The Story of the Earth

Dale H Easley
http://daleeasley.com

Fall, 2018

Table of Contents

“The conscious purpose of science is control of Nature; its unconscious effect is disruption and chaos.”

William Irwin Thompson

A Philosophy of Teaching

Perhaps you've had the opportunity to be served in a restaurant by a really good waiter. He exudes competence without being snotty. Neither does he suck up. You feel important and cared for—never patronized. If he suggests a particular dish, you're open to trying it because he has first listened to and clearly understood what you want for the evening. And if anything isn't as you wish, he takes responsibility for correcting it. You will never see a good waiter blaming a customer—the customer is always right, even when he isn't. Most importantly, the good waiter has something special to share with the customer and is enthusiastic about it.

Similarly, a teacher has something—an idea, a way of understanding the world—that students lack. The effectiveness of that teacher depends on his or her ability to communicate those worthwhile concepts, not the amount of material presented nor the performance of students on a test. That communication in turn depends on three things:

Relationship: the context in which communication takes place. There is always a relationship present between the teacher and each student. A teacher does not speak into a void, but into a space provided by the student. Though that space is shaped by many factors beyond the teacher's control, the teacher's skill in listening and empathizing determines his or her ability to understand the nature of that space and to shape it in preparation for accepting the ideas the teacher presents. Our tendency is to focus on the things present in a relationship and to seek to get rid of the disagreeable ones. However, removing something bad is no guarantee that something good will replace it. A more powerful approach is to focus on the things that are missing. Then we can determine how best to create them.

Integrity: The teacher must always be honest, admitting mistakes and lack of knowledge, giving true reasons for grades, never intentionally misleading students. But integrity is more than truthfulness. It implies competence. If a man claims to be doctor, integrity requires not only that he have the required education, but that he has kept up with his field, that he has remained a competent practitioner of his art. The alcoholic doctor whose hand trembles when he operates hardly has integrity, even if he is sober at the time. Likewise, a teacher must be competent in the material being taught, keeping up with new ideas and theories, seriously evaluating what material the student needs to learn. Finally, a major component of integrity is enthusiasm. Enthusiasm is the difference between fulfilling the letter of what you say and fulfilling the spirit.

Responsibility: The teacher must assume complete responsibility for the student's education, no matter that the student is on drugs or was abused at home or simply didn't get a good night's sleep. Being responsible doesn't mean thinking that you can make everything right. Nor does it mean sinking into self-blaming or accepting abuse. Each of these lacks integrity. Instead, it is an attitude that refuses to pass off failures and shortcomings to others. It is a positive, empowered attitude.

You may say that teaching is different from working in a restaurant. Of course, it is. There are no "required" restaurants. But even the best restaurants may sometimes have to resort to tossing out an unruly customer. Still, it is clear that for most customers, being there is a joy and what is being presented is valuable and worthy of respect. The entire dining experience improves the quality of our lives. Shouldn't education be the same?

Part I
Introduction

1 My Story

I came to geology not through a love of rocks but through a desire to travel. However, that travel led to drinking unclean water (a great weightloss method) and a resulting decision to study water resources. Geology proved a route that combined my studies with my love of travel.

In middle school, the worse course I had (then or ever) was earth science. After that, I wanted nothing more to do with geology. However, my college offered a chance to travel—a geology fieldtrip backpacking and camping out west. So the summer after my freshman year of college, at a time when I was an English major, our class visited Yellowstone, the Tetons, the Badlands, and Dinosaur National Monument, hiked tens of miles, camped every night, and journaled daily—I loved it all. Geoloy wasn't so bad after all.

But during the next fall, my sophomore year, my father was diagnosed with leukemia, dying at the beginning of spring semester. The English professor I admired most didn't know how to deal with my emotional vulnerability and pushed me away. I was a mess and switched my major to math, something I was good at and that required no emotional energy nor vulnerability. At the same time, I started taking some geology courses, the equivalent of a minor, though never formally recognized. But they were enough to get me into grad school in geology after two years teaching math in Africa.

My two years in Africa were in most ways wonderful—except healthwise. Besides a bout of malaria, I had a lung infection and multiple bouts of explosive diarrhea and vomiting. I well remember sitting on the toilet with a bucket in my hands. In particular, during the spring of my last year, the seasonal rains failed. The reservoir providing water for the town dried up, and the water supply was intermittent. At the same time, I often frequented a shop in town that served a wonderful curry soup and samosas—triangular, deep-fried, meat pies. Delicious. The shop was a bit of a greasy spoon, and after the rains failed, the spoons became particularly greasy. I picked up something that ripped through my system, screaming "Oh, shit!" the entire way.

When I returned from Africa, I was about 40 pounds lighter than I am today, gaunt to the point of emaciation. I decided clean water was important. And that led me to grad school.

Grad School in Wyoming

I ended up in grad school in geology at the University of Wyoming seemingly by a chance encounter. My Kenyan school had a three-month-on/one-month off schedule, and during my time off, I travelled—gameparks with rhinos, elephants, and lions, and the lakes of the Rift Valley—Naivasha, Nukuru, Begoria, Turkana, and Baringo. At the latter, a 45-minute boat ride took me to Island Camp, where thatched-roof buildings, a swimming pool and bar, and tent accommodations awaited. It was one of the few places I visited more than once.

During my second year in Kenya, I decided that I would study water resources when I returned to the U.S. I had decided clean water is important. Duh! While visiting Island Camp, I went for a stroll. An old couple sat in front of their tent looking at the lake. I chatted for perhaps 20 minutes, but that brief encounter shaped all that came afterward.

The old guy was Don Blackstone, a retired and emeritus geology professor from the University of Wyoming, vacationing in Kenya. I told him what I was interested in, and he replied, “Why don’t you consider coming to Wyoming?”

At the time, geology was one of the hottest fields for employment in the world, driven by sky-high oil prices. When I applied, I was unaware that I was among 800 applicants for perhaps 30 slots. If I’d known, I might have been intimidated. But unlike many geologists, I am good at math, plus I wasn’t trying for one of the oil-related positions. Thus, I stood out enough to get accepted. When I returned home from Kenya, I got in my old wrecked-and-rebuilt Ford Pinto, my first and only car to that point, and drove more than 1600 miles to Laramie, Wyoming, to start graduate school.

In grad school, your most important relationship is with your adviser. I had applied from Africa in the days before the internet, so I knew little about my adviser except for his name, Peter Huntoon. However, I took a class with him that first semester, and he soon took us on an overnight field trip to northern Wyoming. By then it was late September, and it snowed a foot. My hiking boots were still coming back from Africa, so I bought some lined cowboy books with high-traction soles. They performed well enough but fit terribly, eating through my socks and into my heels, as I and the other students hurried and failed to keep up with Huntoon’s hiking to spots he wanted to show us.

On our return drive, we stopped in at the Thermopolis Hot Springs. Soaking in the 105-degree water was a blessed relief. However, I found no relief for my seeming inability to please Dr. Huntoon. I got a bit of insight on a later field trip when he said, “I believe in making a student as insecure as possible. That’s when they do their best work.” I didn’t need any help being insecure, thank you. As to students doing their best work, I couldn’t see that it was being done for Huntoon—of the three students who began working with him when I did, one dropped out of school, and the other two changed advisers.

During that first fall, I took a class in mathematical geology because the course I wanted to take didn’t fit in my schedule. I did very well in the course, and the professor, Leon Borgman, needed someone to work on a project for the Environmental Protection Agency. He decided to fund me, and that summer, I changed advisers.

Dr. Borgman’s approach to working with students was quite different from Huntoon’s. Borgman had trained national-level obedience dogs, and he once said to me, “Working with graduate students is a lot like working with dogs—you don’t start kicking them before they know what to do.” Personally, I was like the dog who responded to a pat on his head with a hump on your leg. Anyway, I thrived under his more gentle approach, and in return he was able to turn over to me much of the project work that he didn’t enjoy, such as writing quarterly reports. I even got to write a proposal for continued funding, a great experience for my future career. I ended up staying on for another four years and completing my Ph.D. under Borgman’s direction.

I tell my students about the importance of developing closeness with a few of their professors. “You’ll need some letters of recommendation someday. And when internships or other opportunities come up, we tend to think first of the students we know best.” But these relatively self-serving justifications are really just an attempt to open a door. Friendships are sufficient in and of themselves.

During the spring after I started working for Dr. Borgman, he took me along on a trip to Las Vegas, the location of the EPA lab supporting our research. Las Vegas might seem a strange place for an EPA office, but it’s the closest city to the Nuclear Test Site, where weapons were exploded and observed after World War II. Water is the limiting resource in that part of the world, so funding research on groundwater fit with the office’s mission. During that trip, I met Dr. Dennis Weber, who worked at a research lab associated with the University of Nevada–Las Vegas. The following summer, Dennis opened his home to me as a free place to stay while working with the EPA. For six weeks, Dennis and I spent most of 24 hours per day together, working on research, eating out at the casinos, hiking, and talking in the nearby dough-nut shop. He took me in once again two summers later when I returned to Las Vegas on another project with the EPA. And i just got an email from him a few days ago.

When I finally got close to finishing up at the University of Wyoming, I first needed to form a Ph.D. dissertation committee of five or so professors or experts in the area of research, a committee including Huntoon, Borgman, and Dennis. Another of my committee members was Peter Shive, a geophysicist and Stanford Ph.D. who worked on an associated project funded by the U.S. Army Corps of Engineers. During my time in Wyoming, Peter met his present, wonderful wife, Gail, an artist and avid bicyclist. (I wrote an article about her [here].) And they, too, became friends I've stayed in touch with since.

I've long since returned to Wyoming with my own daughters. Each spent ten days at a wilderness program that included a first repel off the billion-year-old Sherman Granite that I had repelled off 35 years before, except they did it in the dark. They got to see snowfields in July, as they hiked through the towering Rocky Mountains, including the appropriately name Snowy Range. And hopefully, they have grown to love the natural world as they've hiked through it, run over it, and driven and flown by it.

New Orleans

During my last year at the University of Wyoming, one of my fellow graduate students walked into my office with a professional journal advertising academic jobs. (This was before everything was on the internet.)

"Did you see this job at the University of New Orleans?" he asked.

"No," I replied. "Let me take a look."

At that point, I was just beginning to think seriously about what came next. The job was for a hydrogeologist, someone who works with groundwater, my area of interest. So I applied, got an interview, and got the job. During the interview, I joked, "I wanted to work in the Third World, and New Orleans was as close as I could get in the U.S." Fortunately, the old professor I was speaking with took it as a joke and laughed.

At that time, New Orleans had the highest per capita murder rate in the U.S. But it also had great music, great restaurants, and festivals nearly every weekend—always something for a 29-year-old bachelor to do., though I was woefully ignorant of nearly everything cultural. One of the more experienced professors, Bill Ward, had headed the search committee that hired me, and Bill had a son about my age. Bill became my mentor, guiding me through the academic world that was mostly a mystery to me. For example, during New Faculty Orientation, I was introduced to the Provost of the university. I had no idea what a *Provost* was, and I probably didn't act adequately impressed. The Provost was my *Big Boss,* the top guy for day-to-day operations of the university. Fortunately, Bill educated me. For the first four years, he, I, and a couple more of the old times ate lunch together daily, and listening to their daily chatter was better than four years in classes. And after my fifth year, Bill was my Best Man when I got married.

After my time in Africa, I had chosen to live as simply as possible. I drove an old truck with no AC, no radio, and doghair on the seat, and I lived my first three years in New Orleans without air-conditioning. I drilled hooks into the rafters and hung a couple of hammocks, plus stuck a fan in the window for especially hot days. Admittedly, I didn't get many dates in the summer.

For a certain group of people, such a lifestyle is attractive. Thank goodness. One of my students set me up on a blind date with a zookeeper. I took her out for coffee, not wanting to spend too much on a first date. My date, Jamie, now my wife, and I closed the shop down and then went out for a beer. A couple of months later we were engaged, and the following August, we left for a year in the Middle East.

Qatar is one of the richest countries in the world. I didn't get into water resources to help the wealthy—I wanted to work in poor countries. After Jamie and I returned from Qatar, I began looking for a chance to get involved with organizations aiding the poor, and I attended a conference for **Water for Life,** an organization that sent simple drilling rigs to poor countries and then trained locals how to use them. While at the conference, I learned of an upcoming trip to Haiti, and I signed up.

The flight to Haiti left out of West Palm Beach on an old DC-3, a World War II-era riveted plane with a small tailwheel that made entering the cabin a bit like climbing a hill. Because of all we were transporting, it had to stop at a small Bahamian island to refuel.

Not the latest technology, but the kitchen cabinets of the house I grew up in were made from the floorboards of DC-3s, boards scavenged by my dad from the airport where he worked. I knew DC-3s well, and I knew them to be workhorses that were hard to knock out of the air, much less fall out on their own.

Shortly before I was to leave for West Palm Beach, Jamie and I had our first miscarriage. I was later to learn that quite a few people had similar experiences, but at the time it was overwhelming and lonely. We decided for Jamie to come with me as far as West Palm Beach and stay with her parents until I returned. Her parents are generous, warm, and welcoming, and I knew Jamie would be cared for. What I didn't know was that while in Haiti I would get a tour of a medical clinic with posters on the wall of a developing fetus. We had been so happy over the Christmas holidays when we announced to our families that a baby was on its way.

After one more miscarriage and a second trip to Haiti, we had two wonderful, healthy daughters. And I took a few years off from traveling, volunteering locally in New Orleans at a GED program, teaching math and science, mostly to middle-aged African-American women.

My time in Haiti working on water wells had been eye-opening. I saw lots of projects in a state of disrepair, lots of cases where intentions were good but the improvements didn't last. The head of the GED program gave me an article that had appeared in one of her magazines about a model sustainable development program that a priest had helped start in Fondwa, Haiti. I went to visit and, subsequently, took students to Haiti to study sustainable development.

A couple of weeks before my last trip to Haiti, the Provost of the university canceled my course. He didn't ask me about it, call me, email me, or contact me in any way. By that time, I was serving on a non-profit organization working in Haiti, had developed many local contacts, and already spent about $10,000 on tickets for the upcoming trip. Fortunately, my department chairman let me switch the students to independent-study credits, and we went anyway.

When I returned, I went to see the Provost. He made the excuse that any course going outside the U.S. had to follow a certain procedure, going through what was called Metro College at UNO. (One of my colleagues had been allowed to go with students to Mexico that same summer, but maybe the Provost meant North America. Huh.) So I jumped through the new set of hoops for a few months, got all more paperwork done, and went back to see the Provost. His not-new response? "I can't let you go." He was scared of the potential liability with Haiti. I would have appreciated a bit of honesty when I first went to see him, if only to save myself the paperwork and lost time. I decided it was time to look for a new job.

The University of Dubuque

Jobs at small colleges for geologists are scarce, but that's what I was looking for. One popped up on HigherEdJobs.com at the University of Dubuque. Frankly, I didn't know where Dubuque was, nor was I clear on the location of Iowa. In my mind, I had it closer to Ohio. But the application was online, so I decided to give it a try. Soon after, the UD's Vice President for Academic Affairs, John Stewart, called my office in New Orleans.

"Does it snow up there," was one of my first questions, not the typical interview question. But my wife grew up in Florida, worked and met me in New Orleans, and was ready for seasons. Thus, my question.

"It's in the upper Midwest," John replied, a bit nonplussed at such a question.

Perhaps because the call seemed to come out of nowhere, and I already had a secure job, a house, a wife, and kids, I was less nervous about the call that I might have been. Regardless, John and I soon fell into a good discussion, and I followed up with an email that included a link to my web page. On it, besides course notes and a vita, I had an essay on helping students to find their vocation. Unbeknown to me, *vocation* was a loaded word at UD, a focus at the time as a path for students. One never knows what will click in a job search. I was invited to Dubuque for an interview.

Before I visited, John asked me, "Would you be willing to take the job for this fall semester?" The previous geology and left, and UD needed classes taught. However,I had already committed to team-teaching a course with a friend, plus I had a house I'd need to sell. The spring semester would be as soon as I could move. John's response was to suggest that I wait and interview in the fall, teach a class, and meet some faculty members. Hmmm...

My wife and I are no great fans of delaying a decision. (We were engaged two months after we met.) After talking, I called John back,

"I'll pay my airfare to Dubuque if you'll feed and house me," I offered. John accepted, and I flew into Dubuque in midsummer.

The plane landed at the Dubuque airport, surrounded by cornfields, where John picked me up. I would be staying in a basement apartment in his house. As we drove into town, the flat cornfields gave way to incised streams, then the bluffs of the Mississippi River. Beautiful. And though I didn't realize it at the time, the weather was particularly pleasant during my visit, a real relief after the New Orleans summer heat. After a few days visit, meeting multiple administrators and a few future colleagues, I had an offer. I returned home and started getting the house ready to sell.

We moved to Dubuque in mid-December, arriving on a Thursday. My two daughters had never seen snow fall. On that first Sunday night, both daughters were in bed, wearing footy pajamas, when it started snowing. I brought them out where they danced in the snow on the front sidewalk. The move had gone well. I hoped my new job would go as well.

2 Why Geology?

“Why are you taking geology?” I often ask my students, though I already know the answer.

“I need a lab science requirement,” they usually reply. Often they’ve heard that geology is the easiest way to meet that requirement. “Rocks for Jocks,” they snicker. But when I submitted this week’s midterm grades, a third of the class was failing. Huh. It’s not that I take pride in the failure rate, but neither do I like having my course dismissed as fluff. (And most of them will manage to pull their grades up once they get serious about doing well.) In fact, geology is like most things in life —you get out of it what you put into it. So my challenge is to help students see beyond requirements toward the benefits of putting effort into understanding geology. If I can’t answer the “Why?” question myself, why should I expect them to be able to? And if they can’t understand why, I doubt many of them will be motivated beyond getting whatever grade they see as a minimum to meet their needs.

Students have a lot of things vying for their time—jobs, sports, courses in their major, and their social life. It only makes sense for them to apportion their time accordingly. One would hope that they could see the relative value of their activities, but I see little evidence. The takehome pay for a $10/hour job, 20 hours/week, is $2800 over the semester. My 4-credit course currently costs $3400. Yet, they will make the job a higher priority, even if it means dropping the course. How does that make sense? Or they’ll put in 20 hours a week at a sport that they actually have to pay to compete in and will never earn a cent from, yet will often miss class for. Huh.

Look, I was a student once, too. I put a lot of time into choir and the school newspaper and girls. But the only time I ever dropped a course was the semester my dad died, and only then after I missed another week from flu later in the semester. It was Russian IV, not something I needed, even as a free elective. And next fall, my daughter will be captain of the crosscountry team at her college. She also runs track, works in the admissions office, and is active on campus. I told her I’d be disappointed if she graduated with a 4.0. She promptly made one of two A- grades. My point was that if she graduated with a perfect gradepoint, she should have gone to a tougher college and/or done more things outside the classroom—outside her comfort zone. So I’m not opposed to the time my students devote to things other than geology. They just shouldn't go about it blindly. Deluding ourselves is way too easy. And costly.

First, admit those conflicts: There are significant financial reasons to do well enough in this class, and there are significant aspects of your life pulling you away from the time needed to do well. In order to get yourself motivated and persist for the duration of the course, you need to find the best goal that is desirable and attainable. The reality is that it is easier to be pulled towards something you find appealing than to push yourself to do something you think you *ought* to. So try this:

Think of three reasons why you want to learn about geology.

Notes:

Geology has a strong historical component, plus the science of geology has its own history. Understanding both how the Earth has changed through time and how our thinking about it has changed are key parts of this course. Key terms related to both include these:

Catastrophism: Before we understood the ancient age of Earth and the processes that shape it, we tried to explain the things that happened, particularly those that scared us, with superstition, what geologists rcall *catastrophism.* Even recently, an Iranian cleric blamed *promiscuous women* for causing earthquakes, and an American minister blamed Hurricane Katrina on a gay festival. Blaming others for bad things we don't understand is still too common.

Uniformitarianism: As our understanding of physical processes increased, we began to understand how those processes, given enough time, shape we what see today—the present is key to the past. That's uniformitarianism.

Relative and absolute time are the two ways geologists speak of time. Relative time is simple determining if something is *older or younger.* For example, if each day when I come home, I get the mail and toss it in a box, the oldest mail is at the bottom of the box. But if I pick up a letter and look at its postmark, I can read a specific postmark and determine that is it *17 days olds.* That's absolute dating. We'll discuss this in lab soon.

Plate tectonics is the theory that states that the surface of the Earth consists of large slabs of brittle rock that come together, pull apart, and slide by each other. In the second section of the course, we will study in detail how these interactions take place.

3 Seeing as a Scientist

When you were a baby, one of the first patterns most of you recognized was the face of your mom. Not even the whole body. Just the face. And as adults, we still tend to see faces everywhere—in tree bark, in the clouds, even on a cheese sandwich (including the famous one looking like the Virgin Mary, now on display in a Las Vegas casino). That drive to look for patterns is both a tremendous strength and a horrible weakness. But science helps us overcome some of the worst weaknesses.

The scientific method is built upon looking for observations, but it adds a crucial step—testing the resulting predictions. It works like this:

1. Make observations. Look around and see things that aren't apparent. Focus. Really see.

2. Check for patterns. Do things occur the same way over and over?

3. Guess why. (This is our hypothesis). Unfortunately, our tendency at this point is to blame things we don't like upon people we don't like. "An Iranian cleric says earthquakes are due to promiscuous women." Hah. We'd never be that stupid in the U.S. Yeah? Rev. John Hagee said Hurricane Katrina was due to a planned gay pride celebration. Go figure.

4. Use your hypothesis to make a prediction that you can test. In fact, the ability to *test* a hypothesis is what makes our educated guess scientific. Are results/patterns reproducible? Does *data* support your prediction or explanation? When Hurricane Katrina hit New Orleans, the gay section of town was relatively unaffected. But over 900 churches plus a couple of seminaries were destroyed. Did God miss?

5. Revise your explanation/hypothesis and try again. Science keeps try to do better. No answer is *The Final Answer*. We can do better.

Certainly, data is open to interpretation. A rose by any other name would smell as sweet. But there are limits, eh? Calling a groundhog a bird won't help it fly. Thinking about the data and reasoning that supports an assertion is a key part of scientific literacy, a major reason for requiring a lab-science course as part of almost every college curriculum in the U.S.A.

