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ABSTRACT

The investigations for topics 9-14 in the earth science course developed by The University of the State of New York for secondary schools are contained in this supplement to the syllabus (ED 046 749). The topics in this supplement include the erosional process, the depositional process, the formation of rocks, the dynamic crust, interpreting geological history, and landscape development and environmental change. Each set of topic investigations is preceded by the Investigations-Understandings Matrix which illustrates the relationship of the investigation to the major understandings. It can also be used to relate multimedia materials to the topic. The laboratory investigations are presented in two forms: teacher laboratory guide sheets and student laboratory guide sheets, which may be easily duplicated to provide structured procedure for the students. The level of difficulty of each investigation is indicated on the teacher guide sheet as easy, challenging, or difficult. Although these activities are in a supplement, they are considered essential to the core of the course. (PR)

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EARTH SCIENCE

SUPPLEMENT TO THE SYLLABUS

PART 3, TOPICS 9-14

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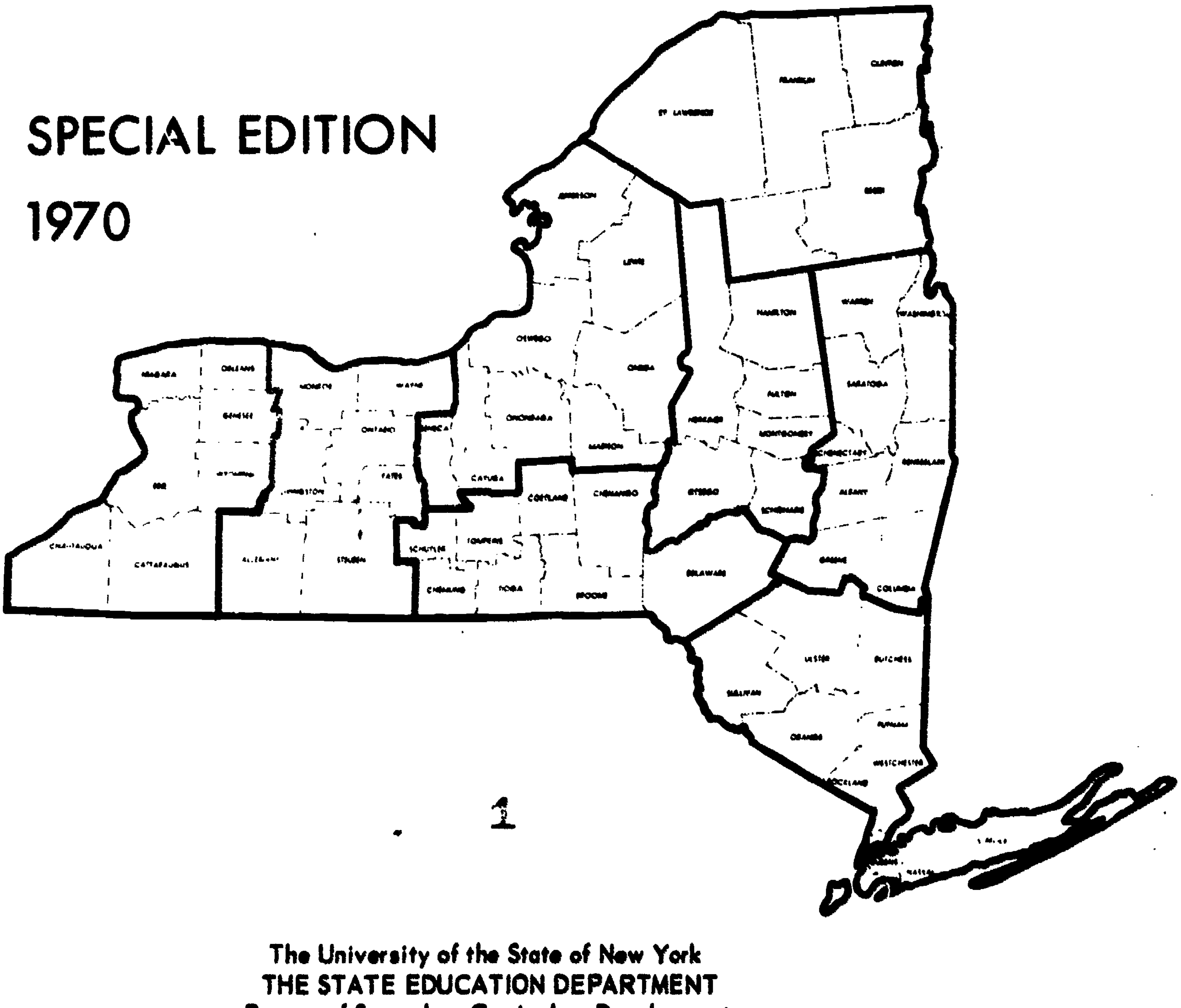

The University of the State of New York
THE STATE EDUCATION DEPARTMENT
Bureau of Secondary Curriculum Development
Albany, New York 12224

topic IX

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TOPIC IX - THE EROSIONAL PROCESS

How Is the Earth's Crust Affected by Its Environment?

Time Emphasis: 6 days

(■ = filled square in the chart)

TOPIC OUTLINE		A-1a	A-1b	A-1c	B-1a	B-2a	LTI #16	LTI #17	LTI #18	LTI #19	FE - #1	FE - #2	FE - #3	FE - #4	FE - #5			
INVESTIGATION		A-1a	A-1b	A-1c	B-1a	B-2a	LTI #16	LTI #17	LTI #18	LTI #19	FE - #1	FE - #2	FE - #3	FE - #4	FE - #5			
Estimated Time (Periods)		1	1	2	1½	2												
A. Weathering																		
A-1 Evidence of Weathering	*What Is Some Evidence That Earth Materials Weather?*																	
A-1.1 Weathering processes	A-1.11			■							■	■	■	■	■			
	A-1.12	■			■						■	■	■	■	■			
	A-1.13										■			■				
A-1.2 Weathering rates	A-1.21		■	■														
	A-1.22	■			■							■						
A-1.3 Soil formation	A-1.31	■										■						
	A-1.32																	
A-1.4 Soil solution	A-1.41		■															
B. Erosion																		
B-1 Evidence of erosion	*What Evidence Suggests That Rock Materials Are Transported?*																	
B-1.1 Displaced sediment	B-1.11						■					■	■		■			
	B-1.12																	
B-1.2 Properties of transported materials	B-1.21				■								■					
B-2 Factors affecting transportation	*How Does the Transportation of Rock Materials Take Place?*																	
B-2.1 Gravity	B-2.11																	
	B-2.12																	
B-2.2 Water erosion	B-2.21							■					■					
	B-2.22					■							■					
	B-2.23					■							■					
	B-2.24												■					
	B-2.25								■	■			■					
B-2.3 Wind and ice erosion	B-2.31						■											
	B-2.32																	
B-2.4 Effect of erosional agents	B-2.41																	
B-2.5 Effect of man	B-2.51																	
B-2.6 Predominant agent	B-2.61											■			■			
PROCESS OF INQUIRY OBJECTIVES																		
Mathematical Skill	PIO-1		■	■		■							■					
Measurement Skill	PIO-2	■	■	■	■	■					■		■					
Creating Models	PIO-3			■		■												
Analysis of Error	PIO-4		■	■		■							■					
Data Analysis	PIO-5		■	■	■	■							■					
TITLES		Soil Formation	Reaction Rate and Particle Size	Rock Abrasion	Nature of Sand	Stream Flow	Soil Erosion	River	Stream Pit	Stream Sediment	School Building and Grounds	Pit	Stream	Cemetery	Beach			

Multimedia: Check Multimedia Section of Supplement for reference to this topic.

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Challenging (1)

IX-A-1a: SOIL FORMATION

QUESTION:

What is some evidence that earth materials weather?

MATERIALS:

Two soil samples, one top soil the other subsoil. If possible, both should be derived from igneous rock. (This usually can be picked up easily in any gravel bank within a 50 mile radius of the Adirondacks and in isolated areas in the rest of the state.) Other necessary materials are: a magnifier, teasing needle, coarse-grained granite, crushed granite (10 ml.), small containers. If available, stereo microscopes work very nicely for viewing the soil samples.

SUGGESTED APPROACH:

1. Give students the materials listed above, and ask them to follow the instructions listed in the student section of this investigation.

2. You may wish to put a list on the chalkboard of the similarities and differences found by the students. This listing often forms the basis for a lively postlaboratory discussion.

PRECAUTIONS:

1. Some of the materials used in this investigation may be discolored due to oxidation. Most students, however, will be able to distinguish between the fragments of quartz and the dark colored ferromagnesium minerals such as mica and hornblende.

2. Washing the samples to enable observation of the larger particles is a good idea, but will increase the laboratory time beyond the normal period.

TYPICAL RESULTS:

1. The students should be able to generalize the relationship between depth of soil and effects of weathering on the parent rock.

MODIFICATIONS:

Use any residual soil and its parent rock. The problem here is that New York State contains very little residual soil. Students should be made aware that New York's soil is predominantly transported.

REFERENCES:

Investigating the Earth, pp. 274-275, Teacher's Guide, pp. 334.

IX-A-1a: SOIL FORMATION

QUESTION:

What is some evidence that earth materials weather?

INTRODUCTION:

The weathering of granite results in a number of byproducts such as small chunks of quartz and mica, colloids, and ions. The common minerals of granite weather at different rates in the same environment. Those that weather most slowly remain as fragments; those that weather more rapidly form colloids and ions and are eventually transported away by infiltrating ground water and surface running water. In this particular investigation, you will study the products of granite that accumulate when weathering occurs.

OBJECTIVES:

When you have finished this investigation, you should be able to explain the relationship between soil, weathered rock, and the parent rock.

METHOD:

1. Examine the granite and soil samples given to you in whatever detail you wish. One of the questions you may wish to ask is: "What happens when you place a small quantity of each material in a separate test tube of water, shake the test tube, and let it settle?"

2. As you progress through your examination of the various samples, make a list of the similarities and differences between them.

QUESTIONS:

(A-1.12) 1. How are the granite and the two soil samples similar to each other and how are they different?

(A-1.12) (A-1.22) 2. Can you identify any of the minerals that are present in the granite as well as in the soil samples? What are they? What are the properties which allowed you to identify them?

(A-1.31) 3. What arrangement can you make of the materials as they would be found from the surface of the ground downward?

Easy (1)

IX-A-1b: REACTION RATE AND PARTICLE SIZE

QUESTION:

What is some evidence that earth materials weather?

MATERIALS:

Four different size quantities of marble chips, dilute hydrochloric acid, balances, 250 ml. beakers, timer, lab aprons, graduated cylinders, safety glasses, sieve kit.

SUGGESTED APPROACH:

1. Preparation of Materials:

   a) Marble chips may be obtained at very reasonable cost from local nurseries. Approximately 5 gm. will be needed for each student group.

PRECAUTIONS:

1. The students should wear the lab aprons and safety glasses at all times during this investigation.
2. Particles larger than 4 mm. may take more than one class period to dissolve.
3. Do not substitute test tubes for beakers.
4. The teacher may want to experiment to find the best acid concentration to complete the reaction in the time desired. A 1 to 3 ratio by volume may be satisfactory.

MODIFICATIONS:

Use Alka Seltzer if rock material isn't available.

IX-A-1b: REACTION RATE AND PARTICLE SIZE

QUESTION:

What is some evidence that earth materials weather?

INTRODUCTION:

In this exercise, you are going to investigate the relationship between the particle size of a particular rock and the rate of reaction of an acid on it.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. state the relationship between reaction rate and particle size.
2. relate reaction rate versus particle size to weathering in the natural environment.

METHOD:

1. Crush the marble chips until the largest particles are less than 1/2 cm. in diameter.
2. With a sieve kit or homemade wire screens, separate the rock into four different size fractions. The fractions should range from about 4 to 5 mm. down to a coarse dust.
3. Mass 5 gram portions of each of the four sized fractions of rock.
4. Place 100 milliliters of the dilute hydrochloric acid in each of the four 250 milliliter beakers.
5. Add the rock to the acid (GENTLY) and measure the time needed for the rock to be completely dissolved (when no more bubbles are given off).
6. Prepare a graph of your observations (particle size versus length of reaction time).

QUESTIONS:

(A-1.21) 1. What interpretation can be drawn from your graphs?

(A-1.21) 2. What controls in this investigation allow you to interpret the relationship between particle size and reaction rate?

3. What experimental errors might be present in this investigation that were not taken into account?

(A-1.21) (A-1.41) 4. How is this investigation related to naturally occurring geological processes?

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Challenging (2)

IX-A-1c: ROCK ABRASION

QUESTION:

What is some evidence that earth materials weather?

MATERIALS:

Bottle or covered cans, balance, soaked rock, (soft limestone or shale), screen, clock, graph paper, large bottle (for rock debris).

SUGGESTED APPROACH:

1. Angular, freshly broken chips of limestone or shale, soft enough to abrade, provide the best material for this investigation. The chips should be soaked at least one hour prior to the period they are to be used. This soaking enables the material to absorb water and reduce experimental error.
2. Discuss the factors that might affect the rate at which rocks wear.
3. A brief discussion of how one might go about studying the specific factor of time should be undertaken. This discussion should include controls, experimental error, suggested time intervals, measurement, and graphing of the data.
4. After each group has completed their shaking time, have them dispose of the water in a common container.
5. Following completion of the investigation, a chart of all the student data should be made so that the students can prepare graphs on the complete set of data.

PRECAUTIONS:

1. Presoaking is essential to accurate student measurements.
2. Chips should not be used more than once, since the rounded fragments do not erode as easily and the results in the succeeding investigation will be quite poor and difficult to interpret.
3. The rate and manner of shaking of the different groups should be as similar as possible.
4. In order to get standardized results, it will be necessary to express the abrasion as a percent of weight lost rather than an amount.

TYPICAL RESULTS:

If the procedures are standardized, the results of the students should be quite similar. The data, although scattered, should illustrate an increase in the mass lost per unit time. A leveling off of the weathering rate may become evident if the times become extended. This leveling is due to the particles becoming sufficiently rounded to reduce the rate of weathering significantly.

MODIFICATIONS:

1. Use other variables such as different types of rocks, rhythms for shaking, or amounts of water.

REFERENCES

Investigating the Earth, pp. 17-19, Teacher's Guide, pp. 42-44

IX-A-1c: ROCK ABRASION

QUESTION:

What is some evidence that earth materials weather?

INTRODUCTION:

The materials of the earth are undergoing continual change, both chemical and physical. As the result of these changes, the materials can be changed in size, shape, and composition. This investigation is concerned with the physical changes that rocks undergo as they are carred in a stream as a result of contact with the streambed, as well as other materials in the stream.

OBJECTIVES:

When you finish this investigation,you should be able to:

1. state the relationship between time and the effect of mechanical abrasion on rock fragments.

METHOD:

1. Take two spoonfuls of soaked rock. Using the balance, determine the mass and record it. Place the rock in the jar provided, add 500 ml. of water and shake the jar for the assigned number of minutes with the motion agreed upon by the class.

2. Pour the liquid contents of the jar through a screen into another bottle. Place the material which did not pass through the screen on a paper towel.

3. Determine the mass of the materials on the paper towel and record it.

4. Compare the materials on your paper towel with those of groups having different shaking times and describe any differences which are evident.

5. Stir the contents of your discard bottle and measure out 100 ml. Mass a piece of wet filter paper, record the mass, and place it in a funnel. Pour the 100 ml. of discard liquid through the filter paper and record the mass. Calculate the mass of suspended materials per 100 ml. of waste water.

6. Place 25 ml. of the filtrate from Step 5 in a massed evaporating dish and evaporate to dryness. Mass the dish and its contents and calculate the mass of dissolved material per 100 ml of water.

7. Determine the percent of change in mass for the particular time you shook the contents of the container. Place your data with that of the other groups on the summary data chart provided on the board.

$$\text{percent change} = \frac{\text{initial mass - final mass}}{\text{initial mass}} \times 100$$

8. Using the data collected by the entire class, draw a graph consisting of shaking time versus percent of mass lost.

QUESTIONS:

(A-1.11) 1. Why were the rock fragments presoaked before you used them?

(A-1.21) 2. What generalization can you make after comparing the observations of your remaining rock chips with those of the other groups who had different shaking times?

(A-1.21) 3. What interpretation can you give of your graph of the data compiled by the class?

(A-1.21) 4. How can you account for the leveling off of the curve as it approaches the longer shaking periods?

5. How many grams of rock per 100 ml. went into suspension? into solution?

(A-1.11) 6. What comparisons can you draw between this investigation and the natural environment?

Easy (1.5)

IX-B-1a: NATURE OF SAND

QUESTION:

What evidence suggests that rock materials are transported?

MATERIALS:

Sand from a local beach, stream bed, and sand pit; sandstone (different varieties), crushed granite, dropping bottles of diluted hydrochloric acid, test tubes, magnets, balance, small cans, magnifiers (10X), optional: Stereo microscopes.

SUGGESTED APPROACH:

1. This investigation is quite open in nature. The student should be allowed to investigate a wide number of properties of the sand.

PRECAUTIONS:

1. Label the specimens of sandstone. The sandstone will become spotted with acid; so have different specimens for each class.

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IX-B-1a: NATURE OF SAND

QUESTION:

What evidence suggests that rock materials are transported?

INTRODUCTION:

Sand is the result of many earth processes. In this investigation, you will make a large number of observations concerning the "nature of sand" and gain an insight into its source area, transportation media, and area of deposition.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. detect differences in sand samples.
2. make inferences as to the origin of sand, and weathering agents responsible for its condition.

METHOD:

1. Examine the sands available. Use both the unaided eye and your magnifier. Note the size and shape of grains, their color and transparency.
2. Using any of the materials provided, determine the properties of the dominant material in the sand. Record the properties of any other materials that you think are present. NOTE: Diamonds and gold are found in sands in some parts of the world.
3. Fill two small cans of equal size with different sands. Compare their mass. Examine the samples with the magnifier and test them with a magnet. Record your observations.
4. Take the crushed fragments provided and examine the particles. Compare these to the samples of sand. Record your observations.
5. Place some of the crushed particles in a test tube half filled with water, shake them and allow them to settle. Record any sorting that might take place.
6. Examine the specimens of the various kinds of sandstone. Try to rub some of the grains off. Note what happens with each specimen.
7. Put a drop of hydrochloric acid on each sandstone specimen and record what happens.

QUESTIONS:

(B-1.21) 1. In what ways were the sands that you observed different from each other?

(B-1.21) 2. In what ways were the sands that you observed similar to each other?

(B-1.21) 3. What characteristics did the dominant material in the sand have? Did you observe any other materials with differing characteristics in the sand? If so, what were their characteristics? What characteristics do all the materials in the sand have in common?

4. What were the similarities and differences you observed in the light and dark-colored sands?

(A-1.22) 5. What were the similarities and differences you observed between the crushed particles of rock and the particles of sand you observed? Based on the similarities of the crushed material and the sand, what possible relationship between the two could be drawn?

6. What inferences would you like to make about where the sand originated? How was it transported? How was it deposited? If given more time and the necessary equipment, do you think you could investigate these materials longer and come up with additional observations? What would you do?

(A-1.12)
(A-1.22) 7. What observations did you make when you compared the various kinds of sandstone in regards to their:

a) ability to rub off grains

b) reaction to acid

c) color changes after application of the acid

Easy (2)

IX-B-2a: STREAM FLOW

QUESTION:

How does the transportation of rock materials take place?

MATERIALS:

Trough (3' to 6' in length), thin-walled hose with adjustable clamps, support for trough buckets for dispensing and collecting water, stop watch, coarse sand, protractor, fine silt, small bits of paper folded like butterfly wings.

SUGGESTED APPROACH:

1. The apparatus should be set up as indicated in student directions.

2. When investigating the effects of slope, the volume must be kept constant. When the effect of a change in volume is investigated, the slope must be kept constant.

3. When investigating variations due to grain size, slope and volume must remain constant.

4. Follow the investigation with Field Experience #3 ("Stream") so that the investigation may continue.

PRECAUTIONS:

1. Emphasis should be made that the investigation concerns a MODEL of an actual stream, and, as such, it does not represent the conditions in a stream exactly.

2. Do not overemphasize the importance of slope since most rivers have a very low slope. Rivers in general probably vary more in volume than in slope. The same river may vary in volume a number of times during the year.

3. The water should be run into the trough and not on the gravel to best approximate the conditions of an actual stream.

TYPICAL RESULTS:

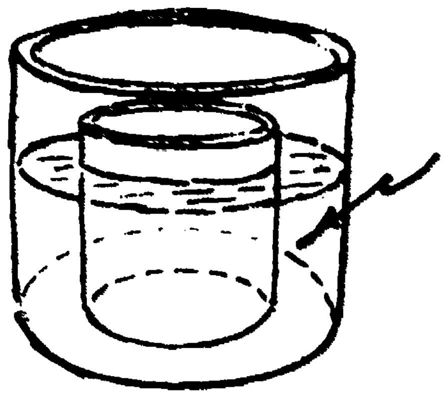
Quantitative results will not be too accurate. However, the students should be able to see the direct relationship between rate of erosion and the slope and volume of a stream.

MODIFICATIONS:

1. MATERIALS: Large, round, straight-sided glass jars (preferably battery jars); smaller round straight-sided glass jars that nest inside the larger ones, clean sand and gravel, dowel sticks or other thin sticks for stirring, heavy white or black paper, graph paper.

SUGGESTED APPROACH:

a) Set up apparatus as shown in the diagram below:



b) Line the inner jar with white or black paper and weigh it down with a heavy object so that it will not move easily.

c) Center the inner jar and place some clean sand and small pebbles in the space between the inner and the outer jar. Then add water to the sand and pebbles to within one inch of the top of the shortest jar.

d) Demonstrate to the students how a stirring stick may be moved around and around in the water to produce a steady flow of water in the space between the jars, causing the sand and pebbles to move. Point out that this is really, in a sense, a "circular creek."

e) Let the students determine the relation of the diameter of the particles moved to the velocity of the water, and then graph their findings. Students may be allowed to work out their own procedures. Bits of paper towel in the water can aid in determining its velocity.

2. To form a large circular creek, cut or saw through the middle of the tread of a badly worn automobile tire to form two halves. Apply white paint to the inside of one of the halves. Partially fill it with sand, pebbles, and water.

REFERENCES:

Investigating the Earth, pp. 279-282, Teacher's Guide, pp. 339-340.

IX-B-2a: STREAM FLOW

QUESTION:

How does the transportation of rock materials take place?

INTRODUCTION:

Streams and rivers vary in their ability to erode earth materials. Two factors that are most vital are the stream's slope and volume. In this exercise you will be investigating the relationship of these two quantities to the ability of a stream to erode the land.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. graph and state the relationship between the variables of slope and volume of stream flow to: the rate of erosion and the particle size capable of being transported.

METHOD:

1. Place the trough on your desk so that the end overhangs about 6 inches. Lift the other end up and support it with books at about a 15 degree angle. Position a bucket full of water so that you can siphon water by means of 2 hoses into the upper part of the trough. Place another bucket on the floor to catch the water after it leaves the trough.

2. Using one siphon, with the clamp opened no more than half way, determine the water velocity (by placing small bits of folded paper in the water and measuring the time for them to go a measured distance down the trough) at two different slopes between 15 degrees and 0 degrees. Record your observations and graph the results.

3. Now position the trough at about 10 degrees slope. This time measure the velocity with the one siphon open and again with two siphons open.

4. Position the trough at 10 degrees slope with one siphon open. Now pour 10 ml. of coarse sand into the trough, record how long it takes for all the sand to be transported away. Next open both siphons and repeat.

5. Position the trough at 15 degrees slope and open only one siphon. Pour in 10 ml. of coarse sand and measure the time for it to be transported. Lower the trough to 5 degrees and repeat. Record the time in both instances.

6. Repeat sections 4 and 5 using 10 ml. of fine silt. Record your observations.

7. Graph your results for steps 2 and 3.

QUESTIONS:

(B-2.22) 1. From your observations, what do you think the relationship is between stream slope and the ability of a stream to erode?

(B-2.23) 2. From your observations, what do you think is the relationship between stream volume and its ability to erode?

(B-2.22) (B-2.23) 3. What do you hypothesize is the relationship between particle size in a stream and the slope and volume of that stream?

4. What could happen in nature in order to produce these same changes in slope and volume that you did in your model of a stream?

topic X

TOPIC X - THE DEPOSITIONAL PROCESS

How Does Sedimentation Occur?

Time Emphasis: 7 days

	INVESTIGATION		A-1a	A-1b	A-1c	FE - #1	FE - #2	FE - #3	FE - #5
	Time Emphasis (Periods)		1	1	1				
TOPIC OUTLINE	A. Deposition								
	A-1 Factors	*What Factors Affect the Deposition of Particles in a Medium?*							
	A-1.1 Size	A-1.11	X			X		X	
		A-1.12	X			X		X	
		A-1.13	X				X	X	
	A-1.2 Shape	A-1.21	X				X	X	X
	A-1.3 Density	A-1.31	X					X	
	A-1.4 Velocity	A-1.41		X	X		X	X	
		A-1.42		X			X	X	
		A-1.43		X	X				
		A-1.44							
	B. Erosional-depositional system								
	B-1 Characteristics	*What Are Some Characteristics of an Erosional - Depositional System?*							
	B-1.1 Erosional depositional change	B-1.11		X					X
	B-1.2 Dominant process	B-1.21		X					
	B-1.3 Erosion-deposition interface	B-1.31		X				X	
	B-1.4 Dynamic equilibrium	B-1.41		X					
	B-1.5 Energy relationships	B-1.51			X				
		B-1.52			X				
		B-1.53							
		B-1.54							
PROCESS OF INQUIRY OBJECTIVES	Mathematical Skill	PIO-1	X		X			X	
	Measurement Skill	PIO-2	X		X			X	
	Creating Models	PIO-3	X	X	X	X	X	X	X
	Analysis of Error	PIO-4						X	
	Data Collection & Organization	PIO-5	X		X			X	
TITLES	Multimedia: Check Multimedia Section of Supplement for reference to this topic.		Deposition of Sediments	Stream Table	Density Currents	School Building & Grounds	Pit	Stream	Beach

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Easy (1)

X-A-1a: DEPOSITION OF SEDIMENTS

QUESTION:

What factors affect the deposition of particles in a medium?

MATERIALS:

Plastic column (80 cm. long x 35 mm. inside diameter), cap or stopper, ring stand and clamp, sorted sediments (pebbles to fine silt...5 ml. of each size), screen sieves, unsorted sediments (100 ml.), watch or clock with second hand, water, graph paper.

SUGGESTED APPROACH:

1. Recommended groups of two students.
2. The apparatus is to be set up as suggested in student sheet.
3. Advanced Preparation: prepare five different sizes of sediment. Gravely sand will serve as an adequate unsorted material.
4. A brief prelaboratory discussion involving the prediction of the relationship between sediment size and settling time sets the stage for the investigation.
5. Have apparatus available,that could be used to find the density of the particles. Some of the students may want to investigate density as a variable.
6. Shape of grains could also be investigated as a variable.
7. One tube should be set up with a fine clay suspension where it can be left undisturbed for a few days to demonstrate the characteristics of a colloidal suspension.

PRECAUTIONS:

1. Make sure sediments are thoroughly sieved.
2. Caution the students to make sure that the hose and stopper are securely in position.
3. Caution the students to time the main body of the sediments. Some particles will settle almost immediately while others will remain in colloidal suspension.
4. Decide on a scale to depict the different sized particles.

TYPICAL RESULTS:

Students' graphs should show a decrease in settling time as the particle size increases (with a leveling off towards the larger particles). The graded bedding usually shows up very well in the tube.

MODIFICATIONS:

1. Simplified version:

   a) Supply the students with a large covered glass jar (i.e., mayonnaise jars), some sediments having mixed particle size and color.

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b) Have students fill the jar 1/2 full with water; add about 150 ml. of sediments. Cover the jar and shake thoroughly. At the end of the shaking, allow the jar to stand quietly for about 5 minutes.

c) Have the students draw a diagram of what they observe.

d) Take a piece of rigid tubing (e.g., cork borer) and push straight through the layers of sediments. Using a solid rod that just fits inside the tube, carefully push the sediments out onto a piece of paper.

e) With a toothpick, smear small amounts of each kind of sediment on small glass squares. Place each glass square over millimeter graph paper and determine the particle size of each layer of sediments.

REFERENCES:

Investigating the Earth, pp. 292-293, Teacher's Guide, pp. 357-358.

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X-A-1a: DEPOSITION OF SEDIMENTS

QUESTION:

What factors affect the deposition of particles in a medium?

INTRODUCTION:

The weathered material of the earth's surface may be eroded away and eventually deposited in the relatively quiet waters of ponds, lakes, or oceans. Unfortunately many of the processes of deposition go unnoticed by us because we are above and not under the surface of the waters. In this investigation you will be able to see, with the aid of a plastic tube, deposition taking place; study some factors which affect it; and observe the products of deposition.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. describe the factors that influence the deposition of sediment in a quiet body of water.

2. describe conditions under which you would expect graded bedding to be formed.

METHOD:

1. Set up the equipment as follows: attach a plastic column, in a vertical position, to a ring stand or some other supporting device. Make sure the bottom cap is tightly in place and the hose clamp is closed. Fill the tubes about 3/4 full of water.

2. Drop small amounts of each of the different sized sediment into the column and record the time each takes to reach the bottom. Repeat this three times for each size. Use the average time for the settling rate.

3. Make some type of comparative scale of the different particle sizes.

4. Construct a graph of the settling time versus grain size for each and draw inferences from the graph.

5. Empty the column, replace the stopper TIGHTLY, and fill the column HALF full with water. Drop a handful of the mixed sediment into the water and record your observations. After waiting several minutes, repeat this procedure once again.

6. After allowing a few minutes for settling, make some observations

concerning the nature of the sediment on the bottom of the column.

7. Develop a technique which will allow you to test the effect that density of particles has on the settling rate.

8. Investigate the effect of particle size on settling rates.

9. Make and record observations of the apparatus your teacher has set up to illustrate colloidal suspension.

QUESTIONS:

(A-1.11) 1. How does size affect the time in which particles settle when other factors are equal?

(A-1.12) 2. What was the pattern of motion of the finest particles in the sample as they settled? What rate of settling did you measure?

(A-1.13) 3. What is your description of the appearance of material which has accumulated on the bottom following the addition of the mixed sample to the quiet water.

(A-1.21) 4. What effect does the shape of a particle have on its settling rate when all other factors are equal.

(A-1.31) 5. What effect does the density of a particle have on its settling rate when all other factors are equal.

ERIC

Easy (1)

X-A-1b: STREAM TABLE

QUESTION:

What factors affect the deposition of particles in a medium?

MATERIALS:

Stream table or tray, approximately 122 x 36 x 9 cm. with drain at one end, siphon tube with clamp, support to raise one end of tray, one bucket of soil, large overflow bucket, water.

SUGGESTED APPROACH:

1. Recommended student grouping (5-6).
2. It is best to set up the apparatus prior to class time.
3. A brief review of the concept of models might help to put the use of a stream table in perspective with the natural environment.
4. If there are sufficient numbers of stream tables available,a demonstration table may be set up and allowed to run for several days, thus more closely approximating the actual stream.
5. Relate observations to topics covered in Topic IX, as well as Topic X.
6. Relate to actual deltas on maps and aerial photographs.

PRECAUTIONS:

1. In a laboratory investigation such as this,the students should be allowed to pursue any reasonable approach to the study of stream deposition.
2. Due to increase in weight as the soil absorbs moisture,the middle of the stream table might buckle....support is needed.
3. The soil should be a fine washed sand or gravel. Organic matter will cause floating debris and will cloud the water to such an extent that the formation of the delta will be obscured. If difficulties arise such as the sand being washed away or the channel changing too rapidly, some fine clay may be added to the sand to stabilize it.

TYPICAL RESULTS:

The students should observe the following phenomenom during this investigation:

1. slope of the delta
2. stream meanders, deposition, and erosion
3. horizontal distribution of the sediments
4. deposition occurring in relatively quiet water

MODIFICATIONS:

1. If at all possible, go to an actual stream so that the students will be able to relate their model to the actual environment.
2. Sedimentation chambers may be constructed or purchased and may be used to illustrate the cross section of a delta.

X-A-1b: STREAM TABLE

QUESTION:

What factors affect the deposition of particles in a medium?

INTRODUCTION:

Streams and rivers play an important role in the processes of erosion and deposition. In previous investigations, the factors which affect a stream's ability to erode have been studied. In this investigation you will see some of these factors in operation as well as observe how they affect the deposition of the eroded material in a model "lake."

OBJECTIVES:

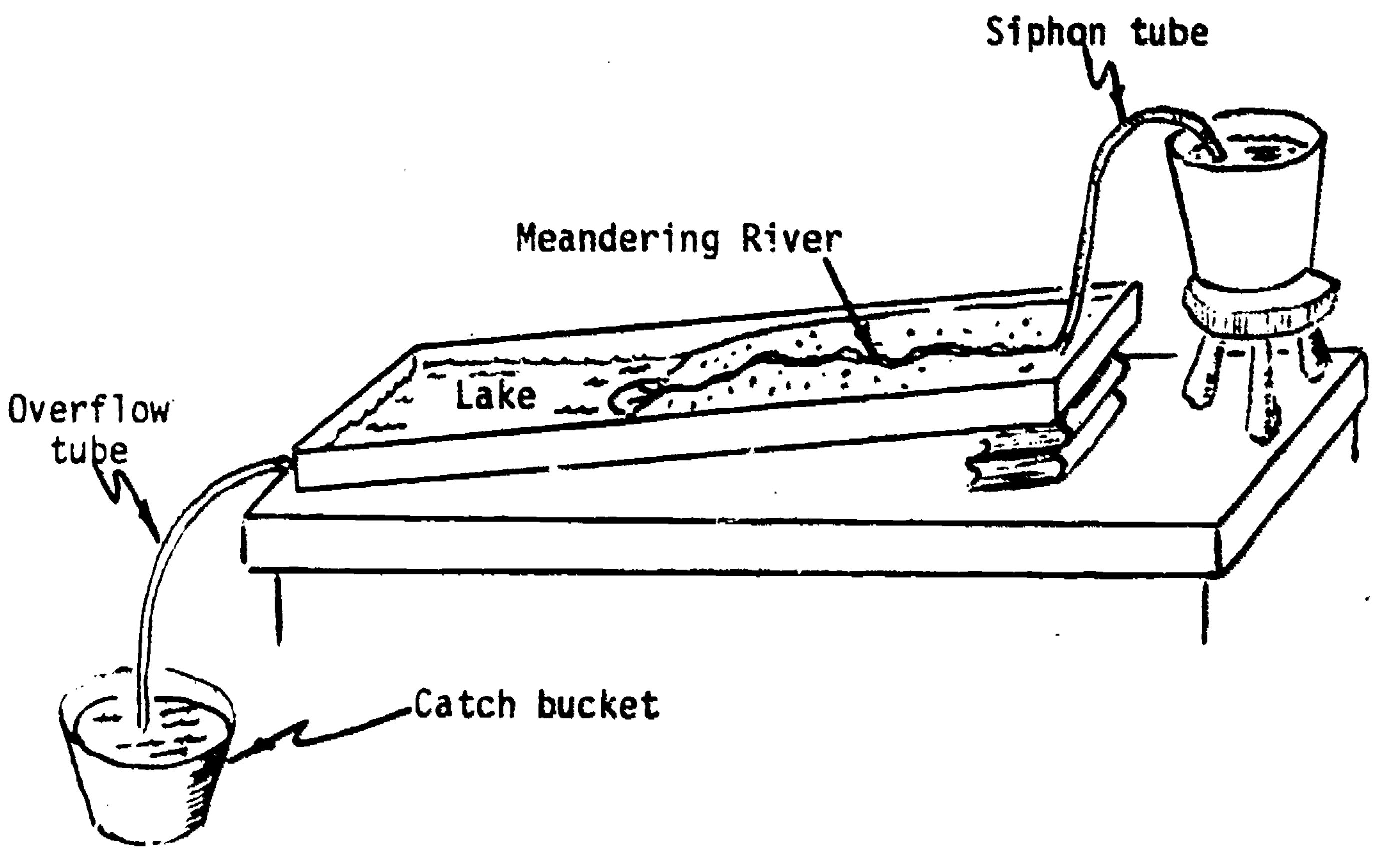
When you have finished this investigation, you should be able to:

1. describe the characteristics of a meandering stream, identifying areas of erosion and deposition.

2. describe the characteristics of a delta formation, including shape, structure, and kind of material of which it is composed.

METHOD:

1. Set up a stream table as illustrated in the diagram below:



ERIC

X-A-1b: STREAM TABLE

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INTRODUCTION:

Streams and rivers play an important role in the processes of erosion and deposition. In previous investigations, the factors which affect a stream's ability to erode have been studied. In this investigation you will see some of these factors in operation as well as observe how they affect the deposition of the eroded material in a model "lake."

