GEOL 591: Initial Experimental Design Exercise

Next week we will begin constructing our class experiment, which we will run over the next several weeks. This experiment should elucidate the impact of silicate composition on microbially-mediated silicate weathering. The metal that we will focus on for this experiment is Ni. Ni is needed in great abundance by methanogens to manufacture enzymes required for metabolism, but is known to be toxic to many microorganisms at high concentrations.

Your assignment for this week is to design an experiment that addresses the following research question:

Research Question: How do increases in silicate-Ni concentration impact microbially-mediated silicate weathering by a native, anaerobic microbial consortia?

Expected results:
We expect accelerated dissolution at low Ni concentrations due to high Ni requirements by methanogens. At high concentrations we expect to see a decrease in microbial biomass due to toxic conditions. This decrease in biomass may correlate to a lowered rate of dissolution in anaerobic reactors.

Your design must include:

- A hypothesis derived from the information provided above as well as your perusal of appropriate literature on Ni, silicate weathering, and methanogenesis.
- Variable(s) to be tested
- Controls
- Replicates
- Materials used, including:
    - Cell type and abundance
    - Starting solution composition
    - Composition of silicate
    - Reactor design
- What will be measured and why
- Over what time scale these measurements will be made
- Criteria to judge whether your results truly address the research question

As always, please utilize available literature for background information as well as ideas as to what others have done in the way of experimental design in similar systems and include these in a list of references. Feel free to include diagrams, schematics, charts, etc. that may help you demonstrate your experiment. Come to class on Thursday, September 22 ready to participate in a discussion on your design as well as your classmates designs.

GEOL 591: Proposal for Future Work (250 points)

Now that we have chosen a stopping point for our experiments and presented data from both institutions it is time to: **a)** critically evaluate the experimental design in light of the results produced, and **b)** consider future experiments and results with respect to this body of work. Often researchers will perform a trial experiment in order to trouble-shoot their experiment---for the purpose of this assignment we will treat our class experiment as a trial run. With this in mind, your final project has **two primary goals**:

1. Evaluate the original experimental design in light of results for your particular data set (i.e., KU-anaerobic; AC-aerobic) and make suggestions for improvement.
2. Predict the outcome of both experiments were they to be continued.

Goal #1: Proposal for future experimental design

In the previous assignment you proposed an experimental design from scratch; as such, it was a bit of a creative endeavor. For the final project, you will need to evaluate our existing design and identify what features need to be changed in order to perform a better experiment. You should clearly explain why you are (or are not) making changes, with **direct** support coming from your **data** as well as the **literature**, and how any changes will impact the expected results. Your proposal can include, but is not limited to, changes in:

a. Your research question (*minor changes only*)
b. Your hypothesis
c. Your specific predictions
d. Variable(s) to be tested
e. Controls
f. Replicates
g. Materials used, including:
    i. Cell type and abundance
    ii. Composition of initial solution
    iii. Composition of initial solids
    iv. Composition of initial headspace
h. Methods to measure your variables
i. Sampling frequency
j. Length of experiment

A productive scientist will do an inventory of analytical capabilities at his/her institution and the costs (if any) associated with those analyses. However, there's nothing to prevent you from suggesting we conduct other types of analytical work, provided you have a compelling argument for why those data are important and can identify a facility that can perform the analysis, the approximate cost of the analysis, and a possible funding source to pay for those costs.

Goal #2: Prediction of longer-term biogeochemical changes to the experiments.