The observations a geologist makes deal with the entire Earth. Much of the public thinks geology is about *rocks.* That's part of it, for sure. But the rocks are just the words that make up the story. *The Story of the Earth* is far bigger, encompassing billions of years plus air, water, and rocks, elements and minerals, but mainly the processes that change the Earth. Science is not so much about what you believe but the patterns you observe, over and over. You may not believe in gravity, but if you slip on the ice, you'll still bust your ass. Understanding that is science in a nutshell.

Notes on a Geologic Investigation:

An example: Geologists hypothesize that the Mediterranean Sea was once early dry. Let's walk through the scientific method and see how they got to that hypothesis:

Geologic observations can come from a variety of direct and indirect measurements. Like an ultrasound can observe a developing baby, seismology uses soundwaves to peer inside the belly of Mother Earth. Seismologists observed a layer beneath the bottom of the Mediterranean Sea tat was widespread and pretty much followed the shape of the sea bottom. The next step, like operating on the baby, was to drill into the seafloor. The first layer was muds that settle out of standing water. But beneath that were layers of evaporites (minerals that form from evaporated sea water), such as gypsum and salt. They also encountered old dunes, windblown in in form. How can we explain such observations? We guess (our hypothesis) that the Mediterranean dried out.

How could such an event happen?

The Mediterranean Sea is connected to the Atlantic Ocean by a small opening, the Straits of Gibraltar. The African Plate is moving north into Eurasia, shifting elevations, opening and closing connections. In addition, periods of glaciation can lower sea level. Some combination cut off the flow of seawater from the Atlantic into the Mediterranean, which has high evaporation rates because of its climate. Eventually, sea level rose or the land dropped sufficiently that seawater began to trickle back into the Mediterranean. As it flowed, it began eroding its path, then flowing faster, then eroding faster, refilling the Mediterranean.

But we're not done with the scientific method. Our hypothesis leads to some other predictions that we can test. What could be some other evidence? How about mud cracks and incised stream channels? They've both been found. Geologists are still working on refining the mechanism by which the Mediterranean dried out, but the theory that it did indeed dry out is well confirmed.

For more on this topic, see [here.]

Part II

Material for Test 1: Where Are We?

4 Iowa Geology

Last fall, I purchased a Honda CTX700 motorcycle, a black beauty with a double-clutch transmission and more power than anything I've owned before. Admittedly, I last rode a scooter. Now I'm passing through the final stages of middle age, even feeling old some days, and I have my hottest bike ever.

Suppose at some point in the future, I, like many other riders, take off my helmet to let the wind flow through my hair, only to lay the bike down to avoid a collision. As I slide across the asphalt on my face, imagine what it looks like—the bones in my cheek and jaw protruding, the soft parts gouged out, and the flesh dragged to the lower part of my face. That is Minnesota. As the glaciers ravaged its face, they dragged the ground up rock-flesh to Iowa to weather into the great soils that now grow corn and soybeans. The gouged-out spots filled with water, forming the *Land of 10,000 Lakes.* And a few hard parts were left sticking up to form low mountains, including the Sawtooth Range.

The geology of Iowa is dominated by the very old and the very new, geologically speaking. (For an overview of the geologic time scale, see [here.]) Hundreds of millions of years ago, shallow oceans covered and uncovered the Midwest multiple times. From those seas, layers of sediment, much of it from the body parts of once-living organisms, accumulated on the ocean bottom, compressing and cementing into the sedimentary rocks that now underlie much of Iowa.

But when Iowa remained above sea level, as it did during the time of the dinosaurs (the *Mesozoic*), sediments were eroded, not deposited, and few rocks of that age or the early part of the time of the mammals (the *Cenozoic*) remain. Only near the end of the Age of Mammals during the Pleistocene Era did the great glacial ice sheets gouge and grind up and redistribute older rocks, forming a layer of *glacial drift* over much of Iowa, rock flour that weathered as the glaciers retreated into the good soils that now grow corn and beans. The last time the glaciers advanced, a tongue of ice licked the belly of Iowa, forming the Des Moines lobe.

However, here in Dubuque we are on the edge of the *Driftless Area*, which includes a bit of Eastern Iowa and Northwest Illinois but much of Southern Wisconsin. The glaciers missed us, and the result is some of the prettiest landscape in the Midwest. The Mississippi River stayed in its course, deepened, and formed the beautiful bluffs alongside. Streams emptying into the Mississippi cut down (incised) as it did, forming rolling hills. And the incising Mississippi exposed deposits of galena, a mineral containing lead.

When Julien Dubuque, a French fur-trapper, came to the area, he met Native Americans who used the galena for producing vibrant body paint, its vibrancy being a property of lead paint that eventually led to its widespread use across the nation. (Unfortunately, lead also causes lots of problems, including neurological damage.) Dubuque obtained the mining rights in the area now designated as the Mines of Spain State Recreational Area.

Before the Civil War, the area near Dubuque and in southwest Wisconsin and northwest Illinois produced about three-fourths of the nation's lead. Down by the river stands the *Shottower*, not the pizza place but a tall building where molten lead was poured through a sieve, dropping 35 feet or so into water, forming spheres as it fell, before being quenched in a pool of water below. The pellets were then sorted and used for lead shot—thus, the name.

In conjunction with the Mississippi River, lead formed the foundation of the economy of Dubuque, the town named after that early fur-trapper.

Through the years, mining has gradually declined, the last mine in the area closing in 1979. Meanwhile, agriculture came to dominate. Much of Iowas was covered with tall-grass prairie when the first European settlers came to the area. Most of that prairie is now gone. Instead, row crops like corn and soybeans dominate. With them come today's main environmental problems:

soil loss: Iowa's wealth lies in its rich soil, but much of that soil has eroded, especially in the hillier regions, such as the Driftless Area. A variety of methods can be used to reduce soil loss, such as planting grass in waterways, plowing along hillsides rather than up and down, planting trees to slow wind, and alternating crops, both in time and space.

water pollution: Fertilizer, manure, and other nutrients entering waterways creates problems all the way into the Gulf of Mexico. Nutrients cause algae to grow rapidly. When it dies, bacteria break down the algae, in the process using up available oxygen in the water—eutrophication. In the Gulf of Mexico, the *Dead Zone* forms seasonally, as much as 9,000 square miles in size, with oxygen levels too low near the bottom to support sea life. See [here.]

energy costs: The costs of agricultural goods is directly related to the cost of energy—fuel for tractors, trucks, and transportation, and natural gas (a raw material for the nitrogen in fertilizer.) In addition, if people spend more of their paycheck on gasoline, less is left for groceries. Profit for farmers is cut on both ends.

Notes on Glaciers:

There have been many periods of extensive glaciation, called *ice ages*, throughout geologic history. We'll talk about their causes later in the course. The most recent ice ages have occured during the time epoch geologists call the *Pleistocene*, beginning 2.6 million years ago and ending about 11,700 years ago. During that time, glaciers advanced and retreated multiple times, leaving behind evidence of their presence:

moraines: long, sinuous lines or dirt tens of feet high that mark the edges and end of the glaciers. They outline the last location of the Des Moines lobe. And if you drive from Dubuque toward Madison, most of the route passes through the Driftless Area, with deep stream valleys and rolling hills. But just outside Madison, in Verona, the road crosses the terminal moraine of the glaciers, and as one continues into the city, the landscape is flattened, with multiple lakes.

glacial erratics: The glaciers forming the continental ice sheets were thousands of feet thick, and they transported huge boulders, made of rock from faraway locations. When the glaciers melted, the rocks were left behind where they didn't fit with the local geology. These boulders are called *erratics.*

drift: the rocks, sediment, and ground-up rock flour transported by glaciers. In Iowa, the weathering of the drift scattered across the state led to the great soils we have, essentially imported from Minnesota.

incised stream: when a stream cuts down deep into the landscape, geologists say it is *incised*, Because glaciers did not come to the Dubuque area, the Mississippi River stayed in it course (not the case further downstream past Clinton) and cut down over long periods of time, aided by meltwater rushing through from retreating glaciers.

U-shaped valleys: In more mountainous areas (obviously not the Midwest) glaciers deepen and widen valleys into a broad U shape. Valleys cut by running water have more of a V shape.

5 The Fabulous Bre-X Minerals

Minerals are the letters of the geological alphabet. They are the building blocks for rocks—mixtures of rocks that help us interpret the past. Minerals have a distinct composition , crystal structure, are solid, natural, and inorganic. Most are combinations of elements, such as halite (salt), NaCl, but a few are pure elements, such as copper and gold.

Gold. Of all the metals, it has been the one that means wealth, status, glory. Compared to gold, silver is an also-ran, relegated to making table knives and goblets. So when Bre-X Mineral announced that it had discovered the largest gold deposit in the world at Busang on the island of Borneo in Indonesia, a lot of people were suddenly interested—geologists and mining companies, stock brokers and investors. At first blinded by the glitter, only later did they realize that they had been taken by one of the oldest scams in the mining world—the *salting* of samples with gold, making the mine's advocates look like fools with no gold. When the samples of the gold ore were finally examined by an independent lab, the faking wasn't even well done. Some samples when examined under a microscope included shavings from gold jewelry. In two days, Bre-X stock dropped 85%, losing $3 billion in market value. Meanwhile, two Bre-X executives had moved to the Caribbean, and a key geologist had apparently committed suicide. How did things get to that point?

Bre-X Minerals was the unsuccessful company of David Walsh, started in 1989 and soon going bankrupt. Using his last $10,000, Walsh flew to Indonesia to meet John Felderhof, discoverer in 1968 of a large gold deposit in Papua New Guinea. Felderhof convinced Walsh to invest in some jungle property, hired a Filipino geologist named de Guzman, and soon drilling began for gold prospects. The first couple of holes showed no gold, and Walsh was ready to shut things down. Suddenly, things began to pick up, even though a dozen other companies had no luck previously. Felderhof claimed that the previous companies had looked in the wrong places, or too shallow, or with the wrong drilling techniques. Whatever. Soon, Bre-X claimed to have *proven* the existence of 71 million ounces of gold, worth about $25 billion, and Felderhof estimated that there were at least 200 million ounces present. Egizio Bianchini, stock broker and supposedly Canada's top gold analyst, said "What most people are now realizing is that Bre-X has made one of the great gold discoveries of our generation."

To produce such a huge deposit, Indonesia required that Bre-X partner with a large mining company. Freeport McMoRan of New Orleans, already in Indonesia and operating the world's largest gold mine, won the right to develop the Bre-X mine. Freeport first undertook some of its own independent drilling, but no significant amount of gold showed up. Stock analysts who follow the mining industry were incredulous, some accusing Freeport of trying to drive down the Bre-X stock. As the possibility of the samples being salted began to be rumored, Bianchini, the gold analyst, weighed in with the statement to his clients that the rumors were "so preposterous, I am not even going to address the possibility." An independent company, Strathcona Minerals, was hired to examine the Bre-X samples and drilled holes next to those of Bre-X and Freeport. After their study, Strathcona concluded, "the magnitude of the tampering with core samples that we believe has occurred and resulting falsification of assay values at Busang, is of a scale and over a period of time and with a precision that, to our knowledge, is without precedent in the history of mining anywhere in the world." So much for the rumors being preposterous.

Even now, it's not clear who is to blame for the salting of the samples. Walsh moved to the Bahamas and later died. Felderhof is in the Cayman islands. But an even more likely culprit, de Guzman, is dead, maybe, from jumping 800 feet from a helicopter into the jungle. I say *maybe* because when his body was found 4 days later, the face was eaten off. Missing were his internal organs, brain, and genitalia. A partial thumb print from mushy, decayed flesh plus a couple of molars are the basis for identification. De Guzman carefully controlled access to the mine site. He and a fellow Filipino, Cesar Puspos, controlled the samples from the time they were collected until they were turned over to a down-river lab for analysis. Most likely, that window of opportunity was when the salting of samples occurred.

Meanwhile, the Canadian Mounties have called off their investigation. With Walsh and de Guzman dead and Bre-X officers refusing to cooperate, the Mounties ran into a dead end. No one has been arrested or imprisoned. In the old days of the gold fields, someone would have gotten strung up. Today, we sue. A lot of angry investors want some of their money back. With $3 billion dollars lost on Bre-X stock, the investors want to know why their advisors encouraged them to get taken by the oldest scam of the gold fields. The lawsuits continue.

Notes on Basic Chemistry:

We've touched on geologic history and its role in shaping Iowa. Now it's time to focus in at the chemical level. The letters forming the words of geology are minerals. To understand minerals, we need to first understand atoms and elements.

Elements

Atoms are our basic building block of the physical world. The simplest model of the atom looks like the solar system, with the nucleus in the center and electrons orbiting around it. The nucleus has two types of particles in it, protons and electons, both much larger than electrons, as the sun is larger than the planet. Protons have positive charges. Neutrons are neutral. Electrons have negative charges. The number of protons determines the element. For example, carbon has six protons, nitrogen has seven, and oxygen has eight. The mass of the element is the sum of the number of protons and number of neutrons. For example, most carbon atoms have six neutrons to go with their six protons. $6 + 6 = 12$ Thus, the mass of most carbon atoms is twelve. We write the number and mass of carbon as $^{12}_{6}$C.

Isotopes and Radioactivity

Though all atoms of an element must have the same number of protons, some have more or fewer neutrons. For example, carbon usually has six neutrons, as stated above. However, another well-known form is carbon-14, $^{14}_{6}$C, which has eight neutrons. However, this heavier form of carbon isn't stable—over time it breaks down radioactively into nitrogen-14, $^{14}_{7}$N.

The breakdown of a radioactive isotope occurs very regularly—half of the carbon-14 (the *parent isotope*) will become nitrogen-14 (the *daughter product*) in 5730 years, its *half-life*. In another 5730 years, three-fourths of the carbon-14 will have become nitrogen-14. And so on. Since carbon is incorporated into the tissue of living organisms, we can study their remains, using the change of the ratio of the stable carbon-12 to the radioactive carbon-14 to estimate the age of the remains. The limit of its usefulness depends on the sensitivity of the equipment we use to determine the relative carbon concentrations.

When we tell time, we use a variety of measures—years, days, seconds—depending on our need. Anthropologists often use carbon dating for things like determining the age of an old campfire from Native American ruins. A geologist is typically looking much further back in time (like using a calendar instead of a stopwatch) and uses radioactive isotopes like uranium-238, ^{238}U, which has a half-life of 4.5 billion years. For more info, see [here.]

Bonding

Atoms combine together to form molecules, which may have very different physical properties than the elements themselves. For example, Na (sodium) is an explosive metal, and Cl (chlorine) is a gas. They combine together to form the compound molecule NaCl (halite, common salt). The way in which atoms combine is determined largely by their outermost electrons—their valence electrons. Na has one, lonely valence electron that it is quite willing to give away. Cl has seven valence electrons but space for eight. Thus, it is quite willing to take the electron that Na wants to give away.

The way in which atoms bond takes four main forms:

Ionic bonds form like NaCl, described above, when atoms give away or accept electrons. An atom that does not have the same number of electrons and protons (balanced, with no net charge) is called an *ion.* In the case of NaCl, the charges are Na^+ and Cl^-, as the chlorine has taken a negatively charged electron from sodium. Thus, they have opposite charges, and they attract each other, forming an ionic bond. Because of the ions they form from attract opposite ends of the polar water molecule, many ionic compounds dissolve in water, like salt does.

Covalent bonds are strong, based on the sharing of electrons. For example, carbon can either give or accept four electrons, allowing it to share electrons in long carbon chains, the building blocks of life. Pure carbon that is extremely heated and compressed becomes diamond, where the carbon is covalently bonded in three dimensions, giving diamonds their extreme hardness.

Metallic bonds are similar to ionic bonds, except the electrons flow freely in a soup of metal atoms, such as copper, Cu. No one electron is attached to any particular metal atom. Thus, if we push electrons in one place, they flow out somewhere else. This flow of electrons is *electricity.*

Weak intermolecular bonds form between molecules that may be bonded in other ways. Diamonds and graphite are both pure carbon, but diamonds are bonded covalently in three dimensions, while graphite is bonded covalently in sheets. Between the sheets, graphite is bonded with weak intermolecular bonds. Graphite is what your pencil lead is made of—there is no lead metal, Pb, in it. When you write, you are dragging sheets of graphite onto your paper.

Minerals

Minerals are specific types of chemical compounds. Their properties include the following:

solid: liquids don't count as minerals.

naturally occuring: man-made solids, like cubic zirconia, aren't minerals, though if they duplicate naturally occurring minerals, such as diamond, we often count them anyway.

having a specific composition: All minerals are formed from bonded elements in specific proportions and manner. The mineral galena is formed from aroms of lead and sulfur, bonded one-to-one as PbS. Quartz is formed from silicon (Si) and oxygen (O), with twice as many oxygen atoms as silicon, SiO_2

having a definite crystal structure: Just as it's possible to connect Legos in multiple structures, atoms bond in a variety of forms, such as carbon forming both diamond and graphite, as discussed above. Temperature, pressure, and the presence of other elements can all affect which structure forms. And some solids, such as glass, don't have a crystal structure at an atomic level. Glass is made from melted quartz, but it is cooled so quickly that crystals don't have a chance to grow. This accounts for quartz scratching glass despite being made of the same elements.

inorganic: Wood is a solid but not a mineral. *Organic* means something is, or once was, alive, or is derived from something that was alive. Gasoline is formed of organic molecules whose original source was microscopic living marine organisms. Only inorganic compounds can be minerals.

6 Igneous Rocks and Dad's Heart Attack

Rocks, a combination of minerals, are the words that we use to create the story of the Earth. Their composition and physical properties determine how they are separated and where on Earth they end up, such as on the continents or in the ocean bottoms.

A year and a half before I was born, my father had a heart attack. My father's doctor put dad on a strict diet—low fat and low cholesterol. The pigs and chickens my parents raised at the time were sold, and the vegetable garden was expanded. When my mom cooked any meat, she would boil it first, then cool it and skim off the fat. My mom was using a process similar to what created the continents, using the lower melting point and density of fat relative to the meat to separate the two. Such differences in physical properties can also separate rocks.

Most of the minerals that form rocks in the mantle and crust are silicates. Silicates may be distinguished by the amount of silica each contains. Olivine and pyroxene have large percentages of iron and magnesium. These form rocks referred to as mafic (or ultramafic) rocks. Rocks with 70% silica or more are felsic. Felsic rocks are lighter in color, less dense, and have a lower melting point than mafic rocks. Felsic rocks behave similarly to the fat, while mafic rocks behave like the meat.

Water boils at 100 degrees C, above the melting point of fat but below that of meat. The melting point of most felsic minerals is around 700 degrees C, while that of mafic minerals is around 1300 degrees C. Thus, if we heat a rock to about 1000 degrees C, then the felsic minerals will melt while the mafic ones will not. Because the felsic material is less dense, it will tend to be buoyed upward, similar to the fat in the boiling water. This separation brings the lighter colored, low density, felsic rocks to the surface to form the continents.

New igneous rock is constantly being formed as volcanoes erupt and intrusions cool. Magma from the mantle is constantly erupting at midoceanic spreading centers to form new oceanic crust. This new rock is mafic and is the most common rock on the Earth's surface: basalt, the extrusive form, and gabbro, the intrusive form. (Look at a map. You'll see a lot more ocean than continent.) Mantle hot spots, such as underlie Hawaii, erupt basalt. In addition, rifting of a continent allows mafic rock to rise to the surface, such as where the Middle East is splitting off from Africa. At subduction zones, melting oceanic crust is mafic, but sediments that are subducted with the plate are often felsic. An intermediate composition may result, such as is found at many of the volcanoes in Washington and Oregon. Occasionally, an eruption of felsic material, such as at Yellowstone National Park, may occur as a continent passes over a hot spot and melts its felsic rock.

Distinguishing felsic from mafic rocks gives us clues about where and how the rocks originated. As we study geology, we can better understand our world and develop more choices about how we live our lives. For example, we have learned how slowly soils form and how quickly humans are causing them to erode. We have learned how the chemicals we release into the air destroy the ozone and speed global warming. As to heart attacks, we have learned that our own choices—food, exercise, smoking—can reduce our chances of a heart attack. Dad chose to stop eating foods that were hurting him and had no further heart problems. Perhaps we can choose to stop doing so many things that hurt the Earth.

Notes on Rocks:

In summary, felsic minerals (like fat) have a lower melting point, a lower density, and lighter color—lower, lower, lighter. They form the scum that floats to the top and stick up—the continents, which are much thicker than the oceanic plates.

Mafic minerals (like meat) have a higher melting point, greater density, and darker color. They form the plates of the ocean basins.

When we talk about felsic and mafic rocks, we are discussing *igneous rocks*, rocks that form from melted rock that recrystallizes. Two other rocks types, together with igneous rocks, form the *rock cycle*:

igneous: form from magma and lava (magma that has come to the surface), previously existing rock that has melted and then recrystallized.

metamorphic: form from preexisting rocks that are squeezed and heated to transform them but have not melted.

sedimentary: form from preexisting rocks that have been broken apart, transported, deposited, and cemented back together.

We'll sketch the rock cycle together in class.

7 The Death of the Dinosaurs

Many thanks to Dr. Bill Ward for his recounting to me the history of UNO's involvement in studying the Yucatan Impact Crater. Bill was my mentor when I started at UNO and my best-man when I got married. He guided me through tenure and extreme ignorance about much of academia and life. I owe him a lot.

The major sections of geologic time are separated by big event—the evolution of species with hard parts that could be preserved in rocks, the Great Dying (a mass extinction) and the extinction of the dinosaurs. The University of New Orleans, where I used to teach, contributed to solving the mystery of how the latter happened.

A widely accepted hypothesis about the cause of the extinction of the dinosaurs at the end of the Cretaceous Period is an impact of a meteorite or comet (bolide) in the Yucatan Peninsula, Mexico. The bolide is believed to have been about 6 miles in diameter, impacting the Yucatan at a low angle, vaporizing rock, setting off catastrophic fires and tidal waves, and blanketing the Earth with dust, which led to acid rain and a plunge in global temperatures. The angle was such that central and western North America were particularly ravaged. As the dust settled out of the atmosphere, large amounts of water vapor remained, causing a rapid rise in temperature to follow the cooling. Thus the dinosaurs and other Cretaceous life were hit with a one-two punch that caused massive annihilation. The acceptance of this hypothesis is relatively new—the previous edition of our historical geology book doesn't even mention it. Evidence stored at the UNO Geology Department helped provide the support that led to acceptance.

