Geology Field Trips as Performance Evaluations

By Callan Bentley

One of the most important goals I have for students in my introductory-level physical geology course is to give them the conceptual skills for solving geologic problems on their own. I want students to leave my course as individuals who can use their knowledge of geologic processes and logic to figure out the extended geologic history of areas they live in or visit. There are tremendous, epic tales lying in the rocks we walk over every day. I try to help students to learn how to read those stories on their own. Field trips therefore serve as a critical evaluation tool of my students' performance and overall learning.

Who, What, and Where

My physical geology students at Northern Virginia Community College in Annandale enroll in a sixteen-week introduction to Earth products and processes. In spring of 2007, 52 students enrolled in the course. Their ages, backgrounds, academic abilities, and motivations were especially diverse, including international, high school, senior citizen, and career-switching students. Among these students were three with documented learning disabilities and another three enrolled as honors students who complete a special research project in geology.

All of my geology classes take field trips to areas with well-exposed rock outcrops, where students observe the rocks' characteristics and identify them. They make observations about superposition and cross-cutting relationships and then establish geologic timing. Where radiometric dates are known, I provide them. Then, the students must interpret the whole day's worth of field

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work and make a coherent chronological geologic story out of all the data. I emphasize that the students make observations about rock outcrops and then interpret those observations in light of the skills and perspective we've been building in lab and lecture all semester. In many ways, the trip is a culmination of the course, as many skills come into play, including rock and mineral identification, interpretation of those rocks in terms of depositional environment (if sedimentary) or orogenic/tectonic causes (if igneous or metamorphic), and deduction of the relative timing of geologic events. In addition, students make many unprovoked observations that then serve as fodder for discussion and interpretation.

Geology is mainly a historical science, not an experimental science. When a scientist is dealing with something as big and old as the planet Earth, manipulating independent variables is not an option. Geologists are like Sherlock Holmes or the protagonists of the modern television series *C.S.I.*: we use the clues found in the present to deduce what likely happened in the past and to infer why it happened. For this reason, the design-an-experiment types of performance evaluations are frequently less applicable to the Earth sciences than they are to chemistry, physics, and certain branches of biology.

Observing student performance in the field is an authentic method of evaluation, as these activities are exactly what geologists do out in the real world. My field trips mimic geologic field work, pure and simple: observation, note-taking, applying geologic logic, and synthesis. Having my students perform as real-life geologists is one of my primary course goals. To evaluate the experience, the students ultimately turn a short paper into me, due about a week after the field trip.

I take my physical geology students to a popular local hiking trail along the Potomac River, the Billy Goat Trail, for good reason: the powerful excavations of the Potomac have revealed a rocky landscape with a dramatic gorge and a major waterfall known as Great Falls. The trail is part of the Chesapeake and Ohio Canal National Historical Park, a 180-mile-long park that hugs the north bank of the Potomac from Washington, D.C., west to Cumberland, Maryland. The trail itself is about twenty miles from the Annandale Campus.

On the Billy Goat Trail, I focus on two major topics. First, we examine the bedrock exposed by the river at this location and discuss its story. Second, we examine the river itself and the processes of incision that have created the dramatic landscape of Great Falls and the Potomac Gorge. (One way to contrast these two foci is to consider the difference between the medium a sculptor works with and the shape of the sculpture that results from their carving.)

My class went on the trip in two sets, based on their lab group. Using a rubric (see Appendix), I assessed their geologic performance on the hike. Each group spent about four hours on the trail. After the trip, I asked for volunteers whom I could interview about the trip. Six students volunteered, Thomas, Brian, Sam, Ashleigh, Matt, and Hassan. In my office and over the telephone, I spoke to each student for about twenty minutes, getting feedback and perspective on the trip.

Analyzing the Data

Both field trips went well. Performing a field study as a real geologist and having the cognitive flexibility to deduce a geologic history is dependent in a large part on the physical conditions of the trip. As the classic Maslow's hierarchy of needs (Maslow, 1943) suggests, basic needs must first be met before any higher-level thinking can be achieved. I was worried going into the field trip about the weather, as inclement conditions could be an obstacle to students getting the most out of the trip. That year, the Washington area had experienced an unusually cold spring. As it worked out, Tuesday was cold but dry with temperatures around 55º F.; Thursday was warmer, approaching 70º F when the sun was out but with two episodes of rain on the trip, including a thunderstorm with drenching downpour at our final stop of the day. All told, these conditions were manageable, though not ideal.