No experiment is a lost cause and many trial experiments become brilliant "drawer" experiments. That is, the experiment is put into a drawer and left undisturbed for a period of time after which the researcher makes measurements that may clarify the original data or subsequent experiments. The second part of your proposal should predict results for both KU and AC experiments assuming they are put into a drawer and analyzed **after 6 months and again after 12 months**. You will need to utilize data from both experiments as well as literature from the Bemidji site to predict the outcome of these experiments. Your prediction must address all of the following:

k. Biomass amounts, population succession and geochemical indicators of microbial activity (including inorganic/organic carbon speciation and aqueous metal concentration)
l. Major electron acceptors and donors available and utilized
m. pH
n. Glass weathering
o. Secondary mineral formation

The paper should take the form of a proposal and should be thoroughly referenced to support your choices and predictions. The paper should be 10-15 pages (double or single-spaced as needed, 12 pt. Times New Roman, 1 inch margins) in length and should include a *problem statement, at least three data graphs or tables with captions, and a reference list*. As always, schematics, charts, and diagrams are encouraged as media to describe your design. The final proposal will be due on **Thursday, December 15 at 5pm**. I would prefer that you email your proposal to me at jenrob@ku.edu. If paper is a must, please put the stapled document in my mailbox and send me an email telling me that it's there.

Geo 591 Feedback: Proposal for experimental design

Topic	Comments	Score
Proposal for future experimental design		
Research Question		/125
Hypothesis		
Predictions		
Variables to be tested		
Control(s)		
Replicates		
Cell type and abundance		
Solution composition		
Silicate composition		
Reactor design		
Measured variables (units, expected concentrations, all phases, analytical equipment)		
Sampling procedure		
Frequency of measurement (will there be a lag phase?)		
Length of Experiment		
Figures/tables (Expt'l design, results, others?)		
Support from data and literature		
What would the Devil's advocate say?		
Prediction of Long-term Biogeochemical Changes in Class Experiment		
Biomass Abundance		/75
Population Succession		
Geochemical Indicators		
Redox		
pH		
Glass Weathering		
Secondary Mineral formation		
Support from data & Literature		
General Components		
Problem Statement		/50
Graphs and Tables		
Clarity/style of written description of design		

Format of proposal (title, page #s, organization, references & length)		

Your grade:

Applied Techniques in Geobiology
GEOL 591

Fall Semester 2005
Format: Laboratory sessions, Readings, Lecture, Discussion
Time: T TH 8:30-9:50 pm
Room: 118 Lindley
Instructor: Dr. Jennifer Roberts; 864-4997; Lindley 104
Email: jaroberts@ku.edu
Office hours: T TH 10:00 am – 11:30 am
Line Number: 29628/29629

Course Description: Geomicrobiology is an emerging interdisciplinary field that combines concepts and techniques from microbiology, geology, chemistry, physics, and mathematics. Microorganisms represent a living component of subsurface systems and impact both water and rock through their metabolic processes. This course is an upper-division undergraduate seminar that examines how microbial processes drive dissolution and precipitation of mineral phases. In addition, it provides students with the opportunity to conduct laboratory research on microbially-mediated silicate dissolution. Students will design, execute, and interpret microbial weathering experiments using a systems-based approach and gain experience with appropriate laboratory techniques.

The course will be run concurrently with a companion course at Allegheny College in Meadville, PA taught by Professor Rachel O'Brien. Students are expected to read relevant peer-reviewed literature and texts on biological and chemical weathering of minerals, and will receive supporting lectures on the theory and practice involved in conducting research on how microbes dissolve mineral phases.

Goals
At the end of this course, students should be able to:

1. Critically evaluate proposed and/or published experimental work.
2. Collect, analyze, and interpret data from a research experiment in geomicrobiology.
3. Predict the physical, chemical, and biologic controls in a geomicrobiologic system.
4. Design experiments to investigate the geomicrobiology of an uninvestigated subsurface system.

Prerequisites: Junior or senior status in science major or graduate status in relevant field of science or engineering.

Format and Expectations: The course will consist of a mixture of lectures, readings, writing and laboratory work. The class will perform a group experiment, which will run for 5-6 weeks during the course. Techniques will be introduced during class meetings but the majority of data collection will be done outside of class. Students should expect to spend 8-10 hours per week outside of class working on writing assignments, readings, or collecting and analyzing experimental data. Additionally, there will be a fieldtrip for KU students scheduled for September 23-25, 2005.