Former professor Al Weidie has had a Mexican connection dating back to his graduate school days working on Gulf Coast geology. (As part of his student accomplishments, he brought home a lovely wife, Ana, from Saltillo, Mexico.) After coming to UNO and helping start the Department of Earth Sciences, Dr. Weidie convinced PEMEX, the Mexican petroleum company, to ship him some cores from wells that PEMEX drilled in the Yucatan Peninsula. (Cores are samples of the rock being drilled through.) When Dr. Bill Ward joined the faculty in 1970, the cores were available for a thesis project by his first graduate student, Bob Marshall.

Cores from near the Cretaceous-Paleogene boundary proved to be difficult to understand. A breccia there was particularly problematic, causing some to accuse Dr. Ward of looking at concrete that had been drilled out in the wells. However, in the breccia were fragments of anhydrite, limestone, and dolomite, and the matrix was dolomitized. Dr. Ward reasoned that all the anhydrite chunks and splinters in the breccia, which spread across the peninsula, would amount to a lot of anhydrite. Its likely source was the Middle Cretaceous, deeper underground. How could it have gotten to its present location? Anhydrite is very soluble, so it had to have been moved quickly and without a lot of water. The mechanism Dr. Ward hypothesized at the time was block faulting. Years later, electric logs and seismic would show that this explanation couldn't be supported.

In the years after Marshall's thesis, a high concentration of iridium at the Cretaceous-Paleogene boundary was found in many places around the globe. The likely source of iridium is extraterrestrial, in comets or meteorites. Its wide distribution at a single time indicated the possibility of a massive impact. The timing also corresponded with the end of the Age of Reptiles. The hunt was on for a large crater caused by the impact. Geophysical evidence indicated the presence of such a crater in the subsurface of the Yucatan Peninsula.

Geologists seldom believe geophysicists unless there is supporting evidence from rock data. The PEMEX wells were known to exist, including one near the center of the proposed impact crater, but the cores from them were supposedly lost. However, someone came across a reference to Marshall's thesis and contacted UNO. In the cores, they found shocked crystals of quartz that have been impacted violently like hitting them with a hammer. Other evidence soon followed, including finding glass microspherules throughout the Caribbean and as far away as Wyoming. In 1995, Dr. Ward and others authored an article that appeared in Geology, presenting much of the petrographic evidence from the subsurface sedimentary rocks for the bolide impact, including a thin section of anhydrite fragments wrapped in altered glass.

As part of a long series of programs on dinosaurs narrated by Walter Cronkite, there was a segment on dinosaur extinction and its possible relation to the Yucatan impact. A camera crew came to UNO and filmed a geologist going into the lab where the cores were stored, across the hall from Dr. Ward's office. The geologist had a flashlight in his hand, looking like an archaeologist entering King Tut's tomb. Suddenly he discovered the long-missing cores. Of course, the geologist passed up a light switch at the door. It looked as if UNO didn't pay the electric bill. Yet there is no doubt that the missing cores helped shed light on the cause of the extinction of the dinosaurs.

Notes on Geologic Time:

The concepts of absolute and relative time are crucial to understanding geology, especially the geology of Iowa. Geology embraces time in ways unlike most other sciences, except perhaps cosmology. Small changes, such as erosion, add up over long periods of time to create big changes, like the Grand Canyon. Slow movements, perhaps an inch a year, add up to distances that move entire continents from equator to pole or shove rocks from deep in the earth to heights tens of thousands of feet above sea level.

The very idea of time is really strange if you think about it. What is a day? A concept measured by the rotation of the Earth. So what's a year? 365 days, my students often reply. Afraid not. Some years. Not leap years. and even that fails on the century mark. Because a year isn't based on the rotation of the Earth. It's based on the orbit of the Earth around the Sun, which takes something like 364 and a quarter days, but not quite. (Actually, we can't even agree on what a year is. See [here].) Regardless, the main idea is that we tell time by something that occurs pretty regularly—the swing of a pendulum, the vibration of a quartz crystal, of the orbit of the Earth. These things are our best guess at *absolute time.*

The regular event that geologists use to date the age of rocks is *radioisotopic decay.* The most famous is carbon-14. Carbon-14 breaks down into nitrogen at a regular rate—half of it changes top nitrogen in about 5700 years (its half-life). This is particularly useful for dating organic material, such as the wood in that Neanderthal's campfire or the Hopi's hut. But other radioisotope's half-life is much longer, like [potassium or uranium, which can be used for much longer time spans. It's like the difference between a stopwatch and a calendar.

But things also change over time. New kids are born, and we suddenly have a younger sister or brother. Similarly, mud settles out of water, accumulates in layers, so the newest layers are atop the older. How old? We don't know. But the youngest are on top. This is *relative time.* The early geologists did not have access to lab equipment, but they could see the layering of sedimentary rock, find fossils within the rock, and determine which rocks were older and younger. This principle was used by geologists to create the *Geologic Time Scale*

Dating

relative dating: younger or older. Each day when I bring the mail from the box and dump it into a pile on the counter, after a week, the older mail is on the bottom of the pile. For more examples, see [here.]

absolute dating: a specific age, often in years. A year is a trip around the sun, not a specific number of days. (There are actually about 365.2422 days in a year, which we deal with by designating *leap years*.) The point is, we tell time based on something that occurs regularly, such as the swing of a pendulum or vibration of a crystal. For the geologist, the *clock* is the radioactive decay of a variety of isotopes elements.

atomic number: An element is identified by the number of protons (positively charged) in its nucleus.

isotope: Also present in an atom's nucleus are neutrally charged neutrons. The number of neutrons plus the number of protons determines the isotope. Carbon has six protons—that's what makes it carbon. But forms of carbon with 6, 7, or 8 neutrons exist. $6 + 6 = 12$, making carbon-12, a stable form of carbon. But carbon-14, with 8 neutrons, is unstable, breaking down regularly, about half converting to nitrogen over 5,730 years.

Another use for isotopes: Because of the different weights of various isotopes, they respond differently to gravity and momentum. This allows us to purify uranium for building nuclear weapons and to estimate past temperatures based on oxygen isotopes in water preserved as ice in ancient glaciers.

Geologic Time Scale

Precambrian: the oldest and largest of Earth's times, beginning about 4.5 billion years ago and ending 541 million years ago when the first fossils with hard parts were found preserved in rocks. Life previous to that left traces that early geologists did not have the equipment to observe.

Paleozoic Era: extending from the end of the Precambrian to 252 million years ago, the Paleozoic was the time of tremendous diversification of life, but it ended with the greatest mass extinction of Earth's history. For us here in Dubuque, two periods withing the Paleozoic are particularly important: the Ordovician (under campus) and the Silurian (younger and under the Dubuque Airport.)

Mesozoic Era: known as the *Age of Reptiles*, especially dinosaurs, rocks of this age are mostly missing from Iowa, especially Eastern Iowa. Sedimentary rocks are mostly deposited in water, and this part of Iowa was above sea level during the Mesozoic. Thus, we had erosion, not deposition. The Mesozoic came to an end with a bang, an impact from space that annhilated the dinosaurs 66 million years ago.

Cenozoic Era: known as the *Age of Mammals*, the death of the dinosaurs opened up opportunities for mammals to spread, grow, and dominate. The Cenozoic continues through today. Starting about 2.58 million years ago, the Pleistocene Epoch was time of widespread continental glaciation.

8 Antibiotic-Resistant Bacteria

At its simplest, evolution simply means change through time. I don't look exactly like my father, nor did he look exactly like his father. However, you could look at my dad and tell that we are related. Descent with modification. What Darwin contributed was a mechanism by which that change occurred. Modern genetics is fleshing out the details.

If one were comfortable lurking in the men's bathroom at UNO, one might observe a startling sight: the percentage of men washing their hands after going to the bathroom is fairly small. I doubt that UNO men are particularly less hygienic than men elsewhere. Instead, our concern about spreading disease has decreased because of the success of antibiotics. Throughout human history, good public health practices—clean water, sanitary disposal of wastes, other measures to slow the spread of disease—have done more to improve human well-being than anything else. However, except in times when an outbreak like SARS or mad-cow disease is in the news, in the U.S. we have come to depend more on treating the disease than preventing it. This has created an environment where the evolution of disease-causing bacteria has speeded up.

Natural selection, a component of evolution, is really very simple. In the case of disease-causing bacteria, some bacteria are naturally stronger (more resistant to antibiotics) than others. If a patient is given antibiotics for a disease, the weaker bacteria are the first to die off. If the full multi-day dosage of antibiotics is taken, hopefully all the bacteria is killed. Hopefully. Often, once the patient is feeling better, he or she forgets to take the last few doses of the antibiotic. Those strong bacteria who resisted the antibiotic hang on, like terrorists waiting to attack again. When your body's natural defenses weaken, these bacteria may reproduce at a rapid rate, but these are offspring of the strong bacteria. When you take the antibiotics this time, they are less effective. Over time, a superbug can develop—a strain of the bacteria against which the antibiotics are ineffective.

One might ask why stronger, more resistant, bacteria exist in the first place. The simple answer is mutation. Bacteria reproduce asexually, so in theory each offspring should be exactly like the parent. However, due to subtle changes in the genetic code, some are a bit different. Most of these mutants are the type that might come to mind after seeing too many bad sci-fi movies. In reality, most mutants die off quickly. However, since millions of offspring bacteria are produced very quickly, the chances of some useful mutation arising, such as resistance to antibiotics, is fairly high, given enough time. And contemporary American behavior has speeded up the process.

Take the example of gonorrhea (CDC link on gonorrhea). Gonorrhea is a sexually transmitted disease. You can avoid it by never having sex with anyone but your spouse (as long as your spouse behaves the same way.) Humans haven't proven too good at celibacy, and at various times gonorrhea has spread like wildfire. If it simply killed off its victims quickly, the fire would go out. But because it lingers in the body and slowly does its nastiness, you have a chance to spread it to others. The discovery of penicillin was a great event for sufferers of gonorrhea, as penicillin was effective against it. At least for a while. Penicillin made behavior that led to gonorrhea less dangerous. More people got it, and more took penicillin. The weak strains of gonorrhea were wiped out, but penicillin-resistant strains became more and more common. Now there is little value in taking penicillin for a gonorrhea infection. Other, stronger antibiotics are needed. And eventually they will fail, too.

Nearly any disease has the potential to become antibiotic-resistant. The Center for Disease Control has said, "Because antibiotics are often overused and misused, they are losing their effectiveness both in the United States and abroad. Even vancomycin—the last defense against infections resistant to other antibiotics—is beginning to lose its effectiveness." Not surprisingly, one of the diseases quickly becoming resistant to all known antibiotics is staph, commonly spread in hospitals. A hospital is a great place to spread disease—the patients generally are already sick so their natural resistance is low, they are in close proximity to each other, and hospital workers are constantly transporting disease from room to room (CDC link on hospitals and antibiotic-resistant disease). Studies have shown that doctors, who should know better, often don't wash their hands between visits to patients' rooms. (See Compliance with handwashing in a teaching hospital.) In the OR they may scrub well enough, but when going room-to-room... See the article on hand hygiene [here.]

The process by which bacteria are becoming antibiotic-resistant is an example of evolution, also described simply as descent with modification. If we understand the process by which antibiotic-resistant diseases arise, we have gone a long way toward understanding the process of evolution. We can then use that knowledge to help prevent other antibiotic resistant bacteria from arising:

- Focus more on prevention than treatment.
- Take your antibiotics for the full term.
- Don't use antibiotics to try to treat something that is viral, such as many kids' ear infections. (Mom: "Just give him something. What can it hurt?" Now you know.)
- Save the most powerful antibiotics for the rare cases when they are truly needed. (Responding to the anthrax scare (CDC link on anthrax) by stocking up on cipro meant that longterm danger was probably increased.) Otherwise the rate at which diseases become resistant to the new antibiotics will increase.

Ultimately, the theory of evolution is like any other scientific model—it can help us make predictions and empower us to change outcomes. We can then slow the rate at which antibiotic-resistant diseases evolve.

Notes on Evolution:

A key part of evolution is the recognition that only those organisms that survive to the point of reproduction pass on their genetics, describing Darwin's great idea, the *natural selection* of survival traits. The ways in which natural selection takes place include these:

Predation: One thing eats another. Get eaten before you reproduce and your genes stop with you. The slow or sickly antelope has greater odds of being caught by the lion. The better hunter the lion is, the more likely he or she won't starve.

Access to resources: The taller giraffe can reach higher to eat the tree leaves shorter ones can't. In times of drought, that might be the key to surviving.

Adaption to the environment: The waxy leaves of desert plants help retain moisture.

Resistance to disease: Plants and animals get diseases, like we do. But only some usually die. Those that fight off the disease get to reproduce.

Sexual selection: A peacock's tail doesn't seem to make much sense for surviving. It is no weapon, doesn't help with flight, and is hard to hide. But if female peacocks (peahens) like it, he gets to pass on his genes.

Reproductive strategy: Some organisms have lots of offspring, like rabbits and cockroaches, but do little to nurture them or help with their survival. Others, like elephants, have few offspring but do everything they can to make sure the babies survive—feeding them, defending them from predators, and teaching them survival skills. What is your strategy?

Part III

Material for Test 2: Where Would We Like to Travel?

9 The East African Rift Valley

When I finished Guilford College with an undergraduate degree in mathematics, I had no idea what I wanted to do except travel. So I applied for a two-year volunteer position teaching math in the highlands of Kenya at a boarding school. The highlands are heavily farmed because of the climate—not too hot because of the altitude but not too cold because of the latitude. Within sight of the school is Mt Kenya, the second highest peak in Africa. It is snowcapped despite being almost directly on the equator. A bit further west is the East African Rift Valley, an arm of the best example in the today's world of a *triple junction.*

Classes met for three months at a time with a month's vacation between terms. During my school breaks, I traveled around Kenya, going on safaris, visiting lakes and beaches, and seeing the cities. Where I lived at an elevation of 6000 feet, malaria was uncommon, but I caught it during my first vacation when I went on a safari that took me to lower elevations. Among other sites, I got to see the Rift Valley. The highlands of Kenya are cut down the middle by a rift that drops the elevation by thousands of feet. From lush damp forests, one descends rapidly to the dry hot valley floor. A string of lakes along the valley represents the terminus of streams off the highlands—water flows in but doesn't flow out. Instead it evaporates. Some of the lakes have, over thousands of years, become very high in dissolved minerals, high enough that evaporites are deposited in some of the lakes in sufficient quantities to be mined.

The formation of the Rift Valley, along with the Red Sea and the Gulf of Aden, is an example of the process of *continental rifting.* In this case, the Middle East Peninsula is being separated from Africa. When a continent rifts, the crust first bulges, explaining the elevations in highlands and north through Ethiopia. We geologists believe the bulge is due to the rise of hot magma from the mantle. The uplift leads to the formation of three-way split, with the central part of each arm of the split collapsing downward to form a graben. Two of the arms of that split continue to grow, in this case the Red Sea and the Gulf of Aden. As they continue to separate, mantle material flows out, forming new oceanic crust and the beginning of a new ocean. The third part of the split, the East African Rift, if it continues to grow, will turn East Africa into an island in the Indian Ocean.

Along the floor of the Rift Valley, I saw the evidence of hot rock still near the surface. As the rift forms, fractures develop through which magma can move upwards. Mt Longonot (photo below) is a recent volcano on the valley floor. Along the flanks of the valley can be seen evidence of old lava flows. At Lake Bogoria are natural hot springs [photo]. Ground water is heated by the hot rock near the surface and comes steaming to the surface, similar to (though less dramatic than) Old Faithful at Yellowstone, a continental hot spot.

One of the reasons for us to study the East African Rift is to better understand the way the Gulf of Mexico formed. Millions of years ago, Africa, Eurasian and the Americas were joined together. Uplift began to occur near where today's GoM is located. Multiple three-way splits formed and grew to form the Gulf. The failed third arm of one passes beneath what is now the Mississippi River. Though earthquakes are rare in the interior of continents, this weak spot accounts for the presence of the New Madrid earthquake zone 2. In the early 1800s, a series of earthquakes occurred at New Madrid so powerful that they rang the church bells in Boston, created new lakes and land, and caused the Mississippi River to briefly flow backwards in places. Back then, few people were living the area, but such an earthquake now could be devastating. It's just a matter of time till it happens.

Notes on Plate Tectonics:

Every field of science has its own revolution—relativity and quantum mechanics in physics, atomic theory in chemistry, evolution in biology. We geologists were a bit late to the barricades, but the Earth is a lot bigger than a test tube (though smaller than the universe). *Plate tectonics* was our revolution, pushed forward by the technological advances coming out of World War II, particularly with respect to understanding the ocean bottom. This theory pulled together lots of observations into a single coherent theory that made sense of them all.

In brief, the theory of plate tectonics states that the surface of the Earth is consists of large slabs of brittle rock that come together, pull apart, and slide by each other. In addition, the slabs that form continents are thicker and lower in density, while those beneath oceans are thinner and denser. The denser oceanic plates get shoved back down into the mantle below, melting, forming volcanoes sometimes, and recycling.

1. We will draw together in class the six types of plate interactions. Take good note—this is one of the most important exercises in preparation for the next test.

2. We will watch the *Earth Revealed* video, *Birth of a Theory*. The link is on the course website. Be ready to answer the following questions about the video:

   - How is the development of plate tectonics an example of the use of the scientific method?
   - Who was Alfred Wegener? What was his contribution to the early stages of what led to plate tectonics? Why were his ideas rejected?
   - Who was Harry Hess? What were his two key contributions to plate tectonics? What led to his discoveries?
   - What are examples of additional support for plate tectonics?

10 Deadly Lake Nyos in Cameroon

When you pop the top on a can of Coke, dissolved CO_2 comes bubbling out. Take another can of Coke scuba diving with you, and the farther down you dive, the less the Coke will fizz when opened. (Drinking it without getting salt water in your mouth is another challenge.) Likewise, if you leave it sitting out, it loses its fizz as most of the CO_2 gradually bubbles off—it equilibrates with atmospheric pressure. Lakes and streams naturally contain small amounts of CO_2, but you don't see them fizz because they are also equilibrated. However, under very rare conditions, such as occur at Lake Nyos in Cameroon1, a sudden bubbling up of CO_2 can occur. In 1986, a massive release of CO_2 created a 250-foot-high geyser in the lake. The cloud of CO_2 released killed 1,700 people.

Lake Nyos, nearly 700 feet deep, is located in a volcanic crater. Volcanic activity deep below the crater releases CO_2, which rises through fractures to where it encounters ground water. There, much of it dissolves into the ground water. The ground water in turn flows into the bottom of Lake Nyos. In most lakes, there is fairly regular turnover in water, with winds and currents bringing bottom water toward the surface and taking surface water downward. However, in Lake Nyos, the bottom water is stagnant. The CO_2 continues to flow in with the ground water, but stays dissolved because of the pressure in the deep lake. Essentially, a bottom layer forms, rich in CO_2, ready like a Coke can to have its top popped.

It is unclear what set off the CO_2 eruption in 1986. Perhaps wind stirred the lake more than usual. Perhaps a landslide. Regardless, something caused some of the cold, CO_2-saturated water to move upwards. When it did, CO_2 began to bubble out of solution. As the bubbles formed, they rose toward the surface, pulling with them more cold water. As this additional water rose, more CO_2 bubbles formed and rose. And so on. What resulted was a huge, rapid upwelling of bottom water, and a massive amount of CO_2 was released suddenly.

CO_2 is about 50% heavier than our everyday mixture of air. And this CO_2 was cold, too. As it erupted from the lake, it stayed low to the ground, moving as fast as 45 m.p.h., flowing in a cloud for more than 10 miles. It was a suffocating cloud, killing nearly every animal in its path. A day later, it still lurked in low spots, still capable of killing a small girl who descended into a ravine. The area was subsequently evacuated. However, people have returned, attracted by the rich, volcanic soils, and tilapia, thriving fish introduced into the lake.

The buildup of CO_2 in the lake is once again extremely dangerous, according to the US Geological Survey. Pilot studies have shown that the lake can be easily degassed, perhaps for a little as $1 million, very little as these sorts of things go. Sticking several pipes into the depths of the lake, starting an upward movement of the water with a pump, and then letting the resulting bubbling lift the water, has been shown to work in slowly releasing the CO_2. Though politics has slowed the development of a full-scale project, a variety of recent events has helped push the degassing project back on track. Until the degassing is completed, Lake Nyos is prepared to kill again.

Notes on Extrusive and Intrusive Rocks:

Igneous rocks that form from lava that is spit out upon the land surface or underwater are *extrusive*—they have been extruded. Rocks that form from the colling of magma (melted rock) on the inside of the Earth are *intrusive.* Just as flour, sugar, egg, and milk can make a cupcake or a pancake, depending on how they are cooked, the same rock ingredients ccan lead to different rocks, depending on how they are formed. *Intrusive* versus *extrusive* is one of the key differences.

Because extrusive rocks cool much more quickly, crystals have little time to grow. Geologists say that they have a *fine-grained texture.* In contrast, intrusive rocks cool slowly, growing larger crystals. We've already discussed the differences between mafic and felsic minerals. When we add that difference in composition to the textural differences, we get the following six rocks:

	felsic	**intermediate**	**mafic**
intrusive	granite	diorite	gabbro
extrusive	rhyolite	andesite	basalt

The composition of lava has a big influence on the type of volcano that forms:

Shield volcanoes are the largest, by far. Think of the Hawaiian volcanoes as examples. These from from mafic lava.

Composite cones (or stratovolcanoes) form at subduction zones. Think of a layer cake, like Mt.St. Helens These are intermediate in composition.

Calderas are large depressions that form after the ejection of lots of lava. They can form on any volcano, but the most famous caldera is Yellowstone. The felsic lava there is so thick that it doesn't flow—it explodes violently and then leave a whopping-big hole in the ground, one that encloses much of Yellowstone National Park.

Most volcanoes occur at one of three locations:

Spreading centers emit lots of lava, mostly mafic and not explosive. These are *fissure eruptions*, along long cracks in the Earth.