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When you have finished this investigation, you should be able to:

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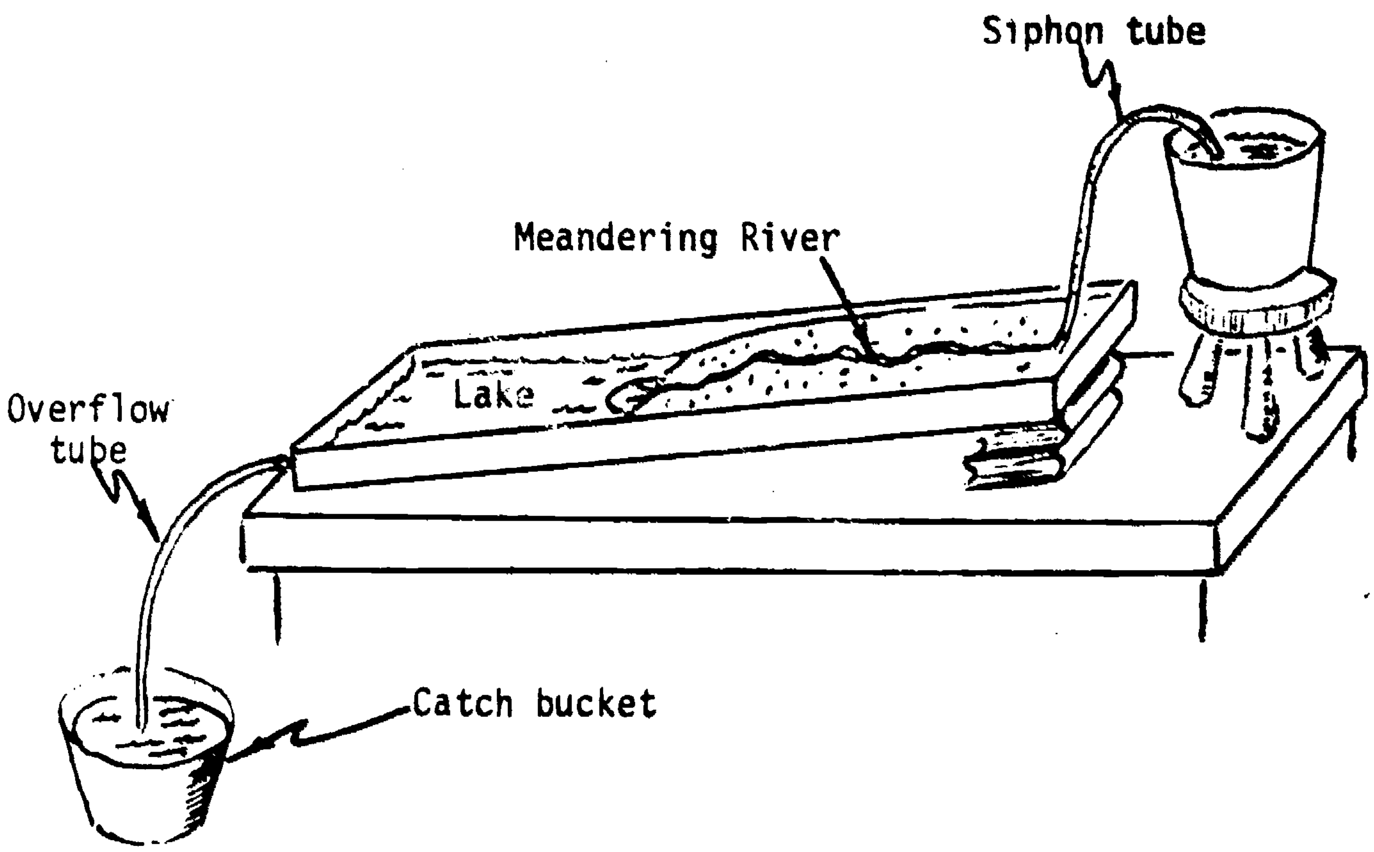

2. Observe and record changes that occur on the land surface, lake, stream itself, and depositional features.

3. Modify the slope of the stream, making it steep near the head and less steep near the mouth. Observe particle erosion and deposition patterns that develop along the stream.

4. Float a small folded piece of paper downstream, or place a few drops of food coloring in the water at the upstream end. Observe its velocity in comparison to grains of sand moving in the stream bed. Which best represents the velocity of the water? Observe the path of the paper or the coloring. Where does it go in relation to the channel walls, and the lake?

5. Select at random four small equal areas of the stream table. Determine what process (erosion or deposition) is dominant in each area.

QUESTIONS:

(A-1.41) 1. As the velocity of the water decreased which particles were deposited first?

(A-1.42) 2. As the slope of your stream decreased, what happened to the velocity of the water flowing in the stream? Describe the horizontal sediment depositional pattern that resulted.

(A-1.43) 3. How does the velocity of particles being transported downstream compare to the velocity of the water transporting them?

(B-1.11) 4. What changes occurred in the total system as a result of the erosional and depositional processes?

(B-1.21) 5. What is your analysis of the process acting in the four selected areas?

(B-1.31) 6. From a plane view of the stream table, where can a boundary be drawn separating areas of erosion from areas where deposition is taking place?

(B-1.41) 7. In what areas on your stream table is it difficult for you to decide which is occurring, erosion or deposition? What is the possibility that both processes are occurring simultaneously?

Easy (1)

X-A-1c: DENSITY CURRENTS

QUESTION:

What factors affect the deposition of particles in a medium?

MATERIALS:

Two plastic or pyrex glass columns joined together, graduated cylinder (50 ml.), two small test tubes, two beakers, (100-250 ml.), grease pencil, timer or watch with second hand, fine sand (1 cubic centimeter), two ringstands, two swivel tube clamps, astrolabe, fine sand and clay (potter's clay from art department works well) mixture (100 grams), graph paper.

SUGGESTED APPROACH:

1. Advanced preparations:

   a. Prepare the two slurries to be used in the investigation:

      *#1 - one part fine sand and clay to two parts water

      *#2 - one part fine sand and clay to four parts water

      Label each slurry with the appropriate proportions.

   b. To save time, the apparatus may be set up prior to the students coming to class.

2. Have the students follow the directions on the student sheets and complete the investigation.

PRECAUTIONS:

1. Be sure the glass tubes used are not the breakable type.
2. The slope of the column should be between 10 and 15 degrees; lower slopes may be necessary if a shorter column is used.
3. Make sure all stoppers and clamps are tightly secured.
4. All slurries must be well agitated when density measurements are made and while being poured into the column.
5. Students should organize themselves so that each knows his responsibility before starting the investigation.
6. This model of a density current serves only to demonstrate what a density current is, but does not really illustrate how a real density current operates. A real density current can be triggered by a very small event such as a sea animal burrowing into the sand on a steep underwater slope. As loose sand begins to mix with the water, a density current forms and begins, slowly at first, to move down slope. As it continues, more sediments are stirred up and the current increases in density, and therefore in velocity, until a major density current able to transport coarse sediments far out to ocean basins is formed. When it reaches a broad, flat area on the ocean bottom, the decrease in slope begins to slow down the velocity of the current and eventually the sediments settle out in the quiet water.

TYPICAL RESULTS:

In the past, this investigation has proved very effective in illustrating the concept of density currents and the important role they play in distributing large sediments on certain portions of the ocean floor.

MODIFICATIONS:

1. Position a plastic tube as described on the student sheet. Fill the tube 1/3 full with a dense solution of salt water. Add fresh water, being careful to maintain the interface between the two. Add a clay slurry and observe what happens when it reaches the salt-fresh water interface. This can be used as a demonstration after the above investigation is completed.

REFERENCES:

Sand, Scientific American (reprint) by P.H.H. Kuenen.

X-A-1c: DENSITY CURRENTS

QUESTION:

What factors affect the deposition of particles in a medium?

INTRODUCTION:

Geologists have found coarse sediments on the ocean floor far from shore but near the mouths of submarine canyons. They have attributed these sediments to "density currents" coming from the continental shelf. In this investigation you will have an opportunity to create a model of a density current and seek an answer to the question, "Could density currents actually carry these coarse sediments that far out to sea?"

OBJECTIVES:

When you finish this investigation,you should be able to:

1. explain the probable mode of transport and deposition for the coarse grained sediments found in the deep ocean basins.

METHOD:

1. Position the plastic tube at an angle of 10 - 15 degrees with the table top. Make sure it is adequately supported and that the bottom cap is on tight. Fill the tube with water (this can be done using a bucket of water and siphon). Make sure you leave enough room in the tube to allow three test tubes of water to be added without spilling over.

2. Prepare slurry #1, unless your teacher has already done so. Either measure or estimate its density and record it. Stir the slurry until it is well mixed and then fill a test tube 1/2 full with it. Shake the test tube well and quickly pour its contents into the plastic tube of water. Mark the distance the slurry travels in 5 second intervals (use a grease pencil and mark directly on the plastic tube). Measure these distances and record them. Examine and record your observations of the materials that settle along the bottom.

3. Empty the contents of the tube; rinse with clear water; replace the bottom cap tightly, and repeat the procedure with slurry #2.

4. Prepare a graph showing the relationship between relative density of the slurry and average velocity of the density current.

QUESTIONS:

1. What is the order by density of the two slurries and tap water?

2. How do you account for the differences in d ,sities?

3. What variations did you notice in the rate of movement of slurry #1?

4. What variations did you notice for slurry #2?

(A-1.43) 5. From your graph, what is the relationship between the densities of the two slurries and their average velocities?

6. If you had an infinitely long tube, which slurry would travel the farthest in a given time? Why?

(A-1.41) 7. Your investigation differed from a real density current in one very important way. A real density current moves over an ocean bottom containing loose sediment, as a result, it stirs up these sediments and the current increases in density as it moves. Did your density current increase as it moved down the tube? If the density of a real density current increases as it continues along its path, what would happen to its velocity? What would happen to the amount of sediment being carried? What would finally act to slow this down and eventually let the sediments settle to the bottom again? Which particles would settle out first?

8. If you were to vary the angle of the tube from 15 to 12 to 9 to 6 degrees and use slurry #1, what would a graph of angle of slope versus average velocity look like? (Draw a rough sketch.)

9. From your graphs and observations, do you think that density currents are the cause of the coarse sediments on the ocean floor? Explain.

(B-1.51) 10. What are the energy characteristics of a density current in motion? Where did the energy originate?

(B-1.52) 11. When the energy of the system is depleted, what will happen to the sediment?

topic XI

How Are Rocks Formed?

Time Emphasis: 12 days

	INVESTIGATION		A-1a	B-2a	B-2b	C-1a	C-2a	FE - #4
	Estimated Time (Periods)		1	3	2	1	1	FE
TOPIC OUTLINE	**A. Rocks and sediments**							
	A-1 Comparative properties	*What Similarities Do Rocks Have to Sediments?*						
	A-1.1 Similarities	A-1.11	■					
	A-1.2 Differences	A-1.21	■					
	B. Minerals							
	B-1 Relation to rocks	*What Is the Composition of Rock?*						
	B-1.1 Composition	B-1.11	■					■
		B-1.12	■					
		B-1.13	■					■
	B-2 Characteristics	*What Are Some Characteristics of Minerals?*						
	B-2.1 Physical, chemical properties	B-2.11	■	■				
	B-2.2 Chemical composition	B-2.21		■				
		B-2.22						
	B-2.3 Structure	B-2.31			■			
		B-2.32			■			
	C. Rock formation							
	C-1 Sedimentary rocks	*How Are Sedimentary Rocks Formed?*						
	C-1.1 Compression cementation	C-1.11				■		
	C-1.2 Chemical processes	C-1.21				■		
	C-1.3 Biological processes	C-1.31				■		
	C-2 Nonsedimentary rocks	*How are Nonsedimentary Rocks Formed?*						
	C-2.1 Solidification process	C-2.11					■	
		C-2.12					■	
	C-2.2 Recrystallization process	C-2.21						
	C-3 Environment of formation	*What Is the Environment in Which a Rock Forms?*						
	C-3.1 Inferred characteristics	C-3.11						
	C-3.2 Distribution	C-3.21						
		C-3.22						
	D. Rock cycle							
	D-1 Evidence	*What Evidence Suggests a Cyclic Model of Rock Formation?*						
	D-1.1 Transition zones	D-1.11						
	D-1.2 Rock composition	D-1.21						
		D-1.22						
PROCESS OF INQUIRY OBJECTIVES	Mathematical Skill	PIO-1						
	Measurement Skill	PIO-2						
	Creating Models	PIO-3			■	■	■	
	Analysis of Error	PIO-4						
	Data Analysis	PIO-5	■	■				
TITLES	Multimedia: Check Multimedia Section of Supplement for Reference to This Topic		Rock Properties	Properties of Minerals	Structure of Minerals	Formation of Sedimentary Rocks	Formation of Nonsedimentary Rocks	Cemetery

Easy (1)

XI-A-1a: ROCK PROPERTIES

QUESTION:

What similarities do rocks have to sediments?

MATERIALS:

Each group of two students should have a piece of coarse-grained granite with clearly distinguishable minerals (preferably pink feldspar, quartz, and black mica); a crushed sample of the same granite; about 15 rock samples including both sedimentary and nonsedimentary types (e.g., sandstone, limestone, shale, conglomerate, basalt,granite, gabbro, obsidian, banded gneiss, schist, slate, marble, and quartzite); a sample of sand or gravel; magnifying glasses; and a teasing needle. (It may be convenient to prepare permanent kits of the above items and place each in a shoebox.)

SUGGESTED APPROACH:

Part I Have the students observe their rock samples and describe them. This can be accomplished by having an individual describe a rock, then ask the other students to hold up the rock sample they think is being described. Repeat this several times and place a master list of the various terms used to describe the rocks on the chalkboard. Ask students to indicate which of the terms on the master list best describe rocks; underline or circle these. Most of these will be textural terms that describe the way individual parts of the rocks are put together.

Conduct a concluding discussion exphasizing the following:

a) Some rocks have characteristics that are very similar to loose sediments (these are called sedimentary rocks). Other rocks have different, but distinctive, characteristics (these are called nonsedimentary rocks).

b) All rocks are composed of minerals, most having more than one mineral present.

Have the students examine the loose gravel (using their hand lenses) and compare the material with the material composing their rock samples. Have them identify any similarities and differences.

Part II Ask students to observe the granite specimen carefully. Is it composed of one, or more than one, kind of mineral?

Have the students examine their sample of crushed granite and divide the pieces into piles of similar materials. Have them make a list of terms that describe how the various rock pieces (minerals) look.

PRECAUTIONS:

1. Students are not expected to learn rock and mineral names, they should, however, learn to recognize sedimentary rocks as opposed to nonsedimentary rocks.

2. It is best to use local rocks and minerals whenever possible, so that the student will be familiar with his local rock types.

ERIC

BACKGROUND INFORMATION:

ROCK AND MINERAL EXCHANGE SERVICE

Teachers interested in swapping rocks, minerals, fossils, and earth science curriculum materials are hereby notified that a clearinghouse for the exchange of earth science materials has been established in McFarland, Wisconsin.

To take advantage of this free, voluntary service, send a list (size and quantity) of the rocks, minerals, fossils, and earth science curriculum materials YOU NEED, along with a list (size and quantity) of the rocks, minerals, fossils, and earth science curriculum materials YOU CAN SWAP, to: J. E. Wall, RMES, c/o Science Department, McFarland High School, McFarland, Wisconsin 53558.

You will be supplied with the names and addresses of those science teachers who can supply your needs on a SWAP basis. To receive additional RMES "Swap Sheets," send a stamped, self-addressed envelope (business size) to the RMES.

Due to the free, voluntary nature of the RMES, only those inquiries accompanied by stamped, self-addressed envelopes will be processed.

Sample RMES "Swap Sheet"

ROCK AND MINERAL EXCHANGE SERVICE

Your name ________ Your home address ________
School name ________ City & Zip Code ________
Street ________
City & Zip Code ________ RMES Code Number ________

I OFFER FOR TRADE (size & quantity):	I NEED (size and quantity):

REFERENCES:

Investigating the Earth, pp. 39-42, 48-50, 332; Teacher's Guide pp. 70-74, 76-77, 87-88, 89-90, 409-411.

XI-A-1a: ROCK PROPERTIES

QUESTION:

What similarities do rocks have to sediments?

INTRODUCTION:

If you were to examine the pebbles or boulders found near a river bank, in a road cut, or at a construction site, you would probably notice the wide variety of types present. If you were to travel to different places around the State or the country you would notice many similarities and differences among the rocks you observed. Since there are potentially an unlimited number of differences among rock samples, scientists find it convenient to group them on the basis of certain characteristics.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. describe the characteristics of sedimentary and nonsedimentary rocks.

2. describe the characteristics of rock components (minerals).

METHOD:

Part I Study your rock samples closely and describe their properties. Check your descriptions by verbally describing one of your rocks and asking your fellow students to hold up their sample of the same rock. If they cannot, then you need to work more on your description. You or your classmates may want to place a master list of terms used to describe rock samples on the chalkboard.

Next, examine the loose gravel with a hand lens and compare it to the rock samples. Place in a pile all those rocks which are composed of one or more of the same types of materials observed in the gravel. Place all the other rocks in another pile. Make a list of all the identifying characteristics of the rocks in each pile.

Part II In part one, you probably recognized that most rocks are composed of small grains. Examine the rock specimen called granite, and then look at the crushed sample of granite. Separate the crushed materials into piles of materials having similar properties (minerals). Describe the characteristics of each pile. Decide which was easier to describe, the piles of minerals or the rocks in part I.

ERIC

QUESTIONS:

(A-1.11) 1. Describe the properties that you observed in the rocks that contained particles similar to those in the gravel sample. What are these kinds of rocks called?

(A-1.21) 2. Describe the properties of the rocks that did not appear similar to the gravel particles. What are these rocks called?

(B-1.11)
(B-1.12) 3. Describe the minerals that you were able to observe in more than one rock. List the number of different minerals you were able to observe in each of your rock samples.
(B-1.13)

(B-1.11)
(B-1.12) 4. Which was easier to describe, the piles of minerals or the rocks in part I? Explain why.
(B-1.13)
(B-2.11)

ERIC

Easy (3)

XI-B-2a: PROPERTIES OF MINERALS

QUESTION:

What are some characteristics of minerals?

MATERIALS:

Samples of some important rock-forming minerals (e.g., quartz, feldspar, hornblende, mica, magnetite, calcite, hematite, etc.) and any minerals of local significance, balance, graduated cylinder, streak plate, nail, glass plate, penny, dilute HCl, and supplementary sheets 1-3.

SUGGESTED APPROACH

1. Discuss with the students the various tests you wish them to perform. Some, such as color and density, should need little discussion while others, such as hardness, streak, and acid test, will need more.

2. Provide students with a mineral identification chart (See Supplementary Sheets) and several mineral samples.

3. Have students attempt to identify the samples. Stress that in some cases they may only be able to limit their identification to several possibilities. (This will be governed by the number of different tests and the number of minerals on the identification chart.)

PRECAUTIONS:

1. It is the process of identification of minerals NOT the actual identification that is of importance in this investigation. Students often form the impression that all samples of a given mineral have a similar appearance to the sample they have worked with. Point out that this is not always the case.

2. If your students use pieces of window glass to determine hardness, make certain that they place the glass flat on the table and scratch it with the mineral specimen. Never have them attempt to scratch the mineral specimen with the glass, since small particles of glass may break and cause injury.

REFERENCES:

Investigating the Earth, p. 575

ERIC

XI-B-2a: PROPERTIES OF MINERALS

QUESTION:

What are some characteristics of minerals?

INTRODUCTION:

Scientists have distinguished several thousand mineral species. Many are quite rare. A few together constitute 99 percent of all the minerals found in the earth's crust. Each mineral has a distinct composition and structure, however, for practical purposes most can be identified by observing a few of their basic properties. In this investigation, you will study some basic properties of minerals and use these properties to identify the particular mineral.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. make observations and perform tests to determine some mineral properties such as color, density, hardness, streak, etc.

2. identify some common minerals by observing their properties and using a mineral reference table.

3. identify some of the most abundant elements found in minerals.

METHOD:

1. Obtain a set of minerals for identification, and run the tests indicated by your instructor. Use a table to record the results of your tests (Supplementary Sheet #3).

2. Using a mineral identification table, identify the minerals based upon the results of your tests.

QUESTIONS:

(B-2.11) 1. Did any two of the minerals you tested yield the same results for all tests? If not, do you think that, given additional samples of different minerals, this could happen? Explain.

ERIC

2. Of the general properties you tested which do you think are most reliable? Least reliable? Explain.

3. Do you think that different samples of the same mineral could yield different results for any of the tests you constructed? If so, which tests?

(B-2.21) 4. Refer to your identification chart and make a list of all the different elements found in the minerals studied. Indicate how many different minerals each element appeared in. Which elements appear to be quite abundant?

ERIC

(MINERAL IDENTIFICATION CHART)

Luster -- The way a mineral's surface appears in reflected light.
Streak -- The color of a fine powder of the mineral - usually rubbed on a streak plate.
Hardness: Soft - can be scratched by your fingernail; medium - cannot be scratched by fingernail but can be scratched by a piece of window glass; hard - cannot be scratched by a piece of window glass.

MINERAL NAME AND COMPOSITION	COLOR	WAY IT BREAKS	LUSTER	STREAK	HARDNESS	OTHER CHARACTERISTICS
Quartz SiO_2	white, gray, pink	shell-like	glassy	white	hard	translucent
Feldspar $KAlSi_3O_8$	white, pink, green	uneven	glassy, pearly	white	hard	translucent on edges
Calcite $CaCO_3$	all colors	Splits into forms like bent over cubes	glassy, dull	white	medium	transparent to opaque - bubbles in HCl
Mica $K(Mg,Fe)_3(OH_1F)_2$-$AlSi_3O_{10}$	black to brown or colorless	splits into thin sheets	glassy, pearly	white	medium	Elastic, transparent thin sheets, flexible
Hornblende $Ca_2(Mg,Fe)_5(OH)_2$-$(Al,Si)_8O_{22}$	black to green	uneven splinters	glassy	dark green	hard	long 6-sided crystals
Garnet $Fe_3Al_2(SiO_4)_3$	red to black	uneven	waxy to glassy	white	hard	brittle, rounded, translucent
Olivine $(Mg,Fe)_2SiO_4$	yellow-black	uneven	pearly-glassy	pale green	hard	granular masses, sugary, glassy grains
Talc $Mg_3(OH)_2Si_4O_{10}$	white, light green	splits smooth in one plane	pearly-glassy	white to green	soft	greasy feel, foliate foliated, massive
Magnetite Fe_3O_4	black	uneven	metallic	black	hard	magnetic, brittle, heavy
Hematite Fe_2O_3	red to black	uneven	metallic to dull	red-brown	hard	brittle, opaque, never in crystals
Limonite $HFeO_2$	yellow, brown	shell-like	dull	yellow-brown	soft to hard	earthy, dull, brittle
Malachite $Cu_2(OH)_2CO_3$	green	fibrous	dull	light green	medium to hard	bubbles in acid (HCl)
Azurite $Cu_3(OH)_2(CO_3)_2$	blue	fibrous	glassy	light blue	medium	bubbles in acid, ore of copper
Cassiterite SnO_2	red-brown	uneven	dull	white-brown	hard	heavy rounded masses ore of tin

ERIC

(MINERAL IDENTIFICATION CHART)

Luster -- The way a mineral's surface appears in reflected light.
Streak -- The color of a fine powder of the mineral - usually rubbed on a streak plate.
Hardness: Soft - can be scratched by your fingernail; medium - cannot be scratched by fingernail but can be scratched by a piece of window glass; hard - cannot be scratched by a piece of window glass.

MINERAL NAME AND COMPOSITION	COLOR	WAY IT BREAKS	LUSTER	STREAK	HARDNESS	OTHER CHARACTERISTICS
Sphalerite ZnS	brown to black	splits into shiny surfaces	waxy	light	medium to hard	brittle, ore of zinc
Galena PbS	gray to black	splits into cubic forms	metallic	gray to black	medium	cubic crystals, ore of lead, heavy
Bauxite $Al(OH)_3$	red to brown	uneven	dull	red to brown	soft to medium	lumpy appearance, massive, odor of wet clay when wet, ore of aluminum
Sulfur S	yellow	shell-like	greasy	white	medium	crackles in heat of hand, brittle
Gypsum $CaSO_4 \cdot 2H_2O$	colorless to white or gray	brittle	pearly to dull	white	soft	used for wallboard and plaster
Graphite C	dark gray to black	splits in one plane	dull opaque	black	soft	used in lead pencils
Pyrite FeS_2	brass-yellow	uneven	metallic opaque	greenish-black	hard	called fool's gold
Asbestos Mg[illegible](OH) Si[illegible]O[illegible]	white to greenish-white	fibrous	silky	white	soft	used to make heat-insulating cloth
Corundum Al_2O_3	yellow-brown	uneven	dull	white	very hard	next in hardness to diamond
Kaolin $Al_4(OH)_8Si_4O_{10}$	white	earthy	dull	white	very soft	used as a clay to make pottery
Fluorite CaF_2	colorless to purple	brittle	transparent to translucent	white	medium	some forms fluoresce under ultraviolet lamp
Halite $NaCl$	colorless	blocky	glassy	white	soft	tastes salty.

ERIC

STUDENT WORKSHEET

MINERAL NAME	COLOR	WAY IT BREAKS	LUSTER	STREAK	HARDNESS	OTHER CHARACTERISTICS

Challenging (2)

XI-B-2b: STRUCTURE OF MINERALS

QUESTION:

What are some characteristics of minerals?

MATERIALS:

Fifteen 1½-inch styrofoam spheres and four ½-inch styrofoam or plastic spheres per group, pipe cleaners, silicate mineral samples (quartz, feldspar, olivine, mica, hornblende, asbestos, etc.), a halite specimen of approximately 2 cubic centimeters, steel knife or scalpel, clay, and a hammer.

SUGGESTED APPROACH:

Part I

1. Discuss with students the relative abundance of silicon and oxygen in the earth's crust.
2. Have students attempt to build a silicon-oxygen tetrahedron and, having done so, have them attempt a double tetrahedra and then a chain of tetrahedra.
3. Construct for the students, or illustrate with a diagram, a double chain and a sheet of tetrahedra.
4. Ask the students what forms they think the minerals would have if the minerals had the various structures that have been considered.
5. Give students samples of silicate minerals that show good crystal form, and ask them to suggest tetrahedral structures for each.

Part II

1. Have the students split a halite specimen, or do it yourself as demonstration. Relate this to the idea of diamond "cutting."
2. Have the students construct a model, using the styrofoam balls, that would explain why halite can be split.

PRECAUTIONS:

1. Construction of double chain and sheet silicate models is difficult, and it is suggested that the instructor practice making them before attempting them with a class.
2. Safety precautions should be discussed and followed to prevent the students from cutting themselves when splitting halite.

TYPICAL RESULTS:

Students will usually construct several incorrect models of the tetrahedron before obtaining the correct one.

MODIFICATIONS:

Give the students prepared models of mineral structures, and have them suggest a form for that mineral's appearance.

REFERENCES:

Investigating the Earth, p. 50, Teacher's Guide, p. 74, pp. 77-82.

XI-B-2b: STRUCTURE OF MINERALS

QUESTION:

What are some characteristics of minerals?

INTRODUCTION:

Some mineral samples appear to have regular or crystal forms. Scientists have found through X-ray studies that these samples have a regular atomic arrangement. In fact, all minerals have, at least to some extent, a regular arrangement. In this investigation, you will be studying models that scientists have constructed for some of the silicate (silicon-oxygen) minerals. You will also investigate a non-silicate mineral (halite).

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. construct a physical model of a silicon-oxygen tetrahedron and justify that model as opposed to other possible arrangements.

2. construct and explain a physical model that shows how silicon-oxygen tetrahedra join by sharing oxygen atoms.

3. given a silicate mineral in crystal form, suggest a possible arrangement of the tetrahedra.

4. construct a model of the molecular arrangement of a mineral having examined its splitting pattern and crystal shape.

METHOD:

Part I

1. Take four of the large spheres (oxygen atoms) and one of the small spheres (silicon atom) and put the five into as compact an arrangement as possible. Check your model with your instructor before proceeding.

2. Build a second model in the same way as the first. Now join the two tetrahedra in such a way as to share one oxygen.

3. Try to build a chain of tetrahedra.

4. Examine the silicate mineral samples that your instructor will provide and see if you can suggest an appropriate atomic structure for each.

Part II 1. Take a large crystal of halite, fasten it to a lump of clay, and split it with a knife in a particular direction. (The best technique for this is to place the blade on the crystal and tap it gently with a hammer.) Describe what you observe.

2. Try cutting the crystal (as above) in various other directions, and describe what you observe.

3. Stack the styrofoam balls to resemble your idea of the atomic structure of a halite crystal, based upon what you observed in steps 1 and 2.

QUESTIONS:

Part I (B-2.31) 1. What is the ratio of silicon atoms to oxygen atoms in a simple tetrahedron? In a double tetrahedron? In a single chain of tetrahedra?

2. If a mineral has a structure of chains of tetrahedra, what do you think holds the chains together?

(B-2.32) 3. Why do you think the mineral mica breaks the way it does?

Part II 1. Draw a sketch of the model you constructed to represent the structure of halite.

(B-2.32) 2. Why does halite split with a plane surface only in certain directions?

(B-2.32) 3. How do you think the atoms would be arranged in a mineral that did not split with any plane surface.

Easy (1)

XI-C-1a: FORMATION OF SEDIMENTARY ROCKS

QUESTION:

How are sedimentary rocks formed?

MATERIALS:

Sediment (sand, pebbles, dirt, etc.), sugar, salt, Portland cement, epoxy, glue, plaster of paris, dilute HCl, samples of sedimentary rock (sandstone, shale, limestone, conglomerate), paper or plastic cups, glass bottles or beakers, and one or more of the following (alum, potassium nitrate, sodium nitrate, potassium permanganate, copper sulfate).

SUGGESTED APPROACH:

1. Since students will have already considered how sediments are formed, ask them how they think these sediments might be converted, in nature, into rocks. Ask them if they can think of any ways in which sedimentary rocks can be formed other than from sediments.

2. Have the students devise and perform procedures for making "sedimentary rocks" in the laboratory. It may be wise to have them clear procedures with you before proceeding.

3. Have the students grow some "sedimentary rock" crystals from a saturated water solution, using one or more of the salts listed under materials above. This can be done by dissolving as much of the salt as possible in a beaker or jar filled with warm water. Place the jar in a position where it can be left undisturbed for a few days. The crystals will "grow" on the bottom of the jar.

4. In a class discussion, examine the results of the students' efforts.

5. Give students the sedimentary rocks for examination. Discuss their interpretations. Stress the processes of cementation, compaction, and solution.

6. This investigation can be concluded by showing the EB film "Rocks That Form on the Earth's Surface."

PRECAUTIONS:

1. Care must be taken in relating the processes the students use in the laboratory to make sedimentary rocks to the processes active in nature. In some cases, the model may not be a very good approximation to what happens in nature.

2. Some of the chemicals mentioned should be used with caution.

TYPICAL RESULTS:

Since much attention previously has been given to sediments, students will most likely devise procedures that employ cementation and compaction. Less likely to be devised is the process of crystal growing, therefore, this may have to be suggested by the teacher.

MODIFICATIONS:

1. Give students several samples of artificially prepared "sedimentary rocks" and ask them to tell how they were made. They should still be given, however, some real sedimentary rocks to examine.

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2. A fishline or piece of nyl can be suspended in the saturated solution (crystal-growing exercise) to act as a support on which crystals will develop.

REFERENCES:

A Sourcebook for the Physical Sciences, pp. 64-65.
Crystals and Crystal Growing, Alan Holden, Science Study Series

XI-C-1a: FORMATION OF SEDIMENTARY ROCKS

QUESTION:

How are sedimentary rocks formed?

INTRODUCTION:

You have already considered how sediments may be formed in nature. The appearances of many rocks found in nature suggest that they may have been formed from sediments. Such rocks are called sedimentary rocks. While many sedimentary rocks are formed from sediments, there are some processes for forming sedimentary rocks that do not require sediments.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. describe the ways in which sedimentary rocks may form.
2. describe how a given sedimentary rock sample may have formed.

METHOD:

1. Devise some procedures for making "sedimentary rocks." Check your procedures with your instructor, and then try them.
2. When you have completed step 1, your instructor will give you some sedimentary rocks to examine. Describe how you think these rocks might have formed in nature.

QUESTIONS:

(C-1.11) 1. Describe the basic processes by which sediments are changed into sedimentary rocks.

(C-1.21) 2. Some sedimentary rocks do not originate from loose sediment; describe how these rocks may form.

3. Relate the procedures you used in step 1 above to similar processes in nature. How were they similar? different?

4. Do you think that different sedimentary rock forming processes could produce similar rocks?

5. Can you tell from examining a sedimentary rock, where it was formed (e.g. river channel, river delta, lake bottom, ocean floor, etc.)? If so, try to apply this to some of the rock samples?

6. Geologists sometimes use the expression "story in the rocks." How do you think this might apply to the rocks you have examined?

(C-1.21) 7. Describe the relationship between crystallization and sediment changing into rocks.

(C-1.31) 8. Is there any evidence of biologic formation in any of the sedimentary rocks that your teacher has provided for your observation?

Easy (1)

XI-C-2a: FORMATION OF NONSEDIMENTARY ROCKS

QUESTION:

How are nonsedimentary rocks formed?

MATERIALS:

Salol, heat source (e.g., stage on overhead projector, hot plate, Bunsen burner, etc.) microscope slides, petri dishes, stereo-microscopes or hand lenses.

SUGGESTED APPROACH:

1. Discuss with the students some possible ways that nonsedimentary rocks may form.
2. Have the students attempt one or more of the techniques for growing crystals from a melt.
3. Have the students design and carry out an investigation to determine what affect cooling rate has on crystal size.
4. Have the students observe some nonsedimentary rocks using the stereo-microscope or hand lens, and infer probable cooling rates.
5. In a concluding discussion, have the students relate what they have done in this investigation to the actual earth processes that form nonsedimentary rock.

TYPICAL RESULTS:

Possible techniques for growing crystals include:

1. Placing small amount of salol on a microscope slide, melt it, and observe crystal formation as cooling occurs.
2. Melt a small quantity of salol, transfer it to a glass petri dish, and place it on the stage of an overhead projector. As cooling occurs, the crystal-growing process can be projected on a screen. (Note: The microscope slide cannot be used for this technique because the heat from the projector lamp will prevent cooling from occurring.)
3. Different cooling rates may be observed by:
   A. Placing a petri dish containing an ice cube on the stage of the stereo-microscope. Place the slide containing the melted salol on the ice cube and observe the rapid cooling.
   B. Place stereo-microscopes at different temperature locations around the room (e.g., near radiators, near a cold window, etc.). Allow students to observe cooling under first one, and then another, of the microscopes.

XI-C-2a: FORMATION OF NONSEDIMENTARY ROCKS

QUESTION:

How are nonsedimentary rocks formed?

INTRODUCTION:

Many rocks are not composed of particles that resemble loose sediment. These rocks often resemble a mass of tiny intergrown crystals. When examined closely, a wide range in crystal sizes may be observed. What factors influence the development of these characteristics in certain rocks?

OBJECTIVES:

When you finish this investigation, you should be able to:

1. identify crystalline rocks as probably being of nonsedimentary origin.
2. describe the relationship between cooling rate of a melt and the resulting crystal size.
3. explain possible earth processes that may result in the formation of nonsedimentary rocks.

METHOD:

1. Place a small amount of salol powder on a microscope slide. Hold the slide over a heat source until the salol melts. (Caution - if the heat source temperature is too high it may break the slide.)
2. Observe the liquid salol under a hand lens or stereo-microscope as it undergoes cooling. Describe what you see.
3. Devise a method for investigating the relationships between the size of the crystals and the rate at which the melt cools.

QUESTIONS:

(C-2.11) 1. How do some nonsedimentary rocks form?

(C-2.12) 2. Describe at least one factor that influences the size of the crystals formed.

topic XII

How Are Changes in the Earth's Crust Produced?

