Earth Science Fieldwork:

"Why Does This Place Look the Way it Does?"

Geology was built upon observations of the natural world. These observations are the clues that scientists use to reconstruct the history of the Earth. Shelly fossils along the Himilayas tell of ancient sea floors that have been uplifted into mountains. Ripple marks since turned to stone tell of ancient shorelines. And scratches along the bedrock in Central Park tell of massive glaciers that—some 20,000 years ago—created a skyline much different than the steel and glass of New York today. That massive glaciers once advanced as far south as New York is not a conclusion derived from mathematical modeling in a lab, but is instead evidenced by those scratches and a host of observed glacial deposits that litter not only New York, but much of the Northeast and Midwest.

The story of a place is written in its landscape, rocks and fossils. Fieldwork investigations help scientists—and students and teachers—tell that story.

Introducing students to the practice of geologic fieldwork can be a tremendous experience. Exploring local geology through inquiry-based approaches emphasizes critical thinking. And by conducting such investigations, students have taken a tremendous leap: they are not merely learning about science; they are doing science! But getting students into the field can be difficult. An alternative is for the educator to visit the field on their own time, returning to the classroom with a series of images and specimens that permit a ***Virtual Field Experience*** *(VFE). Virtual fieldwork offers the experience of exploring an area without leaving the classroom, and it allows multiple "visits" to a site. VFEs can also enhance and extend the experience when actual fieldwork is possible. The Earth is a system, after all, and any one site—virtual or real—can display a host of natural phenomena, from simple erosion and deposition to the principles of superposition and faunal succession to the formation of ripple marks or mud cracks. Ideally, virtual fieldwork in the classroom captures the active experience of a geologist examining an area for the first time: It provides opportunities to actively explore, discover, ask questions, and make observations to answer those questions, ultimately allowing students to develop educated responses to the question,* Why does this place look the way it does?

Fieldwork 101:

Gathering Information & Creating Your Own VFE

What follows are recommendations. These recommendations are intended to help prepare you for fieldwork, but they are just guidelines, not steadfast rules. Bringing the field to the classroom at any scale is better than not bringing the field to the classroom at all. The careful attention to detail described here will prove extremely helpful, but avoid being discouraged if your first trip to the field isn't as productive as you had initially imagined. Scientists of all disciplines continually refine their methods and procedures, leading to more productive and "better" results over time. With time and more fieldwork, confidence will grow. Get into the field, be safe, and do your best to capture the experience in a way that allows you to best reproduce it for your students!

Before Visiting the Site

Understand the Geologic History of the Region

In order to make sense of a local site, it's best to first understand the geologic history of the region before your visit. Did inland seas once flood the area? Have mountain-building events shaped the landscape and its rocks? The ***Teacher-Friendly Guides*** are an excellent source for discovering the history of a region, as well as that history's effect on the rocks, fossils, and other features of the area.

Visit **www.teacherfriendlyguide.org** *to download the regional guides.*

Questions to Keep in Mind

When visiting or examining any area, the ultimate question to answer is: Why does this place look the way it does? But to help answer such an overarching thought, it's important to have certain other questions in mind. These questions will guide exploration, and they will help ensure that important information is recorded during your visit:

- What kind(s) of rock(s) are found in the area? How do you know?
- In what environment did these rocks probably form?
- What is the arrangement of the rocks?
- Are fossils preserved in the rocks? If so what can they tell you about past environments?

- What has happened to this area to make it look the way it does today? (That is, what has happened to the area since the rocks formed?) Why do you think so? (What is the evidence for your claim?)

