis of life, evolutionary theory, and plate tectonics.
3. Students will understand the relationships between science and society in terms of the historical context of modern science and the influence of science on contemporary issues. They will also study elements of public science policy and the methods by which it is developed.

Any course qualifying for either emphasis must contain elements which address all three objectives outlined above. This probably requires modification of nearly every natural science course which is offered at UAF before it qualifies under the new guidelines. Thus each qualifying course must have:

1. a laboratory/field component which emphasizes data collection and analysis, hypothesis building, and experimentation;
2. substantial content dealing with "major concepts;"
3. science-related issues in society and public policy

Effective: May 7, 1990
UAF Core Curriculum in the Natural Sciences and its Assessment

Attachment B

Submit originals and one copy and electronic copy to Governance/Faculty Senate Office
(email electronic copy to fysenat@uaf.edu)

REQUEST FOR CORE NATURAL SCIENCE DESIGNATOR

SUBMITTED BY:
Department
Prepared by
Email Contact
College/School
Phone
Faculty Contact

See http://www.uaf.edu/uafgov/faculty/cd for a complete description of the rules governing curriculum & course changes.

1. COURSE IDENTIFICATION:

<table>
<thead>
<tr>
<th>Dept</th>
<th>Course #</th>
<th>No. of Credits</th>
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<tr>
<th>COURSE TITLE</th>
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<tr>
<th>CONTACT HOURS PER WEEK:</th>
<th>LECTURE hours/weeks</th>
<th>LAB hours /week</th>
<th>OTHER specify type</th>
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   Note: To meet the natural science requirement, courses must have 4 credit hours and include a laboratory. See http://www.uaf.edu/uafgov/faculty/cd/credits.html for more information on number of credits.

<table>
<thead>
<tr>
<th>Existing Course</th>
<th>New Course Pending Approval*</th>
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<td>*Must be approved by appropriate Curriculum Council.</td>
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2. CURRENT CATALOG DESCRIPTION AS IT APPEARS IN THE CATALOG: including dept., number, title and credits

   

   JUSTIFICATION FOR ACTION REQUESTED

   The purpose of the department and campus-wide curriculum committees is to scrutinize course designator applications to make sure that the quality of UAF education is not lowered as a result of the proposed change. Please address this in your response. This section needs to be self-explanatory. Use as much space as needed to fully justify the proposed change and explain what has been done to ensure that the quality of the course is not compromised as a result.
**UAF Core Curriculum in the Natural Sciences and its Assessment**

**ALONG WITH THIS FORM PLEASE SUBMIT THE FOLLOWING:**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td><strong>A</strong></td>
<td>A course syllabus (see page 24)</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>Titles of all laboratory exercises.</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>Title of a representative textbook.</td>
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<tr>
<td><strong>D</strong></td>
<td>Detailed outline of 3 laboratory exercises. Please attach an explanation of how these laboratory exercises have been designed to familiarize students with methods for the acquisition and expansion of scientific knowledge, including: a) data collection and analysis, b) hypothesis building, and c) experimentation.</td>
</tr>
<tr>
<td><strong>E</strong></td>
<td>A list of the major scientific concepts that the course will convey. The attached syllabus should make it clear that the course is organized around these major concepts rather than their application.</td>
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<tr>
<td><strong>F</strong></td>
<td>An explanation of how the relationship between science and society will be explored in the course. Identify where the course public science policy and its development are discussed.</td>
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<tr>
<td><strong>G</strong></td>
<td>A plan for its effectiveness evaluation.</td>
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**APPROVALS:**

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<td>Signature, Chair, Program/Department of:</td>
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<td>Signature, Chair, College/School Curriculum Council for:</td>
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<td>Signature, Dean, College/School of:</td>
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**ALL SIGNATURES MUST BE OBTAINED PRIOR TO SUBMISSION TO THE GOVERNANCE OFFICE**

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<tr>
<td>Signature, Chair, Senate Core Review Committee</td>
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## UAF Core Curriculum in the Natural Sciences and its Assessment

**Attachment C**

**Schedule for Five-Year Assessments of Natural Science Courses in the UAF Core Curriculum**

### Current Five-Year Cycle

<table>
<thead>
<tr>
<th>Fall/Spring</th>
<th>Courses</th>
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<tbody>
<tr>
<td>2009/2010</td>
<td>BIOL 111X, CHEM 105X, GEOS 120X, PHYS 211X, PHYS 212X</td>
</tr>
<tr>
<td>2011/2012</td>
<td>BIOL 115X, BIOL 116X, CHEM 103X, GEOS 100X, MSL 111X, PHYS 115X</td>
</tr>
<tr>
<td>2012/2013</td>
<td>BIOL 103X, CHEM 100X, GEOS 125X, PHYS 103X, PHYS 104</td>
</tr>
<tr>
<td>2013/2014</td>
<td>BIOL 104X, CHEM 106X, GEOS 101X, PHYS 175X</td>
</tr>
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Note. All course numbers preceded by “F” to designate UAF origin. Some actual course assessments are being done out of sequence if the original dates was missed. The overall schedule has become non-uniformly distributed by year so it might be revised. Some courses are taught each semester and the schedule may be revised to alternately sample the fall and spring courses, or require assessment of each if notable different; e.g., historically different instructor.
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Attachment D
Instructor-written exercise based on a (bad) example of scientific research design.

(Based on memo on 2/9/04 from Associate Dean John Aspnes to faculty of courses up for assessment in Spring 2004.)

Students are asked to identify the problems with the design. The problems should include (1) lack of appropriate controls or standards, (2) lack of replication, and (3) highly selective use of data.

Instructors are encouraged to use the following example exercise if they believe it is appropriate for their course(s). This example exercise should only be used during the initial semester of this assessment process because of the possibility that students may be asked the same question twice.

Example Exercise:

Instructions: Read the following description of a scientific study and answer the two questions at the bottom of the page.

Following a major oil spill in lower Cook Inlet, a scientist wants to test whether or not two different cleaning solutions help sea birds recover from the effects of being contaminated by crude oil. Here is the plan for the experiment:

Six oil contaminated sea birds will be collected; these may include glaucous-winged gulls, mew gulls, Bonaparte’s gulls or black-legged kittiwakes. (These are related but different species of birds that are common in the Lower Cook Inlet area). Three birds will be washed in a solution of 1 cup Cheer laundry detergent per 5 gallons of water. Three will be washed in a solution of ½ cup Dawn dishwashing detergent per 5 gallons of water. All six birds will be confined in cages for 1 week after cleaning, and their health status will be recorded at the end of the week.

When the plan was implemented, there were some unexpected results. Three of the collected animals were kittiwakes, and all of these died within hours after being washed. So, the scientist decided to collect and clean 3 more birds, all gulls, so that he would have six survivors at the end of the experiment. The results of the experiment, including those for the kittiwakes, are given in the table below:
Species | Treatment | Status at one week
--- | --- | ---
Mew gull | Cheer | Alive and in good health; ready for release
Mew gull | Dawn | Alive but not feeding, poor health
Mew gull | Dawn | Alive and in good health; ready for release
Kittiwake | Cheer | Dead
Kittiwake | Cheer | Dead
Kittiwake | Cheer | Dead
Bonaparte’s gull | Cheer | Alive and in good health; ready for release
Glaucous-winged gull | Dawn | Alive but not feeding, poor health
Glaucous-winged gull | Cheer | Alive and in good health; ready for release

From these results the scientist concluded that kittiwakes were easily killed by crude oil exposure and so weren’t a suitable subject for the research. He decided to ignore all of the kittiwake results and just consider the results for the gulls.

Based on the remaining results for the gulls only, he concluded that Cheer was the better cleaning solution because all of the Cheer-cleaned gulls were in good health at the end of the experiment.

**Questions:**

1. Identify and briefly describe (1 sentence) two serious errors in the design of the experiment.

2. Identify and briefly describe at least one serious error in the interpretation of the data.
1. This course increased my knowledge of the science of biology, chemistry, geology, physics, oceanography, or physical geography.

   **Strongly Agree**    **Agree**    **Neutral**    **Disagree**    **Strongly Disagree**

2. This course improved my understanding of how scientists conduct scientific investigations.

   **Strongly Agree**    **Agree**    **Neutral**    **Disagree**    **Strongly Disagree**

3. I am better able to understand scientific information presented in the media.

   **Strongly Agree**    **Agree**    **Neutral**    **Disagree**    **Strongly Disagree**

4. This course helped me to better understand how scientific information contributes to the development of public policy.

   **Strongly Agree**    **Agree**    **Neutral**    **Disagree**    **Strongly Disagree**

5. This course made me want to learn more about science.

   **Strongly Agree**    **Agree**    **Neutral**    **Disagree**    **Strongly Disagree**

6. Overall, what I learned in this course will be useful to me.

   **Strongly Agree**    **Agree**    **Neutral**    **Disagree**    **Strongly Disagree**

Page 14 of 15
UAF Core Curriculum in the Natural Sciences and its Assessment

Attachment F

Assessment Report for GEOS 101X, The Dynamic Earth

This insert is 146 pages in length, with Attachment G and H following. The numerous attachments to G are being scanned and will be added later. Scanning some submitted materials is proving difficult, in that student handwriting can become too faint to read, and this may become an obstacle to the idea of creating online copies of full reports.
Core Assessment for Geos 101, Spring 2010

I: Introduction

For the past 8 years Geos 101 has been taught by Paul McCarthy in Fall semester and by Paul Layer and Rainer Newberry in Spring semester. The materials and discussion enclosed specifically concern the spring version, which is slightly different due to different order of labs and lectures (field trips are at the end of spring semester, versus the beginning of fall semester) and different personalities and teaching techniques of the instructors involved. Nevertheless, both versions use the same laboratory exercises and are similar in content and objectives. In both cases a graduate teaching assistant is in charge of a lab section with 5-20 students.

Geos 101 Spring was assessed in 2004; this assessment is to both evaluate the course and to evaluate changes (improvements!) in the course since 2004. With the exception of Spring 2009, Layer and Newberry have taught the course together every year since 2002. Both attend all lectures and generally participate in each lecture, although one is principally responsible for a given lecture. Similarly, both are involved in setting up and modifying laboratory exercises, although Newberry has the primary responsibility for both spring and fall semester labs. Newberry also serves as ‘TA’ for the fall semester Honors Lab, giving him the opportunity to directly evaluate lab effectiveness. The primary written teaching tool is the ‘lab manual’; a document that contains all the lab, pre-lab, and homework exercises and some reading material. It is updated yearly as ideas for labs and their execution are improved.

Expectations of student learning are largely conveyed in the enclosed syllabus (Attachment #1). Our intention is to convey the nature of science and scientific investigations and not merely teach facts to memorize about geology.

The general organization of the course is that the subject for a given lab is covered in lecture during the week immediately before the lab exercise. Students do a 1-2 page ‘pre-lab exercise’ and turn it in during the week of the appropriate lab exercise. The TAs grade these and use them as a basis for assessing the level of student knowledge before the lab exercise begins. The laboratory exercises combine making measurements, analyzing data, and testing hypotheses. For the most part, labs are written “in-house and are gradually changed over time. Some of the measurements are made on maps of various sorts; most are made on physical materials. The role of the TA is to make sure the students understand the lab materials; it’s not uncommon for some students to stay an extra hour or two beyond the 3 hour lab to better understand the material. Most students complete the lab exercises within the 3 hour block, however. Students commonly work together; some work alone. Because the labs are primarily teaching devices, those students who are motivated to complete the lab exercises generally receive high scores. Weekly homework exercises (Attachment #2) are designed to follow-up a given lab; in general the homework exercise of a given week refers back to the lab of the previous week. Students are allowed to use the TA as a resource in completing the homework. The final essay (Attachment #3) counts for a small proportion (5%) of the grade and is a final check that students do understand basic scientific approaches and concepts.

Students sign a ‘contract’ during the first week of class stating that they recognize the need to complete 13 (of 14) labs and 13 (of 14) homework assignments to pass the class. In practice we allow students to pass the class who have completed all the labs but not all the homework assignments.

As part of the 2004 Self-assessment, we made many specific recommendations concerning ways to change (improve) the course. Some of these (Table 1, next page) were largely originated by students. Some (Table 2) were suggested by Newberry and Layer while creating the document. We highlight changes we actually made and (or) attempted in Tables 1 and 2. In particular, we added a break in the 1.5 hour class, we decreased the amount of material presented in certain
lectures, we modified several homework exercises, we created 3-hour ‘Sunday Help Sessions’, we made sure TAs promptly returned labs, prelabs, and homework exercises, we restricted labs to Tuesdays and Wednesdays only (so ALL students attended lab between the Tuesday and Thursday lecture), we created excel spreadsheets for repeated calculations in a given lab, and we decreased the size of the lab sections. Two changes happened due to external forces: (a) we no longer have a lab section restricted to education majors because (for reasons unknown to us) education majors gradually stopped taking Spring Geos 101 and (b) we now have and enforce math and English prerequisites. One additional change we made in the last several years was to institute unannounced ‘in-class’ written exercises, commonly of use with regards to the upcoming homework. We collected and recorded these assignments as a way of assessing class attendance and participation.

Table 1: (mostly) student-based suggestions for Geos 101 Improvements

<table>
<thead>
<tr>
<th>Student complaint</th>
<th>*Approx #</th>
<th>possible solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class meets too early in the day</td>
<td>&gt; 5</td>
<td>move lecture to later in the morning or early afternoon</td>
</tr>
<tr>
<td>Lectures are too simple/ patronizing</td>
<td>2</td>
<td>None really--given the multiple levels of students. This complaint was true for a small number of students.</td>
</tr>
<tr>
<td>Lectures are too difficult; too much material presented</td>
<td>&gt;5</td>
<td>Decrease amount of material presented in lecture; the igneous one (RN) was particularly overwhelming</td>
</tr>
<tr>
<td>90 minutes is too long</td>
<td>&gt;10</td>
<td>Stretching (and question?) break after ~ 45 minutes?</td>
</tr>
</tbody>
</table>
| Homework questions are difficult to understand         | >5        | 1. Introduce each homework exercise in lecture  
2. Some homework exercises (e.g., f metamorphic rocks) were too difficult and need to be modified.  
Announce a (weekend?) study group with TAs present |
| Homework not promptly graded                            | >10       | Previous policy was to wait until most students turned in homework before grading; change to point ‘docking’ for late materials and grading/returning shortly after turned in |
| Homework not promptly turned in                        | >10       | Most students agreed that some uniform system of ‘docking’ grades for late homework should be instituted. |
| Occasional lack of correspondence between labs, lecture, and homework | >5       | 1. Remove (sigh) K-Ar dating homework exercise.  
Review homework exercises for relevance to appropriate lab.  
2. Schedule all lab sections for Tues and Weds; thus all students will have completed lab for a week before the Thursday lecture; homework exercises can be assigned on Thursday to immediately follow-up lab. |
| Pre-labs inconsistently returned                       | >5        | Make sure T.A.s look over and return pre-lab exercises                           |
| Simplify tedious calculations                          | >5        | make excel spreadsheets for performing repeated calc’ns                          |

*approximate number of students who voiced or agreed with this statement
Table 2: Instructor-initiated contemplated changes in Geos 101 (from 2004 Assessment)

<table>
<thead>
<tr>
<th>Contemplated Change</th>
<th>Actual change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Restrict number of undeclared 1st yr students allowed to enroll</td>
<td>None</td>
</tr>
<tr>
<td><strong>More</strong> specialized labs for particular majors</td>
<td>No specialized labs now—limited enrollments</td>
</tr>
<tr>
<td>Smaller lab sections</td>
<td>Labs now usually ≤ 16 students</td>
</tr>
<tr>
<td>Move evening lab times to start earlier</td>
<td>None-Left starting times at ~ 6 pm</td>
</tr>
<tr>
<td><strong>Minimum math prerequisite</strong></td>
<td>Math prerequisite Created AND ENFORCED</td>
</tr>
</tbody>
</table>

Geos 101 contains a wide range of students (Table 3, below for Spring 2010 breakdown), including non-degree students, and students seeking AA, BA, and BS degrees. Students range from freshmen to senior and are predominantly (78%) not majoring in science, math, or engineering. The majority of students were clearly present largely to fulfill the core science requirement. The wide range of class standings and interest levels makes this a challenging class to teach effectively.

Table 3: Student composition of Geos 101, Spring 2010—numbers in parentheses = 2004 percents

<table>
<thead>
<tr>
<th>Major</th>
<th>Non-degree</th>
<th>Freshman</th>
<th>Sophomore</th>
<th>Junior</th>
<th>Senior</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science or engineering</td>
<td>8% (40)</td>
<td>25% (27)</td>
<td>42% (13)</td>
<td>25% (20)</td>
<td>12</td>
<td>29% (22)</td>
<td></td>
</tr>
<tr>
<td>Non-science or undeclared</td>
<td>3% (10)</td>
<td>50% (20)</td>
<td>23% (24)</td>
<td>7% (9)</td>
<td>17% (20)</td>
<td>30</td>
<td>71% (78)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2% (7)</td>
<td>38% (23)</td>
<td>24% (25)</td>
<td>17% (25)</td>
<td>19% (20)</td>
<td>42</td>
<td>100%</td>
</tr>
</tbody>
</table>

The major changes in enrollment patterns since 2004 are a decrease in the proportion of non-degree students, an increase in the proportion of non-science freshmen, and a drop in overall enrollment. The lower number of non-degree students and lower enrollment probably represent the effects of enforcing minimal math and English prerequisites. In addition, a new 100x geoscience course premiered in Spring 2004 (‘Dinosaurs and their World’). As the enrollment in this course matched the decrease in enrollment for Geos 101, we suspect that these courses compete for the same student market. Finally, Education majors no longer sign up in significant numbers for Spring Geos 101. We don’t know why this happened and faculty in the Education department have offered no explanations.

II: Assessments of Course Success

Our evaluation is built around three measurement tools: (1) overall course grades, (2) Core Committee specific questions, and (3) results of the Core Committee survey. Each is presented and discussed separately below.

A. Student grades as a measure of success

Grade distribution as a function of class standing is tabulated below. Of the 42 students registered for the course, 41 (98%) passed and one received an incomplete. The student that received the incomplete irregularly attended class and participated in about half of the lab and homework exercises. Conversations with faculty in this student’s major indicated that this student had highly irregular class attendance and participation habits.
Of those students who received a passing grade, only one (2%) received a barely (D) passing grade—i.e., showed minimal comprehension of the subject matter. A freshman received this grade, perhaps reflecting minimal engagement from a new student with little commitment to UAF.

Table 4: Grade Distribution* Geos 101, Spring 2010—2004 %’s in parenthesis

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>F</th>
<th>TOTAL #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Degree</td>
<td>100%(0)</td>
<td>0%(0)</td>
<td>0%(0)</td>
<td>0%(0)</td>
<td>0%(0)</td>
<td>1</td>
</tr>
<tr>
<td>Freshman</td>
<td>38%(25)</td>
<td>50%(13)</td>
<td>6%(50)</td>
<td>6%(0)</td>
<td>0%(13)</td>
<td>16</td>
</tr>
<tr>
<td>Sophomore</td>
<td>60%(47)</td>
<td>20%(29)</td>
<td>20%(6)</td>
<td>0%(12)</td>
<td>0%(6)</td>
<td>10</td>
</tr>
<tr>
<td>Junior</td>
<td>71%(41)</td>
<td>29%(29)</td>
<td>0%(6)</td>
<td>0%(12)</td>
<td>0%(12)</td>
<td>7</td>
</tr>
<tr>
<td>Senior**</td>
<td>29%(50)</td>
<td>57%(36)</td>
<td>14%(7)</td>
<td>0%(7)</td>
<td>0%(0)</td>
<td>7</td>
</tr>
<tr>
<td>TOTAL %</td>
<td>49%(38)</td>
<td>39%(29)</td>
<td>10%(17)</td>
<td>2%(7)</td>
<td>0%(9)</td>
<td></td>
</tr>
</tbody>
</table>

*Letter grades include + and – with the letter. **One senior has an I for the course.

The proportion of students who received ‘A or B’ (including A-, B+, and B-) rose dramatically (88% vs. 67%) from Spring 2004 and the proportion receiving C or D dropped (12% vs. 24%). The lab exercises are very similar to the ones used in 2004; the homework exercises labs are similar in difficulty although clearer in explanations. We saw no evidence for cheating or copying of papers this spring—where such has happened in the past, miscopying has led to peculiar and commonly hilarious answers. Consequently, we ascribe the larger proportion of higher grades primarily to better lecture attendance and more faithful lab attendance and homework performance. In turn, these are likely due to several reasons, including the enforced prerequisites, prompt return to students of graded materials, mid-term progress reports for ALL students, Sunday afternoon help sessions, smaller lab sections, consistent TA intervention policies. In other words, students EARNED higher grades because they were largely engaged in the course. See later data to indicate that homework and class attendance have some role in increased performance.

A graphic distribution of grades, shown below, indicates that class standing is a major factor in the grade (hence comprehension) for the course. For both seniors and freshmen, a much higher proportion received a ‘B’ than an ‘A’; the opposite is true for Sophomores and Juniors. The freshman population was strongly influenced by the large number of hockey team members (> 1/3 of the freshmen) these students were generally less engaged than the others. We similarly suspect a limited amount of interest taken by the Senior students, who clearly had put off taking their science core requirement for years.
Grades for the class are not strongly related to major, as students majoring in both science and non-science fields received high grades (table 5 below). The average grade for students in Science/Math (outside of geology) was 3.3; that of all non-science/engineering students was 3.2. The distinctly higher average for engineering students is likely because they are petroleum engineers and can see the obvious applications of the course.

Table 5: Grade versus major—numbers in parenthesis are avg grade in 2004

<table>
<thead>
<tr>
<th>Major</th>
<th>% students</th>
<th>avg grade</th>
<th>CATEGORY</th>
<th>% students</th>
<th>Avg grade</th>
<th>St. dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>7%</td>
<td>3.8(3.2)</td>
<td>A-</td>
<td>29%</td>
<td>3.5(3.1)</td>
<td>B+ 0.5</td>
</tr>
<tr>
<td>Geosci</td>
<td>5%</td>
<td>3.5(3.3)</td>
<td>B+</td>
<td>71%</td>
<td>3.2(2.7)</td>
<td>B 0.8</td>
</tr>
<tr>
<td>Elem Ed</td>
<td>24%</td>
<td>3.4(2.4)</td>
<td>B+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undeclared</td>
<td>22%</td>
<td>3.3(3.3)</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science/Math</td>
<td>17%</td>
<td>3.3(3.0)</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hum/Soc Sci</td>
<td>22%</td>
<td>3.0(2.1)</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Includes Geology, Earth Science, and Geography

Number of missing homework assignments is an important predictor for class grade as illustrated in the table below. This is both because homework counts for 20% of the class grade, but more importantly, because doing the homework ‘cements’ concepts taught in lecture and experienced in laboratory exercises. Moreover, completing homework assignments is an indication of dedication to the course, hence to learning the subject matter. Consequently, we believed in 2004 that if we could find ways to get students to faithfully do their homework we could significantly improve student success in the course. **WE FOUND THIS TO BE TRUE IN 2010:** 88% of the students in the class turned in all or nearly all of their homework assignments and this group received higher grades than those in 2004. This compares to 53%—just over half—in 2004. Conversely, nearly 1/5 of the class in 2005 failed to turn in nearly half of the homework assignments. Because the course policy—which students signed at the start of class—allowed students to ‘skip’ one homework assignment, in fact nearly 90% of the students in Geos 101 Spring 2010 actually completed the terms of their course contract.
Table 6: Number of missing homework assignments versus course grade cross-tabulation – numbers in parenthesis are %s of students in 2004

<table>
<thead>
<tr>
<th>Missing hwk</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>F</th>
<th>I</th>
<th>TOTAL %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>19</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69% (43)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>17% (10)</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2% (6)</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>2% (12)</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>5% (6)</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td>2% (4)</td>
</tr>
<tr>
<td>&gt;5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td>1% (2)</td>
</tr>
</tbody>
</table>

However, homework completion was necessary to receive, but not a guarantee of an ‘A’ grade. In particular 70% of the students in 2004 who fulfilled their contracts received an ‘A’, whereas only 57% of those who did so in 2010 received an ‘A’. That is, quality of work was also expected to receive an A grade.

We established ‘in-class exercises’ as an additional component to the grade over the period 2006-2010. Those students who completed these correctly were present in class and paying attention. Those who didn’t either were not in class (nothing turned in) or weren’t participating (low score). In a sense, the ‘in class exercises’ were our low-tech clickers. A plot of in-class exercise points vs. final grade (below) shows a strong correlation between the two. This was true although the actual contribution from the exercises was small (5% of the total grade). That is: students who faithfully attended class generally did better on their lab and homework exercises. However, this was only generally true: some students did not need to faithfully attend class to basically understand the material, and some who faithfully attended still didn’t understand all the concepts presented.

ANOVA treatment of the class data confirms these qualitative conclusions. (1) There was no significant correlation in grade vs. class level (P = 0.3). (2) There was no significant correlation of in-class exercise score with class level (P = 0.66). (3) There was a significant correlation between class exercise score and total grade (r = 0.51, P = .0006).
B. Assessment from dealing with a problem involving bogus data:

Homework Exercise 12  GEOS 101X Spring 2004 (recast as homework 9 in 2010)

This assignment was intended to assess students’ ability to critically analyze experimental design, bogus data and erroneous conclusions from experiments (see next page). The students were presented with two graphs with data similar to that collected in a lab experiment. The data, and the conclusions drawn from the data contained two errors: a ‘bad’ data point (and resulting line fit), and ‘erroneous’ extrapolation beyond the range of measurements.

35 of 42 students (83%) handed in this assignment. The maximum score was 10, the minimum 2. The mean score was 8.4 ± 1.8. The average scores for the other labs range from 9.6 to 6.4, with an overall average of 8.5 ± 0.9. However, the average score was higher in 9 other labs, in other words, students received a slightly lower than average grade for this lab. Overall, the students who handed in this assignment were those that received A’s, B’s or one of the C’s in the course. The students who did not turn in this assignment were also those that received the D, I, and 3/4 of the C’s. Therefore the sample was not representative of the range of students in the class.

32 of 36 of the students or 89% (again noting that these are the ‘better’ students in the class) recognized the outlier and the fact that measurements of different grain sizes were needed; they ‘got’ the assignment (a grade of 70% or greater). Students who received the lowest scores generally failed to answer one or more questions. Students also lost points when they questioned the conclusions based on their own experiences/biases (“the data are bad because I KNOW what is true despite what the data say”) or did not offer ways of collecting additional (more appropriate) data. The question that was missed most often was asking how the original interpretations of the data biased the conclusions. Many answers to this question were of the “a faulty model yields erroneous results” type; rather vague and not really addressing the specific ‘how’ of the question.

Overall it is difficult to assess if this assignment was effective in demonstrating the student’s ability to critically analyze data. On one hand, 89% of the homeworks received show that the students do know how to analyze data (either because of our skill as teachers or because the assignment was too easy), on the other hand, 17% of the class did not hand in the assignment—and these were mostly the poorer students. It would appear that the bulk of students who took the course seriously understood the point and can recognize ‘bogus’ data.

Representative examples of responses from this homework exercise are given in Attachment #4.
In the groundwater lab, each of you collected porosity and permeability data and plotted them. A couple of years ago, GEOS 101 students collected the following data and reached the following conclusions.

**Conclusion #1:** Porosity increases with increasing grain size

**Conclusion #2:** Permeability is constant no matter what the grain size

**Conclusion #3:** You can predict the porosity and permeability for any grain size using graphed lines.

Based on these conclusions, the students calculated plume flow in groundwater through a loess aquifer (grain size = 0.1 mm). For their calculations they used a permeability of 40,000 feet per day and a porosity of 10%. They concluded that the low porosity would mean that not much water was in the loess but that the plume would move rapidly down gradient.

**Questions:**

1. What is suspicious about the porosity data?

2. Identify and briefly describe at least one serious error in the interpretation of the porosity data.

3. What should the students do to test the validity of their grain size versus porosity relationship?

4. Identify and briefly describe at least one serious error in the interpretation of the permeability data.

5. What should the students do to test the validity of their grain size versus permeability relationship as applied to loess?

6. For the students’ groundwater model, how might the erroneous porosity and permeability values bias their conclusions regarding the effect of this plume down gradient?

7. Generalize from your discussion above about key aspects of a scientific study should you look out for in gauging the validity of a scientific study or the conclusions of such a study.
C. Science & Society Essay

Introduction

This question constituted the take-home final exam. Students were told repeatedly in the course that this was a requirement for passing the class. Of the 42 students registered for the course, all but 3 prepared a final essay. The question as stated on the exam:

“1. In a short essay (1000-2000 words) addressing the following questions. You may have to do a bit of research (such as on the internet) to get information on the scientific debate:

The decisions that society, and in particular the United States, has to make regarding issues related to Geoscience are a difficult ones that will have to be addressed in the coming years. These issues include:

Whether to explore and develop oil resources in ANWR or other wilderness areas
What our response should be to global warming
How to teach geology and evolution in schools and universities.

One of the complications in such decisions is that there are often “disconnects” between scientific evidence and public policy or public behavior in U.S. society.

Using one of the examples above, or another of relevance to the earth sciences, briefly discuss the scientific evidence (or lack thereof) that is currently being discussed. How is this scientific evidence used or misused for political agenda? Overall (not just with reference to this particular issue), to what extent do you think that science is divorced from public policy and societal problems? Is this good, bad, or simply unimportant?”

Grading Scheme

Final Essay Rubric

<table>
<thead>
<tr>
<th>Name:__________________________</th>
<th>1. Sufficient length:</th>
<th>0.5 = short  1 = adequate  1.5 = &gt; 1500 words, no dribble</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Presents a controversy</td>
<td>1 = yes  0 = not controversial</td>
<td></td>
</tr>
<tr>
<td>3. DISCUSSES SCIENTIFIC EVIDENCE (or lack thereof)</td>
<td>1 = yes, 0 = no discussion</td>
<td></td>
</tr>
<tr>
<td>4. Sci Evidence used/misused for political agenda</td>
<td>1 = topic addressed  0 = topic not mentioned</td>
<td></td>
</tr>
<tr>
<td>5. Risk-benefit analysis</td>
<td>1 = topic addressed  0 = topic not mentioned</td>
<td></td>
</tr>
<tr>
<td>6. Importance of scientific literacy</td>
<td>1 = topic addressed  0 = topic not mentioned</td>
<td></td>
</tr>
<tr>
<td>7. Is science divorced from public policy?</td>
<td>1 = topic addressed  0 = topic not mentioned</td>
<td></td>
</tr>
<tr>
<td>8. Critical ANALYSIS of Arguments</td>
<td>1 = thorough analysis  0 = no analysis</td>
<td></td>
</tr>
<tr>
<td>9. Evaluation of Arguments</td>
<td>1 = thorough evaluation  0 = no evaluation</td>
<td></td>
</tr>
<tr>
<td>10. Relevance to Geos 101 or other X sci class</td>
<td>1 = uses material from Geos 101  0 = no connection to 101</td>
<td></td>
</tr>
</tbody>
</table>

Numeric & Graphical Results

The average score on the essay was 5.3 ± 2.2 (1σ). This compares to an average of 7.6 on the essay for 2004. However, the two aren’t directly comparable: in 2004 the science and society question was one-third of the take-home final and we asked for 300-500 words. We also employed a different grading rubric. In other words, we had greater expectations for students this year, especially as so many faithfully attended class and turned in assignments.
Essay score is strongly correlated with academic maturity as indicated on Table 7 (below) and the Figure (next page). The Freshman grades are somewhat skewed by the grade for one ‘freshman’ who is a mature adult returning to school after an absence of 20 years and with about 2 years of former coursework not counted by UAF. Taking out this grade drops the freshman average to 4.2 ± 2.2. The data (Table 7) clearly show an improvement from freshman to junior and no change to senior.

Table 7: Essay scores vs. academic maturity

<table>
<thead>
<tr>
<th>Class standing</th>
<th>Average Science and Society essay score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshman</td>
<td>4.4 ± 2.7</td>
</tr>
<tr>
<td>Sophomore</td>
<td>5.1 ± 1.9</td>
</tr>
<tr>
<td>Junior</td>
<td>5.9 ± 2.2</td>
</tr>
<tr>
<td>Senior</td>
<td>5.8 ± 2.5</td>
</tr>
</tbody>
</table>

In many cases freshmen received low scores because they simply didn’t address the question as requested: for example, did not select a controversy or did not present both sides of a controversy. Our impression is that these students have poor reading comprehension or are otherwise unable to respond to a request for an intellectual exercise. Perhaps the good news is that students really do improve in their essay-writing abilities over the course of several years at UAF—if only in the ability to follow directions.

Unlike in 2004, essay scores were significantly higher for science/engineering/math students than for the others (Table 8). That is, despite the generally better writing skills of those not in scientifically-related fields at UAF, the science-related students better addressed the questions posed. On the other hand, the gap between the two isn’t enormous and suggests that non-science students do benefit from this core science course.

Table 8: Essay Scores versus Student Major

<table>
<thead>
<tr>
<th>MAJOR</th>
<th># students</th>
<th>Avg Sci/Soc Essay Score</th>
<th>% with less than 4 points of 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sci/Engn/Math</td>
<td>12</td>
<td>6.0 ± 1.9</td>
<td>8%</td>
</tr>
<tr>
<td>Not Sci/Eng</td>
<td>27</td>
<td>4.9 ± 2.3</td>
<td>35%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>39</td>
<td>5.3 ± 2.2</td>
<td>26%</td>
</tr>
</tbody>
</table>
Although academic maturity and final grade correlate well with the essay scores, ‘in class exercise’ points (a measure of class attendance) correlates poorly with essay score (figure below).

That is, faithful class attendance—and a general understanding of the course material *per se*—was neither required for a high essay score nor guaranteed a high essay score. In other words, we didn’t prepare the students for the final essay through the course material.
Assessment of results

A significant proportion of the class took the question very seriously, as indicated by an essay with considerably more words than the minimum (1000). However, a significant portion of the class missed the point entirely—either the student didn’t present an ‘issue’ or didn’t look at both sides. Such a student (almost exclusively freshmen) received a score ≤ 4.

A considerably larger proportion of the NON science/engineering majors (more than ½) received a poor score (< 5 points out of 10); only 2/11 (18%) of the science-math-engineering students gave poor answers. Since all the students lacking majors are freshmen, and were lumped into the ‘non-science/engineering’ group, these results again stress the differences between scores of the freshmen and the more academically mature students.

By-and-large, score for the ‘science and society’ essay correlate with total scores for the course. There are several possible reasons for the correlation—the major factors are probably both academic maturity and science vs. non-science majors. In general, the better students in the course were either not freshmen or were science/engineering majors—the same groups that wrote better essays.

Frankly, we were disappointed by the bulk of the essays. The majority of students presented no analysis of the ‘science-based’ arguments whatsoever. The students simply accepted as true any supposedly science-based statements in the various web sites.

Copies of student essays are given in Attachment 5

D. Survey and survey assessment

We spent the last class period (1.5 hours) discussing the course with students and having students fill out class evaluations, including the core survey. We allowed approximately 1 hour for class oral feedback (‘I liked this part, I disliked that part’) and then left the room for students to complete the survey forms. The actual survey forms are included as attachment #6. Although we made strenuous efforts to reach all the students, we received only 29 surveys from the 42 students registered for the class (69%). Presumably the students less interested in the class did not fill out a survey. The results, in consequence, are almost certainly not representative of the entire class and are biased towards the more motivated students. The survey and results—given as percentages—are listed below and on the following page.

GEOS 101 fulfills UAF’s requirement for a core science class with lab. In order to improve UAF’s delivery of science courses and to assess the role that science courses play in the general core curriculum, please complete the following questionnaire. Feel free to elaborate on any of your answers below. RESPONSES ARE IN PERCENTS; 2004 RESULTS ARE IN NON-BOLD SMALLER FONT
a. This course increased my knowledge of the science of biology, chemistry, geology, physics, oceanography, or physical geography.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>52%</td>
<td>48%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

b. This course improved my understanding of how scientists conduct scientific investigations.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>22</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>14%</td>
<td>76%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

c. I am better able to understand scientific information presented in the media.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2</td>
<td>20</td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>7%</td>
<td>69%</td>
<td>21%</td>
<td>3%</td>
<td>0%</td>
</tr>
</tbody>
</table>

d. This course helped me to better understand how scientific information contributes to the development of public policy.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>1</td>
<td>18</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>3%</td>
<td>62%</td>
<td>33%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

e. This course made me want to learn more about science.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8</td>
<td>8</td>
<td>11</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2004</td>
<td>28%</td>
<td>28%</td>
<td>38%</td>
<td>3%</td>
<td>3%</td>
</tr>
</tbody>
</table>

f. Overall, what I’ve learned in this course will be useful to me.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8</td>
<td>14</td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2004</td>
<td>28%</td>
<td>48%</td>
<td>21%</td>
<td>3%</td>
<td>0%</td>
</tr>
</tbody>
</table>
g. I consider this course of greater value than the other core science class I’ve taken at UAF.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>7</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>14%</td>
<td>24%</td>
<td>7%</td>
<td>3%</td>
<td>0%</td>
<td>52%</td>
</tr>
</tbody>
</table>

*Not asked in 2004*

h. This class compares favorably with other CORE classes I’ve taken at UAF.

<table>
<thead>
<tr>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>7</td>
<td>14</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>24%</td>
<td>48%</td>
<td>18%</td>
<td>7%</td>
<td>3%</td>
</tr>
</tbody>
</table>

*Not asked in 2004*

The proportion of the respondents that ‘agreed’ or ‘strongly agreed’ with each statement varied between questions, as indicated below. 2004 data in parenthesis.

<table>
<thead>
<tr>
<th>#</th>
<th>Question: Better understand/know/want</th>
<th>% SA or A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Scientific knowledge</td>
<td>100 (87)</td>
</tr>
<tr>
<td>2</td>
<td>How scientists conduct investigations</td>
<td>90 (68)</td>
</tr>
<tr>
<td>3</td>
<td>Scientific information presented in the media</td>
<td>76 (70)</td>
</tr>
<tr>
<td>4</td>
<td>How science contributes to public policy</td>
<td>65 (61)</td>
</tr>
<tr>
<td>5</td>
<td>To learn more about science</td>
<td>56 (54)</td>
</tr>
<tr>
<td>6</td>
<td>Question: information gained will be useful</td>
<td>76 (78)</td>
</tr>
</tbody>
</table>

The first question refers to the obvious purpose of the course, the next five to the ‘hidden agenda’ of the core science classes, and the final question to how much the students value what they learned. To a large extent we think the answers reflect reality.

Question (1) [Scientific knowledge increased]. ratio of strongly agree: agree (~2:3) also matches reasonably well the ratio of students who received an A to those who received a B or C (2:2.5). The percentage who ‘agreed’ or strongly agreed’ (87%) also matches well with the percentage of students who received a score of 6 or higher on the ‘Science and Society’ essay (86%). Based on the agreement of these self Assessments with instructor assessments, we would consider the student responses in general to accurately measure reality.