Subduction zones emit the most volcanic and earthquake energy, like the Ring of Fire around the Pacific Ocean.

Mantle hotspots bring magma from deep in the Earth to the surface at places like Hawaii and Yellowstone. In Hawaii, the melting ocean plate is mafic, so the erup[tions are mostly runny (low viscosity)] while the felsic continental plate beneath Yellowstone melts into thick, explosive magma.

11 Resistant Rocks Stand High in Relief

I grew up in the Piedmont region of North Carolina, with undulating hills and a climate well suited for small tobacco farms. Tobacco was the first cash crop from the Americas, starting from Jamestown, and its profits motivated the first use of slaves, some of which are buried on land I own in back of my childhood home. Winston-Salem, the nearest city, gave its name to two brands of cigarettes originally produced there by R.J. Reynolds Tobacco Company. When I was in sixth grade, our class toured the cigarette factory, the best employer anywhere close. Getting a job at RJR set you up for life, or at least we thought so then. RJR even had its own in-house doctors, dentists, and pharmacists, something my cousin, RJR's comptroller, said helped keep out the unions. It certainly produced employee loyalty.

If RJR at that time represented enlightened capitalism, the tobacco fields represented a more primitive approach, often with child labor. When I started as a nine-year-old picking tobacco, little was mechanized. Occasionally, sleds were still dragged through the fields with horses instead of tractors. Much of the work-force came from us neighborhood kids—the opening of school was even delayed if the crop was late ripening. But using eight summers' earnings, I bought my first car, a wrecked and rebuilt Ford Pinto.

Some of the tobacco I picked may have ended up in the Marlboros that my mother smoked for fifty years and that shortened her life by at least ten years, ending after her third bout with cancer. My father avoided both smoking and becoming a tobacco farmer. He grew up on a tobacco farm and was glad to leave a crop standing to go off to World War II. His father and oldest brother remained behind, continuing to produce tobacco for the cigarettes that American GIs became famous for handing out.

After tobacco, textile mills offered a distant second option for employment, particularly Hanes Mills, also based in Winston-Salem. My neighbor, Minnie Ruth, worked at Hanes and arranged for my mom to shop at the company store where they sold seconds, the pieces that didn't turn out quite right and failed inspection. For decades, my underwear were always from Hanes, stamped *Seconds.*

When the ancestor of Hanes opened the mill in 1901, the crossing of north-south and east-west train lines determined the factory's placement. But the presence of textile mills on the U.S. east coast goes back much further to a geologic feature, the Fall Line. The coastal areas of the Atlantic seaboard are underlain by unconsolidated sediments—sand and muds. But the Piedmont area is underlain by igneous and metamorphic rocks formed millions of years ago by plate-tectonic forces. As streams flow from the Appalachian Mountains to the coast, they drop off at the Fall Line from the hard rock of the Piedmont onto the soft sediment of the coastal plain. The early mills grew up along these rapids and waterfalls that powered their early looms.

Metamorphic rocks are formed by extreme pressure and heat, but not enough heat to melt them. Such pressures are common where rocks are caught between colliding plates, accounting for the metamorphic core of many mountain ranges. Between and preceding the colliding plates, beaches form along the shorelines. Waves rework the sediments, sorting out and removing the fine clay particles, leaving only the toughest minerals to form the sand. Often this is pure quartz, the mineral from which glass is made, a mineral harder than steel. The feldspars and micas weather to clays and wash away. When the sandy quartz beach is caught between the plates, all the space between the grains is squeezed out, and all the quartz is fused together into quartzite, a rock so tough that when a friend of mine accidentally ran his BMW over a chunk, the quartzite sliced through his steel-belted radials.

I grew up exploring Hanging Rock State Park in the Sauratown Mountains, named for a local tribe that smallpox eliminated. Quartzite tops that isolated mountain range in my home county. Those rocky heights were where I first climbed a peak, swam in a mountain reservoir, and hiked in the moonlight while high. The park's bathhouse, reservoir, and trails were built by the Civilian Conservation Corps, young men away from home, finding a job through one of FDR's programs, sending money home to their families, as my dad had a bit later from World War II.

Nowadays, the government successors to the CCC, like Americorps, are constantly under threat of the budget axe. Most textiles are manufactured overseas. RJR was bought out and taken private, moved to Atlanta, and generally gutted. The small tobacco farms I once worked on went out of business years ago. Like a pebble rolling downstream, I and many of my peers left the region for new terranes. And my parents, like the Sauras before them, are dead.

But the quartzite peaks continue to stand high, resisting the erosion that has worn down less tough terrains. And a few small tobacco patches still unexpectedly pop into sight as I drive the roads of my youth, resisting the change that has carried away most of the blanket of broad green leaves that once colored the late summer fields.

Notes on Mountain Building Processes:

The oldest mountains in the U.S. are the Appalachians. They should have worn down long ago except for the process of *isostatic rebound*. It works kind of like lopping the top off a piece of floating wood—if you cut off the piece above waterlevel, it rises up to float higher.

Erosion cuts the top off mountains. Other processes raise them up:

Isostatic rebound, as discussed above is the rising up of mountains (and continents) due to them being made of less dense rock than in the mantle below. As erosion cuts off the top, they rise, the most resistant rocks sticking up the highest. Example: Appalachian Mountains.

Volcanism creates new mountains through volcanic eruptions at subduction zones and mantle hot spots. Example: Andes Mountains.

Continent-continent collisions form mountains by thickening the continental crust at the point of collision. Example: Himalayas.

Block-fault mountains from due to rotation of large blocks of rock, forming ridges along the edges uplifted and valleys along the ridges downdropped. Example: the Grand Tetons.

The mountains are then sculpted by erosion, particularly by Alpine glaciers. Example: the Matterhorn in the Alps.

12 The Pigs of Haiti

Haiti is said to be the only country with a second name, *the poorest country in the Western Hemisphere.* 59% of its populations lives on less than two dollars per day. The policies of the United States government have often made that poverty worse. The US has invaded Haiti multiple times and occupied it from 1915-1934. In 1991, it instituted an economic embargo on Haiti to force out the military dictatorship that had overthrown the democratically elected president, Jean-Bertrand Aristide. The embargo was originally intended to last a couple of months but lasted three years, devastating what remained of the Haitian economy. However, the damage the Haitian people seem to remember most is the US-led eradication of all the pigs in Haiti in 1982-1984.[1]

Called the Creole pig, the pig of Haiti was a relatively wiry, black pig, quite able of scrounging food and even going two or three days without eating. 80% or more of rural Haitian households raised the pigs, totaling more than a million pigs. The American agriculture industry became interested in Haitian pigs because of an outbreak of African swine fever in the Dominican Republic, which shares the island of Hispanola with Haiti. A study by the University of Minnesota estimated the potential damage to American agriculture from African swine fever at between 150*millionand*5 billion. A subsequent US-funded study found some swine fever in Haiti, though the Haitian pigs seemed remarkably resistant to it. Economically, it made sense to pay for the eradication and replacement of Haiti's pigs. Politically, it was possible, because the dictator in power at the time was one of our guys (anti-communist), and his friends stood to make huge amounts of money in the process. As for the Haitian people, the potentially devastating impact was either poorly understood or ignored.

To understand the impact of pig eradication upon the peasants of Haiti, one must recognize the pig's central importance to peasant families. The pig has been referred to as the peasant's bank.[2] A bank is a place for storing financial resources until they are needed, in the meanwhile letting them grow. The Haitian peasants used money brought in from the slaughter of the pigs to pay school fees, pay for weddings and funerals, pay for emergencies, etc. For ex-

[1] Much of the information in this article comes from Swine Fever, by Paul Farmer. In The Haiti Files: Decoding the Crisis. Washington, D.C., Essential Books, 1994, pp. 130-133.

[2] Swine Fever Ironies: The Slaughter of the Haitian Black Pig, by Bernard Diederich. Caribbean Review 14(1), 1985, pp. 16-17.

ample, the year after all the pigs in Haiti were killed, enrollment in rural schools dropped 30%.[3] In addition, agricultural productivity went down, as did protein consumption by the peasants.

At the time of the institution of the program, replacement pigs from America were promised to the Haitian peasants. The peasants called these Iowa pigs four-legged princes. The Iowa pigs required better living conditions than the peasants, including imported food that cost $120-$250 per year, more than the peasants could afford. To receive the pigs, peasants had to show the financial resources to care for them plus construct pigsties that met government specifications. This alone eliminated most peasants from the list of recipients. When the pig-princes arrived, they got sick easily and required veterinary medicine. Yes, they were bigger than the Creole pigs that were exterminated, but required far more resources to keep them alive, much less to make them thrive. Ultimately, the introduction of the replacement pigs was an abysmal failure.

So what can we learn from this experience? Firstly, the decisions of the rich and powerful can have a devastating impact on the poor. Secondly, the poor are generally poor through no fault of their own. Instead decisions made by governments and global industries impoverish them. Thirdly, assumptions based on That's how we do it here can be completely inappropriate in a different environment. Finally, we can recognize the role that we Americans have played in making life worse for many in the developing world and decide that in the future we will work instead to make things better. That will require in turn that we radically increase our understanding and appreciation of others.

[3] Eyes of the Heart: Seeking a Path for the Poor in the Age of Globalization, by Jean-Bertrand Aristide. Monroe, ME, Common Courage Press, 1999, p. 14.

Part IV

Material for Test 3: What Are the Hazards If We Move?

13 Risk Analysis[4]

When *risk* is used in common conversation, it is usually taken to mean something *how hazardous something is.* But for the purposes of this class, I'd like to define it a bit more carefully:

$$risk = (probability\ of\ a\ hazardous\ event) \times (cost\ if\ that\ event\ occurs) \tag{1}$$

Perhaps it's easiest to think of this from the perspective of an insurance company trying to set your auto liability rates: How likely are you to be in a crash? How much is it likely to cost? High speed makes crashes more likely and more costly, so if you get speeding tickets, your rates go up. Those probabilities come from two sources: 1) historical data (how often a teenager crashed in years past or how often a hurricane hit coastal Louisiana) and 2) current measurements of the system (the individual driver's character or the windspeed/barometric pressure/ocean temperature before a hurricane). But once we figure out the likely risk, we are still faced with deciding oon our response.

> *The (small) chance of dying in an aircrash is one of the prices that society agrees to pay for rapid convenient global transportation. Some risks, including nuclear power generation, have caused fewer deaths but provoked greater calls for regulation, whereas others, such as automobiles, cause more deaths but arouse less concern.*[1]

Each year in my environmental geology class, I ask students how many buy bottled water. (In New Orleans, there is a lot of concern over the water supply because public supplies come from the Mississippi River.) Most hands go up. I then ask them how many have driven 70mph or more on the expressway in the last two weeks. Again, most of the hands go up. That they initially fail to see any relation between the two questions demonstrates how selective we humans can be in choosing which risks we attempt to reduce. And in the U.S., we seem particularly torn between wanting the freedom to take risks while wanting the government to shield us from risks.

At the federal level, we have created a number of government agencies to deal with perceived hazards to our society. The Department of Defense is the big spender—historically, warfare has

[4]This essay is based on Risk Analysis and Management, by M. Granger Morgan, Scientific American, July 1993, p 32-41, the source of the opening quotation.

been an obvious health risk. For domestic risks, we have created OSHA to oversee on-the-job safety, the USDA for food safety, the EPA for pollution, the CDC for epidemics and public health, etc. Each of these agencies makes regulations based on risk, primarily using one of three main approaches, utility, rights, or technology:

- The utility-based approach for risk reduction typically uses cost-benefit analysis. Regulations are aimed at maximizing the tradeoff between benefit to society and cost due to imposition of the regulations. For example, during the Carter administration speed limits on interstate highways were reduced in order to reduce consumption of gasoline. A drop of thousands of annual highway fatalities resulted. Speed limits were later raised because the cost to interstate commerce of the slow speeds was believed to outweigh the potential increased loss of life.[5]

- The rights-based approach incorporates the non-economic principle of justice. For example, exposure to pollution should not simply be an economic decision but should protect the vulnerable—the young, old, and weak. For example, this idea was applied to non-humans through the Endangered Species Act.

- The technology-based approach considers what is possible technologically at the time of enforcement. For example, this approach may require that standards of best-management-practices be adopted. A polluter might be required to reduce emissions to the level the current technology makes practical. As technology changes, the regulatory level may be reconsidered.

On the personal level, however, people are less likely to look at the statistics and costs of hazards when ranking risks. Researchers[6] have found three main reasons why we rank risks as we do:

dreadfulness: how awful it seems to people, such as a nuclear bomb planted by terrorists or kids getting cancer,

level of understanding: how well people understand the hazard, such as smoking, where increased education has lowered smoking rates, and

[5] Due to safer cars, seatbelt requirements, better road safety, etc., the highway fatality rates did not rise back as high as their previous rates.

[6] Experimental psychologists Baruch Fischhoff of Carnegie Mellon University, and Paul Slovic and Sarah Lichenstein of Decision Research in Eugene, OR.

number of people exposed: who might be affected at a given time. For example, a plane crash kills more than a car crash on a per crash basis, even though car crashes kill far more in any given year.

So, to continue with our automobile example, a car crash is not particularly dreadful, perhaps because it is so familiar, we understand well how it happens, and it only affects a few people at any given time. Therefore, we tend, at least on an emotional level, to rank it fairly low as a hazard of concern, even though statistically car crashes are major killers.

At a government level, we've addressed the risk from car crashes through safer roads, mandatory car seats for kids, and seat belts for adults. But in many states, we've done away with helmet laws for motorcyclists. (I only ask that for the good of society, if the motorcyclist leaves his helmet at home that he first fill out an organ-donor card.) This apparent contradiction in risk policy is an example of the balancing act needed to create regulations that take into account the expert opinion based on statistical data while addressing the concerns and desires for freedom of citizens. Statistical evidence shows that riding a motorcycle is one of the most dangerous activities available. Yet seldom is anyone hurt other than the rider himself. In my opinion, as long as there is sufficient education about the risks for you to make an informed choice, the risk to others of your behavior would be the major factor in defining whether or not the behavior should be regulated.

14 Shake and Bake

In 2010, two faculty, students, and I climbed Mt. St. Helens in Washington state. Mt. St. Helens is the most active of the volcanoes in the Cascade Mountains, and it still showed the scars from its last major eruption in 1980. That eruption is considered the most disastrous in U.S. history, blowing 1,300 feet off its height, destroying 200 homes, and killing 57 people. And the loss of life would have been much worse if not for the work of the U.S. Geological Survey in evacuating the area in advance of the blast.

THe U.S.G.S. was monitoring Mt. St. Helens for activity (video), watching for an increase in earthquake frequency and gas emissions. In addition,a bulge had started to form on the northern flank of the volcano. It was this bulge that U.S.G.S scientist David Johnston was monitoring on May 18th, 1980, when a landslide set off a lateral blast that travelled at over 300m.p.h. directly toward him. His body was never found. The Cascades Volcano Observatory is now named for him.

In the 30 years since that huge eruption, a glacier accumulated in the cone, reaching as much as 600 feet thick. Trees had grown back, having all been flattened in the blast. The night before our climb, we camped at Climbers Bivouac at 3,700 feet elevation. The hike up the next morning rose 4,500 feet over a 5-mile distance. Tough, but doable. The toughest part was the poor traction in the glacial snow, thick near the top despite our climb being in late July. The alternative, climbing through the boulders separating the glaciers, was little better. However, the view from on top was worth it—Mt. Baker, Mt. Jefferson, and other Cascade volcanoes each way we looked.

On the way down, several us decided to slide in the snow, not a particularly bright idea. We were lucky no one slammed into a boulder. I snapped a trekking pole trying to slow down. At least one group member got her pants packed full of snow.

Notes on Earthquakes and Volcanes:

Earthquakes are difficult to predict in the short-term. For a geologist to say, “There is a 85% chance of a major earthquake in this area in the next 70 years,” is really quite an accomplishment. But the politician that wants to get elected again in two years usually isn’t looking 70 years into the future.

But looking ahead is the main thing we can do to reduce the costs of earthquakes. By planning and building well, we can save lives:

Zoning laws can be used to control the type of structures built in an earthquake zone—no nuclear reactors allowed!

Building codes are established to protect people from collapsing floors and a crushing death.

Emergency response measures put in place plans for providing basic necessities to victims of a disaster. These plans can include evacuation, if given sufficient warning and time.

Versions of the above plans can be used for most natural hazards, a big factor being the time period over which the event unfolds. However, some natural disasters have indicators that something big is about to happen—*precursor events.* For us here in the Midwest, a tornado is one of the most feared events. I haven't yet lived through one—knock on wood—but others have told me that tornadoes are preceded by a strange darkening of the sky, a sort of green color. If we understand better how the disaster develops, we can better respond to the disaster. Let's think about a volcanic eruption. What are precursor events?

Tremors and small earthquakes: As magma moves up to the surface, it sets off small earthquakes, rearranging the overlying rock.

Gas releases: The decreasing pressure allows trapped gases to escape. Some of these enter the groundwater, altering its chemistry in ways that can be monitored in wells.

Heat flow: The magma is hot, and with sensitive equipment it can be detected. See [here.]

Changes in land surface: bulging and other surface changes may reflect the movement of magma below.

Once the eruption takes place, the hazards take multiple forms:

lahars: Many volcanoes are snow-capped, and the lava rapidly melts it. The water mixes with ash and moves rapidly downhill as mudflows, often tens of feet thick, burying villages and roads below.

pyroclastic flows: *Fiery rocks* or clouds of glowing ash are blasted out from the volcano, incinerating everything in their path as they rush downhill at hundreds of miles per hour.

debris avalanches: New volcanic material steepens slopes and adds weight, often causing landslides.

bombs: Depending on the type of lava and the presence of water, explosions may toss large rocks high in the air.

So why would anyone choose to live next to a volcano? They are pretty, and the volcanic ash weathers to good soil. Also, eruptions may not occur often enough that people remember or take seriously the danger. Turning a volcano into a national park may be the best use for it, saving lives. And it may be up to geologists and geology students to make the case for doing so.

15 Pensacola Beach Nourishment Project

Over Easter break, my family and I went to Pensacola Beach, FL. We like to stay in an old hotel right on the beach. However, after being there a little while, it occurred to us that it certainly seemed farther to the ocean than last year. No doubt we're getting older, but age alone seemed an unlikely explanation. In fact, our previous experience indicated that each year the ocean got closer to the hotel, not farther away!

Early the next morning, I awakened before the kids for a walk down the beach. I like to make some coffee, go to the nearby pier, and stroll out to watch the waves and see if the fish are biting. As I strolled out on the pier and looked east, I saw a large boat close to shore, unlike any I'd seen near the beach before. Nearby on the beach were large metal pipes. Bulldozers rumbled over where tourists usually sunbathed. As I asked around, I discovered that Pensacola Beach was undergoing a major beach renourishment program. Hurricanes Erin and Opal in 1995, Georges in 1998, and Tropical Storms Hanna, Isidore, and Lilli in 2002 all eroded the beach, so much so that the State of Florida designated Pensacola Beach as a critically eroded shoreline. Approximately $20 million were now being spent to widen an 8.5 mile stretch of the beach.

Besides erosion due to storms, beach loss occurs due to natural subsidence, sea level rise, and longshore currents. The beaches of the northern Gulf of Mexico lie upon thick packets of sediment deposited throughout millions of years of streamflow. These sediments continue to consolidate and dewater, reducing their volume and leading to subsidence. Not surprisingly, the sediments that subside the most are the newest geologically, such as nearshore barrier islands, including Santa Rosa Island where Pensacola Beach is located (Click for map.). Many of these sediments have been deposited and reworked since the last ice age, about 18,000 years ago, a short time ago geologically. It is natural for coastal sediments to move. In the northern Gulf of Mexico, the predominant current is east to west, causing sediments to migrate in a westward direction. Offshore islands tend to erode on their eastern end and build on their westward end. In addition to these currents, sea level rise has modified coastlines. Islands become more frequently overtopped by water during storms, leading to more erosion. Old shorelines become submerged. A submerged shoreline is the source of sand for the restoration project at Pensacola Beach. Sand from about 65 feet water depth is used to replace sand lost to erosion. The sand was chosen because of its location and to approximate the color and physical characteristics of sand already present on the beach. A barge is used to churn up the sand which is mixed with water so as to create a slurry. That slurry is pumped through large pipes onto the beach. Once there, bulldozers place and smooth the sand, creating new beach several tens of feet into the ocean.

Protecting coastal zones is crucial to us here in Louisiana. Barrier islands, similar to Santa Rosa Island, and coastal wetlands protect us from hurricanes. The Louisiana coast is also incredibly rich in resources and culture. We have the US's busiest port (by volume), more offshore oil wells than Texas, the second greatest concentration in the world of petrochemical plants, a huge seafood industry, and cities that tourists flock to. In our efforts to protect coastal Louisiana, we must seek to understand the successes and failures of efforts throughout the U.S.

Notes on Coastal Processes:

Shorelines are dynamic—they are where the water meets the land. Relative to a specific location, it's impossible to see whether a change in shoreline location is due to water level changing of land level changing. The land elevation can drop due to erosion or subsidence. It can rise due to tectonic sources such as plate collision or isostatic rebound. Sea level can change due to currents, slow changes in ocean-basin size during tectonic movements, and changes in the size of polar ice caps. The change in global average sea level change is called *absolute* sea-level change.

On a human timescale, the melting of polar ice caps is the most significant factor in sea level rise. During ice ages, sea level drops by hundreds of feet. Ice ages have three major causes:

plate tectonics: Ice tends to accumulate only when there are land masses near the poles, such as current-day Greenland and Antarctica. When the continents have been clustered nearer the equators, such as during the time of the dinosaurs, ice doesn't accumulate.

Amospheric gases: The *greenhouse effect* refers to how certain atmospheric gases, such as carbon dioxide, methane, and water vapor, at like the glass on a greenhouse, allowing visible light to reach the Earth's surface but preventing some infrared radiation (heat) from exiting. A buildup of those gases is like improving the insulation on the greenhouse, trapping more heat and warming the Earth. Humans have been adding carbon dioxide and other greenhouse gases to the atmosphere in large volumes by burning fossil fuels, such as coal and petroleum.

