Three Dimensional Geology

Adapted from a previously published lesson plan ("Paper Cores and Problem Solving," Journal of Geoscience Education, v. 45, 1997, p. 381) and used with permission of the author (Brian Poelker, Midwest Central Middle School, 121 N. Church Street, Green Valley, IL, 61546. E-mail: bpoelker@ntslink.net).

Grade level: 9 – 12

Purpose:
To apply geological concepts to a real-life problem-solving situation and to give students an appreciation of the three dimensional nature of rock strata.

Goals:

- Students will use rocks, fossils, and simulated cores to interpret the geology of an area.
- Students will apply their interpretations and make recommendations about the best site for building a subdivision.

Objectives:
On completion of this lesson, students should be able to:

- Work in cooperative groups to measure and analyze paper cores.
- Reconstruct the geological history of the land the paper cores represent.
- Create a topographic map of the area represented by the paper cores.
- Construct a Styrofoam model of the area.
- Assess the geological hazards of the area.
- Recommend the most suitable site for the construction of a suburban development.
- Assess their own work along with the work of his or her teammates.

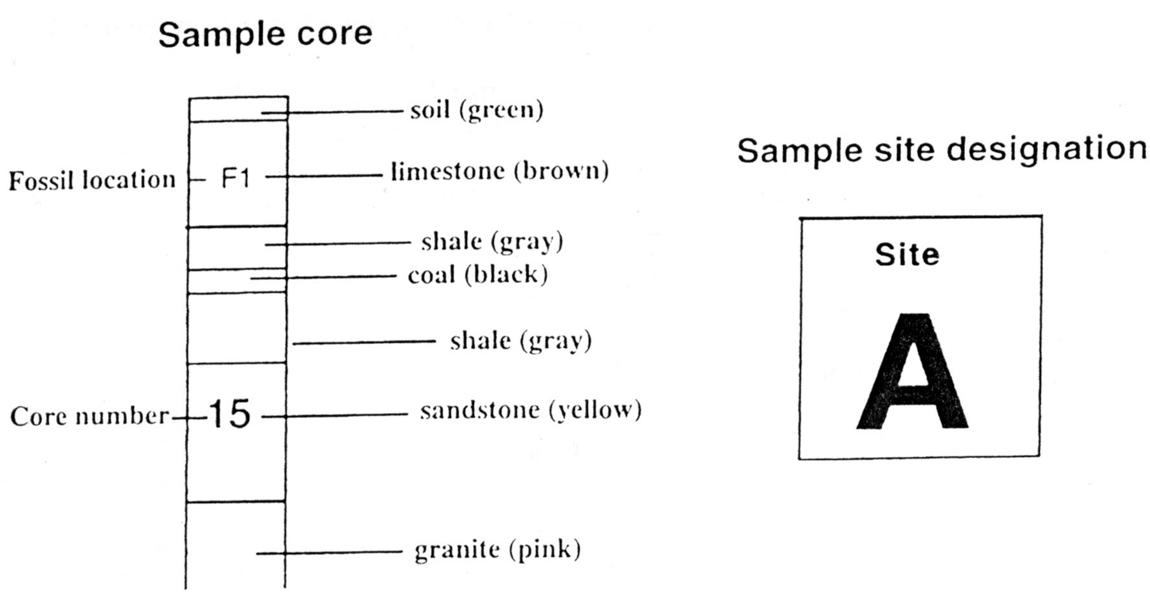
Background:
Students can learn about topography from their observations of the landscape, but the geology of an area does not permit a view of the layers of rock buried deeply below the surface.

"Paper Cores" is a culminating activity that gives students an appreciation for the three-dimensional nature of rock strata and the chance to apply geological concepts studied in class to a new situation. In this activity, students work in cooperative teams to measure and analyze paper cores hanging from the ceiling of the classroom to determine the best site to build a community. The various colors of the cores represent different rock strata. Students identify rock samples and fossils present in the strata and reconstruct the geological history of the area. The height above sea level (the classroom floor) is measured, and a topographic map is made along with a Styrofoam model of the area, which is built to scale. Based on the data collected and the models, students assess the geological hazards of each site and submit all of the above plus a typed report of their recommendations regarding the most suitable location for the building of a suburban development. Each student assesses his or her own work and his or her team and teammates in a battery of evaluations at the end of the project.

