Three examples of the use of inquiry-based, data-centered exercises in geoscienc

Hickson, T.A. and Lamb, M.A.

Geology Department, University of St. Thomas, St. Paul, MN 55105

If you would like digital versions of these labs and the associated digital data files, please go to: http://personal4.stthomas.edu/tahickson/Professional/Pedagogy/pedagogy.html

We provide three examples of exercises developed for geology courses at the University of St. Thomas designed specifically to give students the experience of collecting and/or interpreting geoscience data. The first, the "Mammoth Cave Lab", is used in a Geology of the National Parks course. In this lab, students work with a set of maps of the Mammoth Cave system to discern whether the caves have a preferred orientation and, if so, why? Small groups of students initally make an hypothesis as to whether the caves have a preferred orientation, then they measure the orientation of cave passages on a small subset of the total map collection. These small groups pool their data with progressively larger groups, compiling rose diagrams of passage orientation at each step. This exercise specifically asks students to generate and test a hypothesis, then demonstrates to them that the larger the dataset, the more robust the results. The second, "Red Beans, Rice, and Slope Stability", derives from an article by Densmore et al. (1997) and is used in a sophomore-level geomorphology course. In this lab, students simulate the failure of fractured, sedimentary rock as a river undermines the toe of slope using a simple and easy-to-build experimental apparatus. Initially, students are asked to speculate on the behavior of the experiment before running it, thereby generating an hypothesis. They then run the experiment to determine the behavior of the experimental 'slope.' Finally, they are asked to submit a lab write-up where they describe their results and critically evaluate the experiment. This lab is followed by a group discussion assignment centered on the journal article. The third, "Basin and Range Tectonic Geomorphology," was developed for the same geomorphology course. The lab centers on the question, "can range-bounding fault morphology be used to analyze tectonic activity across the basin and range?" Small groups of students use USGS digital elevation models to map mountain front sinuosity on one 1:24000 quadrangle. Their individual data are pooled into a dataset that represents a transect across Nevada at the latitude of Reno. Students must critically analyze these data, in concert with GPS and seismicity maps, to answer the basic question posed in the lab.

Mammoth Cave Lab

Goals

The goals are for students to:
(1) deepen their understanding of caves, focusing on Mammoth Cave in particular,
(2) practice making and testing a hypothesis,
(3) practice working with real scientific data, and
(4) learn one way that geologists quantify and visualize complicated map patterns.