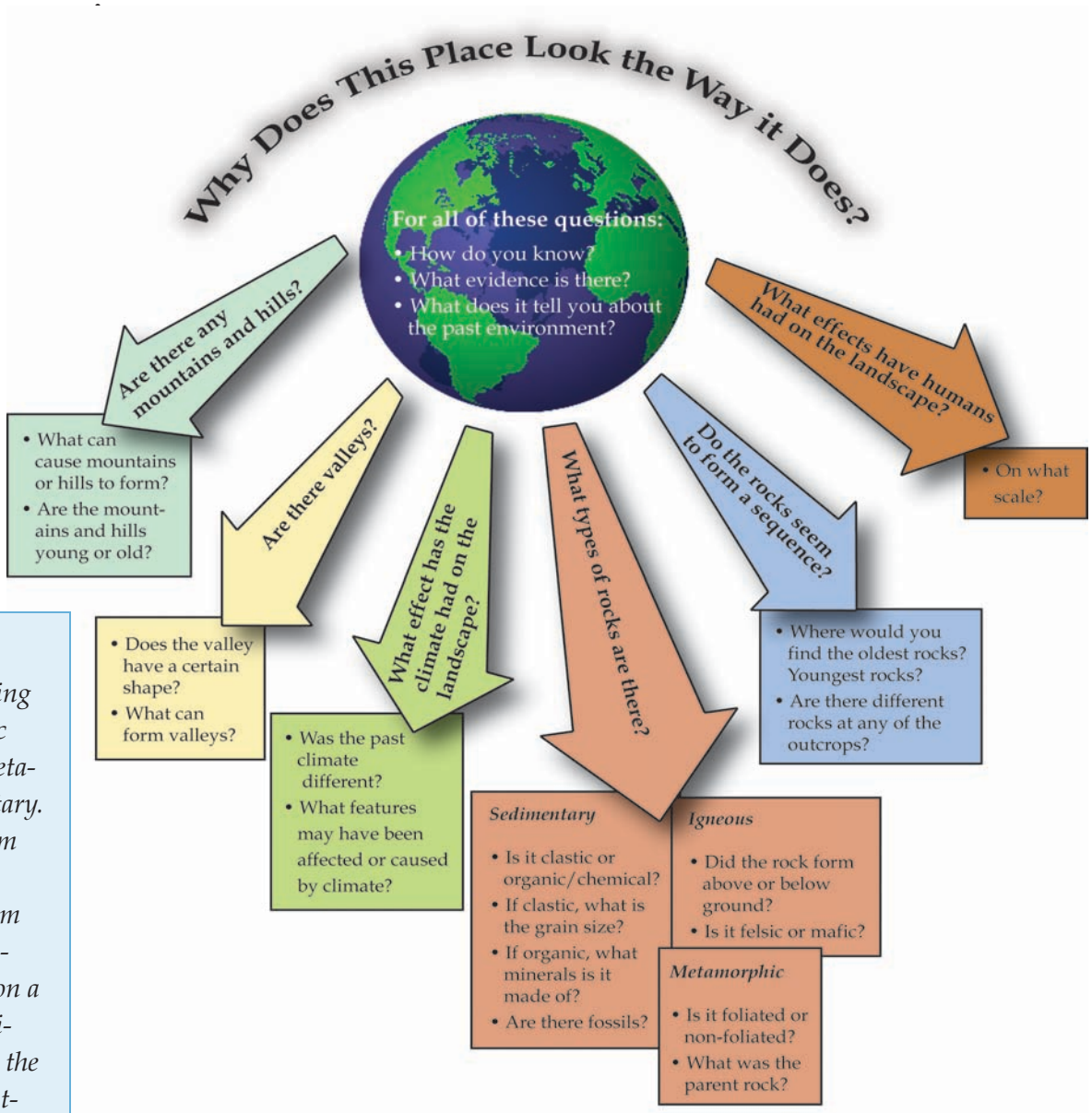

Figure 10.1:
This flow chart shows various paths of inquiry that stem from the question: Why does this place look the way it does?

Three types of rock

Minerals are the building blocks of the three basic rock types: igneous, metamorphic, and sedimentary. Igneous rocks form from cooling molten rock. Metamorphic rocks form by increasing the temperature and pressures on a pre-existing rock. Sedimentary rocks form by the compaction and cementation of sediment particles resulting from the breakup of pre-existing igneous, metamorphic and sedimentary rocks.

