Fourth Grade Students Investigate Stratigraphy through Experiments and Photographs of Snow Layers

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ABSTRACT

This article describes a project in which fourth graders investigated principles of stratigraphy by creating colored sand layers in a clear-sided container and observing photographs of cross sections of snow layers and rock outcrops along roadsides. Students used the National Science Education Standards unifying concept of "evidence, models, and explanations" to investigate stratigraphic principles of original horizontality, superposition, and crosscutting relationships. A pretest/posttest evaluation of the lessons showed that students learned basic concepts of stratigraphy.

INTRODUCTION

Childhood activities can affect a student's decision to study science (Edgett, 1998; Rule, 2001). Filling small bottles with layers of colored salt-sand was a favorite pastime for children in my neighborhood during the 1960's. We made the "sand" by spreading a newspaper page on the sidewalk, dumping a small mound of salt on the newspaper, then rubbing it with the broad edge of a piece of colored chalk, storing each batch in a jar. Friends paid for a bottle of salt with a penny or safety pin, specifying each layer, color by color, until the container was full. Because this was one of the memorable childhood activities that lead to my becoming a geologist, we decided to incorporate a similar activity in the stratigraphy investigation we describe here for elementary students.

So many things in the natural world (lava flows, soils, lake sediments, snow banks) and designed world (cakes, sandwiches, roadbeds, house walls, bed coverings, winter or sports clothing) exhibit layers. Many scientists (paleontologists, vulcanologists, archaeologists, among others) interpret the relationships between layers to help in professional problem solving. Stratigraphy, the study of the order and relative positions of strata, depends upon these principles: the *Principle of Original Horizontality*, which states that because of gravity, sediments are deposited in horizontal beds; and the *Principle of Superposition*, that states in a sequence of horizontal layers, those near the bottom are older than top layers.

In this article, we describe how fourth graders in New York State explored stratigraphy concepts with colored sand layers and photographs of multi-storm snow banks. Oswego County on the shore of Lake Ontario regularly receives large snowfalls each winter because of the great lake's effect. During the winter of 2003-2004, the city of Oswego received over five meters of snow in a series of storms and almost-nightly snowfalls. After each storm, trucks sprinkled gravel, sand, clay and salt on the roads, which was added to the snow banks by snowplows. As snow banks towered two or three meters high, the city used a large snowblower to slice and trim them to widen the road surfaces. The resulting flat faces of these snow banks provided an interesting record of the different snowstorms, sanding/plowing events and homeowner shoveling attempts. We decided to use snow bank photographs to present stratigraphic concepts to our fourth graders as this provided a strong link to familiar real-world experiences.

Standards Applied to Snow Bank Stratigraphy - *The Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) under chapter 4, The Physical Setting, Part C, Processes that Shape the Earth, state, "By the end of the 5th grade, students should know that waves, wind, water, and ice shape and reshape the earth's land surface by eroding rock and soil in some areas and depositing them in other areas, sometimes in seasonal layers." In this investigation of the stratigraphy of seasonally deposited snow banks, students learn how to interpret the relative ages of layers of snow with crosscutting relationships and make connections to other sedimentary strata. Also, the New York State Science Curriculum Standards (the state in which this study took place), under Standard 4 of Science for Elementary Grades, the Physical Setting Standard 2 (University of the State of New York State Education Department, 2003) states, "students should be able to describe the relationships among air, water, and land on Earth." Unraveling the sequence of depositional and erosional events in a sedimentary section supports this curriculum standard. Additionally, the National Science Education Standards' unifying concepts and processes standard suggests focusing on evidence, models, and explanations to approach science topics. As students examined photographs of snow banks, they searched for evidence of different storms, plowing events, and snow removal events through melting, sublimation, or shoveling. They also modeled snow or sediment accumulation by sprinkling layers of colored sand into a transparent plastic cup and by investigating the resulting geometries when parts of layers are removed and additional sand was sprinkled on top.

In the following sections, we review the literature on teaching about stratigraphy, present our lesson activities with teacher observations, and evaluate this endeavor with pretest/posttest results and teacher/student reactions to the lessons.