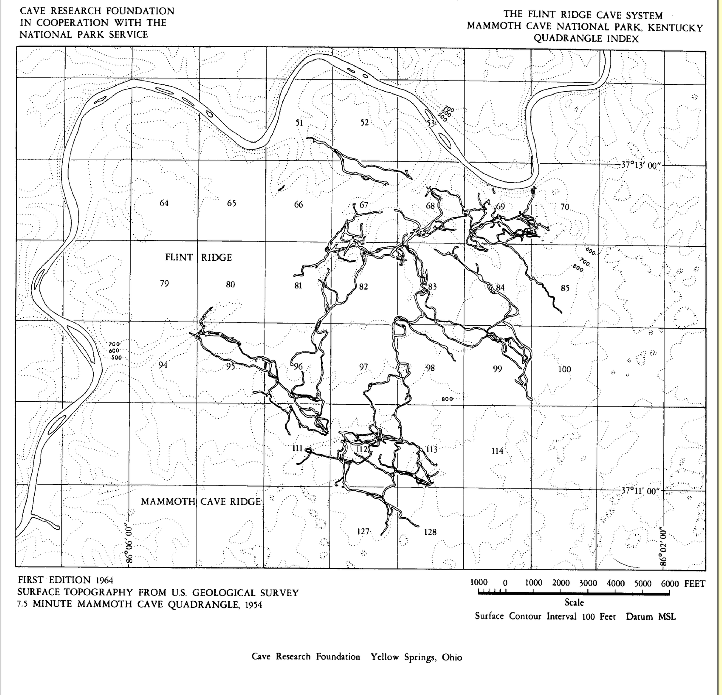

Figure 1. Index map of the cave system

Summary of the Lab

(1) In groups of three, students examine maps of the cave passages at Mammoth Cave (Fig. 1), familiarize themselves with the information on the map and then make a hypothesis about the orientation or lack of orientation of the cave passages.
(2) Using a protractor, students are asked to measure the orientation of all cave passages of a certain length and to record this data.
(3) Students plot the data on a rose diagram (Fig. 2).
(4) Students are asked to evaluate the rose diagrams and reevaluate their hypotheses. They are also asked to make a new hypothesis to explain their results, using the knowledge of caves they have learned so far in class and from reading.
(5) Three smaller groups combine into a larger groups and make a new rose diagram using all 3 data sets (Fig. 3).
(6) They are asked to compare the new rose diagram with the previous ones and reevaluate their previous conclusions.
(7) The instructor compiles all the data, makes a final rose diagram (Fig. 4) and then leads a discussion on the results.

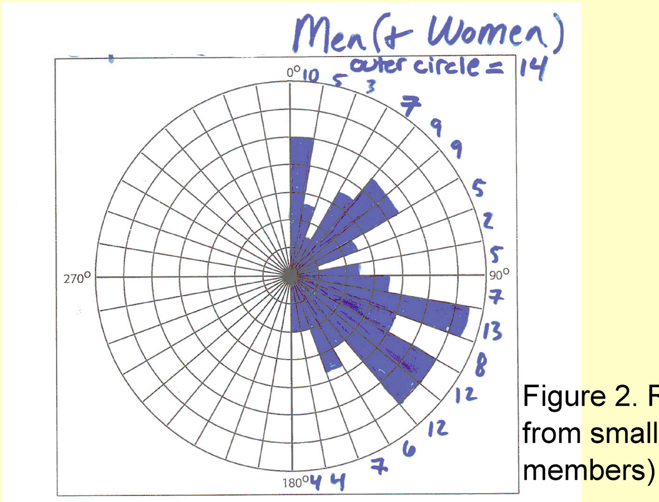

Figure 2. Results from small groups (3 members)

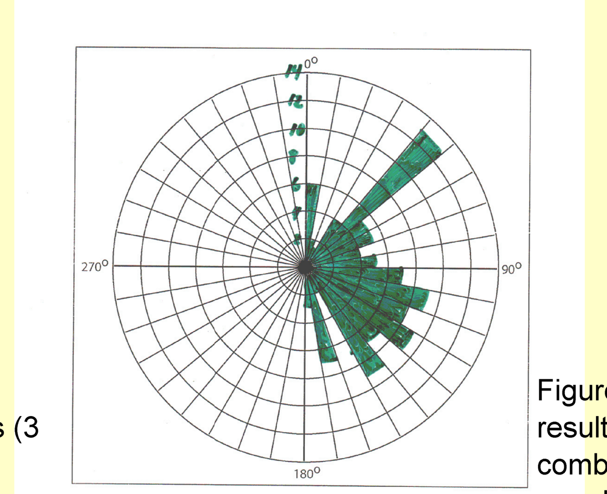

Figure 3. Pooled results from combined groups (9 members)

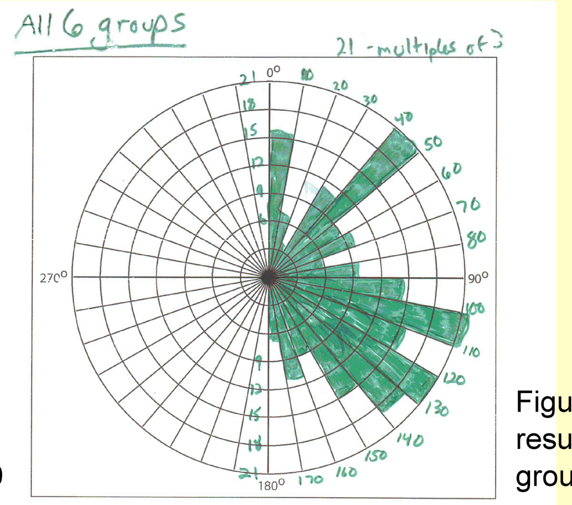

Figure 4. Pooled results from all six groups (18 members)

Red Beans, Rice and Slope Stability

Goals

At the end of this lab students should:
(1) Be able to explain how experiments can be used to understand the long-term behavior of some geomorphological systems.
(2) Be able to explain the role of slope failures in the evolution of slopes and landscapes, for the particular case we're investigating.
(3) Have a better understanding of how the material that makes up a slope may control the nature of a mass movement event.
(4) Be able to describe how this experiment supports the idea that oversteepened toes of slopes may not be evidence of a disequilibrium landform.