A greater source of concern was the extremely rugged terrain of the Billy Goat Trail. Jagged exposures of rock make the trail part hike and part rock-scramble. One particularly daunting section is a steep traverse across a rocky cliff-face. Though not dangerous, this traverse looks extreme, especially to novice hikers. The physical demands of hiking the Billy Goat Trail energized some students, but appeared to intimidate others. Hassan, one of the students on my Thursday trip, told me with glee, "I never thought I'd be climbing up a 70º steep hill." Actually, the traverse only measures 25º or 30º of inclination. Ashleigh, another student on the same trip, remarked, "I didn't expect it to be that rocky. It was hard, physically challenging, [but] a lot of fun."

In spite of these challenges, the students appeared to benefit. Matt, one of the students on my Thursday trip, told me, "I enjoyed it a lot. After I got home, I was impressed by how old it was." Coincidentally, Matt had hiked along the trail a few weeks prior to our field trip: "The trip gave me a new perspective on the same rocks, a new outlook."

Imparting an expanded perspective of the world and our place in it is one of the main goals of my course. Hassan commented on what he had gained:

> You feel like you know so much more about everything. When we saw that amphibolite [a rock interpreted as the floor of an ancient ocean], I was like "Wow, we're just floating on this little crust, and this rock is over 500 million years old. I probably won't be around in another 100 years, and this rock is so much older. What can I do in my life that will leave a mark for the future, the way this rock is evidence of such an ancient ocean?"

Sam, a student on the Tuesday trip, echoed Hassan's impressions of the ancient ocean crust: "It was really cool to see the Iapetus Ocean crust. It's not every day you see something that old. Being out there, your lectures came to life. I could understand more seeing it all for myself, and experiencing the rocks hands-on." Hassan agreed on its value as a learning experience: "It was a good comprehensive, hands-on review. I'm sure that students would do better on an exam after going on this trip than without going on it."

Because I ran the trip twice, I was able to vary the conditions slightly. On Tuesday, I simply observed students' performances in demonstrating geologic field skills, but I didn't specifically state that I would be observing their performance. On Thursday, I made an announcement at the beginning of the trip that I would be paying attention to how students behaved intellectually on the trip. I told them that I would be observing the skills they displayed in rock identification and interpretation: identifying and interpreting geologic structures (like folds and faults), testing hypotheses, and establishing a sequential order of geologic events (a geologic history).

Later, I asked the Thursday students about their reaction to this announcement. Matt told me that the announcement "made me nervous. I knew we weren't being graded on it, but because I was out of it for several weeks this semester [Matt had shoulder surgery with an extended period of recovery], I wanted to prove that I'm not as stupid as my test grades make me out to be. The announcement motivated me . . . to participate and get something right." Hassan was also motivated. He recalled thinking, "Uh oh, I'd better make sure I'm participating." Ashleigh, on the other hand, found the announcement to be a confirmation of what she expected.

One of the first things I had students to do was to examine an outcrop of the local bedrock and identify it. Once the identification had been made correctly, we would attempt to interpret where these rocks came from. I told the students they would have five minutes to make a thorough examination of the rocks and identify them. They set to work, and I wandered around, answering any specific questions that came up (Figure 1).

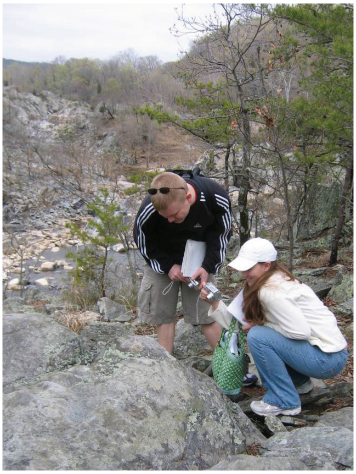


Figure 1. Students Matt and Ashleigh examining texture and composition of bedrock exposures in an attempt to identify it as metagreywacke, a necessary step toward interpreting the ancient environment in which these sediments were deposited.