Questions (2) and (3) were topics more specifically addressed in lecture than in lab and after the first 2 weeks roughly 2/3-1/2 of the class routinely attended class. The lower ‘agree’ proportions for these two questions thus most likely reflect lecture attendance (or lack thereof).

Question (4) was specifically addressed in several lectures (global warming, mineral and energy resources, history of geologic research) near the end of the course when lecture attendance
had dropped to ~½ of the class. Again, the still lower proportion of ‘agree’ can be ascribed to failure to attend class during the critical last few weeks of the semester.

Question (5) again matches well with lecture attendance. Roughly half of the class faithfully attended lecture even though doing so wasn’t required. These students either became or were intrinsically sufficiently interested in science to make the sacrifices necessary to attend 1½ hours of morning lecture twice a week. The 46% of the respondents that did not acquire an additional interest in science most likely were those who were not sufficiently interested to attend lecture. What’s not clear is whether (a) the course turned them off from science or (b) simply failed to ignite an interest. Presumably the 4 ‘malcontents’ were lost to ‘an interest in science’ as a result of the course.

Question (6) most likely reflects student satisfaction with the course, because the question is somewhat ambiguous. In particular, what does the word ‘overall’ imply to a student? That the majority of what ‘I learned’ is useful? That, taking everything into account, some of what ‘I learned’ is useful? Given that only 2 students in the course were geology majors and that only 22% were science or engineering majors we are surprised—but pleased—that such a large proportion of the class felt what they learned was useful. Clearly, a substantial proportion of the respondents felt that the class was worthwhile even though attending lecture wasn’t—hence, that the lab exercises must have been of significant value.

III. Self-assessment

Frankly, we think that at this point Geos 101x spring semester is ‘successful’ in that students who take the course largely enjoy it and think that they benefit from taking the class. (Attachment 6 shows examples of laboratory exercises.) On the other hand, the responses to the ‘science and society’ essay suggest that students learn more about the dynamic earth, but don’t learn much about the nature of ‘science’ itself. In other words, the ‘hidden agenda’ of the core science classes is truly hidden: the students don’t realize it’s there and don’t gain an appreciation for that aspect. The question becomes: to what extent SHOULD we be teaching the students about how to recognize ‘good’ and ‘bad’ science and related topics at the expense of learning more about how the earth works? On one hand, we don’t want to compromise the ‘factoid’ aspect of the course (‘oh, you took Geos 101 at UAF, THAT’s why you don’t know much about geology’), on the other hand, if we want non-science majors to better understand the nature of arguments based on ‘science’, that is if we want them to come away with a better ability to evaluate such claims, we need to do address that topic more directly. The ‘hidden agenda’ technique just doesn’t seem to do it.
Attachment 1: Syllabus
GEOS 101X: "THE DYNAMIC EARTH"
PHILOSOPHY, GOALS, POLICIES
Spring 2010   (TR 9:45-11:15)   Reichardt 201B

INSTRUCTORS:
Paul Layer, Nat Sci 358,  player@gi.alaska.edu, office (474-7608), home (479-2672)
   Office hours by appointment through the Dean’s office
Rainer Newberry, Nat Sci 328,  ffn@uaf.edu, office (474-6895), home (479-0140)
   Office hours TR 11:15 am to 1 pm -- or take your chances and drop by--I'm often in

TEACHING ASSISTANTS:
Section F01:  Wednesday 6:00 – 9:00 PM:   TA: Maciej Sliwinski (mgsliwinski@alaska.edu)
Section F02:  Wednesday 1:00 – 4:00 PM:   TA:
Section F03:  Tuesday 6:00 – 9:00 PM:     TA: Raelene Wentz (ztnew@hotmail.com)
Section F04:  Tuesday 2:00 – 5:00 PM:     TA: Raelene Wentz

GEOS 101X "THE DYNAMIC EARTH"--is the 1st part of the Geology Department's 'depth' core science offering. In this course we (the Teaching assistants, Teaching Associates, and instructors) will try to acquaint you with WHAT SCIENCE IS ALL ABOUT and our current understanding of HOW THE EARTH WORKS. This will require memorizing of a few names (rocks, minerals, structures, major time periods), but mostly we will emphasize how we know what we know. This class is part of the Baccalaureate science core. Students must have a background of at least high school algebra (qualified to enroll in MATH 105) and English (qualified to enroll in ENGL 111).

TEXTBOOKS AND MANUALS:
The lab manual is one that we have put together and is simply identified as ‘GEOS 101 Lab Manual’. BRING YOUR LAB MANUAL TO CLASS (LECTURE) EACH DAY!!!!!!!
The textbook is: The Changing Earth by James Monroe and Reed Wicander
Readings are from both Monroe and Wicander (M&W) and the Lab Manual

TEACHING (and—hopefully—learning) STRATEGY
Our focus is on 'teaching by doing'-- lab and homework exercises. In lecture, we will present information related to doing the pre-lab exercise and being prepared for a given laboratory exercise. The advantage of attending lecture is you will both understand the relevance of, and be better prepared for, the upcoming lab. Reading and homework assignments (see attached syllabus) accompany each lecture. You will find it helpful to at least look over the reading assignment before the appropriate lecture (No Duh!).
You (the student) will do the pre-lab exercise both to acquire the background and to show us how well you understand the background to the lab. This allows us to spend the laboratory period doing the lab exercise rather than lecturing about it. Depending on the lab, you may finish it all in the lab period, or you might need to write up an overview question later, after lab. Finally, to make sure that you understand the topic we present in lab and lecture, you will do a homework problem that will be due after you’ve completed the laboratory exercise for the associated topic. There are no quizzes or midterms in this class because you will be continuously showing us that you do understand each topic—or where you need help.

To pass this course, you will need to complete —in a timely manner—13 (of 14) homework, 13 (of 14) laboratory exercises, and the Final Essay. You must also attend class (and participate in the In-class exercises). YOU MUST ATTEND THE FINAL TWO LABS (FIELD TRIPS). The field trips are critical because this is where you really see the relevance of what we’ve presented concerning geology and the earth.

We encourage you to work in groups for the labs (if you enjoy doing so) but to use your own words and to NOT copy anyone else's work!!!! Please refer to the Student Code of Conduct on pages 47-48 of the 2009-2010 UAF Catalog. If you have a documented disability that requires additional time on homework assignments or labs, or if you require other accommodation, please let us know within the first two weeks of the semester. The Office of Disability Services implements the Americans with Disabilities Act (ADA), and insures that UAF students have equal access to the campus and course materials. We will work with the Office of Disabilities Services (203 WHIT, 474-7043) in order to provide reasonable accommodation to students with disabilities. The key is that if you are having problems in the class, see us ASAP and we will try to help you.

LABS
The first labs will meet Tuesday and Wednesday, January 26 and 27. Written laboratory reports from a given week are due at the start of the following week's lab. A weekly “pre-lab exercise” is due IN LECTURE at the start of class each Tuesday, and is worth 10% of the lab grade. If you do not turn in the exercise IN LECTURE, your grade for the lab will be “docked” 10 points (out of 100). The purpose of the pre-lab is to get you ready for the lab exercise; the reason for turning it in at Lecture is to give the TAs a chance to go over them and see where you need help before the lab starts. Our Thursday lectures should provide the information you need to do the prelab before the Tuesday class. If, after coming to the Thursday lecture, you are still unsure about the prelab questions, consider coming to the Sunday afternoon sessions (which will require advance planning on your part) and (or) contacting (emailing?) your T.A. or an instructor.
Additional notes concerning Labs:
1. Plan to bring your lab manual, **a pencil**, paper, and a calculator to each lab session.
2. You can make up a missed lab **if and only if** you have notified your TA before the lab you will miss and arrange at that time when you will do it. Some labs require extensive set-up and your TA may not be able to prepare a lab especially for you on short notice.
3. It is possible to attend the “wrong” lab section **with approval** from the appropriate TA, however make sure that you are registered for the lab time that you attend most often.
4. We will make every attempt to promptly return graded lab and homework exercises; consequently, we cannot accept materials turned in grossly late...
5. Lab sections are **3 hours long**. We have designed these labs to run the full time for students who have attended lecture, completed the pre-lab, and have read the lab manual. If you aren’t prepared it’s likely to take you SIGNIFICANTLY longer than 3 hours or you will not finish it at all. Please come prepared.

**HOMEWORK**
Exercises are assigned on Thursday and due the following **Thursday at the start of lecture**. We urge you to set aside a regular time each week to work on homework and pre-lab assignments. The assignments are designed so that you can work on them over the weekend. The due date is such that you will have an opportunity to consult with your TA about the homework exercise. Also consider the Sunday afternoon help sessions.

**HOMEWORK HELP SESSION: SUNDAYS 2 – 5, ROOM 230 (THE LAB)**

**IN-CLASS EXERCISES**
Throughout the semester we will be asking a short ‘question of the day’ in class. You will be given a 3x5 card and on that card you will put your name (clearly so we can read it) and the answer to the ‘question of the day’. We will collect those cards during class and look them over as a way to gauge attendance and to see if the class as a whole has ‘gotten’ the topic we are talking about. (We view this as sort of a low-tech clicker system).

**GRADING POLICY :**
As stated above, you must complete 13 of the 14 homeworks and 13 of the 14 labs. This gives you the opportunity to miss a week or to drop the lowest grade. **YOU MUST ATTEND THE FINAL TWO LABS (FIELD TRIPS).** All homework and lab reports, and the Final Essay must be handed in by 10:00 AM May 10.

<table>
<thead>
<tr>
<th>Assignment</th>
<th>Percentage of Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>13 homeworks</td>
<td>30%</td>
</tr>
<tr>
<td>13 labs</td>
<td>60%</td>
</tr>
<tr>
<td>Final Essay</td>
<td>5%</td>
</tr>
<tr>
<td>In-class exercises</td>
<td>5%</td>
</tr>
</tbody>
</table>

If you are missing more than 2 homeworks or labs prior to drop date (February 5) or withdrawal date (March 26) you will receive (copy to your advisor) a written request to drop the course. **We may exercise the option to drop you from the course if you’ve done minimal work, but don’t count on it unless you don’t mind getting an ‘F’**.
Late Policy: Any lab report or homework handed in after the due date will be docked at least 10%. Homework or lab reports handed in after the graded assignment has been returned to the rest of the class will be docked 50%. [Exceptions: documented illness, etc. If in doubt, talk to one of us.] Lab reports not submitted will receive a grade of 0%, even if you attended the lab. Remember that the lowest one lab and one homework grade will be dropped, so if you miss one deadline, it’s not going to be a disaster. Making a habit of doing so, however, will be a disaster.

Plagiarism Policy: It is fine to work with other students, but you must use your own words in answering a question. If two or more students hand in essentially identical lab or homework exercises, we will investigate and probably give at least one of the students a score of 0%.

General grading guidelines/predictors (what you can do to earn a grade in this class)
A = All required homework, prelabs, and lab reports turned in on time and done to a high level.
B = All required homework, prelabs, and lab reports turned in (most on time) with good quality answers.
C = All required lab reports turned in, but some with low grades. Missing or poor quality homework.
D = Attend all labs, but missing a couple of lab reports, poor quality or missing homework.
F = Failure to attend labs, turn in lab reports and homework.

We will be using the +/- grading option to better evaluate borderline cases.

A final word of advice: Attendance at lectures is required and will be assessed in the in-class exercises. Further, it is our experience that students who regularly attend lecture are more apt to turn in their pre-labs and homeworks on time, be better prepared for lab (so they can get through in the allotted time), and get higher grades for the class. We will use the lectures to discuss homework and prelabs and will occasionally have ‘extra credit’ in-class exercises.

THE MOST IMPORTANT THINGS

- Attend Class
- Bring your lab manual to class and lab each day.
- Do the required reading before class.
- Work on the Prelab BEFORE it is due on Tuesday
- Hand in assignments ON TIME
- Ask questions if you do not understand something or have problems with the class.
- Take advantage of Office Hours for the instructors and TAs
- Feel free to ask questions and participate in discussions IN CLASS
- HAVE FUN!!!!!!!!!
## GEOS 101 Syllabus, Readings and Assignments, Spring 2010

<table>
<thead>
<tr>
<th>Week</th>
<th>Lecture</th>
<th>Date</th>
<th>M&amp;W</th>
<th>Lecture topic</th>
<th>Homework/Prelab Due</th>
<th>Lab exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1-21</td>
<td>Ch 1</td>
<td>Introduction, course outline, intro to maps and the earth, Earth coordinate systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1-26</td>
<td>App. B</td>
<td>Topographic maps, topographic profiles</td>
<td>Prelab 1- Topo maps</td>
<td>1. Understanding Topographic Maps</td>
</tr>
<tr>
<td>3</td>
<td>1-28</td>
<td>Ch 8</td>
<td>Properties of materials, seismic waves</td>
<td>HW-1 Diagnostics and Rules</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2-2</td>
<td>Ch 8</td>
<td>Earth structure, locating earthquakes, earthquakes in Alaska</td>
<td>Prelab 2 -earthquakes</td>
<td>2. Earthquakes and Seismic Waves</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2-4</td>
<td>Ch 3</td>
<td>Mineralogy I: systematic identification; compositions</td>
<td>HW-2 Topographic Maps</td>
<td></td>
<td></td>
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<tr>
<td>7</td>
<td>2-11</td>
<td>51-52 451-458</td>
<td>Chemical compositions, X-rays, intro to radioactivity and heat</td>
<td>HW-3 Earthquakes and Waves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>2-16</td>
<td>451-458 Ch 4</td>
<td>Geochronology, Introduction to melting</td>
<td>Prelab 4 – Analytical</td>
<td>4. Analytical Methods</td>
<td></td>
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<tr>
<td>9</td>
<td>2-18</td>
<td>Ch 4</td>
<td>Igneous melts: character, origins, some I.D.</td>
<td>HW-4 Minerals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>2-23</td>
<td>Ch 4 Ch 5</td>
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**SPRING BREAK  Week of March 8-12**

Homework exercises or Prelabs are due IN CLASS on the specified day  
M&W = the Monroe and Wicander text book
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<td>Prelab 8-Hydrology</td>
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<td>3-25</td>
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<td>Ch 7</td>
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<td>Prelab 9-Meta. rocks</td>
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<td>Stratigraphic concepts; geologic units &amp; their orientations; geologic maps</td>
<td>HW-9 Hydrology</td>
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<td>4-6</td>
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<td>Structural geology— faults &amp; folds &amp; environments they form in, map symbols</td>
<td>Prelab 10-Geol. maps</td>
<td>10. Geologic Maps &amp; geologic mapping</td>
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<td>21</td>
<td>4-8</td>
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<td>Big scale structural geology</td>
<td>HW-10 Metamorphic Rocks</td>
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<td>Examples of Alaskan geology &amp; tectonics</td>
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<td>11. Faults, faulting, and geologic maps</td>
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<td>Air photos &amp; Remote sensing</td>
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<td>24</td>
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<td>12. Air Photos &amp; remotely sensed images</td>
</tr>
<tr>
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<td>4-22</td>
<td></td>
<td></td>
<td>Glaciers II: ice ages—causes &amp; effects</td>
<td>HW-12 Global seismicity and geologic cross section</td>
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<tr>
<td>27</td>
<td>4-29</td>
<td></td>
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<td>Oil in Alaska: the ANWR debate</td>
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<td>5-6</td>
<td></td>
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<td>Oral and written student feedback</td>
<td>HW-14 mapping a petroleum trap</td>
<td></td>
</tr>
</tbody>
</table>

5 pm May 11 (Tuesday) --- Final Essay is due. (3:15-5:15 pm Tues is the scheduled exam time for this class)

Homework exercises or Prelabs are due IN CLASS on the specified day

M&W = the Monroe and Wicander text book
Attachment 2: weekly homework exercises
1. Why is it important to read the lab and do the pre-lab exercise before lab?

2. What procedures do you follow and options do you have if you are going to miss a lab?

3. How many labs and homework exercises will be counted toward your final grade? Can you drop the lowest grade?

4. Who is your TA and when do they have office hours?

The inside cover of your lab manual contains many useful conversion factors. Use it!!! Use scientific notation for very large and very small numbers (e.g., $10^5 = 100,000$; $0.0004 = 4 \times 10^{-4}$).

5. Determine: $6$ miles = ___________ inches $10$ kilometers = ___________ centimeters

6. Very accurate GPS measurements taken over time indicate that the Hawaiian Islands (and the whole Pacific plate) are moving at 8 centimeters per year (cm/yr). [This is approximately the rate of normal human fingernail growth. Feel free to test this statement by letting your fingernails grow over the course of the semester!!!]

   a. How many centimeters would the islands move in 50 years? ___________

   b. How many meters would the islands move in 50 years? ________________

   c. How many feet would the islands move in 50 years? _________________

   d. How many years would it take the islands to move 1 meter? ______________

   e. If the Hawaiian Islands are moving at 8 cm/yr, how fast are they moving in millimeters per year (mm/yr)? ______________

       There are $1000 \ (10^3)$ mm in a meter and $1000 \ (10^3)$ meters in a kilometer, so that makes 1 million $10^6$ mm equal to 1 kilometer (km). Further, 1 million years = 1 million “annum” and is abbreviated 1 Ma.

   f. Putting it all together, if something is moving at the rate of 1 mm/yr it’s also moving at the rate of 1 km/Ma!!!!  So how fast is Hawaii moving in km/Ma? __________

   (over)
7. The graph below shows a figure that we will use later in the Earth Magnetism and Alaska Faults lab. It shows the magnetic declination (in units of degrees) as a function of time (in units of years) for Fairbanks, Alaska from 1950 to 2003.

![Graph showing magnetic declination over time for Fairbanks, Alaska from 1950 to 2003.](image)

a. To the nearest 0.1 degree, what was the declination in 1980? _________
b. To the nearest year, when was the declination 27 degrees? _________
c. Based on the trend from 1997 to 2003, to the nearest 0.2 degrees, what would you predict the declination be in 2009? _________
d. Over a 15 year span from 1975 to 1990, on average how fast was the declination changing? _________ Your answer will have the units of degrees per year. Report your answer to the nearest 0.01 deg/yr.

8. Significant figures are important in scientific research including your lab exercises.

a. How many significant figures are in 102.03? ___________
b. How many in 0.0903? ___________
c. How many significant figures in 0.09030? ___________
d. Using significant figures, what is 100.81 + 1.124 ___________
e. Keeping in mind the rules of significant figures what is the product of 124.7 * 1.5 ___________
1. Give the locations of the areas labeled K, E, M, and G on Fig. 3 (page 4) in this week’s lab exercise.

<table>
<thead>
<tr>
<th>Area</th>
<th>¼’s or ½’s, Section, Tier, Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td></td>
</tr>
</tbody>
</table>

2. Use a combination of Figures 2, 12, and Appendix IV (plate 2) for these problems, which refer to the Fairbanks D2 SW 1:25000 map

A. What is the latitude of the northern boundary of the FBX D2SW? ______________ The southern boundary? ______________ (Fig. 2)

B. What is the longitude of the eastern boundary? ______________ western boundary? ______________

C. Now, calculate the dimension of this map in angular units, that is, minutes + seconds: _______'______"__N by _______'______"__W. (The longitude dimension, for example is the difference in longitude between the eastern and western map boundaries).

D. Find the feature labeled ‘gravel pit’ in the SW ¼ of Sect 8, T1S, R1W. What is the pit filled with? __________ What is the funky contour that surrounds the pit and what does it mean? see fig. 6!!

E. Determine the straight line distance between West Valley High School (SW ¼, S6, T1S, R1W) and the Youth Correctional Facility (~7190000N, ~463500E): __________km and __________miles. (See map in appendix IV).

F. In what direction(s) does Cripple Creek (~ 147°52’30”) flow on the map (Appendix IV)? (Use the contours to determine the direction towards lower elevations in the Creek).

G. Find the area with the steepest topography on the Fbx D2 SW map shown in Appendix IV. Identify the location using lat/long, PLOG or UTMs, whichever you prefer.

‘Tailings’ refer to material left over after a mining operation. Which means that something (in this case, gold-bearing stream gravel) was mined (dug out of the ground) in the vicinity of ‘tailings’. Consequently—why is this steep topography most likely present?
3. The map below shows elevations of selected points in meters and the 100 m contour. Draw additional contours on the map using a contour interval of 10 meters. Then briefly describe the shape of the land you’ve contoured.

Land shape:

4. Estimate the elevations (in meters) of the points marked with an ‘x’ on Appendix IV, Plate 2:

1 (W end UAF Ridge)___________, 2 (UAF Museum) ____________, 3 (Nat Sci Hill)____________, 4 (TVC)_______________, 5 (Patty Gym)_______________, 6 (Smith Lake bog)_____________.
In lab you located one earthquake. The Alaska Earthquake Information Center here on the UAF campus locates thousands of earthquakes per year, getting both location and depth (using computers not compasses!). The map on the 2nd page shows features of geological importance in Southern Alaska and the adjacent Pacific Ocean. The location of Anchorage is shown for reference, however the coastline is not shown.

1. The numbers 0 – 5 on the map are depths of earthquakes measured between 1995 and 1997, and are representative of the earthquakes in the region. (There are a lot of them and they’re all of low magnitude.) Earthquakes labeled with ‘0” occurred between 30 and 50 km below the surface and those labeled ‘1’ between 50 and 75 km, so the boundary between ‘0’s and ‘1’s is the 50 km seismic depth contour. Between the 1’s and 2’s is the 75 km seismic depth contour, etc. The 50 km seismic depth contour is drawn for you. **Now draw and label the 75, 100, 125, and 150 km seismic depth contours.**

Based on your contour map, do earthquakes occur randomly in the earth or in a very specific pattern? __________

2. Use the chart below to draw a cross section of the depths to earthquakes (a “seismic profile”) along line X-Y. Do this by locating the position of each seismic depth contour on your map and transferring it to the grid below (the trench and 50 km contour are located for you already). Then draw a smooth curve through the points you located (including the trench).

Draw cross section here:

Earthquakes occur where rocks break, that is, along faults, so your curve represents a very large fault that separates two MAJOR units of rock, specifically the Pacific and North American tectonic plates, and the location of the trench is the surface representation of that boundary. This area is called the Aleutian subduction zone.

3. On your cross-section **and** on the map, label ‘North American Plate’ and ‘Pacific Plate’.

4. Locate the position of Douglas volcano on the profile. [Note: Douglas volcano is located at the surface (0 km depth)]

5. What is the dip of the subduction zone in the vicinity of the trench? __________ °. **Use a protractor to get the angle between a horizontal line and the curve you drew.** Beneath Douglas volcano? __________ °. What’s happening to the Pacific plate under Alaska (North America)???

6. What is the depth to the top of the Pacific plate under Douglas volcano? __________ km.

7. What is the approximate depth of the Pacific Plate beneath all of the volcanoes shown on the map? __________ km.
8. What is the distance between Douglas volcano and the trench along line X-Y? ________ km
   Between Griggs volcano and the trench in a line parallel to X-Y? ________ km
   Between Hayes volcano and the trench in a line parallel to X-Y? ________ km

9. Looking at your map and data from question 12 and the cross sections on page 4, is there a consistent relationship between the location of volcanoes and the distance from the volcano (volcanic arc) to the trench?

10. That is, which is more consistent: the horizontal distance from the volcanoes to the edge of the Pacific plate or the vertical distance (depth) between the volcanoes and the top of the Pacific plate? ________ Could there be a relationship between seismicity and volcanism? _______________________________
1. “Sandpaper” until recently came in 3 basic types: flint (cheapest but least durable), garnet (intermediate cost and durability), and corundum (highest cost and durability). Flint is a traditional name for fine-grained quartz. Corundum is a mineral with a hardness of 9; it lacks cleavage. In contrast, kitchen/bathroom cleansing powder traditionally used feldspar as the abrasive agent; starting about 20 years ago with the widespread use of Teflon-coated pans, cleanser makers switched to calcite. The old cleaners were much more effective on porcelain than the stuff you can buy now, but the older type couldn’t be used on mirrors. Using the characteristic properties of the 5 minerals, briefly describe why they are used for sandpaper vs. cleanser, and why they have the cost, durability, and cleansing properties described above. How does cleavage play a role in these uses? You will find useful information in your mineral ID flowsheet (Appendix I, pg. 2; note hardness scale on the bottom of the page, for example).

<table>
<thead>
<tr>
<th>Mineral</th>
<th>why sandpaper vs cleanser</th>
<th>why cost/durability or cleansing properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corundum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Garnet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feldspar</td>
<td></td>
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</tr>
<tr>
<td>Calcite</td>
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</tbody>
</table>

One reason why there are so many minerals is that different combinations of the same elements can be stable (and formed) under different conditions of pressure and temperature. That is, increased or decreased temperature or pressure will make a particular combination (mineral) turn into a different one. Once you know a bit about minerals you can tell which were formed at high pressure, which at high temperature, which at low temperature & pressure…and determine from minerals in a rock the conditions it has experienced.

For these questions refer to page 8 (not turned in) of the mineralogy lab

2. Some silicate minerals contain water in their structure--as the (OH) group. These are called ‘hydrous’ minerals. Which common silicate minerals (from page 8) are hydrous?

As you saw in the first part of the mineralogy lab, this water can be released from the mineral by heating (remember the vermiculite expanding like craaaaazy?). In general, the higher the water content of a mineral, the lower is the temperature at which it decomposes by heating; the lower the water content of a mineral, the more likely it is to be stable at high temperature. That is, minerals with high water contents (high ratio of OH to O) are stable at lower temperatures; minerals with low water contents (low ratio of OH:O) are stable at higher temperatures. Using the OH: O ratios, list the sheet and chain silicates listed on pg 8 (Mineralogy lab) in terms of likely temperatures of stability, from lowest –Temperature to highest-Temperature:
3. Some minerals are dense due to their composition. What makes galena such a dense mineral?

4. For minerals of the same (or approximately the same) composition, the more tightly the ions are squeezed together, the higher is the density and (usually) the greater is the hardness. Further, the higher density mineral (for a given composition) forms and is stable at higher pressure (where everything gets squeezed together). For example, diamond is the high density (3.5) and hard (10) carbon mineral; graphite is the low density (2.2) and soft (1-2) carbon mineral. Diamonds form deep in the earth’s mantle (and get transported to the near-surface by processes that are still a little fuzzy); graphite is stable (and forms) in the crust. By-and-large the common silicate minerals have roughly similar compositions, and their density differences are largely caused by differences in density of atomic packing.

Based on the relative densities of the major silicate minerals (pg 8, Mineralogy Lab), which silicate structural groups would you expect to form and be stable at high pressure?

_______________________________

at low pressure? ________________________________

5. To summarize—considering both mineral stabilities and compositions of the crust and mantle (Mineralogy lab pages 7 and 8) --(a) why are clay minerals so common at the earth’s surface?

(b) what is the predominant mineral of the mantle?

Why is that mineral so common in the mantle?

(c) When you see garnet in a rock why do you know that that the rock formed at high pressure?

(d) One mineralogical property more than any other is both unique to garnet and diagnostic of garnet (as it occurs in rocks, not in jewelry or sediments). What is this property that allows you to readily identify garnet?
Part A: Mineral compositions

1. Why do the iron (Fe\(^{2+}\)) and magnesium (Mg\(^{2+}\)) ions substitute so readily for each other in minerals?

______________________________________________________________________________

2. Geologists group silicate minerals (& rocks containing these minerals) into two major sets: (a) MAFIC (= rich in Mg & Fe) and (b) FELSIC (= Feldspar & Silica). [Consult Mineralogy lab pg. 8 for major silicate minerals & their formulas, also Appendix I for relative elemental concentrations.]

   list the main MAFIC minerals:_________________________________________________

   list the main FELSIC minerals:_________________________________________________

   list 2 minerals that don’t fall into either group:_________________________________

   Which (felsic or mafic) have the highest Si contents? ____________________________

   Which (felsic or mafic) have the lowest Si?_____________________________________

3. Why are mafic minerals invariably dark colored?_____________________________________

4. Why do the colors of mafic minerals vary—with shades of green, brown, and black?

______________________________________________________________________________

______________________________________________________________________________

5. Why are felsic minerals generally pale colored?___________________________________

______________________________________________________________________________

6. There are circumstances where color is a useful guide to mineral identification and circumstances where color is a useless guide to mineral identification. Explain, giving a specific example of each.

______________________________________________________________________________

7. Why—in general—is color not a particularly diagnostic mineral characteristic, while properties like hardness, cleavage, and crystal shape are diagnostic? [For example, why does the color of quartz vary, but quartz NEVER displays cleavage?]

______________________________________________________________________________

8. Consult Appendix II, pages 1-2. There are only a few minerals that can be dated by the K-Ar technique. What are they and how can you tell these from the XRF spectra?
Part B: Radiometric Dating of minerals and rocks

Potassium-40 (\(^{40}\text{K}\)) is the radioactive isotope of potassium. It decays to argon-40 (\(^{40}\text{Ar}\)) with a half-life of 1.25 billion years and is the basis for the potassium-argon dating method. The age of a sample is related to the ratio of \(^{40}\text{Ar}\) to \(^{40}\text{K}\) (\(^{40}\text{Ar}\) divided by \(^{40}\text{K}\)) as shown on figure 1 to the right.

(A) Hornblende and biotite from a granodiorite on Pedro Dome have been dated by the potassium-argon method. The hornblende has 0.5 weight percent K\(_2\)O which corresponds to 0.5 ppm \(^{40}\text{K}\). The biotite has 8.0 weight percent K\(_2\)O, or 7.5 ppm \(^{40}\text{K}\). [Note: 1 ppm = 1 part per million = 0.0001%]

1. The hornblende contains 0.00275 ppm \(^{40}\text{Ar}\). Determine its \(^{40}\text{Ar}/^{40}\text{K\_ratio}\) _______________
   Now use figure 1 to determine the age of the hornblende. ____________ million years (Ma).

2. The biotite contains 0.0413 ppm \(^{40}\text{Ar}\). Determine its \(^{40}\text{Ar}/^{40}\text{K\_ratio}\) _______________
   Now use figure 1 to determine the age of the biotite. ____________ Ma. Plot it accurately!

3. Why does the biotite have a higher \(^{40}\text{K}\) content than the hornblende? _______________

4. Why does the biotite have a higher \(^{40}\text{Ar}\) content than the hornblende? _______________

(B) A basalt from the Fairbanks area was dated by the potassium-argon method. The basalt is mostly fine-grained and the only minerals that could be identified are plagioclase and olivine.

5. Why would plagioclase or olivine be poor choices for dating by the potassium-argon method? _______________

If we take small pieces of the fine-grained basalt, we find that it contains 1.5 weight percent K\(_2\)O, or 1.5 ppm \(^{40}\text{K}\). The basalt also contains 0.00465 ppm \(^{40}\text{Ar}\).

6. Determine the basalt’s \(^{40}\text{Ar}/^{40}\text{K\_ratio}\) _______________. Now use figure 1 to determine the age of the basalt. ____________ million years (Ma).

7. The basalt has 3 times as much \(^{40}\text{K}\) as the hornblende, but less than twice as much \(^{40}\text{Ar}\). Why is this? _______________

8. In summary: Why do you need to know both the potassium and the argon content of a mineral to date it by the K-Ar method? _______________
In lab we focused on the greater Fairbanks area, where we can see a sequence of events from the igneous rocks. In this problem instead we’ll focus on a single area in which three different igneous events have taken place almost simultaneously.

These are the Cascade volcanic chain, the Snake River Plain-Yellowstone volcanic province and the Columbia River flood basalt.

1. The data below represent 137 chemical analyses from volcanic rocks of the Snake River Plain-Yellowstone (SRPY) Volcanic Province (a) Fill in all rock names on the graph below. (b) Give the names for the two predominant rock types of SRPY: ________________ & ________________ (c) Which of the two is likely to be the ‘yellow stone’ of Yellowstone Nat’l Park? Why?

(d) Which of the 2 is responsible for the calderas of SRPY? (e) Why is this rock type (and not the other) responsible for the calderas?

2. The data below are average chemical compositions of representative volcanic rocks from the Cascades volcanic chain. This is a belt of volcanoes in Western Washington, Oregon, and Northern California, all younger than 15 Ma. Accurately plot each analysis on the graph above and give the rock name below.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>73.12</td>
<td>48.6</td>
<td>61.81</td>
<td>55.68</td>
<td>53.5</td>
<td>68.36</td>
<td>57.92</td>
<td>59.85</td>
</tr>
<tr>
<td>FeO</td>
<td>1.26</td>
<td>10.31</td>
<td>4.05</td>
<td>9.27</td>
<td>8.31</td>
<td>2.82</td>
<td>6.32</td>
<td>5.39</td>
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<tr>
<td>MgO</td>
<td>0.16</td>
<td>6.73</td>
<td>3.28</td>
<td>4.12</td>
<td>5.41</td>
<td>1.14</td>
<td>4.04</td>
<td>3.58</td>
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<tr>
<td>CaO</td>
<td>1.23</td>
<td>10.65</td>
<td>4.87</td>
<td>5.67</td>
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<td>3.07</td>
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<td>5.95</td>
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<tr>
<td>Na₂O</td>
<td>4.08</td>
<td>2.47</td>
<td>3.72</td>
<td>2.7</td>
<td>3.18</td>
<td>3.92</td>
<td>3.49</td>
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<tr>
<td>K₂O</td>
<td>4.47</td>
<td>0.25</td>
<td>1.96</td>
<td>1.48</td>
<td>0.73</td>
<td>3.02</td>
<td>0.97</td>
<td>1.28</td>
</tr>
<tr>
<td>Other</td>
<td>15.68</td>
<td>20.99</td>
<td>20.31</td>
<td>21.08</td>
<td>21.23</td>
<td>17.67</td>
<td>20.46</td>
<td>20.3</td>
</tr>
</tbody>
</table>

Na₂O+K₂O: ____________________________ ____________________________

Name: ____________________________
4. Each caldera of the SRPY province is shown with its age in millions of years (Ma). The oldest is 16 Ma and the youngest is 0.6 Ma. Notice that they get systematically younger in one direction, a pattern that you've seen with regards to the Hawaiian Islands. However, how are SRPY volcanic rocks different in chemical composition (hence, rock name) from those of Hawaii? How are they similar to those of Hawaii? What's the current hypothesis/explanation for the difference in rock types present in SRPY vs. Hawaii? [M&W p. 115,118]

5. Estimate the direction and rate of movement of North America based on the ages and map locations of rocks from the Snake River-Yellowstone igneous province. Recall that 1 km/Ma = 1 mm/year. Show your work.

Direction: ______________ Rate: ______________ mm/yr

Is this different from the movement direction of the Pacific plate? If so, why? If not, why not? (cf., M & W pg 41; Appendix IV page3).

6. In what specific ways are the compositions of volcanic rocks (that is, the rock names) from the Cascades different from those of the Snake River Plain-Yellowstone Province? (Refer to graph on previous page.)

What geologic origin is likely for the Cascades volcanic rocks based on the chemical compositions (that is, the rock names) of the entire suite? (Refer back to the igneous lab, page 1).

7. There's a marine trench located about 100 km to the west of Washington State (shown on the 1st page). Which of the 3 igneous provinces does it parallel? What is the likely relationship between the trench and only one of the 3 igneous provinces? Why—based on the geologic evidence—is this relationship likely?

7. The Columbia River Basalt (CRB) province was an enormous outpouring of basalt, mostly between 15 and 16 Ma. How do the age, rock type, and location of the CRB make it difficult to relate the CRB to either the Cascades or SRPY? [Note: geologists are still arguing about what caused the CRB. No one is quite sure.]

Consequently, what types of tectonic settings (i.e., geologic origins) are clearly ruled out for the CRB?
Figure 1 shows a portion of the magnetic polarity scale for the last 5 million years based on the measurement of dated lava flows on land. This is a blow-up of the top of figure 8 in your Magnetics lab manual. Black stripes are normal polarity, white are reversed. The Brunhes and Gauss are periods of predominantly normal magnetic polarity. The Matuyama and Gilbert are periods of predominantly reversed polarity. The arrow marks the Matuyama - Gauss boundary at 2.48 Ma. Note that it is at the same ‘scale’ as the magnetic polarities in Figure 2.

![Magnetic Polarity Scale](image)

**Figure 1**

Figure 2 shows the seafloor topography, a magnetic pattern, and the interpreted polarity from a 500 km ship traverse that we believe crosses the ridge (spreading center) between the Pacific and Antarctic plates in the southern Pacific Ocean. 0 km is the start of the traverse. The ship sailed from West to East.

![Seafloor Topography and Magnetic Pattern](image)

**Figure 2**

1. Based on a topographic profile collected on this cruise, the researchers believe that the ridge is located at 250 km. Locate this point on the topographic and magnetic profiles with a *. This point is called the **ridge axis**. How does the magnetic anomaly pattern support the idea that the ridge is a spreading center where new oceanic crust is produced? _____________________________________________
   _______________________________________________________________________________
   _______________________________________________________________________________

2. The boundary between the Matuyama and Gauss polarity periods is marked on figure 1 with an arrow. Mark the **two locations** of this boundary with arrows on the magnetic polarity scale on figure 2. The ship crossed these boundaries at _______ km and _______ km.
3. The Matuyama/Gauss boundary represents a major change from a mainly normal one (Gauss) to a mainly reversed period (Matuyama). This change occurred 2.48 million years ago. Our model for sea floor spreading suggests that at the time of this polarity change, the crust showing the change was at the ridge axis. How far has the eastern Matuyama/Gauss boundary moved away from the ridge axis? _______ km

4. How far has the western Matuyama/Gauss boundary moved away from the ridge axis? _______ km

5. Based on these distances, what might you conclude about the symmetry of ridge spreading?
________________________________________________________________________________

6. Referring to your answer to questions 3 and 4, how far is the eastern Matuyama/Gauss boundary away from the western Matuyama/Gauss boundary? _______ km. This represents the amount of oceanic crust created since that time!

7. If we assume that the spreading rate has remained constant for the last 2.48 million years, how fast is the eastern boundary moving away from the western one? _______ kilometers/million years.

8. 1 kilometer/million years is the same as 1 mm/year. What is the total spreading rate of this ridge in mm/yr? ______________________________

9. How could we test the idea that the spreading rate has been constant over the last 3.4 million years? __________________________________________________________________________________
_____________________________________________________________________________________

The following page is a part of an aeromagnetic map of the Fairbanks area. These data were collected with a helicopter using a magnetometer similar to the one that you used in lab. The numbers reflect differences between the measured magnetic field value and the background magnetic intensity. Most of Fairbanks region is covered by soil; the exposed rocks are mostly quartz-rich, iron-poor metamorphic rocks. The most strike feature of the aeromagnetic map is the dumbbell-shaped, NW-trending magnetic “low” outlined by the depression contours, with anomaly values of <5,000 nT. Near the center of the lowest magnetic field values is a large outcrop of 55 Ma basalt along the Chena River.