At the Site

Safety in the Field

At any field site, safety is the first priority. No photograph, measurement, or fossil is worth the risk of personal injury or death. To ensure safe and productive field work, keep the following thoughts in mind:

- Wearing the proper clothing is very important. Long pants are recommended, as are sturdy boots, which will help prevent twisted ankles as you scurry over uneven or loose surfaces.
- While walking through a valley or next to any outcrop, always be on the lookout for rock falls. Remember, slopes with no vegetation tend to produce more falls.
- If more than one individual is climbing an outcrop, do not climb single file. Rocks dislodged from one climber can quickly tumble down the outcrop and hit the next climber.
- When using your rock hammer, protective eye wear should always be worn. If your hammer possesses a sharp pick opposite the flat surface, always use the flat surface when striking. And if you are working with others, notify all in the vicinity before striking any surface with your hammer.
- Never use one hammer to strike another. Metal chips can be broken off and thrown at high speeds.
- Finally, always carry a small, standard first-aid kit.

Documentation & Specimen Collection

Photographs: Once at a field site—for both professional and amateur scientists alike—it is easy to immediately begin taking photographs without recording notes to accompany them. But the lack of proper documentation is perhaps the most common mistake in the field, especially with digital photography, where it is possible to take tens to hundreds of photographs at a site. Also, before you begin photographing it is advisable to first explore the entire location and develop a plan for how you will communicate the site to your students back in the classroom. This plan will guide your photography, and the recorded notes will ensure that every image makes sense long after you've visited the site. Proper documentation includes:

- Note the location and orientation of the photographs you take.

Materials to Take

Documenting the Site:

- *Camera (esp. digital cameras for easy down-load and presentations)*
- *Notebook, ideally* Rite in the Rain *brand*
- *Map of the area, ideally a topographic map*

Recording this information on a map is very helpful.

- In each photograph, it is important to have a sense of scale. For smaller structures (like ripple marks or fossils) or close-ups of an outcrop or rock, it is important to show scale by using a common object, such as a penny, rock hammer, an unsharpened pencil, or (ideally) a clearly-marked ruler. For larger structures, a really great scale is a person, so feel free to step into the picture! The importance of a scale can not be overstated, as the proper identification of geologic features in photographs often depends on knowing the feature's size.

Drawings: Although photographs are key, simple sketches or drawings are also useful for documenting a field site. In fact, subtle changes in rock layers, for example, may not show in photographs, so to capture such features, drawing may be required. Drawing also forces you (or your students) to observe closely. It will be usefull to use either a *Rite in the Rain* notebook (available at www.riteintherain.com) or a large, clear plastic bag to hold your notebook in case of rain. When drawing, keep in mind that you should document the same type of information that is documented in photographs (location, orientation, scale).

Collecting specimens: Rocks and fossils often provide significant clues for interpreting past environments. Layers of basalt indicate past volcanism, for example, whereas shales bearing trilobite and other fossils indicate deposition in a shallow sea. Collecting specimens from a site provides a wonderful opportunity to take a piece of the field into the classroom, allowing you to engage students in hands-on learning. Collecting specimens also permits further study away from the field site. Both time and field conditions limit the study of samples at a site; collecting allows extended study of samples. You can and are encouraged to identify rock, mineral, and fossil types in the field, but studying them indoors with additional tools and references can confirm—or force you to revise—your identification.

Important: Before any rocks or fossils are removed from a site, be sure to confirm that collecting is permitted on the grounds!

