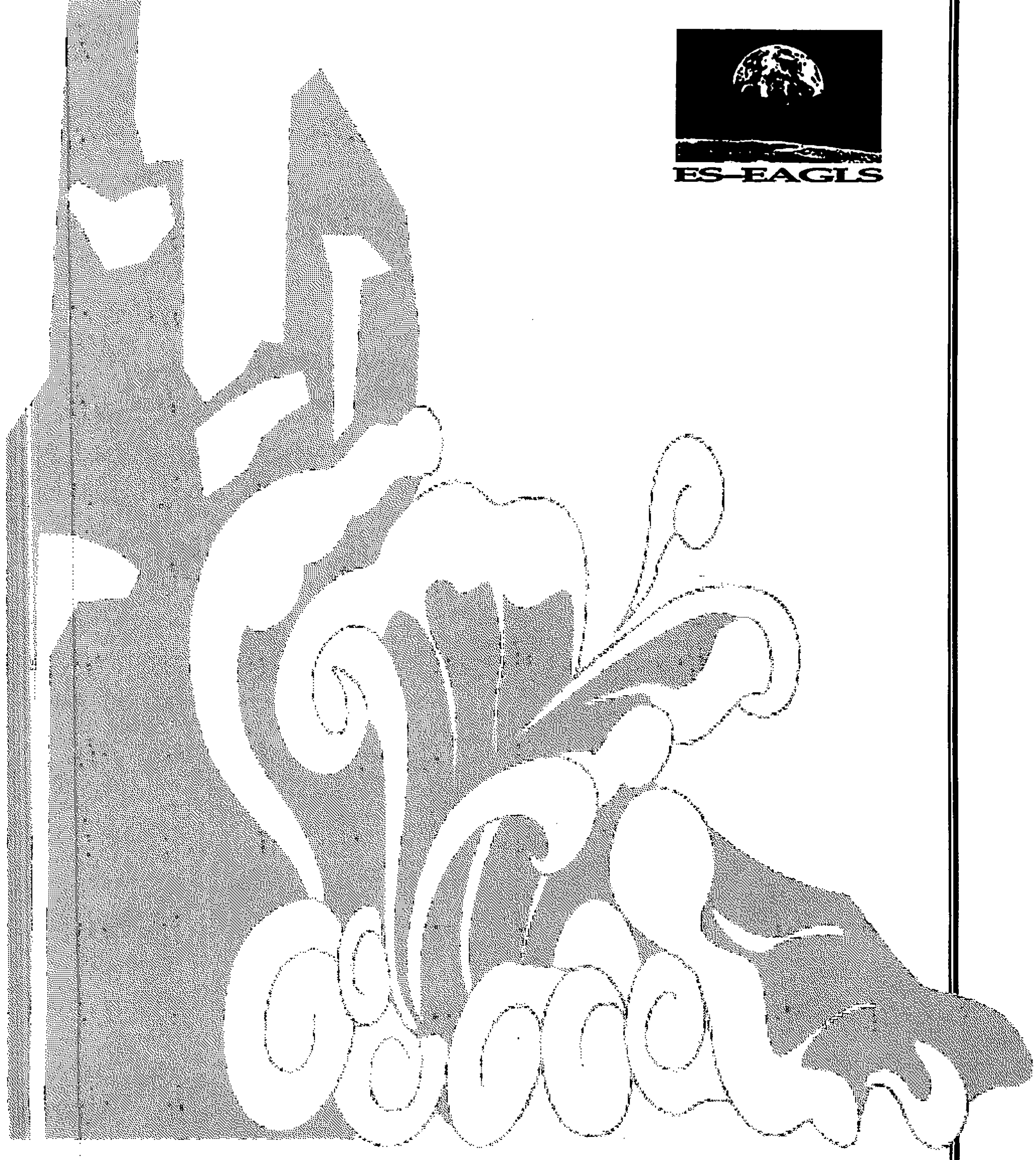
Land & Water Interactions in the Great Lakes

ES-EAGLS



Earth Systems — Education Activities for Great Lakes Schools

The Ohio Sea Grant College Program is one of 29 state programs that works to increase understanding and wise use of the nation's ocean and Great Lakes resources. Projects are conducted in partnership with government, academia, industry, and the general public. Sea Grant fulfills its mission by promoting education excellence, responsive research and training, and broad, prompt dissemination of knowledge and technical information.

Earth Systems - Education Activities for Great Lakes Schools (ES-EAGLS)

This series of publications was produced as a result of Ohio Sea Grant Education Program's project "Cooperative Curriculum Enhancement and Teacher Education for the Great Lakes" funded by Ohio Sea Grant under grant NA46RG0482, project E/CMD-3, with support from The Ohio State University and cooperating schools.

ES-EAGLS are designed to take a concept or idea from the existing school curriculum and develop it in a Great Lakes context appropriate for students in middle and high school.

Education and Series Coordinator
Rosanne W. Fortner

Series Editors

Land & Water Interactions in the Great Lakes EP-082
Amy L. Sheaffer

Great Lakes Climate & Water Movement EP-083
Heidi Miller and Amy L. Sheaffer

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Rosanne W. Fortner

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Great Lakes Environmental Issues EP-086
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Sea Grant
Ohio Sea Grant College Program
Jeffrey M. Reutter
Director

Ohio Sea Grant Publications
The Ohio State University
1314 Kinnear Road
Columbus, OH 43212-1194
614/292-8949
Fax 614/292-4364

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ES - EAGLS

Earth Systems - Education Activities for Great Lakes Schools

Results of studies of student knowledge about the oceans and Great Lakes environments indicate a need for greater awareness and a greater understanding of the impact they have upon our lives. Earth Systems - Education Activities for Great Lakes Schools (ES-EAGLS) are designed to take a concept or idea from the existing school curriculum and develop it in a Great Lakes context, using teaching approaches and materials appropriate for students in middle and high school.

The activities are characterized by subject matter compatibility with existing curriculum topics; short activity time lasting one to three classes; minimal preparation time; minimal equipment needs; standard page size for easy duplication; suggested extension activities for further information or creative expression; teachability demonstrated by use in middle school classrooms; and content accuracy assured by critical reviewers.

Included with the activities are some suggestions about possible ways to use the activities in cooperative learning situations and how lessons can be structured according to the learning cycle.

This is one of a series of subject area activity books being published. The subject of this book is land and water interactions. Other subject areas available are climate and water movement, Great Lakes shipping and other water transportation methods, the Great Lakes ecosystem, and Great Lakes environmental issues. For a more detailed listing of the land and water interaction activities, see the matrix on page 8. Most of the activities in this book were modified from Oceanic Education Activities for Great Lakes Schools (OEAGLS), developed by the Ohio Sea Grant Education Program and revised from 1985 to 1991.
All ES-EAGLS are listed inside the back cover.

LAND & WATER INTERACTIONS IN THE GREAT LAKES

Using *ES-EAGLS Land & Water Interactions*

An accompanying matrix matches activities to the Earth Systems Understandings (ESU), and the Earth subsystems directly addressed (hydrosphere, lithosphere, cryosphere, biosphere, atmosphere). It demonstrates the range of instructional opportunities available for the classroom.

The principles that guided development of the activities should also direct their classroom use:

- Potential for collaborative learning and group decision-making.
- Use of historical and descriptive as well as experimental data.
- Integration of science disciplines in a social context.

It is recommended that the format for the activities be retained when they are used in the classroom. Some short activities are designed for introduction to topics or for awareness. Longer activities focus attention for extended work and are designed to build understanding, synthesis, and application and evaluation skills. The extent and focus of the activities will help teachers decide which are useful in cooperative groups and which are best for use by the class as a whole.

1. Each activity is a question to be explored. Far too many classroom activities are done for the sake of activity alone. If an important and relevant question is the guide for learning, there is greater focus and a readily apparent reason for doing the activity. Be sure to call students' attention to the question driving the exploration, and encourage creative approaches to problem-solving.

2. Most activities are addressed to the student for direct use. Additional notes and answers for teacher use are found in narrow columns on each page so they can be concealed if the page is to be given to students.

3. Activities do not stand alone. They should be linked, before and after, to other curriculum topics and information resources such as the Internet. The best questions are those that lead to more questions!

Cooperative Learning Possibilities

There are many ways to organize the activities with cooperative learning strategies, and all of them are the "right way." You are encouraged to modify strategies to make the activities work in your setting. Some possible strategies follow.

Groups

Divide the class into three or four groups, with each responsible group for certain tasks that will contribute to class learning. Assign each group member a job or task appropriate to the lesson. He or she is then responsible to the group for doing this job. Jobs can be combined, and they should be rotated between group members periodically. Some possible job descriptions are:

Facilitator	Develops a plan with the group so that the group will finish within the time limit.
Recorder	Records plan, answers, and conclusions as appropriate.
Reader	Reads instructions and background material to group.
Artist	Sketches diagrams, posters, and charts as appropriate.
Checker	Checks to make sure the group is following instructions and the plan.
Speaker	Shares group progress report with class.
Materials Expert	Gets lab materials and makes sure things are cleaned up and returned.

JIGSAW

Divide the class into groups of four students each. These are the base groups. Then divide the class differently into four expert groups. One person from each base group will be in each of the four expert groups. (You will need to adjust the numbers of groups depending on your class size.) Each student should be in two groups. Instead of having every student doing all activities, you can assign each expert group a different activity or task on which it becomes the expert. Then have students meet in their base group and share what was done in the expert group and what was learned. Or you could have the expert groups do their activities and then have the base groups rotate through the activities with the "expert" member leading the base group through the activity.

STUDENT TEAMS ACHIEVEMENT DIVISIONS

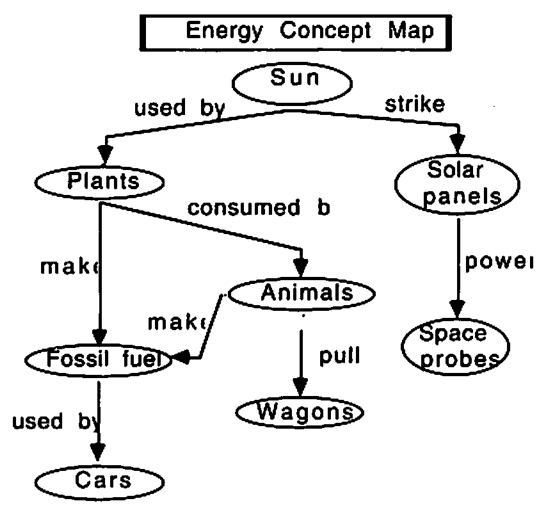
After some type of class presentation such as a lecture, video, or textbook reading, students are divided into teams. Students on the teams work together to make sure that all members of the team understand the material of the presentation. The students then take a quiz individually. Students have a minimum desired score, and the team works to get a high team improvement score (points above the minimum desired score). For more information about this strategy, read *Using Team Learning* by Robert Slavin (Baltimore: The Johns Hopkins Team Learning Project, 1986).

CO-OP CO-OP

This strategy is very student-directed. Students are in teams based on shared interest. The teams subdivide their topics and each student is responsible to research his or her own subtopic. Students then share what they have learned about the subtopic with their whole team. The teams prepare a presentation for the entire class, and they are encouraged to include the class in the presentation in some way. *Cooperative Learning: Resources for Teachers* by Spencer Kagan (Riverside, CA: University of California, 1985) provides more information about this strategy.

ASSESSMENT STRATEGY: CONCEPT MAPPING

Concept mapping is one way of having students show visually their understanding of concepts and the concepts' relationships to each other. This can be done as a pre-assessment or a post-assessment or both to see the change in a student's understanding. A brief strategy for use of concept mapping would be to brainstorm a list of terms that students know about a topic. Add terms that you want to make sure are included. Have students start with the topic at the top or center of a sheet of paper, and then using arrows and labels, students should place the brainstormed terms on the map, showing how they are related. See the example of a student's preliminary energy concept map.



There are many other ways of assessing student achievement, including performance assessment, portfolios, and grading rubrics. To learn more about these strategies you might read:

Aronson, J. 1978. *The Jigsaw Classroom.* Beverly Hills: Sage.

Hassard, Jack. 1990. Cooperating Classroom. *Science Scope.* March, p. 36-45.

Johnson, D.W., R.T. Johnson and E.J. Holubec. 1986. *Circles of Learning: Cooperation in the Classroom.* Edina, MN: Interaction Book Company.

Mayer, V.J. and R.W. Fortner, Eds. 1995. *Science Is a Study of Earth - A Resource Guide for Science Curriculum Restructure.* Columbus, OH: Earth Systems Education Program, The Ohio State University.

Special Supplement on Assessment. March, 1992. *Science Scope.* This issue contains articles on performance assessment, portfolios, group assessment, concept mapping, and rubrics.

Example Cooperative Lessons

Note: Complete information on materials and methods can be found in the activities listed.

Example I: Students will examine evidence of past geologic processes that shaped the Great Lakes Region over time and relate those processes to present-day Earth structures and processes.