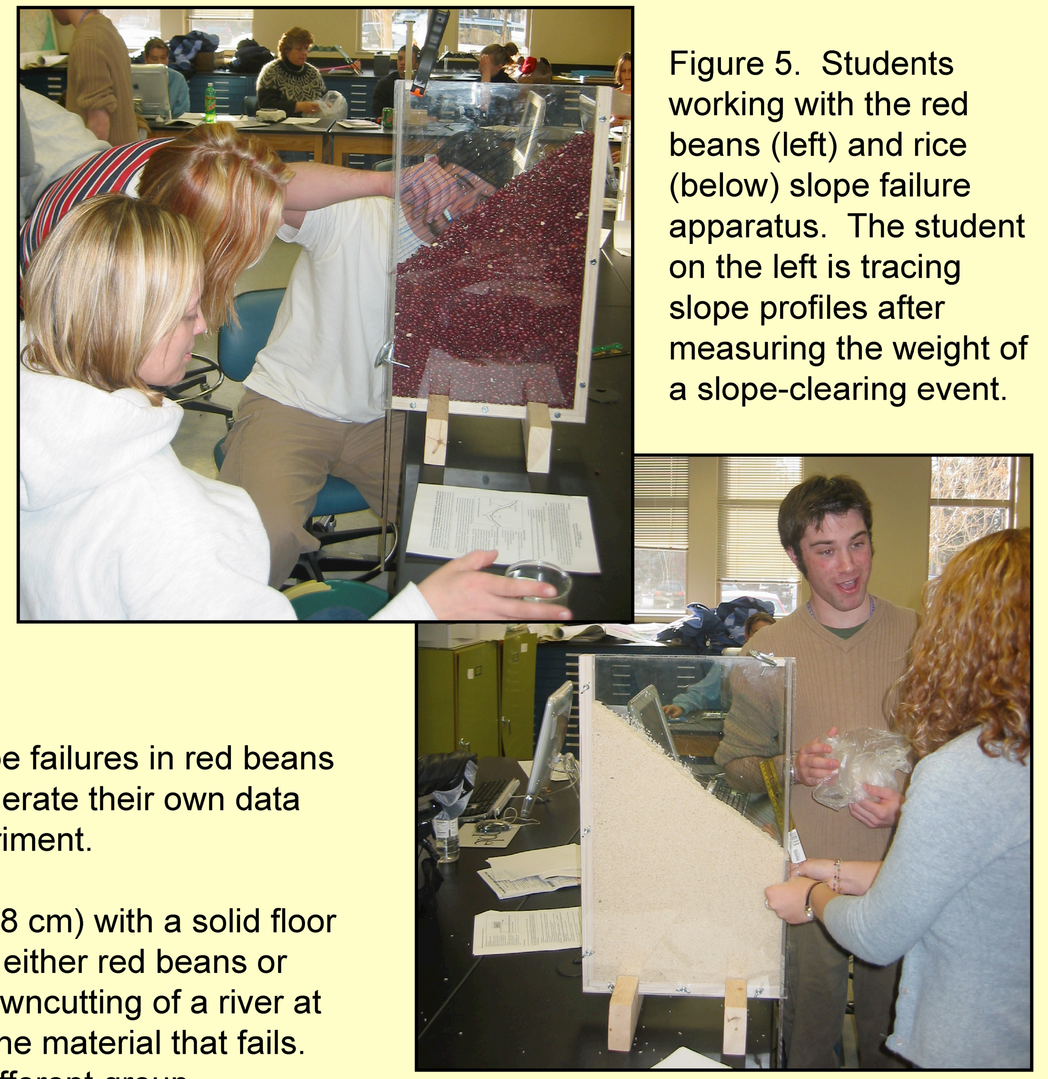

Figure 5. Students working with the red beans (left) and rice (below) slope failure apparatus. The student on the left is tracing slope profiles after measuring the weight of a slope-clearing event.

