From Popcorn to GIS: My Adventures in Using Visualizations for Geoscience

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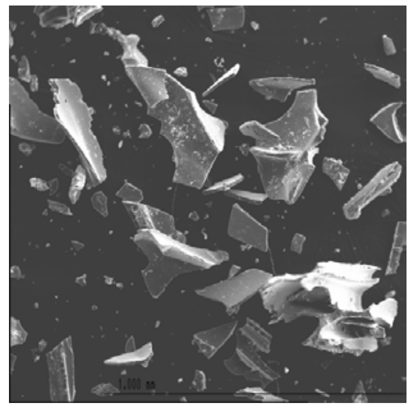
Geology is a visual science. Visualizations are essential to understanding geoscience concepts and communicating concepts to others. They capture students' attention and get the creative juices flowing. At every stage of my career, visualizations have played an important role.

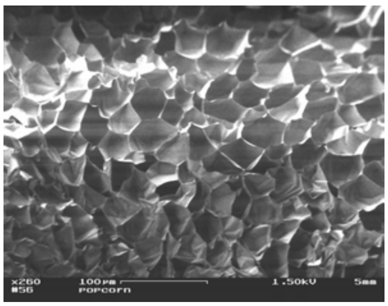


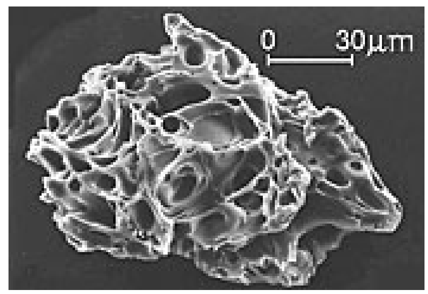
I started thinking about ways to use visualizations when I was in graduate school. At the time, I was studying volcanic ash particles using a scanning electron microscope (see image at right), and using remote sensing imagery and computer modeling to study volcanic plumes. I was bored by the lectures in college classes and wanted to pep up the classes I taught. I wanted to move from abstract concepts to something more tangible. At this time, I also started giving geoscience talks to local schools and realized the importance of visual examples (props, demonstrations, imagery, computer animations) to communicate complex science topics to K-12 students. The visualizations (defined in the broadest sense) were simple: remote sensing images of volcanic plumes, video clips of volcanic mudflows, wooden blocks on long metal rods to show earthquake frequency, fritos to show how ash particles fall.

One of these primitive visualizations demonstrated the movement of lava flows and mudflows. Students often think lava flows move fast and are the most dangerous volcanic hazard, and few students can imagine a mudflow. Karo syrup (representing lava) traveling down a tilted board, quickly demonstrates that lava flows don't move as fast as most students would imagine. A race between the karo syrup (lava) and a dirt-water mixture reminiscent of a mudflow, shows students that mudflows move swiftly down the flanks of a volcano and travel much farther. Students easily draw the conclusion that mudflows are the more dangerous volcanic hazards. This example showed me how important visual representations are to learning and that even primitive visualizations can be effective. I also came to realize how developing visualizations for students helped me think out of the box and be more creative with my own research. On a trip to El Salvador, I used the same lava flow/mudflow demonstration in K-12 classes. Gasps from the students as they witnessed the mudflow, showed understanding and how visualizations can even overcome language barriers.