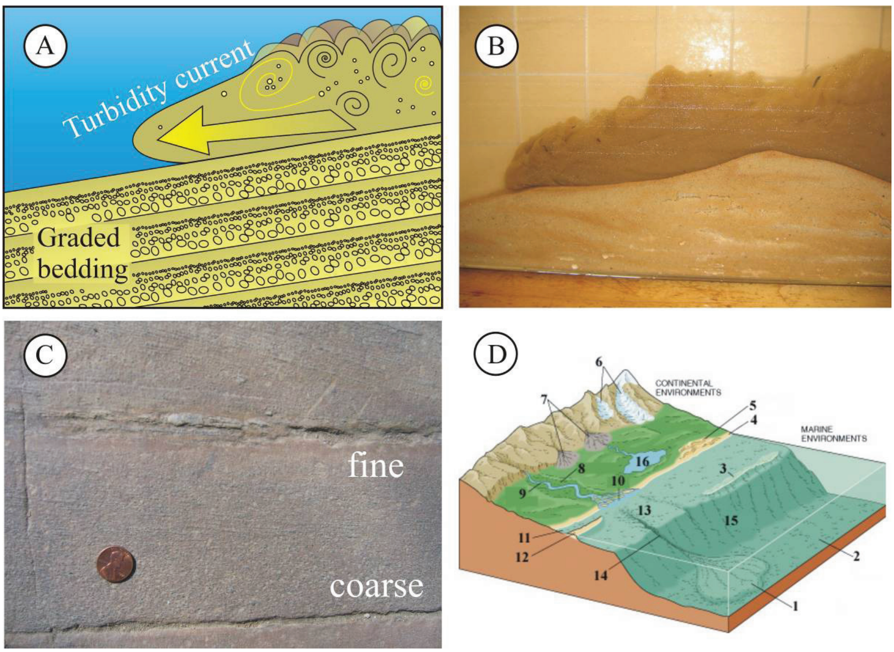
I noticed that most students stuck together in their usual lab groups during this exercise, though some individuals struck out on their own. On the Thursday trip, several students asked me for a bottle of hydrochloric acid, one of the tools we have used in lab to identify the mineral calcite. No one asked for the acid on the Tuesday trip. After the five minutes of exploration, we regrouped, and I asked for their observations about the rocks' texture and composition.

To my students' credit, the rocks exposed along the Billy Goat Trail are complicated, not immediately easy to interpret. However, earlier in the semester I had emphasized greywacke sandstone in our sedimentary rocks lab and metagreywacke in our metamorphic rocks lab. Students correctly pointed out the presence of minerals like quartz and muscovite mica. Based on sand-sized grains and folded layering, some students concluded that the rocks were sedimentary. Other students, who focused on the alignment of muscovite mica crystals, concluded that the rocks must be metamorphic. I was pleased with these results: "You're both right," I told the students. "These rocks were originally sedimentary, but then they were metamorphosed later on."

With their initial impressions confirmed, we tried for a more specific identification. I pointed out a distinctive coarse-to-fine-grained layering in the rocks. In the Tuesday group, I had to push for an identification of this structure, graded bedding; on Thursday, students identified it immediately. Once they had been reminded of graded bedding, students recalled how it formed, as a sequential deposit of heaviest grains first (coarse at the bottom) and lightest grains last (fine at the top). To cement the concept, I had brought along a series of laminated cards with color illustrations of processes we couldn't directly observe on our trip (Figure 2).

One student expressed appreciation for these illustrations, which served as "a good reminder" of processes they had studied weeks before in class. Aided by the illustration cards, students deduced that the rocks they were sitting on had once been deposited in a deep ocean basin (#1 in Figure 2D). At some time after that, the rocks had been subjected to regional metamorphism, which folded the layering and aligned the muscovite mica crystals into parallel foliation. Students in the Thursday group identified the presence of folds without prompting, while the Tuesday group needed prompting to name them as folds.

Figure 2. An example of the laminated "field graphics" I used as visual aids in our discussion of rock types: (A) a schematic diagram of how graded bedding forms through turbidity currents, (B) a photo of a turbidity current in a tank in our geology lab, (C) a photograph of graded bedding in rocks exposed along the Billy Goat Trail, and (D) a diagram showing common sedimentary depositional environments, including #1, deep sea fans, where turbidity currents deposit graded beds of greywacke sand.



"What causes metamorphism and folding like that?" I asked. The Thursday group was quicker to note that mountain-building (due to tectonic collisions) was the cause. Eventually, the Tuesday group reached that interpretation, as well.

In interviews after the trip, I asked students how difficult this first episode of field work was for them. “It wasn’t that hard,” said Ashleigh. “The folding and the quartz were obvious. The coarseness of the sediments was a bit tougher.” Sam said that she had difficulty identifying it as metagreywacke: “It’s a complicated rock. I only knew it because I had taken the time to read the website first.”