Time Emphasis: 13 days

TOPIC OUTLINE

INVESTIGATION		A-1a	A-2a	A-2b	A-2c	B-2a	D-1a
Estimated Time (Periods)		1	2	2	2	2	2
A. Evidence for crustal movement							
A-1 Minor crustal changes	*What Evidence Suggests Minor Changes in the Earth's Crust?*						
A-1.1 Deformed rock strata	A-1.11	■		■			
A-1.2 Displaced fossils	A-1.21	■					
	A-1.22						
A-1.3 Displaced strata	A-1.31						
A-2 Major crustal changes	*What Evidence Suggests Major Changes in the Earth's Crust?*						
A-2.1 Zones of crustal activity	A-2.11		■				
A-2.2 Geosynclines	A-2.21			■			
	A-2.22			■			
A-2.3 Vertical movements	A-2.31						
A-2.4 Ocean floor spreading	A-2.41				■		
	A-2.42				■		
A-2.5 Continental drift	A-2.51						
	A-2.52						
A-2.6 Magnetic poles	A-2.61				■		
B. Earthquakes							
B-1 Wave properties	*What Are Some Properties of Earthquake Waves?*						
B-1.1 Types of waves	B-1.11					■	
B-1.2 Velocities	B-1.21					■	
	B-1.22						
B-1.3 Transmission	B-1.31						
	B-1.32						
B-2 Location of an epicenter	*How Can the Epicenter of an Earthquake Be Located?*						
B-2.1 Epicenter	B-2.11					■	
B-2.2 Origin time	B-2.21					■	

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		A-1a	A-2a	A-2b	A-2c	B-2a	D-1a
INVESTIGATION		A-1a	A-2a	A-2b	A-2c	B-2a	D-1a
Estimated Time (Periods)		1	2	2	2	2	2
TOPIC OUTLINE							
C. Model of the earth's crust and interior							
C-1 Properties	*What Are Some Properties of the Earth's Crust And Interior?*						
C-1.1 Solid and liquid zones	C-1.11						
C-1.2 Crustal thickness	C-1.21		■				■
C-1.3 Crustal composition	C-1.31						
C-1.4 Density, temperature, and pressure	C-1.41						
C-1.5 Interior composition	C-1.51						
	C-1.52						
D. Theories of crustal change							
D-1 Inferred processes	*What Inferences Can Be Drawn About the Processes Which May Cause Crustal Changes?*						
D-1.1 Mantle convection cells	D-1.11						■
D-1.2 Geosynclinal development	D-1.21						■
D-1.3 Isostasy	D-1.31						■
D-1.4 Process relationships	D-1.41		■				
PROCESS OF INQUIRY OBJECTIVES							
Mathematical Skill	PIO-1		■			■	
Measurement Skill	PIO-2					■	
Creating Models	PIO-3	■	■	■		■	■
Analysis of Error	PIO-4					■	
Data Analysis	PIO-5		■	■		■	■
TITLES	Multimedia: Check Multimedia Section of Supplement for reference to this topic.	Evidence of Crustal Movement	Earthquake Watch Analysis	James Hall's Field Trip	The Spreading Sea Floor	Location of an Epicenter	Field Trip Through the Mountains

Easy (1)

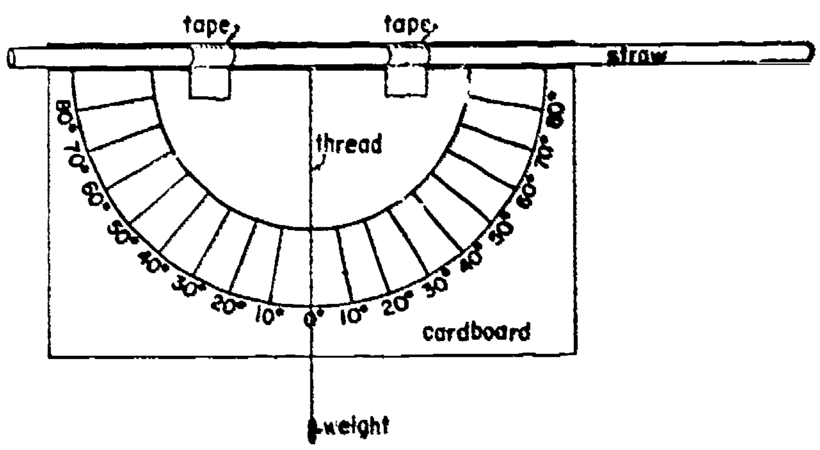
XII-A-1a: EVIDENCE OF CRUSTAL MOVEMENT

QUESTION:

What evidence suggests minor changes in the earth's crust?

MATERIALS:

Color slides and other photographs; specimens of small folds, faults, fossils; geologic maps of New York State and the U. S.; topographic maps; simple compass (for measuring strike); simple clinometer (for measuring dip). See below:



SUGGESTED APPROACH:

1. Students should observe actual evidences of crustal movements in the local area. This is possible in many areas of New York State. Then, these first-hand observations may be supplemented by pictures, specimens, and maps.

2. Conduct a postlab discussion considering such questions as:

   a) Which of the observed changes were rapid? Which were slow?

   b) Did any of the observations lend themselves to more than one interpretation? How could you determine which of the interpretations were most accurate?

PRECAUTIONS:

Try to choose materials, both laboratory and field, that the students can interpret.

MODIFICATIONS:

In lieu of a field trip, plaster or clay models of folds, faults, etc., can be used. There is no substitute, however, for the real thing.

BACKGROUND INFORMATION:

1. Suggestions for field observations:

   a) Tilted rock layers (e.g., Hudson Valley, Orange County, along the Thruway between Utica and Albany, and between Albany and Suffern)

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b) Joints and faults

c) Fossils of marine organisms in rock now located high above sea level

d) Fault blocks (e.g., Lake George Valley, Highlands of the Hudson, The Noses fault in the Mohawk Valley, and areas in the Adirondacks)

e) Interviews with persons who remember earthquakes along the St. Lawrence Valley

2. Suggestions for laboratory investigations:

a) Observations of rock or mineral specimens exhibiting sharp folds

b) Rock or mineral specimens exhibiting joints that have been recemented together

c) Clay layers that can be folded by applying horizontal pressure

d) Photographic slides or movies showing field evidence of crustal movement

REFERENCES:

Geologic pamphlets by the U.S.G.S. or N.Y.S. Geologic Survey on the areas to be visited.

XII-A-2a: EARTHQUAKE WATCH ANALYSIS

QUESTION:

What evidence suggests major changes in the earth's crust?

INTRODUCTION:

Occasionally an earthquake occurs that causes widespread damage and is publicized in newspapers, on radio, and television. Earthquakes occur far more frequently than this, although most have a magnitude small enough so that little or no damage occurs. The frequency of occurence of earthquakes, and the areas most susceptible to them should become apparent when you have concluded this investigation.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. identify regions of high earthquake activity on a world map,
2. relate the world distribution patterns of earthquakes to patterns of volcanic activity and mountain ranges.
3. draw inferences from the pattern of earthquake focus depths and relate them to understandings of the thickness of the earth's crust.

METHOD:

1. Study your completed Earthquake Watch Maps carefully and outline, on your world map (supplementary sheet), areas of high earthquake activity.
2. Outline areas with rugged mountain systems.
3. In a resource book, find information concerning the active volcanic regions in the world, and outline these areas on your map.
4. On a standard size sheet of paper, sketch a coastal area of the world where earthquakes seem to occur frequently. Transfer from the Earthquake Watch Map to your sketch map the approximate locations of as many earthquakes as you are able. Use the following symbols to indicate depth:

   Shallow ---- •
   Intermediate *
   Deep ----- 0

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Easy (2)

XII-A-2a: EARTHQUAKE WATCH ANALYSIS

QUESTION:

What evidence suggests major changes in the earth's crust?

MATERIALS:

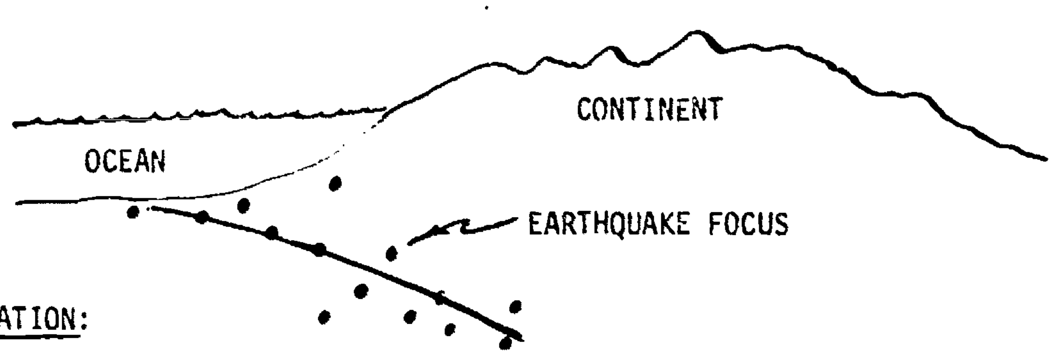
Completed earthquake watch data, blank world map (supplementary sheet), and student handout sheets.

SUGGESTED APPROACH:

1. Have the students study the completed Earthquake Watch Map and discuss any patterns of earthquake activity that they are able to observe.
2. Have them compare the earthquake patterns to the location of mountain ranges and volcanoes.
3. Have the students prepare a vertical cross section of the ocean-continent boundary. On the cross section, have them plot the depths of the earthquake focuses observed, and draw inferences from the pattern which develops.

TYPICAL RESULTS:

1. If a sufficient number of earthquakes is plotted, a clear pattern of the active earthquake belt should result (about 400-500 earthquakes plotted will accomplish this although fewer than 300 are sufficient to illustrate the basic trend).
2. A typical cross section, with depths plotted, should indicate that the earthquakes under continental areas tend to occur at a greater depth than those in oceanic regions. This may be interpreted as a zone of weakness along the crust-mantle interface. If actual depths are plotted, the cross section may look similar to the one below.



BACKGROUND INFORMATION:

The epicenter of an earthquake is the point on the earth's surface directly above the focus.

REFERENCES:

Investigation the Earth, pp. 318-319, Teacher's Guide, pp. 388-389.

XII-A-1a: EVIDENCE OF CRUSTAL MOVEMENT

QUESTION:

What evidence suggests minor changes in the earth's crust?

INTRODUCTION:

We tend to view our environment as being relatively unchanging. It is possible, however, to find evidence of change, even if the changes themselves are too slow to be seen. In this investigation, you will examine evidence in the field that suggests that at least portions of the earth's crust are undergoing change.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. identify and interpret evidence that suggests minor changes in the earth's crust.

METHOD:

1. Record any evidence in the area that suggests changes in the earth's crust. Make sketches or take notes since it may not be convenient to revisit the location.

2. Examine the additional information provided to you by your instructor about the area, and, using your field observations, draw interpretations regarding crustal change.

QUESTIONS:

(A-1.11) 1. Describe any evidence for folding, tilting, or faulting of rock strata that you were able to observe. From these observations draw inferences concerning the past history of the area.

(A-1.21) 2. What does the presence of marine fossils in rock found at high elevations suggest to you?

If you have the information available, you may want to write the actual depth next to the symbol. When you have plotted a number of locations (30-100), you should prepare a cross section of the area showing both the location and depth of the earthquake focuses. When you have plotted all your points, draw a line representing the average depth to the focuses as you cross the boundary between ocean and continent. Draw inferences from the pattern that evolves.

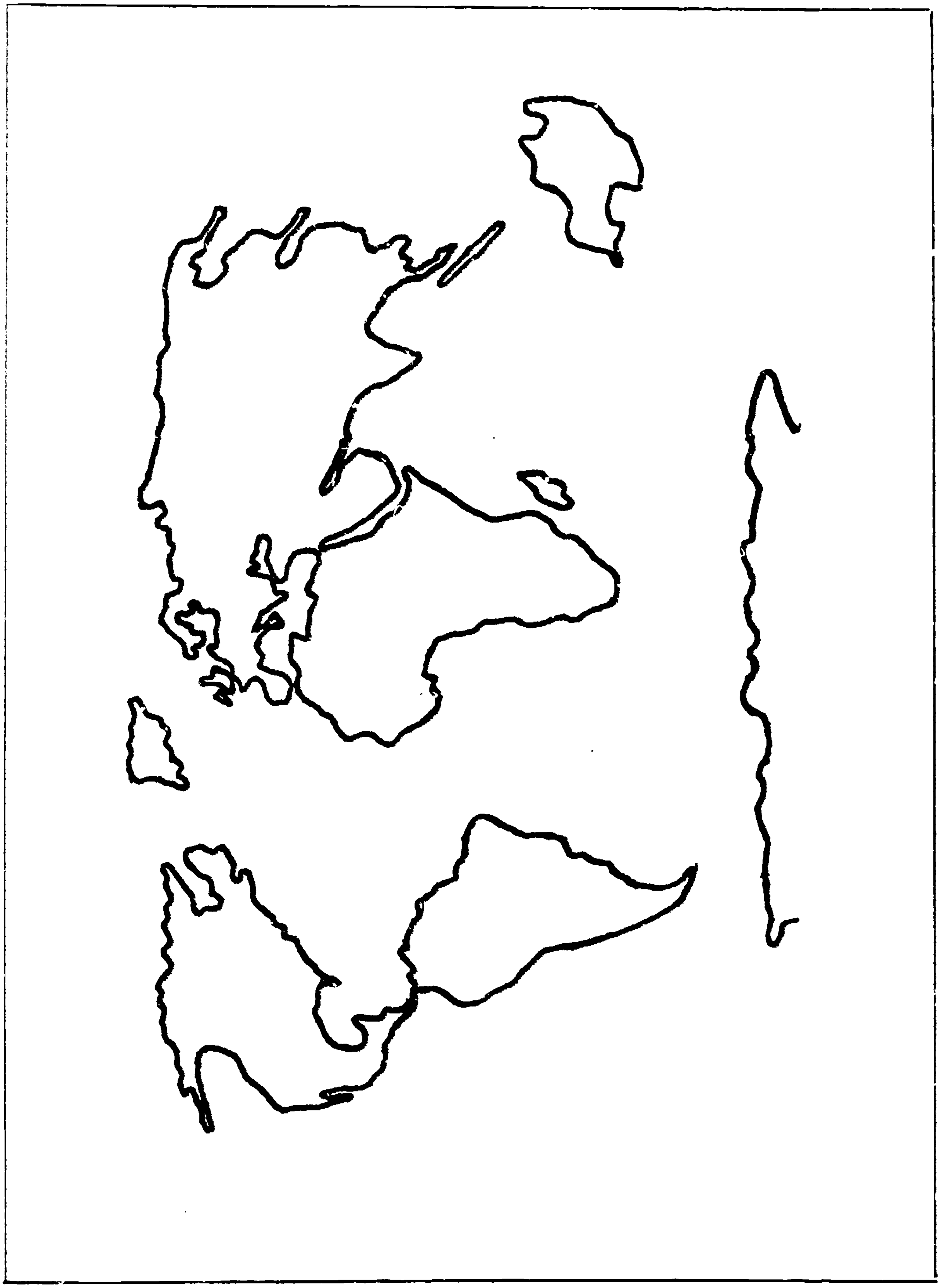
QUESTIONS:

(A-2.11) 1. Describe the zones on the earth's surface where frequent crustal activity can be expected.

(C-1.21) 2. If much of the earthquake activity occurs along the crust-mantle interface, as is sometimes suggested, what can you infer about the thickness of the crust under the continents as compared to the thickness under the oceans.

(D-1.41) 3. What correlations were you able to observe between earthquake activity, volcanic activity, and mountain range locations? How do you think they are related?

WORLD MAP



Challenging (2)

XII-A-2b: JAMES HALL'S FIELD TRIP

QUESTION:

What evidence suggests major changes in the earth's crust?

MATERIALS:

Graph paper, supplementary sheet (map and data table), if possible photographs of outcrops near each of the mapped stations if possible.

SUGGESTED APPROACH:

1. Discuss briefly the route along which the stations are located and the evidence provided of outcrops located at the stations. (Use pictures if possible.)
2. Have students use the data to construct a cross section of the sedimentary rock thicknesses from Buffalo to the eastern-most station.
3. Lead students in an interpretation of the evidence relative to the objectives listed. Through questioning, bring out the apparent discrepancy: although most of the sedimentary rocks seem to be of shallow-water origin, the rocks are of tremendous thickness. Lead students in developing possible solutions to the problem. Emphasize the relationship between the geology of the eastern and western portions of New York State.

PRECAUTIONS:

1. Many students seem to want to start both rock Unit I and II at the surface. It may be advisable to permit the student to do this, for he may discover on his own the fact that two rock layers cannot occupy the same space. Be sure that he understands that rock Unit I extends from the surface downward and rock Unit II from the bottom of rock Unit I downward, before he completes the entire investigation.
2. The data are generalized. The units are lumped together to avoid introducing terminology of formations and geologic age. Only the current thicknesses of the rocks are included. This omits the great thicknesses that must have been removed during the Mesozoic and Cenozoic eras.
3. Vertical exaggeration should be discussed. It would be valuable to have a few students make their cross sections to true scale.

TYPICAL RESULTS:

The cross sections will vary in appearance since students will choose different vertical scales. However, this should not affect interpretations. With guidance, students should be able to develop the geosynclinal concept of a shallow sea environment. Briefly summarized, the pressure of the sediments constantly depresses the sea bottom so that a sediment-filled trough is formed with deformation in the areas of greatest pressure.

MODIFICATIONS:

1. Introduce the "field trip" by telling the history of James Hall and, if possible, showing slides of outcrops found along the east-west route of the trip. (See Background Information for a possible script to such a slide set and an outline biography of Hall.)

2. Obtain a USGS basement rock map (cost about $3.50), and compare the cross-sectional profile made in this investigation with it. You will find a trough on the basement map in the Eastern U. S. that corresponds with stations 9 and 10. But which came first, the sediments or the trough?

BACKGROUND INFORMATION:

Teachers may wish to organize a slide field trip with script similar to this one.

James Hall's Field Trip - To Western New York State - 1838

James Hall was born in 1811 at Hingham, Mass., on the shore of Massachusetts Bay, southeast of Boston. He spent his early years here and no doubt became quite familiar with this salt water coastal environment.

Eventually Hall left Hingham and walked overland to Troy, N. Y., where he attended Rensselaer College (now R.P.I.). As he made this journey through western Massachusetts, he must have seen these folded metamorphic rocks of Ordovician and Cambrian age. These rocks are between 500 and 600 million years old.

As he neared the Troy and Albany area he probably observed rocks like these highly folded ones located near the New York-Massachusetts line. They are of Ordovician age, younger than those in western Massachusetts.

One of the problems that must have frustrated Earth Scientists of this time was the thick layers of sand like these at Glens Falls, N. Y., that covered most of the landscape, hiding from view the bedrock underneath. The concept of continental glaciation had not yet evolved, and would not until 1850 when Louis Agassiz came to teach at Harvard College. About the only bedrock that Hall could have studied in this area were these flat-lying limestones of Ordovician age found along the Hudson River above Glens Falls.

Hall was appointed New York State paleontologist in 1837. In 1838 he organized a field trip from Albany westward across New York State. As he moved west from Albany, he probably studied slightly tipped and deformed rocks like these of Ordovician age near Scotia, just west of Schenectady.

Across the Mohawk River, to the south, but not far from Scotia, he probably observed rocks similar to these that dip slightly to the south and are of Ordovician age.

About 20 miles further west, he could have seen flat-lying rocks of Ordovician age similar to these limestone cliffs exposed along the Mohawk River.

As he proceeded west to Canajoharie he may have been puzzled by these polished and grooved rocks that we now recognize as evidence of continental glaciation. Near Herkimer he may have had opportunity to study rocks similar to these gently tipped limestones and shales, still of Ordovician age.

In the vicinity of Utica, muddy looking, flat-lying, thinly bedded layers of shale about 440-500 million years old may have been observed. These rocks can be traced intermittently westward all the way to the Niagara Gorge at Lewiston.

Hall would not have been able to observe these younger rocks of Silurian age which have been exposed as a result of excavation for a Physics Building on the Syracuse University campus. These thinly-bedded, flat-lying, tan colored rocks are about 50 million years younger than those of Ordovician age which were seen near Utica. These Silurian age rocks can be observed in outcrops from a point just west of Utica to Camillus, just west of Syracuse. One of the fossils common to this rock formation found in the Syracuse area is the Eurypterid. Hall, a paleontologist, probably observed many of these fossils.

As he proceeded west from Camillus, Hall no doubt studied rocks similar to these limestones which outcrop near Batavia and are members of the Devonian period, about 375 million years old. These represent some of the youngest rocks that Hall could have seen on his trip westward.

In the Letchworth State Park area, south of Rochester, along the high banks of the Genesee River, Hall probably did extensive studies of these Devonian age rocks and fossils.

Another outcrop that Hall may have visited is this Devonian age limestone exposed at Indian Falls on Tonawanda Creek about 12 miles west of Batavia.

Near Buffalo, Devonian age limestone can now be seen in limestone quarries where it has been mined for lime and crushed rock. South of Buffalo, Hall may have observed this Devonian age shale rock which is only about 350 million years old.

One of Hall's last stops, and one of the most fascinating was Niagara Falls, where the falls is capped by a layer of Lockport dolostone.

To the south, the Onondaga limestone forms an escarpment which serves to stabilize the level of Lake Erie by forming a resistant lip at the head of the Niagara River.

As a result of this field trip and later ones, Hall was to formulate the theory of geosynclinal mountain building for which he is best known.

REFERENCES:

Investigating the Earth, pp. 312-315, Teacher's Guide, pp. 379-385.

XII-A-2b: JAMES HALL'S FIELD TRIP

QUESTION:

What evidence suggests major changes in the earth's crust?

INTRODUCTION:

More than 130 years ago, James Hall traveled by foot and horse across New York State collecting geologic evidence for the history of the area. In this investigation, you will use data similar to his. You will study photographs of outcrops taken at the data stations which range from Buffalo to a point east of Albany.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. interpret the ancient geologic environment of the area between Buffalo and a point east of Albany.
2. relate the geology of the western portion of the state to that of the eastern portion.

METHOD:

1. Study the map, data, and information for the "field trip" route.
2. On graph paper, make a cross section of the sedimentary rock layers from station 1 to 10. Rock Unit I is above Unit II.
3. Discuss with other students the evidence obtained from the cross-sectional profile and the information on the data sheet.
4. Interpret the evidence, and write a probable geologic history of the area between Buffalo and station 10.

QUESTIONS:

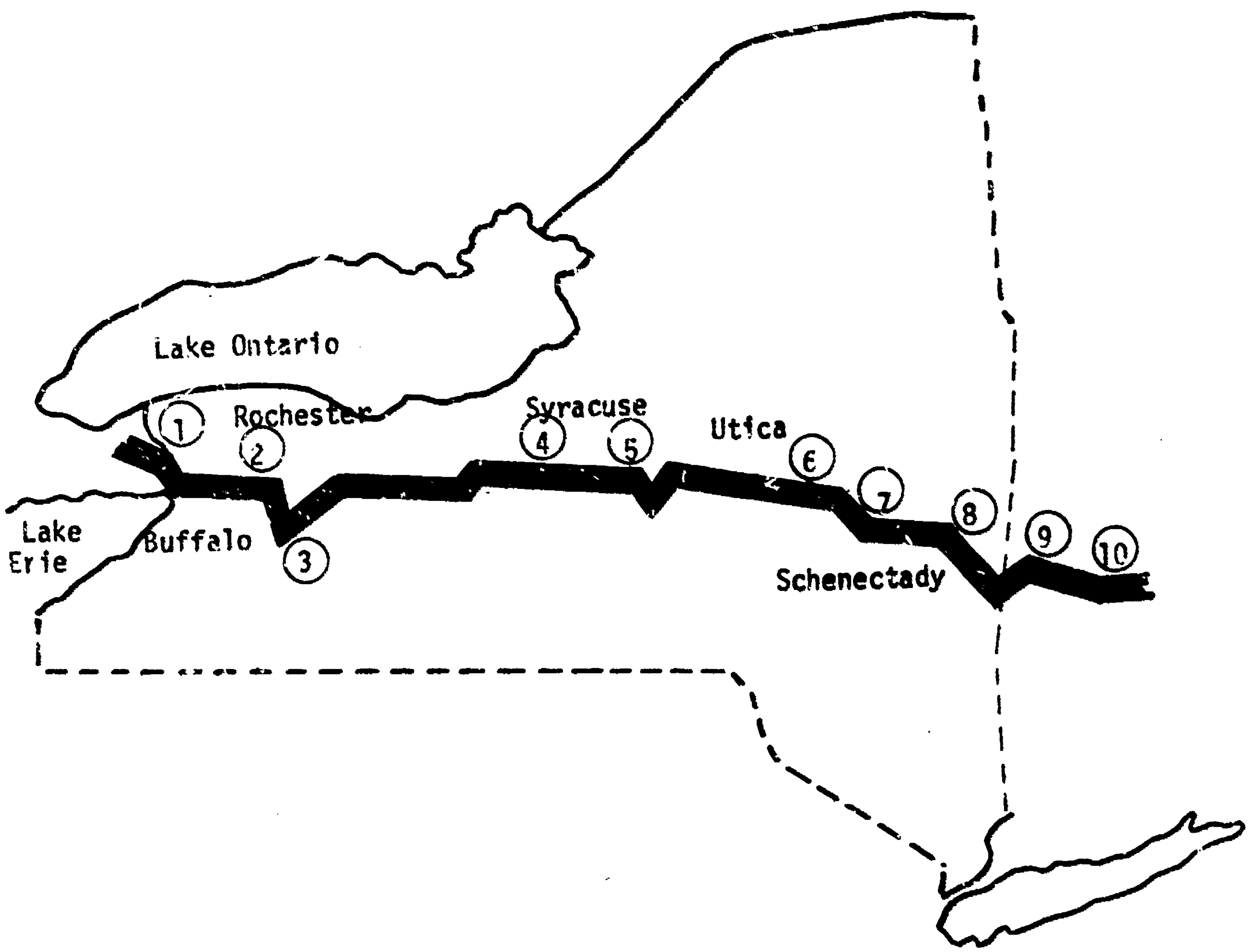
(A-2.21) 1. What evidence indicates that the sedimentary rocks graphed are shallow-water in origin?

(A-2.22) 2. What could explain the extreme thickness of shallow-water deposited sediments?

(A-1.11) 3. How do you explain the difference between rocks at stations 8-10 and those found at stations 1-6?

(A-1.. 4. What do you think happened to rock Unit I and II at sta- 10? Why?

JAMES HALL'S FIELD TRIP



Thickness in Meters of Sedimentary Rocks
Below Surface Along Route Shown on Above Map

Stations	1	2	3	4	5	6	7	8	9	10
Rock Unit I	900	1500	1500	1500	1500	2000	2500	0	0	?
Rock Unit II	300	350	650	3000	3300	3300	3000	3300	3300	?

<u>Adapted from:</u> *Investigationg the Earth*, Teacher's Guide

Rock types found at various stations

1	-	Niagara area - horizontal layers
2, 3, & 4	-	Flat-lying sedimentary layers
5	-	Rocks contain fossil coral
6	-	Fossils and thin layers common
7	-	Warped sedimentary layers
8	-	Rocks contorted and shattered
9 & 10	-	Rocks greatly disturbed - evidence of igneous activity

Difficult (2)

XII-A-2c THE SPREADING SEA FLOOR

QUESTION:

What evidence suggests major changes in the earth's crust?

MATERIALS:

Student sheet and Supplementary Sheet.

SUGGESTED APPROACH:

1. Discuss with the students the concept of a magnetic field and the meaning of a magnetic field reversal. Ask how a magnetic field might be "preserved" in molten rock as it solidifies.

2. After making certain that the students understand the method, this exercise can best be done as a homework assignment.

3. After completion of the assignment, discuss with the students·

   A. The meaning of ocean floor spreading.

   B. The rate at which it is thought to be occurring.

   C. How does it relate to other theories such as the geosyncline theory and the continental drift theory.

PRECAUTIONS:

1. Students sometimes have difficulty realizing that the upwelling occurs along the mid-Atlantic Ridge and spills over in both east and west directions. Therefore, materials of similar age should be located at approximately equal distances east and west of the ridge. The magnetic reversal pattern serves only to identify rock units of the same age.

2. As in most natural systems, the movement has not been perfectly symetrical, the distance the rock has drifted eastward is consistantly less than the distance it has moved westward, therefore an average must be taken and used for computation.

TYPICAL RESULTS:

NUMBER	1	2	3	4	5	6
Distance West (km.)	40	70	80	104	118	134
Distance East (km.)	28	42	60	74	90	102
Average Distance (km.)	34	56	70	89	104	118
Age From Scale(million yrs.)	2.8	4.4	5.6	7.1	8.4	9.5
Rate of Movement (cm./yr.)	1.21	1.24	1.24	1.25	1.24	1.23

The line drawn by the student for question 1 should be about 1.2 cm. long. Africa should have been in the indicated position (question 2) about 2.0 X 10^8 years ago,

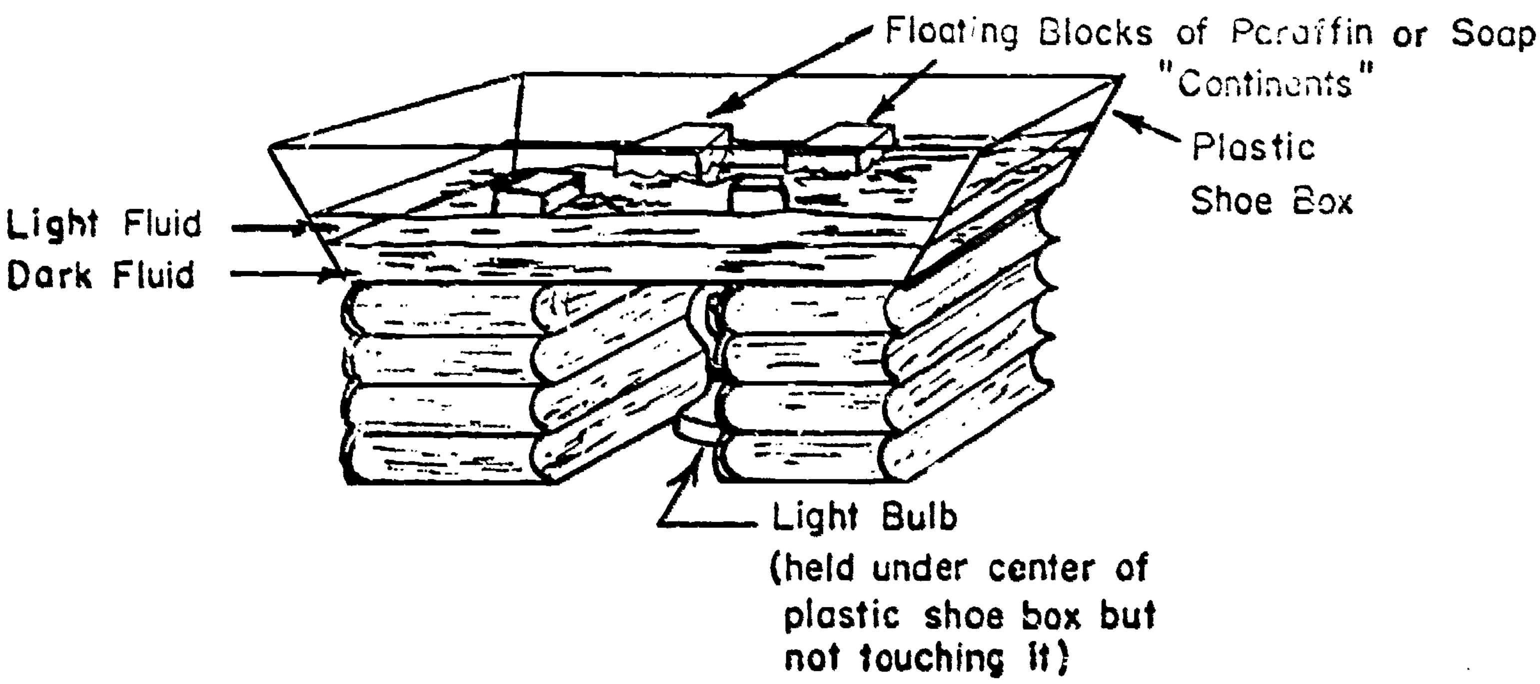
$$\frac{2.4 \times 10^3 \text{ km.}}{1.2 \frac{\text{cm.}}{\text{yr.}}} \times \frac{10^5 \text{ cm.}}{\text{km.}} = 2.0 \times 10^8 \text{ years.}$$

For question 3, correspondence should be excellent at all points used in calculation. Short intervals may not show up on the general profile because of the amount of material magnetized and the lack of sensitivity of the instrument.

MODIFICATIONS:

Sea floor spreading and the Continental Drift Theory can be demonstrated by using the following technique.

1. Set up the apparatus as shown below.



Note: Pour the lighter fluid very slowly, using a piece of cardboard to break its velocity. Try to maintain a sharp interface between the more dense (dark fluid) and the less dense (light fluid). Density of the fluids can be controlled by storing the dark fluid in the refrigerator and the light fluid in a bucket of warm water, previous to class time.

2. Place a transparent lid on the box with a plastic sheet attached to it and sketch the position of the "continents" as they appear before the light is turned on.

3. Observe the light and dark fluids from the side of the shoe box and sketch the interface between the two.

4. Turn on the light and observe both the interface between the two fluids and the position of the paraffin blocks. Make sketches of each at 5-minute intervals for a period of 20 minutes.

5. Relate what you have seen to continental drift and sea floor spreading.

REFERENCES:

Allan Cox, G. Brent Dalrymple, & Richard R. Doell, "Reversals of the Earth's Magnetic Field," *Scientific American*, Feb. 1967, Vol 216:2, pp. 44-54

Samuel W. Matthews & Robert F. Sisson, "Science Explores the Monsoon Sea," *National Geographic*, Oct. 1967, Vol. 132:4, pp. 554-575

J.D. Phillips, "Magnetic Abnormalities over the Mid-Atlantic Range Near 27°N," *Science*, Aug. 25, 1967, Vol. 157, pp. 920-922

W.C. Pitman, III, & J.R. Heirtzler, *Science*, Vol. 154, 1966, p. 1164

XII-A-2c: THE SPREADING SEA FLOOR

QUESTION:

What evidence suggests major changes in the earth's crust?

INTRODUCTION:

When molten volcanic rocks cool and solidify, the magnetic minerals in them are magnetized in the direction of the earth's magnetic field. They retain that magnetism, thus serving as permanent magnetic memories (much like the magnetic memory elements of a computer) of the direction of the earth's field in the place and at the time they solidified.

In 1906, the French physicist, Bernard Brunhes, found some volcanic rocks that were magnetized, not in the direction of the earth's present field, but in exactly the opposite direction. Brunhes concluded that the field must have reversed. Although his observations and conclusions were accepted by some later workers, the concept of reversals in the earth's magnetic field attracted little attention. In the past few years, however, it has been definitely established that the earth's magnetic field has two stable states; it can point either toward the North Pole, as it does today, or toward the South Pole, and it has repeatedly alternated between the two orientations.

Using a combination of magnetic reversal and atomic dating, we shall attempt to make a model of the earth's floating crust. The rift in the Mid-Atlantic Ranges seems to be a place of upwelling so we will concentrate on it. The research vessel *Chain* of the Woods Hole Oceanographic Institute made crossings of the Mid-Atlantic Ridge in 1966, using an instrument which shows intensity and direction of the magnetic field produced by the rock on the ocean floor. The profiles produced by the *Chain* are shown in Figure 1.

Using radioactive dating techniques (principally potassium-argon), volcanic rocks of the ocean floor in this area were given specific ages. The rock ages are shown in Figure 2.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. interpret evidence that suggests that at least portions of the earth's crust are mobile.

2. given appropriate data, determine a rate of movement of a crustal area.

METHOD:

1. Draw a single vertical line through the first peaks to the west of the main rift in the magnetic profile (Figure 1). Read the distance from the main rift on the scale at the bottom of the page (1 mm. = 2 km.), and record it in the data table below.

PEAK NUMBER	1	2	3	4	5	6
Distance West (km.)						
Distance East (km.)						
Average Distance (km.)						
Age from Scale (million years)						
Rate of Movement (cm./yr.)						

2. Repeat step 1 for each set of peaks you see to the west of the rift, and record under 2, 3, 4, 5, 6.

3. Repeat for each set of peaks east of the rift and record under 1, 2, 3, 4, 5, 6.

4. Find the average distance from the Mid-Atlantic Ridge to each magnetic peak.

5. Using the Time Scale (Figure 2), find the age of the rock at each average distance. Record it on the chart.

6. Assuming that the rock has moved from the central ridge, calculate how many cm./year it moved and complete Chart A.

QUESTIONS:

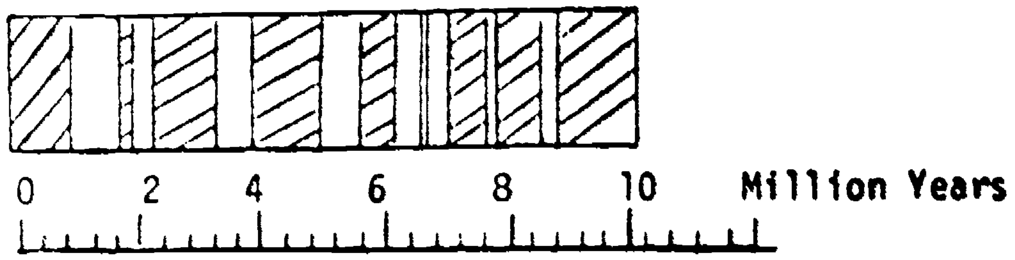
(A-2.41) 1. Describe the age of the nonsedimentary rock found near the oceanic ridge relative to that found farther from the ridge.