Engagement

1. Begin by discussing the concept of geologic time. The class can make predictions about the age of the Great Lakes compared to other events in geologic time. Ask how many students have collected fossils and have them describe rock outcroppings and highway paths cut through rock that they see when traveling to areas in the Great Lakes region. The class can give hypotheses of how the rock layers formed.

2. Topic Preparation: Assign the background reading on Geologic Processes as homework for the next day. Discuss readings as a class or in groups.

Exploration

Jigsaw: Divide the class into three expert groups. A leader selected within each group will have the complete pages of the activities, including teacher notes. Other expert group members will have the student worksheets and other instructions from the activities. Assign each expert group different tasks as follows:

Task 1. Geologic Time. The group leader conducts the activity "When did the rocks in the Great Lakes basin form?" Important concepts are the relative ages of the rock layers when compared to students' ages and other past events, such as the existence of the dinosaurs. Experts can represent the geologic time scale in creative ways, such as constructing a time continuum on a poster or having students spread around the classroom, i.e., one student represents 20 million years. If this average student weighs 100 pounds, then 10 pounds of student represents 2 million years. In the activity here, one ream of paper is one million years, one sheet is 2000 years, and one dot equals one year. The challenge is in representing the magnitude of the time between today and the age when the Great Lakes rock layers formed, and deciding how to illustrate that difference to base groups **(Evaluation)**.

Task 2. Rock types in the region. The expert group completes the activity "How were sedimentary rocks in the Great Lakes basin formed?" They come to a consensus on answers to the review questions and decide how to share what they have learned in their base groups (**Evaluation**). Important questions that experts should be able to explain to base groups include the following: Why do rocks vary based on sediment size and composition? How do rock qualities affect erodibility? In what types of environments were different rock layers formed? A possible simulation could involve layers of different sediments in a transparent container with an explanation of the different ways the layers form. This can be related to shaking the sediment jar in the activity. Experts will teach base groups the characteristics of rock layers in the Great Lakes region.

Task 3. Formation and processes. From the activity "How did rocks and rivers shape the Great Lakes?," the expert group designs an illustration based on the processes discussed in the activity to share in base groups. Experts focus on the components involved in the process of change, including ancient seas, land mass changes, ancient rivers, and glaciers. Experts know the processes that formed and produced mineral resources in the region. They can lead base groups to connect mineral resources with the processes of change that produced the modern Great Lakes.

Base groups meet and share what they have learned in the expert groups.

Elaboration

1. As a class, students explain how the activities complement each other. They suggest ways in which they could teach others about the concepts they have learned.

2. Students explore the Internet for sites related to geologic processes, archaeology, and fossils.

3. If a natural area is nearby, classes can take a field trips to find and identify rock samples located near their schools.

Evaluation

Assessment - Students produce a timeline concept map with the following terms. Base groups should help each other understand the concepts, but students are responsible for developing their own timelines.

Map Title: Geologic processes in the Great Lakes region.

Concept terms: Precambrian, Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, Permian, ancient rivers, sandstone, shale, limestone, dolostone, salt, gypsum, metamorphic rock, igneous rock, ancient seas, Niagara escarpment, glaciers, lake formation, modern geologic resources, rock hardness, Bruce Peninsula, Door County, geologic time, Jurassic period, fossils, lake depths. Students should feel free to use additional concepts that they can apply to the activities.

Example II: Students will develop an understanding of how erosion processes affect the Great Lakes shoreline and what measures are taken to address erosion in the region.

Engagement

1. Have class members who have traveled along a Great Lakes coast share what they observed along the shore.

2. Topic preparation: Assign the background reading on Shoreline Processes as homework for the next day.

3. Students predict rates of erosion for Great Lakes shorelines and test hypotheses through the activities.

Exploration

Jigsaw: Divide the class into four expert groups. Assign each group a different task as follows:

Task 1. Shoreline Processes. Complete the activity "What causes the shoreline to erode?" Conduct a shoreline simulation and prepare the data table to share with base groups. Students in base groups complete shoreline predictions using the Great Lakes outlines after learning about the types of shorelines in the region from the expert group members.

Task 2. Erosion Prevention. This group investigates the shoreline simulation model using shoreline protection devices in "Can erosion be stopped?" Expert group members familiarize base groups with types of protection devices and base groups predict which method is most effective. Experts then explain the data table to base groups. Task groups 1 and 2 should coordinate their efforts.

Task 3. Change in Shoreline (1954-1973). Complete the activities "How fast can a shoreline change?" and "How much land has been lost?" for the earliest two years. Decide how you will coordinate your findings with the expert group for the latter years.

Task 4. Change in Shoreline (1973-1981). Complete the activities "How fast can a shoreline change?" and "How much land has been lost?" for the latter two years. Coordinate your data and conclusions with the expert group for the earlier years.

Leaders will conduct the activities and help the expert groups discuss review questions **(Evaluation)**. Base groups meet to share their findings and coordinate the themes from the different activities.

Elaboration

1. As a class, discuss how the activities are interrelated. Were there any inconsistencies between them? Did the shoreline simulation differ from evidence observed in the aerial photographs?

2. Have students discuss whether they thought shoreline changes observed occurred at a more or less rapid rate than what they would have predicted.

3. Students can explore Internet sites related to shorelines and other topics.

Evaluation

Assessment - Assign a portfolio element in which students demonstrate their knowledge. Base groups are to develop a product surrounding concepts from the activities and other topics that relate to coastal processes. The product might be an oral report, written report, bulletin board/display, video, series of diagrams/posters, or some combination of the above. They could also create a role play with several decisionmakers involved in shoreline management and explore the ways to coordinate varied interests affected by coastal issues.

Additional Jigsaw Suggestions

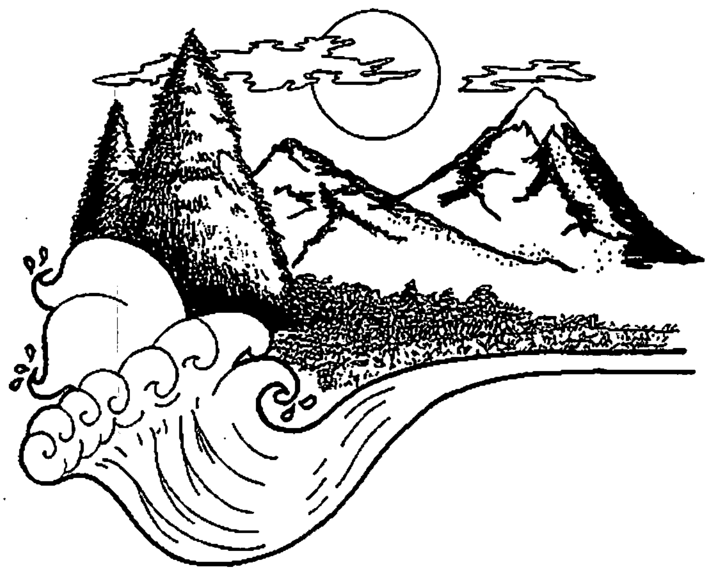
1. In "How well do you know the Great Lakes?" students work in groups, one for each lake.
2. In "What evidence of glaciation exists in the Great Lakes region?" the class can be divided in half so that one group completes activity A, the other activity B for a group discussion.
3. Students divide into teams in the activity "What evidence of glaciation can be found on Great Lakes beaches?" Groups present their data to the class for discussion.
4. In "What natural wonders of the Great Lakes relate to land/water interactions?," travel agent (expert) groups market the best location spots of a certain lake to client (base) groups.

Making connections

There is always a danger in producing curriculum materials designed for infusion. How can we facilitate getting new material into the existing flow of classroom subject matter? In this project, we have designed several kinds of connections to assist teachers in finding not only the place where the new materials fit, but also the justification for fitting them and the ancillary resources that can contribute to their effectiveness. The connections we see are demonstrated here and in the charts on the following pages.

EARTH SYSTEMS EDUCATION

http://www.ag.ohio-state.edu/~earthsys

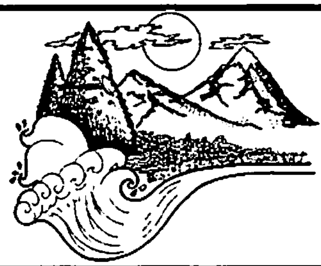


Earth Systems Education is a program of curriculum restructure in which teachers take responsibility for critical evaluation of their science curriculum, including content, classroom processes, learner outcomes, and assessment, and strive to make changes that create a curriculum more responsive to human needs and future quality of life. Earth systems education is based on integration of traditional science disciplines for a more comprehensive understanding of the interactions of Earth subsystems: the hydrosphere, lithosphere, atmosphere, biosphere, and cryosphere.

Efforts are guided by a Framework of Seven Understandings (p. 8 and 117) developed by science teachers, science educators, and scientists to represent fundamental desired results of all of science education. Each activity in this set addresses a number of the Understandings and two or more Earth subsystems, and includes suggestions for extending learning.

The process of curriculum change is assisted by scientists and science educators through development of materials such as these. Additional materials available for Earth Systems Education include a resource guide for science curriculum restructure using Earth as a focus. The guide, entitled *Science is a Study of Earth,* includes research background, teacher experiences, and samples of activities useful at elementary, middle, and high school levels. Another volume of activities is designed to help secondary science teachers address the complex issues of global change. *Activities for the Changing Earth System (ACES)* includes 20 interdisciplinary activities. These publications are available from the Earth Systems Education Program, c/o OSU School of Natural Resources, 2021 Coffey Road, Columbus, OH 43210.

Ohio Sea Grant has also produced regional information and activities about global change. *Great Lakes Instructional Materials for the Changing Earth System (GLIMCES)* includes classroom activities for secondary science, based on *Global Change in the Great Lakes Scenarios.* These can be ordered from Ohio Sea Grant, 1314 Kinnear Road, Columbus, OH 43212-1194.



LAND AND WATER INTERACTIONS		Earth Systems Understandings							Earth Subsystems				
		Beauty & Value	Stewardship	Scientific Process	Interactions	Change Through Time	Earth as Subsystem	Careers & Hobbies	Hydrosphere	Lithosphere	Cryosphere	Atmosphere	Biosphere
pg. #	Activities:	1	2	3	4	5	6	7	1	2	3	4	5
17	How well do you know the Great Lakes?			X	X				X	X			X
21	What can GLIN tell us about land and water interactions?			X			X	X	X	X			
29	When did the rocks in the Great Lakes basin form?	X				X	X	X		X			X
33	How were sedimentary rocks in the Great Lakes basin formed?			X	X	X		X	X	X			X
41	How did rocks and rivers shape the Great Lakes?	X			X	X			X	X	X		
49	What evidence of glaciation exists in the Great Lakes region?				X	X			X	X	X		
65	What evidence of glaciation can be found on Great Lakes beaches?			X	X	X			X				
71	What causes the shoreline to erode?		X	X	X	X	X		X	X			
73	Can erosion be stopped?		X	X	X	X		X	X	X			X
81	How fast can a shoreline change?		X	X	X	X			X	X			
89	How much land has been lost?		X	X	X	X			X	X			
107	What natural wonders relate to land and water interactions?	X	X		X	X		X	X	X	X		X
115	How can a concept map represent land and water interactions?				X	X			X	X	X		X

Framework for Earth Systems Education*

Understanding #1. Earth is unique, a planet of rare beauty and great value.

Understanding #2. Human activities, collective and individual, conscious and inadvertent, affect Earth systems.

Understanding #3. The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

Understanding #4. The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.

Understanding #5. Earth is more than 4 billion years old, and its subsystems are continually evolving.

Understanding #6. Earth is a small subsystem of a Solar system within the vast and ancient universe.

Understanding #7. There are many people with careers and interests that involve study of Earth's origin. processes, and evolution.

* complete Framework on page 117

National Science Education Standards

The activities in *Earth Systems - Education Activities for Great Lakes Schools* have connections to other national developments in science education. Numerous efforts have been underway in the 1990s to restructure science education in response to growing concerns that the historic "layer cake" (discipline-ordered) approach to science lacks relevance to students, prepares them poorly in life skills that demand science literacy, leaves U.S. students lagging on standardized international tests of science knowledge, and ignores or perhaps even perpetuates naive conceptions in science. The primary efforts to change these patterns have emerged from and been supported by national organizations in science and education.

The National Science Education Standards represent the National Academy of Science's attempt to develop guidelines for science curriculum restructure and systemic change in K-12 education. The National Standards include science content standards that express need for integration of disciplines, fewer topics in greater depth, and articulation across grade levels. They do more by providing guidelines for restructuring the teaching of science, the environment for science in schools, and assessment of science learning. The Standards emerged in 1995 as the most comprehensive and perhaps most esteemed of the restructure guidelines.

The following list demonstrates the connections of *Earth Systems - Education Activities for Great Lakes Schools* to many of the National Science Education Standards. Standards preceeded by an asterisk (*) are specifically addressed in this activity set.