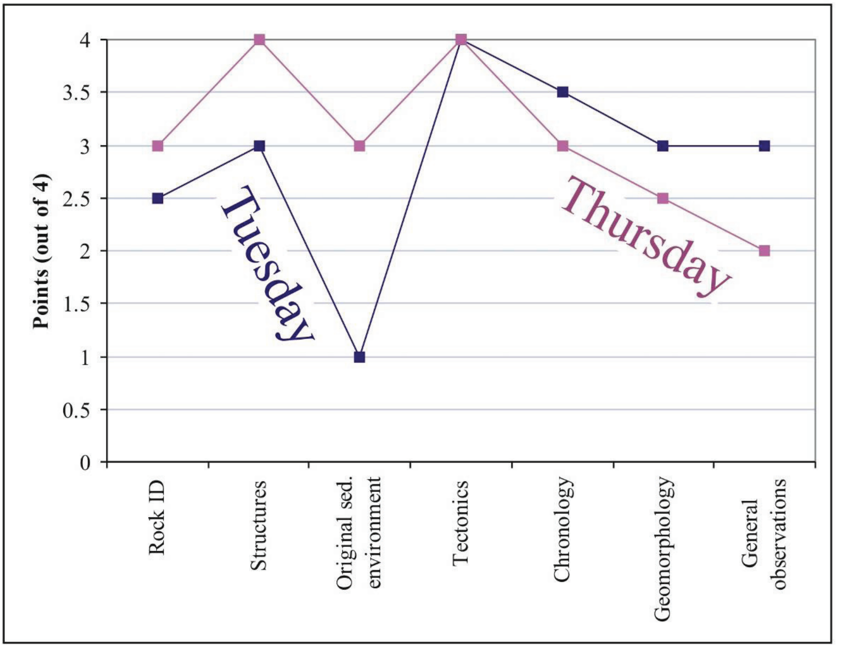
Sam was referring to a website (Bentley, 2007) I had put together summarizing geologic evidence and interpretations of rocks along the Billy Goat Trail. Before the trip, I had posted a link to this website on Blackboard. I suggested that students would get more out of the trip if they read through the materials before the trip. I also reassured them that it would be available for them to use as a reference after the trip while writing up their response papers. On the website, I detailed the evidence for the rocks being metagreywacke, so students who took the time to read it came into the trip primed to make that interpretation.

When I asked students if the website had been helpful, those that had read it all affirmed its value. “It was very helpful,” said Sam. “I wish I had time to finish it,” said Ashleigh. “I only read the first half, but a lot of the stuff you asked about was on the website.” Hassan read the website before coming on the trip, and he estimated that “60 or 70 percent of my lab group read it before. It really depends on whether people use Blackboard.” He suggested that an email with a link to the website might have reached more of the class than just a Blackboard posting. Matt estimated that only 50 percent of the class had read through the website in advance of the trip. He too suggested that these low numbers were due to low use of Blackboard overall.

Another piece of media I prepared for students in advance of the trip was a paper handout of fourteen pages, including a color geologic map of the Billy Goat Trail area, which I distributed as we left campus on the day of the trip. Brian, an honors student who came on both trips, mentioned reading the handout on the drive. Though he did not read the website, he gleaned important information from the handout and, because of that, served as a leader among his peers on the Tuesday trip. (On the Thursday trip, I specifically asked him to keep quiet, so that the Thursday students could figure things out on their own.)

To evaluate the two trips, I used a self-designed rubric (see Appendix) to evaluate the two trips in terms of their performance in tasks like this initial rock identification and interpretation. Each group was scored on fourteen criteria, which were grouped into seven themes that evaluated their performance on the major skills I wanted to see demonstrated. Figure 3 shows a performance profile of each major theme’s weighted average, shown for both of the iterations of the field trip. Originally, I intended to assess five individual students per trip using this rubric, but found that it was impossible for me to focus on that fine level of individual detail while simultaneously physically leading the trip and making sure students didn't miss opportunities for key observations. Evaluating each day's trip as a whole lab section was a compromise position. Figure 3 also illustrates the students' other performances through the rest of the trip.

Figure 3. Performance profiles (in the style of Doran, Chan, Tamir, and Lenhardt, 2002, Figure 4.18) that rank the performance of the Tuesday field trip and the Thursday field trip on seven key themes of observation and interpretation. Rankings are weighted averages of more extensive criteria as described in the rubric (Appendix).