Summary of the lab

In this lab, students simulate how a hillslope evolves through time by looking at slope failures in red beans and rice, replicating a recent study by Densmore et al. (1997). As a result, they generate their own data and analyze them, and they can compare their results with a "real," published experiment.

The experimental apparatus is a narrow (2.54 cm wide) clear acrylic box (57.1 x 36.8 cm) with a solid floor and backwall, but with a sliding wall on the other side (Fig. 5). The box is filled with either red beans or rice. Students lower the sliding door in small increments, simulating erosion and downcutting of a river at the base of the slope (Fig. 6). As the door is lowered, students capture and weigh the material that fails. This lab is typically done in groups of three or four, with specific roles assigned to different group members.

Lab overview:
1. After reviewing what will be done in the experiment, students are first asked to predict the outcome: how will the slope fail and how will slope failures behave through time?
2. Students then practice creating slope failures and work out the bugs attendant to each of their roles.
3. They then run the actual experiment, weighing beans or rice, measuring slope lengths, and sketching slope profiles on the sidewall of the apparatus.
4. After completing the experiment, the group works together to plot their results. Plots of depth of erosion versus weight of material generated typically show a transient behavior until the slope reaches a constant length (Fig. 7).
5. Students then plot the data as depth of erosion versus weight of material generated *per unit slope length*, thereby normalizing their data. These plots typically show a more cyclic pattern of slope failure (Fig. 8).
6. Overlays of slope profile evolution are also made at this time.
7. After completing their group's data analysis, each group shares their data with all of the other groups.
8. At this point, students are given the article by Densmore et al. (1997), which is used as an integral part of a lab write-up.

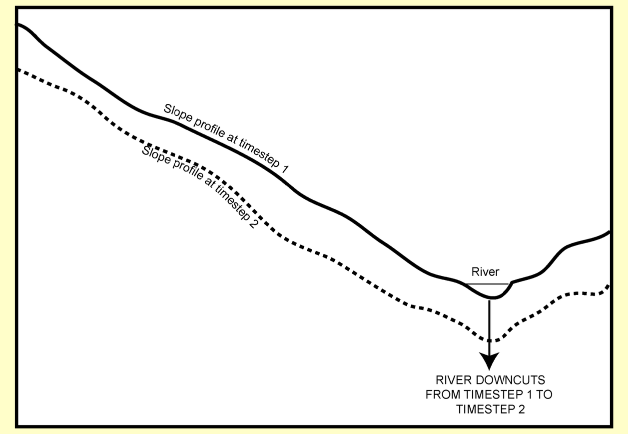

Figure 6. Conditions simulated by the red beans and rice experiment.

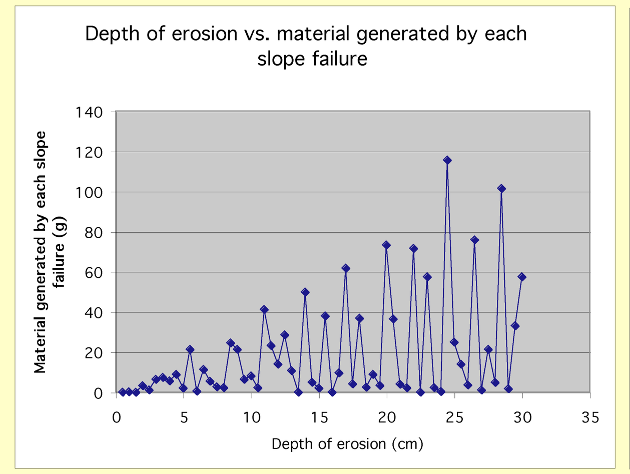

Figure 7. Raw results.