Content standards, Grades 5-8

Science as inquiry
- * Abilities related to scientific inquiry
- * Understanding about scientific inquiry

Physical science
- * Properties and changes of properties in matter
- * Motions and forces
- * Transfer of energy

Life science
- Populations and ecosystems
- Diversity and adaptations of organisms

Earth and space science
- * Structure of the Earth system
- * Earth's history

Science and technology
- * Understanding about science and technology

Science in personal and social perspectives
- * Populations, resources, and environments
- * Natural hazards
- * Risks and benefits
- * Science and technology in society

History and nature of science
- * Science as a human endeavor
- * Nature of science

Unifying concepts and processes
- Order and organization
- * Evidence, models, and explanation
- * Change, constancy, and measurement
- * Evolution and equilibrium
- Form and function

Content standards, Grades 9-12

Science as inquiry
- * Abilities related to scientific inquiry
- * Understanding about scientific inquiry

Physical science
- Chemical reactions
- * Forces and motions
- * Conservation of energy
- * Interactions of energy and matter

Life science
- Biological evolution
- The interdependence of organisms

Earth and space science
- * Energy in the Earth system
- * Origin and evolution of the Earth system

Science and technology
- * Understanding about science and technology

Science in personal and social perspectives
- * Natural resources
- * Environmental quality
- * Natural and human-induced hazards
- * Science and technology in local, national, and global challenges

History and nature of science
- * Science as a human endeavor
- * Nature of scientific knowledge
- * Historical perspectives

Unifying concepts and processes
- Order and organization
- * Evidence, models, and explanation
- * Change, constancy, and measurement
- * Evolution and equilibrium
- Form and function

Benchmarks for Science Literacy

Project 2061 is supported by the American Association for the Advancement of Science (AAAS). Through its book *Science for All Americans*, this project identified science concepts that every high school graduate in the United States should know. Major contributions of this effort include the idea that "less is more," or that a curriculum dealing with fewer concepts in greater detail is preferred over the traditional vocabulary-laden mini-college courses common in U.S. secondary schools. Follow-up work through selected school districts produced several models for implementing the curriculum changes implied by 2061, and has resulted in a set of Benchmarks for designing the course sequences and gauging the progress of students in science through their school careers.

Many of the Benchmarks are addressed through activities in this volume. They are too numerous to list here in their entirety, but the following Benchmarks are among those applicable to the activities.

Examples for grades 6-8 include:

- The cycling of water in and out of the atmosphere plays an important role in determing climatic patterns.
- The Earth's surface is shaped in part by the motion of water and wind over very long times.
- Thousands of layers of sedimentary rock confirm the long history of the changing surface of the earth and the changing life forms whose remains are found in successive layers.
- Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly.

For grades 9-12, these materials address:

- The decisions of one generation both provide and limit the range of possibilities open to the next generation.
- In deciding among alternatives, a major question is who will receive the benefits and who (not necessarily the same people) will bear the costs.
- Scientific research identifies new materials and new uses of known materials.
- The way data are displayed can make a big difference in how they are interpreted.

Other Connections

NOAA Global Change Education Program, U.S. Department of Commerce,
1100 Wayne Ave., Rm. 1210, Silver Spring, MD 20910-5603
(301)427-2089. http://www.noaa.gov/

Great Lakes Environmental Research Laboratory (GLERC) conducts environmental research with an emphasis on the Great Lakes, including toxins in the Great Lakes, natural hazards, ecosystem interactions, hydrology, and effects related to global climate change.
2205 Commonwealth Blvd., Ann Arbor, MI 48105
(313)741-2244. http://www.glerl.noaa.gov/

Canadian Atmospheric Environment Service
Environment Canada, 4905 Dufferin Street, Downsview, Ontario, Canada M3H 5T4

International Joint Commission (IJC) is an appointed commission of representatives from U.S. and Canada who act as advisors of management activities of the Great Lakes and rivers along the border between countries. The IJC incorporates public input and efforts of research, environmental, government and business interests in their ongoing efforts. Main office: 100 Ouellette Avenue, Windsor, ON N9A 6T3.
(519)256-7821; Detroit Office: P.O. Box 32869, Detroit, MI 48232.
(313)226-2170. http://www.great-lakes.net:2200/partners/IJC/ijchome.html

Great Lakes Commission is an interstate commission of the eight Great Lakes states established in 1955 to "promote the orderly, integrated and comprehensive development, use and conservation of the water resources of the Great Lakes Basin."
The Argus II Building, 400 Fourth St., Ann Arbor, MI 48103
(313)665-9135. http://www.glc.org/

Great Lakes Information Management Resource (GLIMR) is an index of Environment Canada's Great Lakes programs, publications, and databases.
http://www.cciw.ca/glimr/intro.html

Great Lakes Information Network (GLIN) is a great place to start exploring the Great Lakes on the Internet.
http://www.great-lakes.net/

National Sea Grant College Program – Great Lakes Network
http://h2o.seagrant.wisc.edu/greatlakes/glnetwork/glnetwork.html (One Web site links all programs below.)
Illinois-Indiana Sea Grant, 1206 S. Fourth St., 104 Huff Hall, Champaign, IL 61820; (217)333-1824
Michigan Sea Grant, 2200 Bonisteel Blvd., Ann Arbor, MI 48109; (313)763-1437
Minnesota Sea Grant, 1518 Cleveland Ave., N., Rm 302, St. Paul, MN 55108; (612)625-2765
New York Sea Grant, SUNY, Nassau Hall, Stony Brook, NY 11794-5000; (516)632-6905
Ohio Sea Grant, 1314 Kinnear Rd., Columbus, OH 43212-1194; (614)292-8949
Wisconsin Sea Grant, 1800 University Ave., Madison, WI 53705-4094; (608)262-0644

Lake Carriers Association
This is a trade organization representing almost all of the U.S.-flag vessels on the Great Lakes. LCA publishes regular updates of shipping traffic and cargo. Address: 614 Superior Ave., 915 W. Rockefeller Bldg., Cleveland, OH 44113-1383. http://ne1.bright.net/lcaships/

Internet Sites of General Interest

Try a search using the name, if the address has changed.
National Climatic Data Center, http://www.ncdc.noaa.gov
U.S. Army Corps of Engineers, Detroit District, http://sparky.nce.usace.army.mil
Sea Grant Network, http://h2o.seagrant.wisc.edu/greatlakes/glnetwork/glnetwork.html
Canadian Great Lakes Information Management Resource, http://www.cciw.ca/glimr/intro.html
NOAA Home Page, http://www.noaa.gov/
Great Lakes Forecasting System, http://superior.eng.ohio-state.edu/, Lake Erie maps updated every 6 hours.

Publications and Other Materials

The Great Lake Erie. A Reference Text for Educators and Communicators. Fortner, R.W. and V.J. Mayer. 1993. Columbus: Ohio Sea Grant. This is the source of information used in most of the activities. Chapters are written by experts in Great Lakes topics, and readings from the book can serve as the content base for additional instruction.

The Great Lakes: An environmental atlas and resource book. 1995. Jointly produced by the Government of Canada and U.S. EPA, 3rd edition. Copies available from Great Lakes National Program Office, U.S. EPA, 77 W. Jackson Blvd., Chicago, 1995. IL 60604.

The Great Lakes Forecasting System, Department of Civil Engineering, The Ohio State University, with support from GLERL, NOAA. This on-line system makes predictions of physical variables of the Great Lakes and gives maps of existing conditions on Lake Erie, updated every six hours. World Wide Web address – http://superior.eng.ohio-state.edu/

Great Lakes Instructional Materials for the Changing Earth System. Fortner, Rosanne W., Heidi Miller, and Amy Sheaffer. 1995. Columbus: Ohio Sea Grant. A book of 31 activities for students in grades 7-12 that investigate the potential of global change on the Great Lakes region.

Great Lakes Solution Seeker CD-ROM. Fortner, Rosanne W., Rick Meyer, and Al Lewandowski. 1996. Columbus: Ohio Sea Grant. Databases and Hypercard program with vital data on Great Lake processes and characteristics.

Living with the Lake Erie Shore. Carter, Charles H., et al. 1987. Durham: Duke University Press. Sponsored by the National Audubon Society. Reference book with photographs, diagrams, and relevant information about coastal processes, shoreline protection, and coastal zone management.

Science Is a Study of Earth: A resource guide for science curriculum restructure. Mayer, V.J. and R.W. Fortner, 1995. Columbus, OH: Earth Systems Education Program, The Ohio State University. Ideas on effective ways to improve science teaching and learning, assess progress, do cooperative learning, conduct workshops, etc. Sample activities for grades K-HS.

Weather and Climate of the Great Lakes Region. Eichenlaub, Val. 1979. The University of Notre Dame Press. Notre Dame, Indiana.

Arts and Literature of the Great Lakes

Many scientists report that their interest in science was at least in part related to their feelings of wonder at the Earth's beauty. As is stated in Earth Systems Understanding #1, "The beauty and value of Earth are expressed by and for people of all cultures through literature and the arts." The developers of ES-EAGLS encourage teachers to use art, music, and literature in teaching. Not only does this address diverse learning styles and stimulate creativity, it also helps students find meaning behind what may otherwise appear to be topics unrelated to their lives.

Much support is available for teachers to include the arts in teaching science. Listed below are some of the resources the authors have found most valuable. Your school's librarian and music teacher may know of other resources that relate to your specific region or Great Lake. Consult local units of the Great Lakes Historical Society and merchants in resort areas of the lakes as well.

Selected Music Resources

Lee Murdock's Great Lakes folk songs are popular in auditorium programs, private performances, and on cassettes. *Cold Winds* and *Freshwater Highway* are our favorite albums. Depot Recordings, P.O. Box 11, Kaneville, IL 60144, (708)557-2742.

Paddle-to-the-Sea. 1990. Narrated, Composed and Performed by Liona Boyd. Winnipeg, Canada: Oak Street Music Inc. Based on the book *Paddle-to-the-Sea* by Holling C. Holling. The original book can be an additional reference for Great Lakes activities, and a supplemental guide is available from Ohio Sea Grant, The Ohio State University.

Pat Dailey is a country rock singer from Bay Village, Ohio. His albums are a mix of bar-room humor and serious songs of the Great Lakes. We use his "Great Lakes Song" and others on the *Freshwater* album most often. Albums are available from Olympia Records, P.O. Box 40063, Bay Village, OH 44140.

Privateer is a Celtic folk duo from the Chicago area that sings traditional Great Lakes songs and original material related to the lakes. Sextant Music, 6342 W. Belmont, Chicago, Il 60634 (312/775-1257).

The Water Song Book, by Dale and Linda Crider. 1981. Gainesville, Florida: Anhinga Roost Company.

Banana Slug String Band, *Dancing with the Earth* album, has an excellent "Water Cycle Boogie" for younger students. Contact them at BSSB, P.O. Box 2262, Santa Cruz, CA 95063.

Selected Art Resources

The Canadian McMichael Collection (Government of Ontario, 1983) from the McMichael Galleries in Toronto includes the best collection of the Canadian Group of Seven landscape artists.

Canada Illustrated: The Art of Nineteenth-Century Engraving. 1982. Toronto: Dreadnaught.

In a Grain of Sand, by Andreas Feininger. 1986. San Francisco: Sierra Club Books. Several photographs protray the beauty of land/water interactions as well as other natural processes.

Imprints of Time: The Art of Geology, by Bradford B. Van Diver. 1988. Missoula: Mountain Press Publishing Company

Poetry

Earth Songs by Myra Cohn Livingston, poet, and Leonard Everett Fisher, painter. 1986. New York: Holiday House, Inc.

Hangdog Reef. Poems Sailing the Great Lakes. This is the only volume we have found specific to Great Lakes topics. Please let us know if you find others!

The Poetry of Geology. Edited by Robert M. Hazen. 1982. London: George Allen & Unwin (Publishers) Ltd.

Geography and Technology

Water. It is one of the most gentle yet most powerful forces of change on Earth. What comes to mind with the phrase "land and water interactions?" Perhaps it is the waves lapping on a Great Lakes shore, or muddy water after a rain. The following set of activities explores various concepts surrounding land and water interactions.

Processes of change occur where land and water interact, such as in the Great Lakes. Water and ice cause fragments of rocks to break off from larger rocks. Fragments hit together, causing finer sediments to form. Erosion moves sediment along and deposits it. Dissolved minerals seep through the sediment, acting like cement. These and other processes cause new layers of rocks to form over centuries of time.

The processes we see today are not unlike those that characterize the Great Lakes region's geological history. The action of water shapes the land while the land adds sediment to water.

In this set of activities you will examine how the Great Lakes were formed, what unique features exist in the region as a result of land and water interactions, and how ongoing interactions shape the Lakes today. Both land and water supply resources to people. Students will investigate the resources of the region and the characteristics of each Lake that make it different from the others. Even beach evidence can disclose the history and ongoing interactions of land and water. Exploring important concepts through technology and group interactions can give us insight into the processes of change in the Great Lakes region.

Both ancient and modern processes have given each Lake its unique natural and scenic resources. This set will explore geological processes, action of ancient seas and glaciers, and ongoing coastal processes that continue to shape the modern Great Lakes. Both history and the present day give evidence of land and water interactions.