Our next stop was at a set of mafic dikes which cut across the metagreywacke. There, students impressed me with their analysis of these dikes. First, they deduced from their recessed outcrop that they must be less stable than the metagreywacke they cut across. This led them to a hypothesized identification of the rock filling the dike as basalt, a hypothesis later confirmed by a close-up examination. (Technically, it was lamprophyre, but basalt is close enough.) Second, students noted that the dikes were not folded, which indicated that they must have been emplaced sometime after the 460-million-year-old episode of mountain building that deformed the metagreywacke. I was interested in whether students could establish the relative ages of rock units in this fashion, and they did well. Matt said, "I did the reading ahead of time, and so it wasn't hard at all. We practiced that [relative dating] in lab. Everybody should be able to do that pretty easily."

Geologists also have the ability to date rocks absolutely using radioactive isotopes. While the students could not practice this in the field, I did allow them to ask me about whether a specific rock unit had been dated. If so, I reported the age to them. It was also provided in the paper handout. As far as performance was concerned with isotopic dating, I was mainly paying attention to see if students demonstrated knowledge of which rock types could be reliably dated using isotopic methods.

Isotopic dating can be used on mineral crystals to date the time that the crystal formed. With igneous rocks, this is the time that the crystal crystallized from a liquid melt (magma). With metamorphic rocks, it is the time that mineral formed in response to metamorphic conditions of increased temperature and pressure. With sedimentary rocks, though, there are no new crystals being formed. Instead, sedimentary rocks are made up of the broken-off bits and pieces of other rocks. If we were to date those mineral crystals, we would know the age of the parent rock that had eroded to produce the sediment, not the sedimentary deposit itself. This would yield an older age than the time the sand or mud was deposited.

The Tuesday group was good about making this distinction and asked for dates when we encountered metamorphic or igneous rocks. The Thursday lab group, on the other hand, needed substantial prompting to ask for dates. For example, after we encountered granite, I stood there in silence for a while and then said "This is an igneous rock. What particular information can we get from an igneous rock?" At this, several students parroted, "How old is it?"

This prompting, either in regards to the graded beds with the Tuesday trip or to the isotopic ages with the Thursday trip, was frustrating to me. I felt that, due to a lack of skilled performance on the students' part, I was put in the position of intellectually herding them along. In Brian's opinion, "Guiding the students along is contingent upon the students having studied what they were supposed to. With the Thursday group, you were spelling things out, sometimes literally, like with O-R-O-G-E-N-Y." This is true. Though we had been over orogeny (mountain-building) countless times in our classroom discussions of plate tectonics and metamorphic rocks, the Thursday students didn't immediately recognize the cause of the metamorphosis they observed. For fear of spending the whole day there without them getting it, I indeed had spelled it out.

I also asked Brian why he thought the Thursday group was less involved than the Tuesday group. He noted that there were no honors students in the Thursday group, and that, despite warmer weather, the students on Thursday were "less into it. Last time [Tuesday] was jovial. I didn't get the jovial vibe on Thursday."

Brian also compared his own performance on both trips: "The first time, I was taking notes. The second time, I was looking at the rocks a lot more." I had noticed that Brian wandered off on his own that Thursday, examining the rocks. In fact, by sticking his head into a small overhang, he found an exposure of highly-foliated metagreywacke. It displayed a structure we had detailed several months before when discussing metamorphic rocks: gneissic banding (Figure 4). There's plenty of gneiss along the Billy Goat Trail, but usually it outcrops as highly-weathered rocks, covered in lichens. By diverging from the route I had chosen, Brian discovered a beautiful outcrop. After he alerted me to it, I directed the rest of the students to his discovery so they could appreciate the "nice gneiss."

Figure 4. An example of what a student geologist can discover if he gets a chance to explore on his own. Student Brian found a world-class exposure of gneissic banding in highly-metamorphosed metagreywacke along the Billy Goat Trail. (Pocket knife for scale.)