10. Which is greater, the susceptibility of quartz or the susceptibility of basalt? __________

11. Which would you think would have a stronger magnetism and produce a higher magnetic field? ___ Why? __________________________________________________________________________________

12. What is the Earth’s magnetic polarity at 55 Ma (see figure 8 of the Magnetics Lab)? _______

11. Putting this all together, why is the lowest magnetic field measured in the Fairbanks area over an area containing magnetic rocks? ____________________________________________________________
______________________________________________________________________________

12. Based on your analysis of the basalt’s magnetism, on the map, color the area that you think is underlain by basalt. Congratulations, you have just done Exploration Geophysics!!!!!!!!!!!!!!!!!!!!!!!!!!!
Aeromagnetic map of part of the southeastern Fairbanks D-2 and southwestern D-1 quadrangles. Magnetic contours are dark lines; topographic contours are barely visible in light gray.

DON’T FORGET TO COLOR THIS MAP AND HAND THIS MAP IN WITH YOUR HOMEWORK
The Tuscarora formation is a quartz-rich unit of middle Silurian (~ 430 Ma) sedimentary rocks of the Appalachian Mountains. Map A shows the distribution of average grains size in the rocks at over 100 outcrops of the formation stretching from Virginia to New York (note direction of the North arrow). This unit comprises part of the ‘clastic belt’ shown by the box on the more regional map (Map B).

1. Draw curved lines that separate the 4 different average grain sizes on Map A (above). These are essentially contours of grain size in the Tuscarora formation at contour intervals of 1 mm, 2 mm and 4 mm.

2. Use your sedimentary rock classification diagram (Appendix I, pg. 4) to distinguish two different rock types on the diagram above based on average grain size. Lightly shade or color and then label the areas of each rock type on Map A.

3. The Tuscarora formation contains sedimentary structures including graded bedding, current ripple marks, discontinuous beds, and crossbeds. Consult Appendix I, page 4. What was the environment of deposition for this unit?

4. Given the environment of deposition and the change in grain size and rock type, were the sediments of the Tuscarora formation shed from what is NOW the mid-Continent region of the U.S.? If no, FROM WHAT DIRECTION where were they likely shed from? That is, where was the source of the sediment? Give the basis for your answer.

(continued on back)
5. The area shown in map A is represented by the box in map B, below. Using colored pencils, transfer the boundary between the two rock types that you drew on Map A to Map B.

A paleogeographic map shows the configurations of land and water at times in the past. Map B can be divided into 4 land/water types: **highlands (mountains)**, **low-lands (plains)**, **the ocean**, and **the deep ocean**. In order to work that out, we need to know the environment in which a particular rock type formed. Your just worked that out for the Tuscarora formation; use the same sort of information (Appendix 1, pg 4) to help you figure out what lots of carbonate rocks mean.

Then give this some thought: if you had a huge belt of volcanic rocks there must have been a big belt of volcanoes—**so what sort of topography was that like?? (highlands, lowlands, ocean, or deep ocean?)**
6. Based on this sort of reasoning, turn Map B into a **paleogeographic** map by matching the various geographic types (highlands, low-lands, ocean, deep ocean) up with the four rock types (carbonates, shales, clastic and volcanic) shown on Map B and then coloring and labeling the areas for the 4 land/water types above.

   Put your color key for the different types here:

NOTICE THAT THE **CURRENT** GEOGRAPHY IS NOT AT ALL LIKE THE **PALEO**GEOGRAPHY!!

7. What land/water type WAS the Tuscarora Formation? ________________

8. What land/water type WAS directly to the east of the Tuscarora formation? ________________

9. What land/water type WAS directly to the west? ________________

10. How do your answers for the above make sense with respect to the character and variations of the sediment in the Tuscarora formation?

   ____________________________________________________________________

   ____________________________________________________________________

   ____________________________________________________________________

   ____________________________________________________________________

11. We would expect a topographic highland (mountain) to shed sediments in all directions, and for these sediments to form sedimentary rocks. Based on this logic, something is NOW missing to the east of the Silurian volcanic belt. What is it??

   ____________________________________________________________________

   However, there are Silurian sandstones in Ireland and Wales and Silurian limestones in Western and central England. Also, there is good evidence, as we’ve reviewed before, that the Atlantic ocean started opening in the early Jurassic, at about 200 Ma. Prior to that time, at least parts of Wales and Ireland were attached to North America!!!!!!

12. So, what’s a possible explanation for (a) the missing rocks Silurian rocks to the east of the volcanic belt and (b) the Silurian rocks now present in Wales and Ireland?

   ____________________________________________________________________

   ____________________________________________________________________

   ____________________________________________________________________

   (continued on back)
13. Draw a sketch cross-section, showing what the geographic situation may have been like in the Silurian. (Where were the mountains? Where was the deep ocean? etc). Label on this sketch the various rock types and how they fit into a sedimentary model.
Problem # 1
The map on the next page shows monitor well locations with groundwater elevations (corrected to mean sea level), collected by the USGS March 30 to April 3, 1988. Also shown are township, range, and section lines and the Fairbanks Meridian & Baseline. The smaller squares are sections. Refer to the Topographic map lab.

1. Determine the scale of the map from the section line spacing.
   Write it here as a verbal scale: ________________________________
   Write it here as a numerical scale: 1:________________________

2. Determine the locations of the wells with groundwater elevations of 415 feet (west end of map) and 448 feet (east end of the map) in terms of ¼ section, ¼ section, section, tier, range. You might want to refer back to the topographic map in Appendix IV to determine tiers, ranges and section numbers and to orient yourself on this map.
   Well 415:
   Well 448:

3. Draw a contour map of groundwater elevations, that is, a map of the water table. Draw contour lines throughout the area of the map for which there is data. Put in a contour line every 5 feet, starting at 445 feet. Label your contours. Roughly, what is the down-gradient direction? ________________________________

Also shown on your map are 5 sites (Fort Wainwright, the Railroad Industrial Area, two gas stations and the landfill) where hazardous substances have leaked into the subsurface and have impacted the groundwater. [Landfills usually leach contaminants into the groundwater.] Note the location of the Golden Heart Utility (GHU) water supply wells and the UAF water supply wells. There are also a large number of private groundwater drinking water supply wells, not shown on the map.

4. Mark each of the 5 sites with a large colored X and draw an arrow from each contaminant source in the down gradient direction and label the two gas stations as “East” and “West”

5. Draw an O at the two water supplies using a different color. For each of the two supply wells, what sources of contamination (if any) affect them? Again look at the gradient and the arrows you drew, not just the distance between the sources and the wells. When referring to the gas stations, note whether you mean the east or west one.   UAF water supply wells:
   GHU water supply wells:

6. Determine the average groundwater gradient, that is, the slope of the water table, in feet/mile ____________ and in feet/feet ______________ (this is Δh/d; use this number in question 7)

7. Determine the approximate velocity (v) in feet per year of ground water in the Fairbanks flood plain using the equation: v = (K/P)(Δh/d). Use a permeability (K) of 5,000 feet/year, Δh/d from question 6 and an appropriate value for porosity, P, from your lab data and justify the value that you use. Once you’ve calculated the groundwater velocity, calculate how long it will take for typical groundwater to travel one mile.
   Value for P _________ Justification for P _____________________________________________________
   Velocity: ______________ ft/yr Time to travel 1 mile: ___________ yr/mile

Show your work here or on page 4:
**Problem #2:** In the groundwater lab, each of you collected porosity and permeability data and plotted them. A couple of years ago, GEOS 101 students collected the following data and reached the following conclusions. Note that they did collect multiple measurements of some samples and that they did not measure any sample smaller than 5 mm in diameter.

![Graphs showing porosity and permeability data trends](image)

**Conclusion #1:** Porosity increases with increasing grain size based on a best fit straight line from a computer program (Excel)

**Conclusion #2:** Permeability is constant no matter what the grain size

**Conclusion #3:** You can predict the porosity and permeability for any grain size using the lines on the graphs.

Based on these conclusions, the students calculated plume flow in groundwater through a loess aquifer (grain size = 0.1 mm). For their calculations they used a permeability of 40,000 feet per day and a porosity of 10%. They concluded that the low porosity would mean that not much water was in the loess but that the plume would move rapidly down gradient.

Based on your results from your lab exercise (where you did measure loess and other fine grained sediments) answer the following questions:

**Questions:**

1. How do the conclusions of the porosity and permeability of loess that this study reached differ from what you observed in class?

2. Identify and briefly describe at least one serious error in their porosity data and their interpretation of the data. Did you ever see a porosity as high as 75%? That is, what is biased about the line that they drew?
3. What should the students do to test the validity of their grain size versus porosity relationship and its applicability to loess?

4. Identify and briefly describe at least one serious error in their interpretation of the permeability data as it applies to loess with a grain size of 0.1 mm.

5. What should the students do to test the validity of their grain size versus permeability relationship as applied to loess?

6. For the students’ groundwater model, how might the erroneous porosity and permeability values bias their conclusions regarding the effect of this plume down gradient?
Duchess County, New York, contains meta-sedimentary rocks but lacks all the faulting complications so common in Alaska. **THERE ARE PATTERNS WAITING FOR YOU** and we want to see what they tell us about the geologic history of the region. Feel free to grab one of your instructors or your TA’s to go through this exercise with you.

Samples of rocks from the area are in the G101 lab (room 230), available most times of day and night for your inspection and entertainment. (However, this is a limited time offer!! Act now!!). Scratchers, acid bottles, streak plates, etc. are also available. Sample locations are shown superimposed on an elderly topographic map. Hint: Lay the samples out on the map in their proper locations. It makes it easier to see relationships.

Based on their compositions, **most of the rocks started out life as shales; one was a sandstone, and two were (Mg-rich) limestones.** As indicated on page 175 of Monroe and Wicander, in meta-shales the main diagnostic minerals are chlorite, biotite, garnet, staurolite, and kyanite. In meta-limestone the diagnostic minerals are talc, amphibole, pyroxene, and olivine (see next page).

1. **Complete the chart below, with an entry for each rock.** I have filled in some diagnostic minerals and a few of the other entries. In doing this exercise, start by determining which rock was the sandstone. It has been metamorphosed: what is it now? Do the same for the two samples that which were once limestones. What are they now? The other 11 samples were once shale, but they now have different names (e.g., slate, phyllite, schist…) depending on their metamorphic grade (Appendix I, page 5). Compare them to DC-2 to see what chlorite phyllite looks like. Refer to the charts in appendix I to remind you of how to identify different metamorphic rock types and metamorphic grades based on textures & mineralogy. Recall that if no diagnostic minerals are present, you can’t say much about the metamorphic grade.

<table>
<thead>
<tr>
<th>Rock #</th>
<th>DIAGNOSTIC MINERALS</th>
<th>ROCK NAME</th>
<th>ROCK PARENT</th>
<th>METAMORPHIC GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC-2</td>
<td>chlorite</td>
<td>phyllite</td>
<td>shale</td>
<td>greenschist</td>
</tr>
<tr>
<td>DC-3</td>
<td>chlorite</td>
<td>phyllite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC-5</td>
<td></td>
<td>schist</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC-6</td>
<td>tiny garnet, biotite,musc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC-7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC-8</td>
<td>staurolite, garnet, biotite</td>
<td></td>
<td></td>
<td>amphibolite</td>
</tr>
<tr>
<td>DC-9a</td>
<td>staurolite, garnet, biotite, muscovite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC-10</td>
<td>none</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC-12</td>
<td>Staurolite, biotite, garnet, muscovite</td>
<td></td>
<td></td>
<td>schist</td>
</tr>
<tr>
<td>DC-13</td>
<td>none</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC-16</td>
<td>Fe-poor (pale) amphibole</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. **Write the names of the diagnostic minerals in each sample on the map (last page) near the sample number.**
3. Draw three lines on the map. All **three lines will refer to metamorphosed shales only**, not to metamorphosed sandstone or limestone. The first line will separate those samples that **contain** biotite from those samples that lack biotite. The second line will separate those samples that **contain** garnet from those that lack garnet. The third line will separate those that contain staurolite from those that lack staurolite. I’ve put other mineral sites on map to help you draw your lines. Your lines should run roughly north-south. Write the appropriate mineral name on the side of the line where the mineral does occur. THESE LINES ARE CALLED ISOGRADS. Your isograds should be broadly similar to those you drew onto page 13 of the metamorphic rocks lab (with different orientation).

The figure to the right shows the stability of some minerals as a function of pressure and temperature (dashed lines). Each line defines a series of P & T conditions. The mineral name that appears on the right (high temperature) side of the line is only stable at temperatures at or higher than the line. For example, metamorphism of a shale along the normal P-T path (heavy dashed line) will result in biotite forming IF the rock experienced temperatures greater than ~400°C. This would happen at a minimum pressure of ~4 kbar, due to being buried to a depth of about ~14 km. If the rock were less deeply buried (and thus reached a maximum temperature less than ~400°C) the rock wouldn’t contain biotite.

4. According to the P-T diagram above, if metamorphism followed a ‘normal’ P-T path, approximately what **minimum** temperature, pressure, and depth are required to form **garnet** in a meta-shale?

\[ T = \sim \quad \text{____________________} \quad P = \sim \quad \text{____________________} \quad \text{depth} = \sim \quad \text{____________________} \.

5. According to the P-T diagram above, if metamorphism followed a ‘normal’ P-T path, approximately what **minimum** temperature, pressure, and depth are required to form **staurolite** in a meta-shale?

\[ T = \sim \quad \text{____________________} \quad P = \sim \quad \text{____________________} \quad \text{depth} = \sim \quad \text{____________________} \.

\(\text{⇒ Now you have the information that you need to label the 3 mineral isograds on your map with the approximate P, T, and depth that they represent. DO SO, now.}\)

6. Based on the changes in minerals seen in the meta-shales, there is a **general increase** in metamorphic grade seen in Dutchess County. **In what direction** (to the east or to the west) does the grade **increase**?

____________________

7. One of the marbles contains amphibole, the other doesn’t.

a. What is the sample number of the amphibole-bearing one?__________
b. You can estimate the approximate P & T that this marble experienced by noting the location of the sample relative to the isograds you drew on the map and the P & T you wrote next to each isograd. Based on this information, approximately what pressure and temperature did this marble experience?

c. P = ________ kbar  T = _______ °C. Plot this point along the Normal P-T path on the diagram to the right.

d. Why does this marble sample contain amphibole, and not talc, or pyroxene, or olivine? Refer to the figure to the right to help you with your answer.

e. In contrast, why does the amphibole-absent marble lack amphibole (and also lack talc and pyroxene and olivine)? (Refer to page 12 of the metamorphic lab).

f. What information does the amphibole-absent sample give about the pressure and temperature that this rock experienced? (this is a trick question) Why?

8. Approximately what P & T did sample DC-10 experience? Why doesn’t it contain any garnet, or biotite, or amphibole?

9. Use your answers from #s 4 and 5 here. a. If one drilled straight down into the earth and the temperatures increased following a ‘normal’ geotherm, then one would first encounter biotite in metamorphosed shales at approximately what depth?___________ km.

b. How many kilometers deeper would one have to drill to first encounter garnet in meta-shale?___________ km.

c. How many km still deeper would one have to drill to first encounter staurolite in meta-shale?___________ km.

10. Measure the distance on the map between the lines that define where biotite and where garnet first occur: ________ km. (measure perpendicular to the lines). Measure the map distance between the lines that define where garnet and staurolite first occur: ________ km. Compare these distances to the distances you estimated for question 9b and 9c. In what way does this part of Dutchess County appear to be ‘standing on its side’?
10. Measure the map distance from Purgatory Hill (near sample DC-12) to the staurolite isograd: ________ km. Use that distance to estimate the P,T conditions that the rocks near Purgatory Hill experienced.

\[
T = \text{________ oC} \quad P = \text{________ kb} \quad \text{Humm, why might ‘Hell Hill’ be a better name??}
\]
Mapping of vegetation–rich area in interior Alaska reveals a few outcrops, contacts, and bedding orientations, as shown below. Based on fossil evidence and bedding orientations, we constructed a stratigraphic column: unit A is the oldest and unit G the youngest. Note the unconformity!

Definition: a skarn is limestone that has been contact metamorphosed (see M&W, pp. 171-72).

1. Turn this into a geologic map by creating contacts between units; use different colors for different units. Remember to use different patterns (e.g. lines vs. dashed vs. dotted) for contacts depending on degree of certainty. Remember to add symbols for any structures present on the map and then to add them to the legend below the map.

2. Draw a geologic cross section Y-Y’ (on back of page folded over). The terrain is essentially flat (no topography) Note: the line between Y and Y’ denotes where the cross section goes; it is not a fault. Make sure that the contact dip directions and amounts on your cross section agree with those on the map.

3. What must be underlying the skarn to cause the metamorphism? Make sure that you (schematically) draw this on your cross section.

4. What structure dominates the center of the map and involves units A, B, C and D? This structure needs to both on the map & cross-section. What is the map evidence for this structure?
The keys to sorting out complex geology are: older rocks are generally under younger rocks; younger geologic units/features cut across older ones; younger rocks contain inclusions of older ones. Below is a complex-looking (but not unrealistic) geologic cross-section through an area we’d like you to figure out. It contains 2 faults (F1 and F2), two igneous units (H,L; H is fed by a dike), numerous sedimentary units (A,B,C,D,E,F,I,J,K), one metamorphic unit (G), and 5 unconformities (I, II, III, IV, V), 3 of which are labeled with roman numerals. Letters and numbers do not imply any age order. The rocks contained within units H and J will tell you whether unit H is a sill or a flow.

Use the information contained in the cross-section to complete the stratigraphic column at the left.

1. **List** the oldest unit at the bottom and increasingly younger units going up, with the youngest at the top of the column.

2. On the cross section **trace** all five unconformities on the cross section **using colored pencils**. (Note that the present surface is not considered to be an unconformity, nor are intrusive contacts.). Now **identify** on the cross-section the other unconformities (II and III) that are not already identified.

3. **The age of an unconformity is between the age of the youngest unit that’s affected by it and the oldest unit that is above it.** Unconformity #I, for example must have happened between the formation of units G and E. Consequently unconformity ‘I’ should be listed in the ‘unconformities’ column (to the left) at a height between that of units G and E. **List** all the unconformities (by Roman numeral) in their proper age sequence and at the proper ‘height’ in the “unconformities” column. Draw a horizontal line from the Roman numeral to the place on the geologic unit column where there are 2 units separated by the appropriate unconformity.

(continued on the other side)
(4) **List** the two faults in their age sequence in the “faults” column, located (as in #3) between the geologic units just older and younger than the fault. Draw a horizontal line to the geologic unit column and position the line between the 2 units just older and younger than the fault. Both faults are dip-slip. **Indicate** whether each fault is normal or reverse with an ‘N’ or ‘R’ adjacent to the fault symbol in the column.

(5) On the far left side of the ‘geologic unit’ column (previous page), **indicate with arrows** when the folding of units C, D, I and E occurred and when tilting of units J and K occurred. Again, the folding must have happened after the youngest unit that is folded and before the oldest unit that isn’t folded.

(6) A ‘sill’ is an igneous unit that intrudes between two beds, parallel to the bedding. Is H a **flow** with feeder dike or **sill** with feeder dike? Explain how the types of rock clasts (shown by their patterns) in H and J help you to unambiguously answer this question.

**Subduction Zone Seismicity:**

(7). The figure to the left is from an introductory textbook *(Earth: Portrait of a Planet by S. Marshak,)* published in 2005, ant the one below is from your text on page 194!!.

Given what you know about the relationship between earthquakes and volcanoes that you determined in lab and in homework 3, what is wrong with these pictures?

____________________________________________________________________________________

____________________________________________________________________________________

(8). What does this say about the validity of what appears in introductory texts?

____________________________________________________________________________________

(9). One of the regular patterns seen on the Earth is that of trench, subduction zone and a long line of volcanoes. (Refer to Appendix IV, Plate 3.) What does the general pattern of earthquakes occurring around the world show us? Why are earthquakes common in some regions, and rare in others? What relationships do you see between lines of volcanoes, plate margins and earthquakes?

____________________________________________________________________________________

____________________________________________________________________________________
The Grinnell glacier is a cirque glacier in Glacier National Park, Montana. Over the years, geologists have tracked the movement of 20 rocks on the surface of the glacier, recording their position at various times. The movement of the rocks records the movement of the ice carrying them. A map of the glacier is on the next page and data for rocks on the glacier are given in the table below. The arrows on the map (next page) show the direction and amount of movement of identified rocks, but not the rate (speed) of movement. You will find it handy to re-read Chapter 14 in your textbook.

A. Movements based on rocks
1. Fill in the chart below by calculating the average rate of movement (the speed) in feet/year for each rock studied. The first entry is shown as an example. Round to the nearest foot/year.

<table>
<thead>
<tr>
<th>Rock #</th>
<th>Period</th>
<th>total years</th>
<th>total feet</th>
<th>avg ft/yr</th>
<th>Rock #</th>
<th>Period</th>
<th>total years</th>
<th>total feet</th>
<th>avg ft/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>47-1</td>
<td>1947-57</td>
<td>10</td>
<td>380</td>
<td>38</td>
<td>59-3</td>
<td>1959-69</td>
<td>355</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-1</td>
<td>1950-64</td>
<td>530</td>
<td>530</td>
<td></td>
<td>59-5</td>
<td>1959-66</td>
<td>320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-2</td>
<td>1950-69</td>
<td>700</td>
<td>700</td>
<td></td>
<td>63-1</td>
<td>1963-66</td>
<td>110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52-1</td>
<td>1952-62</td>
<td>485</td>
<td>63-2</td>
<td></td>
<td>1963-69</td>
<td>190</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52-2</td>
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2. LABEL each arrow on the map with the appropriate speed of rock movement (the first one is done for you).
3. CONTOUR the speed data. Enclose all those points with an average speed of ≥50'/year. Then enclose all those with ≥45'/yr, 40'/yr, and 35'/yr. Label the contours.
4. EXPLAIN THE PATTERN OF VARIATIONS IN SPEED YOU SEE.

5. How does the variation in glacial flow velocity compare to the idealized Fig 14.8 (pg. 367) in your textbook?

6. Draw a BIG arrow showing the general direction of ice movement, based on the rock data.

B. Movements based on ice limits
1. Limits for Grinnell Glacier are shown for years between 1887 and 1969. Draw arrows showing the general that the glacier has moved. What is this type of glacial movement called?

2. The horizontal and vertical lines on the map (next page) are spaced 2000 feet apart. Use this scale to estimate the distance that the edge of the glacier has moved (a) in the Grinnell Creek area (1887-1937) _______ feet and (b) the Upper Grinnell Lake area (1937-1969): _______ feet. Use these distances to calculate the average rate of glacier edge movement and label on your map with a BIG arrow showing direction and speed.

C. Wrap-up
   Explain how the heck a glacier can be moving in two opposite directions simultaneously (your BIG arrows should show this)!!! Or what the heck is going on!!!???
This homework relates to class discussions of petroleum depositional settings.

The map on the following page shows the locations of some wells drilled into a township (36 sections or square miles). The elevation of the top of a reservoir sandstone unit (= contact between the sandstone and an overlying shale unit) in feet above sea level is shown for each well.

1. As shown on the map, the verbal scale is 1” to one mile. Write in the numerical scale on the map in the space provided.

2. Construct a contour map of the top of the sandstone (= contact between the sandstone and the overlying shale) at a 100-foot contour interval. Label the contours.

3. What is the approximate elevation of the oil-water interface? ______ Add an additional contour that defines this interface and shade in the area that contains oil.

4. Construct a cross section (using the chart to the right) from X to Y showing the elevation of the top of the reservoir rock based on your contour map. This is also the contact between the sandstone below and the shale above. Show the elevation of the oil-water interface on the cross-section. Shade in the reservoir rock unit where we would expect to find oil.

5. The sandstone unit is approximately 400 feet thick in this area. Add the lower contact of the sandstone unit to your cross-section, keeping in mind that the upper and lower contacts of a unit will be approximately parallel to each other.

6. What type of hydrocarbon trap is present in this map area? [See pages161-162 in Monroe and Wicander for a description of oil and gas traps].

   What role does folding play in this trap? What role does the shale play?

   ____________________________

   ____________________________

   ____________________________

   ____________________________

   ____________________________

Add fold axes to your map with the appropriate symbols

7. Imagine that this is an old hydrocarbon field in which the wells are no longer usable, but some oil is still present in the reservoir. If we were to put a new well along the X-Y cross-section with hopes of getting oil from the old field, where would be the best position? Show its location with a star on your cross section and then show where that would be on the map. Why did you choose this position?
In what section and ¼ section (to nearest ¼ section) is your well located (see Topo lab)?
________________________________________. Explain your reasoning.

8. If we were to use your cross section to search for oil outside of the immediate map area, but in the vicinity of the map area, which direction would we want to look: Towards X? towards Y? NW of line X-Y? SE of line X-Y?? __________________________________________

What is it about the structures of the reservoir rock that you see in the cross section makes the direction you chose more favorable?
________________________________________
________________________________________
________________________________________

9. You’ve already determined the numerical horizontal scale for the cross-section (Q#1). The vertical scale for the cross-section is 1” = 400’ (also expressed as 1:4800). Determine the vertical exaggeration for your cross-section _______________________

How would a cross-section with no vertical exaggeration for this area look different from yours?
Map of a township showing the elevations of points in wells where they contact the top of a reservoir sandstone unit. Elevations are in feet above sea level. Solid black dots represent “producers”; wells that produce oil and (or) gas. Open circles with tick marks represent “dry holes” that encountered only water.
This page is left blank so that you can lay the cross section on the contour map. Use it to elaborate on your answers, if needed.
Attachment 3: final essay assignment
In a short essay (~1000-2000 words = 2-3 pp. single spaced, size 10 font) address the following discussion item. You will have to do some research (e.g., library or internet) to get information on the scientific debate. Please find at least two written sources with opposing viewpoints. Include citations to your references (websites, article sources, authors, etc.) at the end of your paper.

The decisions that society, and in particular the United States, has to make regarding issues related to Geoscience are a difficult ones that will have to be addressed in the coming years. These issues include:

- Whether to explore and develop oil resources in ANWR or other wilderness areas
- What should our national effort be in the area of developing or promoting alternative (non petroleum) fuels such as uranium – the basis of nuclear energy
- What our response should be to apparent problem of global warming
- How to teach geology and evolution in schools and universities.

One of the complications in such decisions is that there are often “disconnects” between scientific evidence and public policy or public behavior in U.S. society.

Using one of the examples above, or another of relevance to the earth sciences, briefly discuss the scientific evidence (or lack thereof) that is currently being discussed. In your answer, SPECIFICALLY address ALL OF the following questions:

- How is this scientific evidence used or misused for political agenda?
- How are potential societal benefits balanced with potential risks?
- How important should scientific literacy be for the general public (you) in order for the nation and our leaders to make informed decisions?
- Overall (not just with reference to this particular issue), to what extent do you think that science is divorced from public policy and societal problems? Is this good, bad, or simply unimportant?

As a soon-to-be-graduate of GEOS 101, put your new skills regarding the geosciences to good use AND MAKE SURE YOU:

- Critically analyze both sides of the argument being made. You might find it helpful to identify motives and causes behind the argument, any biases or what someone would hope to gain from their argument.
- Evaluate the argument being made. You might find it helpful to criticize validity of the evidence being used, or the conclusions being drawn from the data.

These are just some helpful suggestions; just make sure you include more than a reiteration of a source. The goal of this assignment is to go beyond just quoting what scientists and politicians have said about the issue and to analyze and evaluate the arguments being used.
Have a great summer!!!
Attachment 4:

Two examples of “Hydrology Homework: one with a score of 10/10 and one with a score of 6/10”
Problem #1
The map on the next page shows monitor well locations with groundwater elevations (corrected to mean sea level), collected by the USGS March 30 to April 3, 1988. Also shown are township, range, and section lines and the Fairbanks Meridian & Baseline. The smaller squares are sections. Refer to the Topographic map lab.

1. Determine the scale of the map from the section line spacing:
   a. Write it here as a verbal scale:
   b. Write it here as a numerical scale: 1:

2. Determine the locations of the wells with groundwater elevations of 415 feet (west end of map) and 448 feet (east end of the map) in terms of ¼ section, ¼ section, section, tier, range. You might want to refer back to the topographic map in Appendix III to determine tiers, ranges and section numbers and to orient yourself on this map.
   Well 415:
   Well 448:

3. Draw a contour map of groundwater elevations, that is, a map of the water table. Draw contour lines throughout the area of the map for which there is data. Put in a contour line every 5 feet, starting at 445 feet.
   Label your contours. Roughly, what is the down-gradient direction?

Also shown on your map are 5 sites (Fort Wainwright, the Railroad Industrial Area, two gas stations and the landfill) where hazardous substances have leaked into the subsurface and have impacted the groundwater. [Landfills usually leach contaminants into the groundwater.] Note the location of the Golden Heart Utility (GHU) water supply wells and the UAF water supply wells. There are also a large number of private groundwater drinking water supply wells, not shown on the map.

4. Mark each of the 5 sites with a large colored X and draw an arrow from each contaminant source in the down gradient direction and label the two gas stations as "East" and "West".

5. Draw an O at the two water supplies using a different color. For each of the two supply wells, what sources of contamination (if any) affect them? Again look at the gradient and the arrows you drew, not just the distance between the sources and the wells. When referring to the gas stations, note whether you mean the east or west one. UAF water supply wells: North to South only.
   GHU water supply wells: North to South only.

6. Determine the average groundwater gradient, that is, the slope of the water table, in feet/mile ________ and in feet/feet _________ (this is Δh/d; use this number in question 7).

7. Determine the approximate velocity (v) in feet per year of ground water in the Fairbanks flood plain using the equation: v = (K/P)(Δh/d). Use a permeability (K) of 5,000 feet/year, Δh/d from question 6 and an appropriate value for porosity, P, from your lab data and justify the value that you use. Once you've calculated the groundwater velocity, calculate how long it will take for typical groundwater to travel one mile.
   Value for P ________ Justification for P ________
   Velocity: _______ ft/yr
   Time to travel 1 mile: _______ yr/mile

Show your work here or on page 4:
Problem #2: In the groundwater lab, each of you collected porosity and permeability data and plotted them. A couple of years ago, GEOS 101 students collected the following data and reached the following conclusions. Note that they did collect multiple measurements of some samples and that they did not measure any sample smaller than 5 mm in diameter.

![Graph showing porosity vs. grain average diameter and permeability vs. grain average diameter.]

Conclusion #1: Porosity increases with increasing grain size based on a best fit straight line from a computer program (Excel)

Conclusion #2: Permeability is constant no matter what the grain size

Conclusion #3: You can predict the porosity and permeability for any grain size using the lines on the graphs.

Based on these conclusions, the students calculated plume flow in groundwater through a loess aquifer (grain size = 0.1 mm). For their calculations they used a permeability of 40,000 feet per day and a porosity of 10%. They concluded that the low porosity would mean that not much water was in the loess but that the plume would move rapidly down gradient.

Based on your results from your lab exercise (where you did measure loess and other fine grained sediments) answer the following questions:

Questions:

1. How do the conclusions of the porosity and permeability of loess that this study reached differ from what you observed in class?

   We concluded that grain size does affect permeability.

2. Identify and briefly describe at least one serious error in their porosity data and their interpretation of the data. Did you ever see a porosity as high as 75%? That is, what is biased about the line that they drew?

   The highest porosity we found was 55%. They measured wrong.

   We concluded that grain size does not affect permeability.

(over)
3. What should the students do to test the validity of their grain size versus porosity relationship and its applicability to loess?

4. Identify and briefly describe at least one serious error in their interpretation of the permeability data as it applies to loess with a grain size of 0.1 mm.

5. What should the students do to test the validity of their grain size versus permeability relationship as applied to loess?

6. For the students' groundwater model, how might the erroneous porosity and permeability values bias their conclusions regarding the effect of this plume down gradient?

[Handwritten responses]
Geos 101

Homework 9 - Hydrology

Name: ____________________________ Lab Day/Time/TA: ____________________________

Problem #1

The map on the next page shows monitor well locations with groundwater elevations (corrected to mean sea level), collected by the USGS March 30 to April 3, 1988. Also shown are township, range, and section lines and the Fairbanks Meridian & Baseline. The smaller squares are sections. Refer to the Topographic map lab.

1. Determine the scale of the map from the section line spacing.
   Write it here as a verbal scale: ____________
   Write it here as a numerical scale: ____________

2. Determine the locations of the wells with groundwater elevations of 415 feet (west end of map) and 448 feet (east end of the map) in terms of ¼ section, ¼ section, section, tier, range. You might want to refer back to the topographic map in Appendix IV to determine tiers, ranges and section numbers and to orient yourself on this map.
   Well 415: NE ¼, SE ¼, SEC. 22, TIS, R2W
   Well 448: SW ¼, NE ¼, SEC. 28, TIS, R1E

3. Draw a contour map of groundwater elevations, that is, a map of the water table. Draw contour lines throughout the area of the map for which there is data. Put in a contour line every 5 feet, starting at 445 feet. Label your contours. Roughly, what is the down-gradient direction? ____________

Also shown on your map are 5 sites (Fort Wainwright, the Railroad Industrial Area, two gas stations and the landfill) where hazardous substances have leaked into the subsurface and have impacted the groundwater. [Landfills usually leach contaminants into the groundwater.] Note the location of the Golden Heart Utility (GHU) water supply wells and the UAF water supply wells. There are also a large number of private groundwater drinking water supply wells, not shown on the map.

4. Mark each of the 5 sites with a large colored X and draw an arrow from each contaminant source in the down gradient direction and label the two gas stations as “East” and “West”

5. Draw an O at the two water supplies using a different color. For each of the two supply wells, what sources of contamination (if any) affect them? Again look at the gradient and the arrows you drew, not just the distance between the sources and the wells. When referring to the gas stations, note whether you mean the east or west one. UAF water supply wells: ____________
   GHU water supply wells: ____________

6. Determine the average groundwater gradient, that is, the slope of the water table, in feet/mile and in feet/feet ____________ (this is Δh/d; use this number in question 7)

7. Determine the approximate velocity (v) in feet per year of ground water in the Fairbanks flood plain using the equation: v = (K/P)(Δh/d). Use a permeability (K) of 5,000 feet/year, Δh/d from question 6 and an appropriate value for porosity, P, from your lab data and justify the value that you use. Once you’ve calculated the groundwater velocity, calculate how long it will take for typical groundwater to travel one mile.
   Value for P ____________ Justification for P ____________
   Velocity: ____________ ft/yr
   Time to travel 1 mile: ____________ yr/mile

Show your work here or on page 4:
Problem #2: In the groundwater lab, each of you collected porosity and permeability data and plotted them. A couple of years ago, GEOS 101 students collected the following data and reached the following conclusions. Note that they did collect multiple measurements of some samples and that they did not measure any sample smaller than 5 mm in diameter.

![Graphs showing porosity and permeability vs. grain average diameter]

Conclusion #1: Porosity increases with increasing grain size based on a best fit straight line from a computer program (Excel)

Conclusion #2: Permeability is constant no matter what the grain size

Conclusion #3: You can predict the porosity and permeability for any grain size using the lines on the graphs.

Based on these conclusions, the students calculated plume flow in groundwater through a loess aquifer (grain size = 0.1 mm). For their calculations they used a permeability of 40,000 feet per day and a porosity of 10%. They concluded that the low porosity would mean that not much water was in the loess but that the plume would move rapidly down gradient.

Based on your results from your lab exercise (where you did measure loess and other fine grained sediments) answer the following questions:

Questions:

1. How do the conclusions of the porosity and permeability of loess that this study reached differ from what you observed in class?

   *Answers:*

   1. Their conclusions were totally opposite and they have refine grain points on the graph. The porosity should be 25 up and permeability was changed to.

2. Identify and briefly describe at least one serious error in their porosity data and their interpretation of the data. Did you ever see a porosity as high as 75%? That is, what is biased about the line that they drew?

   *Answer:*

   They had to have done a measurement really wrong to get 75%.
3. What should the students do to test the validity of their grain size versus porosity relationship and its applicability to loess?

They need more data for fine grained material.

4. Identify and briefly describe at least one serious error in their interpretation of the permeability data as it applies to loess with a grain size of 0.1 mm.

Look to answer 3
Incomplete data.

5. What should the students do to test the validity of their grain size versus permeability relationship as applied to loess?

They need fine grained data.

6. For the students' groundwater model, how might the erroneous porosity and permeability values bias their conclusions regarding the effect of this plume down gradient?

They will get the wrong velocity if the porosity and permeability are way off.
Essay Examples

This section contains examples of essays that range in grades from “excellent”, 10.0 to “poor”, 2.4

Two examples of “excellent” essays which scored a “10.0” and followed the rubric to the letter.
How to Teach Geology and Evolution in Schools

Allow me to begin by saying that I chose this topic because it is an interesting debate for me personally, having lived in many different parts of the country and having attended several different high schools and colleges in the past. In addition, I am studying the sciences, yet I also believe in God. How can these co-exist? CAN they co-exist? It is for these reasons that I chose to write about teaching geology and evolution in schools, and what I believe is the best approach to the topic based upon my research and personal experiences. To begin, we will address geology and evolution in their basic terms, their controversy in schools, and examine potential solutions to the issue.

Geology:

Geology, as we have discussed in class, is the study "of the Earth, the materials of which it is made, the structure of those materials, and the processes acting upon them. More particularly, geology focuses on how the earth’s materials, structures, and processes and organisms have changed over time (Hobart M. King 2010)." As we have learned, the earth is dynamic - it is changing, forming, evolving. Geology studies the processes that drive these changes; they study the past to better understand the present – and potentially the future.

Evolution:

Evolution is the driving force behind geology in the sense that it is change! The best definition for evolution I have come across is from Douglas J. Futuyma in his book Evolutionary Biology (Futuyma 1986): "In the broadest sense, evolution is merely change, and so is all-pervasive; galaxies, languages, and political systems all evolve. Biological evolution ... is change in the properties of populations of organisms that transcend the lifetime of a single individual. The changes in populations that are considered evolutionary are those that are inheritable via the genetic material from one generation to the next. Biological evolution may be slight or substantial; it embraces everything from slight changes in the proportion of different alleles within a population (such as those determining blood types) to the successive alterations that led from the earliest protoorganism to snails, bees, giraffes, and dandelions."

Evolution then, in biological and geological terms, is genetic or morphological changes in organisms or materials over time that adapt that organism or material to best fit its environment. It is an integral component in understanding science and its processes because of the fact that things change! If processes or organisms stayed the same, there would be no need for adaptation or change. But change exists, processes occur that drive change, and it is largely through geological studies that we are aware of these changes. Therefore, geology and evolution are fundamentally associated with one another and are essential to understanding life as it exists today.