Source: Flower Pot Island from *The Great Lakes Atlas*, 1995.

Learning about the land and water of the Great Lakes region does not mean only land and water are studied. The Earth is a system that operates as a whole, and nothing happens without affecting something else.

There is not just one "scientific method." Studies of the Earth system usually do not involve experimenting in the traditional sense, but instead using observational data, historical records, models and such to detect trends and predict future interactions.

Geologists say, "the present is the key to the past." The kinds of data we can collect today about land, water, and other Earth components and processes have the potential to show us what has happened in Earth's past and what is likely to happen tomorrow. We can gain access to the data about the past through the Internet, especially through the Great Lakes regional database sites like the Great Lakes Information Network (GLIN) at http://www.great-lakes.net and CIESIN, described in its own Web page below. As part of your studies about land and water, the authors hope you will update the information in the book by gaining access to the complete databases online.

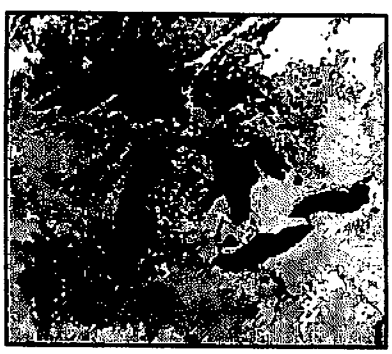
CIESIN

Interactive Applications
Metadata Resources
Data Resources
Information Systems and Resources
Information Cooperative
Education and Training
Services
Programs
Job Opportunities

INFORMATION FOR A CHANGING WORLD

CIESIN was established in 1989 as a non-profit, non-governmental organization to provide information that would help scientists, decision-makers, and the public better understand their changing world. CIESIN specializes in global and regional network development, science data management, decision support, and training, education and technical consultation services. CIESIN is the World Data Center A (WDC-A) for Human Interactions in the Environment.

Great Lakes Regional Environmental Information System



The Great Lakes Regional Environmental Information System (REIS) is a regional directory and data access system being developed by CIESIN with support from the U.S. Environmental Protection Agency (EPA). While highlighting the EPA's Great Lakes Program and the Great Lakes National Program Office (GLNPO), GLREIS provides directory information for both EPA and non-EPA data. GLREIS has been awarded McKinley Group's top Magellan "four-star" ranking.

How well do you know the Great Lakes?

Many people, including a large proportion of those who live close to the Great Lakes, do not have a basic understanding of the individual characteristics of and the differences between the lakes. Since it is difficult to understand many of the Great Lakes issues, such as global warming, pollution, and water use without a basic understanding of the lakes, this activity is designed to help visualize the differences in the volume, length of shoreline, human population distribution, and fish populations of the Great Lakes.

OBJECTIVES

In this activity, you will develop a perception of the differences between the Great Lakes in water volumes, length of shoreline, human population distribution, and the amount of fish harvested from each lake.

PROCEDURE

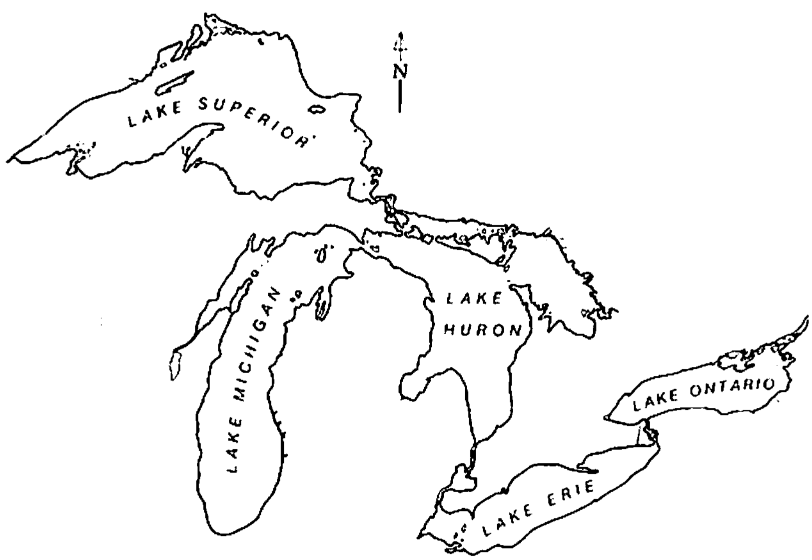
1. In this activity you will work in groups. You will be assigned to an expert group and a base group.

   Expert Groups

   There should be a total of five expert groups, one assigned to each lake. Each expert group studies one lake to become "experts" on that lake.

   Base Groups

   The base groups should have five (or more) people in them; in this group students from the different expert groups come together to share their knowledge. There must be at least one member from each expert group (in other words, a representative from each lake) in each base group so that every lake has a spokesperson.



Source

"How well do you know the Great Lakes?" by Heidi Miller, in GLIMCES, *Great Lakes Instructional Materials for the Changing Earth System*, Ohio Sea Grant Education Program, 1995.

Earth Systems Understandings

This activity relates to ESU 3 (science methods and technology) and ESU 4 (interactions).

Materials

Each base group (of five students) will need:
- A set of five labeled strings as described in step 1 of *Using the Data*.
- 100 squares of blue paper.
- Five strips of paper that will be placed next to the coastline of each lake (one strip for each lake).
- Twenty "fish" (they could be washers, corn kernels, or peanuts...).
- A pen or pencil.

Each of the five expert groups will need:
- Access to a map of the Great Lakes.
- A copy of the *Great Lakes data* (other resource books are optional).

Teacher's Note

Groups should each have a large working surface that all can gather around.

2. Gather in base groups. Discuss the following and make your group's best guess about the characteristics of the Great Lakes.

3. *Shoreline:* Arrange your labeled set of five strings to form a model of the outline of the Great Lakes.

4. *Volume:* Distribute 100 squares of blue paper among the lakes to represent all of the water contained in the lakes. For example, if your group thinks that the water is divided equally among the lakes, then put 20 blue squares into each lake.

5. *Human populations:* Cut five strips of paper, which will be placed along the shoreline of the lakes (one for each lake). The total population of people living in the Great Lakes watershed is 33.2 million. Divide that number among the Great Lakes. For instance, if your group thinks that about half of the people in the Great Lakes watershed live on Lake Superior, then they would write 16 million on a strip of paper and place it next to the Lake Superior coastline. The goal is not to get the number correct but to start thinking about where people are located around the lakes.

6. *Fish:* Try to predict the amount of fish taken from each lake for human food. Collect 20 "fish" from your teacher. These 20 fish represent all of the fish taken out of the Great Lakes. If your group thinks, for instance, that almost all of the total fish come from Lake Superior, then they should put 18 or 19 fish in that lake.

7. After the base groups have made their guesses, leave the lake models in place and move into expert groups. Your group is assigned to one of the lakes. Look at the actual data available on your lake so that when you move back to base groups you will be able to correct the guesses originally made.

8. Return to base groups to correct the models and discuss the review questions.

Review Questions

1. What was the most surprising thing about this activity? Discuss why.

2. Which guesses were not close to the correct answers? What reasoning led the group to its wrong decisions?

3. Why do the majority of the people live around Lake Erie?

Teacher's Notes

5. Instead of writing actual numbers on the strips of paper, the lakes could be ranked from 1-5 for most population to least population.

7. You may either give them the correct percentages or have the students figure them out.

Answers

1. Students may find the amount of fish taken and the amount of people living on Lake Erie surprising because of the lake's relatively small size.

2. Answers will vary.

3. There are several reasons, one is that Lake Erie has a somewhat milder climate, early trade routes were along its shores, and large population centers developed early.

4. Why don't the length of coastline and the amount of water correspond?

5. How did the groups work out differences in opinion in order to come to common agreement?

Answers

4. The depths of the lakes are very different.

5. Answers will vary.

EXTENSIONS

1. As a class or individually, make up a question pertaining to the Great Lakes (for instance: "Which lake (on a map of the Great Lakes) is Lake Huron?" or "Which of the Great Lakes has the largest human population living in its watershed?") and ask the question to a variety of people either around the school or in the community. This may lead to interesting discussions concerning the possibility that the voting public may make uninformed decisions.

2. Try to find an additional set of data about the Great Lakes such as average depth, fish populations, average water retention time, level of pollution, etc. to present to the class or to lead the class through, as with the other data sets.

USING THE DATA

These notes should help with interpreting the *Great Lakes Data* chart and with setting up the experiment.

1. *Shoreline:* In order to make strings that depict the relative lengths of shoreline of the Great Lakes, use the relative length data in the shoreline section. Any unit of measurement may be used as long as it is used consistently. The measurement units will depend on the amount of space available for the lesson. For instance, if the lesson will be taught outdoors, a large unit of measurement may be used, such as meters. In this case, the Lake Superior string would be 3.0 meters long. Make sure each string is labeled with a piece of tape.

2. *Water Volume:* The student groups each have 100 blue squares, which represent all of water in the Great Lakes combined. To find how 100 squares should be distributed, look at the relative volume section in the volume category. It lists 54 for lake Superior. This means that 54 of the squares should be in the Lake Superior string model (over half of the water is in Lake Superior).

3. *Human population:* The total population data figures are rounded off in the section *Population* to the nearest million. The students attempt to guess the numbers in this category. It is interesting to realize that Lake Superior has only .6 million people living near it. This is less than 2 percent of the total population of the Great Lakes watershed.

4. *Fish:* The row labeled *percentage* in the fish section of the chart indicates the number of pounds of fish that would come from each lake if the total number of pounds from all the lakes was 20. Each base group of students should be given (or make) 20 "fish" so that they can make their best guess as to how the fish should be distributed in their string bordered "lakes."

Great Lakes Data

		Superior	Michigan	Huron	Erie	Ontario	Total
Shoreline (*with Islands*)	(miles)	2,726	1,638	3,827	871	712	10,210
	relative length	3.0	1.6	3.8	0.9	0.7	10.0
Volume [a]	(cu. miles)	2,900	1,180	850	116	393	5,439
	(km^3)	12,100	4,920	3,540	484	1,640	22,684
	relative volume	54	22	15	2	7	100
Human Population in Watershed	U.S. & Canada (1990-91)	607,121	10,057,026	2,694,154	11,682,169	8,150,895	33,191,365
	population to nearest million (approx.)	0.6	10.0	2.7	11.7	8.2	33.2
Annual Commercial Fishing Harvest	U.S. (lbs)	2,877,240	44,000,000	4,747,267	5,793,590	232,551	57,650,648
	Canada (lbs)	1,648,681		6,378,861	40,620,666	1,212,728	49,860,936
	Total	4,525,921	44,000,000	11,126,128	46,414,256	1,445,279	107,511,584
	Relative amount of fish harvested	1	8	2	9	0	20
	Number of fish species	45	78	87	100	90	

[a] Measured at Low Water Datum.
Note: The total shoreline is greater that the sum of the lakes because connecting channels are included.

References

Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data. Coordinated Great Lakes Physical Data. May 1992. Agencies represented include: U.S. Department of the Army, Department of Commerce, and Department of the Interior; Environment Canada, Department of Fisheries and Oceans, and Natural Resources Canada.

Extension Bulletins E-1866-70, Michigan Sea Grant College Program. 1985. Cooperative Extension Service, Michigan State Univ. E. Lansing, MI.

The Life of the Lakes, Michigan Sea Grant and Michigan State University (1991 Data).

What can GLIN tell us about land and water interactions?

GLIN, The Great Lakes Information Network on the Internet, has many resources that relate to the concept of land and water interaction.

Go to GLIN:
http://www.great-lakes.net/
(Note: Web addresses sometimes change. Do an Internet search on the words great lakes if necessary.)

Objectives

In this activity you will:

- Discover how locations on the Internet, specifically on GLIN, relate to concepts of land and water interaction.
- Observe how different Internet sites complement each other.
- Explore options for GLIN searches.

Procedure

Access the GLIN Home Page through Netscape or another browsing program. On the GLIN Home Page are several options. This procedure will explore a few of them.

A. Search for sites that relate to land/water interactions. For example, under topics dealing with environmental issues in the Great Lakes investigate areas such as:
Land – land use, topography, geology, classifying shorelines;
Water – watersheds, water levels;
Interactions and processes – erosion, weather, and climate.

B. Search for sites covering land-related topics. Find what you would consider important geologic information regarding land/water interactions in the Great Lakes region. Several options are shoreline classification, erosion, crustal movement, and landforms. How are shorelines classified in the Great Lakes region? Find the Canadian Great Lakes Shoreline Classification (Hint: Search "shoreline." Find information about Great Lakes Coastal Zones).

Earth Systems Understandings

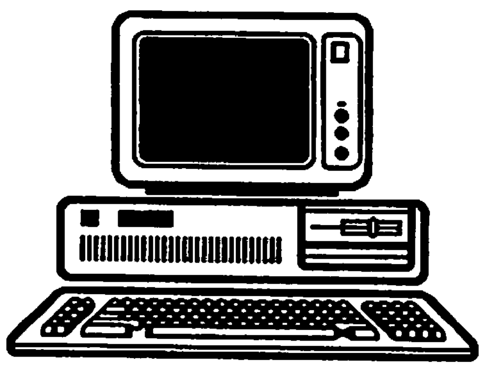
This activity addresses the use of technology in communicating information to various audiences. It explores ESU 3, and ESU 7 and allows for individual creativity while doing Web searches.