Brian's focus on following where his curiosity led him was a powerful testament to the power of geologic exploration. Truly, that's half of what I wanted students to be doing along the trail. On the other hand, I had to balance this impulse to let the students roam free with a desire to expand their perspective with an appreciation of deep time and a demonstration of the tectonic and rock cycle processes we had been learning in class all semester. There is no perfect way to run a field trip like this, but Brian demonstrated the power of untrammeled independent inquiry: "I walked the same path, but I saw different things. I think I got more out of it this time [Thursday]. It showed me that you can see new things the second time in the same place." Hassan was apparently yearning for something similar: "I wish we had the means to do a trip like this two or more times in the semester." Brian summed up the difference in perspective nicely: "The first time it was like an itinerary. The second time, it was an experience."

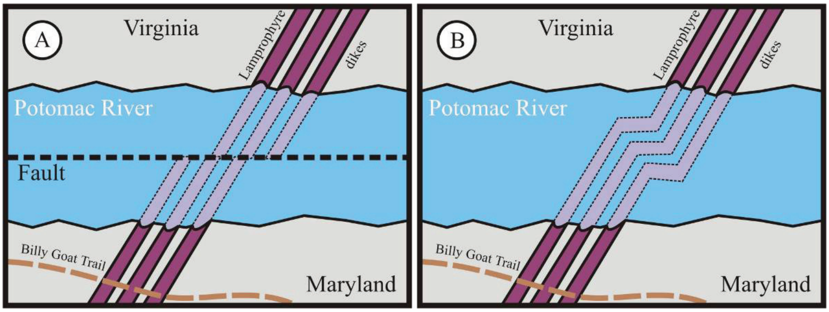
One of the items on my rubric (Appendix) was a catch-all category for unprompted student observations. I wanted to assess whether students were noticing things and asking about them. As Figure 3 shows, the Tuesday group asked more unsolicited questions about what they noticed. There was less of this on Thursday, indicating a lack of engagement that day.

An overarching goal of the trip was to allow students to experience what real geologists do. By using geologic skills and logic in new terrain, I hoped to give the students a taste for field work, considered by many geologists to be one of the most enjoyable things about a career in the Earth sciences. Matt said to me that he guessed our trip was "pretty small scale compared to what you guys do in the real world." After the trip, Hassan told me that, "The trip gave me and my classmates some real respect for geologists. This is not just me; I'm quoting other students who said, 'Wow. These guys work hard out here in the rain and in the forest.'"

There are two additional incidents I would like to mention in this analysis. First was an examination of a faulting hypothesis. Second was the method by which the students learned several other rocks later in the hike.

I mentioned earlier that the igneous dikes the students were so adept at figuring out were mafic and unaffected by mountain-building deformation. These same dikes are offset on the opposite sides of the Potomac River. The Maryland side of the river's dike outcrops are offset about 30 feet to the right of the Virginia side. I asked students if the dikes were offset by a fault or if they were simply jagged in shape to start with, precluding the need for a fault to explain the offset. I then held up a laminated card (Figure 5) illustrating these two hypotheses and asked students to evaluate which of them might be true.

Figure 5. Illustration shown to students on a laminated card contrasting two possible explanations for offset mafic dikes on either side of the Potomac River. Hypothesis A suggests that the dikes were originally planar and were later cut by a fault parallel to the river's course. Hypothesis B suggests that the dikes were originally jagged in shape, meaning that no fault is necessary to explain their offset.



Later, Hassan recounted to me that this was one of the skills highlights of the trip: "It was a good challenge. We had to ask ourselves what we have learned that will give us a clue to whether there is a fault there or not." Students first suggested the obvious: swim to the bottom of the river and look. Other students pointed out that this was dangerous and that likely the bottom of the river was covered in sedimentary deposits, anyhow. These layers of sediment would obscure the trace of the dikes at river bottom. One student noticed that the extremely straight trend of the Potomac River along this stretch was a piece of evidence in favor of the fault hypothesis: the river would have taken advantage of the crumbled rocks along the fault zone as it cut downward. The fault, therefore, would have controlled the linear shape of the river.

Students needed some prompting to get to the idea of exploring the shapes of the dikes where they outcrop on land. Once they had come up with this as an idea to test whether the dikes were in fact linear, I showed them photos of less-accessible regions of the area. In the photos, the dikes swerve and branch in a very un-planar way, so they could have been originally jagged in shape along the river course. Ultimately, the question has not been resolved by geoscience. I revealed this to the students, and encouraged them to continue to think of ways to test the two hypotheses. Again, the laminated cards appeared to be a useful addition to the thought process (Figure 5). Hassan commented that "the two explanations were best illustrated when you showed us those pictures."