Milankovitch cycles: Over the scale of tens of thousands of years, the Earth slowly changes its orbit around the Sun. The shape of its pathway and the tilt and orientation of its axis all change at different predictable ways. For instance, the pathway around the Sun alternates slowly over about 100,000 years between more circular and more elliptical and back again. When these three cycles line up together, winters become more extreme, and ice accumulates. We find a record of these changes preserved in ice dating back 800,000 years or more recovered from the ice caps. Besides continental ice sheets, glaciers in mountains, *Alpine glaciers*, also grow and retreat, marking changes in climate. See [here.]

Most waves are due to wind, except for tsunamis that are mostly caused by earthquakes. In the open ocean, as a wave passes the water moves in a circular motion. The father down into the ocean one goes, the smaller the circular motion becomes, petering out at the *wave base.* The depth to the wave base depends on the *wave length*, which is the distance from wave crest to wave crest.

As a wave approaches shore and the water becomes more shallow, the wave base reaches the bottom of the ocean and begins to drag and slow. Gradually the top of the wave gets ahead of the bottom, over-steepens, and breaks onto the beach, and the water runs back down the beach.

If you go walking along a beach and watch the waves, they seem to come in nearly straight-on. That's because they are bent as the portion nearest the beach starts to drag first and slow, bending the wave—*wave refraction.* However, the waves don't hit the beach perfectly straight-on, and the water runs back due to gravity down the beach slope. A grain of sand is washed up the beach by the wave, then carried back down by the retreating water, making a zig-zag path that creates movement along the shore. This *longshore drift* is a major movement of sand and drunken tourists along the beach from in front of one hotel to another.

A enclosed body of water near the ocean, connected to it, but protected from its full force is an *estuary.* Estuaries are very rich biologically, being a safe place for reproduction, full of potential food, and flushed of waste by tides. Biological organisms can eat, poop, and reproduce. Lake Potchartrain in New Orleans is an example of an estuary.

Tides are due to the gravitational attraction of the moon and sun. The daily times of high tides vary because the moon Orbits the Earth in about 27–29 days, depending on how you count it, giving the appearance of rising later each day, the amount depending on latitude. The tide size depends on the shape of the local coastline, the most famous spot being the Bay of Fundy in Canada, where the tidal range can be over 50 feet!

Organisms that live in the tidal zone are adapted for the changes in water level. For example, an organism that lives in the zone between average high tide and average low tide has an average day sometimes submerged and sometimes out of the water. It has to be able to handle both. But between average high tide and annual high tide is a zone that on an average day is not submerged. But once in a while it is, and any organism living there has to be able to handle this occasional occurence,

16 Geology and Jazz

I turned 29 the year I moved to New Orleans. I was almost a Ph.D. and about to become a new geology faculty member at a big state school, the University of New Orleans. I found a cheap house to rent within walking distance of campus. When I arrived, my landlady issued an immediate warning, “It’s not safe to go to the French Quarter.” Of course, I headed there as soon as possible. I went alone, not yet knowing anyone, and I loved New Orleans from that first day.

New Orleans is best known as the birthplace of jazz, but I grew up without a stereo. Later, I listened to Barry Manilow and Billy Joel and top-40 countdowns, guided by popular culture until college. There, choir, piano lessons, and classes emphasized mostly classical music. I found myself in New Orleans, barely able to tell jazz from elevator music.

I wish I could say that I had some great musical awakening in New Orleans, and I did indeed stir from my slumber, but I was more like a hungry teenager at a buffet who shovels down everything he can, sometimes hardly tasting it. I saw Dick Dale, the last of the surfing guitarists, the Meters, champions of New Orleans funk, and Aaron Neville singing “Amazing Grace.” Back then, the Rebirth Brass Band played on Jackson Square for tips. I went to shows, drank beer, and bobbed to the music—blues, zydeco, brass bands, and Cajun bands. I went to festivals—Jazz Fest, the Strawberry Festival, the Greek Festival, the Seafood Festival, the Hispanic Festival, and the French Quarter Festival. I ate lots of good food—beignets, po’boys, crabs, crawfish, oysters, muffalettos, Italian, Greek, Mexican, Cajun, Creole—at fine restaurants and holes in the wall. I absorbed the culture as my cholesterol spiked, but I lacked an intellectual framework to stick it onto, unlike the walls of my arteries upon which the cholesterol built up.

I left New Orleans for Dubuque, Iowa, 15 years after arriving, with a wife and two kids, departing eight months before Hurricane Katrina. In Dubuque, I met Jim Sherry, a world-class musician who had deposited himself upon the shores of the Mississippi after teaching jazz in Thailand. Family was the only explanation I discovered for his unlikely, but fortunate for me, arrival. We decided to develop a course we called “Geology and Jazz,” initially linked by alliteration and our common desire to go to New Orleans. But as the conneection of our friendship grew, so, too, did our understanding of the conneection between our two fields.

New Orleans started on the natural levee of the Mississippi River, whose ancestral rivers built Louisiana from salt and mud and sand and more mud and more sand as the super-continent Pangaea split apart and the Gulf of Mexico opened. As ocean water splashed into the rift, it evaporated, leaving its salt behind to form an unstable foundation for the future state. As the water deepened, mud and sand accumulated, their weight squeezing the salt into domes that popped toward the surface, with the oil and natural gas that accumulated around them becoming natural resource wealth. As deltas built out into the Gulf, the state grew—good soil, flat land, future plantations. And the breakup of Pangaea and the movement of the North American plate eventually brought Louisiana to the perfect latitude for growing cotton. All the pieces were in place for agricultural abundance but one—labor. And that could be imported.

The African chunk of Pangaea moved a bit further south as the Atlantic opened. The evolution of humans there under the more-intense equatorial UV radiation led to lots of protective melanin in human skin. Those humans that migrated out of Africa to northern climates gradually lost their melanin, needing to produce more vitamin D in their skin. These washed-out looking white people took Louisiana from the more heavily pigmented Native Americans, exterminated or sickened most of them, leaving few as potential laborers. But the darker-skinned Africans could be enslaved by the light-skinned northern Europeans, enriching the Brits, the French, and the Dutch, and providing cheap labor to enrich the plantation owners. The plantation owners themselves then produced cotton and wealth without needing to dirty themselves physically, though sullying themselves morally.

The plantation owners and their white foremen treated female slaves as entertainment, and mixed-race offspring abounded. New Orleans developed a subculture around quadroon balls—a quadroon being a lady one-fourth African and three-fourths white, considered the most beautiful mixture. Rich white planters upriver from New Orleans would negotiate at the balls for a concubine, promising, for example, to send an offspring for advanced study in France. Some were trained as classical musicians.

New Orleans became one of the few places in the South where free people of color could have a somewhat decent life, owning homes, and being employed, all before the Civil War. Prior to that war, life for slaves was nothing like Disney's *Song of the South* nor contemporary racists' delusions. To help make their existence bearable, call-and-response music helped pass the long days in the field, and drum circles, like in Congo Square, helped maintain their syncopated rhythms, together birthing the blues, the root of nearly every truly American music, including rock and roll.

At the end of the Civil War, instruments from marching bands were left behind. The recently freed slaves adopted the brass instruments. But another ingredient for the musical gumbo was needed—the input of the classically trained mixed-race musicians. They lived in a world of relative wealth, freedom, and education compared to the former slaves, with little mixing. But a court case changed their status.

In 1896, the Supreme Court upheld in the case of *Plessy versus Ferguson* the separate but equal doctine of segregation. A mixed-race man, seven-eighths white Homer Plessy, resisted being forced to sit in the blacks-only cars in the segregated trains in Louisiana, a planned protest to challenge Louisiana's latest segregation law that in 1890 required separate train cars for blacks and whites. Under Louisiana's law, Plessy was classified as black. From then until well after *Brown versus Board of Education*, black was black, mixed was black, Negro was separated in the segregated south. Legally, the former slaves and their descendants were thrown into the same group as the educated mixed-race New Orleanians. In fact, only in 2000 did the U.S. census allow people to check more than one box under "race."

So, in the late 1800s, the blues, brass instruments, and classically-trained musicians were all thrown together. One more thing was needed—a place for the ingredients to stew, a place for the musicians to perform. Vice often funds other entertainment—Today we have gambling in Las Vegas gambling funding musical shows, and in the late 1800s until 1917, New Orleans had Storyville, the whorehouse district. No matter how many times one samples the merchandise per day, there's plenty of time for other entertainment. Music and alcohol filled the need. Louis Armstrong, the King of Jazz, got his start as a teenager playing trumpet in a Storyville whorehouse. Other Jazz musicians, such as Buddy Bolden, preceded him, but Louis is who we remember.

In 1917, a reformer closed Storyville, in 1920 Prohibition began, and in 1927 the worst flood in U.S. history broke the back of the sharecropper system that had perpetuated slavery under a new name. Jazz poured out of New Orleans as part of the Great Migration. Blacks headed to Chicago, New York, Kansas City, Memphis, and St. Louis. And they took Jazz with them to the speakeasies that sprang up during prohibition.

For my students at UD, studying jazz is like a history course—it's not alive for them. Here in the Dubuque, cover bands dominate, and the summer Friday outdoor series —*Jazz at the Clocktower* may have an occasional local high school or college jazz band but otherwise is relatively jazz-free. But when Jim and I take them to New Orleans, the jazz heritage transforms. The horns blast, and the students dance. They mix with young, old, black, white, college students from Tulane, tourists from the world over, and locals down for a good time. Somewhat dry academic lectures are transformed by ancient rhythms. Syncopation moves down from the head, felt, not just intellectualized. *Laissez les bon temps roller.* Let the good times roll.

Notes on Deltas and River Processes:

New Orleans is located on the Mississippi delta. A *delta* forms where a stream meets a body of standing water, such as the ocean or a reservoir. It gets its name because the Nile River delta is shaped like the Greek letter Δ.

When the water in a stream slows, it drops the sediment it carries. The faster it is moving, the larger sediment it can carry, but the larger sediment also drops out first as the water slows. When a stream floods and tops its bank, the coarsest material drops out to form the *natural levee* of the stream. The flat land nearby forms the *floodplain* of the stream. It water usually stands but trees grow, this area forms a *swamp,* usually fairly close to themain stream channel. Farther away and at a slightly lower elevation, no trees grow in the *marsh.*

The channel itself can take a variety of forms, including a *meandering* path, such as the Mississippi River south of St. Louis, or a *braided stream* with multiple channels that usually form when the stream has more sediment than it can carry, such as the outwash from a glacier or after deforestation leads to increased erosion.

A stream carries its sediment in three main ways:

bedload: large sediment bouncing along the bottom of the stream;

suspended load: mostly clay that stays in the water, not really floating but held up by the charged nature of the clay's surfaces; and

dissolved load: salt, calcite, and other soluble minerals that rainwater dissolve and carry away.

When water slows, instead of transporting sediment, it *deposits* it.

As streams go downhill from its headwaters towards its delta, most change in predictable ways:

- channel size gets bigger;
- discharge, the volume of water carried per unit time, increases;
- sediment load increases;
- sediment size decreases; and
- velocity increases. The increase in velocity goes against our intuition. If we want to go whitewater rafting, we go toward the mountains, not the coast. But much of that movement of the water doesn't result in it advancing farther downhill. Instead, it goes in eddies, hydraulics, and around boulders. Its net movement is actually less that in a place like New Orleans, where the Mississippi is very deep and wide and has little friction with its channel to slow it.

17 Out from the Ice

In the summer of 1999, I taught geology in Innsbruck with the UNO program. Shortly before I arrived, one of Innsbruck's most celebrated guests departed for Italy. Oetzi had arrived naked in 1991. 1991 had a particularly hot summer, and Oetzi's was the 7th body to melt out of the ice of Alpine glaciers. Hikers discovered his body and reported it. A policeman was dispatched to inspect it. His initial response was to treat the body like just another hiker that had to be jack-hammered out of the ice. However, he couldn't get the job done, so the body lay for another four days while other people came and collected some of his clothing and tools. Finally, an Austrian doctor led a team that got Oetzi free of the ice. Unfortunately, the five days spent getting Oetzi out did more damage to him than the 5,300 years he lay frozen.

Yes, 5,300 years. Oetzi is the oldest mummified human ever found, almost 2,000 years older than King Tut. Oetzi was about 5 feet 2 inches tall, weighed about 110 lbs, and was probably between 40 and 53 years old. As he was being extracted from the ice, under him was found a copper axe, dating him to the Copper Age. He wore animal skins, shoes lined on the inside with grass, and a grass cape. He carried an unfinished yew bow, arrows in a quiver, a flint knife, a leather pouch, and a wooden frame possible used as a backpack. His internal organs were preserved. He seemed to have been fairly fit despite arthritis in the neck, lower back, and one hip, plus broken ribs, calcium deposits indicating heart disease, and a fractured jaw. He was carrying a bit of food—a sloeberry, some mushrooms, and a few gnawed ibex bones. Recent isotopic work indicates that he was a vegetarian, at least for part of the time leading up to his death.

Most bodies coming out of glaciers are fairly ground up and decayed. That Oetzi was so well preserved was a fluke. Apparently Oetzi was walking across the Alps near what is now the Austrian-Italian border. He grew tired or sick or took refuge from a storm. Whatever the case, he lay down in a natural rocky crevice, never to rise again[7]. If Oetzi had been exposed for long, animals would have destroyed his carcasse. However, snow quickly buried him, freezing his body for centuries to come. As the Alpine glacier formed on top of him and began its grinding flow downhill, the shallow depression in which his body lay protected him.

[7]Recent evidence by researchers in Balzano, Italy, indicates that the Iceman died from an arrow shot to the shoulder.

What was Oetzi doing up in Alps? Perhaps he was hunting ibex or herding sheep. Or maybe he was fleeing danger. The broken bones, especially his jaw, may indicate a violent conflict. The unfinished yew bow was cut from trees that grew lower down the mountain. Grains of wheat and corn in his belongings indicate that he had been in an agricultural area. The ripe sloeberry indicates the time of year was late summer or autumn. Konrad Spindler of the University of Innsbruck has guessed that Oetzi was a herder who came down from the mountains and got caught up in some conflict such as a raid from a neighboring valley. He escaped back up the mountains, only to die from exhaustion and the early snowstorm. Perhaps. Oetzi's past remains a mystery.

When Oetzi was discovered, some speculated that he was a hoax, a mummy from somewhere else placed into the ice to mislead scientists. However, DNA analysis of Oetzi shows that he was of European descent. Though the Austrians originally recovered and claimed his body, a careful survey of the border showed that he was slightly on the Italian side. When Oetzi left Innsbruck in January, 1999, it was for Bolzano, Italy. There he is on display in a climate-controlled case in a darkened room in his own museum.

Human civilization has only been around for 10,000 years or so. Not much in the 4.54 billion years of Earth's existence. But in our brief time, we've radically altered its surface, changing the makeup of plants and animals, and more recently, of the atmosphere. The melting of glaciers, such as the one that once covered Oetzi, is but one result of the changes we've caused.

18 Fatal Flood

We will watch together in class the video *Fatal Flood*[8], a documentary about the 1927 Mississippi River flood that was the worst in the nation's history, transforming both culture and politics. Echoes of the flood reverberated across the U.S. and into its future, including through the time of Hurricane Katrina.

This is one of my favorite videos. It combines geology with sociology, history, and political science—an integration that is central to the thrust of this course. Most of you are not science majors, nor are you likely to take a science course after this one. Beginning to see the connection of science to many other areas of life is a significant thrust of the course. Be sure and take a look at the review questions related to the video.

[8] The video is [here.]

Part V

Material for Test 4: What Resources Are Available?

19 A Good Vein

My mother could not stand dust in the house. Unfortunately, the log cabin that she and Dad built themselves in the late 1940s was along an often-used dirt road. The cabin was mom's first and only home after marrying Dad, the place where she lived for the next 65 years. She wouldn't count as home the six months in assisted living at the end of her life nor the time living with her in-laws while work on the cabin began. Dad's parents lived a mile or so up Easley Road from the cabin site. Grandma Easley talked constantly, revelled in the illustrious past of *her people,* and disparaged the Easley clan into which she'd married. Mom found grandma's constant gossip and judgements grating and was glad to move to the small cabin despite its having no running water nor toilet. A nearby spring and outhouse met their needs initially. However, after Dad grew tired of carrying buckets of water up the hill to the cabin from the spring below, he decided to dig a well.

Dad was not well-educated, neither in school nor through personal reading. He was good with his hands, and that kept our family comfortable. As he began the process of digging a well, I think he had in mind some underground network of natural pipes or maybe something more organic—a kind of Mother-Earth circulatory system. If he could just tap into it, he'd have an abundant water supply. His view is not quite as ignorant as it sounds when I write it—the heavily weathered rock beneath our home had relatively low permeability, but the underlying fractures collected and transported much of the water.

Dad began hand-digging wells within sight of the cabin's front door. He seems to have had no rhyme or reason for placing them except seeking to bump into, in his words, "a good vein of water." His first two attempts bottomed out on solid bedrock while yielding no significant water. When the third well once again struck bedrock, Dad tried a new approach. He put half a stick of dynamite down the hole to open up the bottom. Not much effect. So he put *several* sticks of dynamite down the hole. According to Mom, the blast threw rocks over the rooftop of the nearby house. Dad was ahead of his time—he fracked the low-permeability rock! The resulting reservoir at the bottom of the well was about eight feet in diameter and about the same depth. Above it was the five-foot-diameter shaft that Dad had dug, with a total depth of about 35 feet. Across the middle of the reservoir, Dad installed a horizontal pipe so that if any of us kids fell in, we'd have something to hang onto. However, as some of my students like to point out, if we'd fallen in, the pipe would probably have broken or broken us.

Until the summer after Dad died, the well top was covered with a wooden box, five feet on a side and about four feet high, that had an opening in top to allow a bucket to pass through. Covering the whole thing was a gazebo with four corner posts, a shingled roof above, and a wind vane on top. A rope connected the bucket to a pulley in the top of the gazebo and then to a windlass—a round log around which the rope wrapped and through which passed an iron bar connected to a handle used to turn it. By this means, we could crank up a bucket of water only 20 feet or so from our front door.

From the well house, a sidewalk and then steps led up to our driveway and two-car garage, perhaps another 20 feet away and six feet higher in elevation. The garage was built from debarked logs, creosoted to prevent rot, and with a tin roof and wood-slat sides, painted white. Across the driveway, a line of black pines stood on a narrow two-foot-high ridge separating the driveway from an old dirt road that led a mile or so past the house to Town Fork Creek, which bordered a side of our bottomland. Dad and I fenced the bank so we could pasture cows, pausing our work on one hot, summer day to strip and walk the sandy creek-bottom, then lying in it to wash off the sweat.

The Westmorelands owned the adjoining farm, bordering us all the way from the main road to Town Fork Creek, just upstream from our property. Uncle Paul and Aunt Hope were not relatives, though they were the closest to grandparents I had, and were called Uncle and Aunt in the southern tradition of respect for the importance of their relationship to our family, a relationship too strong for Mom to consider linking them to the dust drifting down toward us.

Along his property next to Town Fork Creek, Uncle Paul had given Frank Loflin permission to dip sand. Frank had a small barge on the creek with a pump mounted on it. An auger churned the creek bottom, and the resulting slurry was pumped onto land and through a sieve that was elevated high enough for a dump truck to back under. The sand was intended for Frank's clients and his concrete business. These dump trucks passing on the dirt road just uphill from our house raised the clouds of dust that Mom battled. In the summertime heat of our unairconditioned home, we opened the windows through which the billowing particles drifted. Mom was obsessed with keeping our home spotless, and the dust was an enemy to be forcefully repulsed. Thus, Dad was drafted into battle, soon escalating to chemical warfare.

Dad was a mechanic at the airport 30 minutes away in Winston-Salem. Anything tossed out at the airport had a fair chance of landing at our house—our kitchen cabinets were built from the floorboards of DC-3s. Included in the airport waste stream were 55-gallon drums of solvents used for cleaning parts and degreasing engines. Dad decided they were perfect for keeping down the dust on the dirt road near our home.

When I was quite young, perhaps six or eight-years-old, I can remember helping Dad load one of the drums onto the back of our tractor. The tractor was an old 1948 Ford-Ferguson, a predecessor to the Ford Redbelly that was popular in the tobacco-growing region. It had a three-point hitch on the back with a crossbar to which we could connected balls for trailer hitches and various farm implements. On the day I most remember helping, we tilted the drum of liquid onto the crossbar so that it lay sideways, the bung at the low point. Dad climbed onto the old tractor, started it, and lined up the bung over one of the tire tracks in the dirt. I took a pair of large pliers and opened the bung until the liquid began to slowly drain out. Off Dad went, driving the tractor up and down from in front of our house to where the dirt road met our driveway. Each tire track got a good coating of the oily fluid.

Near the garage, a cut through the pine trees allowed access to the road from our driveway, and 50 yards or so towards the main highway, the driveway and dirt road connected. Together, these formed a loop that we could circle on our bicycles or, later, on a go-cart that Dad salvaged from somewhere. As we would loop around, I can remember the oily dirt underneath the tires, looking a bit like a chocolate brownie that had been squished. Meanwhile, the fluid was doing an exemplary job of holding down the dust.

My dad was not alone in pouring waste fluids on the road to keep down dust. For example, the Times Beach, Missouri, Superfund site also began with application of waste oil on dirt roads. Superfund is the common name for a federal law passed in 1980 to identify and clean up the worst of the nations abandoned messes. Other examples include old mines and inactive industrial sites. Among the chemicals at Times Beach were PCBs and dioxin. We have no idea what was in the drums Dad brought home from the airport. But like my Dad, many people did not associate the waste fluid they dumped on the ground surface with the ground water that someone in the future might drink. Most did not realize that the oily dirt itself would become toxic.

Ignorance of chemistry was hardly limited to my Dad. For example, dioxin is naturally occurring in low concentrations but is also created as a byproduct of activities that involve that involve burning organic material when chlorine is present. In the case of Times Beach, the source of the dioxin was the byproduct from a company producing an antibacterial chemical used in soap, toothpaste, and disinfectants used around the house. In the 2004 attempted assassination of Ukrainian President Viktor Yushchenko, dioxin was a key ingredient in a poison used, resulting in chloracne, a disfiguring of his face that was not fatal but required hospitalization and skin grafts. Thus, our increasing understanding of the toxicity of dioxin shifted its destructive application from accidental to intentional.