Materials

- Students will need WWW access.

Suggested Approach

Few schools have enough computers for all students to be on the Internet at one time. A single computer can serve 3-4 students at once. Teams can rotate to the computer while other groups do related activities.



How are shorelines classified under this organization?

What does each of the categories mean?

Find the subaqueous (literally, "under water") scheme. What kinds of entries are there?

C. Shoreline classification is one component affecting land/water interactions. A related concept is the erodibility of different shoreline areas. Where would you find information on erosion prone areas in the Great Lakes region? If you wanted to purchase shoreline property, where would you go to find relevant information to aid your decision making? (Hint: Find names of relevant erosion publications on different Web sites).

How could these publications help make decisions surrounding issues of land and water interaction?

D. 1. Water levels also affect land and water interactions. Find sites with lake level data and graphs. One source is the U.S. Army Corps of Engineers with sites related to lake levels. Print an image to share with the class. You can even call a gauge station to learn about water levels at a specific site. Find a Web address providing this service and locate the gauging station site nearest your school. Make a list of other important Web addresses with information about water levels.

2. Coordinating water level data is important, especially over an international boundary, such as the Great Lakes. How are hydraulic and hydrologic data coordinated between the U.S. and Canada? Find information on the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data. This explains the coordination of work between the two countries.

3. What is the history of the coordination between countries? Why is this coordination important? What is the IJC? How does its work relate to issues of land and water interactions?

The World Wide Web is not only interactive but also offers means by which to print images for use by students in presentations or group discussions.

Answers

B. It is a three-tiered scheme. The categories are Geomorphic classification, Shoreline protection classification, and Subaqueous classification.

Geomorphic classification – geomorphology and geology.
Shoreline protection classification – proportion of the shoreline protected.
Subaqueous classification scheme – the material found in the nearshore area.

There are six entries under the subaqueous scheme. They are: clay, sand, sand/gravel slag over clay, bedrock (resistant), bedrock (non-resistant), and unclassified.
Source: Government of Canada, 1996.

C. Examples are: "Great Lakes Floods and Erosion Prone Area Maps" by Department of Fisheries and Oceans, Environment Canada and Ontario Ministry of Natural Resources.

"A Guidebook to Drought Planning, Management and Water Level Changes in the Great Lakes" by the Great Lakes Commission.

"The Role of Vegetation in Shoreline Management: A Guide for Great Lakes Shoreline Property Owners" by the Great Lakes Basin Commission.

Publications could help government agencies and private owners be aware of the most erosion-prone areas when planning projects.

D. 1. See U.S.ACE, Detroit District. See also the Canadian Hydrographic Service, which coordinates telephone access to gauging stations *(Source: Government of Canada, 1996).*

2. The coordination began in 1953. Have the class discuss the challenges of managing a resource across international borders. Standardizing data is one way of helping agencies communicate and coordinate their activities.

3. IJC stands for International Joint Commission representing interests in both the U.S. and Canada.

USACE Detroit GLHHB

Current Levels
PROVISIONAL
GREAT LAKES DAILY LEVELS IN METERS (IGLD 1985)-- MAR 1996

DAY	SUPERIOR* DAILY MEAN	SUPERIOR* RUNNING MEAN	MICHIGAN-HURON* DAILY MEAN	MICHIGAN-HURON* RUNNING MEAN	ST. CLAIR* DAILY MEAN	ST. CLAIR* RUNNING MEAN	ERIE* DAILY MEAN	ERIE* RUNNING MEAN	ONTARIO* DAILY MEAN	ONTARIO* RUNNING MEAN
1	183.32		176.42		175.10		174.10		74.79	
2	183.31		176.40		175.09		174.08		74.79	
3	183.32		176.40		175.08		174.07		74.78	
4	183.32	183.32	176.40	176.40	175.09	175.09	174.08	174.08	74.82	74.80
MARCH										
MAX	183.61(1986)		177.12(1986)		175.80(1986)		174.88(1986)		75.37 (1952)	
MIN	182.74(1926)		175.58(1964)		174.05(1934)		173.20(1934)		73.94 (1935)	
AVG 1918-1994	183.26		176.35		174.89		174.05		74.66	
AVG LAST YEAR	183.19		176.47		175.08		174.29		74.72	
AVG LAST MONTH	183.34		176.40		175.02		174.02		74.76	

* THE COORDINATED MEAN LEVELS SHOWN ARE THE AVERAGE OF MORE THAN ONE GAGE

* DUE TO A DIFFERENCE IN ROUNDING METHODS, THE COORDINATED LEVELS MAY DIFFER FROM THE CANADIAN MEAN LEVELS BY +/- .01

Source: U.S. Army Corps of Engineers, Detroit District lake level data – online (format modified).

E. Weather and climate processes affect land/water interactions. Storms may produce floods and generate waves that affect shorelines. Try to find some weather forecast data online. Find images of surface water temperatures, wind fields, or wave heights on the Great Lakes (Hint: Satellite images)

How might climatic changes such as temperature affect land-water interactions, for example along a beach?

This is an example of the technology exchange described in Earth Systems Understanding #3. While technology of one type can bring information to research scientists from the natural world, such as in satellite images, another type of technology, namely computers and the internet, can share the same images with scientists in a classroom.

Internet sites are interrelated. Return to the GLIN Home Page. Previous searches were based on environmental topics in the Great Lakes. Now find some interesting places within the region that relate to land/water interactions.

Teacher's Note

A good site for images is the Great Lakes Forecasting System. http://superior.eng.ohio-state.edu/

See also Marine forecasts for the Great Lakes, Environment Canada. *Source: Government of Canada, 1996.*

E. Ice will erode beaches differently than water, because ice can freeze in cracks in rock walls, expanding to add pressure and increase erosion.

F. Two locations of interest to National Oceanic and Atmospheric Administration (NOAA) are Old Woman Creek, Ohio, and Thunder Bay, Michigan.

F. Find out how Great Lakes coastal zones are managed. Locate information on the work of NOAA in the Great Lakes basin (Hint: Find places of interest in the Great Lakes that are sanctuaries and reserves).

Locate two coastal sites in the Great Lakes basin that particularly interest you. Why are these important? Can you find a photograph of one of the sites?

G. OCRM stands for the Office of Ocean and Coastal Resource Management program. They work with the Great Lakes shoreline as well as marine coastlines of the U.S.

G. Investigate further the Coastal Programs Division of NOAA. (http://wave.nos.noaa.gov/ocrm)

What is represented by the acronym OCRM? How is it related to the Great Lakes region?

H. Answers will vary.

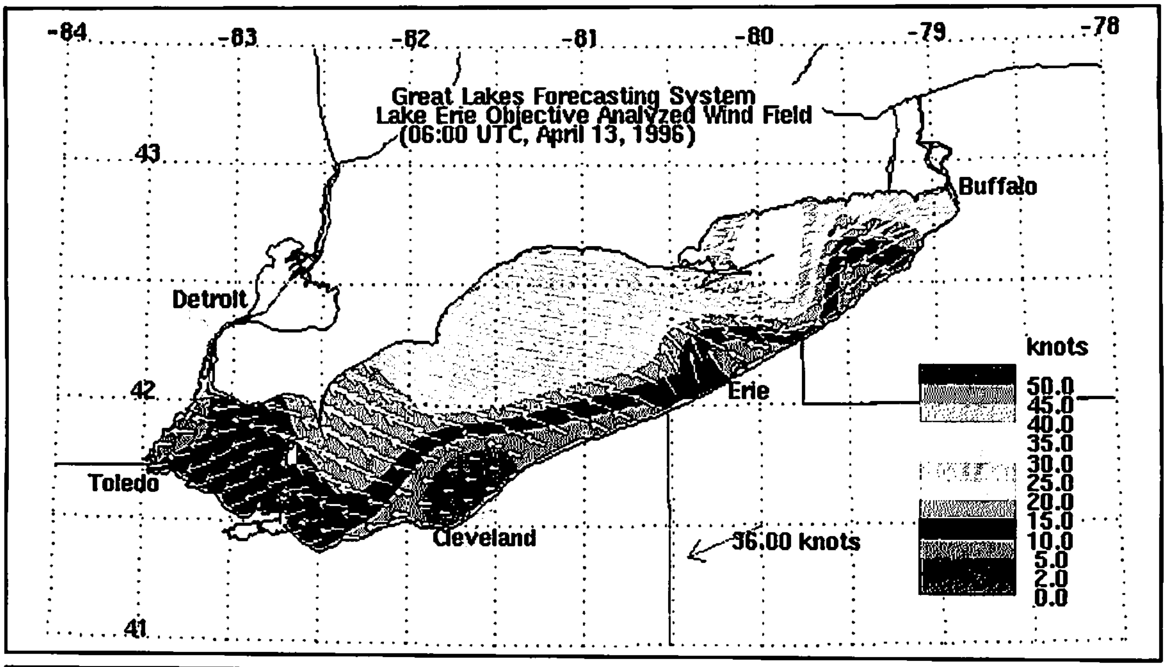
H. Learn more about coastal management within a particular state. For example, start with Michigan. There are many interesting features including photographs. Locate and report some "gee-whiz" information about your own state.

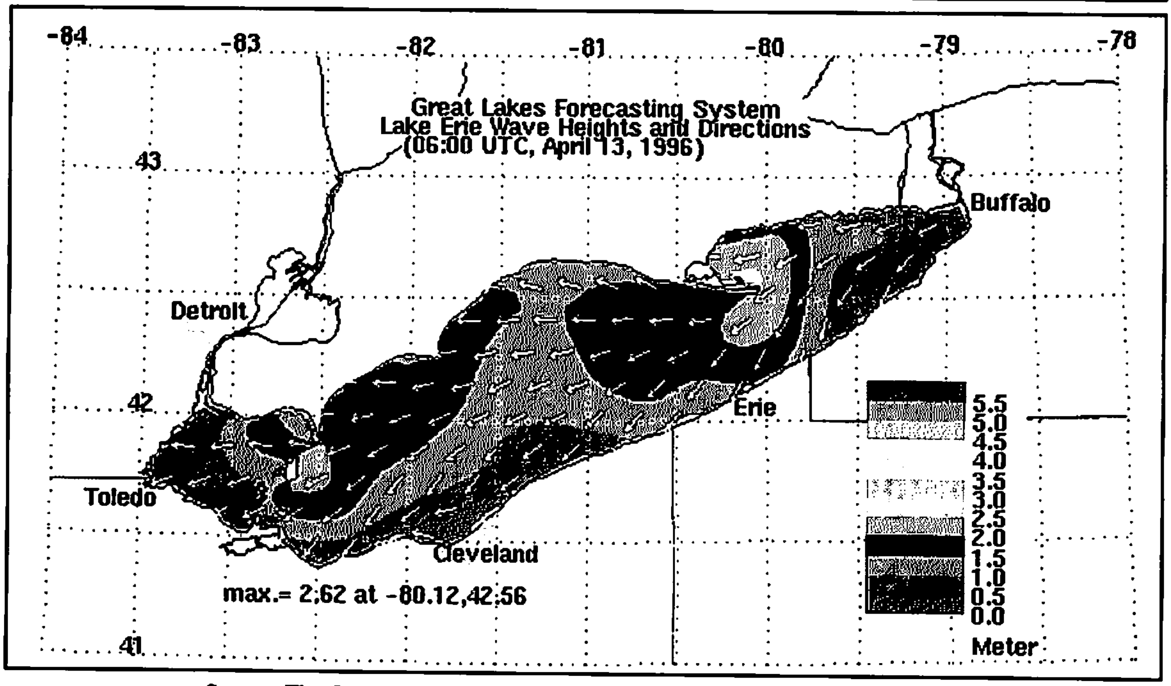
As you can see, there are various interconnections possible when surfing the Internet. Remember this information source when you are doing research that calls for current data. It is much more up-to-date than most encyclopedias!

USING WHAT YOU HAVE LEARNED

1. With your team, develop an electronic scavenger hunt for a special fact about your state in relation to the Great Lakes. Establish a starting place on the Internet and give a series of clues to lead to the discovery of the fact. Give your clues to another team and see how long it takes them to find the "prize" fact.

2. "Bookmarks" are used on the Internet browsing software to mark your place on certain "pages," just as if you were reading from a textbook. Find Internet sites to accomplish the following, and write the bookmarks (URL addresses) on a list you can keep:
   - shoreline erodibility on Georgian Bay ______________
   - highest water level on Lake Ontario ______________
   - satellite image of Buffalo ______________
   - coastal marshes along the Great Lakes ______________
   - water surface temperature on your Lake ______________
   - Great Lakes Coastal Recreation Site ______________





Source: The Great Lakes Forecasting System, The Ohio State University.