2. Draw a line that represents the amount of movement which occurs on one side of the Mid-Atlantic Ridge in one year.

3. If the distance from Africa to the Ridge is 2400 km., how long ago was Africa over the ridge?

(A-2.42)
(A-2.61) 4. Below is a Polarity Reversal Time Scale devised by scientists. Does the polarity of your calculated model correspond to this at all points? (Lined areas

are Normal Polarity; white areas are Reversed Polarity.)



5. Explain in your own words how the work you have done in this lab could lead you to believe in a floating crust theory.

FIGURE 1: ROCK POLARITY ACROSS THE ATLANTIC

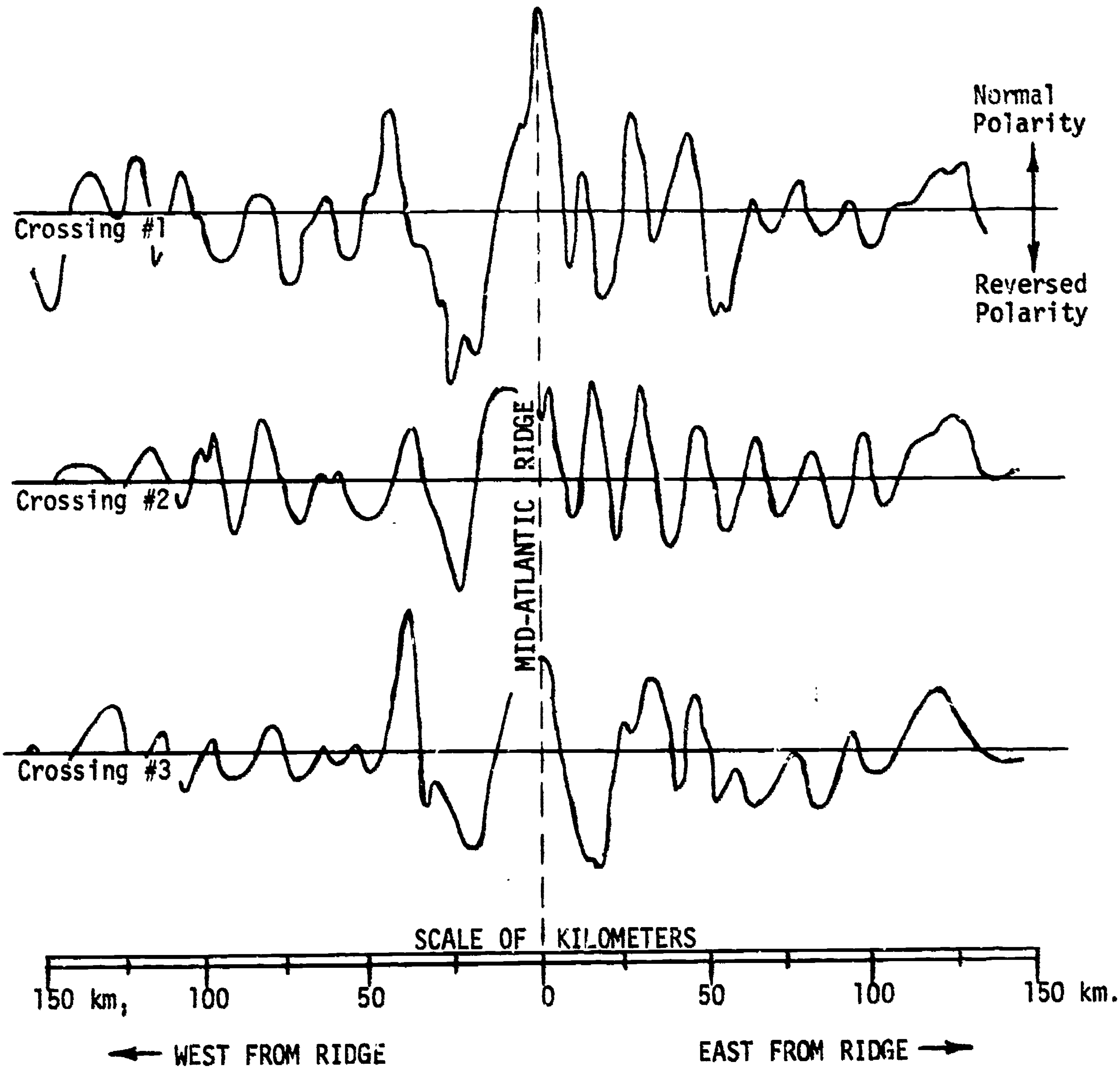
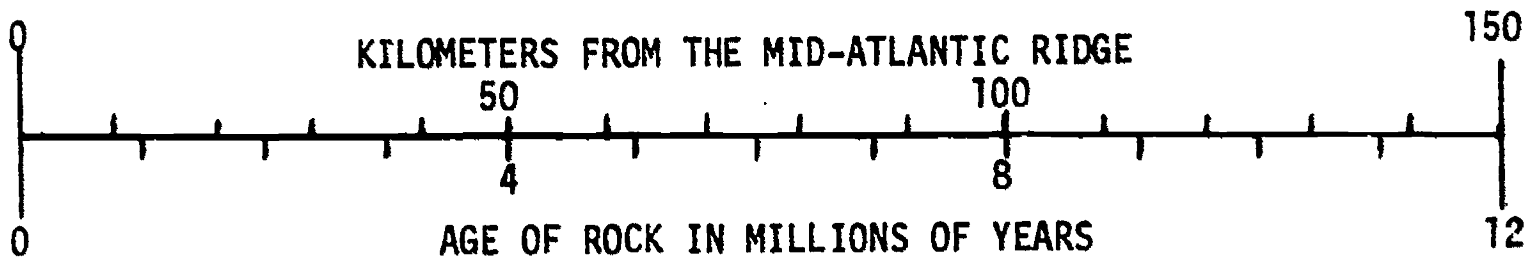


FIGURE 2: ROCK AGE DETERMINATION SCALE



Challenging (2)

XII-B-2a: LOCATION OF AN EPICENTER

QUESTION:

What are some properties of earthquake waves?

MATERIALS:

Seismogram recordings of the same earthquake from three different stations, graph paper, globes, drawing compasses or string, and marking crayons.

SUGGESTED APPROACH:

1. Discuss with students the characteristics of and the differences between P- and S-waves.
2. Discuss with the students the operation of the S- and P-wave time-travel graph (Supplementary Sheet #1). This may pose some difficulty to the students, so make sure they understand fully how to use it. (See Background Information.)
3. Let them "read" the seismograms and, after having determined the distance to the epicenter for the three stations, let them attempt to locate the epicenter. The latter can be accomplished by constructing intersecting circles on a globe with radii equal to the distances from the epicenter. The intersection of the circles will locate the epicenter. Circles can be drawn either using a compass or string.

PRECAUTIONS:

1. Students may have difficulty drawing the circles on the globes and also in understanding the geometry behind this technique. Some assistance may be needed here.
2. A globe is best for this investigation, since only a small area on a flat projection can be used without getting involved with distortion.

TYPICAL RESULTS:

Because the technique for constructing the circles is difficult to carry out with accuracy, the circles will probably not intersect at a point but rather will indicate a small area, the center of which can be assumed to be the location of the epicenter.

MODIFICATIONS:

Provide seismograms from cities within the U. S. for an earthquake whose epicenter is also located within the U. S. It should then be possible to use a map instead of a globe for locating the epicenter.

BACKGROUND INFORMATION:

The S- and P-wave Time-travel Graph has been constructed by plotting S- and P-wave arrival times, measured at recording stations around the world, versus the known distance of the epicenter from the station receiving the waves. Because the stations were different distances from the epicenter and since the P-wave travels faster than the S-wave, the time gap between arrivals increases with increasing distance from the epicenter.

XII-B-2a: LOCATION OF AN EPICENTER

QUESTION:

hat are some properties of earthquake waves?

INTRODUCTION:

If an earthquake is of sufficient magnitude, the shock will be felt hundreds of miles away. Most earthquakes, however, can only be felt close to the epicenter if at all. Geologists use an instrument called a seismograph to detect earthquakes. This is very sensitive even to weak shocks. From the recorded information of a seismograph, scientists are able to tell how far away the earthquake occurred. When the information from stations in different locations is compared, they can determine the location of the epicenter.

OBJECTIVES:

When you have finished this investigation,you should be able to:

1. Determine from a seismogram the P- and S-wave travel time difference, and with a graph of time vs. distance traveled, determine the distance of the recording station from the epicenter.

2. Locate the epicenter of an earthquake given the distances of three recording stations from the epicenter.

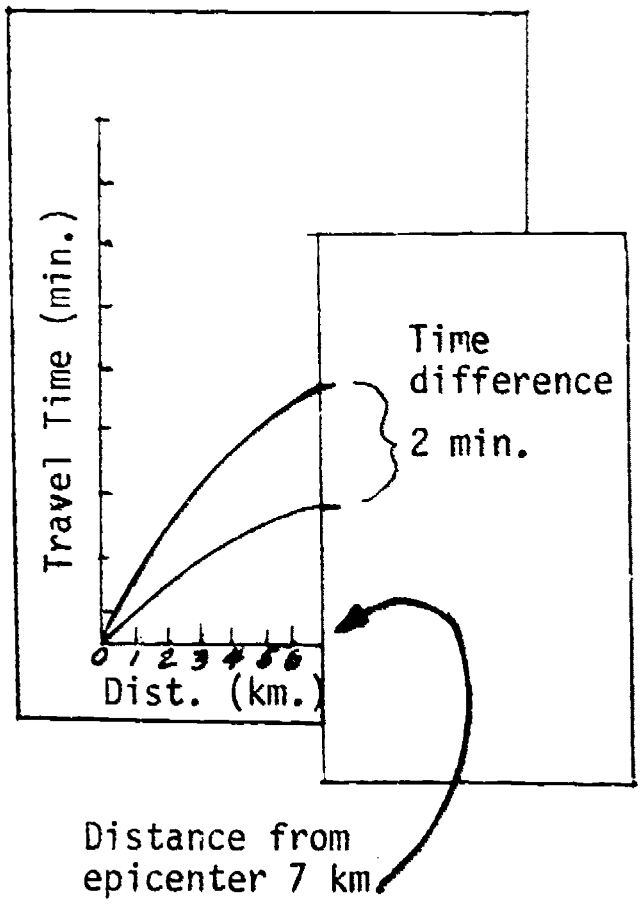
METHOD:

1. Observe the P- and S-waves on the seismograms (Supplementary Sheet #2). Determine the difference between the arrival times of the P- and S-waves on each graph in minutes and seconds.

2. Position a sheet of paper along the time axis of the S- and P-wave Time-travel Graph (Supplementary Sheet #1) and make two marks on the edge representing the P- and S- arrival time difference measured at one of the stations.

3. Slide the paper along the P- and S- curves, keeping the marked edge parallel to the time axis, until the distance between the curves matches the two marks on the edge of the paper (see diagram).

4. Make certain the paper edge is still parallel with the time axis, and then follow the edge down until it intersects the distance axis. The reading at that point will represent the distance the seismograph station was from the epicenter of the earthquake.



5. Repeat the above process for the other two seismograph stations.

6. You now know the location of the three seismograph stations and the distance each is from the earthquake eipcenter. Now devise a method for locating the epicenter on a globe.

QUESTIONS:

(B-1.11) 1. Describe the two major waves that move outward from an earthquake epicenter.

(B-2.11) 2. If the difference in arrival times of P- and S-waves at a station is 4.6 minutes, how far from the epicenter is the station?

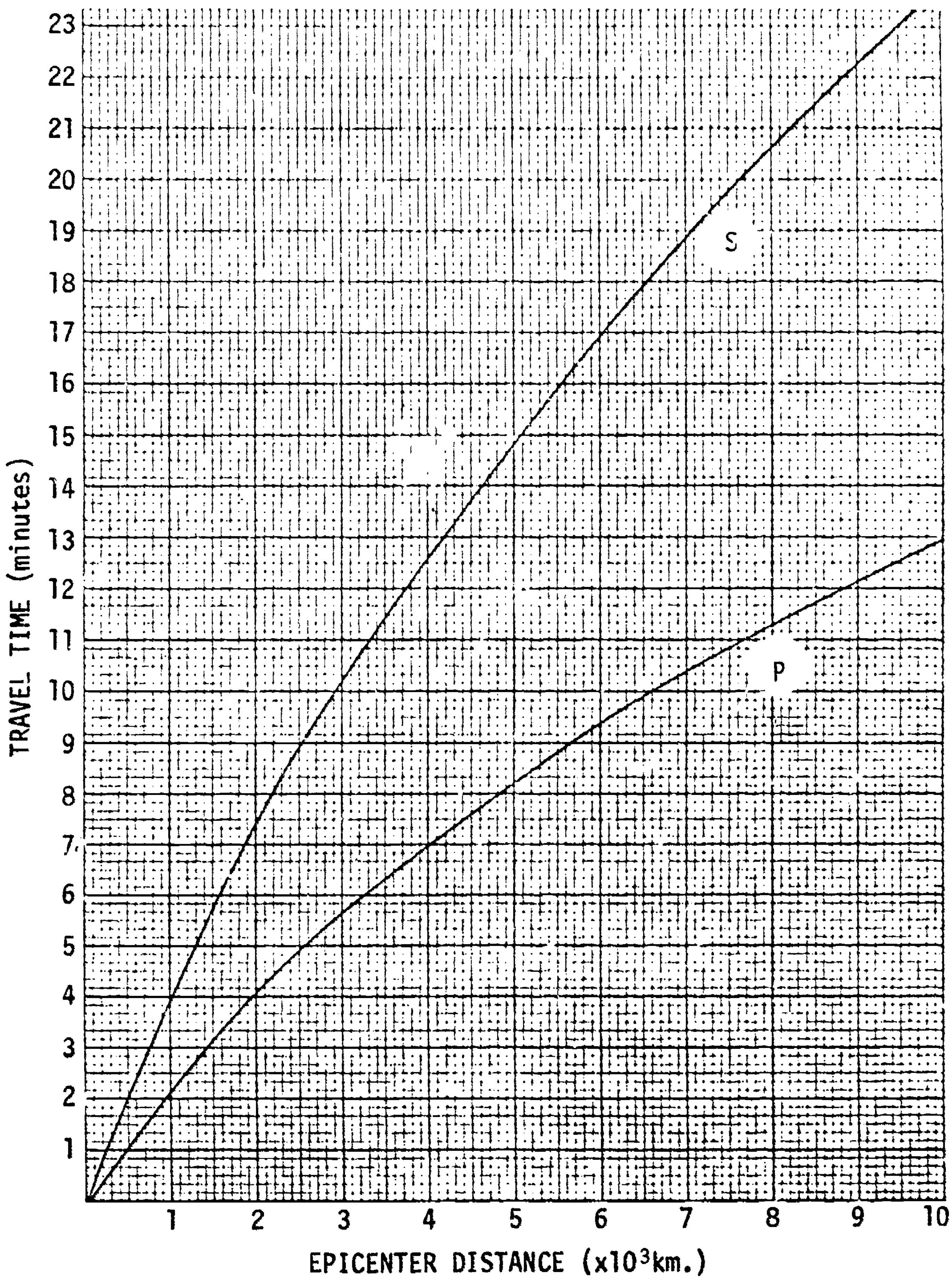
(B-2.21) 3. If a station situated 4000 km. from an epicenter receives a P-wave at 3:20 p. m., what time did the earthquake actually occur?

(B-2.11) 4. Why is the travel-time graph applicable for all earthquakes? What assumptions must be made?

5. Why was it necessary to know the distance from the epicenter for at least three recording stations to be able to locate the epicenter?

(B-1.21) 6. If both the S, shear, wave and P, compressional, wave were traveling through the same medium, which would have the greatest velocity?

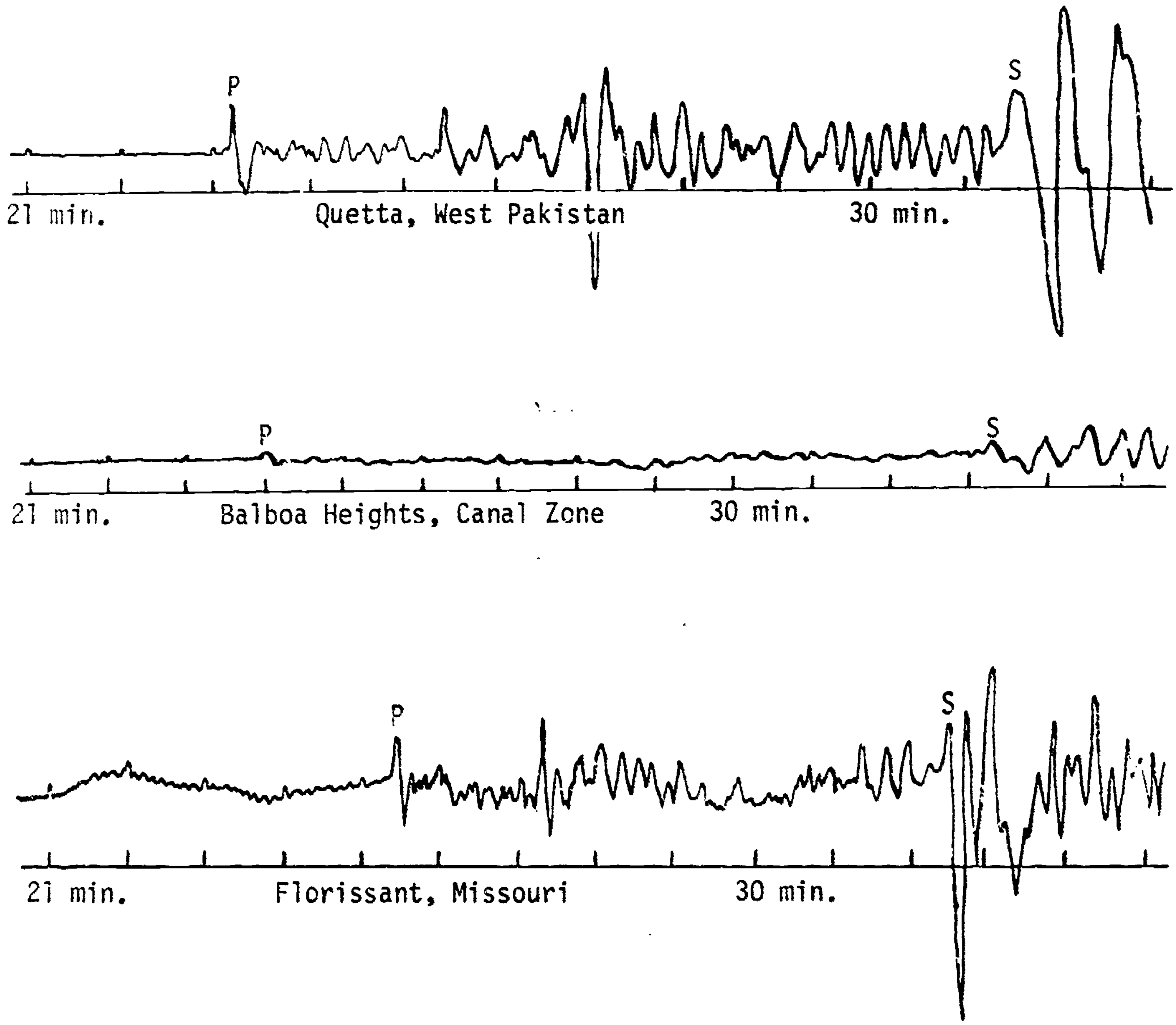
Earthquake S- and P-wave Time-travel Graph



Adapted from:

Investigating the Earth, Laboratory Manual

SEISMOGRAMS



Adapted from:

Investigating the Earth, Laboratory Manual

Challenging (2)

XII-D-1a: FIELD TRIP THROUGH THE MOUNTAINS

QUESTION:

What inferences can be drawn about the processes which may cause crustal changes?

MATERIALS:

Student handout sheets, including the supplementary sheet; Rocky Mountain or Sierra Nevada Field Trip kits, available from several suppliers (opitional but recommended).

SUGGESTED APPROACH:

1. Show filmstrip or slides for Rocky Mountain or Sierra Nevada Field Trip. Advise students to take notes of interesting features. (Commentary may be taped to maintain pace and save you from trying to read in the dark.)

2. Make certain the students understand that all predicted curves are based on the assumption that the crust material is composed of granite and that at a constant depth of 20 kilometers below sea level there is a crust-mantle interface. The mantle rock represents a more dense form of rock than the granite crust.

3. Have the students complete the graphs by plotting in the actual measured data for each of the curves.

4. In post-lab, discuss the interpretations of the graphs. Assist the students in reaching the conclusion that the mountains must have "granite roots," and that a constant crust-mantle interface at 20 km. below sea level is improbable.

MODIFICATIONS:

1. Sierra Nevada Field Trip - Use the commercial slide kit, and have the students prepare their graphs from the tables below

Location	Distance in Kilometers	Elevation in Meters	Predicted Gravity cm./sec.^{2}	Observed Gravity cm./sec.^{2}
Point Lobas	0	0	979.9	980.2
Near Carmel	5	120	979.9	980.1
Near Salinas	18	17	979.9	979.7
Near San Juan	24	170	979.9	979.8
West of San Juan	30	70	979.9	979.6
Near Hollister	46	100	979.9	979.6
Diablo Range	89	830	979.7	979.8
Cen. Valley	105	30	979.9	979.7
Sierra Foothills	118	83	979.9	979.7
Mother Lode Reg.	132	730	979.7	978.4
Yosemite Valley	163	2600	979.1	978.4
Tuolme	177	3300	978.8	977.6
Tioga Pass	197	3300	978.9	977.6
Mono Lake Area	211	2170	979.2	977.5

a) Data show acceleration of gravity along the route based on the assumption that acceleration of gravity if 979.908 cm./sec.^{2} at 37°N latitude, and that there is a decrease of 0.0308 cm./sec.^{2} per 100 meters of elevation.

b) Data are based on the assumption that the crust-mantle boundary is at 35 km. below sea level.

REFERENCES:

Investigating the Earth, p. 345, Teacher's Guide, pp. 421-433, '65 ESCP Text pp. 14.21 to 14.24

XII-D-1a: FIELD TRIP THROUGH THE MOUNTAINS

QUESTION:

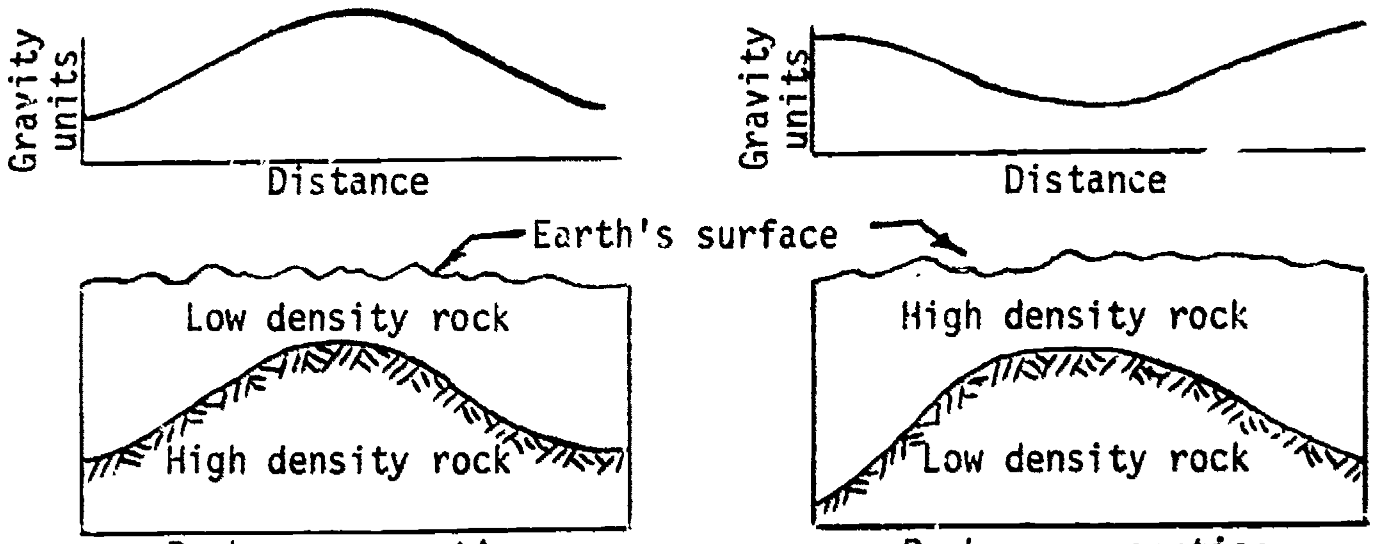
What inferences can be drawn about the processes which may cause crustal changes?

INTRODUCTION:

In this age of space exploration and moon landings, it is difficult to realize the extent of man's lack of knowledge concerning the interior of the earth. We have never sampled the mantle rock which lies below the relatively thin granite crust of the continents. Our knowledge of the nature of this mantle material and its location is based on indirect evidence such as gravity and heat flow measurements.

Gravity Measurement:

Your bathroom scale is actually a gravity-measuring device. The greater the gravitational pull on you, the more the spring in the scale will compress. Geologists use a very sensitive meter to measure extremely small changes in the pull of gravity. They have found that these small changes in gravity are related to the density of the rocks under the surface. Refer to the diagram below.



Rock cross section

Rock cross section

Heat Flow:

Although the sun is the primary source of energy at the earth's surface, small amounts of heat radiate from the earth's interior. Some of this heat is thought to be produced by the radioactive decay of atoms found in the nonsedimentary rock called granite. If this is the case, you would expect slightly more heat flow to occur in areas under which the rock granite is found.

With this information, you are now ready for a field trip through the mountains.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. describe how mountains affect the thickness of the earth's crust.

METHOD:

1. Observe the pictures that your teacher has provided for you.

2. Observe the graph of the area (supplementary sheet) over which your field trip has extended.

3. Plot on the graph the actual measured values given in the table below.

Location	Distance from Grand Junction	Gravity	Heat Flow
Bird City	600 km.	978.78 cm./sec.^{2}	4.2 cal./cm.^{2} yr.
Joe's	500	.80	4.3
Last Chance	420	.80	4.5
Denver	310	.41	5.8
?	290	.32	6.0
Idaho Springs	260	.21	6.9
Silver Plume	235	.11	7.1
Loveland Pass	225	.09	7.4
Vail Pass	200	.12	6.9
Vail	180	.14	6.5
Glenwood Springs	90	.25	4.3
New Castle	70	.32	4.5
Grand Junction	0	.59	5.0

4. Draw inferences concerning the depth to the crust-mantle interface based upon your interpretation of the graphs.

5. If you do not agree with the constant 20 km. below sea level as it is drawn on the cross section, sketch on the graph sheet a crust-mantle interface as you think it should be.

QUESTIONS:

1. Why is there a gravity "low" over the mountains even with a constant depth crust-mantle interface? Why a heat flow "high?"

2. What kind of a pattern for gravity and heat flow would you expect if the mountain had deep granite roots?

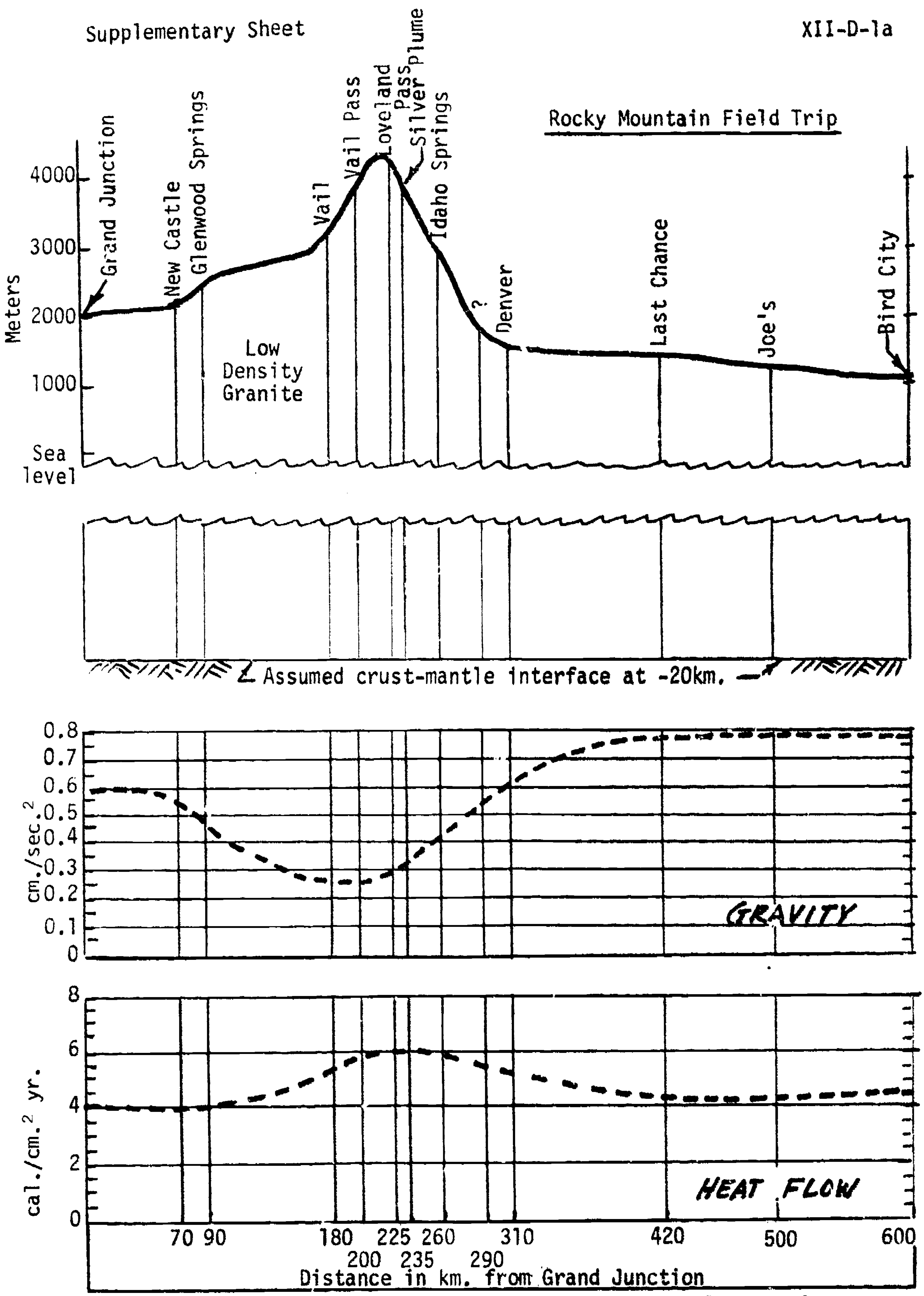
3. How does the actual measured pattern compare with your deep root prediction?

(C-1.21) 4. How does the thickness of the crust under mountains compare with the thickness in adjacent areas?

(D-1.31) 5. Relate the position of the granite mountain in the more dense underlying rock to the position of a floating piece of wood in water.

(D-1.11) (D-1.21) 6. Describe a mountain building model that would explain the data observed in this investigation.

7. What relationships can you observe between the pictures taken along the field trip route and the scientific data gathered?



Predicted Values assuming the Crust-Mantle Interface to be 20 km. below sea level.

topic XIII

ERIC

How Can Geologic History Be Interpreted?

Time Emphasis: 15 days

TOPIC OUTLINE

INVESTIGATION		A-1a	A-1b	B-1a	C-1a	C-1b	C-2a	D-1a	FE-#1
Estimated Time (Periods)		2	1	0½	1½	1½	1½	2	
A. Geologic events									
A-1 Sequence of geologic events	*How Can the Order in Which Geologic Events Occurred Be Determined?*								
A-1.1 Chronology of layers	A-1.11		■						■
A-1.2 Igneous intrusions, and extrusions	A-1.21		■						
A-1.3 Faults, joints, and folds	A-1.31	■	■						
A-1.4 Internal characteristics	A-1.41								
	A-1.42								
B. Correlation techniques									
B-1 Correlation	*How Can Rocks and Geologic Events in One Place Be Matched to Another?*								
B-1.1 Continuity	B-1.11	■	■						
B-1.2 Similarity of rock	B-1.21	■	■						
B-1.3 Fossil evidence	B-1.31		■	■					
	B-1.32			■					
	B-1.33	■							
B-1.4 Volcanic time markers	B-1.41		■						
B-1.5 Anomalies to correlation	B-1.51								
C. Determing geologic ages									
C-1 Rock record	*What Does the Rock Record Suggest About Geologic History?*								
C-1.1 Fossil evidence	C-1.11				■	■			
C-1.2 Scale of geologic time	C-1.21								
	C-1.22				■				
	C-1.23				■				
C-1.3 Erosional record	C-1.31		■			■			
C-1.4 Geologic history of an area	C-1.41					■			
C-2 Radioactive decay	*How Can Geologic Ages Be Measured by Using Radioactive Decay?*								
C-2.1 Decay rates	C-2.11								
	C-2.12						■		
	C-2.13						■		
	C-2.14								
C-2.2 Half lives	C-2.21								
	C-2.22						■		
C-2.3 Decay product ratios	C-2.31								

	INVESTIGATION		A-1a	A-1b	B-1a	C-1a	C-1b	C-2a	D-1a	FE - #1
	Estimated Time (Periods)		2	1	0½	1½	1½	1½	2	
TOPIC OUTLINE	D. The fossil record									
	D-1 Ancient life		*What Does the Fossil Record Suggest About Ancient Life?*							
	D-1.1 Variety of life forms	D-1.11								
		D-1.12							■	
	D-1.2 Evolutionary development	D-1.21							■	
		D-1.22							■	
		D-1.23							■	
PROCESS OF INQUIRY OBJECTIVES	Mathematical Skill	PIO-1	■			■		■	■	■
	Measurement Skill	PIO-2	■			■				■
	Creating Models	PIO-3	■	■	■	■	■	■		■
	Analysis of Error	PIO-4				■				
	Data Analysis	PIO-5	■	■			■	■	■	
TITLES			Geologic History of N.Y.S.	Geology of the Grand Canyon	Footprint Puzzles	Geologic Time Line	Correlating Rock Outcrops	Radioactive Decay	Variation Within a Species	School Building and Grounds

Multimedia: Check Multimedia Section of Supplement for reference to this topic.

Challenging (2)

XIII-A-1a: GEOLOGIC HISTORY OF N.Y.S.

QUESTION.

How can the order in which geologic events occurred be determined?

MATERIALS:

1. Student handout sheets and supplementary sheet.
2. Optional materials include:
   a) Educational leaflet #20, Geology of N.Y.S., a short account.
   b) N.Y.S. road map
   c) Slides or photographs of rock outcrops and surface features along each one of the cross-sectional routes

SUGGESTED APPROACH:

1. Ask the students to study the N.Y.S. geologic map for the particular symbols used, scale, etc. Ask the students to suggest possible cross-sectional models that would explain the pattern of rock outcrops observed on their geologic map.
2. Have students determine over which rock layers they would move if they traveled from Olean to Buffalo, and from Binghamton to Syracuse to Watertown.
3. Have the students examine the Geologic Structure Section (see supplementary sheet #1). Be sure they understand the symbols used and the concept of a structure diagram.

PRECAUTIONS:

1. Make certain students understand that the cross-sectional diagrams have an exaggerated vertical scale.
2. The cross sections are drawn to a larger scale than their geologic maps.

MODIFICATIONS:

1. Use New York State locations other than those suggested above. If at all possible, use your own location.
2. See Investigation 20-1, *Investigating the Earth*, 1965 edition. (paperback).
3. Give students necessary data, such as dip of bedrock, elevation of outcrops, direction of dip, type of bedrock, etc., and have them construct a structural cross section.

4. Have the students use stereo pairs of photographs, and, on a transparent plastic overlay, have them trace a particular formation along its outcrop. This would be similar to walking the outcrop. This can be done in one of the stereo booklets available from several suppliers.

   If the stereo-pair booklet is not available, individual stereo pairs may be obtained from the Map Information Office, U.S. Geological Survey, General Services Administration Building, Washington, D. C. 20242, at a cost of $1.00 per 9"x9" photograph. The following are recommended:

   Arizona set #4 - consisting of 3 photos
   Wyoming set #7 - consisting of 2 photos

   For other possibilities, refer to U. S. Geologic Survey Professional Paper #590, Selected Aerial Photographs of Geologic Features in the U. S.

REFERENCES:

1. *Geology of New York*, Educational Leaflet #20, New York State Museum and Science Service (this includes both a descriptive text and a geologic map; one copy is free to each New York teacher who requests it, (additional copies are $1.).

2. For information regarding the following areas: Watkins Glen, Niagara Falls, Cayuga and Keuka Lakes, Lake Ontario, see *Problem Book* and *Teacher's Guide*, SRA, Inquiry Development Program in Earth Science.

XIII-A-1a: GEOLOGIC HISTORY OF N.Y.S.

QUESTION:

How can the order in which geologic events occurred be determined?

INTRODUCTION:

What type of bedrock is beneath the soil you walk on? How old is it? How did it form? How far would you have to go to find a different kind of bedrock? In which direction?