It was Rachel Carson who first drew significant attention to the truth that not all living is better through chemistry. By that time, my Dad was in middle age, and as I've said, he was hardly the type to keep up with literature about the environment. Despite that, he certainly had no intention of poisoning his family nor himself. And establishing exposure and resulting harm is impossible, However, the fact remains that when I was 19, Dad was diagnosed with leukemia and began chemotherapy. Looking back, it is a bit ironic that exposure to chemicals may have been the cause of his contracting leukemia and that a different set of chemicals was injected into his veins, aimed at restoring his health by destroying all his white blood cells.

Only later, in graduate school, did I recognize that the waste Dad dumped on the road might have entered our well. By that time, many years had passed, and only Mom lived at the house. She resisted switching to piped-in water, finally doing so not because of health concerns but because of constant worry that the well was going to go dry, despite its having lasted for decades. During most of those decades, Mom also smoked Marlboros, once again a huge negative health effect of which we were unaware when Mom first smoked. She, too, died of cancer.

There are those who argue that in the face of life's uncertainty, *Ignorance is bliss.* Or they argue that scientists are perpetrating hoaxes upon the American people. Certainly there have been some cases of misbehavior, and there have been some times when it is easier to turn a blind eye than confront the truth and work for change. Still, it's hard to see how Mom would have been worse off knowing the truth about smoking. Eventually after doctors identified the health effects, she made the choice to quit. And the airport is no longer allowed to send home with its employees drums of waste fluids. In both cases, I give thanks for scientists and government regulators.

Recently, I began the task of selling the house, removing decades of accumulated memories—old shoes from the 50s, toys from my childhood, and old black-and-white photos—but leaving scattered about the three-acre lot multiple old barns and outbuildings in various states of disrepair. A log barn, painted green has a few windows with glass from an airplane, one pane of which has a hole where my baseball went astray. Up the hill, the old road passes by, now covered with gravel—no sand trucks and little dust in decades. Instead, a cable blocks passage, locked to keep out four-wheelers and uninvited hunters. Between the road and house, the old well cover still stands, now brick that I laid the summer after Dad died. As I lift its cover one last time, I see small roots penetrating the shaft walls and the refleection of the water below. The mercury-thermometer-shaped well, though no longer used, probes the earth, monitoring the flow through a good vein.

Notes on Groundwater:

Key terms:

1. Recharge—where water enters the ground. I draw clouds and rainfall and show it soaking into the ground.

2. Unconfined aquifer: The water is free to soak downward with no low-permeability *confining layer* to impeded its journey (downward arrow). An *aquifer* is rock or sediment containing sufficient water to supply springs and wells.

3. Water table—the point below which all the openings in the rock and soil are saturated with water. As the rain infiltrates, it reaches the water table (dashed line), which forms the top of an unconfined aquifer. In a wet climate, the water table mimics the ground topography—high under hills and lower elevations in valleys.

4. Porosity—percentage of the sediment or rock made up of openings into which the water may seep.

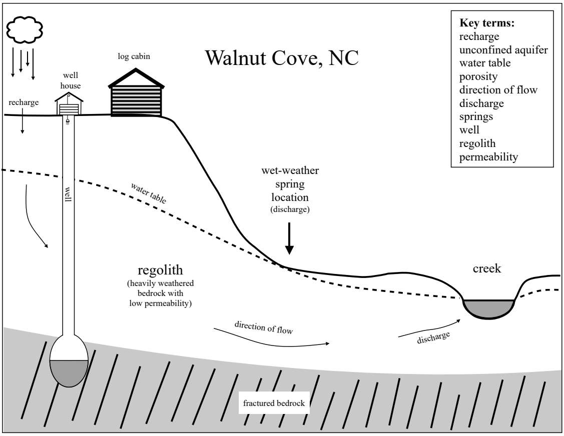
5. Direction of flow—water flows downhill. If the elevation of the water table is lower, then that is the direction the water flows (directional arrows).

6. Discharge—where the water leaves the ground for the surface. The banks of the creek are one location (arrow); springs are another.

7. Springs—Where ground water flows onto the ground surface. If the water table intersects the ground surface, water may seep out, forming a spring (mark location). In an unconfined aquifer, the water table changes seasonally. In wet weather, it rises.

8. Well—another point of discharge, this one being manmade. My dad's well penetrated through the low-permeability regolith into the fractured bedrock below. Regolith is a layer above the bedrock of unconsolidated material, often formed from heavy weathering of the bedrock itself.
   Thought question: Why isn't the water in the well at the height of the water table? (Insufficient water drains out of the low-permeability regolith before it evaporates in the huge hole dad dug.)

9. Permeability—a measure of the ease with which water passes through the aquifer.



Example of an unconfined aquifer system.

20 The Case for Clean Water

Recently I had a bout with intestinal flu that left me feeling wrung out. As I trudged back and forth from the bathroom, I tried to look at the bright side: I had a flush toilet, running water to wash my hands, and a warm bed to rest in. My wife brought me refrigerated Pepto-Bismol to ease my discomfort. If things got really bad, I could call the doctor. Compared to many of the people in Haiti and other developing countries, I have it pretty good.

You might argue that I was trying to rationalize away my own discomfort. But what should really make me uncomfortable is the fact that worldwide, diarrhea is the leading killer of children under 5. Let that sink in for a few minutes. Children are dying from diarrhea. Imagine your child, little brother or sister, or neighbor becoming dehydrated, wasting away to the point of death. Surely you would do something.

Most of the childhood cases of diarrhea come from drinking contaminated water. I'm not talking about pesticides or some exotic chemical—I'm talking about feces in the water. Scoop a bucket of water out of a stream, open well, or spring, and chances are there are things living in it that can kill a child, if not an adult. But many people—over a billion people worldwide—don't have access to clean water. Providing clean water is fairly straightforward—we have the technology and it doesn't cost much.

An example from Haiti shows how simple improving water supplies can be. Fondwa, Haiti, is hilly, with springs near the tops of most ravines. Pigs, chickens, and people wade in the water, and when I was there I didn't see any pigs with diapers. If a simple concrete and stone capture box is built over the spring and water is piped by gravity flow to a nearby faucet, then contamination of this water source is largely eliminated. As long as each person keeps her bucket clean, the family has clean water.

I also said that providing clean water is cheap. To build a spring capture system in Fondwa costs about $1600 and serves 300-400 people. The money buys concrete, stone, and pipe. The people of the community do the work. Frankly, I can't imagine worrying about $1600 if Ananda or Tess were really sick. We've probably spent close to that on diapers. But the median income in Haiti is $60 per year. Yes, I said per year. There's not a lot of excess cash floating around.

Haiti is an extreme example of poverty, but there are other parts of the world as bad off. For a little bit of money, we could make a big difference. Ultimately, I'd love to see Haiti move to selfsufficiency, beyond the need for charity. I hope Ananda and Tess will support themselves someday, too. That won't happen simply saying it ought to. I've got to invest in my kids' lives for years to come. Likewise, I believe the international community and people of good will need to invest in the lives of the poor, and providing clean water is a way for the investment to show immediate results.

Notes on Water Resources:

The hydrologic cycle shouldn't be much of a stretch for business majors—what comes in, what goes out, what stays. Instead of money, we look at water. We'll sketch the hydrologic cycle together in class.

Clean freshwater is crucial for life but most of the world's water, about 97%, is in the oceans. Desalination is too energy intensive for it to be practical in most places, except in the Middle East where there is plenty of relatively cheap energy resources. Most of the freshwater in frozen, tied up in glaciers and the polar ice caps—the ice caps are the only locations with enough water to impact global sea level. When they melt, sea level rises. During ice ages, sea level falls.

By far, the most freshwater available for use is groundwater. About half of the U.S. population gets their drinking water from groundwater, as does nearly all of the rural population.

In terms of the total amount of water used, surface water dominates, partly because of its use in hydrothermal power plants, such as coal-burning plants that generate electricity. Also, a lot of surface water is used for irrigation of crops. However, the big center-pivot irrigations systems that dot Nebraska and easter Colorado use groundwater pumped from large-diameter wells at rates of a thousand gallons per minute or more. You can see a smaller version in a field to your rights soon after you come off the bridge into East Dubuque.

21 The Value of Clean Water and Sanitation

My father said, “The value of a good stink-stink has always been underestimated.” *Stink-stink* was the term of my youth for a bowel movement, which my father took ritually each morning upon his *throne.* He usually took the comics with him to read while mom used the time to wash my hair in the kitchen sink. We had no shower, only a bath, so to remove the adolescent grease from my head, I’d grab a towel from the bathroom before Dad occupied it, lean over the sink, and have mom scrub my hair. We learned to warn Dad when we were ready to rinse, lest he flush and scald my scalp. The old plumbing in the house did not adjust well to the sudden change in pressure due to his flush, and the cold water would be diverted to the toilet, leaving only near-boiling water in the faucet above my head. Dad kept the thermostat particularly hot so that, mixed with cold, the hot water would last through the morning for all the family.

Nowadays I am a hydrogeologist and statistician. My training began under that faucet. Why did that old plumbing seek to scald me when Dad flushed? What were the odds of being burned, and how could I reduce them? A simple intervention—yelling to Dad ahead of rinsing—reduced my pain immensely. Low cost and appropriate to the situation. Such are the best of practices in water development. Likewise, Dad’s emphasis on *a good stink-stink* had profound merit. Only years later did I discover the world’s abundant lack of sanitation and the fact that diarrhea is the leading killer of children under five years of age. Dad was on to something—the combination of water resources and good sanitation could change the world.

Appropriate technology is the term used for modernization appropriate to the current conditions of a group of people. For example, installing an electric water pump in rural Haiti where electricity is often non-existent is a sure failure. However, a dependable hand pump can be a tremendous improvement over nearby streams. In one area I visited in southern Haiti, gastrointestinal illness was reduced an estimated 80% by introducing and maintaining hand pumps. If each villager keeps his or her bucket clean, the family can have clean water to drink and use around the house. The energy for pumping the water comes from the person needing it, not from some undependable far-off source over which the village has no control.

The development community moved beyond focusing on appropriate technology to *sustainable development,* or sustainability (See [here.]) The reason was pretty clear on my first visit to Haiti—if there is no sense of local ownership and no resources for maintenance, the technology soon falls into disrepair. I saw multiple failed water projects with a variety of technologies all deemed appropriate, and all having failed and been abandoned. Money is far easier to obtain for new projects than for maintaining old ones. Maintenance requires systemic change, education, infrastructure support, and community building. That takes too long for most Americans, who would rather do a two-week volunteer trip—a vacation that also makes them feel good about themselves but produces little lasting change. *Sustainable development* focuses on the longer commitment and local empowerment.

One of the biggest challenges of sustainable development is the rapid change in available technology, much of which cannot be foreseen far into the future. For example, much of Africa has skipped the step of stringing miles of telephone lines, going straight to cell phones. Huge amounts of copper are saved in the process. It's very difficult to predict the future use and shortages of such resources when one can't predict the future technologies that will replace or use them. Still, to try to empower people, avoid environmental degradation, and think of future generations, seems to me to be worthy goals despite the limitations of our foresight.

Notes on Sustainability and Environmental Justice:

The 1987 Brundtland Report defined *sustainable development* as meeting "the needs of the present without compromising the ability of future generations to meet their own needs." This definition includes both a recognition of needs and of limitations, particularly of the availability of resources. A major criticism of this definition is that we do not know the limits of human ingenuity, and therfore cannot foresee the creative ways that we will deal with future resource shortages. For example, water is in short supply in much of the Mideast, but desalination of Persian Gulf water has radically increased the size population that can be sustained. However, the concept of sustainable development, if used in planning, does force us to look at impacts upon future generations. Some impacts, such as processes that pollute the air or water or degrade the soil are clearly not sustainable, and alternative must be pursued.

Considering impacts on future generations is one component of *environmental justice*, which according to the U.S. Environmental Protection Agency is "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." A criticism of this definition is that it is focused on humans but that the environment encompasses all species. In times past, we have recognized the rights of other species, if only to exist, such as in the 1973 Endangered Species Act signed by President Richard Nixon. Still, the concept of environmental justice, like that of sustainability, pushes us to widen our discussion to include a broader set of *interested parties*.

The concept of considering interested parties applies to almost every student's major. For example, suppose your first job out of college is as a police office. Who are those interested in your job performance? Your boss, certainly. Your community? State and national police organizations? The press? Organizations aiming at reducing police violence? Community-watch organizations? The list goes on. And if any of them feel ignored or are dissatisfied, you'll probably hear about it. So searching out interested parties early rather than later is important for your career.

Throughout this section, though the focus is primarily upon water, the bigger question is about *best*—what is the best way to improve both people's lives and the future of the world? How do we decide?

22 Pulling the Plug on Lake Peigneur

In 1980, I was taking some of my first geology courses at Guilford College, NC. On the bulletin board outside my professor's office appeared an article about a Texaco drilling rig that was sucked down a hole, draining a lake in the process. It sounded like something out of a bad science-fiction movie. But for the people of Jefferson Island and New Iberia Parish, it was only too real.

In the early morning hours of November 20th, 1980, the drilling rig began to tilt. Not too unusual. The rig was on the soft bottom mud of Lake Peigneur, and the crew was exerting a lot of force as they tried to unstick the drill stem where it had just seized at about 1230 feet depth. Unsticking the drill stem at such a shallow depth should have been fairly easy, but it wasn't. As they tried, the tilt of the rig got worse, leaning two to three feet. Something was badly wrong. The crew decided to release the barges tied to the rig and get off. Shortly afterward, the rig overturned and then disappeared into the lake. A whirlpool one quarter mile in diameter formed, and the entire lake disappeared into a crater formed where the rig had been. Along with it went a second drilling rig located nearby, plus 11 barges and a tug from a canal that had connected the lake to the Gulf of Mexico, 40 acres of Lake Peigneur's Jefferson Island, a house trailer, and more. The canal reversed flow, and a 50-foot waterfall formed where the Gulf water flowed into the crater. Within two days, Lake Peigneur filled back up, and nine of the barges popped back up like toys in a bathtub.

Lake Peigneur held 3.5 billion gallons of water prior to the accident. It takes a mighty big hole in the ground to suck up that much water. It so happens that one was readily available—the Diamond Crystal Salt Mine. The Diamond Crystal mine had been operating since 1920, excavating salt from increasingly deep shafts. Pillars of salt were left to support the 80-foot-high roofs of the shafts, which were as wide as four-lane highways. Texaco had accidentally drilled into one of those shafts. Water dissolves salt, explaining the formation of the massive crater as water poured from the lake into the mine. Fortunately, the 50 miners who were in the lower levels of the mine when water started pouring in were able to evacuate safely, though three dogs died. Two fishermen on the Lake were able to walk through the mud to shore after their boat bottomed out as the lake drained.

How could such an accident happen? Apparently through miscommunication. Texaco was aware of salt mines in the area and had contacted the Corps of Engineers, which in turn contacted Diamond Crystal. Where the communication broke down is unclear. Texaco, Diamond Crystal, and a contractor operating the rig sued each other. In an out-of-court settlement, Texaco and the rig operator paid Diamond Crystal an estimated $45 million. Texaco paid Live Oak Gardens on Jefferson Island another $12.8 million for damages. The mine was closed, and Diamond Crystal soon got out of the salt business. It is now used for storing petroleum.

23 An American in Qatar

In 1994-95, I spent a year in the Middle East, a Fulbright Fellow who received requests for sperm donations despite having foolishly thought he might have an impact on the water resources in Qatar. Instead, I had been more of a trophy, not personally but generically, like a penis-stiffening rhino horn or a glass-eyed ibex head. The royal family controlled most of the natural water resources of the country which, with three inches of rain per year, were pretty limited. All practical sources of water came from desalination of Persian Gulf—scratch that, Arabian Gulf—waters using the abundant natural gas that propelled Qatar towards becoming one of the world's richest countries. Still, for a brief time, I was a celebrity, even appearing on Qatari television, a predecessor of Al-Jazeera, as a B-list big fish in a desert.

Whenever I was out and about and ran into a local Qatari, an invitation for coffee almost always followed. The people of my host country were invariably gracious and welcoming. With one dangerous exception—when they were behind the wheel. The anonymity coupled with the power of technology allowed escape from a restrictive society. Their cars became secret hideouts and pimp mobiles. The Qatari behind the wheel and the Qatari in the corner office gave no indication of originating in the same culture. Being a woman in a car was to invite unwanted advances, including having a cassette tape of introduction tossed in the window. Being at an isolated bach alone with your wife was to invite a local in a truck to drive a quarter-mile across the sand just to slowly pass 10 feet away. Daring to stroll through a cross-walk was to invite being run over by a driver in sunglasses peering anonymously through his windshield. Yet such behavior would never happen in a face-to-face encounter, or at least we never experienced it.

When my wife and I first arrived at the Doha airport, married only a couple of months prior and practically on our honeymoon, an Egyptian engineering professor had picked us up. That night, he and his wife graciously took us out to eat—at the Taco Bell, one of the many American fast-food restaurants that seemed to dominate the dining possibilities. But we wanted to know more about the local culture, and Khalid became my interpreter. Early in my time in Doha, I met him at the American consulate. He was a big, jovial guy who wanted to learn more about Americans—not exactly a consulate groupie, but certainly an active presence. Khalid became the one who gave me the greatest look inside the windshield.

But being a pet koi for rich people of nearly unlimited resources wasn't my goal. In fact, I applied not for Qatar but Sudan—I studied water resources in grad school after two years in Africa, and I wanted to help poor countries. However, a new eruption in Sudan's multi-decade civil war kept Americans out, so the Fulbrighters offered me Qatar as a consolation prize. No doubt, it was just as well, because after I applied, I met the zookeeper who became my wife. Qatar beat Sudan as a place to spend the first year of marriage.

My wife and I enjoyed our year-long honeymoon in what one travel book called "the most boring city on Earth," perhaps because of its lack of bars, dance halls, and fine dining. Yet we had a great time—climbing to the highest point in Qatar (a sand dune), swimming at night in the bioluminescent coastal waters, watching flocks of flamingoes as the tide crept in a quarter mile across the nearly flat coastline, pulling chunks of gypsum from the sabbkha, or lying in our apartment and reading out loud from bad books and good—my first encounter with the original Ian Fleming—shopping in the souk, buying Persian carpets with tiny knots tied by Afghan child labor, eating out at least once nearly every day, teaching the local Arabs geology and mathematics and songs from the Lion King, watching camel races and real camel jockeys (not an ethnic slur but young imported boys who put little weight upon the camels back)—all of it filled a year both joyful with new experiences and people and frustrating in my inability to make any difference with the use of water resources.

With no trees in Qatar, most of the building were of concrete. Khalid's apartment was typical—a living room area with carpets and a brightly colored painting or two, overstuffed chairs, and a shut door to the back where any female family members lurked unseen. Most of the housework and cooking was done by Pakistani or Indian women or boys who quietly brought in bowls of rice, chicken or lamb, and Arabic tea. Invariably, a bare bulb hung from a wire overhead, beneath which I began to learn more about Qatari life and customs. However, at times, Khalid seemed as mystified by the changes taking places in his country as someone on the outside looking in.

Once the university semester started, I grew to enjoy the daily break for snacks that the Engineering Department, mostly Egyptian, had built into its schedule. I've never before or since eaten so much falafel. We took turns purchasing the snacks, so when my week came, I diversified into baklava and other wonderful pistachio treats from a nearby bakery. The tea, too, was super-sweet, served in the same little cups used for Arabic coffee. The baklava, like my presence, introduced a bit of variety in the gatherings, and both seemed welcome.

At a wedding celebration that Khalid invited me to, a large tent was erected whose inside floor was then covered with dozens of carpets. Large stuffed sofas ringed the outer edges. Platters of rice with a whole lamb in the middle were placed on the carpet, around which we men gathered to eat with our hands—even I knew to use the right hand only. Another time, my wife was invited by a co-worker to a wedding celebration. At the nicest hotel in Doha, the women gathered, dressed in their black abayas. But once the doors were closed so men couldn't see them, they revealed to each other the designer dresses and jewelery beneath. As the wedding buffet was opened, the women descended upon it vulture-style in what my wife first viewed as repulsive and wasteful but came to see as a celebration of abundance, something lacking a generation or so before.

In the spring before I left, Khalid invited me to visit some friends camping in the desert. By then, I was pretty trusting despite his picking me up in his SUV well after midnight. Still, I wondered, "How are we possibly going to find a tent in the desert the dark?" I suppose I had in mind my college camping trips—2-person tents, a few flashlights, lying out looking at the stars.

As we drew close to our destination, I saw a glow. A huge tent with neon lights powered by a generator rose up out of the desert, looking a bit like *The Aladdin*, a Las Vegas casino. We parked alongside it with four or five other SUVs and entered the tent.

Inside, the Qataris (all male, of course) were watching bodybuilding videos by another cross-cultural icon—Arnold Schwarzenegger. I don't recall the assembled group taking much notice of my arrival. An American? No big deal. They were polite but not particularly interested, probably used to Khalid dragging along another new American. After a while, someone pulled out an *oud*, a type of Arabic guitar, and another person kept time on a tabla. Many of the group joined in singing songs that most seemed very familiar with. The occasion reminded me more of a church youth group than a frat-house party. I was meeting Arnold's acolytes. Like Arnold, they seemed to be synthesizing their past, their aspirations, and their dislocations. The world they knew, as was mine, was not so much being terminated as transformed.

24 Global Warming

I had planned today [21 May 2014] to be in North Carolina for my mother's cancer surgery, but the surgeon decided instead on ordering more tests. This may be her fourth incidence of cancer despite coming from a family where members regularly live into their 90s. One major difference: My mom smoked Marlboros for 50 years. But how does this relate to global warming?

The earliest data on the harm of smoking was a statistical correlation be- tween smoking and certain types of cancers. However, we know that just because two things are correlated doesn't mean one causes the other. I even teach that in my statistics course. And I also teach that statistics doesn't prove anything.

It only shows that something is highly unlikely to be purely random. In the case of smoking, tobacco companies used these two facts to fight for years against regulations, despite the accumulation of evidence that not twice as many people got lung cancer, not three times as many, but 11 times as many smokers got lung cancer as non-smokers. No proof there, but really, what do the odds have to be in order to act? In the meantime, thousands of people died years sooner than they would have if we had regulated smoking sooner. The profits of the tobacco companies mattered more than people's lives.