3. Here are two examples of images obtained from the Internet. What relationship can you detect between wind and wave directions? Why do you think this technology would be important? Who would benefit from this type of information? (Hint: What economic sectors are related to changes on the lake?)

Teacher's Note

The wind and wave directions shown are not the most prevalent for Lake Erie. See activities in the Climate and Weather collection of ES-EAGLS.

History of Land and Water Interactions

The land and water of the Great Lakes are not only natural resources, they are also historical resources. They are part of a story that is millions to billions of years old.

Lakes, basins, valleys, and rock formations mark the passage of time. Land/water interactions have a long history. This history is the focus of the next five activities. The first three investigate the geologic processes that formed the present-day basin, while the last two deal more directly with the effects of ancient glaciers and what they left behind.

The Earth is dynamic. Forces under the surface shaped the land above shifting rock and forming basins. Such was the activity forming the igneous and metamorphic rock in the northern part of the basin. On the surface, ancient seas and then glaciers formed additional rock layers by washing various types of sediments away from existing rock layers, forming new ones. Many forces were active both above and beneath the surface.

The Lakes drained, filled, and took on the resemblance of what we see today. They also mark history, revealing what took place in the region's past. The Great Lakes region connects the past with the present in the ongoing land and water interactions of today.

The Great Lakes are historical as well as natural resources.

Teacher's Resources

The Great Lake Erie. 1993. Edited by Rosanne W. Fortner and Victor J. Mayer. Ohio Sea Grant Education Program, Columbus, OH: Ohio Sea Grant Publications, The Ohio State University. Copies are available from Ohio Sea Grant Publications,1314 Kinnear Road, Columbus, OH 43212.

The Great Lakes. An Environmental Atlas and Resource Book. 1995. Jointly produced by Government of Canada and U.S.EPA, 3rd ed. Copies are available from:
Great Lakes National Program Office
U.S. Environmental Protection Agency
77 West Jackson Blvd
Chicago, IL 60604
EPA 905-B-95-001

Geologic Processes

The following are selected readings from Dr. Jane E. Forsyth's "The Geologic Setting of the Great Lakes" in *The Great Lake Erie*: The geologic setting of these lake/river basins began far earlier, with the formation of the bedrock in which these basins occur. In most cases this bedrock is sedimentary rock of Paleozoic age (roughly 200 to 600 million years old), but the rock surrounding Lake Superior, the northernmost and deepest of the Great Lakes, is much older igneous and metamorphic rock, Pre-Cambrian in age (one to two billion years old). These very old rocks actually occur down below the younger, Paleozoic sedimentary rock in the south, forming the so-called Pre-Cambrian "basement" rocks there. Northwards they rise nearer the surface until they occur at the surface, forming a broad Pre-Cambrian upland around the Lake Superior basin and throughout much of Canada, called the "Canadian Shield."

These igneous and metamorphic rocks were formed by mountain-making processes – volcanoes, intrusions and metamorphism – that were active through much of Pre-Cambrian time. Ancient sediments, buried by younger sediments and subjected to intense mountain-making pressures, became the metamorphic rocks, while molten material in deep batholithic intrusives and in volcanoes at the surface contributed magma and lava that hardened into igneous rock. Igneous and metamorphic rocks are the most resistant rocks of all in the Great Lakes region, so the land around the Lake Superior basin is especially high and hilly. Even so, some of these rocks are somewhat less resistant, allowing erosion, first by streams and later by glaciers, to cut a little deeper where they occur, also helping to create the basin of the largest of the Great Lakes.

Following the long Pre-Cambrian history came the accumulation of extensive Paleozoic sediments that developed into the bedrock surrounding the other Great Lakes, sediments that never covered the Pre-Cambrian rock in the Lake Superior region. These Paleozoic sediments began with a deposit of sand, weathered from the older igneous and metamorphic rocks and washed into the shallow intermittent sea that had spread across the entire lower Great Lakes and midwestern region. Limy sediments precipitated next from clear sea water, and the lime was subsequently recrystallized into layers of limestone and dolomite (the magnesium-bearing form of limestone).

During Silurian time, while the limestone (dolomite) was being deposited in the shallow open ocean, great reefs or other shallow marine bars developed, cutting off broad segments of the sea and allowing very little inflow of new sea water. In these closed basins, intense evaporation took place, causing precipitation of salts, mostly lime, but also gypsum and salt. Oil and natural gas are also obtained from rocks of this age, as well as from older (Ordovician and Cambrian) limestones, where these rocks lie deeply buried.

About midway through the Paleozoic Era, the nature of the sediments changed. Mud, and later sand, began washing into the sea. The mud represented fine-grained sediments eroded from a rising land mass on the eastern shore of this ocean, and the change from mud to sand reflected the increase in height and steepness of this rising land. These muds formed the rocks known as the Ohio (or Cleveland) Shale, of Devonian age, and the sands formed the Berea and Black Hand Sandstones of Mississippian age. Evidence for the location of this rising land east of the Great Lakes is the increasing coarseness of all marine sediments in that direction.

As the mountains rose, many rivers developed on their slopes (including) drainage in the form of the Laurentian/Erigan River system, whose valleys represented the lowlands destined to become the basins of the future Great Lakes. The depth of the erosion was affected not only by the location of the rocks, but also by the erodibility of the rocks themselves. Some of the sedimentary rocks, like sandstone or solid limestone or dolomite, are more resistant to erosion than other rocks, and when erosion takes place they tend to make ridges or hills. Where weak, nonresistant rocks like shale occur at the surface, on the other hand, lowlands are created, such as the low river valleys that would ultimately become the basins of the Great Lakes.

With the advance of the earliest of the several Pleistocene glaciers, about a million years ago, the preglacial rivers in the Great Lakes area were blocked by the ice and in many cases were destroyed. Glacial erosion widened and deepened their valleys, with the deepest erosion done by the last (Wisconsinan) glacier because of its greater thickness in basins already deepened by earlier advances. The ice of all the glacial advances was of course thinner, and therefore did less erosion, farther south, where the shallowest of the Great Lakes, Lake Erie, occurs.

As the ice retreated back toward the north, a whole series of ice-dammed lakes was formed in each of the Great Lakes basins. Each lake left deposits: sand beaches and sand bars along the old shorelines, clay settled out on the deeper lake bottoms and deltas wherever major rivers entered these lakes. Sandy beach ridges dramatically mark the shorelines of each ancient lake in the Great Lakes region. Glacial retreat was more common than advance, so generally lake levels in each of the Great Lakes basins lowered through time.

Forsyth, Jane L. 1993. The Geological Setting of the Great Lakes. In *The Great Lake Erie.* Edited by Rosanne W. Fortner and Victor J. Mayer. Ohio Sea Grant Education Program, Columbus, OH: Ohio Sea Grant Publications, The Ohio State University.

When did the rocks in the Great Lakes basin form?

It is sometimes difficult for people to get a feeling for very large numbers or long periods of time. In this activity you will get an idea of how long ago the rocks in the Great Lakes Basin formed.

Objectives

After successfully completing this activity, you will be able to:

- Describe in general terms the expanse of geologic time.
- Explain how long ago the rocks in the Great Lakes Basin formed.
- Compare the ages of Great Lakes rocks with some other events in ancient and modern time.

Procedure

The accompanying page is a sheet with 2000 dots on it. Let each dot represent 1 year of time. The first dot in the top line represents the current year. Each dot after that one is a previous year.

1. Draw a circle around the dot that represents the year you were born. Now draw circles around the dots that represent the years that your brothers and sisters (if any) were born.

2. Draw squares around the dots that represent the year that Mt. St. Helen's exploded (1980), the year your school building was built, the year the light bulb was invented (1879), and the year the Declaration of Independence was signed (1776).

Source

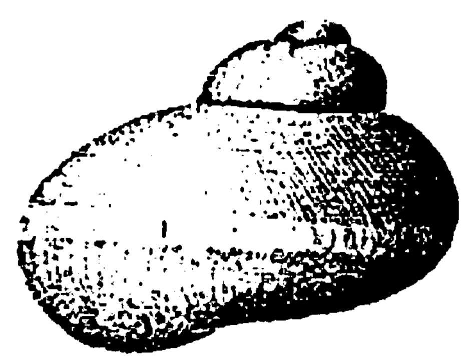
Modified from "When did the rocks in the Great Lakes basin form?" by Dan Jax. In *Great Lakes in My World.* 1989. Lake Michigan Federation.

Earth Systems Understandings

ESU 5 (change through time): Planet Earth is more than 4 billion years old, and its subsystems are continually evolving. An extension addresses ESU 6 (Earth as subsystem).

Materials

- A sheet of 2000 dots.
- Ruler.
- Pen or pencil.
- Ream of paper (unopened).



Source: Art on this page created by Sue Abbati in *The Fossil Fauna of the Islands Region of Western Lake Erie*, compiled by Lulu M. Bowe, Ohio Sea Grant Program.

3. A ream of paper consists of 500 sheets. If each sheet of paper in a ream is identical to your sheet of dots, how many years would one ream of paper represent?

4. How many reams of paper would be needed to represent 10 million years? 40 million years? 400 million years?

5. Measure the thickness of a ream of paper.

6. How tall would a stack of paper have to be to represent 400 million years of time? How many meters is this? How high would such a stack reach on the side of the school building?

Many of the rocks in the Great Lakes Basin formed from about 600 to 225 million years ago.

Remember how the year you were born was represented by one dot on the top line of the dot page?

Answers

3. One ream of paper represents one million years.

4. You will need 10 reams of paper to represent ten million years, 40 reams for 40 million, and 400 reams for 400 million years, respectively.

5. A ream of paper is approximately 5cm thick.

6. 400 million years = 400 reams x 5 cm/ream = 2000 cm. This is 20 meters.

Evaluation

Human-like organisms began to evolve about 2 million years ago. Devise a scale to compare this amount of time (2 million years) to the time when rocks formed in the Great Lakes Basin.

Evaluation

Experiment with graphs and charts to demonstrate the difference between the two values. The difference will be very large, which makes it challenging to create a scale. Individual students could represent a certain number of years, and participants could extend the geologic time scale around the room.

Extension

1. We often observe geologic processes on Earth. Processes of change occur in the universe as well. How does the interaction of Earth with the sun and moon relate to Earth System processes? How do these processes affect rock formation during Earth's geologic time?

2. The rock layers in the Great Lakes basin are actually older than some of the dinosaurs that existed during the Cretaceous period, 70-141 million years ago, and during the Jurassic period 146-195 million years ago. How high would a stack of paper need to be to represent the later years of either period of dinosaurs?

Extension Hints

Erosive processes of land and water interactions are related to tides and the moon, evaporative processes that form rock layers are related to the sun, and meteors affect topography.

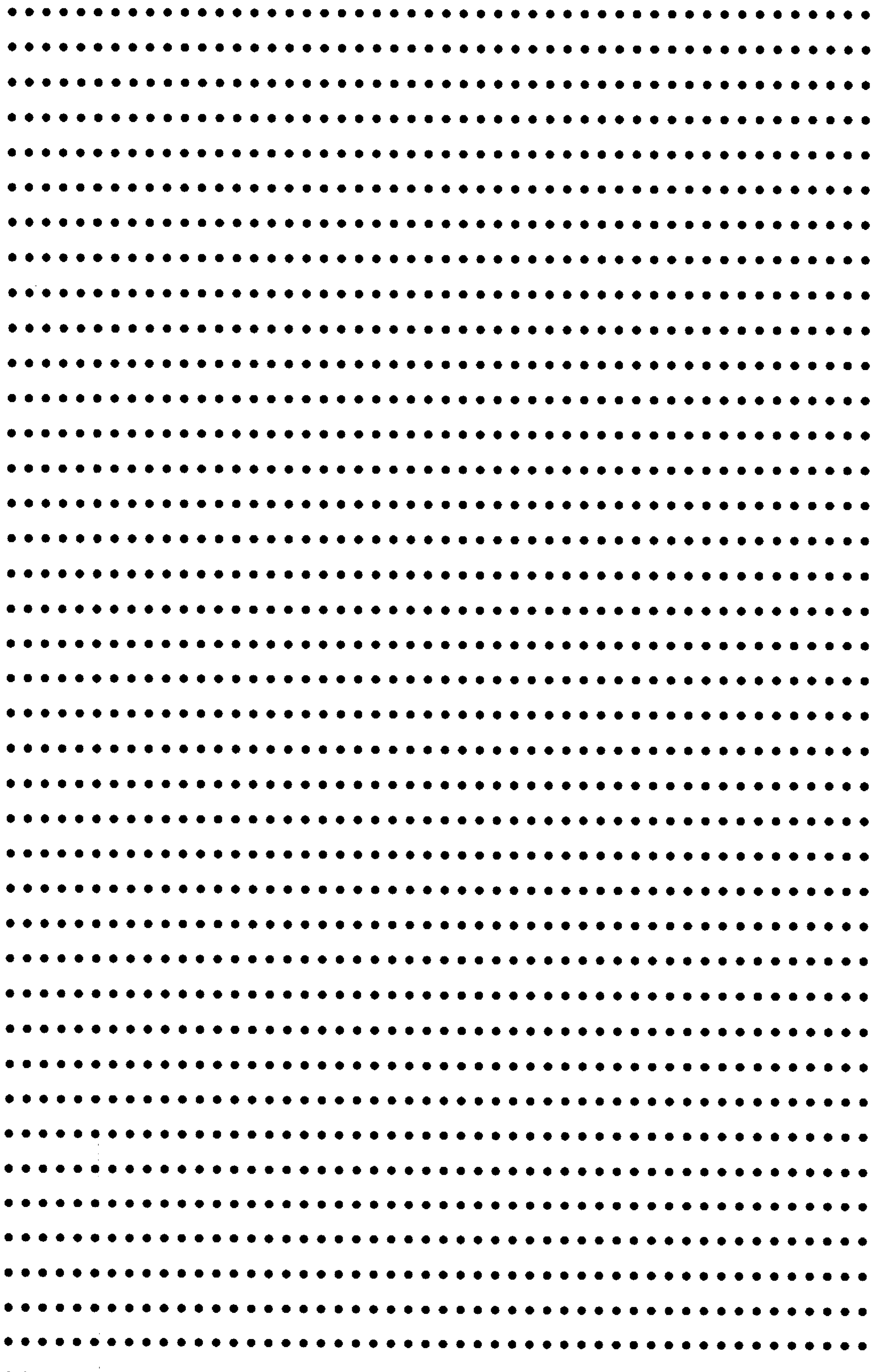
Find a height needed to represent the middle of the late Cretaceous, or 80 million years ago, and a height that would represent 160 million years ago, or the late Jurassic period, i.e., 160 million years = 160 reams of paper x 5 cm/1 ream = 800 cm.