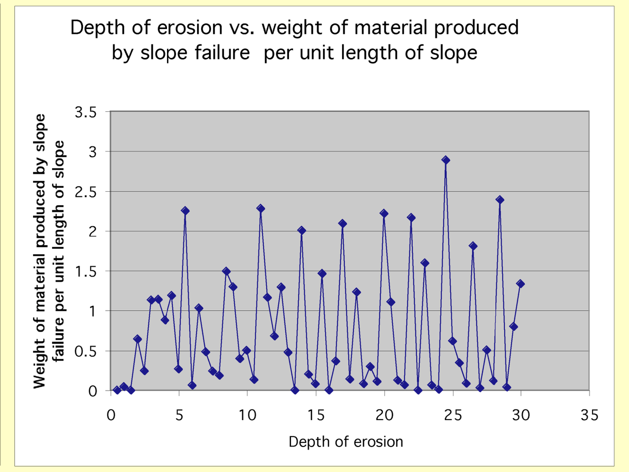

Figure 8. Normalized results.

Reference:
Densmore, Alexander L; Anderson, Robert S; McAdoo, Brian G; Ellis, Michael A, 1997, Hillslope evolution by bedrock landslides, Science, Vol.275, no.5298, pp.369-372.

Basin and Range Tectonic Geomorphology

Goals

In this lab, students are asked to answer a basic question: can relatively simple, morphometric techniques be used to demonstrate that tectonic activity varies across the Basin and Range province (Fig. 9)? Ultimately, it is their goal to answer this question. In addition, other goals of this lab are:

1. To be able to understand and use digital elevation models (DEMs).
2. To give students a strong example of how geomorphology can be used to understand a big tectonic issue, how to collect appropriate data, how to analyze those data, describe the results, and make conclusions.
3. Provide basic proficiency with two computer tools that students can use for their course project: MacDem and ImageSXM (NIH-Image).

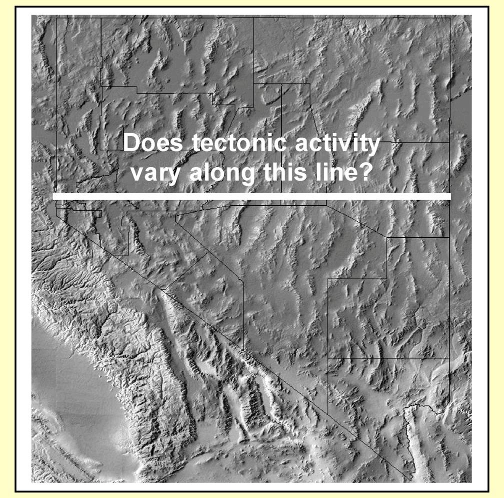

Figure 9. The DEM transect.

Summary of the lab

It is assumed that, prior to this lab, students know that the Basin and Range is a zone of active extensional (normal) faulting. We then pose the question in this way: "I would like to know if there is an east to west change in the relative amount of tectonic activity across Nevada, at about the latitude of Lake Tahoe (Fig. 9) and whether or not this activity is expressed in the geomorphology of the ranges. We have a lot of people in this class and we can make use of this: many hands make small work." The remainder of the lab includes the following:

1. The instructor and students collectively, through group discussion, figure out (a) what exactly it is they want to know; and (b) what methodology they should pursue to answer the basic question on Figure 9. This discussion is directed, in that we want the students to make use of DEMs in their analysis and to analyze these DEMs in an east-west transect.

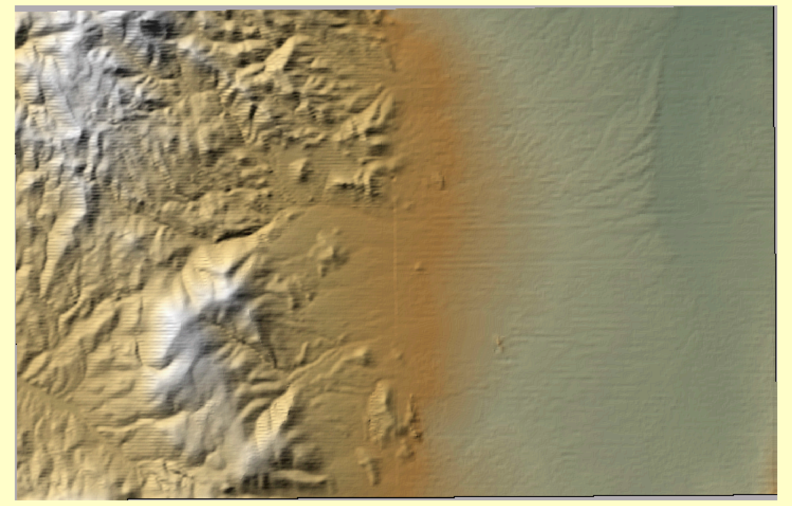

Figure 10. Example of one of the DEMs used in the exercise.