With respect to global warming, profits from oil and coal companies are being used to fund organizations, such as the Heartland Institute, to fight a political battle. They fight to maintain their short-term profits. However, for society as a whole, long-run prevention is much cheaper than remediation. For example, my mom's surgeries have cost far more than the profits a tobacco company made off her purchases. And do the years lost from her life not also have value?

Unfortunately, such short-sighted values are too common. I have shown my students a map from 1981 indicating a 4% chance in any given year of a great hurricane hitting the coast at New Orleans, a city where I lived for 15 years. The statistics weren't proof that a hurricane would hit. Lotteries and places like Las Vegas depend on you ignoring the odds. But by ignoring the odds, more than a thousand people died in New Orleans and billions of dollars were lost. Science gave us its best prediction, but we chose to value other things more.

In the past, there have been some successes in using statistics to save lives. The year after we started requiring car seats for children, car fatailities for kids aged 2-6 declined 27%. Weren't those kids lives worth more than the $80 or so it cost for a car seat? Nowadays, you'd have a Congressional fight about a $80 tax on new parents. So which of these historical decisions do we wish to be our model with respect to global warming? I come down on the side of car seats, on the side of prevention even if it costs more upfront.

25 Even Granite Falls Apart

The Rhodesian civil war had ended over five years earlier. We had a map and a borrowed Peugot 504. Nothing could go wrong.

When David and I drive into the national park, surprisingly few people are camping. The campground varies little from those back in the States—gravel roads, marked camping spaces among the trees with spots for tents, a picnic table, campfire rings, and boulders to sit on. There's even a showerhouse with hot water. David and I pitch our tent under tall evergreens old enough to have been planted by the British colonialists. The Brits started the Boy Scouts, and our tent is an old green boyscoutish thing we borrowed along with the car. Zimbabwe may now be independent, but we'll likely have a cup of tea later. Very civilized, in a British sort of way.

David and I are not great friends, but we are both young 20-somethings teaching math in Kenya, a fact that has brought us into the same orbit. And we both like to travel and see new sights, soon hiking to an overlook on a granite dome so steep and high that Cecil Rhodes called it "World's View." He chose to be buried there.

Because of its durability, granite is the preferred option for countertops and tombstones. Little Johnny may forget the cutting board when chopping his carrots, but granite is tougher than his knife. That pretty white alternative, marble, is softer. It's easier to carve and shape, but a tombstone of pure marble doesn't last like granite. It dissolves away with the rain, leaving a marker of lost significance.

That night we meet white Rhodesians in the campground. A brother and sister, faces well-worn, seem much older than us—maybe even in their 40s. They invite us to their campfire.

"You've been in Zimbabwe all your life?" I ask.

"Yes. I loved growing up here. But the last 20 years have been pretty tough," the brother replies.

"Bad times," the sister adds. "The war lasted fifteen years. Brutal."

"We formed convoys to get the kids to school. The Rhodesian military trucks had V-shaped bottoms so that landmines would blast outward instead of killing the people inside," the brother says. "Our military was among the best in the world for its size. Very creative."

He pauses.

“Still, sanctions, a cut-off of supplies from Europe... We were too outnumbered,” he adds.

“But we’re staying,” the sister says. “This is home.”

Robert Mugabe, the first and only president of the newly independent Zimbabwe, has welcomed whites to stay.

The brother picks up his guitar, the firelight upon his face, and begins singing Neil Diamond’s “Solitary Man,” the Eiseley Brothers, and pre-Graceland Paul Simon.

David and I sing along. “So far away from home, so far away from home.”

Granite is one of the most durable of rocks, made predominantly of large crystals of harder-than-steel quartz and feldspar. But the pull of the moon and the shifting of huge tectonic plates produce cracks, weak spots where warm and cold air and a little moisture enter, and the granite slowly disintegrates over billions of years. Some of the blocks of granite gradually become spheres, producing what look like the gods’ enormous marbles for some inscrutable game of chance.

On another morning in another part of Zimbabwe, David and I decide to drive around a bit, soon realizing we are low on fuel. My trusty map shows a station down a nearby road. As we draw close, no BP/Exxon/Mobil appears. Instead, we unexpectedly approach a dusty military compound. David and I heard that some tourists went missing in this area dominated by Mugabe’s 5th Army Brigade, a division trained by the North Koreans.

“Get us out of here,” I whisper to David.

But we are too late. An armed guard runs out from the gate, shouting, “Stop the car. Out.”

As I open the door, I hold the map in my hand.

“See,” I say, pointing. “There’s a gas station on the map. That’s what we were looking for.”

“Stand over there,” the guard says. Then he begins searching our car.

David and I watch nervously. We’re young and ignorant of colonial history, just out to do good—both teaching at mission schools such as the one Mugabe attended when young.

As the guard continues to rummage through the meager belongings, an officer drives up in a Peugot 504, the upper-class car of choice. He rolls down the window, and speaks to the guard in a language I don’t know. I point to the map again, holding it up toward the car, 10 feet away. Though I can't understand the officer's words, I read his expression, "Stupid tourists." He orders the guard to dismiss us, rolls up his window, and enters the gated compound.

Inside old thermostats is a sandwich of two different metals fused together, like granite's quartz and feldspar. They shrink and expand at different rates, causing the sandwich to deform and bend, touching contacts that turn on or off the heat. Inside the granite, the tiny differences are magnified by expansive time. The bonds sever, and the granite disintegrates.

Notes on Weathering:

Weathering is the natural process of altering rocks and minerals into different forms:

mechanical weathering: the breaking apart of a rock into smaller pieces through processes such as the expansion fo freezing water.

chemical weathering: the alteration of a rock through processes such as the *dissolving* of minerals, *hydrolysis* of feldspar into clays, and *oxidation* of metals, like the rusting of iron.)

biological weathering: the alteration of rocks and minerals due to the action of living organisms, including tree roots but particularly the activity of microorganisms in soil.

Think about the difference between how limestone and granite weather. Limestone is formed mainly from calcite, a mineral that dissolves (chemical weathering). *Karst*, the landscape formed when lots of limestone dissolves, is characterized by sinkholes, caves, and disappearing streams. But when granite weathers, mechanical weather separates the quartz and feldspar than form it. The quartz is tough and weathers slowly into sand. The feldspar weather chemically through hydrolysis into clays. A mixture of sand, silt, and clay forms a soil called *loam*, the kind of good soil that much of Iowa is known for.

26 Roosevelt, My Dad, and Older Students

As a geology professor, the justification I give for talking about President Franklin Roosevelt is that he was responsible for starting the Soil Conservation Service, the CCC, and other programs that reduced soil loss in the U.S. However, the real reason for discussing FDR is the honor in which he was held by my father's family. Roosevelt was the first U.S. President that I can recall hearing about when I was a child. On my father's side of the family, Roosevelt was honored more regularly than motherhood, and much more often than the local preacher. When my mother married my father, she was 19, too young at that time to register to vote. She would tease with my paternal grandfather that she was planning to register Republican. When she turned 21, she went to town to register, only to find that she was registered already—as a Democrat! The Easley family was saved from shame by my grandfather's political connections.

But what did Roosevelt do that inspired such loyalty? According to my dad, Roosevelt gave the poor hope that things were going to get better. After the Depression hit in 1929, unemployment, loss of homes, and hunger left many struggling just to survive. The Grapes of Wrath (both the book and film, but especially the book) captured the sense of loss, the injustice, the meanness of life. Through the CCC, the WPA, and such, Roosevelt's programs helped provide jobs and support for families that were barely getting by. Through the introduction of Social Security, Roosevelt pushed for reducing poverty among the elderly. Through support of unions, the working poor got a better voice to speak out against injustice. To these were added both reform of the banking system and creation of the Soil Conservation Service, making less likely the future occurrence of the devastation chronicled in The Grapes of Wrath.

In both The Grapes of Wrath and my family's history, farming is linked with the Great Depression. In the summer before the Great Depression hit, my father raised a crop of tobacco to pay for his expenses when he started high school. After working the entire summer, he sold his crop just as the Depression hit. After expenses, it brought one dollar. Tobacco was the cash crop in rural North Carolina, and during the Depression my father's family lost the farm. My grandfather began to drink, eventually dying of cirrhosis of the liver. My Uncle James, dad's oldest brother, was able to take over payments on the farm, but for decades afterward siblings, nieces, and nephews claimed that Uncle James had stolen their birthright. It apparently gave them some excuse for their own dysfunctional lives. In my father's view, the farm would have been lost completely if it weren't for Uncle James. As it was, the old family home was kept open to any of the family who needed a place to go. (My psychotic uncle lived there for nearly 50 years.) Meanwhile, Uncle James stayed home on the farm so that my dad was able to attend and graduate from high school, the first in the family.

When Dad finished high school, jobs were not to be had in rural North Carolina. He began raising tobacco. As soon as World War II began, my father left a crop of tobacco standing in the field and enlisted. He served seven years, first in the Army and then in the Army-Air Corps when it was formed. There, he learned how to work on airplanes. After World War II, he could have gone to college on the GI Bill. However, he thought that at 29 he was too old. Soon after the war, several small airlines were started. He used his aircraft-mechanic skills to land a job at Piedmont Airlines where he worked for the next 33 years. However, as early as I can remember, dad had risen in his job as high as he could go without an education. He used to tell me that the other guys moving up at work were no smarter but they had the education. He wanted me to get one. He started saving for me to go to college from the time I was born.

My first experience saving money was from earning money picking tobacco as a kid. I saved enough to pay for an old rebuilt Pinto that I drove for 13 years. Though today I seldom plant even a tomato, having worked in the tobacco fields is one of the things that ties me to my father. Another tie is a belief in the value of education. Like Dad did, I've already started a savings program for the college education of both my little girls. It's not a huge amount, but it will be a tie for them through me to their grandfather, whom they will never get to meet. Perhaps it is the tie to my father that makes me happiest to be teaching at UNO. Unlike the student body at a traditional college like Tulane, I teach where the average age of students is 27, close to Dad's age after the army. It's where most of our students work at least part time. And it's where, if my dad had chosen to go to college, he might have found more people like he was.

Notes on Resources:

For this test, we've focused on three main resources: water, energy, and soil. The combination plays a huge role in the well being of any society. And all three require proper management in order to be used sustainably. I hope that you now better understand the physical processes affecting these resources so that in the future you can help hold politicians, friends, and family accountable for better caring for them.

Part VI
A Better Future

27 A Meteorite?

"I've got a meteorite to show you," the old guy said. Probably in his early 80s, with glasses resting on hairy ears on a big head resting on a skinny neck, he'd shown up in front of my office at the university. I'm one of the few geologists in the area, and he wasn't the first to assume that I know about meteorites. Most were after affirmation that they were about to get rich. Money, not knowledge.

The old guy had a small bag, strong canvas, and from it he lifted a dark brown rock the size of a small cannonball. I took a quick look.

"I figure I can get a couple of hundred thousand dollars for it," he said.

Just then his cellphone rang, a flip-phone with big number buttons. He answered it and spoke to what seemed to be a nurse. I overheard him mention sores on his foot as I left him to his privacy. Walking into my office, I looked up some info about identifying meteorites. The old guy wandered in behind me and sat in a chair, uninvited.

"I need to take the weight off my feet," he said. He once again pulled the rock out of his bag and placed it on my desk with a thump.

I printed out a pamphlet I'd found and gave to him.

"I'm no expert on meteorites, " I told him. "But I know a bit about rocks, especially the local ones."

I paused, but the old guy didn't say anything.

"This isn't likely to be a meteorite."

He looked at me but said nothing, then glanced at the pictures in the pamphlet.

"See this layering?" I continued. "It's common in sedimentary rocks, not meteorites. This is most likely an iron concretion. The iron is deposited by water moving through the ground."

"This has as lot of iron in it," he replied. "Feel how heavy it is."

I wasn't sure if I was getting through to him, so I just sat and waited to see what he'd say next.

"I've got these problems with my feet," he continued.

I nodded.

"The sores on one won't heal up. And I have a lot of nerve pain," he said.

"Diabetes?" I guessed.

“Yeah,” he replied. “And I was born feet first. They hooked straps on both my legs and pulled for hours. Crushed the veins. Now there’s not much blood flow. You can’t even feel a pulse.”

He looked down at his legs, then at a new pair of shoes.

“I came into town today for my new diabetes shoes. The medicine for the nerve pain numbed my feet, and a year ago I broke my toe. It still gives me trouble.”

His shoes looked nice—oversized black tennis shoes with Velcro closures poking out below white socks and skinny legs, mostly covered by blue jeans.

“They are going to have to operate and put in shunts,” he continued. “The last work cost me nearly a thousand dollars. And I figure eventually they are going to have to take off my leg, maybe both of them.”

I knew Medicare only covered 80% of most bills. He was looking ahead to needing money. Thus, the meteorite.

“I was in the army for two years. Maybe the V.A. will help out with the artificial legs,” he said. “They’ve got a lot of practice with them.”

I turned toward the computer, found an email address, wrote it down, and handed it to the old guy.

“There are meteorite experts down in Iowa City,” I said. “Start by having a relative take a photo and email it to this address.”

“Some teacher found a sliver of one over in Wisconsin,” he replied. “They gave her a hundred thousand dollars to study it. I figure this one is worth twice that.”

The old guy looked as his watch.

“I eat at 11:30,” he said. “It’s past that. I thought I saw a place for food as I walked in.” His blood sugar was probably dropping.

“The dining hall is right next door,” I replied.

He looked unsure of himself.

“I’ll point you there,” I said.

I got up and walked him out. Some pastries sat on a table in the hallway, left from a morning seminar.

“Just what I need,” he said, as he snagged one and ate it in three bites.

Then we shuffled slowly up the stairs to the front door, where I pointed out the university cafeteria across the alleyway.

“It’s a buffet,” I told him. “All you can eat. Only about seven or eight dollars.”

28 Restoration: Creating Consensus

Each year, I listen to multiple talks addressing restoration while at a conference focused on the upper Mississippi River. For young presenters, restoration seems to be an almost Biblical before-the-fall concept, a Garden-of-Eden time before Europeans arrived and screwed up everything through destruction of wetlands and prairies, construction of dams, mass murder of indigenous species and peoples, and introduction of invasive species and agriculture. Seldom do they remember that the horses that Plains Indians rode are an invasive species brought by the Spanish, though they recognize the Spanish as invasive. But a long time ago, the Plains Indians were themselves an invasive species and before that, Homo sapiens radiated out of Africa to invade Europe, not a great time for Homo neanderthalensis.

All this talk of ice ages and invasive species leads to the question of whether there is a *best* time to restore things to. Mathematics seems to offer us the best objective standards upon which to base decisions, but that is an illusion. For example, Excel will perform a best fit of a line to a cloud of data points. Straightforward, eh? Anyone who has been through calculus can generate the equations, and anyone who has taken statistics can find the line, no Excel needed. But underlying the *best* in best-fit is an assumption about what *best* means. Generally, in math we mean a minimization of squared deviations—a least-squares approach. But why that? For a simple reason—it's mathematically easier to find derivatives of squared deviations than the absolute value of deviations. But *easy math* (an oxymoron to some) is no justification.

I have been unable to find any example of *best* that doesn't involve some sort of value judgement. I have a Christian-philosopher friend who argues otherwise, but ultimately, his statements shift to something based on faith. God created a world with objective truth at its foundation, providing guidelines for living that maximize human flourishing. And as best I can tell, the system holds together—if you accept the fundamentally religious foundation. (Perhaps accepting that religious foundation is why do so many conservatives love the 1950s.)

Unfortunately, I don't accept the religious foundation. I say "unfortunately" because to do so would make much that follows a lot easier. However, I see the concept of *best* as socially constructed—humans made it up. Don't get me wrong—that doesn't devalue it, as far as I'm concerned. In fact, it makes it more precious and hard fought, generating consensus, at least for a short time, about what is important to our community. And that we choose to agree to abide by a community decision about best is humbling—we as a group think better than each individual. What an accomplishment it is if we can bring together environmentalists, accountants, libertarians, public health officials, stock brokers, the Corps of Engineers, hunters and fishermen, and all the others who might care about a little piece of wetland along the Mississippi River and hammer out an agreement on the way to manage it.

Consensus-building is not *group-think,* the sort of people-pleasing behavior I spent years in therapy and self-help groups dealing with. People-pleasers struggle with conformity, loss of creativity, and helping design camels that were meant to be horses. But people-pleasing is not consensus-building. In the Quaker college where I studied, I saw that consensus isn't easy nor does it mean that we all agree. Nor is it a nimble way to make decisions and get ahead of the market. Building consensus is usually slow, sometimes tedious, and can be blocked by any individual who is unwilling to go along with the decision of the community. But going along does not mean agreeing with. It simply means a choice not to actively oppose the community's decision nor to work against it once the decision is made. For me, it took years for that Quaker lesson to sink in.

At its root, building consensus is far more respectful of all views than a top down or even each-vote-counts approach. It guarantees each person is heard, their many diverse views carefully considered, and that the decision arrived at can be supported by the entire community. In the environmental field, we're more likely to talk about *interested parties* or *competing users* than about diversity, but the concept is the same—get as many viewpoints as are available, consider as many people affected by a decision as possible, and work toward an agreement all can support. Diversity becomes a strength. And given today's political climate, we *must* get people together to calmly discuss alternatives and agree on a path forward.

Epilogue: Why I Tell Stories

> *...horrible teacher. Instead of explaining the material needed for the test, he tells stories of his geological adventures that pertain to absolutely nothing on the tests. I've heard stories about his daughters, mother, father, sister, and uncle; however, I have actually learned very little about geology.*

Reading a student review that trashes me as a teacher, such as the one above from RateYourProfessor.com, sticks with me far longer than a positive review. In fact, most teachers I know react to the negative reviews, not the positive. We argue that they are unfair, that the student is vindictive, that the students don't meet us halfway, that they are lazy, etc. But our attempts to rationalize them away at best numb a bit of the pain but do not remove the knife that has been stuck into us.

A better response is to keep the knife out of the classroom.

I've made my living as a science teacher for more than 25 years. I've supervised graduate theses and undergraduate research, published scientific articles, and given numerous presentations. But two years ago, I decided to hire a writing coach, a young adjunct with an MFA. The first thing I learned was how different the training is for a writer versus a literature professor, much less a scientist. As an undergrad, I was an English major until soon after my father died my sophomore year. I love Steinbeck, Doestoevsky, Chaucer, and Shakespeare. My younger daughter's middle name is Dora, for the madame who ran the whorehouse on Cannery Row. I love including stories as part of my courses. In fact, Niles Eldredge, a well-known paleontologist, has said,

> Our narratives—our stories—should give kids a sense of the intellectual (and sometimes derring-do!) adventures of actually doing science. If we let storytelling like this into the science curriculum, we instantly humanize science, make it relevant to the random child, and automatically make it seem more inviting, less hard. We can do this without watering down scientific rigor, with its canons of evidence that are justly the hallmark of scientific research, innovation, and progress.

Do you see a conflict? Eldredge advocates stories of "adventures of actually doing science" and my student reviewer condemns my "stories of geological adventures." Can you imagine Eldgredge in my classroom?

"I'm pleased to introduce our speaker for today, Niles Eldredge, internationally known paleontologist from the American Museum of Natural History."

"Thanks for inviting me. Geology changed my life. I started college as a Latin major but switched majors when I took my first geology course. Geology is a grand story of the Earth."

"Clearly, this won't be on the test. I think I'll get up to go to the bathroom and not come back," thinks the student.

An opportunity lost. Or perhaps Eldredge would have a great way of breaking through to the student, to make the value of stories apparent.

Eldredge's specialty is evolution, and humans have evolved as story tellers—our oral abilities seem genetic, unlike our writing abilities. Stories have survival benefit—increasing group unity, providing purpose and motivations, and giving a group a sense of identity, of being special even to the point of self-sacrifice for the good of others.

Storytelling in science is a bit trickier. Scientists tend to be skeptical of stories, wanting to see the data and make their own interpretations. To them, stories are sales-pitches, propaganda, or pure entertainment. And to students, stories are often old guys wasting time reliving their glory days. In other words, a waste of time—not on the test.

However, storytelling is not without parallels to recent emphasis in science teaching upon "doing science." The problem with spending lots of time gathering data and working through other parts of the scientific method is that students often fail to make the connections to broad concepts, similar to my students problem with storytelling. Like many Ph.D. candidates, students learn quite a bit about very little.

So what is the solution? Focused repetition with variation. The repetition takes the form of a spiral, coming back to a topic but at a higher level. Each time, we hook ideas into the previous experience and basic concepts. The form this takes when using storytelling in science is something like this:

1. Tell an abbreviated version of the story.

2. Provide students with a written version that is more complete, including key concepts and definitions.

3. Do an activity that utilizes the concepts to solve a real-world problem.

4. Have the students write their own story.

To improve my own abilities, last January, I joined with a theater professor to team-teach a course on *Storytelling in Science.* I also did a one-class test-run of the concept at a nearby seminary after Pope Francis released his encyclical on the environment. The task I gave the students was to develop a story from their own experiences about climate change that they could use in their home churches. I was blown away by their creativity. Seminary students. Writing stories about their personal experiences with climate change. Wow.

Appendix A: Review Questions

Review Questions for Test 1

Note: Some of the answers to these review questions are in this book, but some require that you take decent notes during class presentations, and some will become clearer through the lab exercises.

1. What is the password for pdf files on the class website?
2. Why study science? Why study geology? How is geology more than the study of rocks?
3. What is the scientific method? Explain the steps in your own words.
4. What makes a prediction scientific or not?
5. What is uniformitarianism? How is it different from catastrophism? Use each to interpret the cause of a natural disaster.
6. What is the difference between absolute and relative age dating? Give examples of each.
7. How does the thickness of the continents compare to the thickness of the ocean bottoms? the composition?
8. Be able to sketch the rock cycle.
9. Why do we think the Mediterranean Sea was once a desert?
10. What are some principles for relative dating? Be able to use them to determine relative age of layers of rocks.
11. What is an isotope? What is radioisotopic decay? What is it used for?
12. What parts of continents are the oldest? Where nearby can some of these rocks be found? Why are they at the land surface?
13. How can oxygen isotopes be used to estimate past water temperatures? Explain. What is the purpose of the isotope dance demonstration?
14. What age rocks is Dubuque built upon? What resources were found in these rocks? How did they originally form? What age rocks are under the Dubuque airport?