Materials to Take

Collecting Specimens:

- *Rock hammer, chisel-head is preferred*
- *Goggles or other eye protection*
- *Resealable bags or small specimen boxes, ideally clear durable bags, like freezer bags with white areas for writing*
- *Small boxes or plastic totes for carrying bagged specimens*
- *Permanent marker for labeling bags and/or boxes*
- *Specimen labels (a few examples are available at the end of this chapter)*

Miscellaneous Items:

- *Hand lens, about 10x*
- *Tape measure and/or measuring stick*
- *Scale to include in photographs*
- *Pocket knife*
- *Compass to allow proper orientation within the site. If available, a brunton compass is useful for measuring the angle, or dip, of bedding*
- *First-aid kit*
- *A GPS unit is beneficial, but not truly necessary*

So, what do you need to know about collecting specimens?

- You first need to confirm that collecting specimens at the site you are visiting is legal. Typically, collecting is not allowed in parks, so be sure to check.
- Just as you made decisions about photography based on how you will communicate the site to students, collect specimens that will help tell the story of the site back in the classroom. If rock types change from area to area, either vertically or horizontally, then specimens of each type are ideal.
- Before collecting a specimen, take a photograph of it ***in situ***, both close-up as well as from a distance. Don't forget to include an object for scale in the photograph!
- Document the location from which the specimen is collected, preferably on a map of the area. Labeling the specimen with a number that corresponds to the same on your map is an effective technique.
- Specimens should be broken directly from the outcrop so the exact source is known. Eroded rocks scattered about on the floor of the site may have originated from multiple locations.
- The weathered surface of rocks often carries a different appearance than a "fresh" break. Ideally, collected specimens possess one weathered surface but are otherwise not weathered. Rocks broken directly from outcrops will ensure fresh surfaces.
- As specimens are collected, place each in a separate resealable bag, noting on the bag with permanent marker each specimen's location as indicated on your map.

An **in situ** *object is one that is situated in its original position.*

Back in the Classroom: Virtual Field Experiences (VFEs)

Perhaps the most critical step after your trip to a field site is to, once back in your lab or classroom, examine all of your photographs, illustrations, specimens, and notes associated with each. Sometimes even the most diligent geologist forgets to record notes that, in hind sight, are critical. It is therefore recommended that one makes sure that his or her notes are legible and complete. Recopy your notes. Such an activity will not only ensure legibility for the future, but it will help indicate any gaps in your note taking. If gaps exist, then it is easiest to fill them when your memory of the site is fresh.

Once your materials from the site visit are in order, it is time to

develop an activity that will allow your students to experience the site much like you did—but in the classroom. One recommended activity is the *Virtual Field Experience* (VFE). Scientists in the field do not have a single possible way to operate, nor do they have a guide explaining what they see at every turn. In the field, one might pick up a rock and take a closer look, or pull out a magnifying glass and look at a cliff face. Exploration drives inquiry in the field; inquiry and exploration are the goal of VFEs.

The concept of VFEs can take on multiple forms. For example, kits containing maps, printed photographs, and specimens (with notes on the map indicating where the specimens were collected or photographs taken) can be produced. Or, your digital photographs can be embedded within a PowerPoint presentation, website, or Google Earth tour with notes indicated where the specimens were collected. But keep in mind that these electronic presentations may take on a very linear, directed feel. In that respect, be careful that your VFE does not turn into a Virtual Field *Trip*. Virtual Field Trips have become increasingly common at many levels of education. But these experiences are typically guided tours rather than opportunities for inquiry. An online search will yield many examples of these tours, as will a search of the Digital Library of Earth System Education (DLESE). Such resources clearly have value, but they are passive experiences for students. VFEs, in contrast, stress the importance of inquiry; learning for understanding involves students figuring things out.

In considering VFEs as a recurring practice, initial experiences are perhaps more guided than the later experiences; allow a gradual transfer of responsibility from teacher to student. But VFEs ideally offer the same opportunities for exploration as those provided at an actual field site, with occasional moments of discovery that lead to new questions about the site. By asking such questions and then seeking answers, students are doing science. And it is perfectly reasonable to virtually visit a site several times for further data collection, or to study different concepts at the same site. Scientists, of course, do this exactly.