STRATIGRAPHY LESSON LITERATURE

Stratigraphy concepts can be taught in creative, concrete ways. Francek and Winstanley (2004) categorized stratigraphy lesson ideas involving food from print and web resources. They concluded that the activities generated student interest, promoted active learning, supported national science standards, and offered opportunities for integration of different subjects with earth science. However, they cautioned teachers to consider health and safety issues such as food allergies, hot equipment, and cleanliness, along with costs, preparation time and clean-up time. Some lessons that address stratigraphic concepts include modeling of rock

Figure 1. Snow bank showing shoveled area that was later filled in with new snow.

Figure 2. Snow bank with evidence of past shoveling of a walkway. The thick dark layer near the top is a snow-sand mixture from the road placed by the snowblower that sliced the surface flat.

layers with cake and icing (Wagner, 1987), with pudding, crushed cookies and sprinkles (Olson, Rule, and Dehm, 2004), with gelatin, banana slices and whipped cream (The Society for Mining, Metallurgy, and Exploration, Inc, 2005), and Snickers candy bars (Newsom, Hagerty, Spilde, Adcock, and Sorge, 1999). These edible food models may be built, sliced, folded, faulted, and intruded, with students seeing the order of events and the effects they produce.

Olson et al. (2004) used snow layers as an analog of clastic sedimentary rocks while Rule, Olson, and Dehm (2004) connected icicles and snow bank caves with stalactites and solution features. In these two studies of fourth graders exploring snow bank features through photographs and schoolyard fieldtrips, students developed an understanding of how different colors and textures of snow bank layers are produced, reinforcing their knowledge base of sedimentary and erosional processes.

Another idea for modeling a stratigraphic section is to create a sequence of hand-sized or larger rocks in the classroom (Eves and Davis, 2000). Students may measure and make observations of these samples, then use a map to correlate different sections.

Gunckel (1994) described an ideal field project for elementary and secondary students at a well-bedded lacustrine tuff with abundant leaf fossils. Students lucky enough to have this opportunity, learned to sample the outcrop, record, and analyze data. However, if your students are not able to study a stratigraphic section in the field, they may benefit from the lesson we implemented with our students that is described below.

LESSONS

Sand Layers - Working in groups of three, students created layers of colored sand in clear plastic cups, noting the order of the colors of sand sprinkled. When the cup was two-thirds filled with colored sand layers, they took a spoon and scooped a trench through the layers. After this "erosion," students continued adding colored layers to see the resulting configuration. They kept notes on their investigation and wrote a "report" paragraph, explaining how the pattern of layers was formed. The instructor assessed their performance by observing and assisting them during the activities, and then reading their reports, in particular looking for the following components: layers at the bottom of the cup are laid down first; layers are generally flat; and scooping disrupted the flat layers, allowing later sand to fall into the low spots and touch earlier sands.

Snow Bank Layers - Students applied their new knowledge of original horizontality and superposition of layers to snow bank photographs (See Figures 1 and 2). Different snow bank photographs were shown in an electronic slide presentation and students discussed the sequence of deposition. Students learned that the word "deposition" comes from the root word "deposit". The instructor related this to banking: making a deposit, adding money to an account, was similar to adding (depositing) snow or sediment on the land. Students talked in their groups about the sequence of events depicted in the photographs, then suggested ideas and cited photographic evidence to support their ideas.

Students also learned about a new concept, crosscutting relationships. They recalled how the scooped-out surface of their initial layers of sand disrupted the pattern of the previous and following layers of sand. Several of the snow bank photographs showed places where people had shoveled away (eroded) parts of the snow bank that were then covered by new snow. Students used evidence to unravel the depositional and erosional history of the snow banks.

Stratigraphy Diagrams - The instructor provided electronic photographs of outcrops along roads and had the students identify the layer sequences and crosscutting relationships there. At the end of the activity, students were required to interpret simple drawings of rock layers and draw their own.