Please come to all class meetings with your assigned readings, course notes, lab notebook, and a calculator. All students should have a three ring binder for course readings and handouts. For "data discussion" sessions, come to class with your data and any analysis that you've done as well as notes concerning calibration curves and instrument parameters.

Readings: Readings will be from the following books or will be from selected journal articles. The professor will provide Xerox copies of readings at least one week before they are due. The following texts will be on "reserve" in the instructor's office. They can be checked out for a maximum of 24 hours. If you feel you need a basic reference for Microbiology I suggest that you purchase either the Atlas and Bartha text or the Madigan et al. text. These are available both new and used at www.amazon.com or alternatively you can check them out at the library.

Microbial Ecology: Fundamentals and Applications, (1998) Atlas and Bartha, Benjamin/Cummings, Menlo Park.
Geomicrobiology (2002) Ehrlich, Marcel Dekker, Inc., New York.
Subsurface Microbiology and Biogeochemistry (2001) Fredrickson and Fletcher, Eds., Wiley-Liss, New York.
Ground-Water Microbiology and Geochemistry (2001) Chapelle, John Wiley & Sons, Inc., New York.
Geomicrobiology: Interactions Between Microbes and Minerals (1997) Banfield and Nealson, Eds., Reviews in Mineralogy Vol. 35, Mineralogical Society of America, Washington D.C.
Brock Biology of Microorganisms (2005) Madigan and Martinko, Prentice Hall, Upper Saddle River, NJ.

Grading Scheme:

Lab Reports	20%	Group Presentation of Weathering Experiment	15%
Writing Assignments	30%	Proposal for Future Work (due during final exam week)	25%
Proposal for Experimental Design	5%	Fieldtrip and Report (KU students) Participation in Peer Sessions (AC students)	5%

Each week, students will have either a lab report or writing assignment due. Unless noted by your professor, these are due one week after they are assigned at the beginning of the class period. Weekly assignments are subject to a **20% penalty per day** for each day they are late. Late materials that involve our research experiment (Proposal for Experimental Design, Group Presentation, and Proposal for Future Work) will not receive course credit.

Lab Reports: This will be a short write-up that presents the data collected during the lab with some brief analysis. Your reports should be ~2 pages in length and include professional figures and tables.

Writing Assignments: These are tiered assignments that prompt basic knowledge and synthesis of specific theoretical and practical topics covered in the seminar. These comprise a significant portion of your grade and should be given commensurate effort. Writing assignments have no set

length but should be thoughtful and complete. Resources outside of those presented in class may be necessary and those references must be thoroughly cited.

Proposal for Experimental Design: Students should submit a 1-2 page written document that poses our research question, an experimental method to address the question, and the specific parameters that will be monitored throughout the experiment. This assignment is due on September 22 (no extensions possible) and will be part of our discussion on experimental design for the class experiment.

Group Presentation: The group presentation will be based on data collected for the class experiment run over the course of the semester. Students will be responsible for a portion of the experiment and will collect a complete data set. Data discussion periods will be a venue to discuss that data in preparation for the final presentation. The final presentation must be a group effort that synthesizes all students' data sets and gives a well-supported interpretation of the data. KU students will give a power point presentation and 30-minute oral presentation to students at Allegheny College, while Allegheny students will make a similar presentation to KU students on the data collected over the course of their parallel experiment.

Proposal for Future Work: At the completion of the group experiment data from all students at both institutions will be distributed to everyone. These data will be used to create individual synthesis papers. Each student will use the data set as a platform to design a follow-up experiment. The premise of the experiment must be explained in detail along with the design, parameters measured, resources needed, and time frame necessary. This should take the form of a proposal and should be thoroughly referenced to support your research approach. A testable hypothesis should be presented as well as expected results. The paper should be 10-15 pages in length.