On the Thursday trip, our hypothesis-testing led us to search for the dikes where they outcropped on the Maryland side of the river. We found suitably-oriented fractures in the rock, but I found that students didn't want to check out the rocks inside to see if they were in fact the same stuff. This perplexed me, and I stated blankly to the class, "You guys really need to come up here, stick your head in here, and check to see if this is lamprophyre (the mafic rock) or just more metagreywacke." Even after this admonition, only a few of the Thursday students stepped forward. Most of them just stood there silently.

I later asked my interviewees what had happened. Thomas, a student who is generally quiet but participated extensively on the field trip, remarked, "I think it was because people didn't want to be wrong about identifying the rock. There was a lot of pressure to get it right, standing in front of the whole group like that." Brian agreed, "I think they were afraid of being perceived as stupid. There might be a sense of shame. It seemed a lot more prevalent Thursday than Tuesday." Ashleigh and Matt reported a similar sense, with Matt stating, "People don't like to call out answers and be wrong. They're timid." To me, this incident was a wake-up call about setting up these explorations. It's probably better to let students explore on their own, rather than setting up the trip amphitheater style, with all the focus on one or two performers.

Along similar lines, as the trip progressed and we were getting further along the trail, we encountered two additional rock types: migmatite, which is metagreywacke that had been heated up to the point that it partially melted (yielding granitic magma), and amphibolite, a metamorphosed mafic rock, which is interpreted as slices of ancient ocean crust. With these new rocks, I prompted students about five minutes in advance that soon they would see a new rock, and I wanted them to call it to my attention as soon as they saw it. In retrospect, this technique was less successful than the technique I used at our first stop. At the initial stop, I gave students five minutes to explore on their own. When they were hiking down the Billy Goat Trail, I think most of the students' attention was focused on figuring out where to put their feet. Very little attention was left over for spotting new rock textures or compositions.

Once we stopped (at my prompting), these two rocks elicited more powerful emotional responses in students than the previous rocks. Speaking of the migmatite, Sam said, "It was amazing to see the rock cycle in action. It was neat to see something that was half and half, igneous and metamorphic. It was cool to see it in its natural environment [as opposed to a disembodied sample in the lab]." Matt and Hassan agreed that the amphibolite was one of the highlights of the trip for them. Both spoke to me about the power of recognizing that, high up in the continent, they were standing on ancient oceanic crust, a rock over half a billion years old that was originally emplaced in an ocean that no longer exists. Hassan told me that while we were at the amphibolite outcrop, he thought, "This is amazing. Most people don't know that this was the bottom of the ocean at one time. That was definitely a highlight."

In spite of the powerful resonance of these two outcrops, the five-minute warning technique was less satisfying to the students and to me, as the person trying to evaluate their performance. Both Ashleigh and Matt emphasized this. Matt explained, "I really liked the first stop, where we were [identifying] rocks on our own. I was hoping we would do more of that. It was more hands-on. We had time to focus and pay attention on what we were surrounded by."

Developing Strategies to Increase Student Learning

At the end of the trip, as we got in the vans to drive back to campus, I reminded students of the basic chronology and scope of events that they had deduced. I also reminded them of the website available for them to consult when they wrote their papers. I offered to look over any rough drafts students produced, and to answer any questions they had in person or via email. Between the trip and the paper's due date, I received six emails from four students asking specific questions for clarification. Two sent me drafts of their papers, including one student who sent me both a first and second draft. I gave the students my suggestions and clarifications, as well as help with grammatical issues.

I sent an email reminder to all students about the due date for their paper and its importance (5 percent of their course grade), reminding them of my willingness to review their works. I included a link to the website for those who do not frequent Blackboard with any regularity.

I found the interviews with the six participating students quite useful. The interviews quickly evolved into a conversation with the students that was frank and insightful. These students were perceptive and friendly, exhibiting strong metacognition and powerful motivations to do well. Talking with them was a real pleasure, and I would like to work more interviews into the semester's schedule. These students have much to teach me!

Values and Claims

In general, I would rank these trips as a valuable experience for my students and an insightful assessment for me. Students came away with a physically rigorous day outside, hiking in a park less than twenty minutes from our campus, but which only three of the fifty participants had ever visited before. They therefore expanded their knowledge of the physical layout of our hometown area. Students gained insight into how the skills geologists learn in class get applied in the real world. They were able to practice *in situ* rock identification and interpretation, as well as observing, measuring, and interpreting rock structures like folds, dikes, and migmatites.