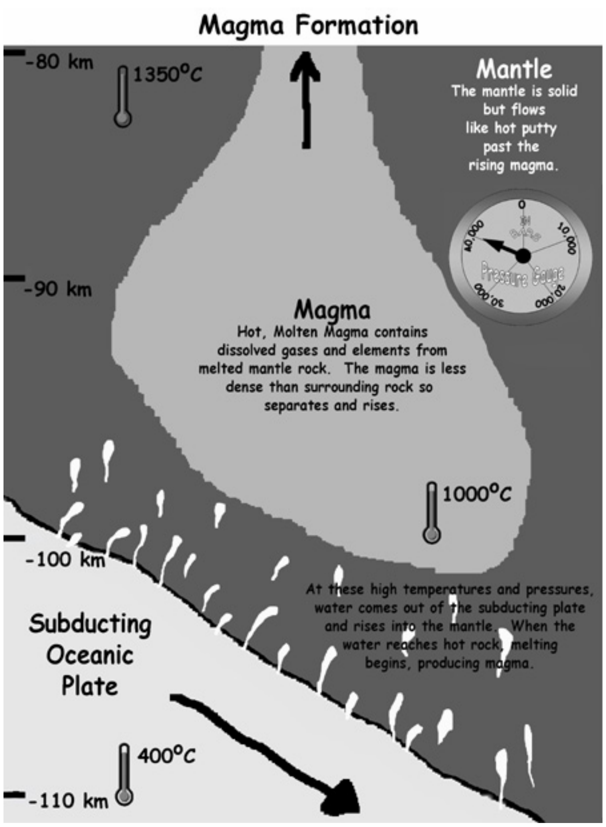
While in El Salvador, I asked K-12 students to tell me the names of volcanoes in their country. Consistently, students would not include volcanic lakes, and when we tried to tell them that they were volcanoes, our explanations were met with disbelief. Again, visualizations were required to demonstrate this important concept. We used a red water balloon to represent the magma under a volcano. The balloon was buried under a pile of sand (the volcano). Then we popped the balloon and watched what happened as the "magma" erupted from the volcano. Concentric cracks developed around the volcano's summit as the magma was extruded and eventually the summit collapsed to form a crater. I synthesized rainstorms to fill the crater with water, and student disbelief was washed away. This experience showed me how important visualizations can be in convincing populations about the reality of volcanic hazards. No amount of words could communicate what this demonstration did in only 5 minutes.

These experiences served me well when I started writing volcanic hazards curriculum for the US Geological Survey's Cascade Volcano Observatory and Mount Rainier National Park. Some of the challenges we faced were getting middle school and high school students to understand how gas bubble expansion in magma leads to an eruption, and how magma travels from the subducted plate to the earth's surface. We popped corn to illustrate gas bubble formation, and used SEM photos of the popped corn to show the microscopic holes made when the corn popped (students compare these features to gas bubble holes in pumice).



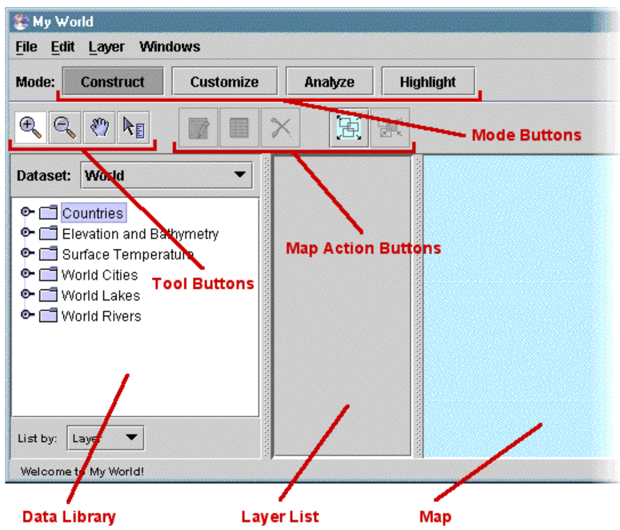


Scanning Electron Microscope images of gas bubbles in popped corn (left) and gas bubbles in volcanic ash (right).



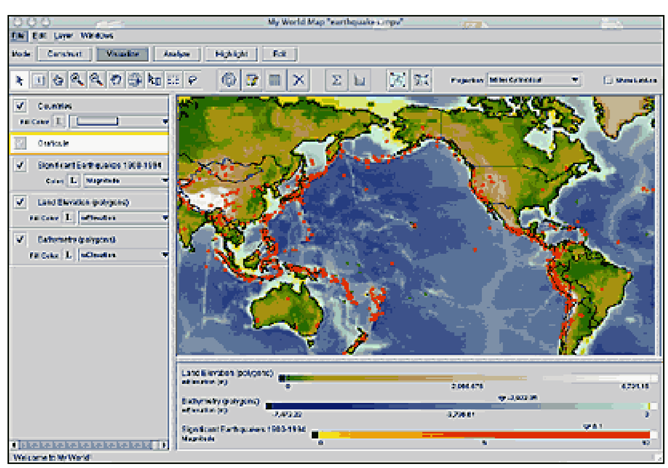
How magma travels to the earth's surface was the hardest concept to demonstrate. By working with educators, we realized how important it was to make this abstract process real by relating it to things the students were familiar with. *How hot would it be at 500 km below the earth? What is the texture of magma like at that depth? (oatmeal-like) How many cars would you have to stack on top of each other to equal the pressure felt at this location?* We developed a series of cartoons to show the process, annotated the cartoons with fun facts, and wrote a teacher narrative to go with the cartoons. I found that my own understanding of this geological process was enriched as I was forced to describe the process in lay-person's or familiar terms.