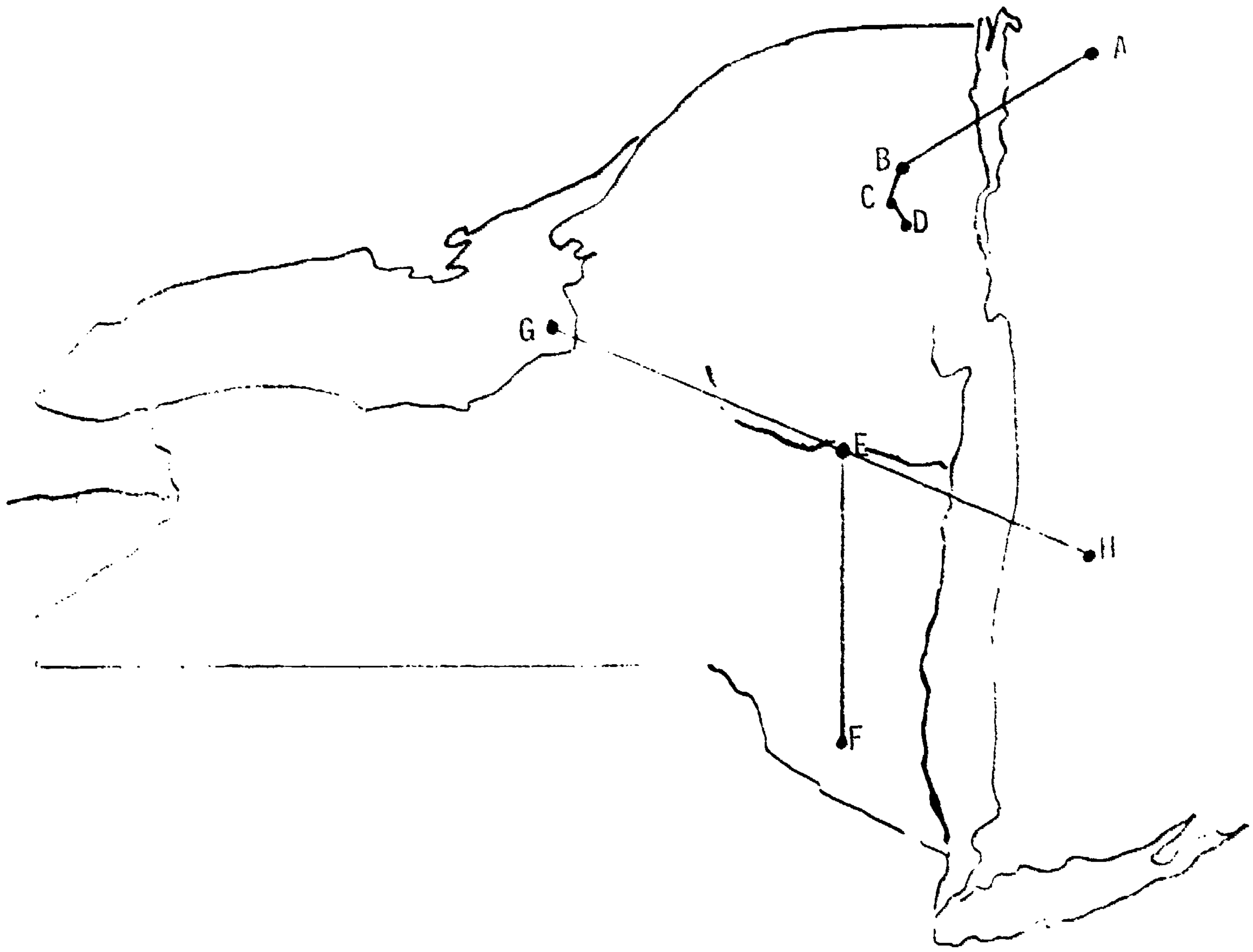
OBJECTIVES:

When you have finished this investigation, you should be able to:

1. determine from a geologic map the type of bedrock present at a given location, and relate a subsurface cross section to it.
2. deduce, from the type of rock present, a general geologic history of the area.

METHOD:

1. Study your geologic map of New York State carefully. (See Student Reference Tables.) Determine the meaning of all symbols used as well as the scale.
2. Study the Geologic Structure sections on the Supplementary Sheet. On the Diagram (next page), the points A, B, C, D, etc., are positioned for you. They are not drawn to the same scale as your geologic map.
3. Locate on your geologic map the general positions of lines: A-B-C-D, E-F, and G-H (If you wish to draw them on your map, use a lead pencil so the lines can be removed.)
4. A New York State road map may be helpful in locating some of the towns mentioned.



QUESTIONS:

1. If you could drill a hole at Binghamton, what rock layers would you pass through? List them in order of age. How do you know?

2. Approximately how thick is each of the layers listed in the answer to question one? How do you know the thickness of the top and bottom layers?

3. Does the area between Binghamton and Syracuse have the same geologic history as the northeastern part of the State? The same rock type? Which area is older? Explain.

(B-1.11) 4. If you walked along the banks of the Mohawk River, where would you find outcrops of Ordivician rock? Of Silurian rock?

(A-1.31) 5. Note the arrows near Dolgeville on cross section (G-H). What do they represent? What is their age relative to the rocks in which they are found? Explain.

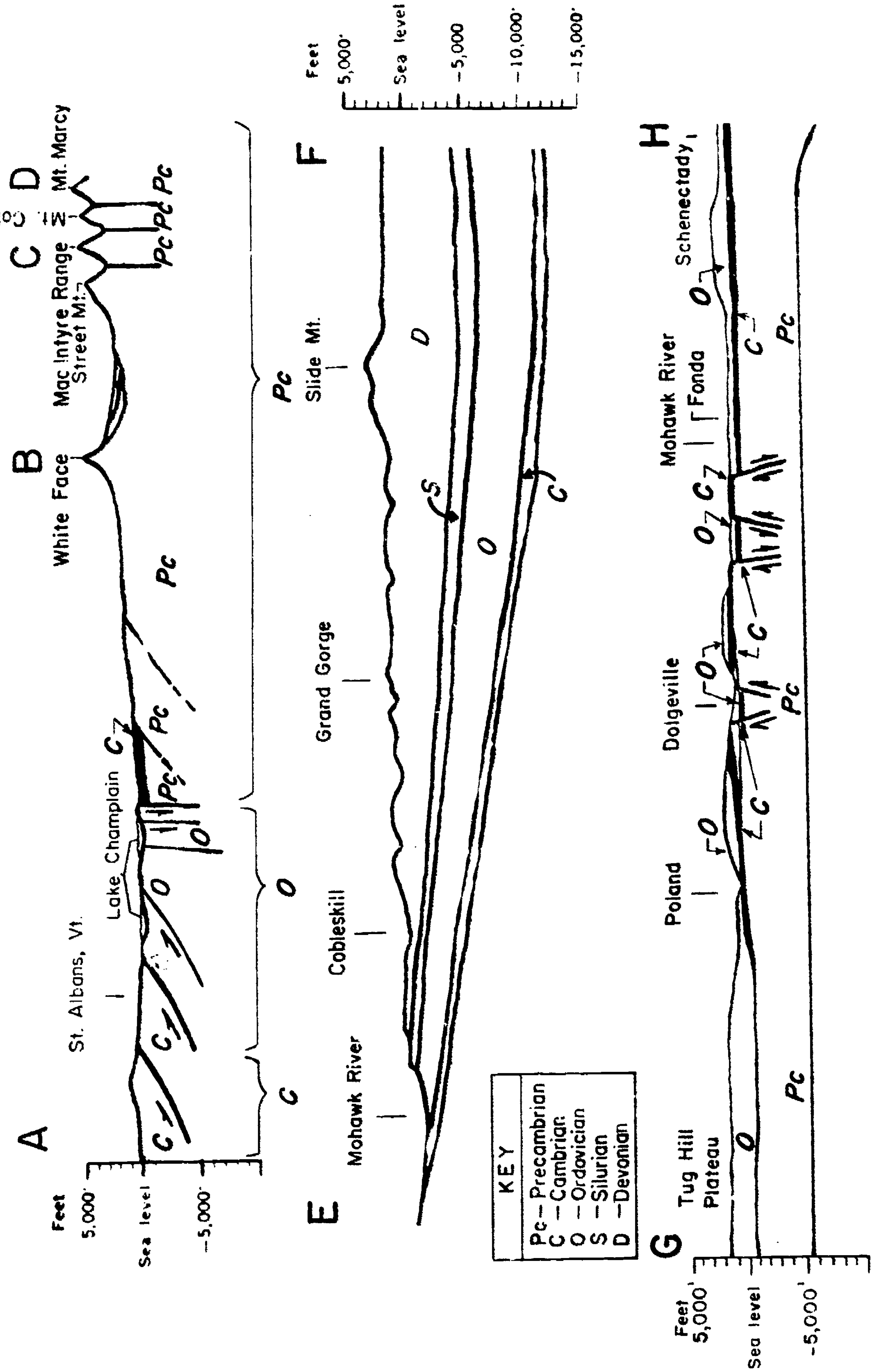
(B-1.11) 6. How could you trace the extent of a particular rock layer, for the purpose of drawing a geologic map of an area?

(B-1.21) 7. What evidences would you use to determine if you were on the same rock layers as you traveled along a route?

(B-1.33) 8. Certain fossils, such as, favosites which are found mainly in Silurian rocks of New York State are also found in other parts of the world. What does this suggest about the rocks in these other areas?

ERIC

GEOLOGIC STRUCTURE SECTIONS



LIST OF GUIDEBOOKS AVAILABLE FROM NEW YORK STATE GEOLOGICAL ASSOCIATION

Information on Field Guidebooks

Please understand that the Association is not in the publishing business and that the Office of the Permanent Secretary has no salaried staff but operates free-of-charge as a service to the geological profession.
Financial transactions, therefore, must be kept at a minimum.

Orders for guidebooks (see listing of contents) will be filled postpaid upon receipt of cash, check, or money order made payable to Philip C. Hewitt, Secretary, New York State Geological Association, State University College, Brockport, New York, (see price list below). Please order by year of publication.

1957 through 1965 guidebooks......... $2.50 per copy
1966 and 1967 guidebooks............. $3.25 per copy
1968 guidebook....................... $6.00 per copy

IMPORTANT: Invoices, order forms, standing orders, etc. cannot be processed.

NOTE: The Association maintains a nearly complete permanent file of field notes and guidebooks of the Association Meetings (1925 to present) which may be consulted by interested parties at the Office of the Permanent Secretary, Department of Geology and Earth Science, State University College at Brockport, New York 14420.

List of Field Guidebooks

1957	29th Annual Meeting, Wellsville, N.Y. (N.Y. State Geological Survey) (60 printed pages, 3 fold-out maps)	$2.50
1958	30th Annual Meeting, Peekskill, N.Y. (The City College of N.Y.) Field Trips and Pertinent Articles: (62 printed pages, 7 fold-out maps)	2.50
1959	31st Annual Meeting, Ithaca, N.Y. (Cornell University) (48 printed pages)	2.50
1960	32nd Annual Meeting, Clinton, N.Y. (Hamilton College) (66 printed pages, 3 fold-out maps)	2.50
1961	33rd Annual Meeting, Troy, N.Y. (R.P.I.) (101 printed pages)	2.50
1962	34th Annual Meeting, Port Jervis, N.Y. (Brooklyn College) (81 printed pages, 4 fold-out maps)	2.50
1963	35th Annual Meeting, Binghamton, N.Y. (Harpur College) (98 printed pages, 5 fold-out maps)	2.50
1964	36th Annual Meeting, Syracuse, N.Y. (Syracuse University) (126 printed pages, 1 fold-out map)	2.50
1965	37th Annual Meeting, Schenectady, N.Y. (Union College) (122 printed pages, 2 geologic color maps)	2.50
1966	38th Annual Meeting, Niagara Falls, N.Y. (State Univ. of N.Y. at Buffalo) (139 printed pages)	3.25
1967	39th Annual Meeting, Newburgh, N.Y. (State University College at New Paltz) (150 printed pages, 3 fold-outs with map & sections)	3.25
1968	40th Annual Meeting, Flushing, N.Y. (Queens College, City University of N.Y.) (253 printed pages, 5 fold-out maps)	6.00
1969	41st Annual Meeting, Plattsburgh, N.Y. (State University College)	
1970	42nd Annual Meeting, Cortland, N.Y. (State University College)	

Easy (1)

XIII-A-1b: GEOLOGY OF THE GRAND CANYON

QUESTION:

How can the order in which geologic events occurred be determined?

MATERIALS:

Student sheets, slides, maps, plastic models, stereo aerial photographs, and/or fossils of the Grand Canyon.

SUGGESTED APPROACH:

1. Discuss terms such as intrusion, unconformity, fault, etc.
2. Slides or filmstrip of Grand Canyon may be shown if available.
3. Permit students to complete the lab as a homework assignment.

PRECAUTIONS:

1. The Grand Canyon is such a vast area that you should center student attention on only portions of it at any one time. They can be successful in interpreting single events, but do not ask them to interpret the history of the entire Canyon all at once.
2. 'e prepared to help, by questioning, students who quickly become "lost" in the complexity of the Canyon.
3. Encourage students to constantly relate back to the materials used in step 1 while answering the questions.

BACKGROUND INFORMATION:

At the base of the Grand Canyon is the Vishnu Schist, a sedimentary-derived rock. The first step was probably the deposition of sediments in a shallow sea. The thickness of the material is estimated to exceed 5 miles. Based on studies of the rock's composition, the rate of deposition approximately equaled the rate of subsidence in the depositional basin. The Vishnu materials were further buried deeply enough to initiate metamorphism of the materials along with associated volcanic activity.

Uplift, as at least deformation of the crust, caused the metamorphism to be completed. At this time, igneous intrusions and/or recrystallization produced granitic material.

Uplift and succeeding erosion produced a peneplane-like surface. Next, subsidence and deposition resulting in the Grand Canyon series, more than 12,000 feet thick, occurred. In turn, these were uplifted, block faulted, and eroded.

Submergence and deposition occurred repeatedly to produce the various unconformities that appear in the layers.

As a "final" step, the Colorado River eroded a channel, and as uplifting continued, the river became entrenched and the canyon deeper until the present depth of more than 1 mile was achieved.

XIII-A-1b: GEOLOGY OF THE GRAND CANYON

QUESTION:

How can the order in which geologic events occurred be determined?

INTRODUCTION:

One of the foremost tourist attractions in the U.S. today is the Grand Canyon. To the average person, it is a place of beauty and wonder, too large for the mind to comprehend. To the earth scientist, it represents one of the best examples of geologic history in the world.

On the upper levels of the canyon, normal seasonal changes are observed, while on the canyon bottom the climate remains the same the year around.

The exposed rock ranges from Precambrian age through Paleozoic and Mesozoic to Eocene. It is, at the same time both young and old, inviting and forbidding, peaceful, and violent.

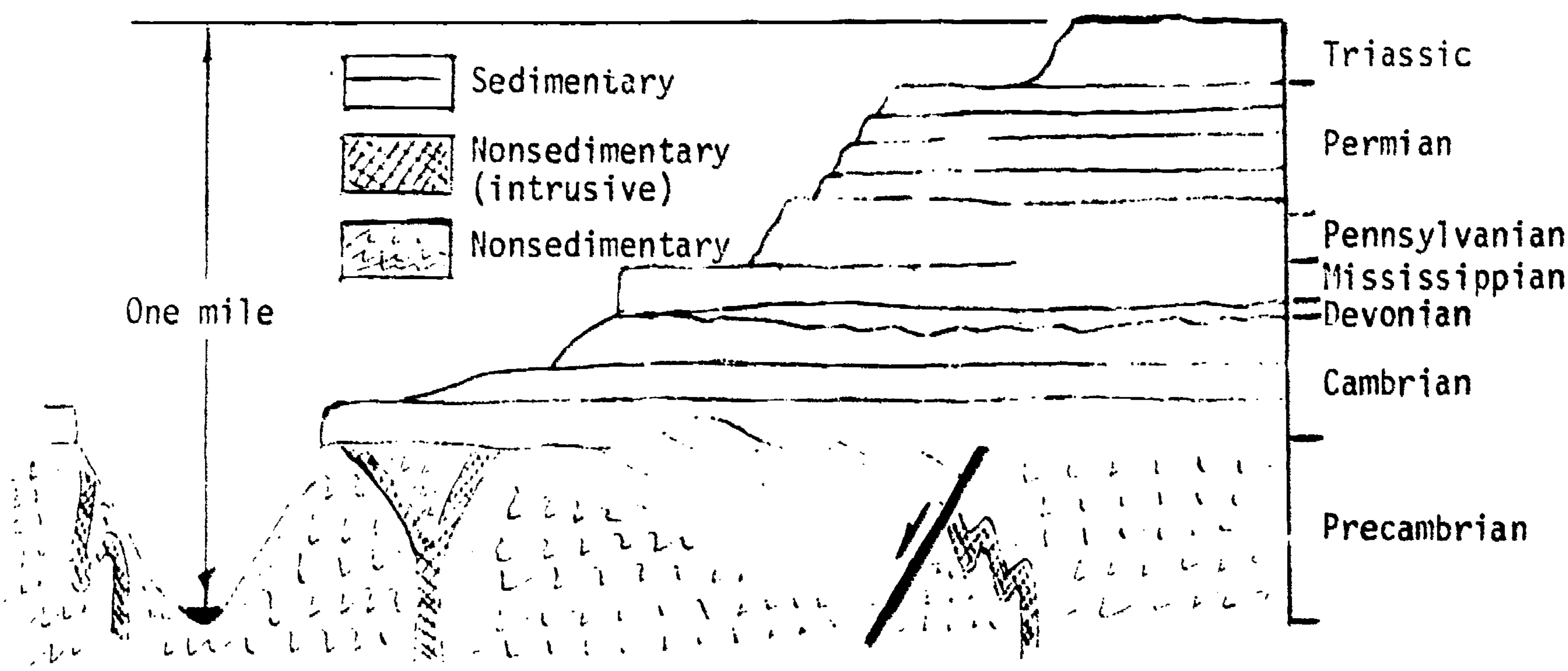
OBJECTIVES:

When you finish this investigation, you should be able to:

1. determine relative ages of rocks and make inferences about the geologic events which produced them.

METHOD:

Examine the diagram below and answer the following questions:



QUESTIONS:

(A-1.11) (A-1.21) 1. Which rocks are older, the sedimentary or nonsedimentary ones? Explain.

(A-1.21) 2. What is the age of the intrusive rocks relative to the rocks surrounding them?

(C-1.31) 3. What does the irregular surface between the sedimentary and nonsedimentary rocks suggest?

(A-1.31) 4. Notice the arrow indicating movement along a fault. What is the age of this fault relative to the Precambrian rocks? To the Cambrian rocks?

(B-1.11) 5. If you wanted to trace the boundary of Triassic rock in order to draw a surface map, how could you do it?

(B-1.21) 6. How could you determine if a rock at a particular elevation on one side of the canyon was the same as one at an identical elevation on the other side?

(B-1.31) 7. In which rocks would you most likely find fossils? In which ones would they most likely not be present? Explain.

(B-1.41) 8. From the diagram, and your knowledge of earth science, give a brief geologic history of this particular region of the Grand Canyon.

Easy (.5)

XIII-B-1a: FOOTPRINT PUZZLES

QUESTION:

How can rocks and geologic events in one place be matched to another?

MATERIALS:

Student sheet containing first section of fossil footprints, transparencies containing entire puzzle which can be blocked out in sections. (See Supplementary Sheet #1)

SUGGESTED APPROACH:

1. As a homework assignment, give students the first section of the footprint puzzle. Ask them to interpret what might have taken place to result in such footprints and whether they can tell anything about the size or type of animals that made them. Do not mention that there is more to come until the second day when the new-found evidence is introduced.

2. Remind students that the paleontologist is a type of detective who tries to reconstruct the past,and,in doing so, he forms a number of hypotheses, the best of which are supported by the greatest amount of evidence. Use a transparency of the homework section of footprints, and have students describe their interpretations and their evidence.

3. Show a transparency of the second portion of the footprints, and ask if anyone wants to modify his interpretation or has evidence for a new one.

4. Project the completed puzzle,and ask for completion of the interpretation. Accept any reasonable interpretation that is consistent with all the evidence. Encourage students to criticize each other's interpretations and to defend their own with evidence. Remember, there is no one right answer.

5. Remind the students of I-A-1b - Puddle Observations.

PRECAUTIONS:

1. Do not reproduce Supplementary Sheet #1 for student use.

2. Do not prejudice students toward accepting one interpretation as the correct one.

3. Be sure students make interpretations that are directly derived from the data and are consistent with them.

4. If you feel it is important for students to realize they are working with dinosaur footprints you may have to tell them so. Most students seem to favor birds unless reminded of the age or told a size scale.

TYPICAL RESULTS:

A class can develop several hypotheses that are defensible. Some examples are enemies fighting, a mother picking up a baby, one of the animals flies away, and the tracks have been made at separate times.

ERIC

MODIFICATIONS:

Have students:

1. Make casts and molds of present-day animal tracks.
2. Interpret present-day animal tracks.
3. Make their own tracks in as many different ways as possible (running, hopping, crawling, skipping, etc.), and present them to each other as puzzles.

REFERENCES:

Investigating the Earth, p. 416, Teacher's Guide, pp. 522-523, 525-527

XIII-B-1a: FOOTPRINT PUZZLES

QUESTION:

How can rocks and geologic events in one place be matched to another?

INTRODUCTION:

The scientists who study fossils, paleontologists, are like detectives, trying to reconstruct the geologic past from scattered clues and incomplete evidence. Like detective work, the clues and evidence always can be interpreted in more than one logical way; there are only better and worse hypotheses, not right and wrong ones. In this investigation, you will work with a set of fossil footprints and, based on the evidence, hypothesize the action that might have taken place to produce them.

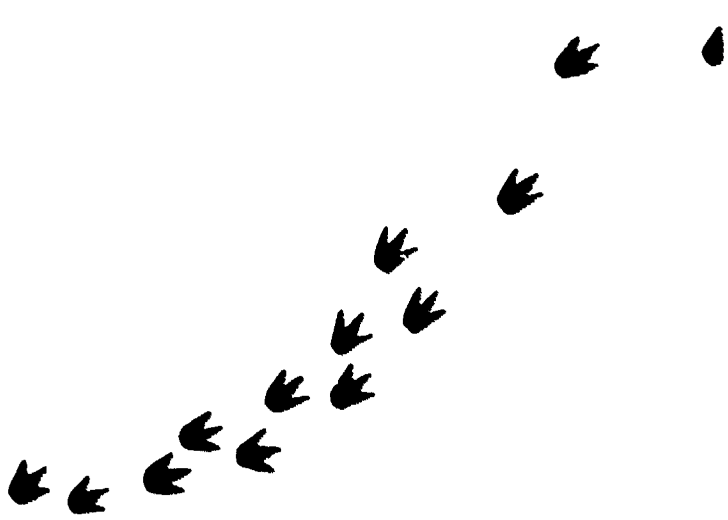
OBJECTIVES:

When you finish this investigation, you should be able to:

1. interpret the footprints as a record of some event that occurred in the geologic past.
2. describe a probable action occurring during the event.

METHOD:

1. Study the fossil footprints. Write an interpretation of what may have taken place.



QUESTIONS:

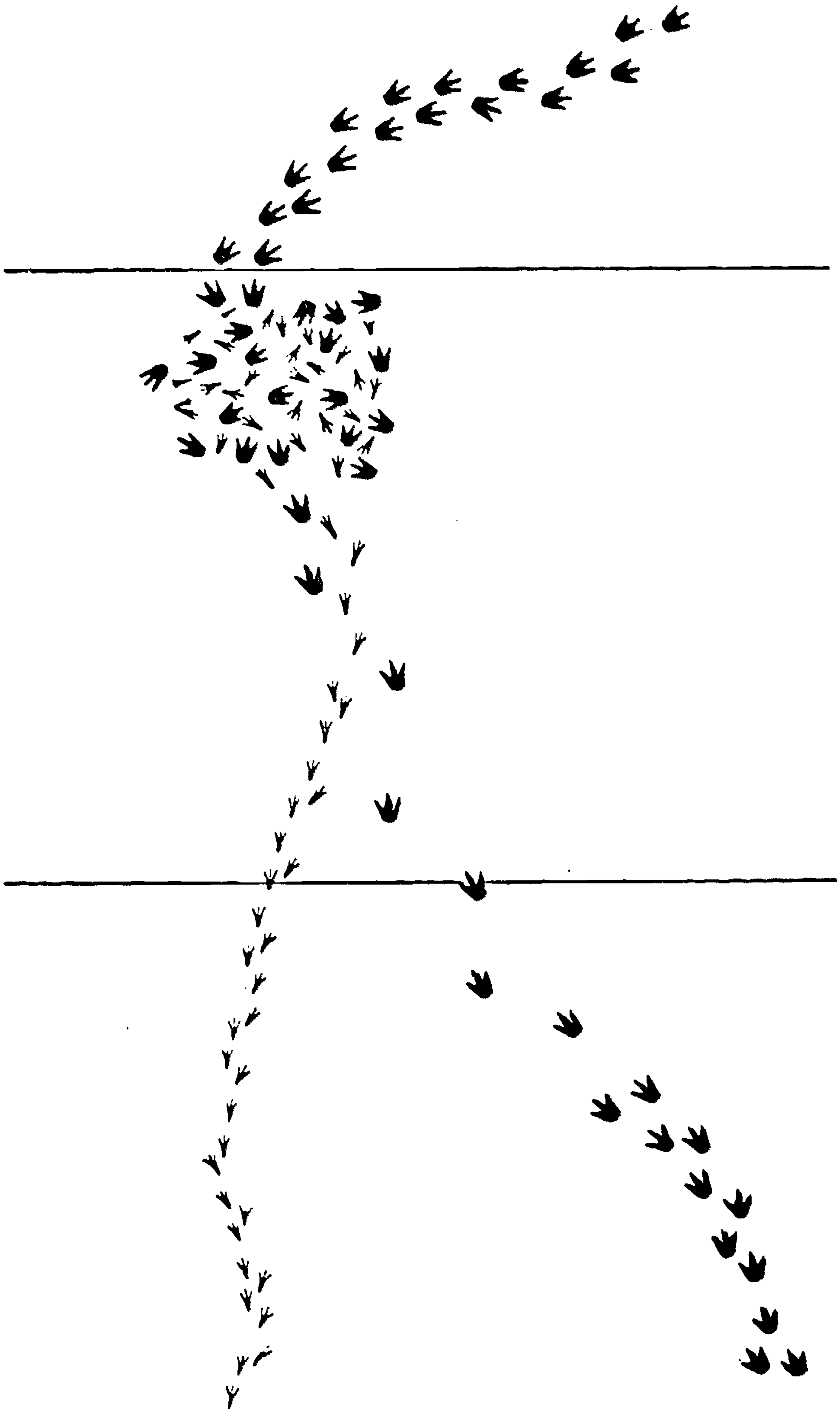
1. What kind of animals do you think made the footprints? How big were they? Why do you think so?

2. What event occurred that caused the footprints? Why do you think so?

3. Could any other events have caused the footprints? Why?

(B-1.32) 4. What sort of environment do you think this was at the time the footprints were made? Why?

(B-1.31) 5. Were the footprints found in sedimentary or nonsedimentary rock? Explain.



Adapted from:
Investigating the Earth, Teacher's Guide

Challenging (1.5)

XIII-C-1a: GEOLOGIC TIME LINE

QUESTION:

What does the rock record suggest about geologic history?

MATERIALS:

Adding machine tape, at least 5 meters long per student, list of events and ages of things in the geologic past (see Supplementary Sheet), and meter sticks.

SUGGESTED APPROACH:

1. Briefly discuss the expanse of geologic time with the students. Ask them how a model could be constructed to represent the expanse of geologic time.

2. Give the students the list of events and ages, and instruct them to make a time line that will include every item on the list. Suggest that they decide on the scale they want to use before making any marks on the adding machine tape. If any students want more or less than 5 meters of tape, allow them to have it.

3. Have the students compare their time lines; this can be done easily by lining up the lines on the floor or taping them to the wall. Discuss with them any questions or problems resulting from the time line.

4. If possible, permit the students to use an area of the gym or corridor so they can get a better idea of the relative lengths of time.

5. In postlab, impress upon the students ideas such as:

   A. man's recent arrival upon the scene

   B. the long periods which were apparently "lifeless," or at least left few or no fossils

   C. there are popular misconceptions such as the cave man living during the age of dinosaurs

PRECAUTIONS:

1. Some students have a great deal of difficulty establishing a scale and marking it on the tape. Check every student after the first few minutes of work.

2. Don't turn this into an art project. However, neatness and accuracy should be encouraged.

3. Allow enough time at the end of the period to roll up the longer strips of paper.

4. The teacher may want to update the chart yearly to keep the numbers accurate.

TYPICAL RESULTS:

Unless students are careless, most of them should have their tapes scaled correctly and most of the items placed correctly on the time line. Many will have difficulty with the more recent dates and will want to change their scales so that they can fit in everything. You might ask several students to determine how long a strip they would need in order to fit everything on it. In some cases, it may extend to over 30 meters.

MODIFICATIONS:

1. If you have included astronomy in your course, you may want to have students make a double-scaled time line and on the second scale place astronomical objects and their estimated distances in light-years.

REFERENCES:

Investigating the Earth, pp. 384-387, Teacher's Guide, pp. 475-478

ERIC

XIII-C-1a: GEOLOGIC TIME LINE

QUESTION:

What does the rock record suggest about geologic history?

INTRODUCTION:

Most of the geologic events we have studied happened a very long time ago, but it is difficult for most of us to comprehend the vastness of time that has passed since these events occurred. In this investigation, you will make a geologic time line which will help you to visualize the relationship of these past events to present events in geologic time.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. construct a time line which includes these dates.
2. compare the existence of living things on the earth with the entire extent of geologic time.
3. compare man's existence on the earth with the entire range of geologic time.

METHOD:

1. Examine the list of events and ages. Determine a scale for your time line and obtain a section of adding machine tape long enough to include all the events.
2. Plot the time line according to your scale. Include all the listed events.
3. Plot the geologic eras (e.g. Pre-Cambrian, Cambrian, Ordivician, etc.) using your reference table as a source of information.
4. Compare your time line with those of others.

QUESTIONS:

(C-1.23) 1. How does man's existence on earth compare with the duration of geologic time?

(C-1.22) 2. For what percentage of time has there been evidence of life on earth?

3. Did you have difficulty plotting any of the events on the list? Why?

(C-1.11) 4. What information, prior to recorded knowledge, was used to place the events in geologic history in order? Before this information can be used in this manner, what ideas or concepts must be accepted? Explain.

SUPPLEMENTARY SHEET

Geologic Time Line

1. Inferred age of the earth (based on meteorite and moon rock evidence)	4.5	X 10^9 yrs. (before the present)
2. Oldest rocks found on earth	3.3	X 10^9 yrs.
3. Carbon from plants (algae) Rhodesia	2.6	X 10^9 yrs.
4. Fungi - Canada	1.7	X 10^9 yrs.
5. Early sponges (archaeocyathids)	6.0	X 10^8 yrs.
6. Ostracoderm (jawless fishes, earliest vertebrate)	4.8	X 10^8 yrs.
7. Coal age forests and Appalachian Mountains	3.3	X 10^8 yrs.
8. First mammal-like reptiles	2.25	X 10^8 yrs.
9. Rise of dinosaurs	2.0	X 10^8 yrs.
10. First birds (Archaeopteryx), huge dinosaurs	1.5	X 10^8 yrs.
11. Dinosaurs died, Rocky Mountains rose	8.0	X 10^7 yrs.
12. Modern mammals, first horse (Hydrachotherium)	5.0	X 10^7 yrs.
13. The Great Plains, elephants come to North America	1.8	X 10^7 yrs.
14. First man (Homo habilis) - Africa	1.72	X 10^6 yrs.
15. Last U.S. continental glacier	1.0	X 10^4 yrs.
16. Beginning of Julian calendar	1.974	X 10^3 yrs.
17. Mt. Vesuvias destroys Pompeii	1.891	X 10^3 yrs.
18. Columbus discovers America	4.78	X 10^2 yrs.
19. Galileo's first telescope	3.61	X 10^2 yrs.
20. American Civil War	1.00	X 10^2 yrs.
21. First U.S. satellite in orbit	1.2	X 10^1 yrs.
22. Man lands on the moon	1.0	X 10^0 yrs

Difficult (1.t)

XIII-C-1b: CORRELATING ROCK OUTCROPS

QUESTION:

What does the rock record suggest about geologic history?

MATERIALS:

Student handout sheets and Supplementary Sheets #1 and #2, one Earth Science Curriculum Project Basic Fossil set for each group of two or three students (optional), appropriate real fossils (optional).

SUGGESTED APPROACH:

1. Ask the students how they might correlate, in terms of relative age, rock outcrops found in widely scattered areas.
2. Develop the concept of "index fossils" and how they are used to correlate rock units.
3. If you have the basic fossil sets available, allow the students time to become familiar with the appearance of their "index fossils."
4. Assign the exercise of correlating the rock units as homework.
5. During a postlab discussion, use the chalkboard or overhead projector to work out the sequence. You may want a student who feels that he or she has successfully completed the investigation to do this in your place.

TYPICAL RESULTS:

The outline below represents a series of logical deductions which will lead to one possible interpretation of the relative ages of the rock units. This outline should be used in conjunction with the probable solution diagram on a following page.

Key: 9/15 indicates that 9 is younger than 15

A) 5/2 & 20; 5/8; 5/18; 18/11; etc. Therefore, 5 is youngest.

B) 2 & 20/14 & 19; 2 & 20/13; 13/1 & 18; 18/7; etc. Therefore, 20 and 2 are second youngest.

C) 5/8; 8/1; 8/7; 8/16; etc. Therefore, 8 can be placed somewhere between 5 and 1 & 18.

D) 14 & 19/13; 13/1 & 18; 1/7; etc. Therefore, 14 & 19 are third youngest.

E) 13/1 & 18; 1 & 18/17; 1/7; etc. Therefore, 13 is fourth youngest.

F) 1/7; 1 & 18 are found together; 1 & 18/17; etc. Therefore, 1 & 18 are fifth youngest.

G) 1 & 18/17; no further data on 17. Therefore, it is somewhere below 1 & 18.

H) 1/7; 7/12; 12/11; etc. Therefore, 7 is sixth youngest.

I) 12/11; 7/12; etc. Therefore, 12 is seventh youngest.

J) 12/3 & 15; no further data on 3 & 15. Therefore, 3 & 15 are somewhere below 12.

K) 11/10 & 16; 10/4. Therefore, 11 is eighth youngest.

L) 10/4; 10 & 16 are found together. Therefore, 10 & 16 are ninth youngest.

M) 4/9; 4/6. Therefore, 4 is tenth youngest.

N) Therefore, 9 (and/or 6) is oldest.

The geologic age diagram gives you the actual location and age.

MODIFICATIONS:

1. Use photographs of actual outcrops, instead of the block diagrams, on which the above mentioned fossil zones have been sketched in. Note: the sequence of zones is the important point here, and not the veracity of the photographs. (Slides also could be used in this case.)

2. Use real instead of plastic fossils.

3. Cut "geologic columns" or "core samples" out of strips of paper. To represent fossil zones, place either the numbers of the fossils, pictures of the fossils, or the appropriate fossils on the column, in the proper sequences. So as to simulate outcrops, place the columns around the room, and have the students "visit" them to gather data.

   a. insert some unidentified fossils into the column.

   b. invert one or more of the columns, and bring in the concept of overturned anticlines.