The Issue:

The debate over teaching these sciences in schools lies in the belief that these two (science vs. religion) are fundamentally opposed to one another; one purporting evolution, the other attributing the creation of all things to God. However, aside from any moral judgment, it is evident from the sciences (including geology) that different species, the earth, organisms, and even rocks have all changed and evolved over time. Science exists that proves change has occurred! So why is there a debate? Devout evolutionists claim such theories as the "Big Bang" and the "Bubble Theory" to explain how life, and therefore evolution, began (Yarris 1993). Devout creationists claim that God literally created the earth in six days and that all species present on the earth were made that way in the beginning (Institute for Creation Research 2010). According to either side, both theories fundamentally cannot at the same time – one disproves the other. However, the debate to teach one or the other, or both, in schools has become a contentious topic over the years. Many people find themselves in a struggle between "science and religion".

Teaching Geology and Evolution in Schools

As we have learned, seen, and even felt this semester, geologic processes have occurred on earth for millions of years, which have shaped the earth into what we see today. It is easy to identify changes in rocks,
landforms, and even fossils through the study of geology. Species present on the earth today were structurally different than their fossils found in different parts of the world. In essence, it is apparently obvious change has occurred throughout the earth and its species. So how should these facts be taught in schools in ways that all could benefit from? To me, it begins with dispelling misinformation. Many people don’t know geologic processes; they aren’t familiar with the concepts we have learned this semester. In addition, the media (for their own reasons) purports the debate to be either/or. Many people believe it is either religion OR science. Most people don’t realize the two can co-exist. In my view (and I am a believer in God), science and God go hand in hand. If God did in fact create the earth, then he would abide by the natural laws we abide by. (ie. Things just don’t appear – there has to be a way, a means of creation) I believe that way IS through evolutionary processes. Not all evolutionists are crazy, not all religions are zealots. The two are NOT mutually exclusive. Evolution should be taught in schools because it exists, there is no sense in hiding that fact. However that does NOT take away the possibility that a Creator used natural laws as a means to create. If evolution were taught in schools in a way that didn’t come out and say, “all people who believe in God are wackos”, the debate would be much less heated. Again, the two are not mutually exclusive.

It is my conclusion that based on what we have learned this semester, the earth IS dynamic. It IS changing and evolving. One way of helping people understand the fundamental role played by evolution is for them to see the evidence we have seen this semester. For me, the hands-on aspect helped me understand the concepts much better than any exam or book could have. If evolution is to be taught in schools, this method of helping students to understand should be used, in conjunction with the understanding that evolution does not dispel a belief in God.

How is this scientific evidence used or misused for political agendas?
Scientific evident has been misused, in my opinion, to push a purely evolutionary political agenda in the form of lobbying groups that dispel any notion of God in schools and universities. These lobbying groups include the National Center for Science Education, the Discovery Institute, and the National Science Teachers Association (National Center for Science Education 2010). While the agenda of encouraging evolution to be taught in schools is not a misuse alone, the misuse stems from the assumption, as mentioned, that evolution vs. creationism is mutually exclusive, which in my opinion, will automatically polarize the political process and voters in general. A much better approach would be one of inclusion, as mentioned above.

How are potential societal benefits balanced with potential risks?
In my view, the potential benefits of teaching evolution in schools, with the caveat that doesn't dispel creationism, is win/win for everyone. The approach currently held by many scientists and lobbying groups is full of risks – risks that the issue will continue to be misunderstood, will continue to polarize voters, and will only lead to more talk and no action. I personally have never attended a school that has taught creationism (only as a means to strengthen evolutionary theory), which turned me away from the subject as a youth. As I gained more knowledge on the subject, the more I gained my current viewpoint. If teachers taught the subjects together, or even taught evolution with the understanding that it does not mean there is no God, I would have been much more open to the idea and to learning the subject.

How important should scientific literacy be for the general public in order for the nation and our leaders to make informed decisions?
It is fundamental, in my opinion, for the public to be actively involved (both in process and understanding) in the political process. No matter if the issue surrounds evolution or oil in ANWR, the public (i.e. the voters) needs to be informed. This begins in the classroom, in schools and universities. This is one reason I chose this topic. If the public is not involved (and soundly so) there will be no debate, which will ultimately lead to less and less innovation.

Overall, to what extent do you think that science is divorced from public policy and societal problems?
Is this good, bad, or simply unimportant?
Overall, I would argue that science IS divorced from public policy in this country. Too often, political decisions are made on a purely circumstantial basis and not on any well thought-out, debated, scientific basis. In addition, too often decisions are made on “spur of the moment” information, basing decisions on PURELY current opinion without much of a regard to scientific evidence. A good example of this would be drilling for
oil in ANWR, which people either strongly support or strongly oppose without knowing much, if any, scientific detail. This disconnect is bad in my opinion because science forms so much of our lives in this technological era. If the public is to form opinions on key issues, it should do so with an informed opinion based on facts, not just political rhetoric. A major current topic is global warming. Decisions that can affect our way of life need to be based off of sound scientific evidence, and not assumptions. If politicians rid every American of their gas-guzzling vehicle, and it turns out vehicle emissions are NOT the problem, it causes problems. Before decisions are made, there must be a balance of scientific and public knowledge and opinion. This will, in my opinion, help smooth current societal problems, and problems faced in the future.

Works Cited


In 1960, the Arctic National Wildlife Range was established. Over the years since, the Range has been expanded, has experienced a name change to Arctic National Wildlife Refuge and has become the subject of an ongoing nationwide debate about energy production vs. environmental protection. The debate is fueled on one side by concerns regarding U.S. energy independence and by desire for economic development and on the other side, by concerns for wildlife preservation and global warming. To drill or not to drill, that is the question. The problem is how to weigh the arguments and evidence to balance the issues.

So how much oil is there in ANWR? Can it be extracted economically? Can the economic benefits from the oil development offset the environmental risks involved?

The first question is how much oil could be extracted from ANWR. The information available is remarkable only in its uncertainty. Because ANWR has not been opened for exploration, the estimates have been made on the basis of seismic data and other geologic information inferred from what is known about the North Slope area. This results in estimates that can only be expressed in probabilities. Both sides of the debate misuse the data. The pro-drilling camp generally claims that there is recoverable oil in the amount of 16 billion barrels, while the environmental faction counters with a number of only 4 billion barrels. If you look at the estimated probabilities for these numbers, there is a 95% probability on the 4 billion barrels and a 5% probability on the 16 billion barrels. The different factions are merely using different ends of the probability scale and rarely mention the uncertainty involved. It is interesting to note that in the table of these figures shown on ANWR.org, a pro-drilling advocacy site, the probabilities are listed. However, when the estimates are used within the text explanations, the writers always use the high end of the scale. In discussions regarding the amount of oil in ANWR, the pro-drilling camp also like to throw in statements regarding the amount of oil produced in the current North Slope oil fields. This appears to be an effort to imply that ANWR could be expected to produce as much oil as the current fields. Unfortunately, simply being in the same region as other oil producing lands does not guarantee the presence of extractable oil. The only way to find out for sure is to drill.

The oil extraction issue is complicated by the economics of oil. There is a cost to extract the oil, to transport the oil, and to refine the oil. Whether or not it is economically feasible to develop an oil find is dependent upon the price of oil at the time of development as well the costs of extraction. The fluctuation of these costs make the feasibility of developing ANWR something that changes every time it is discussed. Currently, the oil companies have access to other oil resources that are less expensive to develop, with less political opposition.

The pro-drilling side also claims that economic impact of development in ANWR will produce 700,000 new jobs, both from direct employment by companies that are developing the fields and from associated economic growth. However, there appears to be some question around that jobs figure. In a 2001 Time magazine article, Douglas Waller states "that number comes from an 11-year-old study commissioned by the American Petroleum Institute that economists complain wildly inflates the employment potential. "It's just absurd," says Eban Goodstein, an economist at Lewis and Clark College, who predicts the real job growth will be less than one-tenth that number." A lower number of new jobs would have a significantly lower economic impact than the 700,000 new jobs the pro-drilling side would like to claim.

The environmental issue most frequently associated with the ANWR drilling debate is the Porcupine Caribou Herd. The herd migrates through the coastal plain and there is concern that development of the coastal plain for oil will constrict the calving ground for the herd and will result in an irreversible decline in the herd numbers. While this did not happen with the Central Arctic caribou herd that occupies the Prudhoe Bay oil fields, wildlife biologists indicate that "both the terrain and the demographics of the Porcupine herd are vastly different". However, the Porcupine herd is over 100,000 strong and caribou are not an endangered species. In this case, the impact to the herd might translate into a economic and cultural impact to the Gwich'in people who hunt the migratory herd.

Another environmental issue is that of oil spills and other direct damage caused by the development. The latest North Slope oil spill in 2006 due to BP's neglect of corroding shows that the oil companies have not been diligent in maintenance in the oil fields that they have already established. What-
ever they might promise for new oil fields, it is unlikely that proper prevention steps will be taken without significant state and federal resources dedicated to ensuring that the company is doing so.

Both sides of the ANWR debate have been using a mix of emotional arguments and science, but only the parts of scientific studies that support their position. One can see why. Either definitive data is in short supply as it is with the oil estimates, or there is too much uncertainty to be sure of what will happen, as with the future of the Porcupine caribou herd. The wide range of probabilities give both sides the opportunity to claim that they have the “facts” while describing contrary arguments as “myth”. To make a decision based on evidence, one must have some sense of what is actually known and the certainty of that data. Currently neither side of the argument appears to be providing much evidence, but sound bites abound.

Robert J. McMonagle, in his book *Caribou and Conoco*, studies the decision making process in Washington, D.C. around ANWR environmental policies. He contends that the debate has been largely a symbolic argument. Both sides of the issue have defined their positions with symbols that they feel are likely to appeal to the public. The Pro-environment side uses images of the Porcupine Caribou Herd and ANWR as “pristine” wilderness. Drilling proponents counter with arguments that the “footprint” of any drilling would be small or that only a small portion of the refuge would be drilled. In his study, he found that shifts in the political ideology of Washington policy makers can occur without “any fundamental change in the available information on which policy is supposedly based.”

This symbolic argument has resulted in a deadlock. As of 2010, the ANWR coastal plain is not fully protected as wilderness, but there also has been no drilling. This leaves unanswered the question of how to balance the potential societal benefits of more energy with the potential risks of developing the area. The balance is even harder to conceive when parts of the equation cannot be quantified. Some of the pro-drilling argument can be quantified, such as the amount of oil, the cost of extraction and the benefits of energy production within the U.S. This leaves many of the environmental arguments looking weak because we, as a society, have not figured out how to quantify some environmental benefits. When there is a direct benefit, such as with a watershed area, the benefit can be linked to what is known of the cost of water purification and water use. When damage is done due to toxins or an oil spill, we can quantify by adding up the costs to clean things up. But how do you quantify the benefit of an undisturbed wilderness?

Historically, the American attitude toward land resources has been that the land is valuable in direct proportion to the profit that can be made through its use. When the issue is protecting an area as wilderness, the value is placed on how “pristine” the area is, untouched and unmarked by man. This comes through very clearly in the arguments made regarding ANWR. When the writer is pro-environment, the coastal plain is described as pristine. When the writer is pro-drilling, the plain is a barren stretch of land. This raises the question of how you can explore an area for resources if you devalue it simply by relatively minor exploration (not development) and suggests that perhaps “pristine” is the wrong standard. It is quite possible to have a thriving wilderness with occasional signs of human presence. However, until there is an agreed standard to quantify the benefits from wilderness lands, one should expect the environmental lobby to oppose the exploration of ANWR and fiercely defend the pristine standard as it is much harder to protect wilderness when there is a known resource of quantifiable worth up against an unquantifiable benefit from protecting lands.

The pro-drilling side acknowledges that oil production in ANWR would be 15-20 years out at the soonest. If, that is, there is extractable oil, and they are allowed to go in and find it, and if the oil companies don’t have other easier resources to extract when they find it. However, given the current questions around climate change from hydrocarbon use, the proper question may be “Should we be drilling for more oil or developing non-carbon alternatives.” But that is another societal question, with its own science debate. In the meantime, the general public and our legislators need to educate themselves on the science issues so that they know when they are being told only half the story. They need to know when to ask “just how did you come up with that number?” and they need to know how to evaluate the scientific methods behind the studies that are quoted in the sound bites.

In this issue, as with many issues, the general public only hears the sound bite science; the snippets of the studies and conclusions that support one side or the other. In the early 90’s, the Fox cable network, FX, ran a half-hour news show where they addressed only one topic out of the day’s news. One day, I caught the show when they were discussing a health study in the headlines that day. The headlines were suitably dramatic and controversial. On the show, they interviewed the doctor who ran the study. She explained the purpose of the study, the assumptions that they had started with and how the
study was set up. My response was “Oh. Makes sense now.” When the media is in charge of informing
the public regarding the substance of a scientific study, it will go with the elements of the study that they
believe will capture attention. This does not really serve the public interest. When you look for the source
of the information, you cannot always get access, although the internet is making it easier. Many times,
even on the internet, you find that you must pay for access to the study or that the study is proprietary
information of a corporation. If people are not concerned about this, then they should be. It is hard to
make a good decision when you don’t have all the information.

The element of the ANWR debate that caught my attention was that most of the debate and the
policy making had only the most superficial relationship to the science data available. People are using
the science only to reinforce what they already believe. As the current oil spill in the gulf is giving the pub-
lic a very negative image of oil development, I do not believe that the current deadlock on exploration in
ANWR will be broken without the factions coming to an agreement of exactly how much oil is enough oil
to counteract the risks to the coastal plain.

End Notes:
2. This entire site is an example of how to misuse science information to promote a cause. Arctic Pow-
   <://www.anwr.org/>. 4. McMonagle, Robert J. Caribou and Conoco : Rethinking Environmental Politics in Alaska’s ANWR and
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Two examples of “very good” essays, grades < 8.0
Whether evolution should be taught in schools is a controversial topic that has entered television sets and political arenas across the country. On one side of the argument is a conviction in a higher power that does not leave room for the theory of evolution. On the other side of the argument is a simple attempt at keeping education educational. Somehow the theory of evolution has been portrayed as a thought that undermines all religion and simultaneously removes the world of a moral conscious. The reality is however that evolution is no more of an incendiary topic than gravity. The theory of evolution need to be taught in school.

Throughout human history religion and science have been at odds. New scientific theories seem to make the church nervous because of fears of undermining fundamental pillars of faith. The theory of evolution is no different. Evolution would suggest that instead of two original humans, we came from a gradual change in species adaptation over millions of years. Obviously this suggestion does contradict one of the main stories in the book of the Bible Genesis. Understandably this has made people uncomfortable because after all if Adam and Eve were not actually real what other parts of the Bible are not real. This is where opposition to teaching evolution in schools stems from. A fear that children will go off to school and in a day return as heathens. The fact is that teaching evolution has no hidden political or faith destroying intentions. Teaching this theory is no different that teaching gravity. It is a scientific theory that is undergoing tests and being developed as technology increases and more research is conducted. True science is void of political agenda. Evolution has been misused as an anti-god rally cry giving it an unfair representation in the media and in national opinion. With images of fish stickers and t-shirts donning the shoulders of rable rousing youth trying to buck the system, what really is nothing more that a scientific theory has become something else. The controversy between teaching it in public schools or not lies not within the theory itself but within image of the theory.

Teaching in schools should not be based on this image but on the hard facts. The ever growing fossil record of pre-hominid and hominid development is extensive and revealing. Anyone willing to listen a little bit can see there has been a shift over millions of years from primates to hominids to modern humans. This does not however mean that the fossils are jumping out of their rocks to say that there is no god. If anything I would think that evolution would help in a belief in god by being a prime example of planned destinies.

One of the biggest problems with this issue is a simple problem of semantics. As Professor Layer discussed in class it is essential that great care is taken when choosing words when discussing this topic. In my own experience I have been asked multiple times “Do you believe in evolution?” And every time my answer is no. There is no more belief involved in my view of evolution than there is in my view of gravity. This is why teaching evolution in school is a non-issue. It does not have anything to do with belief systems and therefore does not have any effect on them. Teaching evolution and the Bible have absolutely nothing to do with each other. Neither of them undermine each other because they are completely unrelated. Science does not have room for belief within it and religion does not have any room for fact within it. Facts and faith are two completely different languages that will never be related. This is why the word belief should never be used when discussing evolution and also why teaching it in schools really has no effect on anyone's faith.

It is critical that our youth understand our natural world and how it works. Allowing children in this country to grow up only being told that the earth is no more than six thousand years old is criminal. Science is an essential part in every human's existence because it is inescapable. Even those of us that go on to be English or History majors science is what allows all of us to have electricity and motorized transportation. To deny children of any knowledge of this powerful tool solely based on an unwarranted fear is criminal. School is supposed to be a place of education where there is no
bias in what is presented. All views of subjects should be welcomed and heard and all theories should be heard as well. As important as it is that there are classes presenting different scientific discoveries and theories so too should there be classes presenting different religious views. Of course not all views can be presented but we should try to present as much as possible. The real controversy of this topic does not lie in the downfall of religion but in the disenfranchisement of our youth.

It is time that society moves past the age old science versus religion dichotomy and understand that these topics are not mutually exclusive but merely different routes to answer different questions. There is no need to pit one against the other because they really have no common ground to fight over. Belief and facts are different turfs. We never send a baseball team to play a soccer game against a football team so why should be expect science to explore the field of belief or religion to explore the realm of fact. For the sake of future generations and the success of our world I hope that someday we can move forward from this argument.

Sources

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To drill or not to drill? Whether or not to explore and develop oil in the Arctic National Wildlife Refuge known as ANWR is a major question that society has been faced with for many years. There are many opposing viewpoints to the drilling issue; many people think ANWR should be explored and developed, and there are those who think that it should be left alone so as not to destroy the land or disturb the wildlife living there. There are many issues to be addressed when exploring the issue of ANWR and of science in general: how the scientific evidence from the issue can be used or misused for political agenda, the balance of potential societal and environmental benefits to potential risks, why it is important for the general public to be scientifically literate, and how divorced science is from public policy and societal problems.

Political agendas use and misuse scientific evidence related to ANWR in order to sway the public opinion on the issue. According to Steve Venegas of Business Week Online, with the help of our pandering politicians and biased media, environmentalists are “planting seeds of propaganda.” He provides some examples of environmentalists’ convenient truths. Many environmentalists say that oil spills will contaminate the ANWR ecosystem. The inconvenient truth for environmentalists who say this is that oil-stained sands and oil seeps occur naturally in the ANWR coastal plain. Another convenient truth is that drilling will harm the caribou and other wildlife. The inconvenient truth of this is that caribou and other wildlife are flourishing in the Prudhoe Bay area near ANWR, and that this same area has provided billions of barrels of oil over almost four decades. Venegas believes that the oil fields in ANWR coastal plain can be safely developed with existing technology and innovative designs. He also believes that we can reduce our oil consumption through social engineering and alternative energy sources. Many people bend the evidence to persuade others to think the same way they do about the drilling issue, which takes away from the scientific aspect and turns it into too much of a political argument.

There are many potential societal and environmental benefits and potential risks that are not always equally balanced. Some of the reasons to open ANWR are national security, increasing domestic production, reducing foreign imports, and creating new jobs. Anwr.org states that ANWR could produce a million barrels a day, and 150 billion cubic feet of gas per year. It also shows that 75% of Alaskans support opening ANWR to responsible development. Of the 1.5 million acres of the Coastal Plain, less than 2,000 acres would be affected by development. Oil and gas producers support drilling in ANWR and believe exploration and production can be done in an environmentally safe manner. However, because it is an important wildlife habitat, many people are concerned that developing ANWR would hurt the land, endanger wildlife, and not recover enough oil to make the effort worthwhile. Environmental groups oppose drilling in ANWR because of the environmental and ecological value it has. The pros of drilling create many potential societal benefits, but would not benefit the environment. The cons of the issue presents the potential risks of how drilling could affect the wildlife.

Scientific literacy is important for the general public, because it allows the nation and our leaders to make informed decisions. This is not just with reference to the issue on ANWR; it is helpful to be informed on any scientific issue to be able to make better decisions that are important to our country and even the whole world. In his Entrepreneur article, Tony Myers states that, “having a population that has strong literacy skills also places a country in a better position to meet the complex social challenges that it faces.” Myers also says that a highly literate population will be better able to deal with issues of governance in a highly diverse society. Being scientifically literate also helps create more informed debate, which is needed to help countries determine how to best allocate scarce resources across competing priorities, such as education, health, investment in infrastructure and social programs. It is critical for people to be able to make informed decisions, and being scientifically literate aids them in doing so.

Many problems arise in society and in public policies related to science. It is good that science is involved in many public policies that are made; it is important and is not something that should just be ignored and not taken into account. It is bad when science is divorced from public policy because it causes even more problems. Science can also be a big part of many societal problems. An example of both a societal and public policy problem is the issue of the contaminated water out in North Pole. People who live in North Pole are just recently finding out about their water being contaminated, and nothing is being done to correct the problem. This is a problem for those living in North Pole because they either have to haul their water or continue drinking and using the bad water. Dan
Vergano, a writer for USA Today, states that “science and politics mix badly.” Vergano explains how conflict over stem cells, climate and other science has left the U.S. with a system that is plagued by charges that science is being politicized. Evidence of this can be seen in President Bush's decision in 2001 not to sign a climate treaty on economic grounds inflamed charges that science was being ignored. The discovery that a Bush administration lawyer had edited climate science summaries in 2005 further caused scientists to be alarmed. In March, President Obama released "scientific integrity" guidelines for federal scientists, saying the "public must be able to trust the science and scientific process informing public policy decisions." (Vergano) It is important for the public to be able to trust scientific information not only for public policy decisions, but also for their own personal benefit and decision making processes. Vergano goes on to quote David Goldston of the Bipartisan Policy Center in Washington who said, “It's difficult in some cases to distinguish science from policies, but now there are no incentives not to.” This shows that science should not be divorced from policies and that it is important for the two to be assessed together in order for better decisions to be made.

The decision or whether or not to explore and develop oil in ANWR is still a heated argument today. There are those who are in favor of drilling, and those who are against it. Everyone has their own opinion and reasons for thinking what they do about the issue, which leads to the opposing viewpoints and concerns that need to be addressed in the exploration of the issue. Concerns such as how the scientific evidence from the issue can be used or misused for political agenda, the balance of potential societal and environmental benefits to potential risks, why it is important for the general public to be scientifically literate, and how divorced science is from public policy and societal problems are all prevalent to the drilling issue and to science in general. And so the question still remains, to drill or not to drill? The answer has yet to be decided.

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Four examples of “good” essays, grades between 6.0 and 8.0
The geology of the earth provides the foundations for energy, economy, and life as a whole. The history of the earth has allotted a wealth of natural resources to sustain these foundations, but it is our job as humans to decide how to utilize them. As human populations grow, and industries and technologies expand the issue of fulfilling the demand for energy continues to grow.

Much of the world’s power is currently supplied by fossil fuels. Unfortunately the burning of these fuels is dirty, resulting in the release of CO2, pollution, and ultimately contributing to greenhouse gases and climate change. With rising fossil fuel prices, and worsening environmental conditions the demand for alternative fuels is increasing. Engineers and scientists are scrambling to develop the next dominant energy supply. Among propositions is the development of nuclear power. Nuclear power harnesses the energy released when atoms are broken apart, or undergo “fission”. This prospective is both exciting and dangerous. A study done by MIT states that the supply of mine able uranium ore is enough to sustain development of 1000 reactors and fuel them for 500 years (Ansolabehere et al.). This is a large supply of energy that must at least be explored.

There are two types of nuclear fuel cycles being proposed. Conventional thermal reactors cycle fuel once through and then directly dispose of the remains. Another method of reactor operates on a “closed fuel cycle” waste products would be separated from material that is still fissionable. This fissionable material that is still usable is the recycled. Closed fuel cycles extend the life of resources, and produce less toxic waste, but are more expensive (Ansolabehere et al.). If nuclear fuel is developed decisions will have to be made about which type of reactors to build, while one is more expensive, it is safer and more affective. Energy policies must weigh environmental impacts, safety and waste management along with economic feasibility.

The main reasons nuclear power is so controversial include the safety implications, and waste management issues. In 1986 an accident with a reactor in Chernobyl caused catastrophe for both the environment, and the health of surrounding populations. Increased radiation levels led to countless cancer cases, birth defects and deaths (World Nuclear Association). This shook the world and gave nuclear energy a bad name. Stephen Ansolabehere et al from the MIT study state that they believe that with current safety standards accident probability would average to about 1 incident per 50 years, and with improvements could be significantly reduced. They blame the accident at Chernobyl on poor safety protocol, and if nuclear power were to be revived serious consideration would be put into proper management. The MIT study proposes many safety precautions, that they believe make nuclear power a safe and viable option.

Karl Grossman argues that use of nuclear power is reckless. He points out flaws in current plans to expand nuclear plants. The effects from any accidents, and the likeliness of these events, he argues, are too great to outweigh any benefits gained from nuclear power. Most nuclear sites in the United States operate only 2 or 3 reactors. Plans to expand these sites want to double this amount on each site. Grossman points out that if something were to go wrong in one reactor it could create a chain effect, and with 4-6 reactors in each site the effects would be multiplied. Grossman also points out that new studies show that any amounts of radiation can lead to death, and no level is safe. Adverse affects of any reactor malfunctions are undeniable, but technology is constantly changing and improving, it is important to look at current issues and proposals.

It can be difficult to make informed decisions about controversial matters that are so reliant on probability and statistics. Data can be analyzed and represented in so many ways that the same data set can be manipulated to support opposing claims. To make an informed decision about the safety of nuclear power, or any controversial issue, it is important to be able to know what these numbers mean. The way an accident is reported can attribute the cause to human carelessness, or simply to the grave danger of the nature of the subject, and the ability to sort facts from emotional arguments is vital, especially in issues such as nuclear power where devastation resulting from misuse has had such adverse affects.

Nuclear power is a nonrenewable resource, which produces waste. There is potential for developing ways to recycle this waste, but these technologies have not been perfected to the point of being usable. Carbon fuel sources were developed without the worries of waste and emissions, and these emissions are having negative environmental impacts. With the development of nuclear power we have the benefit of forethought. Before implementing plans waste management systems can be tested and perfected.

Radioactive isotopes take millions of years to break down, so ultimately unless we can find a way to recycle this material we are going to be stuck with it for quite a while. In the U.S. a proposed solution is to reposition the material at Yucca Mountain in Nevada. If consumption of nuclear power increases then more of these repositories will be needed to dispose of nuclear materials (Stephen Ansolabehere et al.). This method of “disposal”
seems more like simply pushing the problem under the rug, because the material is not gone, it is just relocated. Yucca Mountain is located on or near 32 earthquake faults, and in an area that could be subject to floods, leakages, and volcanic activities (Grossman). These issues make the idea of storing radioactive waste here even more dangerous. Reposition at Yucca Mountain is a sub-issue of the issue of nuclear power. Grossman argues against nuclear power, while Ansolabehere et al. argues for the use of nuclear power, but they both argue against reposition. When forming an opinion about a controversial issue it is important to look at the sub-issues, and not be misled. When making policies issues are often lumped together. If presented the issue of whether or not to develop nuclear power and waste disposal at Yucca Mountain were presented as the only option then policy makers would be more likely to dismiss the proposal. It is important to be educated about all sides of an issue, and look at policies and agendas closely to make sure that all sides of the issue are being presented accurately.

There is evidence that nuclear waste could be recycled, irradiated, and used as scrap metal in appliances, automobiles, furniture, etc. (Grossman). If this material can be successfully irradiated this would be an exciting opportunity. If irradiation in some way did not meet standards or was unsuccessful the marketing of radioactive cars and toasters could result, an idea that turns some people off. If this happens, it will be even more important to be informed consumers, and to be educated about potential risks and rewards of such materials.

Nuclear power is a sub-issue of energy management and development. Some arguments against nuclear energy attack its nonrenewable waste producing nature, saying that if new energy sources are going to be developed they should be based on resources that cannot be depleted, and those that are not going to be a potential source of pollution. It takes a lot of research and critical thinking to form educated opinions.

Nuclear power has the capacity to reduce carbon emissions while providing affordable energy for generations to come. However, it comes with some costs. Waste management solutions are less than perfect, and the dangers of reactor failures could be catastrophic. Careful weighing of the benefits and rewards is needed to decide if nuclear power should be the energy source of the future. Scientific evidence can provide good resources to base these decisions upon, they are just resources, it is up to individuals to make interpretations.

Science is an important part of today’s society, but scientific evidence cannot be taken as fact. Science attempts to prove or disprove hypotheses or theories, not to create facts. Science can give great insights, but must be looked at in its contexts, and constantly re-evaluated. One of the most important things science has to teach is the importance of skepticism. Just because something is presented as true does not make it true. It is important to ask lots of questions to get good answers. There is no right or wrong way to look at things, but looking at limited amounts of information only leads to limited answers and decision.

Meeting energy needs in the future will not be cut and dry. There will be many controversies over the economy, environment, safety and effectiveness of different ideas. Whether or not nuclear power is developed is just one aspect of this battle. There are many other options for meeting energy needs including renewable sources such as wind, solar, geothermal, and biopowers. All of these resources need to be looked at as viable options, and decisions need to be made. Through careful investigation and thoughtful analysis of scientific data it is possible to change the world. Better education leads to more informed decisions.

After looking at the evidence about nuclear power, weighing the balances and rewards, I think that no matter what conclusions are drawn, the most important is to realize that new energy resources need to be explored, and simply continuing to rely on fossil fuels is not a viable option. There are many other potential resources available, and perhaps relying solely on one option in the future will only recreate the same problems. As individuals it is important to look at personal energy usage, look for ways to cut down and conserve, and to demand alternative energy sources in the consumer market. Will the atom hold the solution to the energy crisis? I am not sure, but at least it is raising awareness about the social, environmental, and political issues related to energy.

Citations:


Drilling in the Arctic National Wildlife Refuge

The price on gasoline rising at the fuel pump, make the oil under the Arctic National Wildlife Refuge (ANWR) very attractive. Scientific evidence is being used to evaluate the amount of oil in ANWR by different organizations and on the benefits and hazards of drilling. Scientific data is being used and misused for the political agenda of these major organizations, such as ANWR.org, Department of Energy, Defenders of Wildlife, and other political figures. The many benefits that can potential help society have many potential risks that can damage the arctic ecosystem if drilling was allowed in ANWR. Scientific literacy is very important for the people to know so that they can be informed and understand statistics and documents that are used to support the cases of politicians. Being literate in science will allow the people to make sure that the leaders of our nation make the correct decisions. Science definitely becomes separate from public policy and societal problems when the government begins to ask for money to make these changes in trying to save the environment or to convincing the public that drilling will be profitable for everyone.

Scientific evidence is being twisted by many different organizations to convince others to believe their case. Department of Energy believes that ANWR should be developed because the United States Geological Survey (USGS) team estimates a million barrels of oil can be recovered and replace the United States dependence on foreign oil. According to the “Natural Gas Facts” sheet released by the Department of Energy, the oil and gas producers claim that they can explore and produce ANWR in an environmentally safe manner using new and safer methods. The Defenders of Wildlife claim that the only reason oil companies wants to drill ANWR for more money and that it would not lower gasoline prices if they begin to develop it. They claim that the amount of permits given out has almost doubled since 2002, yet prices have not been lowered. The Defenders of Wildlife also believe that the U.S. only has about 3% of the world’s oil reserve and that they would not be able to influence the oil prices at all. The fact sheet on the website of the Defenders of Wildlife claim that polar bears will be threatened by the drilling because of instances where polar bears ran away from their den and babies when a seismic vehicle tracked too close to the den. All of these organizations use scientific evidence to support their claims. The only real way of knowing how much oil can be found in ANWR will require drilling. Even the GSGS team ranged the amount of oil that could possibly be drilled from five percent to ninety percent. The organizations used the highs and lows of the range to convince the public to believe their side and to further their causes.

The benefits that can be gained for society are balanced with the potential risks of drilling ANWR. Societal benefits according to the fact sheet released by the USGS is that potentially the United States can produce more than a million barrels a day and not rely so much on the export of Iraqi oil. This would benefit the society of the United States because it could produce more jobs, less dependence on foreign oil, and potentially lower the cost of fuel. These benefits are balanced by the potential risks from drilling in ANWR and according to the Defenders of Wildlife they include the decline of animal populations in the Arctic and the destruction of the entire landscape in Alaska. That the drilling of 2000 acres of land out of the 19 million acres would completely wipe out the polar bears, grizzly bears, muskoxen, caribou, and birds that live in ANWR.

Scientific literacy is important for the general public to understand and know to insure that the nation and our leaders make informed decisions, instead of focusing on the money. Being able to
interpret data and know what is being presented is important for any person to make an informed decision on a topic. Scientific data and evidence can be easily twisted and used for any organizations political gains. It is also being used by politicians to further their agendas and to be placed in the position in the first place. In general, the citizens living in the United States care mostly about money and how it will affect them if new laws are passed. As long as a person feels that they are benefiting at the lowest cost, they will be happy electing or going along with whatever organization promises it to them. By understanding the data presented than a person can make and informed decision and possibly educate others who may not understand so that they may make an informed decision as well.

Science is divorced from public policy and societal problems when money enters the picture. The key focus to all the arguments about ANWR is the amount of oil that will be recovered from the fields. The big oil companies are the only ones who benefit from the production of ANWR. The opposing view claims that the amount of oil that can be found in ANWR would only make up three percent of the worlds supply and have no effect on the price of oil. Politicians seem to join in on whatever side will get them elected or to allow them to stay in power and ignore most of the other scientific facts. The Politicians seem to care more about what will make the people happy, instead of what scientific data suggests.

Drilling in ANWR has been an issue for almost thirty years now. The scientific evidence that the GSGS has presented has been used to convince others of their point. ANWR.org use the 95% estimate of oil that the GSGS has presented and the Defenders of Wildlife use the 5% estimate to make their points. The benefits that can be gained from drilling in ANWR have many potential risks that need to be examined, such as the Arctic ecosystem. The public, who elects the national leaders and vote on policies, needs to be able to interpret the scientific data presented. Science is examined and used to solve societal problems and develop public policy, but is not always followed through when the costs begin to arise. If science is to be combined with public policy and to solve societal problems, than everyone needs to deal with the extra costs involved.

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ANWR – To Drill or not to Drill? That is the question...

Every since the oil seeps were first spotted in the 1002 region, there has been an ongoing battle over whether it should be drilled for oil, or left alone because of the “pristine” area that it is. Much like it's next door neighbor Prudhoe Bay originally was, the 1002 region is thought to be a potential pay with a nice chuck of reserves to be tapped. Because the area is included in ANWR though, it has never been drilled and, therefore, there are no real numbers representing what is up there. What it comes down to though, is we need to just nut up, check it out to see if the area is worth producing, and start punching holes.

In 1995 Congress approved exploration of the 1002 area, but Clinton, for whatever reason, decided to veto it. Since then, there has not been any approval to get in there. According to studies done by the USGS, it is estimated that the 1002 area possibly contains up to 16 billion barrels of oil, and this has been used by both sides of the feud to argue their points of view. Anti-drill campaigns claim that the amount of estimated oil in the 1002 area is there, but in reality it is not worth it. They say that it will only decrease the dependance on imported oil by a slight bit and is not worth ruining the “beautiful wasteland” that makes up the area. In a sense, this is true. Regardless if the 1002 area is drilled and sucked perfectly dry, the US is still going to be importing oil. This is an unavoidable truth that comes with our heavy demand and use of oil. But, at the same time, any additional oil produced does still decrease the dependance on imports that much. You would also think that there would be a little national pride involved also. As a government, I would be ecstatic to explore, drill, and produce domestic oil, regardless of the amount, rather than importing the same amount from another country over the course of 25 or 30 years. The Bush administration used this tactic when pushing arguments about drilling the area saying that it needed to be produced to decrease foreign dependance and increase national security. Too bad it never resulted in anything.

Another thing that comes into play is that Prudhoe Bay is slowly decreasing production levels every year. There will be small increases in production with advances in recoverability techniques and technology, but sad fact is that production is decreasing. The pipeline was designed to handle just over two million barrels per day, but today is only flowing at around 700,000 barrels per day. With the decreasing production, and no additional reserves being added, it will eventually become not economically feasible to continue operation of the pipeline. This should be another huge motivator to drill the 1002 area. It makes no sense to not drill one area and consequently have to stop production from another area because it has become to expensive.

The potential societal benefits of drilling in the 1002 area, in my opinion, are not balanced with the potential risks. Depending on what side of the argument you are on, your opinion could severely differ. The risks involved include the destruction of nesting and birthing grounds of many animals, increased pollution and spills that would kill vegetation in the area, and ultimately, the destruction of a “pristine environment.” I believe this is wrong though. Much like everyone complained about the wildlife going to be destroyed with Prudhoe Bay, the wildlife of the 1002 area will be fine. And as far as the area being a “pristine” area, it is not. Having seen it, I can attest to what is literally a barren wasteland. According to an article by Charli Coon in 2001:

Opponents of drilling in ANWR claim it is the nation's last true wilderness, a hallowed place, and a pristine environmental area. Though such attributes describe much of ANWR, they do not accurately portray the 1002 Area. In a July 20 Washington Times article titled "Hardly a Pretty Place: Use ANWR for Oil Exploration," Jonah Goldberg, editor of National Review Online, described it this way: "[I]f you wanted a picture to go with the word 'Godforsaken' in the dictionary, ANWR would do nicely." He is not referring to the ANWR parcels often highlighted in the media and on postcards with picturesque landscapes and endearing wildlife scenes. Rather, he is describing the flat, treeless, coastal plain area at the top corner of ANWR where the oil is located. As he notes in the article, winters on the coastal plain last for nine months; there is total darkness for 58 consecutive days; and temperatures drop to 70 degrees below zero without the wind chill. Summers are not much better. The thick ice melts, but it creates puddles on the flat tundra and attracts thousands of mosquitoes.
Opponents also allege that drilling in the 1002 Area would adversely affect the porcupine caribou. These same naysayers predicted similar results for Arctic caribou in the nearby oil fields of Prudhoe Bay. Since drilling began there over 20 years ago, the Arctic caribou herd has grown from 3,000 to 27,500. Nor is there a threat to the polar bear. Alaska's polar bear population is healthy and unthreatened. No polar bear has been injured or killed as a result of extracting oil in Prudhoe Bay. Furthermore, the Marine Mammals Protection Act, which protects the polar bear in existing oil fields, also would do so on ANWR's coastal plain.

As Donald Lambro notes in "Meeting Demands for Energy," a July 23 article in The Washington Times, oil production and wildlife have coexisted side-by-side for years. For example, there are 46 oil wells in the wetlands of Louisiana's Atchafalaya National Wildlife Refuge, where endangered species such as the American bald eagle and the Louisiana black bear are thriving.