15. Review the history of Dubuque.
16. Why are rocks of Mesozoic age largely missing from Iowa?
17. What is the history of glaciation in Iowa and Dubuque? What were several effects?
18. What is the Driftless Zone?
19. Why are there so many lakes in Minnesota?
20. How can you tell if a sediment has been transported by ice or water?
21. Give two geologic reasons why Des Moines and Dubuque look so different.
22. What are several of today's environmental challenges in Iowa? How have we sought to reduce those impacts?
23. Explain the impact of excess nutrients upon water quality. What are sources of these nutrients?
24. What are major influences on Iowa's weather?
25. What is the difference between a rock and a mineral?
26. How are elements in a mineral bonded together? Know the four ways.
27. What is the difference between felsic and mafic silicate minerals?
28. Be able to identify the properties of calcite, quartz, mica, copper, galena, halite and diamond.
29. What are some common minerals that are not silicates? Why is each important?
30. What are evaporites? Name two.
31. How does the density and melting points of mafic and felsic minerals influence where they are found (on continents versus ocean lithosphere).?
32. What is a hydrogen bond? Why does it matter? How is it different from the four main types of bonds in silicate minerals?

33. What evidence supports the hypothesis that the dinosaurs were destroyed by a meteorite impact in the Yucatan, Mexico.
34. Where do the oldest rocks in Iowa appear at the surface? What is their pattern beneath the surface?
35. Be able to determine the relative age of layers of rock, such as we did in lab.
36. How did Siccar point play a role in the development of uniformitarianism?
37. How fast do tectonic plates move? What are some ways in which we determine their rate?
38. How is the evolution of antibiotic-resistant bacteria speeded by the inappropriate use of antibiotics?

Thought questions

1. How does geology connect to the natural features of the Dubuque area?
2. How does geologic history connect to agriculture in Iowa?
3. How does geology connect to current environmental issues in Iowa?
4. How does geologic history affect the making of underwear in North Carolina?

Review Questions for Test 2

1. Be able to sketch plate interactions for convergence, divergence, and transform boundaries. You should be able to do six sketches. Know example locations for each (e.g., Andes).

2. Who was Alfred Wegener? Who was Harry Hess? How do each relate to the establishment of plate tectonics? Be able to explain the patterns each saw.

3. Be familiar with the essay about Lake Nyos. What is the impact of dissolved gases upon eruptions?

4. What are three indicators that a volcano is soon to erupt? Think of other natural hazards for which there are indications prior to their occurrence (precursor events).

5. What are the the three tectonic locations at which most volcanoes occur? What is a pillow basalt?

6. Describe the main events of the eruption of Mt. St. Helens.

7. Be able to compare the hot spot at Yellowstone with the Hawaiian hot spot.

8. Be able to distinguish texture from composition in igneous rocks. What are the main six types we examined in lab?

9. What is the impact of cooling rate upon texture?

10. What are the plate tectonic settings where each of the rock types is found?

11. What are obsidian and pumice?

12. Why hasn't the Earth already cooled off?

13. Be able to explain a phase diagram of temperature and pressure.

14. What are Mt. Kenya and Ship Rock?

15. What is the origin of the Gulf of Mexico? How did the origin of the Gulf influence the location of the Mississippi River? the New Madrid Fault Zone?

16. What is the origin of the Louanne Salt? Why is it important to the oil industry?

17. What is the history of the Mississippi Delta? (changing of location, etc.)
18. Explain what happened at Old River. (Shreve's cutoff, the Control Structure, the 1973 flood, etc.)
19. What are the main feature of the continental margin and the ocean bottom? How do we know?
20. What is a black smoker?
21. What is an atoll? How does it form?
22. How are active and passive margins different?
23. How do the east and west coasts of the U.S. differ from each other and from north to south?
24. What are five different types of data that supports plate tectonics?
25. What are four processes that form mountains?
26. Be able to identify the world's major mountain ranges from a world map and discuss how each range formed.
27. Be able to connect the rocks (igneous, metamorphic, and sedimentary) and processes of the rock cycle to the tectonics which helped form them.
28. What is the relationship between mountain building, plate tectonics, and the rock cycle?
29. Be able to look at a rock and predict the tectonic setting in which it formed.

Thought questions

1. How does geology connect to your favorite vacation spot?
2. How does geology connect to the features of your favorite park?
3. How does geology connect to jazz?

Review Questions for Test 3

1. What is the definition of risk, including its two components? What are the two main approaches to estimating probabilities of hazardous events? Apply the concept to auto insurance, earthquakes, floods, and other natural hazards.

2. What lessons can past earthquakes provide us for improving future success in surviving them?

3. What are the three approaches to risk analysis that we discussed in class? Apply them to a decision.

4. How do earthquakes transmit energy? How does this allow us to determine the epicenter? What scales are used to quantify earthquakes?

5. What is the relationship between plate tectonics and the location of earthquakes and volcanoes?

6. Why are earthquakes at subduction zones likely to cause tsunamis? How does their depth compare to earthquakes at other locations?

7. What is viscosity? How are mafic and felsic magmas related to temperature, viscosity, and explosivity?

8. What are the different types of volcano landforms (shield, etc.)? How do they compare in shape and size? What are their hazards?

9. What are fissure eruptions?

10. What is a collapse caldera?

11. What are precursor events?

12. How can we reduce risk from volcanic eruptions and tsunamis?

13. What is the difference between scientific prediction and an ethical decision?

14. What is beach nourishment?

15. What is a shoreline? How does it move? Why?

16. What is relative sea level? How does it differ from absolute sea level? What causes changes in absolute sea level?

17. What are the differences between waves and tides?
18. What are coastal wetlands? What is an estuary?
19. How does a wave travel and break?
20. Explain wave refraction and longshore drift.
21. Who was Oetzi? What did we learn from him?
22. How has global climate changed throughout geologic history?
23. What causes ice ages? What are some effects?
24. What are the two main types of glaciers? How do they move?
25. What evidence currently exists of past glaciation?
26. The area encompassing much of Nevada has interior drainage. What does that mean?
27. What is a drainage divide? What is a drainage basin?
28. What are the major drainage patterns? How are they influenced by the underlying geology? (See lab notes.)
29. How does a stream change as it goes towards its mouth in terms of discharge, velocity, sediment load, channel morphology, and sediment size?
30. How are meandering and braided streams different? Where are you likely to find a braided stream?
31. What are three ways a stream transports sediment?
32. What is runoff and base flow?
33. What is urbanization? What are its effects upon flooding and base flow?
34. What is a delta?
35. What commonly causes floods? What caused the 1993 Mississippi River flood?

Questions for Fatal Flood

1. What part of the country is the focus of the video?
2. What was the history of the Percy family with respect to government and the Klan?
3. What is sharecropping? How was it often abused?
4. How were blacks and whites treated differently during the flood?
5. What was Will Percy's solution? How was he undermined by his father? What did Will then decide to do?
6. What was the effect on internal migration? on national politics?

Thought questions

1. Why have many early civilizations developed on deltas?
2. How does geology connect to the types of drainage patterns that develop?
3. How does geologic history connect to risk from natural hazards? Think of three hazards.
4. How does geology connect to Herbert Hoover being elected President

Review Questions for Test 4

1. Sketch the hydrologic cycle, labelling each part and indicating with arrows the direction of movement.
2. Who are competing users for the water in the reservoir behind a dam? How are they affected seasonally?
3. Where is most of the world's water? How is it used?
4. Be able to sketch a confined aquifer (Bighorn Basin) and unconfined aquifer (Walnut Cove, NC).
5. What is the difference between porosity and permeability?
6. Be able to calculate a groundwater gradient, determining flow direction. Use Darcy's Law to calculate velocity.
7. How do springs form?
8. How do caves form? What is karst?
9. What is subsidence? What causes it? What is a sinkhole?
10. What are three reasons oil prices are at their current level?
11. What happened at Lake Peigneur?
12. Explain the process by which petroleum forms.
13. Explain the process by which coal forms.
14. Where does the U.S. get much of its oil? Why?
15. What is the difference between renewable and non-renewable energy? Provide examples of each.
16. What is the link between the OPEC oil embargo and third-world debt?
17. Provide examples of events in the Middle East that have affected oil prices.
18. What was the Overland Trail?
19. What was the Great American Desert? What turned it into part of the breadbasket of the world?
20. How do deserts form? Know the five ways. Be able to sketch a rain- shadow desert.

21. What is the greenhouse effect? Be able to sketch it. What role does carbon dioxide play?

22. What is the urban heat island effect?

23. What are the main current issues with respect to global warming? Give three examples of relevant data.

24. How has atmospheric carbon dioxide varied since the industrial revolution?

25. What are the differences between mechanical and chemical weathering? biological?

26. What are the main processes in soil formation? Be able to sketch a typical soil profile in a humid climate. How would it be different in a desert or rainforest environment?

27. What are the differences between the weathering of granite and limestone? How do the resulting soils differ?

28. How have we attempted to overcome soil erosion from water and wind?

29. How did the extermination of Haiti's pigs relate to deforestation and soil loss?

30. What was the Dust Bowl?

Thought questions

1. How does energy policy relate to the growth of terrorism?

2. How does energy policy relate to the fall of the U.S.S.R.?

3. How does energy policy relate to global climate change?

4. If you had a few extra dollars, how could you best use them to make the world a better place?

5. What is the relationship between natural resources and population growth? What are the two most effective ways to slow human population growth?

Appendix B: Example Tests

Example Test 1

Note: On the actual test, I provide space for each answer. The printed test is four pages long.

Instructions: The first 12 questions refer to the slides we will view together in class. The 13th slide is a reference to help you with the test. Please use the space provided to answer the questions.

1. **4 pts** What is the difference between catastrophism and uniformitarianism? Use each approach to explain the earthquake damage shown.

2. **3 pts** How is the figure shown related to the history of Dubuque? Give three examples.

3. **4 pts** Why does Minnesota have so many lakes? Explain three results of the process that formed them.

4. **4 pts** Dubuque is on the edge of the white area at the center of the figure shown. What are two effects of what is represented?

5. **2 pts** Were the rocks shown likely transported by water or ice? Why?

6. **3 pts** What are three ways in the figure shown that the farmer has attempted to reduce erosion? Explain.

7. **4 pts** What are the four ways elements bond to form minerals? **Extra credit:** Name a mineral with each type of bond.

8. **4 pts** Explain the process you would go through to attempt to determine if the mineral shown is a) quartz, b) calcite c) gypsum, or d) halite. Do not simply say which one you think it is. Say how you would check properties to determine which mineral is shown.

9. **4 pts** What is the process shown? What are three other characteristics of water that result from hydrogen bonds?

10. **3 pts** How do felsic and mafic rocks differ in (a) melting point, (b) density, and (c) color?

11. **4 pts** James Hutton spent hours observing and drawing the rocks shown. What are two features he noticed that helped him develop the theory of uniformitarianism? Explain.

12. **4 pts** Thought question: How does geology relate to the making of underwear in North Carolina? (Include at least 3 steps.) Why have most textile mills now left that area?

13. **6 pts** Briefly summarize three stories from this section and explain their relevance to geology. (For credit, you must provide at least two sentences per story.)

14. **3 pts** What makes a prediction scientific or not? Give an example.

15. **3 pts** What is the difference between relative and absolute dating? Explain in terms of a brother or sister.

16. **3 pts** What is radioisotopic decay? What is it used for?

17. **3 pts** Explain the phrase, "Resistant rocks stand high in relief." Why do waterfalls occur?

18. **4 pts** Pick one environmental issue Iowa faces, either discussed in this class or in the news. Why is it an issue? What is or can be done about it?

19. **3 pts** What are evaporites? Name two.

20. **3 pts** Thought question: How does geologic history connect to agriculture in Iowa? Show the connection through at least three steps.

21. **3 pts** Phosphorus is a nutrient essential for growth but can be a problem when it pollutes our waterways. Explain why Iowa faces a problem with nutrient pollution. Why does it matter?

22. **2 pts** Water contains hydrogen and oxygen. Oxygen has two isotopes, one heavier than the other. How does this affect evaporation? How can we take advantage of this to determine past conditions? (Think of the isotope dance.)

23. **4 pts** What is the difference between a rock and a mineral? What are three properties of a mineral?

24. **9 pts** Sketch and label the rock cycle, including the processes that form the rocks.

25. **6 pts** What are three things that contribute most to you doing well in this course? What are three things that do not contribute or get in the way of your success? (Don't just put an answer and it's opposite for the two, such as *studying, not studying*. That's worth only one point, not two.)

26. **5 pts** What was one review question not used on the test that you prepared for? Answer it.

Example Test 2

Instructions: The first 13 questions refer to the slides we will view together in class. Please use the space provided to answer the questions.

1. **(6 pts)** Complete the igneous chart shown with the corresponding rock name.
2. **(10 pts)** Identify five types of evidence for plate tectonics. Explain briefly how each supports plate tectonics.
3. **(3 pts)** Each of the circled mountain ranges formed in a different way. Explain each.
4. **(6 pts)** a) What are the three tectonic locations at which most volcanoes are found? b) What are three precursor events that indicate a volcano may soon erupt?
5. **(2 pts)** On the figure shown are three variables—temperature, pressure and wet/dry status. Explain how to interpret this diagram at point E and how that is relevant at subduction zones.
6. **(2 pts)** a) What is the origin of the salt shown? b) How does that salt influence the accumulation of oil in the Gulf of Mexico?
7. **(2 pts)** How does the feature shown relate to the opening of the Gulf of Mexico?
8. **(3 pts)** How does the east coast differ geologically from the west coast? Explain. What is the main factor causing coastlines to differ from north to south?
9. **(2 pts)** How does the feature shown form?
10. **(2 pts)** How does the feature shown form?
11. **(2 pts)** How does the feature shown form?
12. **(7 pts)** Harry Hess and Alfred Wegner each contributed key ideas that led to plate tectonic theory. a) Explain Wegner's key idea and what led to it. Why was it rejected initially? b) Explain Hess's two key ideas and what led to each.

13. **(6 pts)** Describe briefly three of the videos or stories from this section. To receive full credit, you must link them to geology.

14. **(4 pts)** We've discussed two prominent examples of hotspots in the U.S.A. Tell how they are similar and how they are different.

15. **(8 pts)** Based on the chart in question 1, what type of rock is likely to form

    (a) at an eruption at a mid-oceanic spreading center: __________

    (b) deep beneath the ocean bottom: __________

    (c) at an eruption at Yellowstone: __________

    (d) deep inside a continent: __________

    (e) at an eruption at the Andes: __________

    (f) at an eruption in Hawaii: __________

    (g) deep beneath the Andes: __________

    (h) at an eruption at Mt. St. Helens: __________

16. **(1 pt)** The Earth is 4.6 billion years old. Why hasn't it already cooled off?

17. **(2 pts)** Where are the youngest mountains currently growing in the contiguous U.S.A.? Where are the oldest rocks at the surface?

18. **(6 pts)** Sketch and label an oceanic-continental plate collision.

19. **(2 pts)** What is the impact of cooling rate upon texture (crystal size) of igneous rocks? Explain in terms of the table from Question 1.

20. **(12 pts)** Give an example of a plate tectonic setting at which each of the following rock types would form. Explain the process enough to show you understand it. For each, give a specific location, such as an National Park or mountain range, where you might encounter these rocks.

(a) igneous:

(b) sedimentary:

(c) metamorphic:

21. **(4 pts)** What is the connection between geology and jazz? (1 point for each item.)

22. **(3 pts)** Think of one of your favorite natural areas for vacationing or getting away. How does geology relate to its features? (1 point for each item.)

23. **(5 pts)** Think of one of the review questions that you prepared for this test that has not been asked. Answer it here.

Example Test 3

Instructions: The first 21 questions refer to the slides we will view together in class. Please use the space provided to answer the questions.

1. **(3 pts)** (a) What is risk? Give the definition we've been using in class. (b) How does the figure shown relate to that definition?

2. **(4 pts)** What are two ways of determining the probability of a hazardous event? Explain each with an example of its use.

3. **(6 pts)** We discussed three ways of making ethical decisions about reducing risk, such as in deciding whether or not to require car seats for children. On an recent field trip to New Mexico with students, we went white-water rafting. For each of the three ways discussed in class, explain how you would decide whether wearing life-jackets while white-water rafting should be required.

4. **(4 pts)** a) in the figure shown, identify the two points marked in red and yellow. b) Explain two differences between P and S waves.

5. **(2 pts)** How does the speed at which P and S waves travel relate to the size of the three circles shown. What are the circles used for?

6. **(6 pts)** In the figure shown, the red areas indicate deep earthquakes, green are intermediate depth, and yellow are shallow. Explain the pattern for each using your understanding of plate tectonics. For (C), explain how an earthquake may lead to a tsunami. (A drawing is fine.)

7. **(4 pts)** What is viscosity? How does it related to the difference between mafic and felsic magma? What kind of volcanic landform is the lava shown likely to produce? Why?

8. **(4 pts)** a) In what geologic setting is the type of volcanic landform shown likely to be found? Explain how it forms. b) Describe two ways of predicting the eruption of a volcano.

9. **(2 pts)** In what geologic setting is the type of volcanic landform shown likely to be found? Explain how it forms. (Think *Yellowstone.*)

10. **(3 pts)** What is the difference between relative and absolute sea level? How do you interpret the feature shown?

11. **(4 pts)** Lake Pontchartrain, shown in the figure, is an estuary. What is an estuary? Why are estuaries particularly rich biologically? Explain, not just with one-word answers.

12. **(3 pts)** What is the process shown? Why is it important for understanding how beaches change over time?

13. **(7 pts)** (a) What are the three most important factors causing ice ages? (b) What are the two main kinds of glaciers? (c) What are two types of evidence of past glaciation?

14. **(3 pts)** What is the stream pattern shown? What are two ways in which the stream shown might form?

15. **(3 pts)** What is a drainage divide? What is a drainage basin? (Explain both in terms of the figure.) Explain the purple area labelled *Interior Drainage.*

16. **(3 pts)** What is a delta? Think of two reasons why many early great civilizations developed on deltas (Nile, Mesopotamia, etc.). Explain.

17. **(3 pts)** What were three factors contributing to the 1993 Mississippi River flood?

18. **(3 pts)** What are three ways sediment is transported by streams, two of which are shown? Explain each.

19. **(5 pts)** Describe five ways a stream changes from headwaters to mouth in terms of discharge, velocity, sediment load, channel shape, or sediment size.

20. **(5 pts)** What is urbanization? In the figure shown, which discharge curve, A or B, represents the stream after urbanization? What are three ways urbanization affects flooding?

21. **(6 pts)** What are three videos or stories that were part of this section? Explain how each relates to geology. You need to provide at least **two sentences** per example. **Extra credit:** Name and explain a 4th story.

22. **(3 pts)** What is beach nourishment? (And don't put shrimp or a Corona!) What are a benefit and a potential problem?

23. **(2 pts)** What is the difference between tides and waves?

24. **(3 pts)** If you were in charge of protecting people from an earthquake, what would be your plan? Include at least 3 parts.

25. **(4 pts)** (a) What is a sharecropper? (b) How was the sharecropping system often abused? (c) Most sharecroppers were African-American. How were they treated differently from whites during the flood? (d) What happened to many of the sharecroppers after the 1927 flood was over?

26. **(5 pts)** What is one question you reviewed for this test that did not appear on it? Answer it.

Example Test 4

Instructions: The first 12 questions refer to the slides we will view together in class. Please use the space provided to answer the questions.

1. (**3 pts**) a) In the figure shown, what is the top of the blue layer indicated by A? Explain what it is and why it's important.
2. (**4 pts**) What is a) porosity and b) permeability?
3. (**3 pts**) What is the relationship between the figure shown and the *Great American Desert*? How was the desert transformed into part of the *Bread Basket of the World*? Explain.
4. (**3 pts**) What is a spring? What makes some springs hot?
5. (**2 pts**) Why do most of the world's caves form in limestone? Explain how they form. **Extra credit:** Name two of the cave formations shown.
6. (**4 pts**) What is karst? What are two common features?
7. (**6 pts**) This morning gas prices for the cheapest grade were \$2.59 at the station near my house. In the fall of 2013, the price was \$3.54. In September, 2012, the average price nationally was \$3.85. In the fall of 2014, the price dropped to \$1.49. What are three factors affecting oil prices? Explain each, giving specific examples.
8. (**4 pts**) Shown is a figure about the greenhouse effect and three important gases that cause this effect. Explain the process sufficiently to show you understand it. Then explain how at least one of the gases has been increased in the atmosphere by human activity.
9. (**4 pts**) Shown is a graph of global temperatures since the late 1850s. Politicians argue about the role of humans in the increase shown. Give one argument for each side.
10. (**3 pts**) Shown are three deserts, marked A, B, and C. Explain how each formed. **Extra credit:** Name deserts A and C.
11. (**7 pts**) Shown is a marker for the Overland Trail in southern Wyoming. a) What are two things you notice about the ground surface? is a typical soil profile. b) Why does Iowa

have such good soil? Give three reasons. How is the organic layer different in c) a desert and c) a rainforest.

12. (**6 pts**) Pick any three videos or stories and explain how they relate to geology, using at least two sentences each.

13. (**6 pts**) We've discussed three resources in this section. Name each and given an example of its importance. Be specific.

14. (**6 pts**) What is the difference between renewable and non-renewable energy sources? Give two examples of each.

15. (**4 pts**) Explain how both coal and petroleum form, giving three similarities and one difference.

16. (**4 pts**) What are two major factors in determining where we get our oil? Provide an example of each.

17. (**2 pts**) What is subsidence? What causes it?

18. (**8 pts**) Pick an issue related to your own career that is impacted by multiple competing users, such as the example we used in class of managing water behind a dam. Name four sets of those competing users. How would each want the issue dealt with?

19. (**5 pts**) Sketch a confined aquifer, such as the Bighorn Basin, labelling the recharge and discharge areas, confining layer, and direction of flow.

20. (**6 pts**) Sketch an unconfined aquifer, such as at my home in Walnut Cove, NC, labelling the recharge and discharge areas, water table, probable spring location, and direction of flow.

21. (**5 pts**) What are three ways you think this course could be improved? What were two things to continue doing?

22. (**5 pts**) What was a review question that you prepared for but was not asked. Answer it.