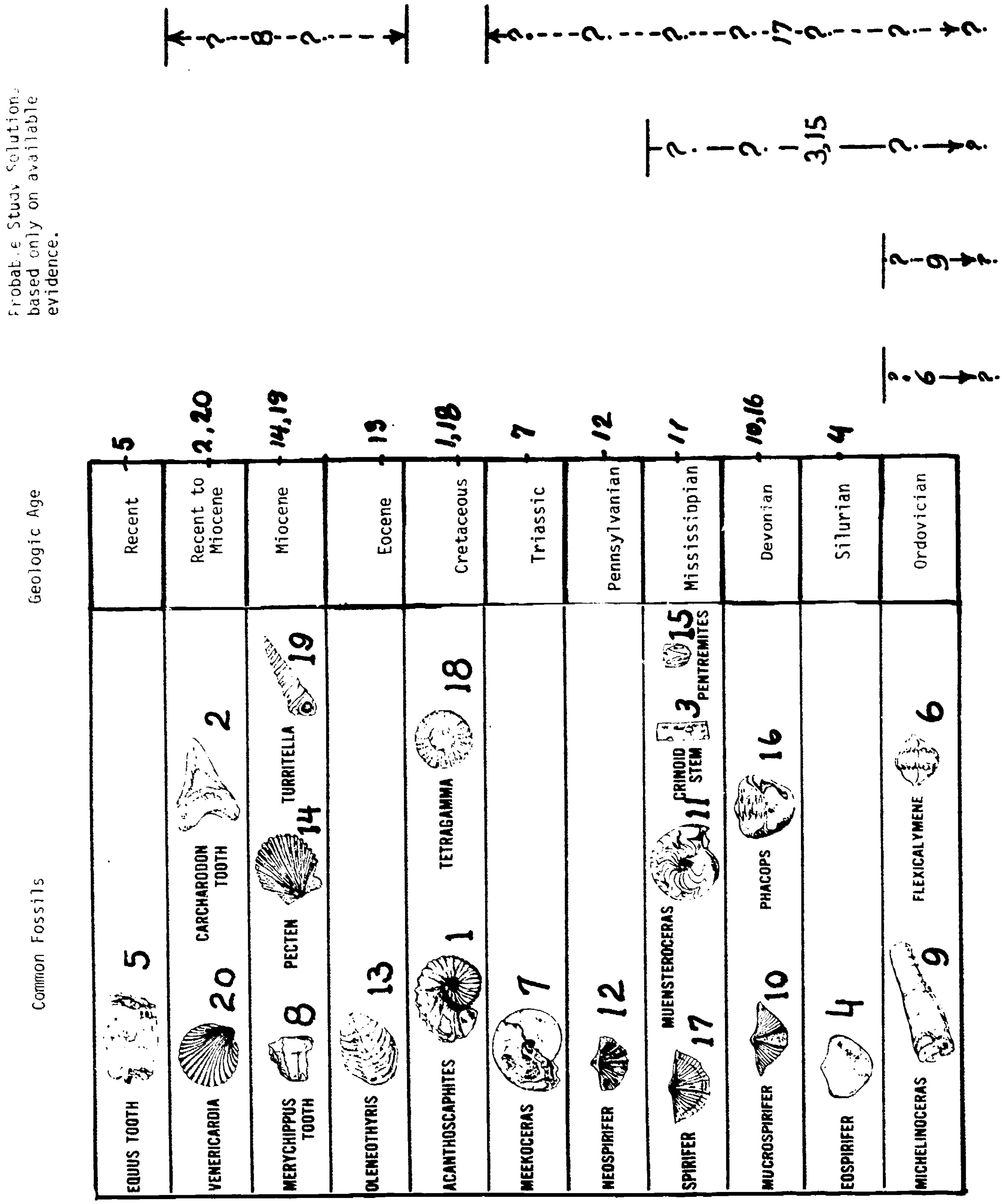
4. Use the block diagrams and the associated fossils in an attempt to interpret the past history of the area.

REFERENCES:

Investigating the Earth, pp. 414-420, Teacher's Guide, pp. 521-527

TYPICAL RESULTS:

PROBABLE SOLUTION DIAGRAM



XIII-C-1b: CORRELATING ROCK OUTCROPS

QUESTION:

What does the rock record suggest about geologic history?

INTRODUCTION:

The early geologists attempted to put order into this puzzling array of fossil types which confronted them. In this investigation, you will attempt to find the relative age of a number of fossils. Try to think of the problem as an early geologist would. See if you can appreciate some of his problems.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. determine the relative age of rock units using index fossils.
2. make inferences as to why fossils are used as one basis for the theory of evolution.
3. make inferences as to why the sequence of fossils in some cases varies from column to column.

METHOD:

1. Look at the block diagrams of rocks containing fossil zones. (Supplementary Sheet #2)
2. Arrange the fossils in order from youngest to oldest. Be sure to record your reasons for the sequence in which you place them.

QUESTIONS:

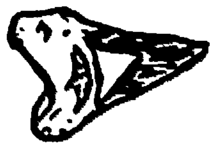
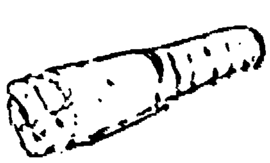
(C-1.11) 1. Which of the fossils appeared first? How do you know?

(C-1.11) 2. Which of the fossils appeared most recently? How do you know?

(C-1.31) 3. What reason can be given to explain why layers 7 and 12 can be found under 18, and also under 1, but not under the combination (1 and 18)?

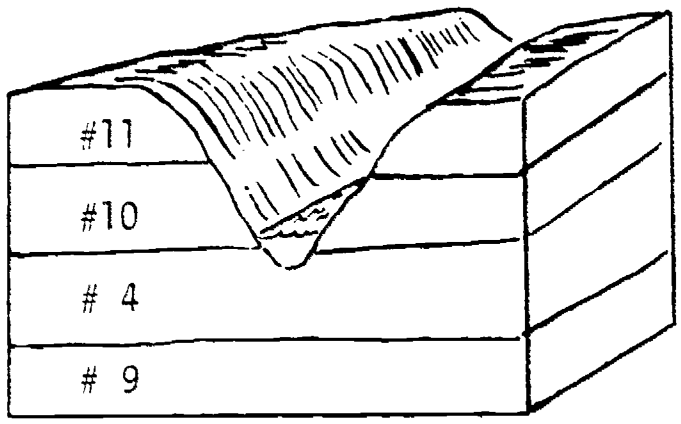
(C-1.41) 4. Notice that some fossils, such as 10 and 16, can be found together in some cases but not in all. Give a reason for this occurrence.

LIST OF FOSSILS

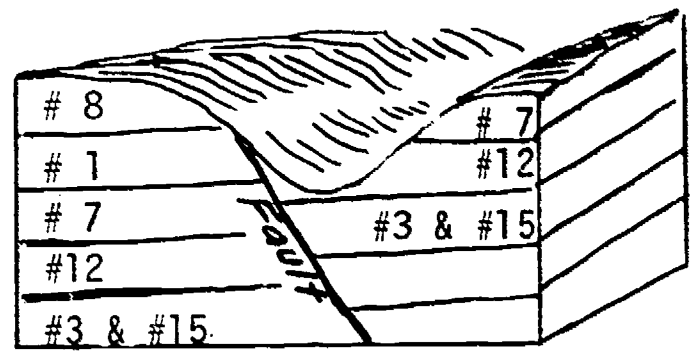
1. ACANTHOSCAPHITES 
2. CARCHARODON TOOTH 
3. CRINOID STEM 
4. EOSPIRIFER 
5. EQUUS TOOTH 
6. FLEXICALYMENE 
7. MEEKOCERAS 
8. MERYCHIPPUS TOOTH 
9. MICHELINOCERAS 
10. MUCROSPIRIFER 
11. MUENSTEROCERAS 
12. NEOSPIRIFER 
13. OLENEOTHYRIS 
14. PECTEN 
15. PENTREMITES 
16. PHACOPS 
17. SPIRIFER 
18. TETRAGAMMA 
19. TURRITELLA 
20. VENERICARDIA 

SUPPLEMENTARY SHEET #2

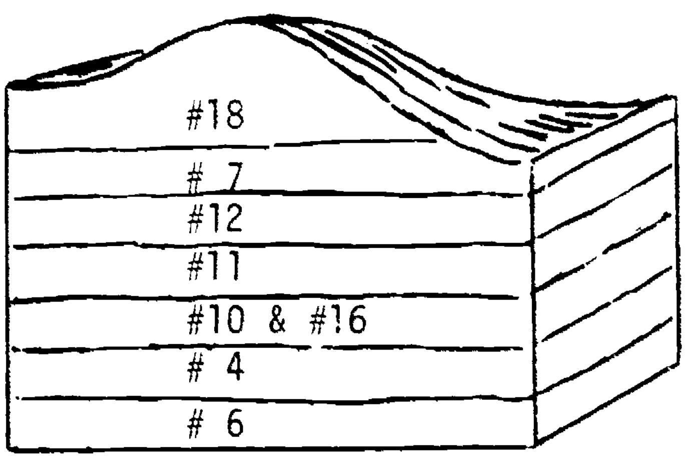
SIX WIDELY SCATTERED ROCK OUTCROPS



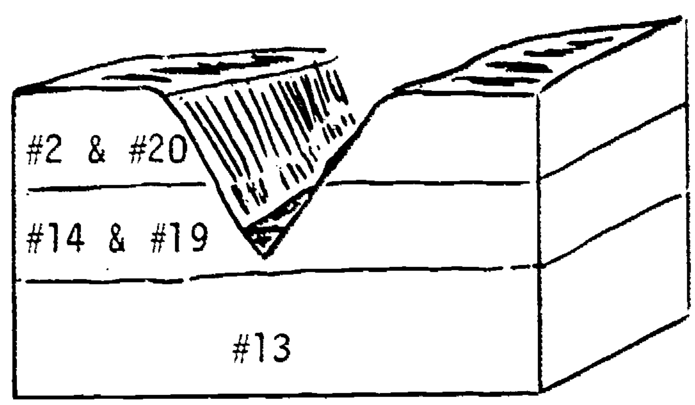
Outcrop #1



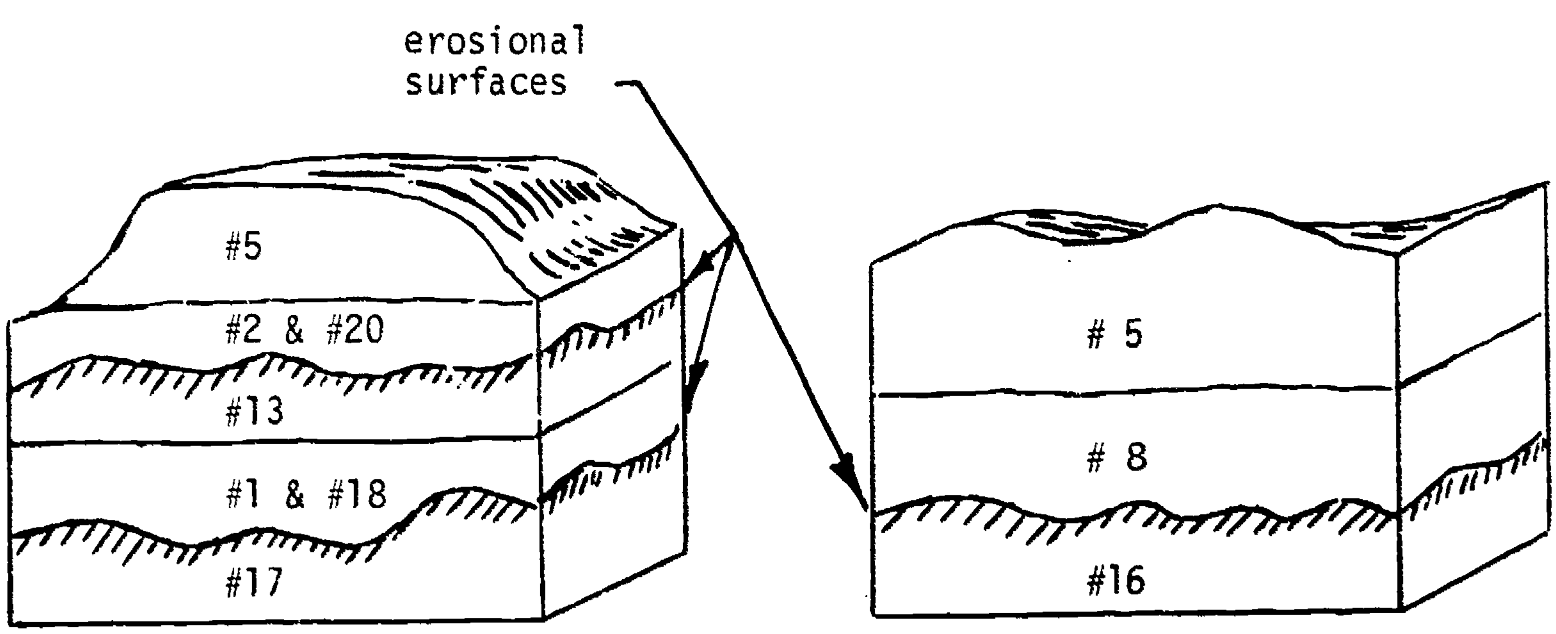
Outcrop #2



Outcrop #3



Outcrop #4



Outcrop #5

Outcrop #6

Easy (1.5)

XIII-C-2a: RADIOACTIVE DECAY

QUESTION:

How can geologic ages be measured by using radioactive decay?

MATERIALS:

Shoeboxes with lids, 50-100 pennies (or pieces of dried field corn) per group of 2-3 students, graph paper.

SUGGESTED APPROACH:

1. If possible, demonstrate radioactive decay with a Geiger counter and a sample of some radioactive rock or mineral; ask students to describe what they hear (or see). Remind them that radioactive decay is used to measure geologic age and ask them how they think this works. Accept all answers, be sure the idea of half-life is mentioned,then indicate that this investigation deals with a statistical model that illustrates the concept of half-life.

2. Have each group of students place about 100 pennies in their shoebox, with the same sides up. Have them cover the box, hold it level, and give it a single sharp shake. Then open it and remove all pennies that have flipped over. Record the number left in the box. Repeat this until no more pennies are left in the box.

3. Have the students graph the number of shakes vs. number of unflipped pennies left in the box after each shake.

4. Have each group color one penny with nail polish and repeat step 2. Have them find out how many times the box must be shaken before the colored penny flips over. Collect and compare the data.

5. Have the students share their data by placing them on the chalkboard in the following chart form. (Use an * to indicate shake during which colored penny flipped.)

Student Groups	Shake one	Shake two	Shake three	Shake four	Shake five
Group 1					
Group 2					
Group 3					
Group 4					
Averages					

Have the students graph the average number of pennies flipped during each shake versus number of shakes.

6. Lead students in a discussion which:

a) answers questions like those on the student sheet, and

b) analyzes the validity of this investigation as a model of radioactive decay

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PRECAUTIONS:

1. Careful analysis of this model shows it to be weak in a number of aspects. Unless used with great care, it can give rise to serious misconceptions. Therefore, students should be led to analyze the model critically, noting all the ways in which it is deficient. They should be encouraged to suggest a more valid model. In such a model, the objects representing nuclei should:

   a) change spontaneously and at random

   b) change without application of external energy

   c) remain "on the scene" instead of being removed

   d) not be able to undergo the reverse change

2. Be sure students hold the top of the box tightly in place.

3. If the Geiger counter is used for the demonstration, be sure to hold the radioactive material far enough away so that individual clicks, not a steady buzz, are heard.

4. The concept of a random event is a difficult one for students to grasp.

TYPICAL RESULTS:

Graphs of class data should be smooth curves closely resembling actual graphs of decay rates of radioactive elements. This will not be true for individual data which is based on a small number. The students should realize from the class data that the chance for a particular penny to flip is random.

MODIFICATIONS:

1. Use thumbtacks, placing them heads down and removing all those which land points down after a single shake.

2. Use grains of corn (dried), removing those which happen to point toward one pre-designated side of the box. This can be repeated using two and then three pre-designated sides of the box. The resulting graphs will be different and can serve as models of the different decay curves obtained for radioactive elements which have different half-lives.

REFERENCES:

Investigating the Earth, pp. 378-379, Teacher's Guide, pp. 471-473, 482-483

ERIC

XIII-C-2a: RADIOACTIVE DECAY

QUESTION:

How can geologic ages be measured by using radioactive decay?

INTRODUCTION:

You know that the process of radioactive decay of certain elements present in some minerals is used to determine geologic age. What characteristics of radioactive decay enable the geologist to use this method as the most accurate one known? In this investigation, you will work with a statistical model that illustrates the process of radioactive decay.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. graph "particle decay" versus "time."
2. explain why the graph from an individual experience is not as smooth a curve as that derived from pooled class data.
3. relate the model to actual radioactive decay by analyzing the model's strong points and weaknesses.
4. use the graph of class data to predict time elapsed when given percentage of decay, or to predict percentage of decay when given time.

METHOD:

1. Place about 100 pennies in the shoebox, with the same sides up (e.g., all tails). Cover the box, hold it level, and give it a single sharp shake. Open the box and remove all pennies that have flipped over. Record the number of pennies left in the box.
2. Repeat step 1 until no more pennies are left in the box.
3. Color one penny with nail polish and repeat steps 1 and 2 until the colored penny flips over. Record the number of shakes necessary before this happens. Compare your data with the class by constructing a chart on the chalkboard.
4. Graph your data obtained from steps 1 and 2; plot number of shakes vs. number of unflipped pennies left in the box.

5. Repeat step 4, but use class data in which the entire number of pennies left in all the boxes, after each shake, have been totaled.

QUESTIONS:

1. How is the graph of your own data different from the graph of class data? Why is it different?

2. What is the half-life for the penny model?

(C-2.12) 3. What is the probability of a particular penny being flipped over by a single given shake? How does your answer to this question compare with the observations from step 3?

4. In what ways do the pennies behave like radioactive nuclei? In what ways don't they behave like radioactive nuclei?

(C-2.13) 5. a. There are 5,731 pennies in a shoebox, all heads up. The box is given one sharp shake. About how many pennies will flip over?

b. The box in (a) is repeatedly shaken; after each shake all pennies that have flipped over are removed until 471 pennies remain in the box. About how many shakes have been given to the box?

(C-2.13) (C-2.22) 6. If organic matter containing carbon-14, which has a half-life of 5,700 years, died only 10 years ago, would you expect to be able to determine an accurate C^{14} age for it? Why? What if it had died 100,000 years ago? Why?

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Easy (2)

XIII-D-1a: VARIATION WITHIN A SPECIES

QUESTION:

What does the fossil record suggest about ancient life?

MATERIALS:

Plastic fossil sheets, actual fossil samples, metric ruler, calipers, graph paper.

SUGGESTED APPROACH:

1. Distribute plastic fossil sheets and have students observe and record their observations. Limit them to 5 minutes.
2. Have the students draw a light line with pencil across the sheet to get a random sampling of fossils.
3. Have students measure the length, <u>or</u> width, of each fossil which is touched by their line.
4. Have the students graph frequency (number of individuals with a certain length) vs. length, or frequency vs. width of the fossil (this can be done as homework).
5. Have the students discuss the meaning of the curve in relation to the population mixture and possible reasons for size variation.

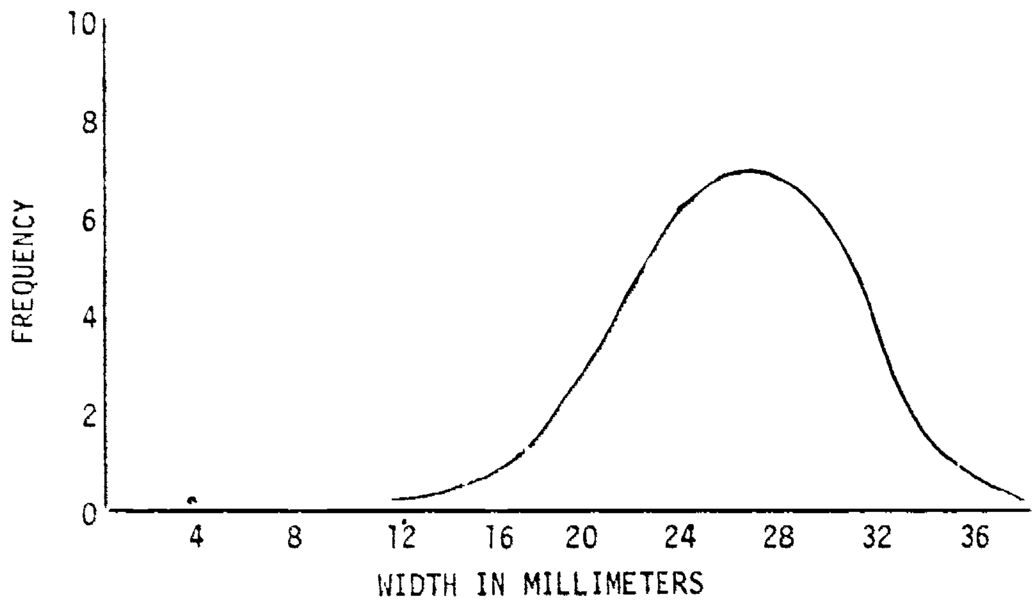
PRECAUTIONS:

1. Students will need some technique for identifying those fossils they have measured; small pieces of masking tape work well.
2. Students will require a definition of frequency. They should be instructed to round off their measurement to the closest minimum unit appearing on the graph (e.g., for length and width of brachiopods they should round off to nearest millimeter). They should then record the number of individuals who have a length of 24 millimeters, number with length of 25 mm., 26 mm., etc. This information then can be plotted as frequency.

TYPICAL RESULTS:

1. The student should obtain a good bell-shaped curve with frequency vs. any characteristic.
2. Almost all students will be able to conclude that, within a species, most individuals will have similar characteristics although some minor variations may be observed.
3. The students will give reasons for the existence of atypical individuals within the general population such as climate, age, food supply, and mutation.

GRAPH OF FREQUENCY VS. WIDTH FOR ONE SPECIES



MODIFICATIONS:

1. Have the students repeat the process with a second but different sheet and compare their results.
2. Have the students repeat the process with a real fossil population or use a real fossil population in lieu of the plastic sheet.
3. Have the students graph the number of ribs vs. frequency instead of length or width.
4. Have the students graph length vs. width. (A lens-shaped scatter-gram will be obtained.)
5. Have the students measure and record their own heights. They can then plot a curve of height versus frequency that the height occurred within the class. In order to have good results you may have to round the height of each student to the nearest decimeter.

REFERENCES:

Investigating the Earth, pp. 421-423, Teacher's Guide, pp. 529-531

XIII-D-1a: VARIATION WITHIN A SPECIES

QUESTION:

What does the fossil record suggest about ancient life?

INTRODUCTION:

Fossils give evidence of a great many kinds of animals and plants that have lived in the past under a variety of conditions. Fossils are classified into species. Variation within a species can be observed, measured, and described.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. observe and describe, by means of frequency curves, the variations present within a species.

2. describe a species in terms of ranges of characteristics which allow for the observed variations.

3. explain why species variations are necessary to the theory evolution.

METHOD:

1. Record any observations you can make concerning the sample you have been given.

2. Draw a light pencil line across the sample given you.

3. Measure, to the nearest millimeter, and record the characteristics, indicated by your instructor, of each individual the pencil line touches.

4. Graph the characteristic vs. frequency (number of individuals having the same value) of occurrence for each individual measured.

QUESTIONS:

(D-1.21) 1. On what evidence could you decide whether or not this group is a single species population?

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(D-1.22) 2. Suggest possible reasons for the variations found.

(D-1.23) 3. Fossils from other geologic times have been found which resemble those which you have examined, but they are not exactly the same. What does this evidence suggest to you?

(D-1.12) 4. Considering the fact that in most environments today more than one type of living organism is found, give an explanation why the fossil sheets contained only one basic life form.

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topic XIV

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TOPIC XIV - LANDSCAPE DEVELOPMENT AND ENVIRONMENTAL CHANGE

What Causes Landscapes?

Time Emphasis: 15 days

INVESTIGATION		A-1a	A-1b	A-1c	A-2a	B-1a	B-1b	B-1c
Estimated Time (Periods)		FT	2	3	2	FT	1	1
TOPIC OUTLINE								
A. Landscape characteristics								
A-1 Quantitative observations — *What Are the Landscape Characteristics That Can Be Observed and Measured?*								
A-1.1 Hill slopes	A-1.11		X	X				
A-1.2 Stream patterns	A-1.21		X	X				
A-1.3 Soil associations	A-1.31	X				X		
A-2 Relationship of characteristics — *How Are Landscape Characteristics Related?*								
A-2.1 Landscape regions	A-2.11		X		X	X		
	A-2.12		X		X	X		
	A-2.13		X					
	A-2.14		X		X	X		
B. Landscape Development								
B-1 Environmental factors — *How Is Landscape Development Influenced by Environmental Factors?*								
B-1.1 Uplifting and leveling forces	B-1.11					X		
	B-1.12		X	X		X		
	B-1.13		X		X	X		
B-1.2 Climate	B-1.21					X	X	
	B-1.22	X	X	X	X	X	X	
	B-1.23					X	X	
	B-1.24		X	X		X		
	B-1.25		X					
	B-1.26							
	B-1.27					X		
B-1.3 Bedrock	B-1.31				X	X		
	B-1.32		X	X	X	X		
	B-1.33		X	X	X	X		
	B-1.34		X	X	X	X		
	B-1.35		X			X		
	B-1.36					X		
B-1.4 Time	B-1.41							
B-1.5 Dynamic equilibrium	B-1.51					X		
B-1.6 Man	B-1.61		X	X		X		
	B-1.62							X
	B-1.63					X		
	B-1.64					X		
	B-1.65							
	B-1.66					X		
	B-1.67			X		X		
	B-1.68							
PROCESS OF INQUIRY OBJECTIVES								
Mathematical Skill	PIO-1							X
Measurement Skill	PIO-2	X	X	X	X	X	X	X
Creating Models	PIO-3	X	X	X	X		X	
Analysis of Error	PIO-4	X						
Data Analysis	PIO-5	X				X	X	X
TITLES		Till Fabric Field Trip	Regional Aerial Photo Studies	Local Aerial Photo Studies	Identifying Landscape Regions	Landscape and Soils Field Trip	Plotting Evidence of Glaciation	Exponential Population Growth

Multimedia: Check Multimedia Section of Supplement for reference to this topic.

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Challenging (1/2 day)

XIV-A-1a: TILL FABRIC FIELD TRIP

QUESTION:

What are some landscape characteristics that can be observed and measured?

MATERIALS:

Magnetic compass, jack knives, shovels, rose diagrams (Supplementary Sheet), clipboards (optional).

SUGGESTED APPROACH:

1. Before leaving on the field trip, ask students to make a list of all evidences they can think of which would indicate direction of ice movement in an area. They probably will not list till fabric without your help. Tell them that tills usually contain elongate pebbles (longer in one axis than the others). These tills are thought to have been smeared out on the surface as the glacier moved past. Ask the students how elongate pebbles would probably come to rest when deposited by this mechanism. Would the long axis point in the direction of movement? Actual research has indicated that most would point in that direction, however, many of them apparently roll into position and are situated at right angles to the first group.

   Next ask how a study of a till could be made to determine direction of ice movement. Students should come up with some form of a till fabric study technique.

2. At the till site, the technique suggested on the student sheet can be used successfully.

3. If the technique described is used carefully, a pattern showing a distinct maxima will develop. Sometimes, a secondary maxima will develop at right angles to the first. The first group is inferred to be those pebbles that slid into position; the second group probably rolled into position, usually referred to as "sliders" and rollers" respectively.

4. Students should work individually or in groups of two. When finished, data should be shared and a direction of glacial movement decided upon. If no pattern develops, discuss possible reasons.

5. Have the students plot direction of movement on a wall map.

PRECAUTIONS:

1. Between 20 and 50 pebbles should be measured before a pattern can be interpreted. Students may have a tendency to infer a direction after only a few pebbles have been measured.

2. Stress the importance of accuracy in the determination of the orientation of the long axis of the pebbles.

TYPICAL RESULTS:

The results should produce a distinctive pattern which should compare to other glacial directional features in the area such as drumlins and glacial scratches on bedrock.

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MODIFICATIONS:

1. A till fabric rack can be constructed and used as illustrated in the MacClintock reference.

2. If time is limited, have each student remove only two or three pebbles, and pool the information on one rose diagram when finished.

3. If a field trip is impossible, a large slab of till might be removed from a bank and brought to the classroom where it could be dissected. The orientation of the slab should be measured and recorded at the original site before removal.

REFERENCES:

Paul MacClintock, "A Till Fabric Rack," *The Journal of Geology*, Vol. 67, No. 6, November 1959.

Paul MacClintock and J. Terasmae, "Glacial History of Covey Hill," *The Journal of Geology*, Vol. 68, No. 2, March 1960.

XIV-A-1a: TILL FABRIC FIELD TRIP

QUESTION:

What are some landscape characteristics that can be observed and measured?

INTRODUCTION:

Most areas of New York State exhibit some kind of evidence for previous glaciation, however, not all of this evidence gives any clue as to the direction the ice moved through the area. The glacial geologist is continually looking for new approaches which will help him complete his understanding of the glacial history of his area. One such approach is the "till fabric study" which you will be conducting in an area near your home.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. identify whether or not a soil is a glacial till.

2. state evidence that suggests that a landscape region probably developed under a different climatic environment.

METHOD:

After arriving at the study site, you should:

1. Determine if the layer of material you choose to work with is really a till and not some other form of deposit. If you can uncover a pebble with scratches on its surface, you can use it as proof of "till."

2. Using the shovel, square off a vertical face about 2 or 3 feet in each dimension, measure and record on the bottom of your rose diagram the direction parallel to your working face.

3. Level off a spot at the foot of your vertical working face large enough to support your clipboard in a horizontal position. Position the clipboard so that the bottom of the rose diagram is parallel to the working face.

4. Choosing uniform size till pebbles (1-1½-inch size works best), carefully remove them, without destroying their orientation.

5. Decide which slot on the rose diagram the long axis of the pebble would be most nearly parallel. Make a symbol (I) in that slot. Continue the process for 20-50 pebbles, until it is obvious that you have a distinct pattern developing.

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6. After returning to the school you will want to transfer all the individual data to one rose diagram. Be careful to correct for variations in the directions of the working faces.

7. Decide on the direction of ice movement through the area.

Note: Different till fabric results, occurring at two different elevations in the same till bank, has in some instances been used as proof of two glacial advances in the area, each from a different direction.

QUESTIONS:

(A-1.31) 1. Describe the characteristics of the soil in which you conducted your investigation.

2. What was the direction of glacier movement in your area?

3. Do the data indicate the direction of ice movement during the entire time the glacier occupied the area?

4. Is there any evidence that the land surface (e.g., valleys, hills, or mountains) influenced the direction of glacier movement?

5. Were you able to find any other evidence, in the general area of your till fabric study, that would substantiate your results (e.g., glacial striae or long axis of drumlins)?

(B-1.22) 6. What evidence can you cite that would suggest that this landscape region may have developed under an extreme glacial climatic condition?

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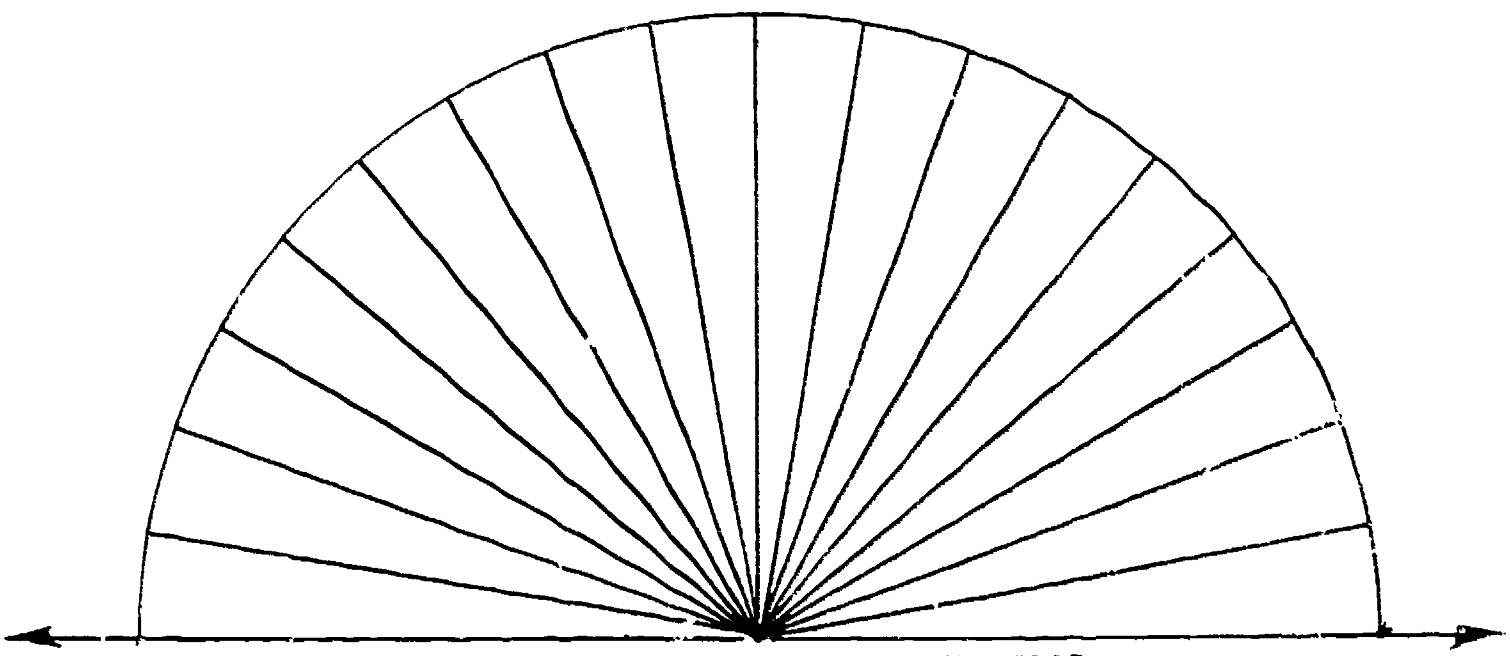
SUPPLEMENTARY SHEET

TILL PEBBLE ORIENTATION

Date ____________________ Location ____________________

Collector ____________________ ____________________



DIRECTION PARALLEL TO WORKING FACE

RECORD DIRECTION HERE: ____________

Total Number of Pebbles ______

NOTES:

Challenging (2)

XIV-A-1b: REGIONAL AERIAL PHOTO STUDIES

QUESTION:

What are some landscape characteristics that can be observed and measured?

MATERIALS:

Each student, or group of two students, should have: stereo viewer, landform map (See Supplementary Sheet #1), and one or more of the aerial photograph sets indicated under Background Information. (For ordering, see Supplementary Sheet #2.) Topographic maps of the same areas are optional.

SUGGESTED APPROACH:

1. Discuss briefly the use of stereoscopes.
2. Allow students to begin work, following the directions on student handout sheet.
3. After completion of the aerial photo study, involve the group in a discussion of their conclusions.

PRECAUTIONS:

1. Individual aerial photos must be ordered several months in advance of the using date to insure receiving them on time. (See the order sheets on Supplementary Sheets.)
2. Students may have trouble using the stereo viewers.
3. Don't contaminate student thought by introducing a lot of geomorphology terms. Most landforms can be recognized and possible origins inferred by the use of common sense and the experiences they have had during this course of study.

MODIFICATIONS:

1. Teachers may wish to use sets of photographs found in stereo atlases, which are available from several suppliers.

BACKGROUND INFORMATION:

Calif. 25. Badwater, Death Valley

Lat 36°15' N.; long 116°45' W.
Photographic scale: 1:48,000.
Date flown: Nov. 27, 1948.

Map Reference: U.S. Geol. Survey Furnace Creek, Bennetts Well, Ryan, and Funeral Peak 15-min quadrangles, scale 1:62,500

Features illustrated (set nos. Calif. 25 A-B in southeast corner of photographs). - Badwater, almost the lowest point in the United States, is a spring fed sulfate marsh in the reentrant on the north side of the fan in the center of photograph 25B. The broad white area west of Badwater is subject to flooding and is crusted with rock salt. North of this area, extending to the foot of the gravel fan, is massive rock salt: to the south is rock salt that has been smoothed by flooding. At right is the faulted front of the Black Mountains; the Badwater Turtleback - metasedimentary rocks of Precambrian age - is overlapped at the north by volcanic rocks of Tertiary age.

Calif. 30. Horizontal movement on San Andreas fault

Lat 35°16'N.; Long 119°50' W.
Photographic scale: 1:20,000
Date flown: July 22, 1957

Map reference: U.S. Geol Survey McKittrick Summit and Painted Rock 7½-min quadrangles, scale 1:24,000

Features illustrated (set nos. Calif. 30 A-B in southeast corner of photographs). - Photographs show offset drainage, well-defined scarps, and trenches in Quaternary deposits along the trace of San Andreas fault and subsidiary faults. The area slopes gently to the southwest to the [illegible] Plain and is crossed by parallel intermittent streams that locally meander. The streams are [illegible] northeast of the trace of the fault.

Fla. 1. Beach ridges, St. Vincent Island

Lat 29°40'N.; long 85°10'W.
Photograph scale: 1:43,000
Date flown: Nov 1, 1942

Map referemce U.S. Geol. Survey Indian Pass and West Pass 7½-min quadrangels, scale 1:24,000

Features illustrated (set nos. Fla. 1 A-B in northeast corner of photographs). - The island is made up entirely of beach ridges and intervening marsh. It has grown southward about 4 miles, during the present sea-level stand. The pattern of ridges suggests that three erosional intervals interrupted the process of island growth (C.A. Kaye, written commun., 1961).

Kans. 2. Flat-lying limestone and shale in the Flint Hills

Lat 39°17'N.; long 96°25'W.
Photographic scale: 1:20,000
Date flown: Sept 18, 1937

Map reference: U.S. Geol. Survey Manhattan sheet, scale 1:250,000

Features illustrated (set nos. Kans. 2 A-B in southeast corner of photographs). - Flat-lying cherty limestone and shale of Permian age in northeast Kansas. The white bands are outcrops of limestone; the wider gray bands are intervening beds of shale. Area is prairie; trees grow only in valleys on the banks of Cedar Creek and its tributaries that are incised below the Flint Hills Upland.