According to an article by Pamela Miller, pollution is a major concern with drilling the 1002 area. She talks about examples of pollution and environmental mishaps at Prudhoe Bay like that which will happen when drilling ANWR. She says “At Endicott, contractors for British Petroleum illegally disposed of hazardous drilling wastes containing benzene and other toxics for at least three years until a whistleblower came forward. Some of the waste reached the surface and workers were exposed to hazardous fumes. In February 2000, BP was ordered to pay $15.5 million in criminal fines and to implement a new environmental management program, and to serve 5-years probation for its failure in reporting the dumping. BP also paid $6.5 million in civil penalties. Its contractor pled guilty to 15 counts of violating the Oil Pollution Act of 1990 and paid a $3 million fine. A huge cleanup job remains across the North Slope.” I don't think things like this will happen when the 1002 area is drilled. Of course, there will always be pollution of some sort from minor spills of a drum of diesel to the exhaust that comes out of all the equipment, but nothing as serious as what she talks about. Regulations are extremely tight these days and the oil companies are under tight watch now, especially after the things they've done in the past.

The benefits of drilling the region include oil production, natural gas production, an increase in job opportunities, increased royalties paid to the state which will in turn increase the states economy, regardless of the amount, it will decrease the amount of foreign oil being imported, royalties will be paid to the native cooperations and land owners of the area, and more. In Charli Coon's article, he says that “Drilling in the 1002 Area would occur during the harsh winter months, when operations would require the use of iced airstrips, iced roads, and iced platforms. The 16 billion barrels of oil that lie untapped there would be more than enough to replace the oil Americans would purchase from Iraq over 58 years.” To me that is pretty serious.

I believe scientific literacy for the general public should be extremely important. Anyone can say, “Yeah, drill cause we need oil and shouldn't buy it from Sadaam...” or spout off about what they think on an issue, but to really make a significant statement about a topic, you must understand the facts, all the points of view on it, and the causes and effects of what you are speaking about. I believe it is especially important for the nation's leaders to be scientifically literate since they are the ones making all the decisions about serious issues in the end. With decision-makers that are not well versed and literate enough to make a knowledgeable decision about something, nothing good can result.

I think that science is divorced from public policy and societal problems to an extent, but not severely. A lot of public policy is based on political standpoints, rather than scientific evidence, which I think may be the reason for a lot of societal problems. If there was hard scientific facts and evidence to base every decision and policy on, there would probably be a lot less uncertainty and ill effects from bad decisions. Based on this, I think the separation between science and public policy is a bad thing.

Sources:
“Tapping Oil Reserves in a Small Part of ANWR: Environmentally Sound, Energy Wise”, Charli Coon, August 1, 2001
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What I Know and What I’ve Found:

Bristol Bay, Alaska has always been home to one of the earth’s most astonishing wildlife demonstrations, and the locals, for thousands of years, have thrived off of this miraculous event. Every summer millions upon millions of salmon return from the ocean to Bristol Bay. Salmon runs every summer in the chief river systems surrounding Bristol Bay revenue more than $110 Million annually for the state of Alaska (Sherwonit). This revenue comes from subsistence fishing, commercial fishing and sport fishing. Because of its’ untouched, unspoiled surroundings, Bristol Bay is a hot spot for fishing enthusiasts and hunters alike.

Pebble Mine is a very large, very controversial, gold, copper, silver and molybdenum (this is used to strengthen steel) mineral deposit; in fact, it is possibly one of the largest deposits of this sort in the world! It can be found in southeast Alaska, near Bristol Bay. Currently Pebble Mine is proposed to be one of the largest open pit mines the world has ever seen. Open pit mines are implemented when the mineral being sought after is near the surface and easily extractable; they’re expanded until the mineral is exhausted or until it becomes uneconomic. According to PebblePartnership.com, Pebble mine intends to ‘change the lives’ of Southeastern Alaskans. This mine proposes to that it will diversify the local public. How? According to the website ‘Regional and Alaska-hire focus, workforce development programs, 1000 high-skill, high-wage operation jobs, 2,000 construction-phase jobs and business opportunities.’ But, at what cost? Is this what the people of Alaska want? What evidence is there to ensure Alaskans there is little to no risk in building this gargantuan mine?

Villagers and Pebble Mine advocates are clashing, to say the least. The most major forces rivaling the Pebble Mine Project are the local native communities, environmental groups, fisherman of all sorts and citizens of Alaska that this project may affect. A survey conducted in 2006, called the Pebble Mine Public Opinion Research Survey concluded that nearly 60% of the southeastern Alaska residents polled were opposed to Pebble Mine. Of the subjects polled (265 I believe) nearly 50% had lived in the Bristol Bay area since at least 1973, and 57% of that 265 were Alaska Native. 96% of these residents had heard of Pebble Mine before being asked to participate in the survey.

Alaska residents, not only Alaska Natives, are concerned that establishing Pebble Mine will demolish the pristine environment surrounding the Bristol Bay area with nothing substantial in return for this destruction. Although Northern Dynasty Management (NDM), the company researching the claim, estimates there is nearly $150 to $200 billion worth of minerals in the ground, in comparison to other industries mining gives a minimal amount back to state and local governments. According to Alaska state rep Paul Seaton, "State revenue from mining generally amounts to only about 0.7% of the mined resource value, while an additional 1% is paid to municipalities. State revenue from oil and gas amounts to about 20% of total production value, while an additional 2% is paid to municipalities. State revenue from fisheries amount to about 2.8% of the total production value, while an additional 2.5% is paid to municipalities, excluding property tax, vessel and license fees."(PebbleMineFacts.com) It is statements like this that the Pebble Mine advocates are leaving by the way side. Although NDM states that the local communities will be helped and not hurt by implementing this mine, is it really worth it? According to an annual report submitted by NDM, ‘Unexected environmental damage from spills, accidents and severe acts of nature such as earthquakes are risks which may not be fully insurable and if catastrophic could mean the total loss of shareholders' equity.’ Essentially, we’re fucked if something goes wrong. Not only are Alaskan’s fucked and out of 3,000+ jobs, but our $110 Million annual revenue is down the drain because the fish are… dead.

One of the goals that Pebble Mine has put out is to maintain ‘environmentally responsible co-existence with the surrounding fisheries, wildlife and ecosystem’ but according to the EPA (Environmental Protection Agency), mining in the western United States has contaminated stream reaches in the headwaters of more than 40 percent of the watersheds in the West."

With all this said… how is this evidence used or misused for political agenda? Pebble Mine advocates are not putting everything on the table. They’re only putting what they want on the table and leaving it up to the general public to either go by what they say (which can be easily done with enough media campaigning for them) or do some digging on our own. In this day and age, media has an extremely high influence on the average person, and people aren’t as likely to go out on their own and research these topics. The evidence I’ve found is not being misused necessarily… its not being used at all! Without really
looking for it, you can’t find it. It won’t be on the Pebble Partnership website… It won’t be obviously
displayed in any of NDM’s documentations. One really has to dig to find it.

The risks of Pebble Mine (in my eyes, and although I don’t think this should be an opinionated
essay, I can’t help but insert foot here) greatly outweigh the benefits. Although there will be X amount of
minerals mined worth XX amount of money, who’s to say this mine will last? And when it is gone (and
some day it will be gone, could be 15 years, could be 50 years), what do we do? Fort Knox has been up and
running for 15+ years without an environmental incident. That is amazing, but Pebble Mine will be greatly
larger than Fort Knox, using more explosives, more chemicals, more vehicles and more laborers. Pebble
Mine will be put smack dab in the history and livelihood of Alaskan’s. It will knock out centuries of history
by simply being there. Chemicals or no chemicals… Just being at the headwaters of Bristol Bay will affect
the salmon in turn affecting the people. And what happens if cyanide is put in use (as it is with most mines
extracting gold) and it leaks. If there can be oil spills can’t there be cyanide spills as well?

I almost feel there should be a pro’s and con’s paper put out for publication (and there very well
may be already). There are so many statistics and so many facts to know about what may or may not
happen with this mine that the average person has to put a lot of effort in to keeping up with anti and pro
mine organizations. The pertinent information is not put out into the media, its not put out at arms reach,
you really have to dig. I don’t think a valid decision can’t be made in regards to Pebble Mine (yay or nay)
without individuals being informed at the utmost in regards to all the uncertainties that go along with this
subject. Who, what, when, why and how aren’t good enough when it comes to such high stakes.

Because of this class and the passion about science that the professors and TA’s demonstrated, I was
able to read and understand a survey called Report of Investigations 2009-4 SURFICIAL GEOLOGIC
MAP OF PARTS OF THE ILIAMNA D-6 AND D-7 QUADRANGLES, PEBBLE PROJECT AREA,
SOUTHWESTERN ALASKA, that was published by State of Alaska Department of Natural Resources;
Division of Geological & Geophysical Surveys. I came across this survey while doing research on Pebble
Mine and although it doesn’t have anything to do with the mine itself, only the history of the topography
(you might say?), I was able to read it and for the most part understand it; I could look at the maps with all
the contours and arrows and understand them. I was amazed! This made me realize that scientific literacy,
especially in this day and age is essential. How can one make an informed decision if they can’t understand
the documentation put in front of them? How can one research if he/she can’t decipher what may be real or
fake?

Science in the 21st Century seems optional. When I say that I mean that before taking this class (and
Chem 100 with Duffy) I never saw a need for real science. I thought that all I’d ever need to do to find out
the valid facts on an issue was Google it, and although the majority of research for this paper was done
online, it required extensive looking. This particular essay has made me realize that science has become
separate from political and societal problems. That’s not to say that science isn’t at the root of these
problems, or that these problems don’t involve science, but I will say that science (possibly because of lack
of scientific literacy in this day and age) is not put at the forefront of issues as it should. Science is proof.
Or disproof; Or the attempt of proof or disproof. Science is not an opinion, its not media shoved in your
face trying to make you make a decision based on majority. The lack of substantial science in public policy
and societal issues is detrimental.

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Five examples of “fair” essays grades between 3.0 and 6.0
The scientific evidence for teaching evolution in schools is very well supported for political agenda. When you first think about this topic you may feel that it’s totally wrong, but when you think a little bit deeper it actually makes sense. Many political leaders such as George W. Bush, support teaching evolution as well as intelligent design because it gives students a chance to see two different viewpoints (Associated Press. “Bush: Schools should teach intelligent design.”). While talking with Bush, the Associated Press from Msnbc.com wrote, “I think that part of education is to expose people to different schools of thought.” Bush said. ‘You’re asking me whether or not people ought to be exposed to different ideas, the answer is yes.’” For some other leaders, like supervisors within school districts, chose not to even deal with evolution because they feared that offenses and arguments would arise from parents (Wiles, R. Jason. “The Missing Link.”). They know that if something like that happened, the school could be pulled out of certain science programs that they were a part of based on that particular states’ educational laws (Wiles, R. Jason. “The Missing Link.”). Jason Wiles wrote in the Arkansas Times that teachers weren’t allowed to use the “e-word” (evolution) or even refer to rocks as 50 million years old but as “very, very old rocks.” This is pure evidence that the political end of this issue is taking it way out of hand. This is exactly like the issue of Christmas. To be politically correct you need to say “Happy Holidays” instead of “Merry Christmas.” I don’t agree with that one bit. Geology is essentially evaluating evolution. I personally believe in creationism not evolution from the stand point of wanting to know where life actually came from, but evolution is real. We have specific evidence throughout out our earth’s history that act as proof to our eyes. This issue gets very complicated when governmental and political peoples step in when deciding what our education should consist of. It seems that political peoples don’t want to lose their current standing within society. They want to have control, but they also have a duty to please everybody which is impossible. That is why this is a very debatable topic that will continue far into the future.

The potential societal benefits balanced with potential risks are very clear. The potential societal benefit of teaching evolution in the schools is that the students get the truth of how the world that they live in is the way it is. Geology is very interesting, and anyone would say that it’s a very interesting and intriguing topic whether they want to major in it or not. To understand geology though we have to be at least taught the fundamentals like evolution to help us understand what we see in our world today wasn’t the same in the past. The Geological Society of America says that if students don’t get taught the concepts of geologic time and the origin of different species, they will never get the full understanding of how the processes around them in their environment form their world. The potential risks for teaching evolution in schools are of course testing someone’s religious beliefs, but it all depends on how you approach and express evolution when teaching it. If evolution gets interpreted wrong by a student it raises questions and can eventually lead to a complicated debate within the state and school district. One major political risk when approaching evolution in schools is that some schools will avoid the topic altogether and let students miss the most fundamental parts of geology. Meg Sommerfeld mentions, “if teachers worry that teaching evolution will create controversy, they will simply avoid the topic altogether… [which] is precisely what their opponents want.” The risks involved in this issue seems like they are risks to students but mainly a risk to political figures. It sounds like a “I got you where I want you” sort of “game.” It doesn’t sound like the adults are much too worried about the students’ education, but only about their personal status.

The importance of scientific literacy for the issue on teaching evolution should be very important. The type of society that we live in today requires a strict line between two opposing sides in order to solve a conflict. In order for nations to make informed decisions for individual schools on the issue at hand has to be handled carefully and taken in as a very important subject in evaluating education. The leaders that control the educational standards need to take charge and understand the student’s point of views. Students need to understand both sides of a conflicting subject especially when it lays a foundation for their future learning and understanding. If you miss out on the important basics in school, you will never understand or it may be completely confusing by the time you reach the end of your schooling. Nothing would really make sense. Pro evolutionist leaders from different organizations try their hardest to keep the teaching of evolution in the educational curriculum. They really are the ones who are concerned with the students’ education. They want the students to benefit in their future and to be more prepared. Leaders like this believe that evolution should be taught as a theory and not as a fact so students can still have that opportunity of believing what they want (Sommerfeld, Meg. “Lawmakers Put Theory of Evolution on Trial.”). Overall, leaders need to definitely keep evolution in the educational curriculum because giving students the chance to see two different sides of understanding geologic time will help them make their own decisions based aside from
their own individual religion. Just because you go to school doesn’t mean that you have to believe everything that is taught to you especially when it comes close to judging your own belief system. At least you were exposed to it and not set with one particular side to base your faiths on. The beauty of America that we have today is the freedom of speech. If you have a concern and want to express your ideas, you have the opportunity to do so. Students don’t have to set back and be forced to believe what teachers say. They have a chance to give feedback. In a way, this also helps in the process of making decisions on whether or not a certain curricula should be eliminated in the educational system.

I think that science is a touchy issue with public policy and societal problems. This is because science, especially geology, has such an enormous time span of changing processes that we are trying to understand. We are trying to understand our past to help us prepare and make better decisions for our species in the future. There are some things in science that we know has happened, and we have a full understanding of its origins and its results, but for most things we have doubts because we don’t fully understand. For a lot of the science I think we will never fully understand because we always want to find that evidence to help make us believe that something is true. I think evolution is a good thing to be taught because I do agree with leaders that say it gives students options to believe what they want. There is much evidence throughout our earth’s history that show the changes of evolution within many species and the environment. When it comes to understanding the very beginning of life and the appearance of humans evolution has no right to be taught as the source of that occurrence. Again, I don’t believe that we as humans evolved from apes. I believe God created man in his own image. How do you explain for how evolution even started? Where did all these organisms originate from? How did the universe even begin for life to even exist as a tiny speck in space? These are questions that can never be answered. It’s a deep thought that is nearly un-comprehendible. I believe that it is questions like these that are meant to be unanswered because we all have to make a choice of whether or not to follow by faith. We can’t always have the answers, and we can’t always understand everything even though we really want to. Evolution is not bad but just needs to be taught and presented in the right form. It does need to be taught as a theory and not fact and needs to be expressed in a way that will raise questions but won’t be taken as a forceful belief.

Bibliography


Science and Public Policy: A Necessary Relationship

Global warming, or climate change is a very serious issue that the United States government and society as a whole must try to solve. There has been much scientific evidence that proves climate change is occurring, and if ignored, it could bring about severe damage to America. Despite this evidence, there is still many who question whether humans are the cause of the climate changing, or if it is completely natural. Whatever the case, a response must be made to this pressing issue. Before the government can take any action, there are key questions that must be answered first.

- How is scientific evidence used or misused for political agendas?
- How are potential societal benefits balanced with potential risks?
- How important is scientific literacy be in order for America’s leaders to make informed decisions?
- To what extent is science divorced from public policy?

With answers to these questions, the United States will be able to make a good decision about how to respond to climate change.

For the issue of climate change, scientific evidence is both used and misused to achieve a political agenda. The U.S. Global Change Research Program (GCRP) writes in their article, “Climate change impacts on the United States: The potential consequences of climate variability and change,” that “sea-level rise will very likely cause further loss of coastal wetlands…and put coastal communities at greater risk of storm surges” (2001). The Government Accountability Office (GAO) uses this evidence to push forwards efforts to prepare for the inevitable results of climate change. On the other hand evidence shows that carbon dioxide levels and temperatures are rising. Many people assume that because there are more carbon emitters in the late 20th century, humans are the cause of climate change, or an acceleration of climate change. People such as Al Gore in An Inconvenient Truth ignore the fact that the climate is in a natural warming phase and use rising carbon levels to further his political agenda. So although there are people in the United States government who would use scientific evidence for good, there are others who would misuse it. But it is the misuse that makes balancing benefits and risks difficult.

There are always risks involved with every societal benefit, especially with an issue as big as climate change. The overall benefit of reacting to climate change is the well being of humanity, but various risks will have to be taken for the different approaches to reacting. If humans are a leading cause of climate change then we must work to lower carbon emissions. The risk involved with this option would be the damage that the economy could face moving to more expensive but more environment friendly energy options. The risk involved with preparing for climate change would be making sacrifices in order to adapt and prepare for predicted disasters, especially for coastal communities. Efforts are being made to balance all the benefits with the potential risks, such as the GAO’s report to congress about adaptation to climate change. It writes about what America is doing and what it can do to effectively adapt to climate change. But in order to properly balance and make an educated decision, proper education must be attained by all.

Education and scientific literacy is very important for government officials and all of society in order to make the best decision. The government must know the facts about climate change because they are the leaders of the United States, and in order to make the best decision for this country they must have a well-rounded education about the issue of climate change. Even though the officials are the leaders, in a democracy, the people hold the real power of a decision. Once the people of America are educated on the scientific truth of climate change, and not the stuff charged with a political agenda, then work can really be done to react to climate change. The people can then elect officials that will hold the scientific truths first and work to react to climate change based on scientific findings. Unfortunately, the facts of science have rarely been able to work with public policy in order to best serve the people of America.

In the history of science and public policy, the two have had a poor relationship, and America is no exception. When someone is trying to decide whom to listen to, the one with the most money almost always speaks loudest, even though in may not be the voice of truth. Unfortunately politicians are just as susceptible to this as any other person is, and many times the person or group that gave the most campaign money to a elected official will often get the most attention once they get into office. If a candidate receives funds from someone during their campaign, they are obligated to support whatever the cause is even if it means pushing aside scientific truth. The
Government Accountability Office (GAO) is one institution that puts science ahead of a political agenda. In their report to Congress about climate change adaptation, they put the needs of the American people first even when it may be costly, “individuals and institutions whose futures will be affected by climate change are unprepared both conceptually and practically for meeting the challenges…it presents” (p. 1). If all of the government could follow the GAO’s example, than science can always be used with public policy. For issues involving scientific research, it is very important if not completely necessary for science to be involved with the making of public policy. But since the power of money is so great, all politicians must put science and the welfare of the American public before their aspirations for another term in their current office.

In conclusion, science is an important part of the American society, and if societal problems are to be effectively solved, than science is needed. For issues that involve scientific study like climate change, proper research must be done, and political agendas must be put aside. For issues involving civil rights, free speech, gun laws, and other similar ones, it is either a matter of opinion or protecting the rights of a minority force in society. But issues like climate change have no room for personal opinion, for the rights involved in such issues are the rights of all Americans. No matter what the answer to this difficult issue is, if science is put ahead of money and political agendas, the solution will be found.

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Ifs”. They simply come up with these things as scare tactics to get their way. Granted, there are always chances of oil spills, but there are chances associated with all things in life. It’s like saying we shouldn’t produce electricity because there’s a good chance that some children will get electrocuted. Maybe we shouldn’t construct any wind turbines because it will destroy the natural beauty of a landscape. Many people also like to say that “The evil oil companies are only interested in making money”, but in reality, that’s what any good company does. Otherwise they would be out of business. Through the use of environmental regulations and modern, environmentally friendly, methods of drilling and exploration, it is possible to reap the benefits of our natural resources without destroying the natural beauty that is in the Arctic National Wildlife Refuge.

Educating the general public about science is important. However many theories, such as evolution, are touted as facts within the scientific community. For many people, it takes as much faith to believe they evolved from a swamp critter, as it does for them to believe that some all-knowing, omnipotent being created them from a bucket-o-clay. If the educational system is going to teach “theories”, then they should at least present all sides, not just the more popular, or politically correct one.

Overall science is a great thing, but policy makers use it in the wrong ways. Anyone can manipulate the data to show whatever numbers or “proof” they want. In a way, that’s probably true of most humans. People will tend to believe a certain thing and try to shove it down the throats of others, like evolution or art appreciation. “They appreciate art, so you should too, or we’ll call you intolerant.” Policy makers tend to use the fancy charts and graphs and “facts” they’ve created to persuade people to join their cause. So, science can be related to public policy in a bad way.

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Connecting the Dots

The world focuses on debates regarding almost every aspect of life. Everything is discussed including education reform, global warming, economic decision making. It is important though when people debate a topic to understand the material they are debating and to know both sides of the argument. Like any other well built argument it is important to know the facts and to understand the concepts. An issue that is central to the lives of many Alaskan citizens is ANWR. The debate is whether or not there should be drilling in ANWR as well as where the drilling should occur. ANWR holds the possibility to be one of biggest oil sources but many people fear the repercussions of drilling, but exploratory drilling is necessary to determine ANWR’s potential. Many people suffer from a form of ignorance that hinders their understanding of the ANWR situation and therefore can cripple their ability to make sound decisions both scientifically and economically. There has always been a difference of views between the professional and public sector of the nation regarding this subject. In order to better understand ANWR and the debate that ensnrods it one must look at the facts, see both sides of the argument and use science and common sense to find the answer for the issue.

To gain a better understanding of an argument it is important to look at the basics. First off, what is ANWR? ANWR stands for the Arctic National Wildlife Reservation which is located at the northern half of the state of Alaska. According to “What is ANWR and where is it?” an article on the ANWR website ANWR is located: “North of the Arctic Circle and about 1,300 miles south of the North Pole” (Web, 2010). ANWR contains several diverse types of wildlife that most fear will be affected by the drilling in ANWR. Some of the wildlife located in ANWR includes: caribou, polar bears, and several species of birds as well as many others. The debate about ANWR is mostly focused on the impact that drilling will have on the wildlife. There are those that are for drilling in ANWR and defend it with little impact to the species inhabiting the area and then there are those against drilling in ANWR feeling it is important to defend the species that might be endangered. So for the purpose of deciding if drilling is the right choice it is important to break down both sides of the argument, look at the benefits and possible negative consequences, and then come to a well informed decision.

There are several groups that oppose the possibility of drilling in ANWR; usually those groups are some form of organization dedicated to protecting the wildlife. Many of those organizations fear that drilling in ANWR will ruin the lifestyle of these animals and could cause the possible extinction of certain species. One notable organization against ANWR is Defenders of Wildlife. Their opening webpage helps create a picture of how the members of the group feel about drilling in ANWR. It states that the wildlife reserve is under attack from “Big Oil Lobbyists,” and that despite the common belief, drilling in ANWR would lower gas prices. Well to understand if that is true it is crucial to look at the facts presented by this organization. First, understanding the group’s position on the impact of drilling on the various forms of wildlife present in ANWR, according to the Defenders of Wildlife website ANWR is a unique form of reservation because it encompasses different ecosystems including arctic, subarctic, and boreal systems. The Defenders of Wildlife, like other organizations of its nature, list all the different types of animals that will be impacted and how their way of life could be totally destroyed. Regarding drilling in ANWR this is what the Defender’s had to say:

“The proposed oil and gas development would occur on the 1.5 million-acre coastal plain found along the Beaufort Sea. This area is the most sensitive in the entire refuge and habitat loss that occur here will impact the entire Arctic Refuge. The coastal plain habitat within the Arctic Region is also unique from other regions of the North Slope of Alaska because it is relatively narrow (only 15-40 miles across), limiting the alternatives for animals using these areas” (Web, 2010).

. The polar bears of the plain are in considerable danger because of their delicate nature. The drilling for oil in their habitat could cause den abandonment, death, harassment, and increased hunting dangers. Safety of the animals is very important to the organization, but they also think drilling for oil would not help the economy so therefore it should not occur. The organization supports abandoning oil and searching for cleaner, more environmentally friendly forms of energy. The members of Defenders of Wildlife cite a reason not to drill in ANWR is that it will not help lower gas prices. They support this with evidence from drilling in other locations. “For eight years, under the Bush Administration the number of oil leases on public lands almost tripled. It didn’t help gas prices, which doubled in 2008, and it didn’t make us energy independent” (Web, 2010). Therefore, if it is not economically efficient why
should there be drilling in ANWR? Well this is only one side of the argument and being one side proves to only generate ignorance.

The other side of the debate rests with those that feel drilling in ANWR is not so criminal. This includes some politicians, oil companies, but most importantly several geologists. They believe drilling in ANWR will not impact the environment the same way that some other people believe, and that it can provide added benefits to society. Some believe the resources available in the coastal plain of ANWR could trump the oil supplies in Prudhoe Bay. By looking at the success of Prudhoe Bay one can see that the potential of ANWR may not be as troublesome as some environmentalists think. According to the ANWR website Prudhoe Bay has greatly increased scientific understanding. “Millions of dollars of research on wildlife resources and their habitat on Alaska’s North Slope have not only immeasurably increased the scientific understanding of arctic ecosystems but have also shown that wildlife and petroleum development and production can coexist” (Web, 2010). Now technology allows the facilities for oil production to be compatible with wildlife sustainability. “Experience at Prudhoe Bay and Kuparuk along with rapidly evolving drilling and production techniques will further minimize environmental impacts and surface use in future frontier arctic petroleum provinces such as ANWR” (Web, 2010). Most people worry about the drilling in ANWR but the fact is right now all that needs to be done is some exploratory drilling which can be done without impacting the environment. The only way to actually support the numbers of barrels that could be produced is through the exploratory drilling. While it is nice to hear that there might be loads of oil just waiting to be tapped, it is better to know that the oil is actually there and where it is. The area of the oil drilling is minimal and will not have as huge an impact to the environment as some would like the population to believe. According to the article on the ANWR website there could be enough oil to help the nation’s future energy needs.

“Domestic crude oil production, which has already declined from nearly 9 million barrels per day in 1985 to about 6.6 million barrels per day in early 1995, is projected to decline to less than 5 million barrels per day in 2010. Even with only a modest growth in the U.S. crude oil demand, the deficit in U.S. supplies will be on the order of 10 million barrels per day, which will have to be made by new discoveries or imports. ANWR’s contribution will therefore be critical to national energy needs.” (Web, 2010)

The possibility of new forms of energy should still be pursued since one day there will not be enough oil to produce, economically speaking. For the mean time though, there is too many things that require oil, and not enough time to produce an energy source for them. It will take time to switch energy sources. Drilling in ANWR is not as devastating as some would have it seem. It can still support the ecosystems while discovering how much oil is actually there. Perhaps, once the population knows how much is actually there they will not feel the desire to tap the oil in ANWR. In the mean time it seems sufficient to say that tapping oil in ANWR does not appear to be unreasonable, that does not mean one should not stop looking at the facts. A person should still look at both sides of the argument, and look at the information both uses before making a decision. An informed decision is always better than an ignorant decision.

Work’s Cited

Global warming has now been accepted as a real environmental problem. The trouble is what to do about it. First it is important to understand what global warming is and what it is doing. Once this is understood people have a better chance of doing something about it. There are a multiple things that can be done about global warming.

Global warming is caused by an increase in Carbon dioxide in the atmosphere. While it is necessary for the planet to trap some Carbon dioxide and other gases to much of it causes an increase in surface temperatures. Things such as; burning fossil fuels like coal, gas, oil, and cutting down forests dramatically increases the levels of these problematic gases in Earth’s atmosphere. Changes are already noticeable. The habitats of many plants and animals are no longer there or livable. Glaciers are melting causing sea level to rise. Storms are becoming more severe and prolonged droughts are more common (climatecrisis.net).

The problem caused by the gas increase in the atmosphere has come to be known as the greenhouse effect. It got this name because like the panels on a greenhouse, the gases trap heat in. There are six main gases that contribute to this are: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF₆). Scientists also consider water vapor a greenhouse gas. The sun heats the earth and drives the planets climate and weather. In turn the earth radiates the heat energy back out into space. The greenhouse gases trap some of this energy. The more greenhouse gases in the atmosphere, the more energy is trapped, the higher the surface temperature increases (globalissues.org).

Some effects are already noticeable. Ice has been recorded melting all around the world and most dramatically at the poles. The sea is rising at a faster pace than a century ago. The amount of precipitation has increased on average around the world. Global warming has already had an effect on the animals of Earth. A study by Bill Fraser reports that the Adelie penguins are declining. The numbers have dropped from 32,000 to 11,000 breeding pairs in only thirty years. Animals such as butterflies and foxes have began to migrate further north into colder climates. Spruce bark beetles are very deadly to spruce trees. The amount of these beetles has rapidly ascended recently because of the last two decades hot summers. These beetles are accredited with destroying four million acres of spruce trees (nationalgeographic.com).

So what must be done? Slowing down the warming quickly and efficiently is what is needed. The best way to do this is by limiting the use of fossil fuels, and slowing down deforestation. This is an offense and defense. By limiting the fossil fuels we can directly decrease the concentration of them in the atmosphere. By stopping deforestation and planting new trees we can naturally lower the Carbon dioxide levels. Replanting trees is called afforestation. Energy conservation is one of the best ways to fight global warming. People should make better use of public transport. Cars should be made to be more efficient (ypte.org).

There are two approaches that can be taken to fight global warming. The first is on a big scale level, things that countries, companies, and governments can do. The other approach is things that every individual person can do. In order for the best result both approaches must be taken. According to climatecrisis.net, there are twelve simple tips that could have huge impacts if everybody followed them. These steps all involve lowering the amount of carbon dioxide levels in the atmosphere. By replacing just one regular light bulb with a new florescent bulb could save 150 pounds of carbon dioxide from entering the atmosphere a year. People should drive less and if they do need to drive they should make sure they have up to date, inflated tires. Using public transportation is also good. Using less water will have major results. Changing your showerhead to a low flow one could save 350 pounds of carbon dioxide. Using cold or warm water for your laundry will also save hundreds of pounds. Simple thing like turning down your thermostat and turning off electric devices when they are not in use can save hundreds of pounds. Unplugging your electric devices will have an even better result. Eating less meat will have a huge result on the amount of carbon emissions (climatecrisis.net).
Arguably the most effective large scale attack on global warming was and is the Kyoto Protocol. The Kyoto Protocol was a treaty negotiated in 1997 in Japan. It became enforced in 2005. The Kyoto Protocol is a treaty that is legally binding with industrial countries. The goal is reduce the collective emissions of the greenhouse gases by 5.2 percent. The United States is the largest emitter of greenhouse gases per capita. The U.S. pulled out of the Kyoto treaty in 2001. In order for global warming to be slowed, the U.S. has to do something about their Carbon emissions (kyotoprotocol.com).

It is apparent that both individuals and nations must work together in order to give us the best chance of beating global warming. People and companies must stop worrying about their immediate pleasure and gain, and focus on their and their children's future.

How is his scientific evidence used or misused for political agenda?
-When the idea of global warming was first released to the public, big companies realized how damaging it would be, so they started a propaganda campaign against it. When losing money is involved, scientific evidence often becomes secondary to profit. The entire Bush administration jumped on board the “there is no global warming” train. Even in the face of overwhelming evidence it has taken years before global warming has been accepted as scientifically and publicly true.

How are potential societal benefits balanced with potential risks?
-The risks far outweigh the benefits of not dealing with global warming. While people may have a little easier lives and companies will definitely save money, it is a minimal benefit compared to what could happen if global warming is left ignored.

How important should scientific literacy be for the general public in order for the nation and our leaders to make informed decisions?
-It should be very important. Even when over 90 percent of the scientific community believed in global warming, the general public was still listening to the propaganda. If our country was more scientifically literate then maybe the people would have looked at the evidence themselves and we could have been fighting global warming years earlier.

Overall to what extent do you think that science is divorced from public policy and societal problems? Good, bad, or unimportant?
-Science is divorced from much of societal problems and public policy. Many decisions are made off of present gains in money and usually the most gain will win even if science says it is dangerous. This is very bad for our country. Science is starting to get more authority but it is a slow process.

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An increasingly popular argument in Alaska is the question whether or not to drill for oil in the Arctic National Wildlife Refuge, also known as ANWR. This debate amongst people and politicians in the state is one that raises great concerns and speculations about the area. This area of Alaska has been looked at and researched beginning as far back as the 1900's. The many oil seeps and stains in the area are indicative of the area's petroleum potential. Therefore, Geologists have been very interested in the area and what it has to offer. Although, most geologist will agree, that there is much more to be discovered and research more thoroughly throughout ANWR. They consider it to be the most unexplored area of high potential in North America. Geologists know that the area has all the necessities present that are needed to produce oil.

Drilling in ANWR is not a solution to Alaska's, or America's need for oil, ANWR will eventually run out of reserves. Studies show that with the United States' current consumption of oil, that if we used only oil from ANWR, it would run out in two years or less. There is also significant potential for disaster while drilling, worse than the Gulf of Mexico. These disaster include everything from basic safety measures to damages to the ecosystem. It is know that the ecosystem of the North Slope area is the most fragile of systems in North America, if not the world. There are examples of this that date back to the 1970's, when the very first truck route to the North Slope was made. This road can still be seen today, over 30 years later. The tundra is very delicate and takes a very long time to heal itself. It also has been said that if we started drilling in ANWR today, it would still take approximately ten years before we would actually be using the refined oil, proving that this is not a quick and easy solution.

The media and politicians completely misuse the scientific evidence about ANWR and the surrounding area for their own agendas. They say that drilling in ANWR will lower gas prices, and it will, but only temporarily. It will also cause an economic boom in the area due to increasing the amount of jobs in the area. But both of these things will only last for a short time, in comparison to the amount of time and effort that will be going into it. Also, there is oil potential in the area, but not as much as the media and politicians insist there is. The specific amounts or estimates can not truly be known until the process begins. The promises of lower gases prices are merely a band aid to the overall problem of increasing oil prices in the US.

These risks and potential for risks, are not balanced. Those for the drilling of ANWR describe visions of lower gas prices, an increase in employment, and an overall improvement of the economy. This will also cause oil companies to invest money for their "piece of the pie," in the area. However, I do not believe that these dreams are anything to get excited about. In fact, I think that they are more of a worry, and danger to our environment, than is needed. It is very important that the public be involved in making this decision. It will at some point effect everyone in the area, and areas surrounding the North Slope. An well educated, informed decision can not be made, unless the scientific research can be understood by everyone, most importantly the public and the politicians.

Drilling in the Arctic National Wildlife Refuge should not be considered at this point and time. There are too many other areas that have not been explored, and not just other areas for oil. I am supportive of alternative sources of energy, as well as oil and natural gas. I think that all sources should be researched equally and effectively in order for a real solution to be agreed upon. At least we are all on the same page, knowing that we need to find a solution to the world's energy crisis.
Four examples of “poor” essays, grades <= 3.0

These essays did not follow the rubric or were poorly referenced
To Drill Or Not To Drill

Should we drill and explore for oil in ANWR or no? That is a big topic that has been debated for a couple years now. In this essay I will give you both sides to the story and my own opinion on whether or not we should drill for oil in ANWR.

ANWR, the 19 million acre Arctic National Wildlife Refuge (ANWR) lies in the northeast corner of Alaska. The entire refuge lies north of the Arctic Circle and 1,300 miles south of the North Pole. The Coastal Plain area, comprising 1.5 million acres on the northern edge of ANWR, is bordered on the north by the Beaufort Sea, on the east by the U.S. Canadian border, and on the west by the Canning River. The Kaktovik Inupiat Corporation and Arctic Slope Regional Corporation (both Alaska Native corporations) own 94,000 acres in the Coastal Plain surrounding the village of Kaktovik. At its widest points, the Coastal Plain is about 100 miles across and about 30 miles deep and covers an area slightly larger than the state of Delaware. Along the coastal area, the plain is an almost featureless expanse, barren and dotted with thousands of unconnected small ponds; the area to the south becomes gently rolling, treeless hills which merge into foothills and then into the northern edges of the Brooks Range.

The Alaska National Interest Lands Conservation Act (1980) established the Arctic National Wildlife Refuge (ANWR). In section 1002 of that act, Congress deferred a decision regarding future management of the 1.5-million-acre coastal plain in recognition of the area’s potentially enormous oil and gas resources and its importance as wildlife habitat. The Department of the Interior (DOI) submitted a report on the resources (including petroleum) of the area in 1987 to Congress. Since completion of that report, numerous wells have been drilled and oil fields discovered near ANWR, new geologic and geophysical data have become available, seismic processing and interpretation capabilities have improved, and the economics of North Slope oil development have changed significantly. The U.S. Geological Survey (USGS) commonly is asked to provide the Federal Government with timely scientific information in support of decisions regarding land management, environmental quality, and economic and strategic policy. To do so, the USGS must anticipate issues most likely to be the focus of policymakers in the future. Anticipating the need for scientific information and considering the decade-old perspective of the petroleum resource estimates included in the 1987 Report to Congress, the USGS has reexamined the geology of the ANWR 1002 area and has prepared a new petroleum resource assessment. In the 2000s, votes about the status of the refuge occurred repeatedly in the U.S. House of Representatives and Senate. President George W. Bush pushed to perform exploratory drilling for crude oil and natural gas in and around the refuge. The House of Representatives voted in mid-2000 to allow drilling. In April 2002 the Senate rejected it.

Arctic Refuge drilling was again approved by the Republican-controlled House of Representatives as part of the Energy Bill on April 21, 2005, but the Arctic Refuge provision was later removed by the House-Senate conference committee. The Republican-controlled Senate passed Arctic Refuge drilling on March 16, 2005 as part of the federal budget resolution for fiscal year 2006. That Arctic Refuge provision was removed during the reconciliation process, due to Democrats in the House of Representatives who signed a letter stating they would oppose any version of the budget that had Arctic Refuge drilling in it.

Obama stated in an article titled Presidential Candidates Views on ANWR [Arctic National Wildlife Refuge]: "I strongly reject drilling in the Arctic National Wildlife Refuge because it would irreversibly damage a protected national wildlife refuge without creating sufficient oil supplies to meaningfully affect the global market price or have a discernable impact on US energy security."