Set-Up:
The most time-consuming part of this unit for the teacher is the one time preparation of the cores using construction paper of different colors cut to a width of about four inches. You can either recreate a locality based upon actual core samples or make representative cores to show various strata. The complexity of the cores can be varied depending upon the level of one's students. Once the cores have been assembled, they can be laminated for future use.

As shown in Figure 1. below, each core is given an identifying number, and the various strata present, their sequence, and their thickness are indicated. Each stratum is represented by construction paper of a unique color, and the thickness of the various strata are represented proportionally. The letter “F” followed by a unique number for each genus indicates occurrences of various fossils.

Figure 1.



The ceiling of the room is taken to represent a map of the area under study with each "core" hung from a point on the "map" that indicates its location in the study area (Figure 2). The elevations of the various strata above the floor represent their elevations above sea level. (There is, necessarily, vertical exaggeration.) The locations of the potential subdivisions are indicated by the position of hanging cards with the appropriate letter on them. In short, the students are provided with carefully scaled three-dimensional clues to the geology of the study area.

A scale of 1 cm = 100 m is used for the horizontal dimension; the vertical scale is I cm = 10 m. The difference in scale causes compression of the horizontal axis compared to the vertical axis. Middle level students need to be reminded of this fact. The use of paper cores limits the resolution of the strata. At 1 cm = 10 m on the vertical scale, it is easy to get some very thick coal seams that mining companies can only dream of.

Rock and fossil samples are placed on specimen tables at the sides of the room. The color of the construction paper beneath each rock indicates which stratum the rock represents. The fossils are labeled with the appropriate number. Students use keys and books to identify the fossils (Figure 3).

Figure 2.

Figure 3.

Procedure:

1. Students are presented with the following problem: your company has been hired to select the best site for the building of an exclusive suburban development. The developers have purchased options on four sites (indicated by the letters A, B, C, and D). You and your team must examine the cores and make a detailed report for the developers about potential problems associated with each site based on the presence of steep slopes, weak rock types, and other potentially hazardous features.

To prepare a report, your team will need to:

- Construct a geological column containing all of the rock layers, in order, that have been deposited over the entire area.
- Identify specific geological processes that have occurred near each site.
- Create a topographic map of the entire area and locate the sites on the map (Contour lines of 100 m elevation are recommended for middle-level students.).
- Build a Styrofoam model of the area to scale using 100m contour intervals.

2. Students must develop a plan of action that will allow them to complete the tasks and have it approved by the teacher. Before beginning this project, students in my class have already experienced much work in cooperative teams encountering problem-solving situations. In the previous unit of study, the students worked with geologic processes, rocks and fossils, geologic history, and time scales (GSA The Earth Has a History). They come into the unit equipped with the tools to begin working on the problem but not knowing the answer.

Students could use the DAPIC (Define, Assess, Plan, Implement, Communicate) problem-solving approach that is widely used in the technology industry. In the DAPIC process, students define (D) and restate the problem. They assess (A) the situation to determine the materials and equipment that will be needed to solve the problem. Students must ascertain what information is already known about the problem and what they need to know to solve the problem. They develop a plan (P) to solve the problem and then implement (I) the plan. Students finally communicate (C) their results to classmates and others concerned.

Since students have already been presented with the problem, their first task is to restate it in their own words. Next, they must assess the problem. As they survey the room, they observe cores hanging from the ceiling and rocks and fossils at identification tables. Based on what they see in the room and the problem statement, the students prepare a list of things that they know and need to know.

Student teams then prepare a plan that will solve their problem. Tentative plans are submitted for approval. (Note; planning is often difficult for students and teacher guidance may be required.) If the plan is good enough to successfully begin the project, it is approved. During the implementation phase, students often find that some step has been omitted. In this case, the plan is modified as needed, and they proceed with the project. As students implement their plan, they also update their assessment of the problem daily. The "know" column becomes a summary of what they have learned in the project. The "need to know" column provides a continuing goal for students to achieve each day.

The students make a list of characteristics of the rocks (grain size, texture, color, hardness, reaction with acid) and use the results of their data to identify the rocks using a key that contains unfamiliar terms. As problems with terminology arise, the words are listed in the “ if need to know" column. Upon resolving the problem, students add the new information to the "know" column. They come to know the terms and their importance by constant use in a real setting.