Maine 2. The Horesback along Sunkhaze Stream

Lat 44°57 N.; long 68°25'W.
Photographic scale: 1:24,000
Date flown: May 1, 1956

Map reference: U.S.Geol. Survey Great Pond 15-min quadrangle, scale 1:62,500

Features illustrated (set nos. Maine 2 A-C in northeast corner of photographs). - This gravel ridge - an ice-channel filling or esker - crosses the area from northwest to southeast. It is virtually continuous, as much as 70 feet high, and is bordered by swamps and, locally, by kames. The adjacent rounded hills are of granitic rock.

N. Mex. 8. Normal faults cutting basalt mesa

Lat 35°26'N., long 106°32'W.
Photograph scale: 1:31,680
Date flown: 1935

Map reference: U.S.Geol. Survey Santa Ana Pueblo 7½-min quadrangle, scale 1:24,000

Features illustrated (set nos. N. Mex. 8 A-D in southeast corner of photographs). - The photographs show the eastern half of the Santa Ana mesa near the confluence of Jemez River and Rio Grande (photograph 8A), The basalt flows issued from a north-south trending string of vents, some of which are visible on the west edge of photographs 8C and 8D, and also from a similar line of vents outside the area shown to the east. Numerous north-south-trending faults displace the basalts from a few to 150 feet. The blocks are tilted eastward, and along any one fault of the eastern block has risen relative to the one to the west. The drainage of the mesa has a trellis pattern.

N. Y. 1. Niagara cuesta at Lewiston

County: Niagara
Lat 43°10′N.; long 79°03′W.
Photograph scale: 1:20,000
Date flown: Sept. 25, 1938

Map reference: U.S. Geol. Survey Lewiston 7½-min. quadrangle, scale 1:24,000 (N.Y. only), Toronto sheet, scale 1:250,000
Geology reference: Johnston, R.H., 1964, Ground water in the Niagara Falls area, New York, with emphasis on the water-bearing characteristics of the bedrock: New York Water Resources Comm. Bull. GW-53, 93 p.

Features illustrated (set nos. N.Y. 1 A-B in southeast corner of photographs). - The Niagara River emerges from a narrow gorge cut about 250 feet into a flat upland and enters a broad flat lowland where its channel is wide and its banks are low. The north-facing escarpment separating the upland from the lowlands is the Niagara cuesta, across which the ancestral Niagara river flowed in late-glacial time as a waterfall that has now retreated southward about 6½ miles. The upper part of the escarpment is the massive Lockport Dolomite, underlain by the Rochester Shale and older rocks that erode by sapping. This sapping causes the dolomite cap to be undermined. The lowland north of the escarpment is underlain by Queenston Shale.'

N. Y. 2. Niagara Falls

County: Niagara
Lat 43°05′N.; long 79°04′W.
Photograph scale: 1:24,000
Date flown: May 7, 1963

Map reference: U.S. Geol. Survey Niagara Falls 7½-min quadrangle, scale 1:24,000
Geology reference: Johnston, R.H., 1964, Ground water in the Niagara Falls area, New York, with emphasis on the water-bearing characteristics of the bedrock: New York Water Resources Comm. Bull. GW-53, 93 p.

Features illustrated (set nos. N.Y. 2 A-B in southeast corner of photographs). - Horseshoe Falls and American Falls separated by Goat Island. The falls are about 100 feet high. At the time these photographs were taken, there was considerable ice in the rapids both above and below the falls. The massive Lockport Dolomite forms the lip of the falls and the upper part of the walls of the gorge. Below is the Rochester Shale.

N. Y. 3. Drumlins near Palmyra

County: Wayne
Lat 43°08′N.; long 77°14′W.
Photograph scale: 1:60,000
Date flown: May 6, 1960

Map reference: U.S. Geol. Survey Palmyra and Macedon 15-min quadrangles, scale 1:62,500 Ontario, Williamson, Macedon, and Palmyra 7½-min quadrangles, scale 1:24,000
Geology reference: Fairchild, H.L., 1929, New York drumlins: Rochester Acad. Sci. Proc., V. 7, 37 p.

Features illustrated (set nos. N.Y. 3 A-B in northeast corner of photographs). - Ice moving southward from the Ontario basin formed a large drumlin field on the Ontario plain north of the Finger Lakes. The bedrock, concealed beneath drift, is in large part gently dipping shale and dolomite of Silurian age. The drumlins are oval in plan and range in length from less than a quarter of a mile to more than 2 miles. They are commonly three to five times longer than they are wide. The flat-floored valleys between the drumlins are underlain in part by lake deposits and in part by glacial outwash.

N. Y. 4. Potsdam outliers near Hammond

County: St. Lawrence
Lat 44°22′N.; long 75°46′W.
Photograph scale: 1:19,000
Date flown: May 4, 1960

Map reference: U.S. Geol. Survey Muskellunge Lake, Hammond, Redwood, and Chippewa Bay 7½-min quadrangles, scale 1:24,000
Geology reference: New York State Museum and Science Service. Geological Survey, 1962, Geologic map of New York, 1961. Adirondack sheet: New York State Mus. and Sci. Service Geol. Survey Map and Chart Ser. 5, scale 1:250,000

Features illustrated (set nos. N.Y. 4 A-B in northeast corner of photographs). - Broad tables of flat-lying Potsdam Sandstone of Late Cambrian age rise above lowlands underlain by metasedimentary rocks of Precambrian age. The mantle of glacial drift is thin and patchy, and the grain of the metamorphic rocks is clearly expressed by the irregular shapes of the small hills east of Black Creek.

N. Y. 5. Hickory Lake phacolith

County: St. Lawrence
Lat 44°26'N.; long 75°35'W.
Photograph scale: 1:20,000
Date flown: May 4, 1960

Map reference: U.S. Geol Survey Pope Mills 7½-min quadrangle, scale 1:24,000
Geology reference: Buddington, A.F., 1934, Geology and mineral resources of the Hammond, Antwerp, and Lowville quadrangles: New York State Mus. Bull. 296, 251 p.; geol. map, scale 1:62,500

Features illustrated (set nos. N.Y. 5 A-B in northeast corner of photographs). - The oval-shaped area of numerous small roughly concentric ridges in the southern half of photograph 5B is one of Buddington's granite phacoliths. Although the area has been glaciated, the drift is thin and discontinuous. The lowland that surrounds the phacolith (along Birch Creek) is mantled by fine-grained lake sediments of Quaternary age. The surrounding area of more irregular hills is underlain by quartzite, marble, gneiss, and related rocks of the Grenville Series.

N. Dak. 3. Streeter moraine near Alkaline Lake

Lat 46°38'N.; long 99°25'W.
Photograph scale: 1:60,000
Date flown: July 28, 1952

Map reference: U.S. Geol. Survey Jamestown sheet, scale 1:250,000

Features illustrated (set nos. N. Dak. 3 A-B in northeast corner of photographs). - The massive Streeter moraine with many prominent arcuate ridges (southwest quadrant of photograph 3B) was built by southwest-moving glacier ice. In front of it is an outwash plain. Behind the moraine to the northeast is a broad area of collapse moraine deposits with some lakes and multitudes of small irregularly shaped ponds and swamps.

Pa. 2. Strip mines in anthracite coal near Mount Pleasant

Lat 40°42'N.; long 76°20'W.
Photograph scale: 1:20,000
Date flown: Aug. 29, 1958

Map reference: U.S. Geol. Survey Minersville 7½-min quadrangle, scale 1:24,000

Features illustrated (set nos. Pa. 2 A-C in southeast corner of photographs). - The coal beds occur in closely folded synclines; so, in general, the mines outline synclines and the wooded areas anticlines. In the central part of photograph 2B, for example, the east-northeast-trending belt of strip mines just north of the center of the photographs is along a syncline. The adjacent anticline to the south is marked by a strip of woods that passes through the center of the photograph, and the next syncline passes under the large flat-topped heap of coal-mine debris (gray areas east of center of same exposure).

Near the west edge of the photograph the northern syncline is replaced by several minor folds whose axes rise westward. Rocks stratigraphically below the coal beds are brought to the ground surface. The traces of several thrust faults cross the photographs but are not readily apparent.

Pa. 6. Delaware Water Gap

Lat 40°58'N.; long 75°07'W.
Photograph scale: 1:20,000
Date flown: May 6, 1959

Map reference: U.S. Geol. Survey Stroudsburg and Portland 7½-min quadrangles, scale 1:24,000; Delaware Water Gap 15-min quadrangle, scale 1:62,500

Features illustrated (set nos. Pa. 6 A-C in southeast corner of photographs). - Delaware Water Gap is one of the classic water gaps in the Appalachian Highlands, about 1,200 feet deep and less than a mile wide at the top. The nearly flat top of Kittatinny Mountain at the gap was believed by W. M. Davis to be a remnant of his Schooley peneplain preserved on top of the resistant quartzite that can be seen dipping steeply to the northwest. The course of the river through the ridge has been variously attributed to superposition or to structural control related to joints, faults, or plunging folds.

(Puerto Rico)

P. R. 1. Doline or sinkhole karst topography

Lat 18°24′N.; long 66°51′W.
Photograph scale: 1:20,000
Date flown: Feb. 12, 1963

Map reference: U.S. Geol. Survey Camuy 7½-min quadrangle, scale 1:20,000

Features illustrated (set nos. P.R. 1 A-B in northeast corner of photographs). - Intricate karst topography formed in lower Miocene limestone which dips 3°-5° N. Sinkholes are as deep as 60 meters and towers as high as 40 meters. Apparently bare southern and eastern slopes in the southern part of the area are covered by a mat of ferns in contrast to the densely wooded northern and western slopes. Near the southeast corner of photograph 1B a stream appears at the head of an alluviated valley, flows north and then east and disappears in a cave (in woods), flows underground to the north, reappears in another alluviated valley, flows through a small gorge, and finally disappears in a cave that is near the east edge of photograph 1B.

N. Mex. 7. Fine-textured topography on upper Tertiary sediments

Lat 35°47′N.; long 106°07′W.
Photograph scale: 1:54,000
Date flown: May 27, 1954

Map reference: U.S. Geol. Survey Espanola 15-min quadrangle, scale 1:62,500

Features illustrated (set nos. N. Mex. 7 A-B in northeast corner of photographs). - Fine-textured topography with high drainage density formed on the semiconsolidated upper Tertiary rocks (sandstone, conglomerate, siltstone, and clay of the Santa Fe Group). The drainage pattern is largely dendritic, except for the parallel or pinnate pattern in the northeast quadrant of photograph 7B. Mesas near the west edge of the same photograph are capped by basaltic rocks of late Tertiary or Quaternary age. Buckman is near the northwest corner of photograph 7B.

Tex. 4. High Plains escarpment east of Lubbock

Lat 33°35′N.; long 101°13′W.
Photograph scale: 1:63,360
Date flown: Jan. 23, 1954

Map reference: U.S. Geol. Survey Lubbock sheet, scale 1:250,000

Features illustrated (set nos. Tex. 4 A-B in northeast corner of photographs). - Escarpment on the west side of White River (east half of photograph 4A), a tributary of Brazos River. Massive beds of sand cemented by caliche cap the plains and in many places rest directly on sand and gravel (Ogallala Formation of Pliocene age). Triassic sedimentary rocks crop out near White River. Badlands east of the escarpment have a high drainage density compared with the virtually undissected plains to the west where numerous large shallow depressions are as much as half a mile in diameter.

Utah 1. Open pit at Bingham

Lat 40°32′N.; long 112°08′W.
Photograph scale: 1:37,400
Date flown: June 20, 1950

Map reference: U.S. Geol. Survey Bingham Canyon and Lark 7½-min quadrangles, scale 1:1:24,000

Features illustrated (set nos. Utah 1 A-C in southeast corner of photographs). - This great open pit is nearly 1,500 feet deep and 2 miles in diameter. The ore is disseminated pyrite and lesser amounts of copper sulfides in monzonite, quartzite, and limestone.

Utah 9. Badlands near South Caineville mesa

Lat 38°18′N.; long 110°57′W,
Photograph scale: 1:31,680
Date flown: July 12, 1939

Map reference: U.S. Geol. Survey Factory Butte 15-min quadrangle, scale 1:62,500

Features illustrated (set nos. Utah 9 A-B in northeast corner of photographs). - The mesa is capped by the Emery Sandstone Member of the Mancos Shale; the badlands surrounding it are underlain by the Blue Gate Shale Member of the Mancos. Pediments have been formed between the foot of the badlands and the alluvium along Sweetwater Creek (southeast quadrant of photograph 9B).

Utah 14. Cliffs and domes in Navajo Sandstone, Zion National Park

Lat 37°13'N.; long 112°55'W.
Photograph scale: 1:63,360
Date flown: June 16, 1953

Map reference: U.S. Geol. Survey Zion National Park, Zion Canyon Section, scale 1:31,680

Features illustrated (set nos. Utah 14 A-C in southeast corner of photographs). - Flat-lying massive Jurassic sandstones enclose Zion Canyon (northwest quadrant of photograph 14B) and Parunuweap Canyon (south edge of same photograph). Both these narrow canyons are floored with Chinle Shale. The Navajo Sandstone forms the canyon rim and shows conspicuous north-south jointing The smoother upland away from the canyons is underlain by shales of the Carmel Formation. The Great White Throne, a monolith of Navajo Sandstone, stands just south of the horseshoe bend (Big Bend) in Zion Canyon (northwest quadrant of photograph 14B). Some of the smaller streams that flow in Navajo Sand have meanders that appear to be joint controlled, for example, the stream just southwest of the center of photograph 14B and in the upper part of Parunuweap Canyon (in southeast quadrant).

Wash. 2. Alpine glaciers on Glacier Peak

Lat 48°07'N.; long 121°07'W.
Photograph scale: 1:27,700
Date flown: Oct. 7, 1944

Map reference: U.S. Geol. Survey Glacier Peak 15-min quadrangle, scale 1:62,500

Features illustrated (set nos. Wash. 2 A-C in northeast corner of photographs). - This Pleistocene to Recent andesitic volcano (altitude 10,541 ft.) rises about 6,000 feet above the tops of the adjacent mountains. Glaciers largely conceal the upper slopes of the peak except on its southwest side. The individual glaciers are separated by small arêtes and flow in shallow U-shaped valleys. The glacial dissection of the volcano, although only moderate, is noticeably more advanced than on Mount St. Helens.

Wash 5. Channeled scabland: Cataract in Moses Coulee

Lat 47°30'N.; long 119°45'W.
Photograph scale: 1:73,800
Date flown: Sept. 22, 1952

Map reference: U.S. Geol. Survey Ritzville sheet, scale 1:250,000

Features illustrated (set nos. Wash 5 A-D in southeast corner of photographs). - This great compound cataract (west of center of photograph 5C) includes three recessional gorges that reach back upstream into a broad scabland tract. The cataract to the east started as a double cataract whose members united to leave an island in the gorge below the dry falls. Bretz believes that all three gorges and their cataracts were contemporaneous. To the north the main coulee is a gorge nearly 400 feet deep (northeast quadrant of photograph 5B).

Wyo. 7. Little Dome

Lat 43°25'N.; long 108°52'W.
Photograph scale: 1:23,600
Date flown: Oct. 20, 1948

Map reference: U.S. Geol. Survey Thermopolis sheet, scale 1:250,000

Features illustrated (set nos. Wyo. 7 A-B in southeast corner of photographs). - A small area of Jurassic rocks is exposed in the center of this elongate dome that is largely outward-dipping Cretaceous beds composed of shale and some sandstone. The beds are tightly folded along the southeast-plunging anticlinal axis. The lowlands around the dome are underlain by Cody Shale that is largely concealed by alluvium and terrace deposits.

REFERENCES:

A Descriptive Catalog of Selected Aerial Photographs of Geologic Features in the United States, Geological Survey Professional Paper 590, can be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

XIV-A-1b: REGIONAL AERIAL PHOTO STUDIES

QUESTION:

What are some landscape characteristics that can be observed and measured?

INTRODUCTION:

If the landscape is the result of uplifting and leveling of rock materials at the surface, then you should be able to examine a landscape and say something about (1) the nature of the surface rock, (2) the effect of uplift, and (3) the kinds of leveling processes or agents at work there. You may also be able to say which force, uplifting or leveling, dominates the landscape at present.

In this investigation you will study aerial photos of several different areas in the United States. Describe the landscape in each area observed, and interpret the processes that created the features you observe.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. see a stereo pair of photographs in three dimensions.
2. indicate which processes, uplift or leveling, have been most active in forming the landscape in an area studied by aerial photographs.
3. relate landscapes to the environmental factors which influenced their development.

METHOD:

1. Using the map provided (Supplementary Sheet #1), showing the principle landscape of the United States, find the approximate location of each of the photograph sets that you study.
2. View the photographs provided by your teacher.
3. Answer the following questions about each area:

QUESTIONS:

(A-1.11) 1. What hillslopes with distinctive shapes can you identify?

(A-1.21) 2. What stream patterns are you able to identify?

(A-2.11) 3. Describe the landscape characteristics observed in the photographs.

(A-2.12) 4. Describe any boundaries between landscape regions that you are able to identify.

(A-2.13) 5. Describe the different landscape regions that you observe as you look at various photo sets.

(A-2.14) 6. What landscape regions are you able to identify in the New York State photograph sets?

(B-1.12) 7. Describe evidence of uplifting and leveling forces at work. Which seems to be dominant in each area?

(B-1.13) 8. What effect has crustal uplift or subsidence had on areas where it is evident that it occurred rapidly?

(B-1.22) 9. Describe the areas that appear to have developed under conditions of climatic extremes.

(B-1.24)10. What effect does the balance between weathering and removal of materials have on the steepness of hillslopes? Which photographs illustrate this?

(B-1.25)11. How do hillslopes in dry climates differ from those in wet climates? Which photographs illustrate this?

(B-1.32)12. How can bedrock control the shape and steepness of a hillslope? Which photographs illustrate this?

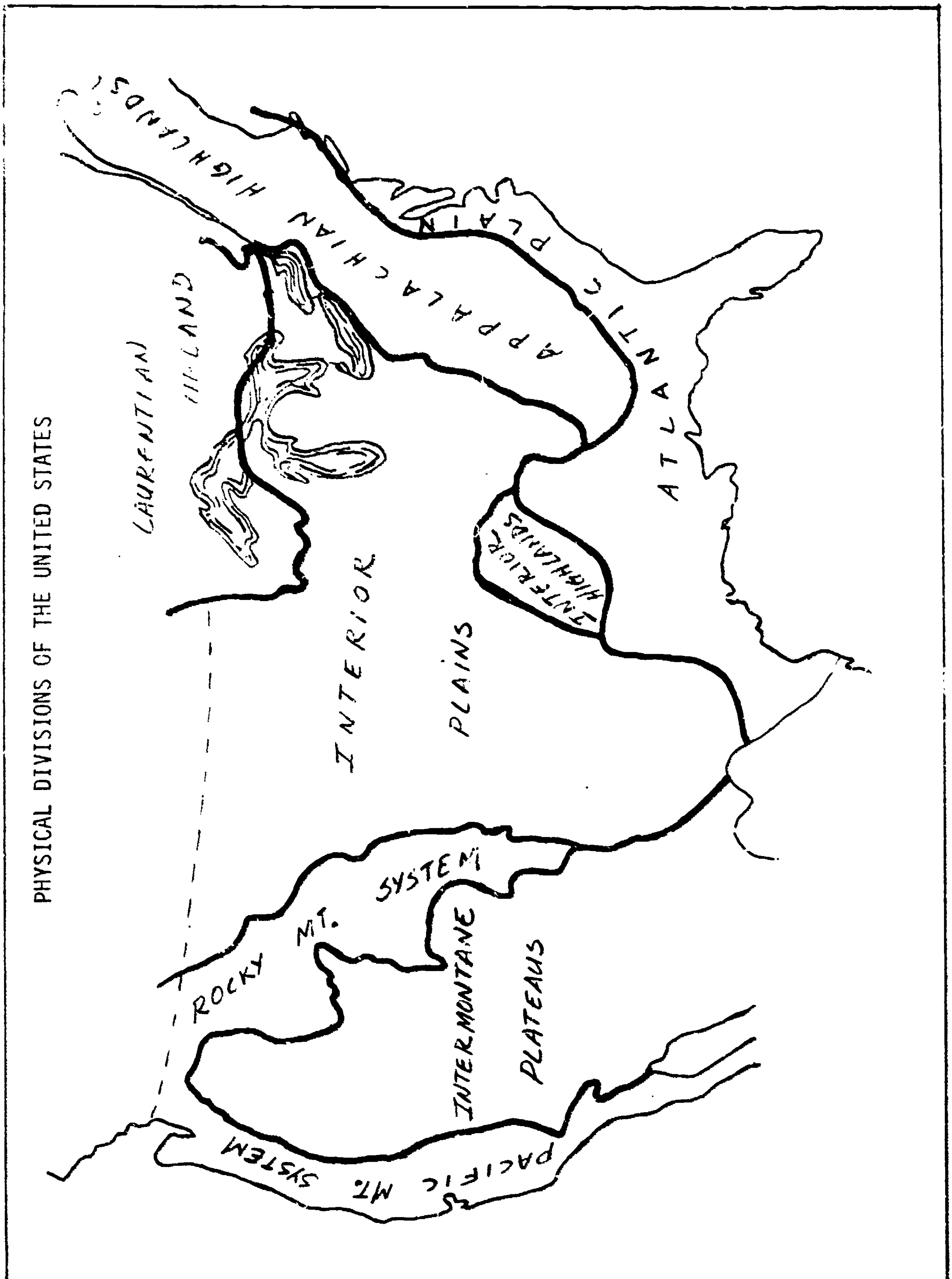
(B-1.33)13. Describe photograph areas where bedrock resistant to erosion has produced landforms such as plateaus, mountains, and escarpments.

(B-1.33)14. Describe photograph areas where easily eroded bedrock has become a low-lying surface such as the bottom of a valley.

(B-1.34)15. How can structural features in bedrock such as faults, folds, and joints affect the development of hillslopes? Which photographs illustrate this?

(B-1.35)16. How do structural features affect stream characteristics? Which photographs illustrate this?

(B-1.61)17. How has the activity of man affected the landscape in the areas studied?


PHYSICAL DIVISIONS OF THE UNITED STATES
LAURENTIAN
APPALACHIAN HIGHLANDS
ATLANTIC PLAIN
INTERIOR PLAINS
INTERIOR HIGHLANDS
ROCKY MT. SYSTEM
INTERMONTANE PLATEAUS
PACIFIC MT. SYSTEM

Photograph sets can be ordered by filling out the form below and checking the sets you want.

ORDER FOR AERIAL PHOTOGRAPHS
of
Geologic Features
In the United States

TO: Map Information Office
U.S. Geological Survey
Washington, D.C. 20242

Please send photographs to:

____

____

____

____

Date:	Do Not Write In This Space
Total ordered	
Remittance: $	

Indicate type of paper: double-weight semimatte or single-weight glossy

Prices of contact prints (subject to revision at any time):	1 to 5 each	6 to 100 each	More than 100 each
	$1.00	$0.90	$0.70

SET	PHOTOGRAPHS	SET	PHOTOGRAPHS
California		North Dakota	
25	2 ____	3	2 ____
30	2 ____	Pennsylvania	
Florida		2	3 ____
1	2 ____	6	3 ____
Kansas		Puerto Rico	
2	2 ____	1	2 ____
Maine		Texas	
2	3 ____	4	2 ____
New Mexico		Utah	
7	2 ____	1	3 ____
8	4 ____	9	2 ____
New York		14	3 ____
1	2 ____	Washington	
2	2 ____	2	3 ____
3	2 ____	5	4 ____
4	3 ____	Wyoming	
5	2 ____	7	2 ____

Challenging (3)

XIV-A-1c: LOCAL AERIAL PHOTO STUDIES

QUESTION:

What are some landscape characteristics that can be observed and measured?

MATERIALS:

Student stereoscopes, aerial photo stereo-pairs covering the local region around your school. The larger the area covered (more photos) the better. See Background Information.

SUGGESTED APPROACH:

1. Ask students if they think they could find evidence for glaciation in their local area if they had a chance to study the area from an airplane.

2. Ask them if photographs, especially photographs that show elevation, would work even better, since you could take as long as you wanted to study one point on the ground.

3. Indicate to them that to a skilled user, aerial photos tell more, in less time, about an area on the earth than any other type of investigation.

4. Indicate that aerial photo studies are usually used in conjunction with actual field sampling and map studies for maximum understanding of the area studied.

5. A good way to begin is to allow students to study the aerial mozaic of their local area and pick out their home. (This can be accomplished best by having a topographic map of the area on hand for comparison.) Allow each student time to view his home and the surrounding terrian with which he is very familiar. This allows him to associate a hill dimension that he knows, with the way it appears on the photos. This will enable him to better interpret dimensions of landforms in areas foreign to him.

6. Ask the students to choose a series of aerial photos covering a larger area (limited only by time and availability of photos), and identify as many landforms and evidences for glaciation (including direction of movement) as they can. They should keep a written record, including sketches, of the photos studied and the area covered as part of investigation.

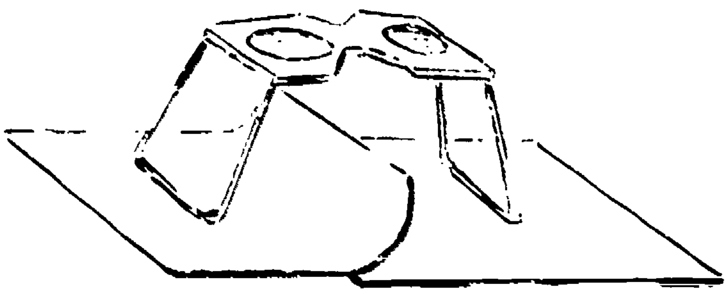
7. At the end of the investigation, the students should pool their information, and defend it, if others disagree.

CAUTIONS:

1. Students, unable to see with both eyes, will not be able to view the photos stereoscopically.

2. Most students, with practice, *should* be able to see three dimensionally.

3. When the two photos (stereo pair) are positioned flat on the table, only a narrow section can be seen stereoscopically. To view a larger area, you must roll the upper photo back slightly (do not bend sharply) as you continue to move the stereoscope to the left.



4. It takes an earth scientist a long time to develop enough skill to identify landforms from aerial photo studies. This should not be the only objective of this investigation. The students will make inferences and adjust them many times when asked to defend them. This is the kind of thinking process to encourage.

TYPICAL RESULTS:

The students should be able to identify outstanding landforms such as drumlins, kames, and eskers if they are present in your area. They may be able to distinguish a distinct lineation of glacial features indicating direction of glacial movement.

BACKGROUND INFORMATION:

Aerial photos and information can be obtained from:

Eastern Laboratory, Aerial Photography Division
45 South French Broad Avenue
Asheville, North Carolina 28801

The usual approach is to first obtain aerial photo index sheets of your local area. When ordering these, be sure to describe your location as accurately as possible. Include county, state, topographic map name, and latitude-longitude information. These index sheets are mosaics of the individual stereo pairs covering the areas. They are arranged so their individual numbers can be read and subsequent orders for these can be made.

PRICES FOR AERIAL PHOTOGRAPHS
(Effective October 1, 1968)

	CONTACT PRINTS	ENLARGEMENTS - DWSM				PHOTO-INDEXES
Approximate Scale	1" = 1667'	1" = 1320	1" = 1000'	1" = 330' or 1" = 660'	1" = 400'	1" = 1 mile
Paper Size In Inches	9½" X 9½"	14" X 14"	18" X 18"	24" X 24"	40" X 40"	20" X 24"
Quantity 1 - 25	$1.25	$2.50	$2.75	$3.50	$8.00	$2.50 per sheet
Excess over 25	$0.90	$2.00	$2.25	$2.75	$7.00	

NOTE: The 9½" X 9½" size works best for this exercise.

REFERENCES:

Aerial Photographs in Geological Interpretation and Mapping, Geological Survey Professional Paper 373 (can be ordered from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402), $2.50, paper cover.

Wanless, Harold P., *Aerial Stereo Photographs* (available from several suppliers of earth science equipment).

Aerial-Photo Interpretation in Classifying and Mapping Soils, Agricultural Handbook No. 294, issued October 1966. (Available from Government Printing Office, Washington, D.C.) 75¢, paper cover.

A Descriptive Catalog of Selected Aerial Photographs of Geologic Features in the United States, Geologic Survey Professional Paper 590 (can be ordered from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402).

XIV-A-1c: LOCAL AERIAL PHOTO STUDIES

QUESTION:

What are some landscape characteristics that can be observed and measured?

INTRODUCTION:

A relatively short time ago, man was unaware that continental glaciation had occurred in North America. When early investigators began suggesting the possibility of a great ice mass covering all of Canada and much of the United States, they were met with much criticism. Today, however, we accept this and continue to gather evidence to help us better understand characteristics such as directions of movement, etc. In this investigation, you will be examining areas near your home for any evidence of glaciation you can find. Try to explain the origin of the various landforms that you see.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. demonstrate three-dimensional viewing of aerial photo stereo-pairs.

2. identify and describe any outstanding landscape features such as drumlins, eskers, moraines, etc., that may be present in your local area.

METHOD:

1. Your teacher will provide you with a stereoscope which will enable you to see aerial photos in three dimensions.

2. Using the aerial mozaic map, locate your home or an area with which you are familiar. Copy down the numbers of the two photographs that cover this area. Ask your teacher for the photographs with these numbers.

3. Study the photographs, using your stereoscope. If you cannot see three dimensionally ask your teacher to check your method.

4. Compare what you have done with the work of other students in the class.

ERIC

QUESTIONS:

(A-1.11) 1. Describe any hillslopes with distinctive shapes which you think could be measured.

(A-1.21) 2. Describe the pattern of streams in the area studied. Do the patterns observed have measurable characteristics? If so, what?

(B-1.12) 3. Which force, uplifting or leveling, seems to be dominant in your area of study? Why do you think so?

(B-1.22) 4. Describe any evidence that suggests that the landforms you have observed may have developed under conditions of a climatic extreme such as glaciation.

(B-1.24) 5. Describe the balance between weathering and removal of materials that exists in at least one hillslope observed.

(B-1.32) 6. Describe any observable effect that bedrock has had on the shape and steepness of hillslopes studied.

(B-1.33) 7. Describe any areas studied where you think resistant bedrock was responsible for features such as plateaus, mountains, or cliffs.

(B-1.33) 8. Describe any low-lying areas, such as river valleys, where you think bedrock was responsible for the landform development.

(B-1.34) 9. Describe any structural features such as faults and folds for which you can find evidence. (They may or may not be present in the area you have studied.)

(B-1.61) 10. Describe any areas studied where it is evident that the activities of man have altered the landscape.

(B-1.67) 11. What evidence for environmental conservation and planning can you find in the area studied?

ERIC

AERIAL PHOTO STUDIES

A skilled earth scientist and aerial photo interpreter can learn a great deal about the basic soil types, rock types, and ground water conditions that exist in an area by a study of aerial stereo photos. This is often accomplished by understanding and recognizing basic landforms. There are only about 36 landforms in the whole world, and, of these, about one-third are rare and not likely to be seen.

Each landform has its own set of characteristics, and aerial photos will exhibit elements of the distinct pattern for each. Black and white aerial photos illustrate six basic elements.

1. Topography - for some landforms this is very definite
2. Drainage - surface drainage pattern
3. Erosion characteristics - gully shapes
4. Black and white tone pattern - produced by near surface conditions
5. Vegetation - cultivated or natural
6. Land use

The following chart contains descriptions of typical glacial landforms which might be found in various regions of New York State.

LAND FORM	BOUNDARY CHARACTERISTICS	TOPOGRAPHIC CHARACTERISTICS	DRAINAGE CHARACTERISTICS	VEGETATIVE CHARACTERISTICS	TONE CHARACTERISTICS	REFERENCES
ESKER	Well-defined curvilinear	1. long, narrow, slightly winding ridges 2. depressions usually occur along the sides 3. usually occur as a single ridge: less commonly, they are found as two or three approximately parallel ridges and, if many miles long, they frequently show a general north-south trend	1. gully form depends upon the size of esker and the type of climate 2. gully spacing and size are related to type and depth of overburden	generally forest covered in humid climates	generally light tones	USGS Professional paper #373, p. 100

Adapted from lecture notes, Prof. D. Belcher, Cornell University

ERIC

LAND FORM	BOUNDARY CHARACTERISTICS	TOPOGRAPHIC CHARACTERISTICS	DRAINAGE CHARACTERISTICS	VEGETATIVE CHARACTERISTICS	TONE CHARACTERISTICS	REFERENCES
KAMES	1. individuals have a near circular to elliptical outline 2. group has an irregular outline	1. individuals are isolated, conical- to irregularly-shaped mounds with steep sidelsopes 2. size is variable: usually below 50 feet in height and less than 400 feet in largest dimension. Kame groups and terraces may be much wider. Kame moraines are composed of a group of knobs with intervening deep depressions.	1. general absence of integrated surface drainage 2. surface rill erosion often present	usually not cultivated: tree or grass cover is common	crests show light gray to white tones	USGS Professional paper #373, p. 122; Aerial Stereo Photographs (Wanless), p. 19
OUTWASH PLAINS	1. with lowland: fan-shaped transitional zone 2. with highland: distinct-linear boundary	1. near-level, broad tracts with few eroded channels: Type I-level outwash plain 2. many steep-sided, small to large pits, sharply depressed below a near-level surface: Type II - pitted outwash plain	1. abandoned, flat-bottomed, intersecting drainage routes are common 2. there is little surface drainage development	1. semiarid climates: grass-covered 2. subhumid climates: forest covered or cultivated	1. general light tones dotted with small dark areas: such terms as "worm eaten," "moth-eaten," and "tapioca-like" are used to describe the color pattern of outwash. 2. uniform light tones are common on the elevated, level, cultivated tracts and on valley train deposits. 3. dark channel and current markings usually appear as flow patterns when large areas of outwash are viewed	Aerial Stereo Pairs (Wanless), p. 84

Adapted from lecture notes, Prof. D. Belcher, Cornell University

LAND FORM	BOUNDARY CHARACTERISTICS	TOPOGRAPHIC CHARACTERISTICS	DRAINAGE CHARACTERISTICS	VEGETATIVE CHARACTERISTICS	TONE CHARACTERISTICS	REFERENCES
TERRACES	there is a distinct linear boundary	1. the area is flat 2. stair-stepped development between river and upland 3. areal extent of terraces may vary	1. surface drainage is generally absent 2. short, steep, V-shaped gullies are notched into the terrace face 3. slackwater areas border the upland	uniform vegetative pattern	1. light to medium gray with small dark spots 2. broad, light-toned current patterns may be present 3. slackwater areas are dark-toned	
LAKE BEDS	generally insignificant	1. a broad, exceptionally flat surface 2. undulating terrain is rare	1. general absence of surface drainage development 2. relatively large streams may cross the flat area 3. artificial drainage is common in humid areas	areas are heavily cultivated. Large, low swamps may be seen in humid areas	1. uniform, drab, dark gray tones over broad areas 2. locally, dark or mottled tones may be present	
TILL PLAINS	generally insignificant	1. young till plains - drift controlled: broad, gently rolling, little dissected plains 2. young till plains - bedrock controlled: the influence of bedrock is made apparent by the increased angularity of streams; an increase in number and steepness of slope of tributaries; or by solution of underlying rock, as in limestone areas	1. young till plains: channelized runoff is not well established. 2. old till plains: a treelike drainage pattern is well developed. 3. shallow till plains: drainage pattern controlled by characteristics of underlying material.	generally cultivated	1. young till plain - drift controlled: mottled pattern: light islands (high ground) with dark surrounding areas 2. young, thin till deposits on unrelated materials: soil mottling and tone contrast is subdued 3. old till plains: uniform light tones with white-laced gullies or dull, uniform tones without white fringed gullies	USGS Professional paper #373 p. 204; Aerial Stereo Photograph (Wanless), p. 86

Adapted from lecture notes, Prof. D. Belcher, Cornell University

LAND FORM	BOUNDARY CHARACTERISTICS	TOPOGRAPHIC CHARACTERISTICS	DRAINAGE CHARACTERISTICS	VEGETATIVE CHARACTERISTICS	TONE CHARACTERISTICS	REFERENCES
MORAINES	generally in[illegible]ig-nificant; th[illegible] may be irregu[illegible] lines or a transitional zone	1. broad belt of disordered hills, ridges, and irregularly shaped hollows 2. lack of hill-top continuity 3. hills are small, when compared to bedrock forms	1. there is a disordered drainage pattern 2. all types of erosion are common.	generally forested or in pasture: partially tilled land; much swamp growth	heterogenous mixture of light and dark tones	USGS Professional paper #373, pp. 104, 106, 122; Aerial Stereo Photographs (Wanless), p. 17
DRUMLINS	a distinct, linear outline - oval to cigar-shaped	1. a group of parallel, oval to cigar-shaped ridges 2. individual ridges have a smooth, streamlined appearance	surface drainage not developed	cultivated or forest covered	light tones when tilled	Aerial Stereo Photographs (Wanless), p.20

Adapted from lecture notes, Prof. D. Belcher, Cornell University

Challenging (2)

XIV-A-2a: IDENTIFYING LANDSCAPE REGIONS

QUESTION:

How are landscape characteristics related?