President Obama could not be more wrong with this issue. When Prudhoe bay was discovered in Northern Alaska during the 1970s, there were an estimated 21 billion barrels of oil present. Currently, there are more than 11 billion barrels of oil under the grounds of ANWR, and even larger prospects in natural gas. This interprets into a major stimulus for the United States economy. Not only would this oil and gas help the global market, it would reduce America’s dependence on foreign oil, and provide hundreds of new jobs for the hindered economy of our time. Furthermore, research has shown that the technological advancements in oil and gas recovery have greatly reduced the footprint left behind by these companies. Over years of trial and error, precautionary steps have been created to insure the safety of the surrounding environment and its inhabitants. Drilling in ANWR would barely touch the 1.5 million acre plot of land subject to exclusion by the United States government. In all aspects of drilling techniques, ANWR would be a no lose situation for
the citizens and wildlife of the United States. Obama has misinterpreted (if he even looked at) the scientific data that the US geologists have collected of oil in ANWR. I believe Obama said this to win the political campaign in California where environmentalists are very strong. With the recent oil disaster in the Gulf of Mexico, people are more cautious about drilling and its effects on the surrounding area. People believe that a disaster as the one that happened in the Gulf could happen in the Arctic National Wildlife Refuge. Obama should use scientific data and not people’s opinions on important decisions. It is very important to use this because it shows exactly what is happening. However throughout his presidency he is getting better at using scientific data to make decisions. In a recent article written by Rob Stein of the Washington Post, “When President Obama lifts restrictions on funding for human embryonic stem cell research today, he will also issue a presidential memorandum aimed at insulating scientific decisions across the federal government from political influence, officials said yesterday.”

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The Yucca Mountain Controversy

Nuclear waste in the U.S. is stored in more than 120 locations. These sites were not designed to store waste in the long-term, so there is a need for a permanent storage facility. In 1982, the U.S. Department of Energy (DOE) was tasked with finding a location for a nuclear waste repository and putting it into operation, as part of the Nuclear Waste Policy Act. By 1987, Congress amended the act to select Yucca Mountain in Nevada as the site of the repository. The DOE studied the site intensively, finding that the site was ideal after examining the rock in a specially constructed lab five miles underground, and running computer simulations of the site. In 2002, after fifteen years of investigation, the plan of building a repository at Yucca Mountain was approved in House Joint Resolution 87. However, critics have pointed out the incompleteness of the design, the great expense in money and resources, and the lack of planning around possible changes the mountain might undergo over the long centuries of its operation. (Associated Content)

The website for Nevada's Agency for Nuclear Projects gives a basic description of Yucca Mountain, "a six-mile long, 1,200-foot high, flat-topped volcanic ridge about 80 miles northwest of Las Vegas," as well as the scale of the waste stockpile that would be placed there - "77,000 tons of hazardous radioactive materials... [will] need to be contained for at least 10,000 years because of the extreme hazards to public health and the environment..." The website goes into more detail about some of the criticisms. The website points out that "The Yucca Mountain controversy involves fundamental issues of a state's right to determine its economic and environmental future and to consent or object to federal projects within its borders." (State of Nevada)

Scientific data on the Yucca Mountain repository is helpfully compiled by an article on the Esmeralda County Repository Oversight Program's website. This article was the one I found most convincing, because it gave specific reasoning behind the choice of the site, ultimately coming out with a positive tone, but not without disclosing all the downsides. The dense volcanic rock of the mountain resists water and heat. Being in the desert also helps ensure that the inside of the mountain is dry; a near-absence of opal and calcite in core samples indicates that this dry state is very stable. On the less than ideal side, there are faults and fractures and the area is considered seismically active. Even minor quakes raise the possibility of serious problems such as changed water flow; if the water table were to become contaminated it would ruin the water supply of desert cities like Las Vegas. Also, there is a possibility that the waste itself could emit enough heat to alter the site in significant ways. While these potential problems are significant, there is no better site available, and the use of special storage containers will ensure that there is no danger of a waste exposure during transport. If a central repository is to be used, Yucca Mountain does seem to be the best choice. (Esmeralda County)

But as the State of Nevada site stated earlier, the issue of state's rights is central to the controversy. The federal government, looking at the welfare of the entire nation, sees the need for this permanent central repository for nuclear waste, increasing the overall safety of the nation and putting a single project behind the various issues of transport and storage. But as soon as they select a location, controversy is inevitable because the people in that area will have to live with an increased danger of waste mishaps. A risk of poor waste containment spread thinly across the nation becomes a better contained risk in one spot, but with much higher stakes should disaster strike. Even if
the site is truly ideal out of all candidates nationwide (and assuming we have no reason to mistrust the people who pick it) the people who live in that area will be opposed to it. This sort of trade-off is problematic for politicians. They have to make decisions that favor the good of the many over the good of the few, but they absolutely hate to admit it. Voters are sympathetic to the few.

The sources I consulted were mostly fair and evidence-based, but they still showed some bias in how they presented the data. The number of years waste needs to be stored was reported as anywhere from 1000 to 10,000 years. Sites such as Nevada's Agency for Nuclear Projects put the danger statistics up front, and they have justification in doing so, since it is central to their argument, but they also decline to go into the dangers we may already be facing as a nation by leaving our waste in temporary storage facilities.

The least informative source I found was Senate Majority Leader Harry M. Reid (D-Nev), whose comments on Obama's recent cutback of the Yucca project were quoted in the Washington Post. Reid used gratuitously melodramatic language, employing words such as "battle," "victory," "protect," "threaten," "terrible," "wasteland" and "dump." Reid implies much about Obama's motives, stating that the president is committed to stopping the project. Obama is not quoted in the article, which suggests that he is trying to distance himself from the decision. A DOE spokesperson states that the Obama administration is "starting the process of finding a new strategy for nuclear waste," which is about as uninspiring a conclusion to the debate as you could get. (Washington Post)

These sorts of soundbites and evasive statements are typical of politicians trying to claim the moral high ground and boost their side while avoiding saying anything substantive. Reid presents the controversy as a crusade against destructive forces and puts his own party, and his president, on the side of heroes. He inflates Obama as much as possible without actually putting words in the president's mouth as far as policy. Meanwhile, the Obama administration seems to have cut funding to the Yucca Mountain project without any alternate plans.

A nuanced view of politicians and their parties is necessary in order to see these issues clearly and outside of the emotionally charged arena of partisan politics. For instance, I am glad that Obama was elected president, but after reading all the sources cited in this paper I am nevertheless concerned about his choice on this matter, which has consequences far beyond his term. I fear that he has allowed the marketing game of politics to stall a decades-long effort to install a facility that is a necessary evil with no better alternatives. I would like to believe that a new strategy for handling nuclear waste could be just around the corner, but considering how long it took for the Yucca Mountain plan to even get off the ground, I suspect that our government has chosen inaction for fear of offending anyone rather than because it was the most scientifically educated decision.
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ANWR: The Great Debate

“Ninety-five percent of the North Slope in this part of Alaska is open for exploration, oil exploration and potential drilling. We drew a line. This five percent, [Alaska’s Arctic National Wildlife Refuge (ANWR)], should be preserved as a wildlife refuge, if you will, a small piece of Eden.” This was a quote taken from Connecticut Senator Joseph Lieberman to address his view on why we should not invest in the drilling in ANWR. ANWAR is an area in the northeastern corner of Alaska that covers 19-million acres. The Coastal Plain, also known as the 10-02 Area, of ANWR is the area of major debate between the economists and the environmentalists.

First off there are the people that believe drilling in the Coastal Plain of ANWR is only going to better our economy. Prudhoe Bay is a prime example of why the Coastal Plain will bring America a better economy. For over thirty years TAPS (the Trans-Alaska Pipeline System) has been running from Prudhoe Bay in the Arctic to Valdez in the Gulf of Alaska. This 800 mile pipeline has produced over 17.7 billion barrels of oil over the years and is estimated to reach 40 years of production. Using a study form the US Geological Survey or USGS they have found that with the drilling of ANWR we could see production of thirty to fifty years, depending on its behavior.

One may ask how any of this information has to do with the production rates of the Coastal Plain; well it does. Prudhoe Bay has exceeded all the expectations by producing over the estimated 9 billion barrels of oil and running for over two decades. If this uncertainty was of such great success for them then it can do the same thing in the Coastal Plain. According to the website www.anwr.org, “The Coastal Plain of ANWR is America’s best bet for the discovery of another giant ‘Prudhoe Bay-Sized’ oil and gas field in North America.” They have approximated that it will produce up to 1.5 million barrels of oil per day lasting around twenty-five years. The drilling will help the economy by saving about 14 million dollars every year because we won’t have to import as much oil. With this major production in way we will also see jobs forming. To run the pipeline we will be creating anywhere from 250,000 to 735,000 jobs which that in its self will help our economy.

There is also the benefit of technology evolving so much. The footprint being made will exceed that of Prudhoe Bay by a significant amount. Because millions of dollars have gone into the research of wildlife resources and their habitat, we better understand how to provide a safe place for the arctic ecosystems and prove that wildlife and petroleum development has been successful. For example, the caribou herds in the area are growing at enormous rates from 3,000 to a high of 23,400 within twenty years. The ANWR website claims that seventy-five percent of Alaskan’s along with legislature, governor and residents of the North Slope Borough say they support the drilling of oil within the refuge but what about all the people who object?

Environmentalists aren’t the only people who will reject the drilling in the Coastal Plain but they are a major group. The main reason why people, like Senator Joseph Lieberman, will reject the drilling is that if they did start drilling today we wouldn’t see any benefit from oil production until at least ten years from now. Why should we wait ten years when we could start today to look for alternatives? These alternatives could and would be natural resources that bettered our ecosystem by reducing the amount of greenhouse gases. According to the U.S. News it would be better to find substitutes for oil because ANWR won’t help with oil prices all that much anyways. The average barrel for oil was at a high of 130 dollars in 2008 alone and the price is only rising. “The U.S. Energy Information Administration, an independent statistical agency within the Department of Energy, concluded that new oil from ANWR would lower the world price of oil by no more than $1.44 per barrel—and possibly have as little effect as 41 cents per barrel—and would have its largest impact nearly 20 years from now if Congress voted to open the refuge today.” This quote says it all. There is such a little impact ANWR would have to the world that it would be better to just leave it as it is. The cost benefit analysis would not to drill in the Coastal Plain so we can save an environment from becoming destroyed.

Allowing there to be drilling in the Coastal Plain of the Arctic National Wildlife Refuge (ANWR) would permit other refuge sites to be open for drilling. Between August and October of 2001 Representative Edward J. Markey, hired the U.S. Fish and Wildlife Service to conduct a study to find out to what extent wildlife refuges would allow oil and gas activity. Markey found that after the National Wildlife Refuge system Administration Act of 1966 for over 35 years there has been a ban on drilling on any refuge in the United States. This has allowed for many companies to illegally drill within the refuge by going at a sideward angle under it. He argues that if we open up the Coastal Plain of ANWR for drilling it will become a domino effect because it would then allow 297 other refuges that have the potential of containing oil and gas to be opened up too.

One also has to realize that there is a chance that the Coastal Plain could produce very little oil in the long run of the production. There is always the chance that experts were wrong in their findings of a mass oil spot. They have made an estimation of production off of other geological landforms in Alaska including that of Prudhoe Bay.
Although Prudhoe Bay is doing an increasingly good job of producing more than expected, what if ANWR produces too little that it doesn’t benefit America at all? The U.S. Energy Information Administration admits that they were wrong when they first reported on ANWR production. There initial analysis was that it would produce 650,000 to 1.9 million barrels every day but now they say it has dropped ranging from 510,000 to 1.45 million every day. No one can be for certain on how much oil will be coming from the Coastal Plain so why take a chance to damage a stable environment?

This issue is of great importance and should be determined by the people of Alaska. It is our land that would be altered with and we would need to decide if it would benefit of enough or not. Also there should be more discussion about the topic before it ever was voted on. Every side should have a say in the pros and cons of it and determine why they believe they are right. If the land belongs to the Alaskans and whether the area could benefit Americans or wont, the Alaskans should have a say on what happens not anyone else. We would be the ones to deal with the outcome of the environment not the rest of the world. If the people were smart they would see that drilling in the Coastal Plain of ANWR wouldn’t benefit us now and we will have to wait anyways for any kind of product. We should invest now in more eco-friendly things instead of waiting to find something that has the potential to gain nothing in society. Americans need to stop having an excessive consumption of nonrenewable resources and start looking for alternatives to help both our economy and the environment. Like Connecticut Senator Joseph Lieberman stated it is in ways “a small piece of Eden.”

Works Cited


An energy crisis is upon us. Many people talk about it, but not a whole lot is being done about it. Our world is so dependent on oil for energy that sometimes the energy crisis is being referred to simply as “the oil crisis”. There are alternative fuel sources out there, a lot of them, and some of them are not really considered or very well known to the public. I’m here to talk about why what is going on in the world isn’t more publicly known.

First off, let’s talk about oil. The amount of oil on the earth is finite. That is to say, we will run out eventually or in time it will become too expensive to find and recover oil that we won’t want it anymore. Oil is also used for a lot more that just fuel. So if we use it all up, we won’t be able to make petrol-based products anymore. Products like asphalt, plastic and even in some medicines. Oil is obviously very important to us as a society and makes a big difference in our lives every day. So the question is how do we preserve it if we need it so badly?

What about alternative sources of energy? A few renewable resources are common knowledge like solar power, hydro-electric and wind energy. This is a common misconception though. Not all alternative resources are renewable; for example, coal and natural gas. Both of which are able to be burned and used for energy but rarely are, but why aren’t they? Coal is downplayed because it’s hard to mind in large quantities and doesn’t burn very clean. Natural gas is the opposite though. Often times it is found with oil, so we have easy access, and it’s one of the cleanest burning things out there. They both have the same problem; they’re too expensive to move around. There are nuclear fission and Shale oil energy sources to consider. But nuclear fission beings with it bad connotations because of the word nuclear, often associated with bombs, and death. Nobody likes either of those. Shale oil is oil that is manufactured from shale stones. This is also too expensive because of the mining process and the process of actually making the oil. But who decided these were too expensive?

How can you put a price on a non-renewable resource? Once it’s gone, do we just stop using plastic? Will potholes in the road go unpaved because we can’t make any more asphalt? All of these alternate energy sources are scientifically feasible, but dismissed because of the costs. Not even brought to the public’s eyes. Do the politicians and government officials really have the right to keep people in the dark about stuff like this? It’s a blatant misuse of scientific data. Shouldn’t the public have the right to hear all the data that is available? It should be up to us to decide how we want our world run.

Overall, is the government to blame for all this? The public needs to know more. Is it really the government’s responsibility to make sure all information is available to us? Should they provide all the information to better educate us or should we be required to find out for ourselves? This essay isn’t here to give us the answers. It’s here to raise questions. How closely related should government and science be? The government could make much more effective decisions if they have all the facts; but then in a vote it will be more than just the government that has to be educated. The people will have to be educated. A public vote can’t be held if the public doesn’t understand the thing they’re voting on. It’s hard to decide whose fault it is, or to say if anyone really is at fault. But you could also say that to be educated in the sciences and decision making are independent of each other. That’s the problem with government and speculation of things. You can’t really KNOW anything for sure. You don’t KNOW how something will turn out or what will be important, you can only guess. I guess that’s the problem with a lot of things in the world. Knowledge is this limited resource that we don’t always have enough of but we still get by without it sometimes. And maybe when the time comes, that’s how we’ll deal with the oil crisis too.
Attachment 6

Selected Labs
GEOS 101  2nd Field Trip orientation of Folds and Faults

Name: __________________________ Lab day, time, & TA __________________________

Introduction
On this field trip we'll try to put it all together for you: folds and faults and rocks and geologic maps and everything!

Sedimentary and metamorphic rocks begin as tabular units of layered rock. Over time, however, rocks may be squeezed, bent, folded, broken, faulted, and generally contorted. Geologists need to be able to describe the three-dimensional orientation or rock units in order to plot them on topographic maps and to interpret their complicated history. In this lab, you will have the opportunity to observe actual folds and faults and to use a Silva compass to measure strike & dip. Finally, you will plot the contact between rock units on a topographic map, to produce your own geologic map of the Beacon Bald area!! (Suitable for framing or refrigerator art).

Part I: Review of Using a the Silva Compass

1) Look at the bull's-eye level on the compass. When the bubble is centered inside the ring, the compass is being held horizontal, or level. Think of the level compass as a horizontal plane.

2) The red end of the compass needle points to magnetic north, not true north. We have set the compasses to compensate for this offset, the magnetic declination (approximately 23°).

3) The Silva compass is designed to easily determine the direction in which you are facing when the compass is held with the mirror end towards you (typically towards your stomach). Turn the knurled knob so that N on the compass is aligned with the white line near the level bubble. Holding the compass with the mirror on the end closest to you, turn your body (and the compass with it!) until the red end of the compass needle is exactly centered in the transparent red arrow outline. When held like this, the compass (and you) are pointing towards true north.

Now turn yourself 90° clockwise (holding onto the compass), so that you (and the compass) are pointing east. The red compass needle is no longer centered in the transparent red arrow outline. Hold the compass in one hand and turn the knurled knob so that the red compass needle is again centered in the transparent arrow outline. If you really turned exactly 90°, the white line near the level bubble now points to the E. If you turned a little less than 90°, the line points towards a number closer to 80°; if you turned a little more than 90°, it will point closer to 100°. The number/direction indicated by the white line is the direction toward which you and the compass are facing!!

Turn another 90° clockwise and again line up the two red arrows. Recognize that the compass reads approximately S (180°). Turn another 90 degrees and again line up the two red arrows; the compass reads approximately W (270°). When the two red arrows are lined up, the compass indicates the direction from the mirror end towards the string end by the number at the white line. Master this technique! You will need to be able to level the compass and determine the direction toward which it points in order to measure the strike of a rock unit or fault plane.

4) Now look at the inside of the compass. There is a small red needle and a scale marked with ° in the center and labeled at 20 degree intervals away from ° (both to the right and to the left). Turn the compass on its side, and the small red needle will point straight down. We will use this needle and scale to measure the dip (or inclination) of rock units, which is the angle between the rock surface and the horizontal.

Part II: Measuring Strike and Dip at the Duckering Stairs Outcrop

1) Go to a well-exposed area where you can find a smooth surface layer upon which to lay your compass and take some measurements. Look for the top of a relatively flat layer at eye height or lower, with a clear space at least 5cm x 5cm. Make sure this layer is representative! It should be roughly parallel to the surrounding layers. In other words, don’t pick a place where the rock looks “messed up.”
2) Estimate the direction of maximum inclination (= dip), and orient your compass so that it points roughly perpendicular to this direction. You're about to measure the strike. Practically, this is the direction in which you, the geologist, would need to walk in order to follow the rock unit if you didn't want to go uphill or downhill. Technically, you'll be measuring the orientation of a line that represents the intersection of the rock unit with a horizontal plane. So make your compass into a horizontal plane and keep it in contact with the rock! Hold your Silva so that it is approximately level, and place either side edge of the compass on the layer to be measured. Keeping one edge on the layer, tilt or rotate the compass until the level bubble is in the middle of the bull's eye. The compass is now parallel to the line formed by the intersection of a horizontal plane (effectively your compass) and the rock layer (on which your compass rests). Your compass is aligned parallel to a strike line.

3) As above, hold the compass still with one hand, and with the other hand turn the knurled knob so that the two red needles are lined up. Look at the direction given by the compass (the closest number on the measurement ring to the white line). **Record this number (or direction, if exactly N, S, E, or W) here ______________ before you forget it! This is the strike!**

Two answers are possible (and correct) for the same strike line (for example, 045° or 225°).

4) Plot the strike on the map below. Start by locating your position on the map, using the map scale and whatever landmarks are handy (which roads and buildings are you facing?). Mark your position with your pencil. Now you use your compass to help plot the strike line. Place the compass onto the paper, oriented so that the parallel lines and arrows (not the needle) inside the compass are parallel to the North arrow on your map. The compass is now aligned on the map parallel to the strike. Move the compass on the page, so that the orientation is the same, but the side of the compass is adjacent to the point marked on the map for your position. Draw a line along the edge of the compass. This is the strike line.

5) Now measure the dip. Place the side of the compass directly onto the rock layer, with the card oriented in the direction of maximum inclination. Look at the scale that the small red needle points to and estimate the number of degrees. This is the dip angle.

Record the dip here ______________ before you forget it.

6) Finally, determine which direction the layer is dipping. Basically, which way does the rock tilt? Dip is always perpendicular to strike, but that leaves two possibilities, 180 degrees away from each other. You need to establish which one is correct. Point your compass in the direction of the maximum inclination and read the general compass direction. You don't have to be exact: either N or NE is OK, but make sure you don't switch N for S! Record this direction after the amount of dip (above).

7) Put it all together: strike, followed by a "/", followed by dip angle and then dip direction:

8) **FINALLY**, Plot the dip tick mark and amount on the map: draw a short tick mark off the strike line in the direction that the rocks dip. Label this tick mark with the dip angle. Done!! Just like a professional!!
**Part III: Witness Recumbent Folds at Birch Hill**

The black rock is a low-grade metamorphic rock called slate. Note that it splits along parallel layers, but it doesn’t have the big, shiny mica layers that you saw at the Duckering stairs outcrop. The white layers within the slate are metamorphosed volcanic ash, similar to the ash deposited today around Anchorage (from volcanoes erupting west of Cook Inlet), or the ash that came out of Mt. St. Helen’s a few years ago. At first glance, it looks like there are several white ash layers interlayered with the slate. Look closer! There is actually only one white ash layer. This single layer is repeated by isoclinal, recumbent folds.

![Diagram of isoclinal folds](image)

**Fig. 3-9.** Isoclinal folds. AP, Axial planes. (A) Vertical isoclinal folds. (B) Inclined isoclinal folds. (C) Recumbent isoclinal folds.

Refer to the idealized illustration above. Recall that the fold hinge is the point of maximum “bending” around which the layers are folded. Note that the layers on either side of the hinge are parallel to each other, that is, the layer has been folded back upon itself = isoclinal fold. For C, the hinge is horizontal, making the fold recumbent.

A. In the box below, make a sketch of the outcrop showing the folded ash beds and the folds.

![Sketch of outcrop](image)

B. Folds, especially recumbent folds, require LOTS of compression! Most geologists hypothesize that the intense folding seen here was caused by a large-scale collisional event. In the meantime, it would be very useful to know the direction of the compressional forces (squeezing), which must have been perpendicular to the fold axis. Convince yourself that squeezing is perpendicular to fold axes by deforming a piece of paper so that it resembles the folds in this outcrop. Ta da! So, to figure out the direction of compression, you need to measure the orientation of the fold axes! But what is the compass direction of these axes? This is not immediately obvious. Your TA will lead you up the outcrop to a place where you can see the hinges clearly exposed. Here the orientation of the axis is apparent. Measure the trend (bearing) with your Silva compass and record it below. Now determine the direction of compression.

Orientation of fold axis: _______  Direction of compression: _______
C. On the last field trip, you examined volcanic flows of basalt at Brown’s hill (remember the petrified wood?), and intrusive rocks from the Fairbanks area. Neither the basalts nor the granitic rocks in the Fairbanks area show any evidence of folding. Use this piece of information to determine the relative timing of events. Did the folding, and the hypothesized collision, take place before or after the basalt eruption? Before or after intrusion of granitic rocks? How do you know?

---

**Part IV: Diagnose the Motion of the Birch Hill Fault!**

1. Volcanic Rocks

The irregular blobs of hard, reddish rock in the softer, reddish matrix were formed when a volcano erupted basaltic lava into a lake or river. Or at least, rocks that look similar to this (blobs with holes, etc.) are known to form today when basaltic volcanoes erupt into bodies of water. If you look closely at the hard lumps within the matrix, you might notice that they look just like pieces of basalt from Brown’s Hill quarry. They have the same chemical composition as the Brown’s Hill basalts, and pieces of similar petrified wood have been found at this location. Use this information to draw some conclusions about the history of these volcanic rocks. Based on what you’ve seen of this basalt unit, what was the surface environment like at the time of its extrusion?

---

2. Metamorphic Rocks

Examine the metamorphic rocks at this stop. Note that they are more-or-less similar to those at the foot of the Duckering stairs. However, these rocks are really deformed. That should make you suspicious... Furthermore, these rocks show no sign of contact metamorphism, despite their proximity to the basalt! The lack of contact metamorphism combined with the abrupt contact between the basalt and the metamorphic rock along a planar surface indicates that the contact between these two types of rock is a _______.

---

3. The Fault

Note that the planar surface bears slickensides, or parallel grooves and scratches formed by movement across the fault. Also notice that the sharp break occurs between basalt, and really beat-up, crushed basalt. The contact between the basalt and the metamorphic rock is about 10 meters away (and harder to see). This means you’re standing in a fault zone 10 - 15 meters wide. This zone contains many faults, not just a single, narrow break, and it separates the basalt (to the W) from the metamorphic rock (to the E).

A. Estimate the strike of the fault by stepping back and lining your compass up with the planar surface. Then move closer and determine the dip (angle of maximum inclination).

Fault strike and dip: _______

B. Use a protractor compass to determine the dip of the slickensides: _______

Note that the slickensides are neither vertical nor horizontal. This means that the rocks on either side of the fault moved sideways and up-and-down, in other words, has both _______ -slip and _______ -slip movement. Study of the slickensides indicates that the side of the fault that moved down also moved to the left.
C. The basalts are actually younger than the metamorphic rocks (right!?)--when the lava flowed out of the volcano, it flowed OVER the metamorphic rocks. Here, however, the basalts are next to the metamorphic rocks. In the boxes below, make a cross-section sketch showing the original configuration of rock (basalt over metamorphic). Then draw in the fault, and show the direction of motion needed to produce the current configuration (basalt next to metamorphic rocks). Label the sides of the fault “U” and “D” (for ‘up’ and ‘down’).

before fault movement

after fault movement

D. There’s one final step to produce what one sees today: erosion. Which side of the fault was preferentially eroded? Why? How did this cause the current topography?

E. Now add the structural information you’ve collected to the attached map (Figure 2). Draw in the fault; put on a dip arrow, and label with the amount of dip; put “U” and “D” and arrows on the appropriate sides of the fault; finally add unit abbreviations for the rocks found on either side. You’ve just drawn your first REAL contact!!!

F. Now for the good part: the geologic interpretation.
(1) Based on the directions of horizontal movement, what type of strike-slip displacement does the fault possess? ______________________. Your TA will review the definition of right-lateral and left-lateral if needed. How and why is this movement related to the right-lateral movement on the major Denali fault? (Ohhhh, remember the juice box experiment a previous lab? No?? Oh, well....)

(2) Based on the dip of the fault (see below), one side is the hangingwall and one side is the footwall. In this case, which is which?

Hangingwall

footwall

(3) You’ll recall that based on the relative movement of hangingwall and footwall, dip slip faults are classified as ‘normal’ (typical of areas undergoing extension) or ‘reverse’ (typical of areas undergoing compression). Which type is the Birch Hill fault? ______________________

How does this contrast with the geologic environment that caused the recumbent folds?

Weird, huh?

G. After you’ve accomplished as much mapping as time allows, clean up the map, add a map explanation (unit labels and names, structural symbols, etc) in the space allotted. Make sure you list the units with youngest on top!
Figure 2: Topographic map of the east end of Birch Hill, Fort Wainright, Alaska. Note scale and contour interval.

Ft Wainright: Beacon - Sage Hill area 1: 5,000 (1 mm = 5 m)

Explanation:
Part V: Approach Hill Quarry

A. The Igneous Rocks: Note the rounded rocks and boulders sitting on the sides and top of the hill. At first glance, these smooth, round rocks appear to be completely out-of-place, perhaps transported by a BIG flood to the top of this hill. In this case, however, the rounding is not due to the abrasive action of sediment in flowing water (like other smooth, round rocks you might have seen in rivers). These rocks get their rounded character from weathering! Your TA will show you at least one place where you can see the effects of weathering in action. The technical term for this type of rounded weathering pattern is exfoliation. Exfoliation is typical of this type of igneous rock.

Notice the thin quartz veins occasionally present in these rocks and the fact that they're not folded. Veins like this are very common in granitic rocks. In other places in the Fairbanks area, such veins are bigger, more abundant, and contain high enough gold concentrations to be mined for gold.

Now look carefully at the surface of the boulders. You should be able to see that the rock consists of equal-sized, dark and light crystals, which are randomly oriented. Sooo—what general type of rock is this??

B. The Metamorphic Rocks: The foliated rocks in this quarry immediately adjacent to the granitic body are similar to, but different from, the metamorphic rocks you just examined at Brown's Hill or the Duckering stairs.

1. Find a location where the metamorphic rocks are in contact with the igneous rocks. Sketch the contact.

What is the nature of that contact? Is it a fault? How can you tell?

Part VI: Summary—work on at home or in the van

A. Approach Hill

1. The Approach Hill granitic body, like all other granitic rocks known in the Fairbanks area, is about 90 million years old, much older than the basalt at Brown's Hill. Using this information, suggest why this body, which we infer to have cooled below the surface, is now at about the same elevation as the basalt, which cooled at the surface.
2. Regional mapping shows that, starting about 500 m away from the Approach Hill outcrop, the metamorphic rocks gradually change in appearance as one approaches it. We consequently infer that the Approach Hill magma caused the differences you noted above by heating the surrounding rocks. We call these CONTACT metamorphic rocks. What is the compositional evidence that these Approach Hill metamorphic rocks are ACTUALLY remetamorphosed Duckering Stairs rocks? Why don’t these two rocks look like each other?

![X-ray patterns for the metamorphic rocks from the base of Duckering Stairs and from the Approach Hill quarry (also see the metamorphic rocks lab).]

3. Approach Hill is an isolated hill in the middle of the Chena River flood plain. In the immediate Fairbanks area, Pedro Dome, Ester Dome, Gilmore Dome, and Cleary Summit all contain significant exposures of granitic and contact metamorphic rocks. From this relationship, geologists infer that the resistance of local rocks to weathering strongly influences the topography. What specific characteristics of the regional metamorphic rocks and the basalts that you’ve seen in the Fairbanks area would make them relatively difficult to erode?
4. Because contact metamorphic effects are rarely present more than 1 km from a granitic body, and because granitic bodies, by definition, cool below the surface (typically much more than 1 km below the surface), one would presume that there would be little, if any, topographic changes caused by granitic intrusion at the time of intrusion. However, as erosion takes place over tens of millions of years, one would expect the covering rocks to be eroded and the harder rocks underneath to be exposed. At that point, one would start to see topographic differences developing.

In the box below, sketch a schematic cross-section to illustrate this model, using Approach Hill as an example. Your finished sketch should show the land surface (a hill with valleys on either side), and indicate the type of rock beneath the hill and valleys.

---

**B. Summary of everything about Fairbanks in a nutshell**

On this and the previous field trip, you examined 55 Ma basalts and a ~ 90 Ma intrusion. Neither type of igneous rock in the Fairbanks area show any evidence of folding. However, as you’ve seen today, the volcanic rocks are cut by faults, and the metamorphic rocks are folded. Igneous suites with only basalt (or basalt + rhyolite) are typical of EXTENSIONAL environments, and igneous suites dominated by intermediate compositions (as at Approach Hill) are typical of SUBDUCTION-related environments.

Use this information to determine the relative timing of geologic events you’ve more-or-less witnessed in the Fairbanks area: subduction, extensional volcanism, metamorphism, collision(?)-related folding, and faulting. List them below, with the oldest (first) at the bottom and the youngest (last at the top). Also list the evidence you’ve employed in making these relative age determinations. Geologists were able to do a lot of such relative age determinations long before radioactive dating techniques were available, and recognized that in many areas there is evidence for many geologic events, each of which must have taken a significant amount of time to accomplish.

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Lots of places in the Continental U.S. are (geologically) pretty booooooring (e.g., Kansas, Iowa, Nebraska…)

Most of Alaska is as geologically complex (and fascinating) as the Fairbanks area. What is there about the relative location of Alaska and Kansas (with respect to plate margins) that makes Alaska so much more interesting?

If you would like to know more about Alaska’s complex and fascinating geology, you may wish to consider taking additional geology courses at UAF, for example Geos 120 (Earthquakes, Glaciers, and Volcanoes) or Geos 212 (Geology of Alaska). And, with a little advance warning, you are welcome to tag along on early fall and late spring field trips for other geology classes.

Jot down notes here about what you liked and disliked about this lab exercise or the field trips in general.
GEOS 101

Metamorphic Textures and Rocks

Name: ___________________________
Lab day & time/TA Name: __________

Introduction

This lab is designed to help you better understand the nature of metamorphism, what it does to minerals, and how metamorphic rocks are recognized and used. You'll conduct some experiments and interpret the data in an effort to better understand some of the major processes involved in forming these rocks. Finally, we use metamorphic rocks to tell us about past geologic events; the Fairbanks area has a fascinating story that you'll interpret from its metamorphic rocks. Monroe & Wicander (Chapt 7) and the last page of this lab contain helpful reference material.

Part I. Experiments with pressure metamorphism

Recrystallization under pressure is an important part of metamorphism. We will examine pressure effects using a hydraulic press to squeeze sediments. Our press is calibrated in metric tons and we have several different piston apparatus for squeezing. We will put the equivalent of 10 tons (=10,000 kg) of mass on the sample. Pressure is weight distributed over a particular area; the smaller the area over which the weight is distributed, the greater the pressure. One “bar” (=atmospheric pressure) equals about \( \approx 1 \text{ kg/sq cm} \). A kilobar (kbar) is 1,000 bars. Fill in the table below for the particular apparatus you use.

\[
\text{Diameter of piston} = \frac{3.4}{\text{cm}} \quad \text{Area of piston} = \pi r^2 = \frac{3.16}{\text{sq cm}}.
\]

For this piston, 10 tons of equivalent weight = \[ \frac{10000}{100} \text{ kg/cm}^2 = \frac{100}{100} \text{ kbar} = 1 \text{ kbar} \].

The pressure that is experienced in the Earth is due to the mass of the overlying rocks: 3.3 km of rock exerts a pressure of about 1 kbar. Thus, for this piston, when the press shows 10 tons of equivalent weight, the pressure is \[ \frac{1}{1} \text{ kbar}, \text{ equivalent to a depth in the earth of } \frac{36}{\text{km}}. \text{ And with just a dinky hand press! You can imagine what sorts of pressures are easily obtainable for real laboratory experiments!}

A. Examine the mixture of biotite and/or chlorite flakes in a matrix of boric acid (Boric Acid is soft and harmless and recrystallizes rapidly at low temperatures and pressures). As initially present, the random orientations of the chlorite/biotite grains in the white matrix represent metamorphic (or igneous) crystals formed under low pressure conditions. Put a tablespoon of sand into the press and pressurize it to 10 tons. Let it sit for a minute under pressure, then take off the pressure & examine the pellet. Does the sample possess foliation? If so, why?

Is it completely foliated? What does this say about the pressure needed to cause complete foliation in rocks??

B. Now try it with some calcite sand. Put a tablespoon or so of sand into the press and crank it up to \( \approx 10 \text{ tons} \). Wait a bit, then pull it out and take a look. Is this sample—despite experiencing significant pressure, more or less crumbly than the squashed boric acid? What's the difference between the two experiments?

Softens and is not foliated at all.

C. Consequently, what role does increase in temperature—along with pressure—play in converting sediments into metamorphic rocks??

High heat allows the sediment to melt and become fluid so they foliate.

Part II: Experiments with thermal metamorphism

Heating is a key part of metamorphism. Old minerals stable at earth surface conditions are destroyed and replaced by new minerals as temperature rises. One particularly common reaction involves minerals that contain water (hydrus) or \( \text{CO}_2 \) in their crystal structure. These minerals dehydrate or decarbonate if heated to high enough temperature. Hydrous minerals aren’t ‘wet’, water is simply a component of the mineral. An example is the colorless mica muscovite, with formula \( \text{KAl}_2\text{Si}_3\text{O}_10\cdot\text{H}_2\text{O} \). It dehydrates to give \( \text{KAl}_2\text{Si}_3\text{O}_8 + \text{Al}_2\text{O}_3 \) (corundum). Rocks that contain muscovite can’t have been heated beyond the upper temperature limit of muscovite. But what temperature is this?? That’s what experiments are for. Similarly, calcite contains \( \text{CO}_2 \) in its
crystal structure: calcite is CaCO₃ and it ‘decarbonates’ to give CaO (lime) + CO₂. Rocks that contain calcite must not have been heated beyond the upper temperature stability limit of calcite.

A. We’ll start with some qualitative experiments, looking at the effects of heat on three different sheet silicates: biotite, chlorite, and muscovite. One would figure that if the mineral looks different after heating, it must have changed, that is, was no longer stable. So, look at the ‘before’ and ‘after’ for the samples of these minerals and fill out the table below. If there has been no change from the unheated sample, write ‘NC’. If there has been a change, briefly describe how the heated mineral looks different from the unheated version.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>400°C</th>
<th>500°C</th>
<th>600°C</th>
<th>700°C</th>
<th>800°C</th>
<th>900°C</th>
<th>1000°C</th>
<th>1100°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorite (green mica)</td>
<td>NC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biotite (black mica)</td>
<td>-----</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscovite (clear mica)</td>
<td>-----</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For each mineral, you determined the highest temperature for which there is no change and the lowest temperature (100°C higher) for which there is some appreciable change. At this point all we can say is that the temperature at which the mineral became unstable is SOMEWHERE in the range between these two different temperatures. Based on these results, at approximately what temperature range does chlorite become unstable? How about biotite? How about muscovite?

How do these results compare to the T-stability graph for minerals on the bottom of page 11?

The results correspond relatively well to the T-stability chart.

B. More Quantitative measurements of mineral instability

The problem with this ‘does it look different?’ approach is that it’s difficult to assess the temperature at which a distinct change actually occurs. We can be much more exact by weighing a water- (or CO₂-) bearing mineral before and after heating. If the mineral looses weight, then H₂O or CO₂ must have been driven off, and the mineral became unstable at a temperature at or below the temperature of heating. If there is no weight loss for heating at 500°C but there is loss for heating at 700°C, then the mineral must have become unstable at a temperature between 500 and 700°C. Using smaller temperature ‘steps’ allows one to accurately assess the precise upper temperature stability of a particular mineral (as we have done for several minerals over the last few years).

From the data provided, however, you’ll notice that not all the rocks lost weight when heated, even though some of these have minerals that contain water (for example, biotite). If a mineral or rock shows no weight change at a given temperature, either the mineral contains no H₂O or CO₂ or the mineral is stable at that temperature. If a mineral loses a lot more weight at even higher temperature, probably the mineral (or rock) was just becoming unstable at the lower temperature and didn’t spend enough time in the oven at the lower temperature. Rock weight loss at several different temperatures is probably due to several different minerals becoming unstable at different temperatures.

For example, kaolinite (a clay) loses ≈12% of its weight when heated at 500°C and shows little additional weight loss at 700°C or 900°C, implying that it is unstable well below 500°C. Additional heating experiments show that its weight doesn’t change when heated to 250°C, but drops a bit when heated to 350°C. All we can say from these heating experiments is that kaolinite becomes unstable at a temperature somewhere between 250 and 350°C. With a lot of time we could nail down the temperature more accurately, as we’ve done for a few of the minerals. In contrast, calcite doesn’t lose weight at 500°C, but lost about 4% of its weight at 700°C and then a gigantic 40% at 900°C. In this case we can presume that calcite is perfectly stable at 500°C, just becoming unstable at ≈700°C and definitely unstable by 900°C (all at normal pressure).
Using the logic discussed above, examine the data and complete Table 2 by listing the approximate instability temperature range for each of the tested minerals and rocks.