When all of the rocks have been correctly identified, teams write a short research report on each one. Fossil locations are also indicated in the cores.

Students use a variety of reference materials to identify the fossils and gain clues to the age of the strata.

Students measure the cores in detail, recording the thickness of the strata and the location of the fossils within particular layers. After they have collected all of the data from all of the cores and correctly identified the rocks and fossils, they are ready to interpret the data. The students organize the elevations and dimensions of the area to produce a topographic map (see Web Resources below). Upon completing the map, they use it as the basis for building a scale model of the area.

Students arrange the strata into a geologic column on the basis of the law of superposition and the ages of the fossils. The distribution of the strata allows the students to deduce the geological processes that have occurred in the area. The rocks identified on the surface are immediate clues to building suitability. Student teams research the rocks and processes associated with each site, looking for possible geological hazards such as steep slopes, proximity to a river channel, weak foundation materials, or potentially active faults. This information becomes part of their report to the developers.

Teacher as Facilitator:
The teacher assumes the role of science coach and facilitator. Each step in the team's plan is reviewed upon completion. If all is well, the students proceed to the next stage. This process allows errors and misconceptions to be recognized and corrected promptly. The teacher is free to move among teams and help as problems arise. Ample resources are available for students to find answers to the questions they pose. Students also complete a mid- point team evaluation form.

Assessment:
Upon completion of the project, students evaluate themselves, their team, and teammates using the self, team, and teammate assessments shown in Table 1. Evaluation instruments are discussed with students in detail at the beginning of the project, and students should be required to document their work and that of their teammates throughout the project. Table 2. shows the basis for evaluating the work produced by individuals and teams.

The warm-up activities are needed to ensure that students have enough background information to be able to begin the problem. Since this is a culminating activity students should have some prior knowledge of rocks, fossils, stratigraphy, geological processes, topographic maps, and geological hazards. The video, <u>The Earth Has A History</u> provides an excellent introduction to this unit. Constant observation of student work as they proceed with the problem enables the teacher to provide additional help to individuals and teams as needed. Repeated measuring of cores brings a level of familiarity to the patterns. Using all the data as clues, students are able to make inferences and reconstruct the geological history of the entire area. They transform the data on paper into a physical reality in the form of a topographic map and a Styrofoam scale model of the area. They submit a typed report, identifying the potential geological hazards of each site and offer their opinion as to the safest location upon which to build a subdivision, based on hard facts and sound evidence.

Print and Video Resources:

- Creath, Wilgus. 1996. Home Buyer's Guide to Geologic Hazards: American Institute of Professional Geologists. Denver, CO: Mido Printing Company. Nuhfer, Ed. The Citizens Guide to Geologic Hazards. American Institute of Professional Geologists, 7828 Vance Drive, Suite 103, Arvada, CO 80003. Phone: 303-431-0831 $19.95.
- Geological Society of America. 1989. The Earth Has A History (video): Geological Society of America, P.O. Box 9140, Boulder CO 80301. Available for $25.00 (15 percent discount to educational institutions for prepaid orders on letterhead or purchase order) from the Geological Society of America; phone 1-800-GSA-1988.

Web Resources

- ISM Geology Online
  http://geologyonline.museum.state.il.us
- Idaho Museum of Natural History
  Teaching Resources – Lesson Plans – Making a Topographic Map
  http://imnh.isu.edu/digitalatlas/teach/lsnplns/topmaplp.htm
- Society for Sedimentary Geology
  K-12 Earth Science - Customized Topographic Maps and Relief Models
  http://www.beloit.edu/~SEPM/Maps/customized_topographic.html

Lesson Specifics:

- Skills: analyze, interpret, compare, synthesize, cooperate as a group member, report, problem solve, communicate
- Duration: author suggests 3 weeks. Can be adapted.
- Group size: small groups and whole class
- Setting: classroom

Illinois State Board of Education Goals and Standards:

- 3.B.3a: Produce documents that convey a clear understanding and interpretation of ideas and information and display focus, organization, elaboration and coherence.
  3.B.3b: Edit and revise for word choice, organization, consistent point of view and transitions among paragraphs using contemporary technology and formats suitable for submission and/or publication.
  5.A.3a: Identify appropriate resources to solve problems or answer questions through research.
  5.A.3b: Design a project related to contemporary issues (e.g., real-world math, career development, community service) using multiple sources.
  6.B.3a: Solve practical computation problems involving whole numbers, integers and rational numbers.
  6.B.3b: Apply primes, factors, divisors, multiples, common factors and common multiples in solving problems.
  6.D.3: Apply ratios and proportions to solve practical problems.
  7.B.3: Select and apply instruments including rulers and protractors and units of measure to the degree of accuracy required.
  7.C.3a: Construct a simple scale drawing for a given situation.
- 7.C.3b: Use concrete and graphic models and appropriate formulas to find perimeters, areas, surface areas and volumes of two- and three-dimensional regions.
  11.A.3c: Collect and record data accurately using consistent measuring and recording techniques and media.
  11.A.3f: Interpret and represent results of analysis to produce findings.

12.E.3a: Analyze and explain large-scale dynamic forces, events and processes that affect the Earth's land, water and atmospheric systems (e.g., jetstream, hurricanes, plate tectonics).

13.B.3c: Describe how occupations use scientific and technological knowledge and skills.

13.B.3d: Analyze the interaction of resource acquisition, technological development and ecosystem impact (e.g., diamond, coal or gold mining; deforestation).

Table 1.

Team/Self-Assessment

This data is confidential. Your classmates will not have access to it.

Your name ____

1. Team evaluation

Scale

3= my team did this all of the time

2 = my team did this most of the time

1 = my team rarely did this

0 = my team didn't do this at all

____ 1. Respected the opinions of all teammates.

____ 2. Discussed all sides of the problem.

____ 3.Listened while others talked.

____ 4.Accepted group decisions.

____ 5.Used class time wisely to complete the project.

____ 6.Made sure all team members could solve all of the problems of the project.

____ 7.Helped all team members understand all aspects of the project.

____ 8. Shared the work in the project.

2. Self Assessment

Circle your opinion of your performance as a member of this team.

outstanding very good average poor no participation

Explain the reason for your opinion. Include an explanation, in detail, of what YOU did and how YOU helped your teammates complete this project.

3. Team member evaluation

Your Name ___________________________________

Name of team member ___________________________

Circle your opinion of the performance *of* this team member.

outstanding very good average poor no participation

Explain the reason for your opinion. Include the contributions of this team member to the project.

Activity Evaluation Rubric

Student work is evaluated both as a team and individually. The following scoring rubric has been developed for materials in both categories.

3 Points: Exceeds expectations. All material is complete and accurate with great attention to detail. Proper units of measure are used. The work is neat and well organized.

2 Points: Meets expectations. The work is complete, but detail may be lacking. The work contains minor errors that do not affect the interpretation of the data or results. Proper units of measure are used. Neatness and organization are acceptable but can be improved.

1 Point: Does not meet expectations but exhibits some effort. Errors occur in the material. Portions are omitted. Proper units of measure are not used or are missing. Aspects of the work are unorganized. Neatness needs improvement.

0 Points: Unacceptable work. Major errors or omissions occur in the material. Proper units of measure are omitted. Material lacks detail. The work is unorganized and messy.

Individual scoring rubric

Materials turned in (rate each using the scale above)

______ Rock data sheet
______ Fossil data sheet
______ Know list
______ Need to know list
______ Rock reports

Team scoring rubric

Materials turned in (rate each using the scale above)

______ Plan
______ Geological column
______ Geological processes
______ Topographic map
______ Scale model
______ Report to developers

Grading

A = mostly 3s, no 1s
B = an equal mixture of 3s and 2s
C = mostly 2s, with an equal number of 3s and 1 s
D = Mostly 1 s, with 2 or less Os
F = mixture of 1s and three or more Os

Table 2.

GUIDE FOR IDENTIFICATION OF COMMON ROCKS

Adapted from Dr. Robert (Skip) Nelson, Illinois State University

Introduction

The use of the following four observations will allow you to identify most of the rocks found in our area. Begin your work by using the observations below and writing down the information for the rock. After you record your observation use them to follow the key. The key will offer a choice. Make your choice and GO TO the next choice indicated by the key until the name of the rock is given.