Be sure to visit* www.virtualfieldwork.org *on a regular basis to find a constantly updated selection of VFEs created by scientists and educators around the country.

A VFE Vignette

To get you thinking about how to deliver a VFE, the following vignette illustrates how a VFE might look in an Earth science classroom. The story reflects a classroom familiar with fieldwork experiences. It is not meant to serve as a standard model for VFEs, but simply one possible outcome. In this example:

Ms. G had taken a hike in the woods and found a rock feature that didn't match its surroundings. Through a VFE that she created, she engaged her students in the puzzle of figuring out why the place looked the way it did. She had shot several photographs at the site, and she brought back a few rocks.

She'd done this a few times over the course of the year, in effect taking her students on virtual fieldtrips. Over time, she'd built up a number of such activities that took her students where she'd been through the power of her description and a framework that she was forever developing.

There were certain things she'd learned to do on each one of these trips (whether with the kids or when she went on her own to create a virtual field trip for her kids). She took a GPS unit and recorded the coordinates of points of interest. She took her digital camera, and sometimes her video camera. She could then incorporate images of the place into both student handouts and into computer slideshows. If it was in a place where she had permission to collect, she'd bring her rock hammer (if she thought she'd need it).

This time, she took a slightly different approach with her use of pictures. She created a quick and simple webpage of the pictures. This was very simple to do with the photo management software that came with her computer. She used the web space provided by the school district. She added a label on the top of the page and gave a few of the photo titles, but she didn't sort through them. She didn't have time for such sorting, for one, but she thought it would be interesting to have the kids figure out which pictures were better for showing whatever it was they wanted to show. Earlier in the year, she'd done more of the sorting through of things like this, but was consciously trying to gradually shift more and more of the responsibilities of learning and teaching to her students.

The class begins by Ms. G talking about the hike she'd taken over the week-end. She was hiking in the woods on a hilltop not too far away, but far enough away and remote enough that it wasn't likely her students had been there.

She told the class that she was walking along the trail through the woods, and

This vignette highlights some elements of Teaching Standards A, B, C, D, and E; 9-12 Content Standards A, D, and F; the Unifying Concepts and Processes; and Program Standards A, B, and D.

then she came around a bend in the trail and found an area that was partly surrounded by vertical rock walls about 10 meters high. She showed several pictures by clicking through the webpage mentioned above. The students got into their regular working groups of three or four. Each group was given two rock samples and a handout that included pictures of the area. Ms. G told the class to take about ten minutes to analyze the information they had about this place and then be prepared to talk about it: "If you think you know something about the area, remember to be prepared to describe how you know what you know."

The handout included a set of questions, but these questions were, for the most part, not new to the students. The question page was titled "Why does this place look like this?" and all the questions that followed were intended to connect back to this main question. The questions that followed the lead question were:

1. What kind(s) of rock(s) are found in the area? How do you know? What environment did these rocks probably form in?
2. Describe the arrangement and variety of rocks shown in the photographs.
3. Tell a story of how these rocks may have formed referring back to the photographs and what you have determined about the rock sample(s).
4. What has happened to this area to make it look the way it does today? (That is, what has happened to the area since the rocks formed?) Why do you think so (what is the evidence for your claim)?
5. If you could go to the site, what else would you want to do to answer the above questions?

Ms. G wanted to teach through inquiry methods. She wondered if this somewhat formulaic approach would be considered inquiry. In all these virtual fieldtrips, she had a good idea of what students would discover. In this case, she expected them to figure out that it was an abandoned quarry, where the limestone came from, that built the old buildings at a nearby university.

In the last year she added what she hoped would be an additional motivation for learning. She'd added a new essential question to her list: "What does learning this empower you to do?" This allowed her to more explicitly teach metacognition (thinking about thinking) and it allowed her to draw out of her students answers to the question, "Why do we have to learn this stuff?" If they answered it themselves, they were being metacognitive and they were getting answers to this important question.