2. Pairs of students are each assigned a single DEM from the transect (Fig. 10) that includes a mountain front. Each pair measures mountain front sinuosity (Bull, 1984) for the ranges on their DEM. Students must (a) ascertain the scale of their DEM and convert it to a TIFF file using MacDEM software, (b) scale their TIFF image in ImageSXM (a variant of the freeware package, NIH-image), then (c) make repeat measurements of mountain front sinuosity in ImageSXM and take the mean of their measurements.

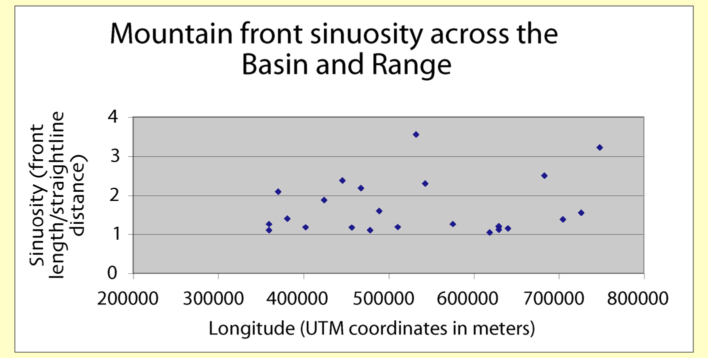

Figure 11. Mountain front sinuosity data across the DEM transect collected by student pairs.

3. Each pair of students then distributes the data that they collect to everyone else so that each student has a representative morphometric statistic for each of the DEM quads analyzed (Fig. 11). They are then given maps of (a) Nevada seismicity, (b) vertical slip rates of normal faults in Nevada (Fig. 12), and (c) recent GPS data showing motions of fault blocks across the region, and each of them creates a lab write-up that includes the following:

-- An introduction and statement of the problem/question that they are trying to answer, drawing from the textbook to support this part of the write-up.
-- A detailed description of the methodology that was used, including a map that shows the location of the study.
-- A data table that presents all of the raw data that they collected.
-- Summary charts that present the results of the research.
-- A "Results" section that verbally summarizes the principal results without providing any interpretation.
-- A "Discussion" section that discusses/interprets the results.
-- A "Conclusions" section that summarizes the main conclusions that can be made from the analysis.

4. Finally, we critique these write-ups during a future lab or lecture session, using peer-review and structured discussion.

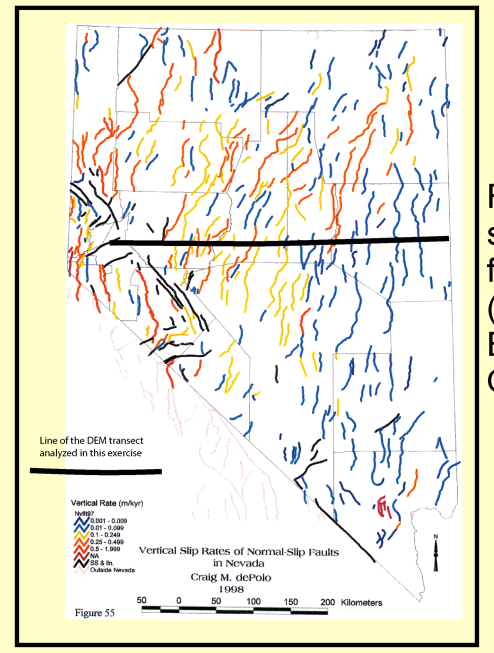

Figure 12. Vertical slip rates of normal faults in Nevada (source: Nevada Bureau of Mines and Geology web site).

Reference:
Bull, W.B., 1984, Tectonic Geomorphology, Journal of Geological Education, Vol. 32, pp. 310-324.