1. First observation: Size of Grains (choose one)

   COARSE GRAINED - (the shape of the crystals in the rock are easy to see)

   MEDIUM GRAINED - (crystals small but distinctly visible)

   FINE GRAINED - (crystals too small to be visible) If the rock has mostly fine grains but includes a few larger grains count the rock as fine grained.

   GLASSY TEXTURE - (no crystals)

2. Second observation: Texture (choose one)

   CLASTIC - the grains were broken off a bigger rock and then cemented together (example: sandstone).

   NONCLASTIC - the crystals were cooled underground. The crystals in the rock interlock to hold the rock together (example: granite).

   NO TEXTURE OBSERVED - all fine grained or glassy are in this category

3. Third observation: Color (choose one)

   LIGHT - white, gray, pink, red, or green (more than 1/2 light)

   DARK - black, very dark green, dark brown, mostly dark with light specks (more than 1/2 dark)

4. Fourth observation: Hardness. **Do this test - for fine-grained rocks only!** (choose one) The hardness depends upon the minerals that the rock is made of or the cement which holds it together. To test for hardness you will use a penny, and a steel nail

SOFT - you can scratch the rock with a penny.

MEDIUM - the rock cannot be scratched by a penny, but can be scratched by the nail.

HARD - the rock cannot be scratched by the nail.

Use your answers from these observations for your choices on the key on the next page.

IDENTIFICATION KEY

I. **COARSE GRAINED ROCKS AND MEDIUM GRAINED ROCKS**
GO TO "A" **Nonclastic** or "B" **Clastic**.

A. **Nonclastic texture** (grains interlock)

1. **Massive rocks (grains scattered in all directions)**

a. LIGHT COLORED ROCKS white, gray, yellow, pink, red. (Coarse grained, nonclastic, massive, light-colored rocks)

i. **Granite**, igneous; feldspar and quartz; crystals are clear, pink, white, may have a small amount of black.

ii. **Quartzite,** metamorphic; quartz, very hard and dense; no reaction to acid; white, brown, purple

iii. **Dolomite,** sedimentary; slow reaction, if any, to acid; gray, white, yellow or brown; replacement of limestone's calcium by magnesium.

B. **Clastic texture** (grains or fragments are cemented together). GO TO "A" Coarse Grained or "B" Medium Grained

1. **Coarse Grained**

a. Rounded grains up to the size of pebbles. No sharp corners or edges. Your rock is **Conglomerate,** sedimentary.

2. **Medium Grained**

a. **Sandstone**, sedimentary, may react with acid depending upon the cementing agent.

b. **Limestone**, sedimentary, reacts with acid

II. **FINE GRAINED AND GLASSY ROCKS**

A. **Fine Grained** GO. TO " 1 " Light Colored or " 2 " Dark Colored.

1. Light colored fine-grained rocks

a. **SOFT -** Your rock is **shale**, sedimentary; clay and silt; layered: fissil (breaks in sheets); light gray, red, or green

b. **MEDIUM**

i. **limestone**, sedimentary; made of crushed shells; white or gray, reacts with acid

ii. **dolomite**, sedimentary; slow reaction, if any, to acid; gray, white, yellow or brown; replacement of limestone's calcium by magnesium.

2. Dark colored fine grained rocks

a. **SOFT** - Your rock is **shale**, sedimentary; clay and silt; carbonaceous, fossiliferous; laminated (breaks in flat layers)

b. **MEDIUM** - Your rock is **bituminous coal**, sedimentary; bands of shiny black material and dull black material; mostly carbon; may contain sulfur