The height when some of the dinosaurs lived would be represented by 4 and 8 m. Compare this to 20 meters, the age of some of the Great Lakes rocks, for a perspective of the magnitude of differences between time periods. The middle rock layers are more than twice as old as some of the dinosaurs.

References

Hertzberg, Hendrik. 1970. *One Million*, Simon and Schuster, New York.

2000 dots



How were sedimentary rocks in the Great Lakes basin formed?

Did you know that you may be living on a sea bottom? Ancient seas deposited various rocks and minerals that are produced in the Great Lakes region today? For example, the 1991-92 Green Index rates Pennsylvania as fourth and Illinois as fifth in coal production in the U.S., while Michigan was fourteenth in oil production. In 1991 Michigan was fifth in the U.S. in nonfuel mineral production (in iron ore, cement, sand and gravel, and stone). Minnesota was seventh in this category in iron ore, sand and gravel (construction), and crushed stone. Most of these sediments, as well as sandstone, limestone, dolostone, shale, clay, and natural gas, indicate that the area has in the past been covered by shallow seas.

The sedimentary rocks in the Great Lakes Basin formed in a series of ever-changing oceans that began about 600 million years ago and ended about 225 million years ago. There were many different organisms that lived in these oceans. Several of them had hard body parts, including shells, that were deposited along with the sediments settling out in those waters and became fossils. Most of these organisms were somewhat similar to organisms living in the oceans today. We can therefore make some hypotheses about what the environments were like in the oceans in the Great Lakes Basin millions of years ago.

OBJECTIVES

When you have completed this investigation you will be able to:

- Describe the environments in which various Great Lakes rocks were formed.
- Recognize physical features in different types of rocks.
- Explain how fossils and rocks are clues to environments of the past.

Source

Modified from OEAGLS EP-10, "Evidence of Ancient Seas in Ohio," by Susan Leach, Upper Arlington Public Schools, and Victor J. Mayer, The Ohio State University.

Also modified from "The Great Lakes environment during rock formation" by Dan Jax. In *Great Lakes in My World*. 1989. Lake Michigan Federation.

Earth Systems Understandings

This activity focuses on ESU 4 (interactions), 5 (change through time), and 7 (careers and hobbies). It also addresses 3 (science methods and technology) as students develop their identification skills.

Materials

- Small jar with sediment and water.
- Samples of rock, including shale, sandstone, limestone, dolostone, salt, gypsum, and coal.
- Binocular microscope with watch glass, tongs, and saturated salt solution.
- Pyrex watch glass.
- Salt solution.
- Heat source (candle, alcohol lamp, or Bunsen burner).

Overview

In this investigation, students study sedimentary rocks, many of which are found throughout the Great Lakes region. These rocks are then related to the geologic history of the region and to the types of environments that must have existed when they were formed. You might want to use this investigation as an introduction to a unit on your state's energy supply. There is a great deal of concern, for example, about full exploitation of natural gas in Ohio. Ohio's coal has a large amount of sulfur in it, which adds to pollution. Therefore, there is a problem in its use. The two methods now being used to reduce sulfur in coal are stack scrubbers and fluidized-bed boilers. Both use limestone to remove the sulfur.

Suggested Approach

The investigation can be used in either an individualized format with each student having access to the necessary laboratory materials, or in a group laboratory with pre-lab and post-lab discussions.

If used in an individualized format, each pair of students should have the set of rocks available, since these are the most heavily used materials. One or two jars with sediment, and four or five setups with microscopes and salt solutions should be available at stations placed around the classroom.

Answers to Questions

1. Students should note that the fragments of rock in the jar settle out according to size. The sand settles first in a layer on the bottom, and the clay settles last, forming a layer on top.

Procedure

Many of the rock types common to the Great Lakes basin are sedimentary in origin. One type is made of pieces (fragments) of rock that were broken or worn from larger chunks. Clay, sand, and gravel are examples of sediments that are fragments of rock. The fragments are then cemented together to form rocks such as shale and sandstone. These are called fragmental rocks.

Other types of sedimentary rocks form from plants and animals that died and fell to the bottom of lakes, swamps and oceans. Their hard parts are cemented into rocks such as limestone and dolostone. These types of rocks are called organic rocks. The soft parts of the plants or animals form coal, oil, and natural gas.

The third type of sedimentary rock forms from the evaporation of water. Minerals that are dissolved in the water precipitate to form rocks such as salt and gypsum. These are called chemical rocks.

In this activity you will learn how the three types of sedimentary rocks form.

1. Shake the jar filled with sediment and water. Allow the sediment to settle. Describe the sediment.

You should have seen that different sizes of sediments settled at different places. This happens to sediments carried by streams and rivers as they enter a lake or ocean. The large heavy pieces settle out first, close to shore. The smaller pieces are carried by slow currents out into deeper water.

At one time the Great Lakes basin was covered by an ancient sea. In the ancient sea, sediments of older rocks became suspended much like what was observed in the jar. Smaller sediments were carried further away from shore, while larger sediments settled along the coastline. Over time these once-suspended sediments settled to the bottom. Over many years they formed new rock layers, younger layers on top of older layers.

Shale is made up of clay, silt, and mud. Such very fine sediments are the last to settle out of streams and currents. Therefore, they will be carried out furthest in a lake or ocean. Sediments making up shale are so fine that they cannot be seen, even under a microscope. Shale is usually dark colored and made of very thin layers. The nature of shale makes it soft, and not as resistant to erosion as other rock types.

2. Pick out the sample of shale from your rock tray. Write down a description of the sample.

Sandstone is made up of pieces of sand. The pieces are large enough so that you are able to see them. If you have walked along a beach, you may recall seeing sand. It is usually found deposited along the edges of lakes and oceans.

3. Identify the sample of sandstone from your rock tray. Describe its characteristics.

Limestone and dolostone are formed of the chemicals calcium carbonate and magnesium carbonate. These chemicals are found in shells and skeletons of many animals and plants. The hard parts of these plants and animals accumulate at the bottom of the lake or sea as sediments. When this sediment is buried, it will change into rock.

Limestone and dolostone are hard. These types of rocks resist erosion better than other rocks like shale. When water erodes these types of rocks, hills form, such as around Lake Superior. Sometimes you can find fossils in these rocks. Often, however, the plant and animal remains have been so broken and ground up that pieces cannot be identified.

Any carbonate will react chemically with hydrochloric acid. This will cause a fizzing to occur.

4. a. Identify the samples of limestone and dolostone from your rock tray. Describe the two rocks.

Silurian rock containing dolomite was formed approximately 400 million years before present. This is resistant rock.

b. Find Silurian rock on Map 1, the Great Lakes geologic map. What features of the Great Lakes region does it form?

Later Silurian dolomite with Devonian limestone formed the belt of the islands in Lake Erie. In fact, Kelleys Island on Lake Erie shows a display of glaciated rock discovered by quarrying that is renowned throughout the world.

Salt and gypsum are produced from sea water when it evaporates. This can happen when a sea is cut off from the ocean, such as when reefs form. If the area is hot and dry, the water will evaporate, and deposits of salt and gypsum will be left. Salt can be identified by its taste. Gypsum is very soft. You can scratch it with your fingernail.

Teacher's Note

The description that students write of the types of rocks should be similar to those in the procedure, but in their own words.

Prerequisite Student Background

Students should have experience in identifying sedimentary rocks and the common minerals. They should be familiar with the geologic time scale. The state's geologic survey would be a resource for obtaining a set of specimens of rocks, or they can be purchased from Ward's Scientific, Rochester N.Y. Specimens should exhibit the characteristics described in the procedure.

Dolostone is a sedimentary rock composed mainly of the mineral dolomite. Dolomite, $CaMg(CO_3)_2$ is the double carbonate of magnesium and calcium. Limestone is made up of calcite, which is calcium carbonate, $CaCO_3$. Thus magnesium is one of the main elements that differs between the two rock types.

4. a. Note that no distinction is made in the activity between limestone and dolostone. You may wish to provide some dilute hydrochloric acid. A drop on limestone will fizz rapidly, whereas on dolostone it will fizz very slowly at first. If dolostone is scratched on the surface, it will fizz more rapidly. Dolostone is slightly harder than limestone; therefore, it effervesces less readily. This is the easiest way to distinguish one from the other.

b. Rocks of Silurian age form the islands between Lake Huron and Georgian Bay. They form Niagara Falls and the peninsulas in Lake Huron and Lake Michigan.

Chemistry Connection

Dolomite: $CaMg(CO_3)_2$
Calcite: $CaCO_3$
Gypsum: $CaSO_4 \cdot 2\,H_2O$
Salt: NaCl

Have students find each element in the compound on a periodic chart. If time permits, review the charges common to these elements that make them combine to form salts.

5. Try this out before you do it with your students. It may be that the tap water will have contaminants that would mask the precipitation and growth of salt crystals. If so, you may need to use distilled water.

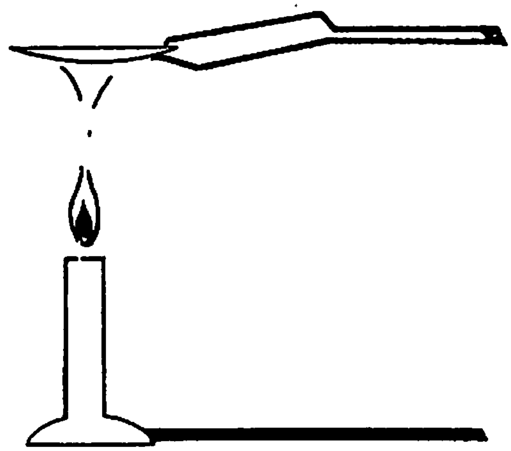
6. Warn the students not to touch the watch glass with their fingers after heating it. They must use a set of tongs to hold the watch glass over the flame and to insert it under the microscope. The salt crystals should appear to be perfect cubes. You may want to have some table salt for the students to look at under the microscope.

7. Their descriptions should be similar to those in the procedure section. Some uses are as follows: lime – concrete, gypsum – glass, salt – road salt, seasoning for food.

8. Coal is black and relatively light-weight (low density). Students may discover vegetative remains in their samples. You might want to discuss the types of coal. Most coal in the midwestern U.S. is <u>bituminous</u>. Other types are <u>lignite</u>, which is very low grade, and <u>anthracite</u>. Anthracite has undergone a certain amount of metamorphism and will be shiny black and quite hard.

When evaporation occurred, salts were deposited, such as lime, gypsum, and salt. These crystallized salts formed new layers.

5. Place a drop of salt solution in the glass. Then place it on the stage of the microscope and examine it. Describe what you see.



6. Using a pair of tongs, heat the watch glass until all the water has evaporated. After the glass has cooled, place it under the microscope. Describe what you see.

7. Identify the samples of salt and gypsum from your rock tray. Describe each sample. What are the salts that precipitated in the history of the Lakes used for today?

Geologists have not been able to actually see how coal, oil, and natural gas form. They believe, however, that these minerals form from partially decayed plant or animal bodies under high pressure and high temperature. <u>Coal</u> formed from plant matter that accumulated in large swamps. Often leaves and stems are found in coal. Coal is black and relatively light-weight.

8. Identify the sample of coal from the rock tray. Describe it.

<u>Oil</u> and <u>gas</u> are thought to form in mud deposited at the bottom of oceans and seas. Later, they move from the shales formed from these muds into sandstones and limestones, where they are held until found by a geologist or driller.

