Chemical and Physical Weathering Field and Lab Experiment: Development and Testing of Hypotheses

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Instructor Notes

Before beginning this exercise, students are responsible for all assigned background reading on weathering. At this point, assigned reading is usually solely from their textbook. The purpose of assigned reading is simply to introduce students to basic principles so that their experiments are unbiased by current research protocol or results. Students are also assumed responsible for a working knowledge of local geology and all relevant formations (they have covered this in a required field introductory geology course).

Below are some suggestions and notes on how an instructor might try to trouble shoot or 'gently' guide students through a very open-ended and primarily self-guided exercise. Also note the Questions to Ponder. The exercises presented here remain purposely 'generic' to be tailored to an instructors local geological area and laboratory resources. At the simplest, students can be provided samples (thus skipping the field collection) and analytical techniques can be limited to the materials listed in the exercise. If available, tools such as an XRD, SEM, or an ICP might also be used to analyze sediment or water samples if appropriate (does the relative percent aragonite, LMC, or HMC affect dissolution rate of carbonates? Are there any discernible micro-structural differences associated with weathering of different materials or materials at different sites? Are there related rock-water compositional chemistry differences between sites associated with bedrock geology and weathering processes)? A key to the success of this project is not what tools are used, but how well a student links that tool directly to the question at hand.

Step 1: Identification and observation of field collection sites

On day 1 of the exercise, students break into working groups that focus on either chemical or physical weathering. It is up to the instructor to determine group size. Smaller groups (2-3 students) seem to work best here. Prior to introducing students to field sites, students are given geologic and topographic maps and UTM coordinates for several potential field collection sites. Students are responsible for locating the sites on maps. Field sites include areas along various streams, rivers, and creeks as well as prominent outcrops of local sandstone, limestone, dolomite, conglomerate, granite, basalt, and gneiss. Several limestone formations are included. Students are responsible for choosing a subset of these sites depending on the goals of their experiment.

Step 2: Formation of hypotheses

This may be the most difficult aspect of the exercise as there are so many directions that can be taken. Students often need help in narrowing or specifying the scope of their hypotheses.

For example, a physical weathering group might make the hypothesis that sediment found at site A (along a river sourced in the Blue Ridge) will be significantly different from sediment found at site B (a stream located in the Valley and Ridge). An instructor might then ask questions that guide students to a more specific set of hypotheses. How might the composition of sediment be different at these sites (depending on upstream bedrock, and relative susceptibility of all upstream source rocks to weathering)? More specifically, can you make an educated quantitative guess about the expected relative percents of each mineral component in the sample you will collect at each site? How might the size and shape of sediment components be different at these sites (depending on distance from source, flow velocity, stream gradient, etc.)? How well sorted might the sediment constituents be (depending on what you know about stream characteristics at each site)?

A chemical weathering group will likely make the hypothesis that the basalt at site A and the quartz sandstone at site B will dissolve less readily that the limestones and dolomite at sites C-F when subjected to a weak acid solution. The instructor might then encourage the group to think about how those limestones might vary in susceptibility to dissolution and why. Will the dolomite be significantly (i.e. quantitatively) more or less susceptible than the limestones to dissolution? Will the basalt and/or sandstone dissolve at all if subjected to a strong acid? Will the dissolution rate for a given sample change as the experiment progresses?

It is important to stress that these are preliminary hypotheses that may be refined once the sites have been visited and samples collected. Students should be encouraged to make several working hypotheses as some may turn out to be difficult to test rigorously once field, lab, and time constraints become obvious. Finally, ask, ‘is this a quantitatively or qualitatively testable hypothesis’? This should lead students to Step 3.

Step 3: Design a field collection and laboratory experiment

Students are given an entire class period to design a data collection and/or experiment design to test their hypotheses. Before making field observations and collecting samples, students should visit the questions pertaining to experiment design in the exercise. The instructor should visit with each group to make sure they have good working hypotheses that can be tested.

Critical to a good outcome is ensuring the students know why they are processing samples in a particular way. In the past, students have spent a tremendous amount of time collecting and sieving a large number of samples in lieu of making detailed and quantitative observations of relative size, shape, sorting, and mineral composition of just a few key samples. The students sieved ‘blindly’ without thinking enough about what the data might reveal in reference to their original hypothesis. Students have also tried to quantify dissolution rates without considering (and standardizing) surface/volume ratios or testing with more than one acid strength.

An instructor might also ask students to consider how the team should collect data together to maximize accuracy. Should one person weigh all samples subjected to an acid solution or should all members do this and take an average? Should one person be responsible for estimating the mean shape of grains in each size fraction or should each person be responsible for a different sample? How might tasks be divided so that samples can be measured regularly (in a chemical weathering experiment) or data can be shared among group members?

Step 4: Collection and data analysis

Students are given approximately 2 weeks to complete data collection and analysis with a final day in class (or portion of the class period) set aside for groups to discuss results in light of original hypotheses. The instructor can accompany groups into the field several times during the project period. This is particularly important early in the first week to make sure students are on track as there will surely be many unforeseen problems with the idealized sampling protocol. A group that is sampling sediment in streams might not have thought about where exactly their sample should come from in that body of water, how much to collect, and how to get it. A chemical weathering group might need help in determining where on an outcrop a sample should be collected (this can vary widely depending on the local geology but fresh vs. previously exposed surfaces should be considered). An instructor might also point out the benefits of replicates and control samples early in the field and laboratory phases of the exercise.

Step 5: A final paper

Students should be familiar with a standard manuscript format. The instructor might choose 2-3 articles for students to use as ‘templates’ for their papers. A valuable addition to this exercise is the submission of a rough draft to the instructor or a discussion of what makes a good scientific paper.

Step 6: Sharing results

Students should be provided with a presentation and discussion format by the instructor. This exercise can be completed with a larger group discussion of ‘lessons learned’. More often than not, some groups will compile results that do not ‘fit’ what they learn in their textbook. If is important (and fun!) to try and track the source of these contradictions (analytical error, poor sampling design, an un-testable hypothesis, or simply recognition that the real world doesn’t always behave or produce as it should!).