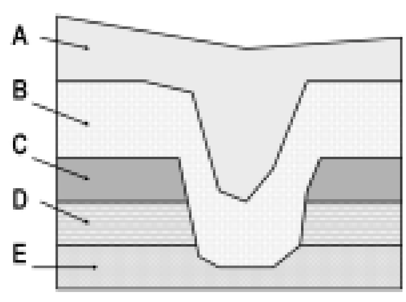
EVALUATION OF THE PROJECT

Sample Population - Two classes of twenty-three fourth grade students each (N = 46) enrolled in a middle class suburban elementary school in central New York State participated in the study. The second author, G. Roth, their regular science instructor, taught all students. Permission to conduct the study was obtained from the State University of New York at Oswego Human Subjects Committee, the school principal, and parents/guardians of the students.

Pretest/Posttest - Identical pretest/posttests were administered to students a few weeks before the lessons and two weeks after the lessons had concluded to

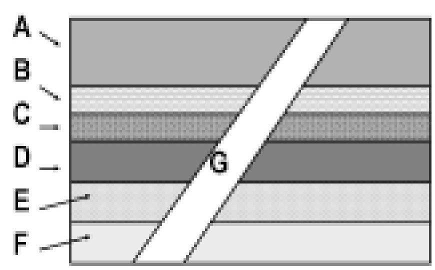
For each mutiple-choice question below, write the letter of the **best** answer in the blank.		
1. _ B _ In science class, what do we mean by a "**bed**"? A. A plot of land B. A layer of rock C. A geologist's chair D. A wall of rock along a road that was cut by road builders	2. _D_ What is **stratigraphy**? A. The study of the Earth B. An approach to solving a problem C. Mapping a straight or flat area of land D. The study of layers of rock to determine the order of events	3. _A_ What is **sediment**? A. Loose sand or mud B. A lava flow C. A strong feeling about something D. Something that has sunk down
4. _C_ What is the Law of **Superposition**? A. Things that are light float to the top. B. The largest volcanoes erupt most violently C. In flat-lying rocks, layers at the bottom are older (were laid down first) D. The oldest layers (those that were laid down first) are those near the top.	5. _B_ What does **crosscutting** tell us? A. Layers at the bottom are youngest B. Something that cuts across other layers is younger C. That all the layers were flat in the beginning D. When layers cut across each other, there is no way to determine what happened first	6. _ A_ What does the **Law of Original Horizontality** say? A. Layers are flat in the beginning B. The horizon is flat line separating land from sky C. If you break this lay, then the order of layers is destroyed D. The original layer is the one that is at the horizon
7. _C_ How can you tell if **erosion** happened? A. The rock color changes B. The layers are much thicker and there are more of them C. There are missing layers or missing parts of layers D. It is impossible to tell	8. _C_ What is an **outcrop**? A. A river or flat-flowing stream B. The harvest from a farm field that is sent to a factory C. A place where you can see the rocks that are usually hidden by grass and soil D. A special backpack for carrying heavy rocks	9. _D_ What is the opposite of **erosion**? A. Washing away of layers B. Not knowing which layer happened first C. Loose sand turns into rock D. Deposition
10 _D_ What is relative dating? A. When people who are cousins go out together B. Determining the exact ages of a layer, such as 2000 years old C. Tell the ages of a rock to the nearest year D. Telling which layers are older or younger than others	11. This diagram shows a snow bank along a road in town. Which layer is the oldest layer? Write the letter of the layer here. _E_	12. Someone dug a trench through the snow bank so that people could get from the stree to the sidewalk. When did this happen? Right after layer _C_ was laid down.
13. Look at the picture of this vehicle in a driveway and the snow bank. The owners of this pickup truck cannot get out of the driveway because of the snow. One owner says she has not been able to drive to work all winter because no one shoveled the driveway. Is this true? Yes No	14. Tell why. There are many lower (dark) layers missing from the driveway area. Someone shoveled snow for several storms, and then stopped.	15 This diagram shows rock layers. Write the letter of the oldest layer (the layer that happened first) on this line. _F_
16 Write the letter of the youngest layer (the layer that happened most recently) on this line. _G_		

Table 1. Pretest/posttest.