As a post-doc researcher, I've been exposed to a whole new set of visualization tools, as well as, a new way of teaching geoscience concepts using inquiry. Prior to my coming to Northwestern, a Geographic Information System (GIS) called *My World*, was developed by Danny Edelson, Eric Russell, and others. This system was designed to be more user-friendly (less complicated) than professional GIS programs, so that middle school to entry-level college students could use it easily. Lessons learned from developing other visualization tools (like *World Watcher*) guided the design of *My World*. Edelson and others designed *My World* to be practical, compatible with school infrastructure, and easy to install. The options in *My World* are segmented into user modes, and queries are structured to help users easily understand the functions in the program. Edelson and others sought to build a GIS that could be used as a tool in science investigations, but not be so complicated that the tool becomes the learning focus. Gridded and vector data can be imported and displayed using *My World*. The software was written in Java and runs on Mac's, PC's, and Linux computers. Currently the software is licensed to a commercial publisher (PASCO: http://www.pasco.com/myworld)



My World is an excellent visualization tool. The software allows students to explore and analyze data at different resolutions. The software helps students plot large amounts of data that would otherwise take too long for students to plot on their own. Students can use the software to view the world in different ways using various map projections. Databases allow students to analyze data rather than get bogged down in formatting and processing data. The software makes it easy to compare data sets spatially or by data attribute. Darlene Slusher (an atmospheric chemist and post-doc at NU) and I are currently developing curriculum that uses *My World* GIS. Lessons are designed to demonstrate the power of GIS as a visualization tool versus the more conventional paper maps or spreadsheets used in many classrooms.

The major objective of the curriculum is to allow students to do science investigations using real data with a tool commonly used by scientists. The lessons are designed to expose students to nature of science processes—developing hypotheses, selecting data, analyzing data, evaluating data quality, putting limitations on data, using evidence to support conclusions, debating ideas using evidence, thinking critically, and dealing with open-ended questions. The lessons are inquiry-based and follow the "Learning for Use"



design structure of: motivate, construct, refine. Student motivation is accomplished by asking an interesting driving question. The question is designed to elicit curiosity. In addition, lessons sometimes include a narrative that sets up an interesting problem or causes the student to realize he/she lacks knowledge in an important area (elicit demand). The lessons are designed so that students construct knowledge as they use the *My World* software. It is assumed that students haven't used *My World* before, so detailed instructions are given for unfamiliar operations as the student works through the lesson. Lessons contain supports for guided inquiry. In places where an understanding of specific science concepts are needed to progress further with the lesson, definitions, a short paragraph, or a student reading is included. Students are asked to analyze data displayed in *My World* or use the software to manipulate data with the expectation of solving a problem related to the driving question. Students refine their knowledge by interpreting the data and applying what they've learned to answer the driving question.

Six lessons were written to cover a broad range of disciplines including: environmental science, geography, and earth science. These lessons are described in more detail on the poster, along with current and future research plans, problems encountered during lesson development, and database descriptions. While developing these lessons, the following questions arose:

- How can we format data faster and easier?
- How do we keep databases up to date?
- How should we test the software in classes?

References:

Edelson, D. C. (2001). *Learning-For-Use: A Framework for the Design of Technology-Supported Inquiry Activities*. Journal of Research in Science Teaching, 38 (3), 355-385.

Edelson, DC, Gordin, D.N., & Pea, R.D. (1999). *Addressing the challenges of inquiry-based learning through technology and curriculum design.* Journal of the Learning Sciences, 8(3/4) 391-450.

Edelson, D.C., & Gordin, D.N. (1998). *Visualization for learners: A framework for adapting scientists' tools.* Computers and Geosciences, *24* (7), 607–616.

Links:

USGS Cascade Volcano Observatory Education Outreach
http://vulcan.wr.usgs.gov/Outreach

Download World Watcher at:
http://www.worldwatcher.nwu.edu/software.htm

To learn more about My World and download a trial version:
http://www.worldwatcher.nwu.edu/myworld