Week	Month	Tuesday	Thursday	Assignment
1	August/ September	30	1 Course Overview Origin/Evolution of Life	Reading: Gould and Gould Writing Exercise #1
2	September	6 Microbes in geologic processes/physiology	8 Scientific method Experimental design	Reading: ASM White paper; Madigan Writing Exercise #2
3	September	13 Microbially-driven silicate weathering	15 The role of pH in silicate weathering	Reading: Barker & Banfield ; Appelo and Postma Design Exercise
4	September	20 LAB 1: Microbial Enumeration	22 Bemidji Overview/ Our experimental approach KU Fieldtrip 9/23-25	Reading: Ruxton Exercise: Lab #1
5	September	27 Construction of microccosms	29 T_0 measurement of pH and biomass	Exercise: Writing Exercise #3 Start Experiment Appelo and Postma

6	October	4 DATA DISCUSSION: Microbial enumeration	6 LAB 2: Headspace analysis	Exercise: Lab # 2
7	October	11 LAB#3: Alkalinity	13 NO CLASS FALL BREAK	Reading: Appelo and Postma Exercise: Lab #3
8	October	18 NO CLASS GSA MEETING	20 DATA DISCUSSION: Gases	Writing Exercise #4
9	October	25 Microbial metabolism/C-cycle	27 Microbial metabolism/C-cycle	Reading: Madigan
10	November	1 LAB 4: Colorimetric analysis	3 DATA DISCUSSION: pH/Alkalinity	Reading: Writing Exercise #5 Exercise: Lab #4
11	November	8 Microbial mediation of redox reactions	10 Microbial mediation of redox reactions	Reading: Appelo and Postma
12	November	15 DATA DISCUSSION: Results & Interpretation	17 Open class for preparation of presentations	
13	November	22 Group Presentations (via teleconferencing)	24 THANKSGIVING	
14	November / December	29 Techniques for identification of microbial communities	1 Layered Communities	Nealson and Stahl; Writing Exercise #6
15	December	6 Course evaluations	8 Proposal for Future Work due 5pm AGU	

Student Consent Form – Sharing Course Work

Once the course is over, Drs. O'Brien and Roberts will select student work to be copied and included in an archive for this course. As educators, this archive is important to us in several ways:

- Reviewing the work will help us reflect on how well students are learning in the course.
- . We often use prior students' work as a point of comment for later students in the course.
- We maintain course portfolios in which we write about the quality of student performance generated in the course. Student work is an important piece of our work that we show to other professors to indicate how much and how deeply students are learning. Once course portfolios are completed, they will also be made available to a wider audience on public web sites on teaching and learning in higher education.
- Drs. O'Brien and Roberts will also use this course and your work as the topic of a research paper on teaching practice in earth science.

This form requests your consent to share your work with your instructors. Because of the small class size it is likely that your work may be selected; all students are being asked for their permissionat the start of the course. If you choose to share your work, you have the choice to have it be anonymous or to have your name be part of the work.

Please check the following designated purposes (if any) to which you give your consent:

_____I am willing to have copies of my coursework available so later students can use it for preparation.

_____I am willing to have copies of my coursework included in my professor's course portfolio.

_____I am willing to have copies of my coursework included in a public web site and/or a professional manuscript.

_____I am not willing to share my work at all.

Please check one of the following:

_____I wish to have my name remain on any work that is used.

_____I wish to have my name removed on any work that is used.

By signing below you give your permission that work you produce for this course may be used with the restrictions and for the purposes you indicated above. You understand that your grade is *NOT* connected in any way to your participation in this project, and your instructor will not receive the list of students who have given permission to have their work shared until after final grades have been turned in for the course. Your anonymity will be maintained unless you

designate otherwise. Finally, you understand that you are *free to withdraw consent at any time,* now or in the future, *without being penalized*.

Signature_____ Date:_____

Please address questions to: name of faculty member, department, phone number, email.