I learned that the students will, with prompting, arrive at approximately the right geologic story for an area, which is a substantial accomplishment when I consider that they can piece together 540 million years of geologic history in a four-hour hike. However, I would have been more satisfied with their performance if it had required less directed questioning from me.

To cut down on instructional prompting on future iterations of this field trip, I will take the following steps before the trip.

First, I will strongly encourage everyone to read through the related webpage in advance of the trip. Instead of merely posting an announcement on Blackboard, I will announce the webpage in class and send everyone an email with a link to the webpage.

Secondly, I will give students a better sense of what awaits them on the trip, including my expectation that they must figure things out and that I will be asking them questions as we walk the trail. It will be a conversation, in other words, not merely an outdoor lecture. As Hassan pointed out, "Honestly, you shouldn't even have to say that, but I think the students could use a heads-up. We're all so busy. A little reminder to study key chapters in advance would be really useful." Indeed, I should tell students to review plate tectonics and the rock cycle immediately before the trip.

Thirdly, I will encourage students to bring their rock identification keys from lab with them on the field trip. After all, I train students in lab to identify rocks using a dichotomous key, and it is unfair to then deprive them of that same tool when we go out in the field. Ashleigh said, "I was used to having that [rock identification key]. Without that chart, I wasn't sure what else to be looking for to figure out it was greywacke."

A fourth step is to warn students explicitly about the rough terrain they will encounter, especially the steep traverse. Ashleigh noted how this would have been useful to her: "Make it clear [to future students] that you really need both arms free. I have bad knees and ankles, and would have appreciated a warning to bring my knee brace with me."

A possible fifth step is to have the campus bookstore order Rite In The Rain waterproof notebooks, so students would at least have the option of purchasing a real field notebook. I noticed on the Thursday trip that as soon as the downpour of rain began, students lost all interest in the geology we has been examining. Matt reported murmurs of discontent among his peers during the two minutes it took me to finish up: "Can we go? Can we go?" he reported them saying, "Can't he just tell us this later?" Certainly no notes were taken as soon as the precipitation began, as students wisely hid their paper notebooks in their raincoats. Hassan enthusiastically endorsed this idea.

On the trip itself, there are two steps I will take next time to make things go smoother. First, if I am attempting a performance assessment on the trip, it would help to have two faculty members along. One instructor could lead the trip, while the second could conduct the performance assessment data collection. Second, I will schedule more independent field work and exploration for the students and do less of the fixed-itinerary, keep-an-eye-peeled-for-a-new-rock-up-ahead technique of introducing new rocks. Identifying and interpreting the metagreywacke at the trip's first stop was more satisfying for students and more revealing to me as an assessor than the high-speed geology we employed further along the trail.

In terms of changes to my instruction as a result of this assessment, I think that the key elements are already in place. At the beginning of the semester, I already know that I will be taking my physical geology students to the Billy Goat Trail. As I teach plate tectonics or rock identification, I will emphasize that "You'll see this on our field trip." Upon reflection, I think what's missing is a review of these key concepts immediately before the trip, as Hassan stated explicitly: "I wish I'd brought my [lecture] notes with me [on the field trip]. I could recall all the information right away. By the end of the trip, all that information was back, but I wish I had remembered it in the beginning."

As always, there is room for improvement. Regardless, I return to my overall impression that the field trip was a beneficial opportunity for me to assess my students' performance and a valuable activity for my students, independent of this assessment. As a final validation of the overall experience, I recall Hassan's statement: "I wish we had the means to do a trip like this two or more times in the semester. I really got a lot out of it."

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Appendix. **Rubric for Evaluating Field Skills and Logical Inference**

	Point value				
Rock ID Composition (minerals)	4	3	2	1	0
Texture	4	3	2	1	0
Final identification	4	3	2	1	0
Original sedimentary environment	4	3	2	1	0
Tectonics					
Structures	4	3	2	1	0
Differential pressure direction	4	3	2	1	0
Metamorphic cause	4	3	2	1	0
Chronology					
Relative dates	4	3	2	1	0
Absolute dates: asking	4	3	2	1	
Geomorphology					
Dikes hypothesis testing	4	3	2	1	0
Incision					
Potholes	4	3	2	1	0
Abrasion	4	3	2	1	0
River floods	4	3	2	1	0
General questions & observations					
COUNT	______				
Rank of quality	4	3	2	1	0