c. **HARD** - Your rock is **basalt**, igneous; black

B. **Glassy** Textured Rocks. Volcanic.

1. Your rock is **obsidian,** igneous; volcanic glass; black or brown; conchoidal fracture

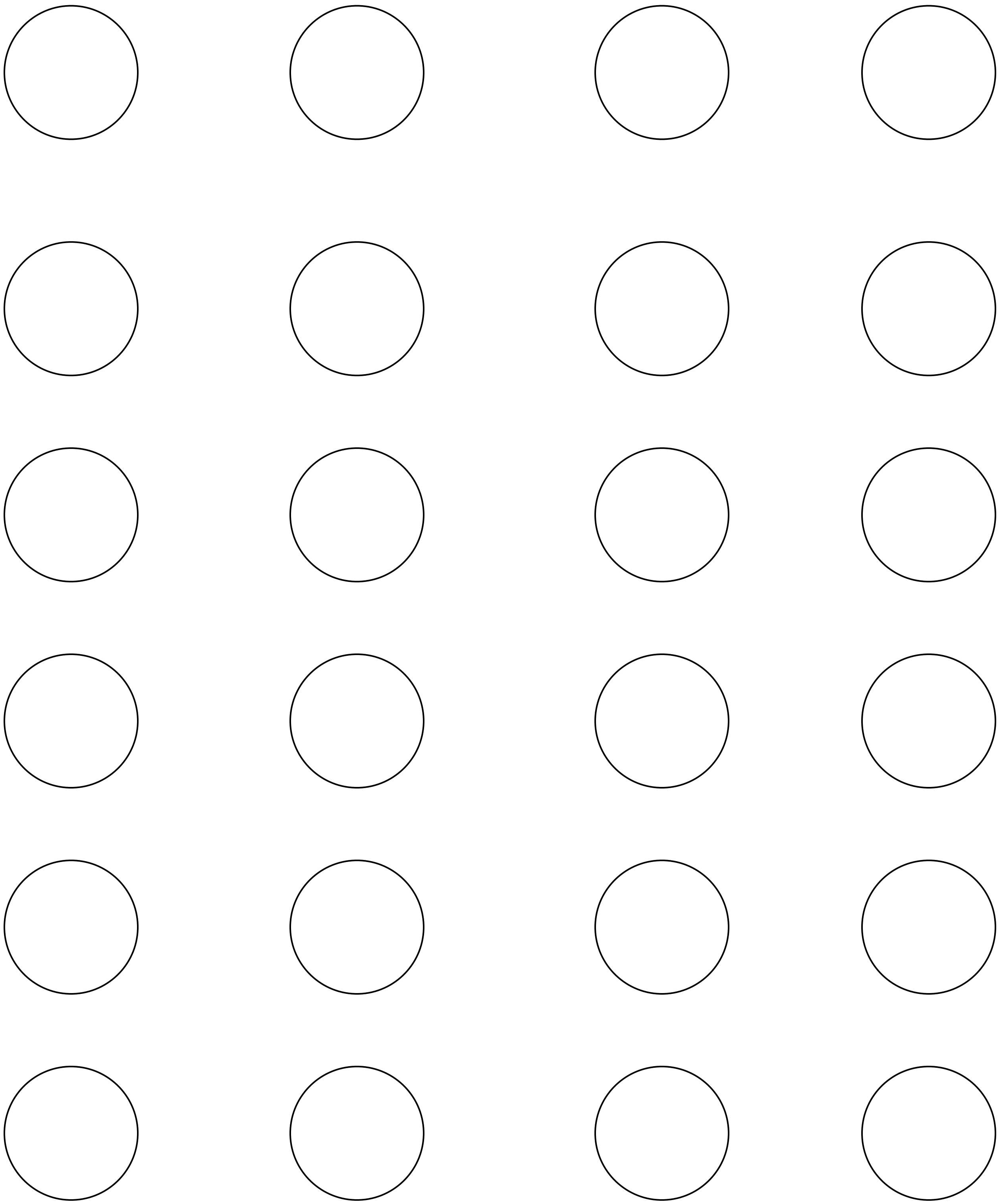
The Geological Column

On this worksheet you will identify the order of the rock strata according to age. **Use the law of superposition** to help you. The cores at each station give you clues. You will need to compare all of the strata from all of the stations to get them in the proper sequence. **The age of volcanic rocks can be determined by measuring radioactive atoms inside the rock** with the mass spectrometer (a very sensitive scientific instrument). The obsidian and the pumice were founds to be 2000 years old (plus or minus a 3% error). **Use the clues from the fossils** to help you also. If there is a fossil in a particular stratum, be sure to indicate the name of the fossil, its time period, and its age.

Work out the column on your paper before putting it on the worksheet. Youngest rocks go on top.