### Table 2 -- Results from laboratory heating of rocks and minerals – For Part II B

<table>
<thead>
<tr>
<th>Rock or Mineral</th>
<th>Mass in grams after heating to listed temperature</th>
<th>Estimated Instability Temperature (°C) range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25°C</td>
<td>150°C</td>
</tr>
<tr>
<td>Duckering stairs Phyllite</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Approach Hill meta rock</td>
<td>8.9</td>
<td></td>
</tr>
<tr>
<td>Garnet Musc. Schist</td>
<td>22.9</td>
<td></td>
</tr>
<tr>
<td>Eclogite</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>Kaolinite (clay)</td>
<td>10.2</td>
<td>10.2</td>
</tr>
<tr>
<td>Illite (clay)</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Vermiculite (clay)</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Chlorite</td>
<td>32.7</td>
<td>32.7</td>
</tr>
<tr>
<td>Serpentine</td>
<td>39.6</td>
<td>39.6</td>
</tr>
<tr>
<td>green amphibole</td>
<td>43.9</td>
<td></td>
</tr>
<tr>
<td>Muscovite</td>
<td>25.0</td>
<td></td>
</tr>
<tr>
<td>Talc</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td>Biotite</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>Hornblende (black amphibole)</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>Pyroxene</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>K-feldspar</td>
<td>10.4</td>
<td></td>
</tr>
<tr>
<td>Garnet</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>Calcite*</td>
<td>10.0</td>
<td></td>
</tr>
</tbody>
</table>

*calcite is stable to considerably higher temperature if the pressure is greater than atmospheric

---

**Graphed results from Table 2 – For Part II B**
1. Based on your data, which of the minerals in Table 2 would not be found in a medium-grade (amphibolite facies) metamorphic rock? The minimum temperature for amphibolite facies metamorphism is ~ 500°C.

2. Assuming that the phyllite sample had experienced normal metamorphism as represented on the P-T metamorphic diagram below, approximately what was the maximum temperature it experienced? 400°C

What do the heating experiment results suggest about the maximum temperature the phyllite actually experienced?

Less than 400°C

How do the two compare? They are relatively close.

5. How does the Table 2 data show that schist has to be of higher metamorphic grade than phyllite?

The rocks changed from 700°C to 900°C for schist vs. where phyllite changed between 350°C to 400°C.

6. What about the hornfels sample? The geologic setting of hornfels in the Fairbanks area suggests that it represents phyllite heated by the adjacent Approach Hill tonalite. This rock type melts at ~900°C. What do the heating experiments suggest about temperatures the hornfels sample actually experienced relative to that of the phyllite?

The apparent phyllite rock has already experienced the temperature to break off the tin.

Part III: Overview of Metamorphic rocks (Monroe & Wicander, Chapter 7)

A. Classification of Metamorphic Rocks

Look at the samples of metamorphic rocks on the large classification charts. Familiarize yourself with their distinguishing characteristics, paying particular attention to textures (foliated vs. nonfoliated, slaty vs. schistose), grain sizes, and overall mineralogy (muscovite vs. chlorite; calcite vs. quartz). These distinctions are essential to choosing the most appropriate name for a metamorphosed rock!

Practice with samples 42 and 202. Use the simplified classification flow chart on the last page of the lab while you examine these rocks and fill out an entry for each on Table 3. Start by determining if (a) foliated/banded vs. (b) poorly- to non-foliated/banded. This IS AN ESSENTIAL FIRST STEP IN CORRECTLY CLASSIFYING METAMORPHIC ROCKS!!! You’ll then need to consider mineralogy, grain size, hardness, and other key characteristics to finish your identification. Once you’ve figured ‘em out, check your answers with your T.A.

→ Then...pick out 5 ADDITIONAL ‘unknowns’ and classify them, filling in entries on the chart (Table 3, page 5) up to the column with ‘rock name’.

B. Metamorphic P-T conditions experienced

The minerals present in metamorphic rocks are formed because (a) the right ingredients were present and (b) the rocks experienced temperatures and pressures necessary for making the minerals. From experimental data on mineral stability (similar to that which we have/will collect/examine) geologists have classified the overall pressure-temperature conditions that rocks can experience, into metamorphic ‘facies’. (→See figure). The chart on the bottom of Page 11 shows the stability range of several key minerals under typical metamorphic conditions. Notice, for example, that the presence of quartz doesn’t tell you anything—quartz is stable under a wide range of pressure & temperature conditions—but garnet and black amphibole (hornblende) don’t become stable until amphibolite facies conditions. In contrast, muscovite is unstable under granulite facies conditions. In fact, the metamorphic facies are DEFINED by the presence/absence of key minerals, assuming that the proper ingredients are present. Unknown #42, for example, contains several minerals, one of which defines the minimum metamorphic conditions, and another the maximum.

→ Figure out the name of the metamorphic facies for Rock #42, and list it on the worksheet.
Also notice that some rock types define a metamorphic facies, for example blueschist (the rock type) is restricted in occurrence to blueschist facies. More information about metamorphic minerals is given on the last pages of this lab.

Use this information (+ last page) to determine the 'METAMORPHIC FACIES' FOR 3 MORE OF YOUR 'UNKNOWNNS'... and list them on your worksheet (Table 3, page 6).

C. ‘Parents’ of metamorphic rocks

Mostly metamorphism just changes the minerals, not the ingredients in rocks. (If you put a pan of cake batter in the oven, you don’t get apple pie, no matter how you cook it.) In particular, mafic ‘parent rocks’ yield mafic metamorphic rocks, Aluminum-rich (clay-rich) parent rocks yield Al-rich (mica + feldspar-rich) metamorphic rocks, calcite-rich (limestone) parents yield calcite-rich (marble) metamorphic rocks, quartz-rich parents yield quartz-rich metamorphic rocks... you get the picture. To remind you of the compositions of metamorphic and parent rocks, XRF spectra of representative examples of igneous, sedimentary, and metamorphic rocks are in Appendix II.

What do the X-ray spectra of slate, phyllite, schist, and gneiss suggest about their parent rock?

They came from the same parent rock.

How do the X-ray spectra of slate, phyllite, schist, and gneiss differ from those of igneous rocks? (It’s subtle).

There is a small amount of titanium, the igneous rock have less Ti.

What igneous rock does amphibolite closely resemble in composition? Thus, what is the parent of amphibolite?

It looks more like Basalt => Basalt is the parent rock.

Use this information to determine the ‘PARENT’ FOR 4 OF YOUR ‘UNKNOWNNS’... and list them on your worksheet (Table 3, page 6). Then write the metamorphic rock & parent names on the appropriate XRF spectra in Appendix II (for your future reference!)

Part V: To “hell” & back: A Virtual field trip in Fairbanks metamorphic rocks

This is really a fun trip and the rocks tell a really interesting story. But because it takes a long time to see everything, you’ll have to take the Reader’s Digest condensed trip. Please keep track of your rock observations by filling in entries for 5 of these rocks on the ‘unknowns’ worksheet (Table 3, page 6). See locations on pg 10.

Stop 1: Bottom of the Duckering Stairs, UAF campus. Describe a representative sample in Table 3 and give the name. What are the key features that lead you to that name?

This is phyllite, the muscovite + calcite + foliation lead to this determination.

Notice the veins and vein samples. Veins are cracks in the earth along which hot water has moved and deposited minerals. What minerals are the veins composed of? (Consult your mineral flow chart). For such veins—that contain the same minerals as the surrounding rocks—the fluids probably came from underlying rocks. What process during metamorphism would give rise to such fluids (hint, think back to your heating experiments)?

The veins are calcite + quartz, this would result from H₂O being driven off and redistributed elsewhere.
<table>
<thead>
<tr>
<th>Sample number</th>
<th>Folded or foliated?</th>
<th>Non-fine grained?</th>
<th>Most minerals harder than glass?</th>
<th>Overall rock color</th>
<th>Visible mineral structure or texture</th>
<th>Rock color</th>
<th>Rock type</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>Folded</td>
<td>Fine</td>
<td>Jacuzzi</td>
<td>Non-fine</td>
<td>Shaly, mica, schist</td>
<td>green</td>
<td>Schist</td>
</tr>
<tr>
<td>42</td>
<td>Folded</td>
<td>Very fine</td>
<td>Medium</td>
<td>Non-fine</td>
<td>Shaly, mica, schist</td>
<td>green</td>
<td>Schist</td>
</tr>
<tr>
<td>202</td>
<td>Non-fine</td>
<td>Non-fine</td>
<td>High</td>
<td>High</td>
<td>Shaly, mica, schist</td>
<td>green</td>
<td>Schist</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: "Unknown" Metamorphic Rock Worksheet

Metamorphic Textures and Rocks Page 6 of 14

Geos 101
Stop 2: Approach Hill. We looked at some igneous rocks from here for the Igneous Lab. Take in the scenery while we review the local rock types. (a) We’ve got a blob of tonalite under the hill and at the crest. (b) Some strange-looking metamorphic rocks are adjacent to the tonalite. (c) Magnetic surveys have shown that the rocks become less and less magnetic as you go down the hill towards the flats. How could this be? Well, they’ve got less and less magnetite in them. The increased magnetite content of these contact metamorphic rocks is due to an increase in recrystallization close to the heat source (the tonalite pluton). Take a look at these metamorphic rocks, and compare them to those at the Duckering stairs

(stop 1).

Now examine the XRF spectra for the two rocks (SEE ABOVE). Are the rocks at Duckering Stairs a likely parent for those at Approach Hill? Explain. They are a parent rock

No, the composition are not the same.

However...are the Approach Hill rocks more or less crumbly than the stop 1 rocks? Less crumbly

Do they contain more calcite, muscovite, or chlorite than the stop 1 rocks, or less? Are they coarser or finer grained? Less calcite set from them along with the underground more heat + hotter coarser

Is it reasonable to ascribe these differences to heating at (relatively) low pressure (contact metamorphism!)? Explain. Yes because the minerals present show pressure experienced was high.

Finally, go back to the heating experiments (Table 2), which include results for the metamorphic rocks from Duckering Stairs and Approach Hill. What do these heating data indicate about the temperatures that these two rocks have experienced?

They have well experienced a 900° not the phyllite

In summary, explain the differences and similarities between the Duckering Stairs and Approach Hill metamorphic rocks and what these similarities and differences imply about their origins.

They are compositionally the same but approach hill got hotter

Stop 3: Baylor Rd. Quarry, off Farmer’s Loop Road. Sample Fbx 12 is representative of the single rock type exposed in this little quarry. Name the rock (pg. 11) and describe its metamorphic grade (page 4), based on the textures present (page 4). The grade was gneissic, metamorphic grade is high.
Just one lousy block up the hill are roadcuts with a completely different rock type, represented by sample FBX 13. Name this rock and describe its metamorphic grade (facies) based on the minerals & textures (page 11).

Given a “normal” geothermal gradient (pg. 4, bottom, how many kilometers below the surface did this rock form?

Now wait a minute! (a) How does the metamorphic grade of the rocks UP the hill compare to that of the topographically lower rocks DOWN the hill? (b) What’s wrong with this picture? (c) What kind of geologic structure must be present to explain this weirdness?

Stop 4: Chena Ridge  Now we drive past the University and west to Chena ridge. The University owns land on the top of “Peregrine Heights Subdivision” which once was a quarry. Name the rocks found in the quarry (THERE ARE SEVERAL!) and describe their metamorphic grade (page 11) and parents (Appendix II). The metamorphic conditions must be constant at a SINGLE spot—differences in rock type are due to different parents, not to different metamorphic conditions. Why are some of these rocks strongly and some weakly foliated?

Stop 5: Tungsten Hill  Your TA will now drive you back through town to the Steese Highway. You proceed up the hill toward Fox, turn right onto Gilmore trail, and drive up to Tungsten Hill. It’s called that because Tungsten was mined here during WWI and WWII. There are lots of road cuts on the way, and you stop enough to recognize that they’re loaded with amphibolite-facies metamorphic rocks. Tungsten Hill itself, however, is different.

The original rock package present here at the “Spruce Hen” Mine (Fbx 15) is different from that at Approach Hill. In particular, it contains a number of marble beds. Metamorphism of a limestone by hot fluids derived from nearby granite plutons produces a rock called “skarn”. (Which is - I kid you not - from the old [medieval] Swedish for “excrement”). These rocks contain garnet, so it is clear that they formed at elevated temperature. Based on their textures, did these rocks form under conditions of high pressure? Why or why not? What does this say about the metamorphism?

Stop 6: Pedro Creek  Wowed by all these fabulous metamorphic rocks, you get back on the Steese Highway and continue on toward Fox. Take a right and head toward Cleary Summit. Then you stop at upper Pedro Creek, get out, and bushwhack a kilometer through the bushes and float of amphibolite facies rocks, cursing your TA. At last a new rock type appears!! Welcome to Fairbanks!! There are blobs of these found throughout the amphibolite-facies metamorphic rocks. They look granitic, but the texture says “No Way!” [To remind you of what a coarse-grained granitic rock looks like, we’ve put out several examples to compare with these metamorphic rocks.]
Name this rock, describe the texture, and describe the parent rock.

This is a coarse, foliated, visible mineral, the point rock is slate, granitic in this case, large phenocrysts.

Why do these rocks look so different from the amphibolite facies rocks on top of Chena Ridge??

They are different! Of different parent rocks.

Step 7: Marshall Dome Last stop! You get back onto the Steese Hwy. and drive north, past Cleary Summit and Pedro Dome. You descend down the ridge examining medium-grade rocks in the road cuts along the way. Instead of turning east and driving down the Steese toward Chatanika, your TA drives north along a small, steep, windy, dirt road. Well, you think it’s dirt, under all the snow and ice. Scary driving! Good thing this is only a virtual field trip! At last you stop, and your pale-looking TA shows you an outcrop of yet another rock type. There are pyroxenes in this rock – a variety called jadeite. Use Table 3 and your mineral flowchart to name the rock and identify some other minerals present.

Jadeite is a rather unusual form of pyroxene. In fact, its presence tells us that these rocks were subjected to very high pressures of ~14 kilobars (bottom, last page of lab). How many kilometers below the surface do you need to bury a rock to build up this much pressure? ~35 kilometers.

Now find the name of the metamorphic conditions expressed by this rock (right, page 4). What does the ‘c’ stand for in the label “Pzc” on your geologic map (page 10)?

Echovite

There are two unusual aspects to these rocks.

One is the metamorphic conditions they’ve experienced. How are these unusual? (right, page 4).

High pressure and medium temperature.

The other unusual aspect is that they sit on top of the nearby amphibolite facies rocks. Assuming that the amphibolite facies rocks formed under ‘normal’ metamorphic conditions, how much higher pressure did these rocks experience?

~6 kilobars

How many kilometers OUGHT to separate these rocks from the amphibolite facies rocks? ~20 km

What’s wrong in this picture??

They are found very close together.

Yikes! Now you’re really weirded out. You run back to the van, dragging your TA after you, and drive as fast as you can back to the good ol’ Duckering outcrop.

While on the trip or once you ‘get back’, be sure to fill in data for at least 5 of the rocks you’ve seen on the field trip on Table 3.

Jot down notes here about what you liked and disliked about this lab exercise.
Simplified geologic map showing locations of stops for Metamorphic Virtual Field trip.
GEOS 101

Metamorphic Textures and Rocks

Lab day & time/TA Name 6-9 Wed

Introduction

This lab is designed to help you better understand the nature of metamorphism, what it does to minerals, and how metamorphic rocks are recognized and used. You’ll conduct some experiments and interpret the data in an effort to better understand some of the major processes involved in forming these rocks. Finally, we use metamorphic rocks to tell us about past geologic events: the Fairbanks area has a fascinating story that you’ll interpret from its metamorphic rocks. Monroe & Wicander (Chapt 7) and the last page of this lab contain helpful reference material.

Part I. Experiments with pressure metamorphism

Recrystallization under pressure is an important part of metamorphism. We will examine pressure effects using a hydraulic press to squeeze sediments. Our press is calibrated in metric tons and we have several different piston apparatus for squeezing. We will put the equivalent of 10 tons (=10,000 kg) of mass on the sample, Pressure is weight distributed over a particular area; the smaller the area over which the weight is distributed, the greater the pressure. One “bar” (=atmospheric pressure) equals about = 1 kg/sq cm. A kilobar (kbar) is 1,000 bars. Fill in the table below for the particular apparatus you use.

Diameter of piston = 3.4 cm. Area of piston = \pi \times \frac{1}{4} sq. cm. For this piston, 10 tons of equivalent weight = \frac{10,000}{0.00000098} kg/cm^2 = \frac{10,000}{1.1} \text{ kbar.}

The pressure that is experienced in the Earth is due to the mass of the overlying rocks: 3.3 km of rock exerts a pressure of about 1 kbar. Thus, for this piston, when the press shows 10 tons of equivalent weight, the pressure is \frac{10}{1.1} \text{ kbar}, equivalent to a depth in the earth of \frac{3.3}{10} km. And with just a dinky hand press! You can imagine what sorts of pressures are easily obtainable for real laboratory experiments!

A. Examine the mixture of biotite and/or chlorite flakes in a matrix of boric acid (Boric Acid is soft and harmless and recrystallizes rapidly at low temperatures and pressures). As initially present, the random orientations of the chlorite/biotite grains in the white matrix represent metamorphic (or igneous) crystals formed under low pressure conditions. Put a tablespoon or so into the press and pressurize it to 10 tons. Let it sit for a minute under pressure, then take off the pressure & examine the pellet. Does the sample possess foliation? If so, why?

\underline{Slightly} Because the minerals are aligned in 1 direction.

\underline{No. It would need a temperature component.}

B. Now try it with some calcite sand. Put a tablespoon or so of sand into the press and crank it up to \pm 10 tons. Wait a bit, then pull it out and take a look. Is this sample—despite experiencing significant pressure, more or less crumbly than the squashed boric acid? What’s the difference between the two experiments?

\underline{More crumbly, this is not foliated.}

C. Consequently, what role does increase in temperature—along with pressure—play in converting sediments into metamorphic rocks??

\underline{Higher temp, pressure the more foliated.}

Part II: Experiments with thermal metamorphism

Heating is a key part of metamorphism. Old minerals stable at earth surface conditions are destroyed and replaced by new minerals as temperature rises. One particularly common reaction involves minerals that contain water (hydrus) or CO₂ in their crystal structure. These minerals dehydrate or decarbonate if heated to high enough temperature. Hydrous minerals aren’t ‘wet’, water is simply a component of the mineral. An example is the colorless mica muscovite, with formula KAl₂Si₃O₁₀(H₂O). It dehydrates to give KAl₂Si₃O₈ (K-feldspar) + Al₂O₃ (corundum). Rocks that contain muscovite can’t have been heated beyond the upper temperature limit of muscovite. But what temperature is this?? That’s what experiments are for. Similarly, calcite contains CO₂ in its...
crystal structure: calcite is CaCO$_3$ and it 'decarbonates' to give CaO (lime) + CO$_2$. Rocks that contain calcite must not have been heated beyond the upper temperature stability limit of calcite.

A. We’ll start with some qualitative experiments, looking at the effects of heat on three different sheet silicates: biotite, chlorite, and muscovite. One would figure that if the mineral looks different after heating, it must have changed, that is, was no longer stable. So, look at the 'before' and 'after' for the samples of these minerals and fill out the table below. If there has been no change from the unheated sample, write 'NC'. If there has been a change, briefly describe how the heated mineral looks different from the unheated version.

### Table 1: Change after heating at

<table>
<thead>
<tr>
<th>Mineral</th>
<th>400°C</th>
<th>500°C</th>
<th>600°C</th>
<th>700°C</th>
<th>800°C</th>
<th>900°C</th>
<th>1000°C</th>
<th>1100°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorite</td>
<td>NC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(green mica)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biotite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(black mica)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscovite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(clear mica)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For each mineral, you determined the highest temperature for which there is no change and the lowest temperature (100°C higher) for which there is some appreciable change. At this point all we can say is that the temperature at which the mineral became unstable is SOMEWHERE in the range between these two different temperatures.

Based on these results, at approximately what temperature range does chlorite become unstable? 500°C

How about biotite? 500°C

muscovite?

How do these results compare to the T-stability graph for minerals on the bottom of page 11?

**B. More Quantitative measurements of mineral instability**

The problem with this 'does it look different?' approach is that it’s difficult to assess the temperature at which a distinct change actually occurs. We can be much more exact by weighing a water- (or CO$_2$-) bearing mineral before and after heating. If the mineral loses weight, then H$_2$O or CO$_2$ must have been driven off, and the mineral became unstable at a temperature at or below the temperature of heating. If there is no weight loss for heating at 500°C but there is loss for heating at 700°C, then the mineral must have become unstable at a temperature between 500 and 700°C. Using smaller temperature ‘steps’ allows one to accurately assess the precise upper temperature stability of a particular mineral (as we have done for several minerals over the last few years).

From the data provided, however, you’ll notice that not all the rocks lost weight when heated, even though some of these have minerals that contain water (for example, biotite). If a mineral or rock shows no weight change at a given temperature, either the mineral contains no H$_2$O or CO$_2$ or the mineral is stable at that temperature. If a mineral loses a lot more weight at even higher temperature, probably the mineral (or rock) was just becoming unstable at the lower temperature and didn’t spend enough time in the oven at the lower temperature. Rock weight loss at several different temperatures is probably due to several different minerals becoming unstable at different temperatures.

For example, kaolinite (a clay) loses ~12% of its weight when heated at 500°C and shows little additional weight loss at 700°C or 900°C, implying that it is unstable well below 500°C. Additional heating experiments show that its weight doesn’t change when heated to 250°C, but drops a bit when heated to 350°C. All we can say from these heating experiments is that kaolinite becomes unstable at a temperature somewhere between 250 and 350°C. With a lot of time we could nail down the temperature more accurately, as we’ve done for a few of the minerals. In contrast, calcite doesn’t lose weight at 500°C, but lost about 4% of its weight at 700°C and then a gigantic 40% at 900°C. In this case we can presume that calcite is perfectly stable at 500°C, just becoming unstable at ~700°C and definitely unstable by 900°C (all at normal pressure).
Using the logic discussed above, examine the data and complete Table 2 by listing the approximate instability temperature range for each of the tested minerals and rocks.

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<td>Eclenite</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>Kaolinite (clay)</td>
<td>10.2</td>
<td>10.2</td>
</tr>
<tr>
<td>Illite (clay)</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Vermiculite (clay)</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Chlorite</td>
<td>32.7</td>
<td>32.7</td>
</tr>
<tr>
<td>Serpentine</td>
<td>39.6</td>
<td>39.6</td>
</tr>
<tr>
<td>green amphibole</td>
<td>43.9</td>
<td>43.9</td>
</tr>
<tr>
<td>Muscovite</td>
<td>25.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Talc</td>
<td>10.2</td>
<td></td>
</tr>
<tr>
<td>Biotite</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>Hornblende (black amphibole)</td>
<td>10.1</td>
<td></td>
</tr>
<tr>
<td>Pyroxene</td>
<td>10.1</td>
<td>10.1</td>
</tr>
<tr>
<td>K-feldspar</td>
<td>10.4</td>
<td></td>
</tr>
<tr>
<td>Garnet</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>Calcite*</td>
<td>10.0</td>
<td></td>
</tr>
</tbody>
</table>

* Calcite is stable to considerably higher temperature if the pressure is greater than atmospheric

Graphed results from Table 2 – For Part II B
1. Based on your data, which of the minerals in Table 2 would not be found in a medium-grade (amphibolite facies) metamorphic rock? The minimum temperature for amphibolite facies metamorphism is \( \sim 500\,^\circ\text{C} \).

2. Assuming that the phyllite sample had experienced normal metamorphism as represented on the P-T metamorphic diagram below, approximately what was the maximum temperature it experienced? [Diagram showing P-T diagram with various metamorphic reactions and phases.]

What do the heating experiment results suggest about the maximum temperature the phyllite actually experienced?

3. How does the Table 2 data show that schist has to be of higher metamorphic grade than phyllite?

4. How do the two compare? [Blank space for student response]

5. What about the hornfels sample? The geologic setting of hornfels in the Fairbanks area suggests that it represents phyllite heated by the adjacent Approach Hill tonalite. This rock type melts at \(-900\,^\circ\text{C}\). What do the heating experiments suggest about temperatures the hornfels sample actually experienced relative to that of the phyllite?

6. [Diagram of a P-T diagram showing the transformation of phyllite to hornfels.]

Part III: Overview of Metamorphic rocks (Monroe & Wicander, Chapter 7)

A. Classification of Metamorphic Rocks

Look at the samples of metamorphic rocks on the large classification charts. Familiarize yourself with their distinguishing characteristics, paying particular attention to textures (foliated vs. nonfoliated, slaty vs. schistose), grain sizes, and overall mineralogy (muscovite vs. chlorite; calcite vs. quartz). These distinctions are essential to choosing the most appropriate name for a metamorphosed rock!

Practice with samples 42 and 202. Use the simplified classification flow chart on the last page of the lab while you examine these rocks and fill out an entry for each on Table 3. Start by determining if (a) foliated/banded vs. (b) poorly- to non-foliated/banded. THIS IS AN ESSENTIAL FIRST STEP IN CORRECTLY CLASSIFYING METAMORPHIC ROCKS!!! You’ll then need to consider mineralogy, grain size, hardness, and other key characteristics to finish your identification. Once you’ve figured ‘em out, check your answers with your T.A.

> Then… pick out 5 ADDITIONAL ‘unknowns’ and classify them, filling in entries on the chart (Table 3, page 5) up to the column with ‘rock name’.

B. Metamorphic P-T conditions experienced

The minerals present in metamorphic rocks are formed because (a) the right ingredients were present and (b) the rocks experienced temperatures and pressures necessary for making the minerals. From experimental data on mineral stability (similar to that which we have/will collect/examine) geologists have classified the overall pressure-temperature conditions that rocks can experience, into metamorphic 'facies'. (See figure). The chart on the bottom of Page 11 shows the stability range of several key minerals under typical metamorphic conditions. Notice, for example, that the presence of quartz doesn’t tell you anything—quartz is stable under a wide range of pressure & temperature conditions—but garnet and black amphibole (hornblende) don’t become stable until amphibolite facies conditions. In contrast, muscovite is unstable under granulite facies conditions. In fact, the metamorphic facies are DEFINED by the presence/absence of key minerals, assuming that the proper ingredients are present. Unknown #42, for example, contains several minerals, one of which defines the minimum metamorphic conditions, and another the maximum. 

> Figure out the name of the metamorphic facies for Rock #42, and list it on the worksheet.
Also notice that some rock types define a metamorphic facies, for example blueschist (the rock type) is restricted in occurrence to blueschist facies. More information about metamorphic minerals is given on the last pages of this lab.

Use this information (+ last page) to determine the ‘METAMORPHIC FACIES’ FOR 3 MORE OF YOUR ‘UNKNOWNs’... and list them on your worksheet (Table 3, page 6).

C. ‘Parents’ of metamorphic rocks

Mostly metamorphism just changes the minerals, not the ingredients in rocks. (If you put a pan of cake batter in the oven, you don’t get apple pie, no matter how you cook it.) In particular, mafic ‘parent rocks’ yield mafic metamorphic rocks, Aluminum-rich (clay-rich) parent rocks yield Al-rich (mica ± feldspar-rich) metamorphic rocks, calcite-rich (limestone) parents yield calcite-rich (marble) metamorphic rocks, quartz-rich parents yield quartz-rich metamorphic rocks... you get the picture. To remind you of the compositions of metamorphic and parent rocks, XRF spectra of representative examples of igneous, sedimentary, and metamorphic rocks are in Appendix II.

What do the X-ray spectra of slate, phyllite, schist, and gneiss suggest about their parent rock?

---

That they all have the same parent rock

---

How do the X-ray spectra of slate, phyllite, schist, and gneiss differ from those of igneous rocks? (It’s subtle).

---

Sedimentary rock have more

---

Titanium.

---

What igneous rock does amphibolite closely resemble in composition? Thus, what is the parent of amphibolite?

---

Basalt. Mafic

---

Use this information to determine the ‘PARENT’ FOR 4 OF YOUR ‘UNKNOWNs’... and list them on your worksheet (Table 3, page 6). Then write the metamorphic rock & parent names on the appropriate XRF spectra in Appendix II (for your future reference!)

Part V: To “hell” & back: A Virtual field trip in Fairbanks metamorphic rocks

This is really a fun trip and the rocks tell a really interesting story. But because it takes a long time to see everything, you’ll have to take the Reader’s Digest condensed trip. Please keep track of your rock observations by filling in entries for 5 of these rocks on the ‘unknowns’ worksheet (Table 3, page 6). See locations on pg 10.

Stop 1: Bottom of the Duckering Stairs, UAF campus. Describe a representative sample in Table 3 and give the name. What are the key features that lead you to that name?

---

Phyllite. Gneiss.

---

Low Indices. Angle of Decline.

---

Notice the veins and vein samples. Veins are cracks in the earth along which hot water has moved and deposited minerals. What minerals are the veins composed of? (Consult your mineral flow chart). For such veins—that contain the same minerals as the surrounding rocks—the fluids probably came from underlying rocks. What process during metamorphism would give rise to such fluids (hint, think back to your heating experiments)?

---

Calcite at 20°C

---

Temperature & Pressure at which amphibolite formed.
<table>
<thead>
<tr>
<th>Sample number</th>
<th>Foliated vs slightly/non foliated</th>
<th>Fine-grained? vs minerals easily identified</th>
<th>Most minerals harder? or softer? than glass</th>
<th>Overall rock color</th>
<th>Visible minerals (list only those that you actually see and identify!)</th>
<th>ROCK NAME</th>
<th>Metamorphic Facies</th>
<th>Parent Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>202</td>
<td>non</td>
<td>(\times)</td>
<td>Solder</td>
<td>Green</td>
<td>Garnet</td>
<td>Eclogite</td>
<td>Impacted</td>
<td>Marble</td>
</tr>
<tr>
<td>42</td>
<td>foliated</td>
<td>(\times)</td>
<td>Light brown</td>
<td>Mica</td>
<td>Schist</td>
<td>Impacted</td>
<td>Schist</td>
<td>Marble</td>
</tr>
<tr>
<td>33</td>
<td>foliated</td>
<td>(\times)</td>
<td>Redding clay</td>
<td>Feldspar</td>
<td>Gneiss</td>
<td>?</td>
<td>Schist</td>
<td>Schist</td>
</tr>
<tr>
<td>127</td>
<td>foliated</td>
<td>(\times)</td>
<td>Black</td>
<td>None</td>
<td>Slate</td>
<td>Slate</td>
<td>Slate</td>
<td>Slate</td>
</tr>
<tr>
<td>60</td>
<td>non</td>
<td>Massif</td>
<td>Pale</td>
<td>Calcite (acic)</td>
<td>Marble</td>
<td>Any</td>
<td>Cinnabar</td>
<td>Cinnabar</td>
</tr>
</tbody>
</table>

| Stop 1        | Foliated                          | Fine grained                          | Brown tan                                 | NA                | Orthopyroxene                                    | Low        | Schist          | Marble     |
| Stop 3 Fbx 12 | Foliated                          | Fine                                   | Brown                                     | Mica              | Slate                                           | Very low   | Schist          | Schist     |
| Stop 3 Fbx 13 | Foliated                          | White                                  | Brownish                                  | Muscovite/Garnet | Schist                                          | 500 - 700  | Schist          | Schist     |
| Stop 4        | Foliated                          | Blue                                   | Browning                                  | Muscovite/Garnet | Schist                                          | 500 - 700  | Schist          | Schist     |
| Stop 6        | Foliated                          | Mixed clay                            | Red                                        | Feldspar          | Gneiss                                          | X          | Gneiss          | Gneiss     |
| Stop 7        | non                               | Non identifiable                      | Black green                                | Green              |                                                 |            |                 |            |
Step 2: Approach Hill  We looked at some igneous rocks from here for the Igneous Lab. Take in the scenery while we review the local rock types. (a) We've got a blob of tonalite under the hill and at the crest. (b) Some strange-looking metamorphic rocks are adjacent to the tonalite. (c) Magnetic surveys have shown that the rocks become less and less magnetic as you go down the hill towards the flats. How could this be? Well, they've got less and less magnetite in them. The increased magnetite content of these contact metamorphic rocks is due to an increase in recrystallization close to the heat source (the tonalite pluton). Take a look at these metamorphic rocks, and compare them to those at the Duckering stairs.

Now examine the XRF spectra for the two rocks (SEE ABOVE).  Are the rocks at Duckering stairs a likely parent for those at Approach Hill? Explain. 

\[ \text{Yes, because it was heated near a pluton.} \]

However...are the Approach Hill rocks more or less crumbly than the stop 1 rocks?  

\[ \text{Less crumbly} \]

Do they contain more calcite, muscovite, or chlorite than the stop 1 rocks, or less? Are they coarser or finer grained?  

\[ \text{More coarser} \]

Is it reasonable to ascribe these differences to heating at (relatively) low pressure (contact metamorphism!)? Explain.  

\[ \text{Yes, because the heat caused the material to become more stable.} \]

Finally, go back to the heating experiments (Table 2), which include results for the metamorphic rocks from Duckering Stairs and Approach Hill. What do these heating data indicate about the temperatures that these two rocks have experienced?  

\[ \text{Approach Hill has already experienced lower pressure} \]

In summary, explain the differences and similarities between the Duckering Stairs and Approach Hill metamorphic rocks and what these similarities and differences imply about their origins.

\[ \text{Both have been heated to low grade metamorphic.} \]

Step 3: Baylor Rd. Quarry, off Farmer's Loop Road  Sample Fbx 12 is representative of the single rock type exposed in this little quarry. Name the rock (pg. 11) and describe its metamorphic grade (page 4), based on the textures present (page 4).
Just one lousy block up the hill are roadcuts with a completely different rock type, represented by sample FBX 13. Name this rock and describe its metamorphic grade (facies) based on the minerals & textures (page 11).

Given a “normal” geothermal gradient (pg. 4, bottom, how many kilometers below the surface did this rock form?

Now wait a minute! (a) How does the metamorphic grade of the rocks UP the hill compare to that of the topographically lower rocks DOWN the hill? (b) What’s wrong with this picture? (c) What kind of geologic structure must be present to explain this weirdness?

Stop 4: Chenal Ridge Now we drive past the University and west to Chenal ridge. The University owns land on the top of “Peregrine Heights Subdivision” which once was a quarry! Name the rocks found in the quarry (THERE ARE SEVERAL!) and describe their metamorphic grade (page 11) and parents (Appendix II). The metamorphic conditions must be constant at a SINGLE spot—differences in rock type are due to different parents, not to different metamorphic conditions. Why are some of these rocks strongly and some weakly foliated?

Differences in rock type are due to different parents, not to different metamorphic conditions.

Stop 5: Tungsten Hill Your TA will now drive you back through town to the Steese Highway. You proceed up the hill toward Fox, turn right onto Gilmore trail, and drive up to Tungsten Hill. It’s called that because Tungsten was mined here during WWI and WWII. There are lots of road cuts on the way, and you stop enough to recognize that they’re loaded with amphibolite-facies metamorphic rocks. Tungsten Hill itself, however, is different.

The original rock package present here at the “Spruce Hen” Mine (Fbx 15) is different from that at Approach Hill. In particular, it contains a number of marble beds. Metamorphism of a limestone by hot fluids derived from nearby granite plutons produces a rock called “skarn”. (Which is – I kid you not – from the old [medieval] Swedish for “excrement”). These rocks contain garnet, so it is clear that they formed at elevated temperature. Based on their textures, did these rocks form under conditions of high pressure? Why or why not? What does this say about the metamorphism?

Low pressure: it was under high pressure – it would be more compact

Stop 6: Pedro Creek Wowed by all these fabulous metamorphic rocks, you get back on the Steese Highway and continue on toward Fox. Take a right and head toward Cleary Summit. Then you stop at upper Pedro Creek, get out, and bushwhack a kilometer through the bushes and float of amphibolite facies rocks, cursing your TA. At last a new rock type appears!! Welcome to Fairbanks!! There are blobs of these found throughout the amphibolite-facies metamorphic rocks. They look granitic, but the texture says “No Way!” [To remind you of what a coarse-grained granitic rock looks like, we’ve put out several examples to compare with these metamorphic rocks.]
Name this rock, describe the texture, and describe the parent rock.

Granite

Why do these rocks look so different from the amphibolite facies rocks on top of Chena Ridge??

Stop 7: Marshall Dome Last stop! You get back onto the Steese Hwy. and drive north, past Cleary Summit and Pedro Dome. You descend down the ridge, examining medium-grade rocks in the road cuts along the way. Instead of turning east and driving down the Steese toward Chatanika, your TA drives north along a small, steep, windy, dirt road. Well, you think it’s dirt, under all the snow and ice. Scary driving! Good thing this is only a virtual field trip! At last you stop, and your pale-looking TA shows you an outcrop of yet another rock type. There are pyroxenes in this rock – a variety called jadeite. Use Table 3 and your mineral flowchart to name the rock and identify some other minerals present.

Jadeite is a rather unusual form of pyroxene. In fact, its presence tells us that these rocks were subjected to very high pressures of ~14 kilobars (bottom, last page of lab). How many kilometers below the surface do you need to bury a rock to build up this much pressure? ____________ kilometers.

Now find the name of the metamorphic conditions expressed by this rock (right, page 4). What does the ‘c’ stand for in the label “Pze” on your geologic map (page 10)?

Eclogite

There are two unusual aspects to these rocks.

One is the metamorphic conditions they’ve experienced. How are these unusual? (right, page 4).

Much higher pressures, lower temps.

The other unusual aspect is that they sit on top of the nearby amphibolite facies rocks. Assuming that the amphibolite facies rocks formed under ‘normal’ metamorphic conditions, how much higher pressure did these rocks experience?

Much higher pressure?

How many kilometers OUGHT to separate these rocks from the amphibolite facies rocks? ____________ km.

What’s wrong in this picture???

They are right next to each other and they should be separated.

Yikes! Now you’re really weirded out. You run back to the van, dragging your TA after you, and drive as fast as you can back to the good ol’ Duckering outcrop.

While on the trip or once you ‘get back’, be sure to fill in data for at least 5 of the rocks you’ve seen on the field trip on Table 3.

Jot down notes here about what you liked and disliked about this lab exercise.
Simplified geologic map showing locations of stops for Metamorphic Virtual Field trip.
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Attachment G

Assessment Report for ATM 101X, Weather and Climate of Alaska

1 INTRODUCTION

1.1 Course Goals

The overall goal of ATM101 “Weather and Climate of Alaska” is to provide students with an intellectual comfort with one of the sciences that contributes to the foundation of skills and knowledge that, when combined with their specific degree requirements, educates them for life. ATM101 provides an introduction to the meteorological processes that underlie the Earth’s weather and climate with an emphasis on how these processes occur in Alaska and impact Alaskans. A student who successfully completes ATM101 should acquire;

i. an understanding of and familiarity with the fundamental scientific principles that underlie atmospheric phenomena

ii. an understanding of and familiarity with the framework in which science explains weather and climate and how research on weather and climate is conducted

iii. an understanding of and familiarity with the ways in which weather and climate research address contemporary societal questions and how this research is used in the development of public policy.

iv. an understanding of and familiarity with the characteristics of weather and climate of Alaska and how that compares and contrasts with global weather processes.