Q 11 & 12 Stratigraphy Diagram

Q 13 & 14 Truck Photo



Q 15 & 16 Stratigraphy Diagram

measure long-term learning. The instrument used is shown in Table 1. The mean student score on the pretest was 40.3% (standard deviation 14.2%), mean posttest score was 86.0% (s.d. 11.8%), and mean gain scores were 45.7% (s.d. 14.8%). This performance indicates that students learned the concepts of stratigraphy from the lessons.

Teacher Observations and Student Reactions to the Lessons - The teacher reported that students were thoroughly engaged in the stratigraphy lessons because of the hands-on activities and the puzzle-like photographs and diagrams. Students associated the colored sand layering with recreational sand art. One student commented, "Mr. Roth, this is just like making sand art in the little glass bottles at the fair."

One student related the concept of erosion to his knowledge of the loss of sand on the Outer Banks of North Carolina. As he explained the problem to the class, the student described the barges and dredges that pump sand back onto shores and out of shipping channels.

Students affectionately called this set of lessons the "Science Rocks!" unit (with an emphasis on Rocks as a verb). They were also impressed with the size of the snow banks. After examining the snow bank and road cut photographs, several students commented that they never before realized how layers tell the history of the snowstorms or sediment deposition. "Cool. You actually see where the salt layers are darker. They are melting the layers of snow below them."

EXTENSIONS

Drummond (2001, p. 218) states, "Within the science of stratigraphy, the most important type of rate calculation is the rate of vertical accumulation of sediment." This idea can be applied to a snow bank accumulation study for upper elementary students living in a snow-rich area. Students can keep track of daily snowfall amounts during a winter and photograph snow banks at the same location, measuring the snow layers periodically. This activity would clarify how some snow deposits are lost through melting, evaporation, or sublimation and thicknesses are decreased through compaction, melting, or recrystallization. Students might also conduct a statistical analysis of the snow layers, as Drummond and Coates (2000) suggest for sedimentary rocks, but simplifying it to the calculation of mean, median, and mode for a sequence, all elementary-level statistics concepts. Schwarzacher (1975) found that the most commonly occurring thickness (the mode) of sedimentary beds was smaller than the mean. The 2004 snowfalls that produced the snow banks we examined fit this pattern of positive skewness: there were many almost-daily snowfalls of a few centimeters each during that winter, but just a few larger snowstorms of a half to over a meter of snow during one storm.

The activities described in this paper can be adapted for use in introductory geology/ Earth science courses at the secondary or college level. Students might use two or three sands/gravels of different colors and sizes to make carefully planned stratigraphic sections with depositional and erosional events, challenging other students to unravel the sequence of events. Afterwards, the sediments may be separated by sieving for future re-use. Another extension of the activities is to ask students to write two different versions of snowfalls, plowing, and shoveling events that account for the snow bank stratigraphy shown in photographs; or, draw two different sketches of snow bank stratigraphy that fit a given set of snowfall, plowing, and shoveling events.

CONCLUSION

Our students enjoyed the sand layering and photograph examination activities. The pretest/posttest shows that they learned to apply the laws of original horizontality and superposition to unravel the order of events in a sequence of layers. The snow stratigraphy photographs we used in the lessons are available at the National Association of Geoscience Teachers web site on the "On the cutting edge " page under "Resources for teaching structural geology" under the title, "Photographs of snow bank structures" (Rule, 2005).

The principles our fourth grade students learned during these activities provide a knowledge base for later learning. A useful tool published jointly by the American Association for the Advancement of Science and the National Science Teachers Association (2001), the Atlas of Science Literacy, provides strand map charts showing the science concepts from the Benchmarks for Science Literacy (American Association for the Advancement of Science, 1993) and their interconnections across grade level ranges. This reference source suggests that early elementary level stratigraphy concepts form a foundation for middle school students' understanding of the ability of erosional agents to level mountain ranges over time and transport huge amounts of sediments and chemicals in solution. An initial understanding of stratigraphy also forms a basis for understanding how thick sequences of sediments bury rock deep enough to undergo melting and recrystallization, which, through tectonic processes, may be forced to the surface or folded and faulted into mountain ranges, continuing the cycle of erosion and deposition. These ideas, in turn, can be connected to mechanisms for the rock cycle and the long history of the earth confirmed by thousands of layers of sedimentary rock, both important later concepts.

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