While she wondered about whether or not what she was doing could truly be classified as inquiry, she had confidence that it was more effective than what she used to do—stand at the overhead and deliver notes.

She believed it was more effective for many reasons, but perhaps most importantly she saw a more clear connection among the different things she taught and it seemed her students did, too. Instead of identifying rocks and minerals for the sake of identifying rocks and minerals and learning something more broadly about taxonomies and dichotomous keys, students now had a purpose for identifying those things. If they figured out what it was, then they also had a good idea of how it formed. If they had a good idea of how it formed, they could use that to understand something about the history of a place. They could use this understanding as part of a story, an unraveling mystery that they were active in unraveling themselves. In this case that story also connected to the human history of the area. This quarry provided the stone that built some of the oldest buildings in the county and at least the first one of those buildings was built by students working together with their professors. This use of story provided a sense of wholeness that had been missing in her teaching.

What the area looked like: The area that was partially surrounded by those vertical rock walls had a flat floor that was largely moist but didn't have any spots where the water was more than several centimeters deep. Bare, flat rock was exposed in several places on the floor of this place. She had paced some of it out to get a rough idea of the dimensions of the place and had taken several photographs.

Her photographs showed the lay of the land for the larger area surrounding the spot. All the hills were about the same height--it looked to the students that she was in the same region as where they lived, and a few recognized that her first pictures included a nearby university's campus. Once this word was out, students knew that it was in the same landscape region. "That means it's all sedimentary rock," said Joe.

This was confirmed by the presence of fossils in some of the samples. As the students studied the rock samples, and the pictures of the cliff faces, you could hear them working through rock ID tables.

"Is it a sandstone?" "No, it's too smooth," came a quick reply. "Look at how flat the sides are. Are they crystal faces?" "That's one ugly crystal if they are. Remember, the other piece looks a lot like this one, but it's got fossils in it. Oh look! There's a fossil on this one too!" "Is it limestone?" "Should we do the acid test?" They tested it with dilute hydrochloric acid and it fizzed. Limestone it was.

One group wanted to know the coordinates immediately, and Ms. G knew but she wouldn't surrender that information without the students first having explained how the area in the pictures came to look the way it did. They didn't

have much to say initially so she made them wait. She knew they wanted to go to the computer and to the USGS map viewer. Once they plugged in the coordinates, they'd see the quarry symbol on the map. (The coordinates were: 75° 31' 56" West, 42° 48' 50" North; Stated in decimal degrees, -75.532; 42.814.)

Another group was more focused on the pictures. Katelyn said, "In 823, you can see rock layers, so it definitely looks like sedimentary rock." Ms. G was standing nearby and was glad they were sorting through the pictures as she'd hoped. "It looks kind of like a gorge, but it looks like there's only one side to it." "There's not really anything that looks like a stream bed, but that might just be missing from the pictures. That's one thing to look for if we were able to go up there." "Or if we knew where it was on a topo map." "Ms. G!" They got her attention. "Can we look on a topo map? We want to know if there's a stream there that might have carved out a gorge." Ms. G responded, "That's a good idea to investigate. I want you to think a bit more before I give you the coordinates though. I will tell you that it wasn't a gorge. It's fairly close to the hill top you see here." She was pointing to a spot on one of the pictures taken from across the valley. "Do you think a gorge would be on a hilltop?"

The group who had wanted the coordinates right off was moving somewhat slower than the other groups. Ms. G wandered over to check in and maybe push them along a bit. She asked, "What can you tell me?" There were shrugs. "What kind of rock is it?" "Sedimentary" is mumbled. "That's right. How do you know?" Another mumble, "Fossils." At least she was getting some kind of answers and they were in very much the right direction, but she was frustrated that she had somehow asked these questions that allowed a one-word way out. "Where did it go?" Ms. G asked. "What do you mean?" came back. "Well, when this rock formed, do you think it was formed all stacked up like this with an almost straight edge sticking out into the air or water or whatever it formed in?" Justin said, "Who cares?" Ooh. They were a frustrating group, but Ms. G kept her cool. "I thought maybe you did when you asked for the coordinates. Come up with an answer that you can support using the information you have and I'll give you the coordinates to look up on the map viewer." She moved on, hoping they'd try to figure it out.