The class syllabus conveys the expectations of student learning (Attachment 1).

1.2. Course Organization

ATM101 is taught each spring by David Atkinson or Richard Collins. Atkinson teaches the course in the odd years (05, 07, …) and Collins teaches it in the even years (06, 08, …). Atkinson and Collins coordinate their teaching so that the objectives and basic curriculum are invariant from year to year, though the personalities and teaching styles vary with instructor. The materials presented here pertain to the 2006 class that was
taught by Collins. The class is also supported by a graduate teaching assistant, who is enrolled in the atmospheric sciences program. In spring 2006 the graduate assistant was Brentha Thurairajah.

The course has a three-hours of lecture (TR) and a three-hour laboratory session. The laboratory sessions were scheduled for evening (M) and afternoon (T) and the students could choose to attend either session. The graduate teaching assistant from the atmospheric sciences program conducted all of the laboratories. The instructor attended occasionally, based on the complexity of the laboratory. The laboratory assignments include both an exercise to be completed during the laboratory session as well as homework questions based on the laboratory that are to be completed during the week. A laboratory report is due the following week that includes the result of the laboratory exercise and the attempted homework problems. The laboratory attendance was recorded for each laboratory. There is a weekly quiz, 10 multiple-choice questions, at the beginning of class at the start of the week (T) that is based on the previous week’s laboratory and lecture material. The laboratory material and results was integrated into the lecture discussion at the end of each week (R). There were three exams (two interim and one final). The three exams are written in the same style (i.e., four questions, each addressing a topic, composed of several sub questions). The weekly quizzes and labs let the instructor keep track of class attendance and follow-up students who miss a quiz or lab to see if they are doing okay.

One grading element of the class is called the participation score that constitutes 5% of the final grade. A student scores the full 5% for attempting all labs, quizzes and exams (i.e. attempting a complete body of work for the semester). The goal of this is to recognize students who are committed to the course but may not necessarily score well on all tests and quizzes. For each piece of work not attempted 0.5% is removed. A student who missed 10 pieces of work gets no participation grade. Collins has successfully used this grading element in teaching undergraduate engineering courses. It allows the instructor recognize participation and effort without having to factor in whether students are shy or extroverted. The participation score reduces the sensitivity of the final grade to poor performance on a given day due to life events (e.g., had a bad day on that quiz day, seasonal affective disorder, missed quiz due to car problems, etc.).
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effect the participation grade results in borderline students (e.g. D+) receiving the next higher grade (C-).

Three guest lecturers were invited as professional experts in their field to discuss Principles and Practices of Weather Forecasting (Eric Stevens, National Weather Service Fairbanks), Climate of Alaska (Martha Shulski, Alaska Climate Research Center, UAF), and Arctic Climate Impact Assessment (John Walsh, International Arctic Research Center, UAF). The guest lecture material was integrated into the curriculum (i.e., in classroom discussion, quiz and exam questions).

Five students agreed to have their exams, quizzes, and laboratory reports copied by the instructor. Of these five students, two earned an A, two earned a B, and one earned a C. Examples of specific student responses are taken from this sample of student work.

1.3 Student Population

A variety of students take ATM101 as a core requirement for their major. We tabulate the major and class rank of the 13 students who completed the ATM101 (Two students appeared on the final roster as having withdrawn) in Table 1. The students ranked from Freshman to Seniors and had a majority of non-science/engineering majors (77%). All 13 students were seeking degrees.

2 ASSESSMENT OF COURSE SUCCESS

We evaluate the success of the course using the following; (i) Student grades, (ii) Exercise on flawed experiment, (iii) Science and society essay, and (iv) Exit survey. We present the results in Section 2 and discuss these results in Section 3.

2.1 Student Grades

Of the 13 students registered for the course, nine students (i.e., 69%) passed (i.e., received an A, B, C or D). Of the four students who received an F, none of them attempted the final exam, two of them attempted the second midterm exam, and three of them attempted the first midterm exam. Of these students, three attempted four or less of the thirteen quizzes and handed in none of the laboratory reports. These three students had effectively dropped the class. This group of four included two Freshman and two Sophomores. One of the four one was a science/engineering major and three were not.
We tabulate the final grade and class standing of the 13 students who completed the ATM101 in Table 2. The average final grade tends to increase with class standing. We calculate the average grade in two ways;

(a) by including all the thirteen students who were registered for the class and

(b) by including only those nine students who passed the class.

We plot these results as a horizontal bar chart, showing final grade as a percentage of each class, in Figure 1. Clearly the variation with class rank is reduced when only passing grades are considered. However, the overall trend remains the same that grade improves with class standing. All of the students who earned an F were sophomores and freshmen. All the students who earned an A were sophomores, juniors and seniors. Overall the students in the class either received a solid passing grade (A, B or C) or failed the class (F), no student earned a D.

The 13 students in the class had 10 declared majors. For the purposes of comparison we group them as into three categories with similar numbers of students (i.e., Arts and Business (AB), General Studies (GS), and Science and Engineering (SE)). We calculate the average grades as average for all students, and average for passing students as we did earlier in Table 2. We tabulate these results in Table 3. SE majors appear to earn the highest grades. We find that the variation of average grade with major decreases when the only passing grades are included in the average grade.

Collins had attended the session “Gender Issues in Science and Educations” at the Winter Meeting of the American Association of Physics Teachers in Anchorage in January 2006. At the session data had been discussed that indicated that students performance in different styles of testing correlated with their gender (e.g., male students score higher on multiple choice tests while female students score higher with full-problem tests). Of the thirteen students in the class seven were female and six were male. Cindy Fabbri of the School of Education recommended that the course employ a variety of testing styles to ensure fairness in grading. We explore the contribution of different components of the class (i.e., laboratory, quizzes and exams) to the final grade. The laboratory reports were completed as homework problems, the quizzes were multiple choice, the exam questions were a mix of multiple choice, interpretation of graphed data, and full-problem questions (Attachment 2). We plot the average scores in the labs,
quizzes and exams as a function of final grades for the nine students who passed the class in Figure 2. Generally students scored highest in laboratory exercises, next highest in the quizzes, and lowest in the exams. The students who earned A grades scored higher in all three areas than those who earned B grades. The same is true for students who earned B grades relative to those who earned C grades. There does not seem to be any systematic difference in performance between different components of the curriculum. Representative examples of work are included (Attachment 2).

Finally, we explore the role of class participation in the final grade. We quantify the participation by the students using the 5% participation score discussed in section 1.2. We tabulate the final grade and participation grade of the 13 students who completed the ATM101 in Table 4. Clearly the students who earned the highest grades submitted complete bodies of work (i.e., a participation score of 5.0) during the semester, and the students who failed the course submitted the least complete bodies of work. We tabulate the student class standing with the participation grade in Table 5. We see that all seniors and juniors submitted complete bodies of work. The students who submitted incomplete bodies of work were freshmen and sophomores. This pattern, where upper classmen generally complete more of their class assignments, is also reported in studies of other core science courses (e.g., GEOS 101 “The Dynamic Earth”). We plot these results as a horizontal bar chart, showing participation score as a percentage of each class, in Figure 3. We tabulate the student major with the participation grade in Table 6. We see that the majority of students (>60%) in all majors submitted complete bodies of work.

2.2 Examination of a Flawed Experiment

This assignment was intended to assess the ability of students to critically analyze experimental data and the consequences of interpreting this data. The students were presented with two graphs from an experiment that examined how the temperature and volume of a fixed mass of air varied with pressure. This experiment was similar to one they had studied in the laboratory and explored key topics about the properties of gases that they had employed in discussing the cooling and warming of air as it rises and falls, cloud formation, and rainfall during the semester. The laboratory handout is reproduced on the next page. The data has an error in the temperature and volume measurements, where at high values of pressure the measurements got stuck at a value and no further
variation (i.e., \textit{temperature} no longer decreased, \textit{volume} no longer decreased) was recorded. The students were required to study the data, through a series of five questions, address the following areas;

a. Identify what they thought might be incorrect in the data from their knowledge of gases and experimental methods.

b. Identify how conclusions based on the wrong data could result in erroneous ideas about meteorology.

c. Compare the erroneous ideas in (b) with their knowledge of meteorological behavior and explain the discrepancies in terms of the true physical behavior of gases.

The laboratory handout is included (Attachment 3).

The students conducted this exercise as the final laboratory report of the semester. The students had two weeks to complete the exercise. The exercise was introduced and discussed during a lab session. All nine of the students who passed the class attempted this exercise. Seven of these nine students (89\%) identified the error in the data and attempted to discuss it in terms of gas behavior and experimental methods (area a). These seven students scored over 50\%. Two of the nine students did not and scored less than 50\%. Four of the seven students successfully addressed how the conclusions based on the erroneous data could result in erroneous ideas about meteorology (area b), and reconciled these errors in terms of their understanding of gas behavior and correct meteorological behavior (area c). These four students scored over 75\% on the exercise.

There was no simple direct correlation between the score on this exercise and the final grades of the entire class. One student who earned a C in the course scored 75\% in this exercise, while the four students who earned A grades, scored between 50\% and 83\% on this single exercise. Representative examples of responses from this exercise are included (Attachment 3).

\section*{2.3 Essay on Science and Society}

An essay was assigned as part of the final laboratory report of the semester with the exercise on the flawed experiment. The students had two weeks to complete the exercise and submit a two-to-three page essay. The essay question is posed below. While the students were not given a formal rubric, the expectations of the essay were discussed
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when it was assigned and again one week before it was due. The students were asked to
draw on and refer to the textbook and the guest lecture by Dr. Walsh as their primary
sources and encouraged to examine other sources (e.g., a cover article had recently
appeared in Time magazine, internet sources).

All of the nine students who passed the class attempted this exercise. All the students
made the effort to type the essay. The essays fell in three broad categories;

i. The student clearly identified the scientific questions, discussed societal
   impacts, and referred to identifiable sources (5 students).

ii. The student made more general statements the scientific questions, societal
    impacts, and identifiable sources and was less careful in referencing the
    sources (2 students).

iii. The student made general statements without substantiating them (2 students).

There is no obvious correlation between the score on this exercise and the student
major. There was no obvious correlation between the score on this exercise and the final
grades of the entire class. One student who earned a C in the course scored 85% in this
exercise, while the four students who earned A grades, scored between 80% and 85% on
this single exercise. Representative examples of responses from this exercise are
included (Attachment 4)

ESSAY

We often hear statements of the following type

"There are disconnects between scientific evidence and public policy or
public behaviour in our society"

with regard to public health, education, and environmental issues. Describe how these
disconnects are evident in terms of scientific understanding of climate change and
public policies about climate. Include a synopsis of some relevant scientific evidence.
Overall to what extend do you think that science is divorced from public policy and
societal problems? Is this good, bad, or simply unimportant?

2.4 Exit Questionnaire

We spent a half-class session in the second last week of the semester discussing the
class with the students. At the end of the discussion we distributed the IAS sheets. The
following week we distributed the questionnaire shown below in class (Attachment 5).
This questionnaire was modeled after that used in GEOS 101 “The Dynamic Earth”
UAF Core Curriculum in the Natural Sciences and its Assessment

which had been provided by the L Duffy, Associate Dean of the College of Natural Science and Mathematics. Eight students completed the questionnaire and returned it anonymously at the end of the class period. These students were eight of the nine students who passed the class. We present a summary of the results in Figure 4.

In summary all eight students agreed (i.e., “strongly agreed” or “agreed”) that ATM101 had improved their scientific knowledge (Q1), 75% agreed that it had improved their understanding of how scientists conduct investigations (Q2), 75% agreed that it had improved their ability to understand science in the media (Q3), less than half, 38%, agreed that it had improved their ability to understand how science impacts policy (Q4), only 25% agreed that it had increased their desire to learn more science (Q5), and 88% agreed that the course was useful (Q6). The results of the questionnaire indicate that the students found the class useful but did not increase their desire to learn more science. Less than half the students agreed that the course helped them better understand the role of science in public policy (Q4).
ATM101 Weather and Climate of Alaska

Exit Questionnaire for UAF Core Curriculum

Spring 2006

ATM 101 fulfills UAF requirement of a core science class with lab. In order to assist the Atmospheric Sciences Program improve our delivery of science courses and to assess the role that science courses play in the general core curriculum, we would appreciate it if you completed the following questionnaire. You are welcome to add any comments in the space below the questions.

Thanks for your participation and good luck in life after ATM101.

Richard Collins
Associate Professor

------------------------------------------------------------------------------------------------------------------------------

EXIT QUESTIONNAIRE

Please read the following statements and indicate your level of agreement;
  1 Strongly Agree, 2 Agree, 3 Neutral, 4 Disagree, 5 Strongly Disagree

1. ATM 101 increased my knowledge of atmospheric science and meteorology.

2. ATM101 improved my understanding of how scientists conduct investigations.

3. ATM101 improved my ability to understand scientific information presented in the media.

4. ATM101 improved my ability to understand how scientific information contributes to public policy.

5. ATM101 gave me an increased desire to learn about science.

6. Overall, what I learned in ATM101 will be useful to me.

------------------------------------------------------------------------------------------------------------------------------

3  SELF-ASSESSMENT

3.1 Discussion of Assessment Data

One of the first things to note is the small number of students in ATM101 and that the statistics should not be over-interpreted. However, we note the following general patterns;

a. Upper classmen generally earned higher grades on average than lower classmen.

b. Students enrolled in science and engineering programs earned higher grades on average than students enrolled in non-science and engineering programs.

c. Students who attempted all the work earned higher grades than those that did not.
UAF Core Curriculum in the Natural Sciences and its Assessment

d. Students felt the course was useful to them but did no feel that the course did a
great job of relating science-to-society and did not draw them into studying more
science.

Results (a), (b), and (c) are not surprising. Students typically improve their class
taking skills as they advance in class standing (i.e., result a), students with stronger
science backgrounds would have a stronger foundation for the course (i.e., result b), the
exam materials followed the quiz and laboratory material and so students completing a
full body of work would both accumulate more credit as well as reinforce concepts for
the exams (i.e., result c). A more critical assessment of the performance of lower
classmen results if we consider that the four students who failed the class were freshman
and sophomores. Thus of 15 sophomores and freshman 27% failed the class.

Result (d) raises a variety of questions. While it is gratifying to have students feel the
course was useful, in 2006 it did not achieve one of its declared outcomes of giving
students an understanding of the relationships between scientific information and
development of public policy (Section 1.1). We discuss this issue further in Section 3.4.
The fact that the course does not increase students desire to learn more science is open to
a variety of interpretations. At this stage we conclude that the students who were not
science majors are established in their majors and taking the class as a core curriculum
requirement regardless of their particular interest.

UAF, like most universities recommends, that students take undergraduate core
courses while they are lower classmen. Our experience in ATM101 shows that these
students do not perform as well as upper classmen. We have given some thought on how
to make ATM101 more “freshman-friendly and -interesting”, these include:

i) Improving the requirements for mathematical calculations and exercises

ii) Providing more tutorial support for computer exercises

iii) Reviewing and rescheduling the laboratories

iv) Introducing perspectives from Alaskan Native knowledge

v) Presenting the course material following contemporary “critical thinking”
methods

vi) Incorporating student interests in curriculum choices

We discuss our strategies for implementing these improvements in the following sections.
UAF Core Curriculum in the Natural Sciences and its Assessment

3.2 Background Requirements and Basic Skills

3.2.1 Mathematical Skills

Several students expressed concerns about the mathematical skills required for the course. We reviewed the laboratory reports and intend to present the worksheets with more structured step-by-step calculations. We feel this would reinforce mathematical skills and also make the “math equation-science principle” connections more explicit for the students. In May 2006, Atkinson and Collins met with Debra Moses of Developmental Mathematics to discuss these issues. She suggested that the current catalog prerequisite requirement “High-school level mathematics” could be better restated as “Grade C or better in DEVM 060 or DEVM 062; or appropriate placement test scores”. Moses also provided Atkinson and Collins with an instructor’s copy of “Introductory Algebra: A Real-World Approach” by I. Bello, McGraw Hill, 2006 to use as a template for the laboratory worksheets. We intend to revise the catalog description and redesign the laboratory handouts.

3.2.2 Computer Skills

ATM101 has a variety of laboratory computer exercises and the textbook comes with an interactive CD. While the laboratory provided software packages that were self contained, the reports required students to plot and graph their results. The instructors assumed that students had access to and experience with plotting packages (e.g. Microsoft Excel®) as had been implicitly assumed in earlier years. In retrospect, this was probably an incorrect assumption. Several students struggled with the data exercises. In future we will integrate a formal “plotting and graphing” tutorial into the first laboratory session, so that all the students feel they are starting with the same computer skill set. Moreover, the students will find these basic skills useful for data manipulation in other classes.

3.2.3 Laboratory Review

During the summer of 2006, we had a student review several of the laboratory exercises. Eliah Kagan (hosted by the Geophysical Institute’s Research Experience for Undergraduates Summer Program, Funded by the National Science Foundation) critically reviewed the ATM1010 laboratory exercises. The summer review allowed Kagan, a junior in physics at Syracuse University, to comprehensively review and update the materials (many of which only existed as hardcopy and not electronically).
UAF Core Curriculum in the Natural Sciences and its Assessment

reviewed the exercises for scientific content, overall coherency and consistency, and “freshman-friendliness-and-appeal”. At the end of the summer, he provided us with a comprehensive package of the laboratories, with updated materials, and a critique of the labs from the perspective of a student. We will use this package as the foundation of the labs in future semesters.

In Spring 2006, the lectures were scheduled on Tuesday and Thursday afternoon, and the laboratory sessions were Monday evening and Tuesday afternoon. We think it would be better if both the laboratory sessions were scheduled after the lecture during the week. In that way, the material for each week would be introduced and discussed in the lecture before the laboratory exercises. The laboratories are carried out in the laboratories of the physics and chemistry departments. This rescheduling will require coordination with both the chemistry and physics department.

3.3 Alaska Native Knowledge

Environmental researchers are increasingly aware of the importance of Native Alaskan perspectives in understanding the environment. Atkinson and Collins feel that ATM101 has the potential to expose UAF students to these perspectives which represent a uniquely Alaskan view of weather and climate. In the spring 2006 semester Collins gave each student a copy of “The Earth is Faster Now: Indigenous Observations of Arctic Environmental Change” by I. Krupnik and D. Jolly, Arctic Research Consortium of the United States, 2002 and discussed some of the issues raised in the book concerning the role of indigenous communities as partners in the conduct of scientific investigations.

However, we wish to develop a component for ATM101 that would expose students to these perspectives more deeply. In May 2006, Atkinson and Collins met with Raymond Barnhardt of Cross-Cultural Studies to discuss these issues. Barnhardt provided us with several CDs (i.e., “Observing Snow”, Alaska Native Knowledge Network Science”, “When the Weather is Uggianaqtuq”) and discussed several texts (i.e., “Watching Ice and Weather Our Way” by C. Oozeva, C. Noongwook, G. Noongwook, C. Alowa, and I. Krupnik, Smithsonian Institution, 2004, “The Arctic Sky: Inuit Astronomy, Star Lore and Legend”, J. McDonald, Nunavut Research Center, 1998) which we are reviewing for integration into the course.
3.4 Critical Thinking

Both Atkinson and Collins have been concerned that teaching ATM101 could turn into “freshman physics and chemistry-lite” as the instructor would feel the need to cover a foundation of “fundamental scientific concepts” before progressing to the “weather and climate” material. This traditional approach reflects the way in which the atmospheric sciences program is structured as a graduate program at UAF that attracts students with undergraduate degrees in science and engineering. However, this hierarchical approach is not necessarily appropriate for an undergraduate class like ATM101. In spring 2005 and 2006, Atkinson and Collins attended the workshops on “Designing Courses for Critical Thinking” with Bill Robertson and Christine Reimers of the University of Texas. Joy Morrison of UAF Faculty Development arranged and hosted these workshops on the UAF campus.

Based on those workshops, we intend to restructure the way in which material is presented in ATM101. We will develop a “data and observation-driven” approach that starts the discussion of phenomena from an observation (e.g., the vertical temperature or pressure profile) and draws the students into the discussion of the underlying physical principles that draws from their current experience and knowledge base. We think this is an important element in providing opportunities for success for freshman- and sophomore-level students. This approach also allows students to engage the class as novice scientists rather than students who need to learn a heap of classical science and math before they can explore weather and climate. A similar approach is being used in the freshman engineering curricula at UAF, (e.g., EE102 “Introduction to Electrical Engineering” with Denise Thorsen of Electrical and Computer Engineering) where the students explore engineering from a guided engineering design approach rather than immediately being presented with a semester of underlying mathematics and physics principles that are detached from a specific engineering project.

The Examination of a Flawed Experiment (Section 2.2) is a critical thinking exercise. The exercise was assigned at the end of the semester. On reflection, we feel that this exercise would be better assigned in the middle of the semester after the students had conducted one or two laboratory exercises, and could then applied the lessons they learned from this exercise to later laboratories. In 2005, Atkinson presented a case-based learning module that was designed as a critical thinking exercise. He presented
UAF Core Curriculum in the Natural Sciences and its Assessment

the class with a discussion of the prediction that by the mid 21st century the Northwest passage will remain ice-free in summer due to global warming. Thus a new major sea route from Europe to Asia will become available in the 21st century. He then asked the students, in teams, to write a briefing for policy makers on the environmental and socio-economic impacts of such a change on different Arctic constituencies (i.e., nations, states and indigenous peoples). The briefings were discussed in class. This exercise allowed students consider the pro’s and con’s of a major environmental question and served to give the students insight into how scientific information impacts public policy. Clearly the two exercises have very different styles and we are reviewing both these exercises as part of the integration of critical thinking in the curriculum.

3.5 Student Interests

Atkinson and Collins recognize that weather and climate is a controversial societal issue as scientist attempt to understand the impact of human activities on the Earth’s climate. To get some idea of where ATM101 students were coming from, before being influenced by the course material and instructor, we conducted an anonymous survey on the first day of class that asked a variety of questions about the environment (Attachment 6). We told the students that the survey was not about getting right or wrong answers but about finding out their backgrounds. The overall results are tabulated in Figure 5. Seventeen students returned surveys on the first day of class. In summary we found that:

- 69% disagreed with the statement “The climate of Alaska is not changing” (Q1).
- 94% of the students agreed with the statement “The climate of the Earth is changing” (Q2).
- 38% agreed with the statement “The effects of climate change are more pronounced in Alaska than elsewhere” (Q10) while 13% disagreed and 19% did not know and
- 35% disagreed with the statement “We can forecast the weather for the winter in the fall” (Q7) while 29% were neutral and 24% did not know.

The statement “The creation of the ozone hole is due to human activity” (Q8) was included to test knowledge of an environmental issue that is scientifically resolved and understood. We found that:

- 50% agreed, while 19% were neutral, 13% disagreed, and 19% did not know.
As we might expect, the percentage of “don’t know” responses increased as the questions became more technical (i.e., “if global warming occurs all parts of the world will steadily warm the same amount” (Q3), “We can accurately forecast the expected weather for the winter in the fall” (Q7), “hurricane activity is increasing due to climate change” (Q11)).

We were also interested in gauging how curious students were about the natural phenomena around them. The students ranked their responses as “often”, “sometimes”, “rarely” and “never”. We found that:

- 71% “often or sometimes” check weather forecasts on the web (Q14)
- 65% “often or sometimes” check weather forecasts on TV or radio (Q15)
- 53% “often or sometimes” check weather forecasts in a newspaper (Q16)
- 57% “often stopped to look at sundogs, haloes and rainbows” (Q17)
- 82% “often stopped to look at the aurora” (Q18)

and

- 18% “often or sometimes” used a weather map (Q19).

The results indicate that over half the students take the time to check weather forecasts and natural phenomena. No student claimed “never” to stop to look at the aurora. However, 6% of the students claimed “never” to stop to look at rainbows and sundogs and to “never” check a weather forecast on the web. The student responses suggest that web dominates as a source of their weather information. Weather maps are clearly considered a specialized reference tool.

In February 2006, Atkinson and Collins met with Cindy Fabbri of School of Education to discuss the survey and suggest modifications. A long-term goal of this survey is to track trends in general understanding of weather and climate. Given our professional interest in examining the survey data over several years, this survey received approval by the UAF Institutional Review Board.

A second goal for the survey was to ask the students what specific topic they wanted covered in the class. This list of responses was presented to the class in the second half of the course as part of a discussion with students about the phenomena we would discuss in the class toward the end of the semester (*Attachment 6*). This approach to topic choice was based on the article “What do introductory meteorology students want to learn” J.A. Knox and S. A. Ackerman, Bulletin of the American Meteorological Society, 2005 and also recommended by Robertson and Reimers. Despite the destruction of New Orleans
UAF Core Curriculum in the Natural Sciences and its Assessment

by Hurricane Katrina in August 2005, no student identified hurricanes as a topic of their interest.

4 CONCLUSIONS

ATM101 could accommodate more than the thirteen students who were registered in Spring 2006. With two laboratory sessions the class could accommodate twice that number within current resources. The fact that seventeen students attended the first class suggests that students are interested in the class and that the enrollment could be increased. Atkinson taught the class for the first time in Spring 2005, and Collins for the first time in Spring 2006. Before 2005 the class had been taught by a variety of instructors due to changes in the atmospheric sciences program faculty. Atkinson and Collins currently plan to develop the class over several years, establish the content and expectation as discussed above, and cooperatively teach it in alternate years. We expect that this process will result in an increase in enrollment.

We would greatly appreciate feedback (i.e., comments and recommendations) from the UAF Senate Committee on the changes we have suggested in section 3.

5 ACKNOWLEDGEMENTS

The laboratory exercises in ATM101 are conducted in the Chemistry and Physics Departments. We gratefully acknowledge the repeated assistance of Marlys Schneider and Sheila Chapin of Chemistry and Robert Parsons and Mary Parsons of Physics during the semester. We thank Patrick Cotter of the Geophysical Institute for assistance in using the walk-in freezer at the Geophysical Institute. We thank Elaih Kagan for his energetic and enthusiastic review and revision of the laboratories. We thank Barbara Day of Atmospheric Sciences for assistance in the preparation of this report. We thank Nicole Mölders, of Atmospheric Sciences for her careful review of this report. The Office of Faculty Development provided partial support for Collins to attend the Meeting of the American Association of Physics Teachers in Anchorage in January 2006.
## TABLE 1: Composition of ATM101 Spring 2006

<table>
<thead>
<tr>
<th>MAJOR</th>
<th>Non-Degree</th>
<th>Freshman</th>
<th>Sophomore</th>
<th>Junior</th>
<th>Senior</th>
<th>Total</th>
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</thead>
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<td><strong>Total</strong></td>
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<td>5 (38%)</td>
<td>6 (46%)</td>
<td>1 (8%)</td>
<td>1 (8%)</td>
<td>18</td>
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</table>

**TABLE 2: Grade Distribution with Class Standing**

<table>
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<th>GRADE</th>
<th>Class Standing</th>
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<th>Sophomore</th>
<th>Junior</th>
<th>Senior</th>
<th>Total</th>
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<td>1</td>
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<td>0</td>
<td>0</td>
<td>3</td>
</tr>
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<tr>
<td>F</td>
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<td>4</td>
</tr>
<tr>
<td><strong>Average</strong></td>
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<td>2.2/3.2</td>
<td>4.0/4.0</td>
<td>4.0/4.0</td>
<td>4.0/4.0</td>
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<tr>
<td><strong>Total</strong></td>
<td>0 (0%)</td>
<td>5 (38%)</td>
<td>6 (46%)</td>
<td>1 (8%)</td>
<td>1 (8%)</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

*Average grade is presented as G1/G2 where G1 includes all grades and G2 includes passing grades only.

**TABLE 3: Grade Distribution with Major**

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<th>GRADE</th>
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<th>SE</th>
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<td>3</td>
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<tr>
<td><strong>Average</strong></td>
<td>2.2/2.8</td>
<td>2.0/3.3</td>
<td>2.7/4.0</td>
</tr>
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</table>

1. AB: Arts and Business – BADM, FORL, JUST, MUSI, PSYC
2. GS: General Studies – GENP, GENR
3. SE: Science and Engineering – APHY, CHEM, XCSC
4. Average grade is presented as G1/G2 where G1 includes all grades and G2 includes passing grades only.
### TABLE 4: Grade Distribution with Participation Score

<table>
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<th>GRADE</th>
<th>PARTICIPATION SCORE$^1$</th>
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<tr>
<td>D</td>
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<td>0</td>
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<tr>
<td>F</td>
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<td>1</td>
<td>3</td>
<td>4 (31%)</td>
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<tr>
<td>Total</td>
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<td>8 (62%)</td>
<td>1 (8%)</td>
<td>1 (8%)</td>
<td>3 (23%)</td>
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</tr>
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</table>

$^1$ Maximum participation score is 5 representing a complete body of work. A score of 3.5 represents 3 pieces of work not submitted. A score of 1.0 represents 8 pieces of work not submitted. A score of 0.0 represents 10 pieces of work not submitted.

### TABLE 5: Class Standing and Participation Score

<table>
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<th>GRADE</th>
<th>PARTICIPATION SCORE$^1$</th>
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<th>1.0</th>
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<th>Total</th>
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<td>Junior</td>
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<tr>
<td>Total</td>
<td></td>
<td>8 (62%)</td>
<td>1 (8%)</td>
<td>1 (8%)</td>
<td>3 (23%)</td>
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$^1$ Maximum participation score is 5 representing a complete body of work.

### TABLE 6: Major and Participation Score

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<th>MAJOR</th>
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<td>SE$^3$</td>
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<td>0</td>
<td>3 (23%)</td>
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<tr>
<td>Total</td>
<td></td>
<td>8 (62%)</td>
<td>1 (8%)</td>
<td>1 (8%)</td>
<td>3 (23%)</td>
<td></td>
</tr>
</tbody>
</table>

$^1$ AB: Arts and Business – BADM, FORL, JUST, MUSI, PSYC  
$^2$ GS: General Studies – GENP, GENR  
$^3$ SE: Science and Engineering – APHY, CHEM, XCSC  
$^4$ Maximum participation score is 5 representing a complete body of work.
UAF Core Curriculum in the Natural Sciences and its Assessment

7 FIGURES

Figure 1: Distribution of Final Grades with Class Standing.

Figure 2: Distribution of Passing Final Grades with Quiz, Lab and Exam Scores.
Figure 3: Distribution of Participation Score with Class Standing.

Figure 4: Results of Exit Questionnaire.
Figure 5. Results of Interest Survey.
MEMO
19 May 2009

To:   Associate Prof. Richard Collins
From:  John Craven, CNSM Associate Dean
Copy:  Prof. Nicole Mölders, Chair, Dept. of Atmospheric Sciences
       Interim Dean Paul Layer
       Submitted SLOA report file

Subject: Comments on your SLOA report for ATM 101X, Spring, 2006

The College of Natural Science and Mathematics is in the processing of implementing improvements to its handling of faculty reports for Student Learning Outcomes Assessment (SLOA) in the UAF Natural Sciences Core. You are an early recipient of this added attention.

Reading your report and those submitted by other course instructors allows me to gain useful insight into the various ways course instructors are confronting the assessment requirements and to see if the general intent of the assessment program is being respected. What you will see in my attached comments is my general overview from reading your report, with particular attention to your recommendations for course improvements. Experience so far suggests that my enthusiasm leads me to consume up to three pages.

Another motivation for this effort is to help maintain visibility for the most important points derived from each course assessment so that future instructors can more easily benefit from your assessment. Further, these important points can be recalled five years hence at the next assessment of the course (or its equivalent) to see if the lessons learned have been taken to heart and the course improved. After all, such outcomes are at the heart of the assessment activity. These points may also be of assistance to the department when next preparing materials for the department’s full program review.

As noted above, I am also sending a copy to your department chair (with the hope that all SLOA reports become subjects of faculty discussion) and I am inserting a copy in the submitted SLOA file. Your assessment of this activity and my comments are welcome, and can also be included with the original report if you wish.

Again, thank you for your timely participation in this assessment activity.
UAF Core Curriculum in the Natural Sciences and its Assessment

UAF Natural Science Core Assessment for
ATM 101X,   Weather and Climate of Alaska,  Spring, 2006
Instructor: Associate Prof. Richard Collins

Notes by John Craven, Associate Dean, CNSM (19 May 2009)

Course Goals: “…ATM 101 provides an introduction to the meteorological processes that underlie the Earth’s weather and climate with an emphasis on how these processes occur in Alaska and impact Alaskans….”

The report on Student Learning Outcomes Assessment (SLOA) for ATM 101X (spring 2006) is provided in four sections, followed by tables, figures, and numerous attachments. It demonstrates that ATM 101X is engaged in the spirit of the Natural Science Core and its requirements.

I. Introduction
The report begins by stating the course goals and provides a useful discussion of the course structure and how it is implemented. The course comprises three hours of lecture and three hours of lab per week, with two available lab sessions that are led by the same graduate TA. A lab includes exercises to be completed during the session as well as homework questions and a laboratory report for later delivery. Lectures include one quiz per week (10 multiple choice questions) that is based on the previous week’s lab and lectures. There are two exams in the semester plus the final exam. Three guest lecturers participated during the semester with subject material that was then “integrated into the curriculum.” Class and lab participation (5 percent of total) is included in the grading system using a clearly defined method. Final enrollment comprised 13 students, with 10 from non-science/engineering majors. For each major classification, only one from each was not a freshman or sophomore; 84 percent were freshmen or sophomores. A detailed syllabus is provided. Attendance is listed as mandatory.

II. Assessment of Course Success
The methods for assessing student successes were grades, exercise using a flawed experiment, an essay on science and society, and the required survey (all per requirements of the Natural Science Core). From the syllabus, 50 percent of the final grade was based on the two exams (10 percent each) and the final exam (30 percent). Quizzes were worth 15 percent and labs 30 percent. The two written exercises were included within the lab grade. Participation was 5 percent. The course did not assign homework in the traditional sense. Four students (freshmen and sophomores) failed the course (grade of F); none attempted the final exam and they demonstrated other traits not consistent with success. No D grades were assigned. Grades improved with class standing. The number of students with grades of A, B, and C were 4, 3, and 2, respectively. The small sample made an analysis of grades and major areas unreliable. There was a nice effort to see if students scores were affected by different methods of participation; lab, quiz, or exam. No obvious difference was reported; e.g., those whose final grade was A gained the higher scores in the three modes of participation. As to overall participation, the juniors and seniors completed all work, while the freshmen and
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sophomores did not. [Note; this increased level of achievement with class rank has been noted elsewhere for some courses, but not for all courses.]

Students were challenged with a set of intentionally flawed data as part of the last lab session and asked to consider the data in light of what they had learned in the semester about data analysis and the behavior of ideal gases. The objective was to critically analyze the data and identify the error(s) in part through answering a series of questions. The syllabus states that the lab portion of the course would provide some training in data reduction but no examples are provided in the report as to how this was done during the semester. Of the nine students who passed the course, it appears as just more than half really understood the error and its potential consequences for meteorological “behavior.” There is little in the way of correlation between final grades and the outcome of this exercise, but again the sample size was small. No opinion is provided as to the outcome versus any expectation of outcome; e.g., was this degree of success considered acceptable and if not what could be done to improve it in the future?

To satisfy the “Science and Society” portion of the Natural Science Core, the students were asked to write a two-to-three page essay related to the last lab’s subject area on climate change and the infamous “hockey stick” diagram of Northern Hemisphere temperature versus time. The question posed were based on the statement “We often hear statements of the following type: ‘There are disconnects between scientific evidence and public policy or public behaviour in out society’, with regard to public health, education, and environmental issues.” The students were given a clear set of instructions as to the assignment’s objectives. The nine students who passed the course submitted essays and five apparently did a good job of meeting the assignment’s objectives. Was adequate discussion carried out in the semester? There is no discussion as to how issues of “science and society” were integrated into the course.

Eight students completed the standard Natural Science Core questionnaire at the end of the semester. A clear majority found the course helpful in improving scientific knowledge, how scientific research is done, ability to understand reports in the media, and that it was useful. [Note. This is a rather standard set of responses.] Scoring quite low were the responses relating to public polity and desire to learn more science. [Note. These too are rather common results.]

III. Self Assessment
Dr. Collins provided a lengthy personal assessment of the course. His main points (while noting the low sample size) are:
1. Upper classmen generally earned higher grades on average.
2. Students of science/engineering earned higher grades on average.
3. Students attempting all work gained higher grades.
4. Students found the course useful but the course was not as successful in issues of science-and-society and did not find most students interested in learning more about science.

I generally concur with Dr. Collins, that the first three items are not surprising, but there do exist examples in some courses for which performance is about even across all class ranks and where the science/engineering students are not the best performers. Dr. Collins
states that the course did not attain its objectives with regard to science and public policy. It would have been interesting (again, subject to the small sample size) to see if it was the non-science/engineering students who were the ones underwhelmed with a desire to learn more about science.

Dr. Collins discusses at some length six ways in which the course might gain greater interest with freshmen and sophomores. These include math skills, computer skills, labs, introducing Alaska Native perspectives, critical thinking methods, and inclusion of student interests in curriculum. An increased grade requirement (C or better) or adequate placement test results were recommended externally. The lab materials are to be revised. A tutorial on plotting and graphing using commercial software will be incorporated into the first lab. A summer student was hired to critically review the lab contents and prepare updated materials; i.e., fresh eyes on the material and more of a student’s perspective. Consideration is being given to moving the lab times to follow the two lectures in the week; all lecture material would then have been presented in the week that is applicable to both lab sessions. Under consideration is how Alaskan Native knowledge of the Arctic environment could be integrated into the curriculum. Alternate pedagogical methods are being considered in order to improve critical thinking skills. A questionnaire was created to learn something about the attitude and/or knowledge of students concerning a range of environmentally related subjects. The intention is to use this questionnaire at the beginning of the course for some years in order to “track trends in general understanding of weather and climate.” The questionnaire also asked about subject areas of students for this course. The outcome of this exercise is not presented in the report.

4. Conclusions
Development of the course continues, with Drs. Collins and Atkinson intending to provide strong leadership in this course and to further define it in ways discussed in the report.

My Summary
Drs. Collins and Atkinson are exercising strong leadership in the further definition of this course and seeking pedagogy appropriate for enrolled students. They have identified numerous issues for consideration, so the next review (in the 2010/2011 academic year) will provide an opportunity to assess their efforts. The requested elements of the required assessment in the Natural Science Core are present. A short list of course strengths and weaknesses in the conclusions section is being used effectively in some reports.