MATERIALS:

Set of topographic maps at a scale of 1:250,000, covering the entire State of New York. See Background Information. (Raised relief maps of N.Y.S. can be used if available.)

Map: Landforms and Bedrock Geology of New York State, 1966. Available from the New York State Museum and Science Service and accompanied by Educational Leaflet No. 20, *Geology of New York, a Short Account*.

Blank map of New York State. See supplementary sheet #2.

SUGGESTED APPROACH:

1. Ask students if, on the basis of their travels in New York State, they could separate the State into general landform patterns.
2. Ask if they could do this more easily if they could see the entire State from a vantage point many miles high. Indicate that this is possible by using map models of the State that show topography.
3. Use the floor to spread out the individual topographic maps, placing them in their appropriate positions until a mozaic of the entire State is formed. Have students stand back a few feet and try to determine where landform divisions should occur. (These maps can be permanently mounted on the wall, by trimming the borders.)
4. Using their blank maps of New York State, have students sketch in landform boundaries while studying the large map mozaic on the floor. Have them indicate some kind of a descriptive name for each landform determined. Using a blank New York State map drawn on the chalkboard, let the students fill in their landform boundaries. Allow a discussion to develop and boundaries to be changed until the entire class agrees on a map.
5. Pass out copies of *Landform and Bedrock Geology of New York State maps*, and ask the students if they can find any reasons why the landform regions they have identified have developed. Is there any relationship between bedrock geology and landform development?

PRECAUTIONS:

1. Modifications may be necessary in this investigation to obtain the objectives.
2. Because the contour intervals on some of the maps are different, make certain the students are aware of this and consider it when inferring landform boundaries.
3. Students may not divide the State into the same landform regions as is indicated on the landform map of New York State. The fact that they have been able to identify landform differences is much more important than agreeing exactly with another map.

TYPICAL RESULTS:

If students have had some previous work with topographic maps, they should be able to identify some basic landforms. They probably will not identify all that are listed on the landform map of New York State.

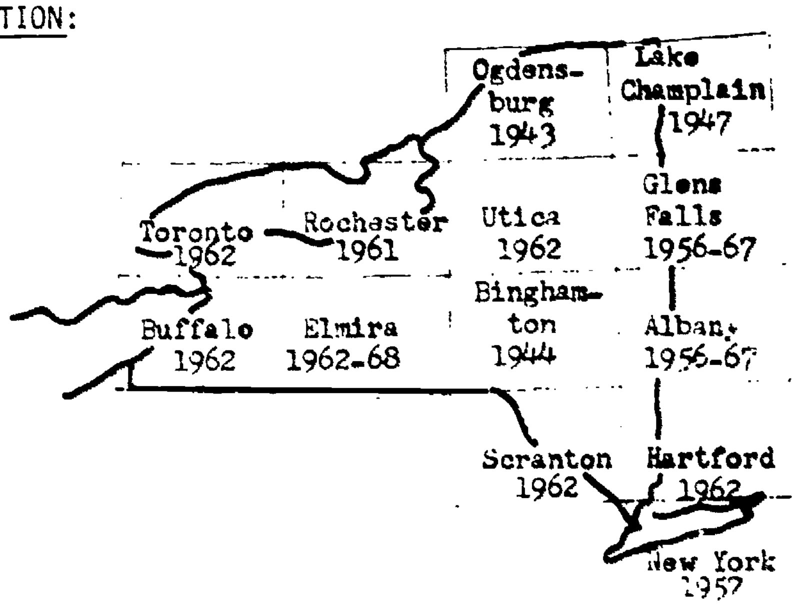
MOFICIATIONS:

1. Have the students start collecting photographs of various areas in New York State a few weeks in advance of the lab. During the lab, they could match these photos with their various landforms. If the teacher has available slides of various parts of the State, they also could be used. Travelogue films of New York State are helpful in observing various landforms.

2. Use raised relief map of New York State to identify landform regions.

3. Take the students on an aerial field trip if facilities are available.

BACKGROUND INFORMATION:



The above maps can be ordered at a cost of $0.75 each from the:

Distribution Section, U.S. Geological Survey
1200 South Eads Street
Arlington, Va. 22202

The scale of the maps is 1:250,000; 1 inch on the map represents about 4 miles on the ground.

NOTE: Prepayment is required, and may be made by money order or check payable to the Geological Survey. Delivery will be expedited by listing maps alphabetically. A discount of 20 percent is allowed on single orders of $20.00 or more.

REFERENCES:

Geology of New York, a Short Account, Educational Leaflet No. 20, pp. 32-35.

XIV-A-2a: IDENTIFYING LEANDSCAPE REGIONS

QUESTION:

How are landscape characteristics related?

INTRODUCTION:

If you have traveled over much of New York State, you have probably observed some different landforms. Some areas are mountainous, others just hilly, and still other areas are low and flat with long stretches of straight highway. You can probably picture in your mind a few different areas of the State and what they look like, but this would not be enough to draw boundaries between these landforms. In order to do this, we need a model of the entire State. In this investigation, you will use such a model.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. match typical photographs with the various landform regions of New York State.

2. indicate the role that bedrock plays in the development of landforms.

METHOD:

1. Help your teacher assemble the map model of New York State.

2. Stand back far enough so that you can see the entire map system, but stay close enough to see the pattern indicating topography.

3. Study the map and decide where you would draw boundaries between landforms. Try to imagine what the area would look like if you were flying over it in an airplane.

4. Sketch the boundaries that you have decided upon on your blank map of New York State. Label each area with some kind of a descriptive name.

5. Work with the other students at the chalkboard to develop a satisfactory map.

QUESTIONS:

(A-2.11) 1. Which regions of the State have the highest elevation? What landscape region would this be?

(A-2.11) 2. Which areas of the State have the lowest and most level topography? What landscape region would this be?

(A-2.12) 3. How well-defined are the boundaries between landscape regions?

(A-2.14) 4. Describe the distinctive landscape regions that you have been able to identify in New York State.

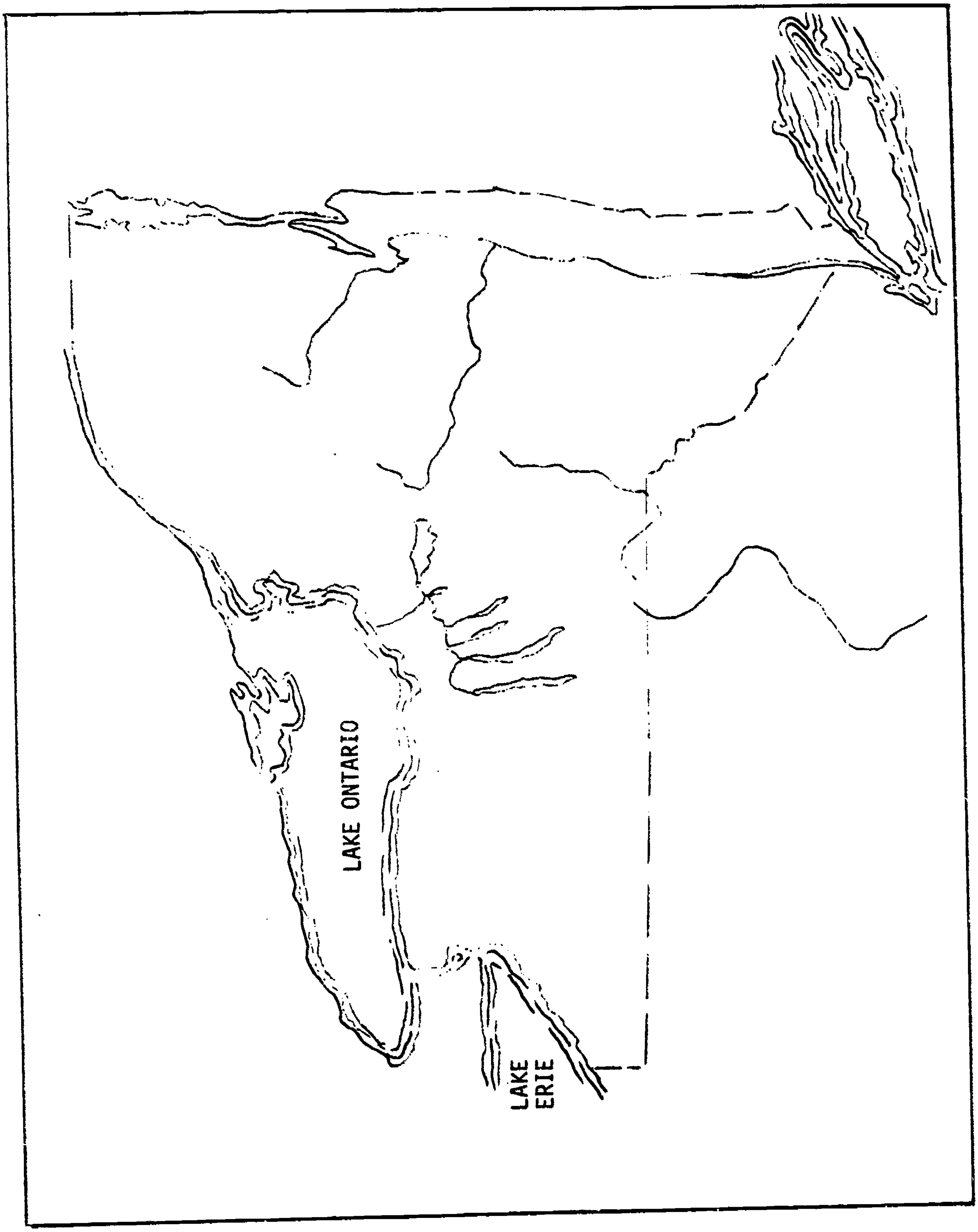
(B-1.31) 5. Which types of bedrock do you think erode most rapidly? Least rapidly? Describe any relationship between kinds of bedrock and landscape regions identified.

(B-1.33) 6. What relationship can you find between the location of rivers and the bedrock pattern of New York State?

(B-1.13)
(B-1.22) 7. Are there any areas where observed landscape characteristics are not directly related to bedrock type? If so,
(B-1.34) can you think of any reasons why they might not be related?

(B-1.32)
(B-1.34) 8. What are the similarities and differences between the Catskill and Adirondacks in topography and structure?

Supplementary Sheet



Challenging (1)

XIV-B-1a: LANDSCAPE AND SOILS FIELD TRIP

QUESTION:

How is landscape development influenced by environmental factors?

MATERIALS:

Topographic maps of the area to be covered, some form of field notebook for each student, soil auger or shovels. (Optional - hand lens, rock hammers, soil pH testing kits, cameras, etc.)

SUGGESTED APPROACH:

1. The teacher should become familiar with the local area before laying out the route for the field trip. This can be accomplished by studying the references cited and by driving through the proposed area before taking the students.

2. The field trip route should be designed to include the following if possible: traverse of two or more State physiographic regions; two or more bedrock types; and areas where well-drained agricultural soil, forest soil and wet bog-type soil can all be sampled. Permission should always be obtained in advance from property owners before taking students to the premises.

3. At least one preliminary period should be spent with students; discussing what they should look for, how to best record their observations, and, in general, becoming familiar with the region they will be observing. Color slides of various stops can be used to preview the trip.

4. While riding, the teacher should point out as many landform features as possible. Have students keep track of their location on topographic maps. Notes and sketches should be made in the notebooks whenever appropriate.

5. At the soil sampling sites have a few of the students dig a 2- or 3-foot diameter pit a few feet deep so that soil horizons can be easily observed and sampled. The following observations may be made:

   a) Identification of bedrock type under soil sample. This can be done from geologic map information or by observing nearby outcrops.

   b) Identify soils as being either transported or residual. Does the soil contain cobbles that are different from the underlying bedrock type? Can the probable source of this material be inferred?

   c) Identify soils as to the mode of deposition:

      1) horizontal layering - running water

      2) unsorted - containing fine grain material, mixed with larger cobbles, some containing scratches on their surface - (glacial till)

      3) fine grain clays blanketing large areas and containing no cobbles - lake bed deposits

   NOTE: If the three soils sampled are all from the same parent material, the student will be more likely to infer the importance of slope of land (drainage), and vegetative cover on their development.

PRECAUTIONS:

1. Make sure students are aware of the type of clothing they should wear on the field trip.

2. A field trip like this will demand a great deal of teacher planning in order to obtain the desired results; however, once completed, it may be used many times in the future and will represent one of the most rewarding learning experiences of the course.

REFERENCES:

Geologic map of the area (available from New York State Museum and Science Service, Albany, New York)

New York State Geological Association Field Guide Books - refer to listing (Investigation XIII-A-1a)

Glacial geology bulletins of the area (available from the New York State Museum)

Soil survey bulletin of your county. Those produced in recent years are very useful in describing bedrock and soil associations, suggested soil usages, etc.

A soil survey published by the U.S. Department of Agriculture that is still in print may be obtained in one of the following ways:

1) A professional user in the area surveyed can obtain a free copy from the local office of the Soil Conservation Service, from their county agent, or from their congressman.

2) For a time after publication, copies may be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

3) Many libraries keep published soil surveys on file for reference.

LIST OF PUBLISHED SOIL SURVEYS IN NEW YORK STATE
AS OF April 1969

1942 Albany and Schenectady
1956 Allegany
*1904 Auburn Area
*1902 Bigflats Area
*1905 Binghamton Area
1932 Broome
1940 Cattaraugus
*1922 Cayuga
*1914 Chautauqua
1932 Chemung
*1918 Chenango
*Clinton
*1923 Columbia
*1916 Cortland
1961 Cortland
*1930 Delaware
*1907 Dutchess
1955 Dutchess
1929 Erie
1958 Franklin
*1922 Genesee
1969 Genesee
*1923 Herkimer Area
*1911 Jefferson
1960 Lewis
*1908 Livingston
1956 Livingston
*1903 Long Island Area
*1902 Lyons Area
*1906 Madison
*1910 Monroe
1938 Monroe
*1908 Montgomery
*1906 Niagara
1947 Niagara
*1913 Oneida
1938 Onondaga
*1910 Ontario
1958 Ontario and Yates
*1912 Orange
1939 Orleans
*1917 Oswego
1940 Otsego
1937 Rensselaer
*1917 Saratoga
*1915 Schoharie
1942 Seneca
1931 Steuben
1925 St. Lawrence
*1928 Suffolk and Nassau
1946 Sullivan
*1903 Syracuse Area
1955 Tioga
*1905 Tompkins
1965 Tompkins
1940 Ulster
*1909 Washington
*1919 Wayne
*1901 Westfield Area
*1919 White Plains Area
1938 Wyoming
1916 Yates

*out of print

XIV-B-1a: LANDSCAPE AND SOILS FIELD TRIP

QUESTION:

How is landscape development influenced by environmental factors?

INTRODUCTION:

The earth scientist uses many tools, such as aerial photos and topographic maps, when making a study of a particular region. But associated with this, he will, whenever possible, do extensive field work. While on these field trips he usually collects samples, makes sketches and photographs, and takes notes that may aid him in drawing inferences about the landscape. During this field trip, you will have an opportunity to do the same.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. describe the general landforms covered on the field trip.
2. describe in terms of color, degree of wetness, and amount of organic material the three or more soils investigated.
3. infer reasons why the landscapes and soils observed on this trip have their distinctive characteristics.

METHOD:

1. Record descriptions and sketches of the various landforms which you see.
2. Keep track of your location at all times on the map provided for your use.
3. Record the exact location of any evidence for glaciation that you are able to observe.
4. By observing bedrock outcroppings along the highway, attempt to keep track of the type of bedrock which you are passing over.
5. You will probably stop at several locations where soil horizons can be observed and sampled. Record as much information about the soils as you are able and make sketches of what you see.

QUESTIONS:

(A-2.11) (A-2.14) 1. What landscape regions were you able to observe?

(A-2.12) 2. How well defined were the boundaries between landscape regions?

(B-1.11) (B-1.12) 3. Which of the two dominant forces, uplifting or leveling, was dominant in each landscape region observed? How could you tell?

(B-1.13) 4. Describe specific changes in landscape development that you were able to associate with crustal uplift or subsidence.

(B-1.21) (B-1.22) (B-1.23) 5. Has the region you observed undergone any change in climate during the last million years? What evidence can you use to support this? What effect did it have on the landscape development in the area?

(B-1.24) 6. How was the steepness of hillslopes in the areas observed related to weathering and removal of materials?

(B-1.31) 7. What changes in landscape development were you able to observe as you passed over boundaries from one bedrock type to another?

(B-1.32) 8. What changes in hillslope were you able to observe as you passed over boundaries from one bedrock type to another?

(B-1.33) 9. What effect does a layer of very resistant bedrock have on landscape development? Describe some of the landforms that may be found in regions having a resistant layer like this.

(B-1.33) 10. Describe the landforms that may be observed in areas underlain by weak bedrock (rock that erodes quickly).

(B-1.34) 11. If your teacher pointed out any structural features such as faults, folds, and joints, describe what effect they had on landscape development.

(B-1.35) 12. Describe any associations between stream characteristics and bedrock type that you were able to observe.

(B-1.51) 13. Describe the environmental factors that are responsible for the landscape development in each region visited. What effect would a change in one or more of these factors have on the landscape observed?

(A-1.31) 14. Describe the various soil associations and their characteristics that you observed on this field trip.

(B-1.27) 15. What effect would a change in climate have on these soil associations?

(B-1.36) 16. Describe any associations between bedrock type and soils that you were able to observe.

(B-1.61) 17. Describe any landscape alterations that the activities of man have produced which you were able to observe on this field trip.

(B-1.63) 18. What relationships were you able to observe between landscape alterations and man's population density?

(B-1.64) 19. Describe any destructive rapid changes in landscape development that you observed that you could identify as being due to man's activity.

(B-1.66) 20. Describe areas observed on your trip where it was evident that careful planning of natural resource use and development was taking place. Describe areas where it was evident that little planning was being done.

(B-1.67) 21. Describe any areas where man was attempting to reclaim a landscape region after it had been misused.

ERIC

Challenging (1)

XIV-B-1b: PLOTTING EVIDENCE OF GLACIATION

QUESTION:

How is landscape development influenced by environmental factors?

MATERIALS:

Four or more contiguous topographic maps of your local area on a bulletin board or wall. Various colored felt tip pens for marking symbols on the map. Reports on the glacial geology of the area, such as the New York State Museum Bulletins.

SUGGESTED APPROACH:

1. Mount four or more contiguous topographic maps of the local area on a bulletin board or the wall.

2. Let the class mark these maps with appropriate symbols to note the glacial features they have found. Students may devise their own symbols or consult one of the references cited in this investigation for the system used on standard geologic maps. The following features may be considered:

   a) glacial scratches on bedrock surfaces
   b) large erratic boulders (identify possible source area if you can)
   c) till fabric information
   d) drumlins (long axis)
   e) melt water deposits (roughly stratified and sorted sand and gravel)
   f) eskers, kames, kame terraces
   g) knob and kettle topography
   h) outwash plains or valley trains
   i) glacial lake deposits (deltaic gravel deposits, evenly bedded sands, layered lake bottom clays)
   j) abandoned shorelines of glacial lakes (beach ridge sand deposits etc.)
   k) abandoned outlets of glacial lakes
   l) location of indicator stones and indicator fans. Erratic pebbles and boulders, consisting of unusual rock types from source areas of limited extent, indicate the direction of glacial movement. For example, the Monyeregian Hills near Montreal contain unusual types of igneous rocks. Erratics of these rocks occur in New York State and clearly indicate the direction of glacial movement. (See Martens: *Glacial Boulders in Eastern, Central, and Northern New York*, in New York State Museum Bulletin, No. 260, June 1925.)
   m) direction of crescentic and lunate fractures, especially on glaciated exposures of quartzitic sandstone, e.g., Potsdam, Oneida, and Shawangunk sandstones. (See Flint: *Glacial and Pleistocene Geology*, Wiley, 1957.)

PRECAUTIONS:

Students may consider their evidence as the "absolute truth." Their conclusions are inferences. Alternative inferences should be encouraged.

MODIFICATIONS:

1. If students are neat in their plotting of data, the same maps could be used in subsequent years with successive classes adding information to the maps.

2. Further research could be done by student committees; e.g., committees being responsible for locating large erratic boulders, glacial scratches on bedrock, or exposures of till.

REFERENCES:

Glacial and Pleistocene Geology by Richard Foster Flint, Wiley, 1957.

Muller: *Pleistocene Geology of Chautaugua County, New York* (New York State Museum Bulletin No. 392, Part II, Albany, 1963).

MacClintock and Steward: *Pleistocene Geology of the St. Lawrence Lowland* (New York State Museum Bulletin No. 394, Albany, 1965).

Check for professional bulletins covering your local area.

XIV-B-1b: PLOTTING EVIDENCE OF GLACIATION

QUESTION:

How is landscape development influenced by environmental factors?

INTRODUCTION:

When an earth scientist investigates a problem, he must decide on, and follow, an organized approach. Especially important is developing a system whereby much diverse observational data can be illustrated and interpreted as conveniently as possible. In this investigation you will have an opportunity to develop such a system.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. describe a logical approach to the study of the glacial geology of your region. The description should include:

    a) evidence you would look for
    b) methods of analysis, including the use of topographic maps, aerial photos, and field observation
    c) tabulation of data that you would collect

METHOD:

1. Mount four or more contiguous topographic maps of your local area on the bulletin board.

2. Decide on a system of symbols that can be neatly drawn on the maps to illustrate various forms of evidence for glaciation. New symbols may have to be added to the key as future evidence is collected.

3. Plot the evidence for glaciation that you have found during your studies of local landscapes.

QUESTIONS:

(B-1.21) (B-1.22) 1. What are your interpretations of the evidence that you have collected? In what climatic environment were these landscape features formed?

(B-1.23) 2. Describe the rate of landscape development that probably existed when these features formed compared to the rate of landscape development in the same area now.

3. What other ways can you suggest to illustrate diverse geologic data, instead of using a map?

ERIC

Easy (1)

XIV-B-1c: EXPONENTIAL POPULATION GROWTH

QUESTION:

How is landscape development influenced by environmental factors?

MATERIALS:

A large number of small uniformly shaped objects (e.g., kernels of corn or dried beans, each group of students will need 2,048 objects to complete the investigation), beaker, stack of paper cups, and graph paper.

SUGGESTED APPROACH:

1. Involve the students in a discussion on human population. Consider such points as:

   a) How long have humans been on the earth?

   b) How do the rate of population growth during early periods of human existence compare with population growth rates of today? Why the change?

   c) If the present doubling period of the world population is about 37 years, how could you best describe, in mathematical terms, the rate of human population growth?

2. Indicate to the student that this investigation represents a model of population growth and will help them to better understand the mathematics of such a growth rate.

3. Provide the students with the necessary materials and handout sheets, and allow them to complete the investigation.

4. When completed, including preparation of the graph which can be done as homework, conduct a discussion during which you may want to consider some of the following:

   a) Are there any limitations concerning the number of people the earth will support?

   b) What limitations will be most critical, i.e., which will limit population growth first?

   c) Are there any areas of the world where these problems are apparent now? If so, is it because of local population densities or is it more widespread?

   d) What factors should be considered in determining an optimal population for the earth? What would you consider an optimal population? Have we reached it yet?

   e) What long-range problems will we face if we overpopulate the earth?

MODIFICATIONS:

1. You may wish to have the students consider the population growth occurring in your own county area as shown under Background Information. For more complete information you may want to obtain the booklet listed under references below or contact your district office director of the Office of Planning Coordination as listed:

   Metropolitan New York - Howard S. Quinn
   1841 Broadway, Room 711
   New York, N. Y. 10023
   (212) 586-7800

Capital District	-	James K. Van Dervort 488 Broadway Albany, N. Y. 12207 (518) 474-8640
Central New York	-	Robert C. Hansen State Tower Building 109 S. Warren Street, Room 302 Syracuse, N. Y. 13202 (315) 474-5951 Ext. 291
Western New York	-	Myron J. Elkins General Donovan State Office Building 125 Main Street Buffalo, N. Y. 14203 (716) 842-2393

BACKGROUND INFORMATION:

(See next page.)

REFERENCES:

Demographic Projections for New York State Counties to 2020 A.D., available from the Office of Planning Coordination.

BACKGROUND INFORMATION:

SUMMARY POPULATION PROJECTIONS (in thousands)

COUNTY	1950	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
ALBANY	239	273	285	303	327	352	381	413	446	482	520	562	607	655
ALLEGANY	44	44	46	47	48	49	51	52	54	56	57	59	62	64
BRONX	1,451	1,425	1,522	1,555	1,576	1,591	1,608	1,625	1,639	1,653	1,662	1,672	1,681	1,687
BROOME	185	213	222	231	245	262	280	299	316	335	354	376	400	424
CATTARAUGUS	78	80	82	82	82	83	84	85	87	89	91	94	97	100
CAYUGA	70	74	77	78	80	82	84	87	89	90	93	95	98	101
CHAUTAUQUA	135	145	151	153	157	162	168	174	180	187	194	202	211	220
CHEMUNG	87	99	104	108	113	120	128	135	[illegible]	149	157	165	174	183
CHENANGO	39	43	46	47	49	52	54	57	60	62	65	69	72	75
CLINTON	54	73	81	86	90	95	101	107	114	119	125	132	139	147
COLUMBIA	43	47	49	51	53	55	57	60	63	65	68	71	74	77
CORTLAND	37	41	44	46	48	50	53	57	61	65	70	75	81	88
DELAWARE	44	44	43	42	42	42	43	43	44	44	45	45	46	47
DUTCHESS	137	176	210	240	275	318	370	432	504	589	685	800	935	1,092
ERIE	899	1,065	1,083	1,102	1,150	1,211	1,282	1,353	1,419	1,485	1,550	1,625	1,709	1,794
ESSEX	35	35	36	36	36	37	38	39	39	40	41	41	42	43
FRANKLIN	45	45	45	45	45	46	48	51	53	56	59	62	66	70
FULTON	51	51	51	51	50	51	52	54	55	56	57	58	60	62
GENESEE	48	54	57	60	62	66	70	75	79	83	87	92	97	102
GREENE	29	31	33	33	34	36	37	39	40	42	44	46	47	49
HAMILTON	4	4	4	4	4	4	4	4	4	4	4	4	4	4
HERKIMER	61	66	68	69	71	74	76	79	81	84	86	89	92	95
JEFFERSON	86	88	89	87	86	85	87	89	90	92	93	95	97	99
KINGS	2,738	2,627	2,704	2,725	2,697	2,671	2,649	2,626	2,606	2,583	2,554	2,529	2,506	2,478
LEWIS	23	23	24	24	24	24	24	24	24	24	24	24	24	24
LIVINGSTON	40	44	48	50	52	55	59	62	66	70	74	79	84	90
MADISON	46	55	57	61	68	75	84	93	102	111	122	135	149	163
MONROE	488	586	644	699	751	807	867	927	988	1,052	1,112	1,178	1,247	1,318
MONTGOMERY	60	57	57	56	55	54	54	54	54	53	53	53	54	54
NASSAU	673	1,300	1,387	1,444	1,511	1,597	1,679	1,743	1,791	1,836	1,879	1,928	1,977	2,021
NEW YORK	1,960	1,698	1,564	1,540	1,506	1,478	1,450	1,424	1,395	1,368	1,335	1,297	1,258	1,217
NIAGARA	190	242	241	248	256	272	291	310	327	346	366	391	418	445
ONEIDA	223	264	280	295	311	332	354	377	399	422	447	474	503	534
ONONDAGA	342	423	457	491	527	568	614	661	709	758	808	863	923	985
ONTARIO	60	68	73	76	80	85	90	95	100	105	110	116	122	128
ORANGE	152	184	223	268	324	394	459	534	620	718	827	927	[illegible]	1,159
ORLEANS	30	34	37	39	40	43	45	47	49	51	53	56	58	60
OSWEGO	77	86	93	99	107	118	129	141	152	164	178	194	211	229
OTSEGO	51	52	54	54	56	58	61	64	67	71	75	80	86	92
PUTNAM	20	32	42	53	67	82	100	121	145	169	196	225	256	287
QUEENS	1,551	1,810	1,946	2,047	2,120	2,181	2,233	2,270	2,301	2,332	2,354	2,378	2,401	2,421
RENSSELAER	133	143	153	163	174	186	200	214	229	245	262	280	301	322
RICHMOND	192	222	260	296	335	381	434	493	545	602	663	730	795	863
ROCKLAND	89	137	182	231	266	307	354	408	462	518	578	647	726	814
ST. LAWRENCE	99	111	120	126	134	143	154	165	176	188	200	215	230	245
SARATOGA	75	89	99	108	117	128	140	154	168	183	199	218	238	260
SCHENECTADY	142	153	161	165	172	182	192	202	211	221	231	243	256	269
SCHOHARIE	23	23	23	23	23	23	24	24	24	25	26	27	28	28
SCHUYLER	14	15	15	16	[illegible]	17	17	18	19	19	20	21	21	22
SENECA	29	32	34	34	35	36	38	39	40	41	42	42	43	44
STEUBEN	91	98	100	102	104	107	110	114	117	120	123	126	129	133
SUFFOLK	276	667	910	1,155	1,380	1,663	2,022	2,463	2,974	3,383	3,751	4,096	4,427	4,720
SULLIVAN	41	45	48	49	50	52	53	55	57	58	59	61	63	65
TIOGA	30	38	43	47	51	56	62	67	73	79	85	91	98	104
TOMPKINS	59	66	75	82	89	96	105	116	127	138	151	164	179	195
ULSTER	93	119	136	149	160	172	187	203	220	237	255	275	297	319
WARREN	39	44	47	49	52	55	58	61	64	67	71	75	79	83
WASHINGTON	47	48	49	48	49	50	52	55	57	60	63	67	71	75
WAYNE	57	68	73	79	85	93	102	113	123	134	147	161	176	193
WESTCHESTER	626	809	856	947	1,044	1,138	1,242	1,351	1,440	1,534	1,632	1,738	1,852	1,969
WYOMING	33	35	36	36	37	37	38	39	41	43	45	47	49	51
YATES	18	19	19	19	[illegible]	19	20	21	22	23	24	25	27	29
NEW YORK STATE	**14,830**	**16,782**	**17,794**	**18,751**	**19,666**	**20,767**	**22,004**	**23,355**	**24,744**	**26,079**	**27,402**	**28,803**	**30,288**	**31,783**

XIV-B-1c: EXPONENTIAL POPULATION GROWTH

QUESTION:

How is landscape development influenced by environmental factors?

INTRODUCTION:

Man is now beginning to realize that he is facing an environmental crisis. Many of the hastily made and poorly planned changes that he has inflicted on his environment are now backfiring and making him pay both in financial terms and in more humanistic terms , such as mental and physical health.

Whenever environmental problems are investigated, it is usually found that the basic causes are the products of man himself, namely his advanced technology and his increasing population density.

In this investigation you are going to investigate the mathematical nature of man's population growth.

OBJECTIVES:

When you have finished this investigation, you should be able to:

1. describe the mathematical nature of man's population growth in the past.
2. extrapolate into the future what the world population will be for any given time, if the present growth rate continues.

METHOD:

1. Place a glass beaker on your desk with two objects in it. This will represent the earth which will hold only a finite population.
2. Place a number of paper cups in a row on your desk (10 should be enough).
3. In the first cup, place two of the objects. In the second cup, place twice as many as in the first cup (4). Record on the outside of the cups the number of objects that have been placed in each cup.
4. In cups 3 through 10, double the number of objects that are in the previous cup (i.e., cup number 3 will contain 8 and cup number 4 will contain 16). Record the amount in each cup on the outside.

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5. Take the beaker with the two objects in it and determine the beaker's height. What is the approximate volume in percent that is without objects? Record this on the table at 0 time.

6. In 35 seconds, add the contents of cup 1 (i.e., 2 objects) to the beaker and record in the table the total population and the approximate percent of the volume of the beaker that is without objects.

7. At 35-second intervals, add the contents of cups 2 through 10 and fill in the table.

Time	Population	% Volume without	Time	Population	% Volume without
0			6		
1			7		
2			8		
3			9		
4			10		
5					

8. Graph your results, total population versus time.

QUESTIONS:

1. Describe the mathematical nature of the population growth of the objects in the beaker.

(B-1.62) 2. Man's population on the earth is thought to have had a slow start with doubling periods as long as 1 million years. The present world population is thought to be doubling at a rate of every 37 years. How would the mathematical nature of this growth rate compare to your investigation?

3. The present world population is about 4 1/2 billion people. If the earth's radius is about 6400 km. and about 3/4 of its surface is covered with water, what is the present density of human population in terms of number of people per square kilometer? (Area of a sphere = $4\pi r^2$)

4. Assuming a continuation of the present population growth rate, what will the density per square kilometer be 37 years from now? 111 years? 1,110 years?

5. Is space the only limiting factor in determining maximum human population? If not, describe others.

INVESTIGATIONS INVENTORY

(An asterisk indicates investigations that must have special reference materials ordered in advance. Check the "MATERIALS:" listing for these labs for specific items)

— I-A-1a Shoebox Observations
— I-A-1b Puddle Observations
— I-A-2a Classification
— I-B-1a Density
— I-B-1b Variable Density of Water
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— *LTI #1 Weather Long-Term Investigation
— *LTI #2 Earthquake Long-Term Investigation
— LTI #3 Sun's Patch Watch
— LTI #4 Air pollution Long-Term Investigation
— LTI #5 - #19
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— FE #1 School Building and Grounds
— FE #2 Pit
— FE #3 Stream
— *FE #4 Cemetery
— *FE #5 Beach
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— II-A-1a Sunspot Analysis
— II-C-1a Roadside Pollutants
— II-C-1b Air Pollution - Human Mortality
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— III-A-1a Earth's Shape
— III-A-2a Earth's Circumference
— III-A-2b Roundness and Smoothness
— III-A-3a Ocean Bottom Profile
— III-B-1a Locating Positions
— III-B-2a Temperature Field
— III-B-2b Contour Mapping
— *III-B-2c Earth's Magnetic Field
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— IV-A-1a Celestial Observations
— IV-A-1b Moon's Path
— IV-A-1c Sun's Path Analysis
— IV-D-1a Planet Phases
— IV-C-1b Heliocentric and Geocentric Models
— IV-D-1c Solar Diameter
— IV-D-2a Orbits
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— V-A-1a Electromagnetic Spectrum
— V-A-2a Heat Transfer
— V-B-1a Changes in State
— V-B-1b Energy Absorption
— V-C-1a Specific Heat
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— VI-A-1a Angle of Insolation
— VI-A-1b Solar Altitude Observations
— VI-A-1c Duration of Insolation
— VI-A-1d Land Water Temperatures
— VI-B-1a Terrestrial Radiation
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— *VII-A-1a Weather Watch Analysis
— *VII-B-1a The Synoptic Weather Map
— VII-C-1a Evaporation
— VII-C-1b Vapor Pressure
— VII-C-3a Adiabatic Cooling and Cloud Formation
— VII-C-3b Dew Point-Cumulus Cloud Formation
— VII-C-4a Air-Water Interaction
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— VIII-A-1a Soil Water Movement
— VIII-A-3a Stream Pollution
— VIII-A-3b Water Purification
— VIII-B-1a The Local Water Budget
— VIII-B-2a Stream Hydrograph
— VIII-C-1a Climate of an Imaginary Continent
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— IX-A-1a Soil Formation
— IX-A-1b Reaction Rate and Particle Size
— IX-A-1c Rock Abrasion
— IX-B-1a Nature of Sand
— IX-B-2a Stream Flow
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— X-A-1a Deposition of Sediments
— X-A-1b Stream Table
— X-A-1c Density Currents
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— XI-A-1a Rock Properties
— XI-B-2a Properties of Minerals
— XI-B-2b Structure of Minerals
— XI-C-1a Formation of Sedimentary Rocks
— XI-C-2a Formation of Nonsedimentary Rocks
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— *XII-A-1a Evidence of Crustal Movement
— XII-A-2a Earthquake Watch Analysis
— *XII-A-2b James Hall's Field Trip
— XII-A-2c The spreading Sea Floor
— XII-B-2a Location of an Epicenter
— XII-D-1a Field Trip Through the Mountains
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— *XIII-A-1a Geologic History of New York State
— *XIII-A-1b Geology of the Grand Canyon
— XIII-B-1a Footprint Puzzle
— XIII-C-1a Geologic Time Line
— XIII-C-1b Correlating Rock Outcrops
— XIII-C-2a Radioactive Decay
— XIII-C-1a Variation Within A Species
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— XIV-A-1a Till Fabric Field Trip
— *XIV-A-1b Regional Aerial Photo Studies
— *XIV-A-1c Local Aerial Photo Studies
— *XIV-A-2a Identifying Landscape Regions
— *XIV-B-1a Landscape and Soils Field Trip
— XIV-B-1b Plotting Evidence of Glaciation
— XIV-B-1c Exponential Population Growth
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