After letting the frustrating group hash it out a bit longer, Ms. G turned her last question for them to the whole class, "Where did the rocks go?" She got the same response as earlier, but from a different student. "What do you mean?" Justin chimed in, more favorably this time, "There doesn't seem to be much of a stream to have washed it away, but it wouldn't form just straight up like that, or at least not having that flat, bare rock right at the base of the

cliff. I think it's an old quarry." From Katelyn's group came an affirmation-- "That's why she wouldn't let us look on the topo maps. It'd be marked and give it away. Can we bring it up on the map viewer now?"

Ms. G had Audrey, from Katelyn's group, bring the map viewer up on one of the computers and plugged in the coordinates. "I knew it. There's the quarry symbol!" Ms. G asked what else she could tell from the map. "It's on the Colgate campus, and there's a dirt road leading into it. I'll bet it's where they got the stone for the campus buildings." Ms. G responded in the affirmative. "Ok, we've figured out why it didn't match the surrounding forest. Now I want you to work through the questions on your sheet and I've got another set of questions that are more specific to the quarry." She handed out a sheet with these questions:

A map viewer is available at ***http://nmviewerogc.cr.usgs.gov/view.htm***

1. Why do you think the quarry was dug in this particular location?
2. Colgate's added a lot of buildings in the last several years, and many of them are stone. But this quarry has obviously been unused for many years. Why do you think they stopped using it?
3. Imagine that Colgate has asked you to find a new quarry site for a new science building they plan to construct. Use the geologic and topographic maps to select another quarry site that would likely contain similar stone. Together with your partners, write a proposal for siting the quarry in a particulary location. In your proposal, you should address not only the nature of the stone the quarry can produce but also at least three other factors that you determine to be important for siting the quarry. Plan to present this to the rest of the class next week. You may use either a poster or a PowerPoint presentation.

References:

National Research Council. (1996). *National science education standards*. Washington, D.C.: National Academy Press.

United States Geological Survey (2005 access date). *The National Map Viewer*. Washington, D.C.: USGS http://nmviewogc.cr.usgs.gov/viewer.htm.

For More Information...

Books

Compton, Robert R., 1962, *Manual of Field Geology,* John Wiley & Sons, Inc.: New York, New York.

Maley, Terry S., 2005, *Field Geology Illustrated, Second Edition*, Mineral Land Publications: Boise, Idaho.

Walker, J. Douglas, and Harvey A. Cohen, 2007, *The Geoscience Handbook: AGI Data Sheets, 4th Edition*, American Geological Institute.

Online

Visti the official home of VFEs at www.virtualfieldwork.org to learn more and explore the online database of educator-created VFEs!

Tips on teaching in the field, including notes on safety, liabilty and other issues http://www.nagt.org/nagt/field/index.html

Rite in the Rain notebooks are available online at http://www.riteintherain.com

Topographic maps are available at http://topomaps.usgs.gov/ or by clicking *Terrain* at http://maps.google.com

Field equipment items are available at http://geology-outfitters.com

Selected Figures
for overheads & handouts

Specimen Labels for Collecting in the Field

Specimen Label

Collection Location:

Rock or Fossil Type:

Geologic Period or Age of Rock:

Collector:

Collection Date:

Specimen Label

Collection Location:

Rock or Fossil Type:

Geologic Period or Age of Rock:

Collector:

Collection Date:

Specimen Label

Collection Location:

Rock or Fossil Type:

Geologic Period or Age of Rock:

Collector:

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