Name of Rock	**Fossil**	**Period**	**Age**
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

Core Elevations – Data Sheet



Geologic Core Worksheet
(Rock 1 = top of core)

Core# ________
Height above sea level ________
Distance from ___ site ________

Rock Fossil/Age

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________
8. ____________________________

Core# ________
Height above sea level ________
Distance from ___ site ________

Rock Fossil/Age

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________
8. ____________________________

Core# ________
Height above sea level ________
Distance from ___ site ________

Rock Fossil/Age

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________
8. ____________________________

Core# ________
Height above sea level ________
Distance from ___ site ________

Rock Fossil/Age

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________
8. ____________________________

Core# ________
Height above sea level ________
Distance from ___ site ________

Rock Fossil/Age

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________
8. ____________________________

Core# ________
Height above sea level ________
Distance from ___ site ________

Rock Fossil/Age

1. ____________________________
2. ____________________________
3. ____________________________
4. ____________________________
5. ____________________________
6. ____________________________
7. ____________________________
8. ____________________________

Sample report to developer:

March 5, 2003

Building Foundation of America
74249 Madison Ave.
Chicago, IL U.S.A.

Dear Developers:

On behalf of R.K.A.J. Geological Association we would like to inform you that it has been a great honor and a challenge well deserved by our association to work for you. Over the past several weeks we have worked hard to locate the best possible building site for the location of your suburb location. Here following, are the results of each site and their surroundings.

Site A is found 1060 kilometers above sea level. The gradient, or the slope which site A is found on, is 10 meters/kilometers. The geological processes around this site include deposition and erosion. The rock strata includes sandstone and sand as the top layers. Shale, Limestone, and Bituminous coal are found beneath the surface of site A.

There are many geological hazards found in the area of site A. The top layers of Sandstone and Sand are not two of the most reliable strata to build on. When sand contains a heavy amount of pressure absorbed with wetness there is a chance of subsidence. Subsidence is when layers contain sinkholes due to pressure and wetness. Site A is also near a very deep valley containing a river which may possibly flood your site over time. Under the top layers of strata lays a layer of Bituminous Coal which at one time might have been mined. If this is in the history of the Coal, many unknown mines could be found under the ground. If these mines were to be unlocated and built upon you may experience sinking in the future.

Site B is found 690 kilometers above sea level. The gradient of this site is 23 meters/kilometers. The geological processes include deposition, erosion, and faulting. The rock strata that is found over the surface of the area include Bituminous Coal. Shale, Limestone, and Dolomite are also found under the surface of Site B.

There are many hazards due to the composition around site B. The most undependable hazard found at this site is Faulting (Earthquakes) and Flooding. Site B is rather close to an active fault line. It is also rather close to a deep valley which contains a river which may flood your site whenever a lot of rain is received in the area. Site B is also found on top of a layer of Bituminous Coal which may subside due to unlocated abandoned coal mines. Bituminous Coal is rather an unreliable layer of- strata to build on.

Site C is found 1550 kilometers above sea level. It has the gradient of 17.9 meters/kilometers. The geological processes found in the area are tilting. The rock strata around site C includes Obsidian, Basalt, Quartzite, and Granite. The top layer of strata is Obsidian, a rock made by volcanic lava over time.

There is one severe problem at site C with a couple of minor problems. The major problem is a volcano in the area of site C is active. This is shown by the top strata of Obsidian. The strata at core number six and twelve show if this volcano was to erupt your site would be covered. Also around this area tilting occurs. If you would build your suburb on a tilting surface you would experience major destruction to your foundation over time.

Site D is located 1350 kilometers above sea level. The gradient of this site is 10 meters/kilometers. The geological processes include tilting in this area. The strata includes Basalt, Quartzite, and Limestone. Basalt is found on the top and is a sturdy building material.

Tilting is the only major problem here. There are some few minor problems also. The minor problem is that, as we told you there is an active volcano at site C. We feel though site D is far enough away that it would be out of the path of destruction in case of a volcano eruption. Site D is located on a sturdy building material also. It also has a high elevation of 1350 kilometers with a gradient of 10 meters/kilometers.

As your geological association we would like to inform you that it was to our disadvantage that none of the site A-D were perfect. At the end of the project when we took all of our data and combined it, we decided that site D came out to be the best site. We would like to thank you for letting us work for you, for it has been a honor.

Sincerely,