The sedimentary rocks and minerals found in the Great Lakes region were deposited in layers on top of older igneous and metamorphic rocks. Some of these layers were eroded. Some were tilted and broken. Some of the history of the region kept in those rocks was destroyed. What is left, however, tells geologists about the events that occurred here long before humans and even the dinosaurs lived.

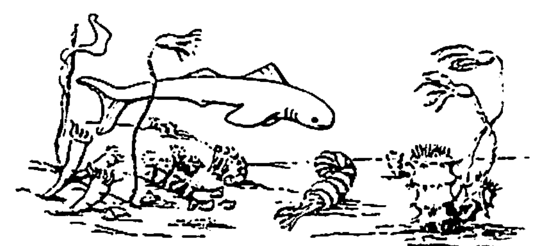
The Great Lakes geologic map shows the distribution of rocks in the Great Lakes Basin. The rocks marked "Precambrian" are igneous and metamorphic. They formed under the influence of great heat and at a time when there were only the simplest kinds of life on Earth, so they do not contain any useful fossils. It is very difficult to imagine what the environment was like during the Precambrian, because we have no clues.

The rocks themselves can give us clues to the environment in which they formed.

Table 1 shows the same sedimentary rocks as in Map 1, only arranged in horizontal layers. The approximate ages of the rocks are given along with the names of the associated time units.

The rocks themselves can give us clues to the environment in which they formed. Limestone and dolomite form in warm, shallow seas. Sandstone and conglomerate form in shallow water near coastlines. Shale forms in deep water that is fairly muddy.

Gypsum and salt form when a shallow part of the ocean is cut off and the water evaporates over a period of time.



Devonian Sea Bottom

Source: Suzanne Abbati, Ohio Sea Grant Program.

9. Using the information in Map 1 and in the paragraphs above, describe the environments that the rocks were deposited in and in which the fossil organisms lived (Complete Table 1).

Review Questions

Apply what you have learned to answer these questions:

1. Were the oceans that occupied this part of North America always the same? Explain.

2. As you look at the different types of fossils that existed over the years, how did the complexity of life change over time?

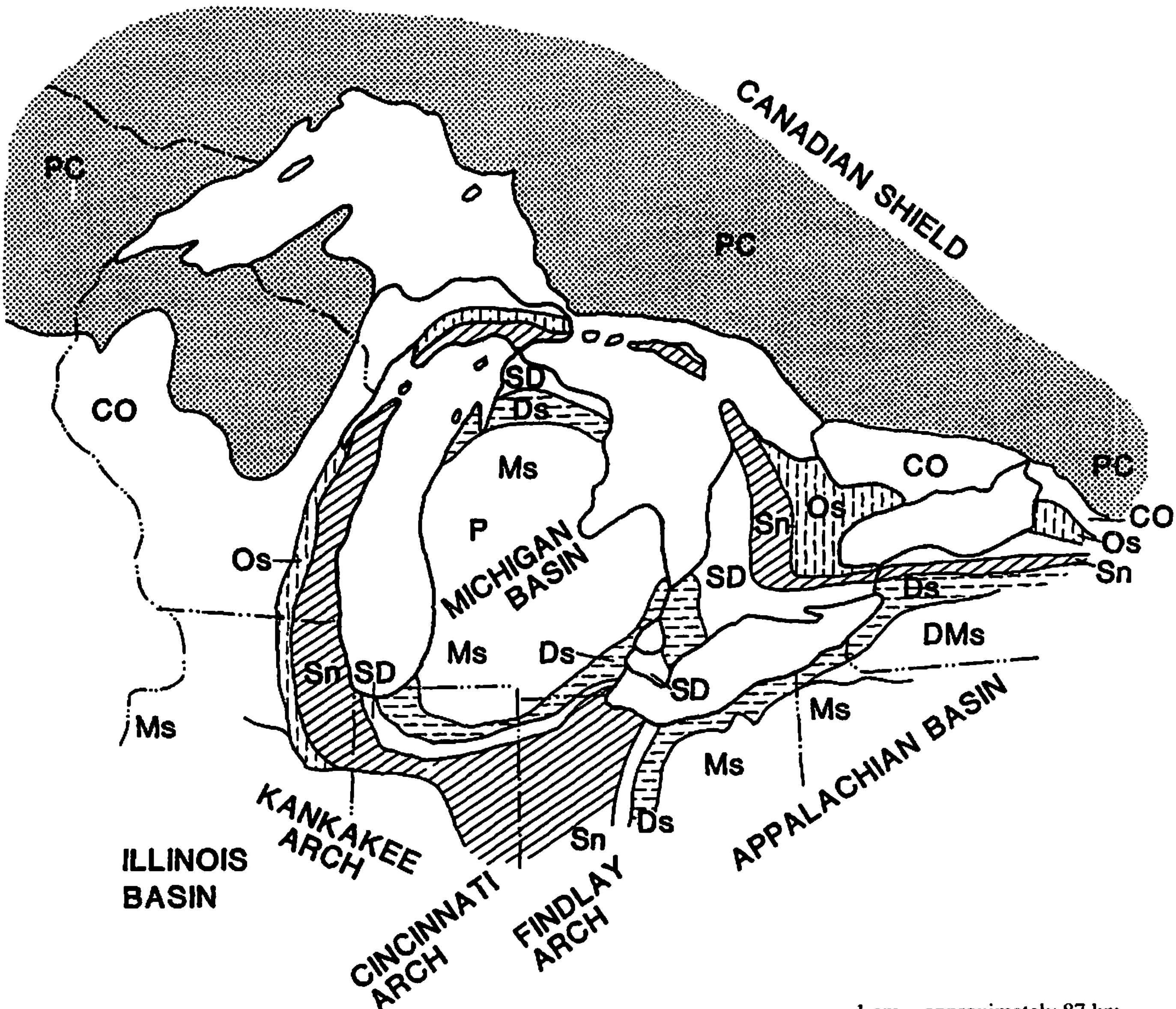
3. If there were an ocean in the Great Lakes Basin today, would the water always be warm? Explain.

4. Explain how rocks and fossils can be used to find out what ancient environments were like.

5. On which type of cliff or shoreline would you likely see the most rapid erosion: sandstone, limestone, or shale? Explain.

6. Which of the samples do you think was closest to the type of sediments that eroded to form the Great Lakes basins? Support your answer.

Map 1. Great Lakes Geologic Map – Distribution of Rocks in the Great Lakes Basin.



1 cm = approximately 87 km

Source: Adapted from "Geologic formations of the Great Lakes basin." Forsyth, Jane L. 1993. *The Great Lake Erie*,with an addition from *The Great Lakes Atlas*, Government of Canada and the U.S. Environmental Protection Agency. 1995.

Key:
- Ms – Mississippian, P – Pennsylvanian
- D – Devonian, Ds – Devonian Shale
- S – Silurian, Sn – Silurian niagaran series
- SD – Areas of Silurian and Devonian rock layers
- O – Ordovician, Os – Ordovician Shale
- C – Cambrian, CO – Areas of Cambrian and Ordovician
- PC – Precambrian

Figure 1. Fossils and the Environments in which the Organisms Lived.

Symbol	Organism	Environment in which it lived
	Brachiopod	Shallow, clean water
	Corals	Shallow, clean water
	Clams (Pelecypods)	Shallow, clear to muddy water. Reef builders.
	Trilobites	Shallow to deep water
	Fish	Open water
	Amphibians	Land animals in wet environments

Table 1. Rocks and Corresponding Ages.

Rocks and fossils	Time unit	Environmental description
	225 mya	
Conglomerate	Permian	
	280 mya	
Coal Sandstone Limestone	Pennsylvanian	
	320 mya	
Sandstone Shales	Mississippian	
	345 mya	
Shale Limestone Shale	Devonian	
	400 mya	
Gypsum Salt Dolomite Sandstone	Silurian	
	440 mya	
Limestone Shale	Ordovician	
	500 mya	
Limestone Dolomite	Cambrian	
	600 mya	

EXTENSIONS

What is a paleontologist? How is a paleontologist different from a geologist? How do these careers relate to each other?

Examine your sample of coal again. Why do you think this is used as a fuel? Do research on the nature of coal to support your answer. What are the environmental issues surrounding the use of coal as an energy source?

Answers to Questions

1. The rock layers were affected by land changing forces beneath the Earth as well the action of ancient seas and glaciers on the surface. Students can develop these ideas to include why different rocks were formed during changing environments and why the properties of the rock layers vary based on their origins.

2. This is an interesting question because Precambrian rock actually occurs beneath the entire basin but is exposed around Lake Superior and covered by younger rock layers in other regions of the area.

3. Glaciers were thicker and heavier to the North and thinner to the south, which explains in part the depths of the Lakes. Also, the bedrock is different under each Lake.

DEBRIEFING QUESTIONS

Have groups reassemble to discuss the following:

1. How did the rock layers of the Great Lakes basin form?

2. Where is the oldest rock found?

3. From what you have learned so far, what were some of the reasons for the Lakes' different shapes and sizes?

Write a summary to share with the class.

REFERENCES

Montgomery, Carla W. 1992. *Environmental Geology*. 2nd ed. Dubuque, IA: Wm. C. Brown Publishers. 465 pp.

Historical Geology or Earth Science – any introductory text.

How did rocks and rivers shape the Great Lakes?

The rocks in the Great Lakes Basin are of two main types: metamorphic/igneous and sedimentary. The metamorphic/igneous rocks formed long ago, when molten rock hardened and the heat changed other rocks nearby without melting them. This happened over one billion years ago.

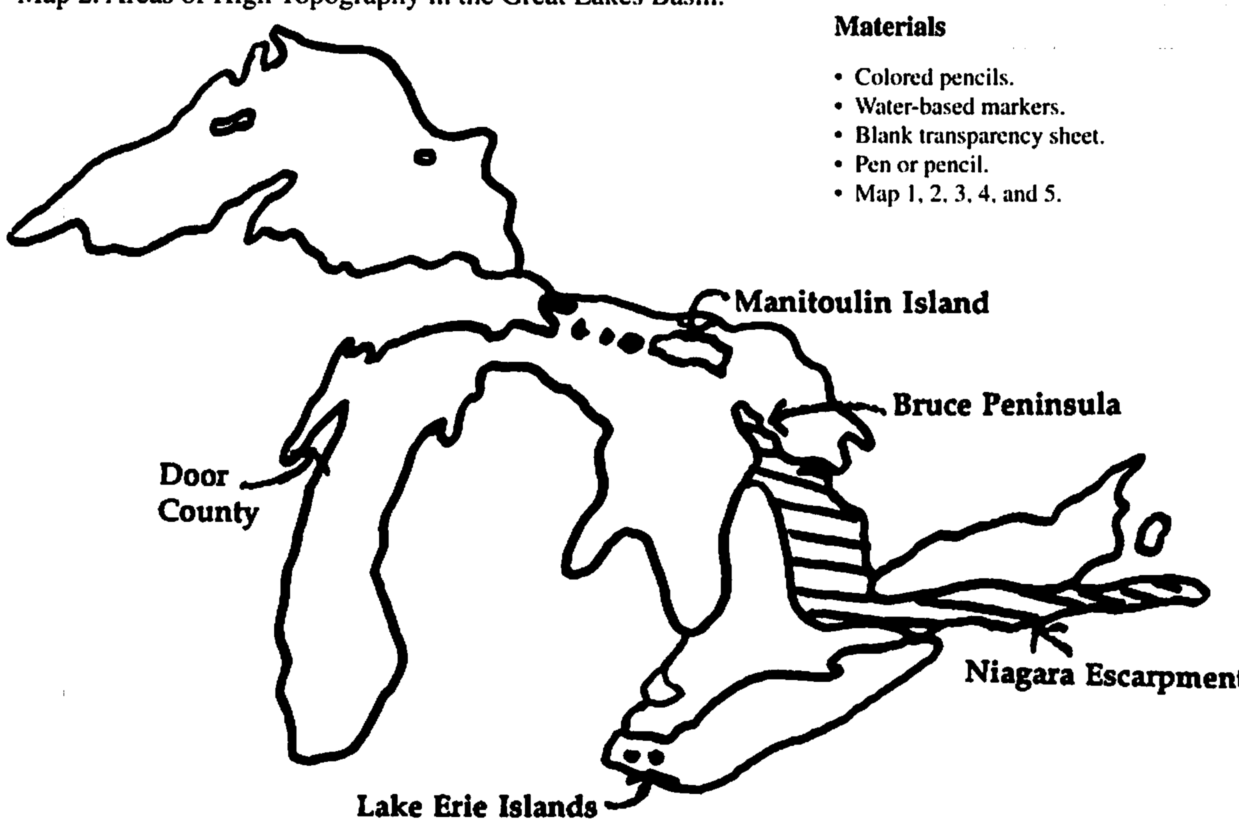
The sedimentary rocks in the Great Lakes Basin formed in an ocean that covered most of the basin beginning about 600 million years ago. Different types of rocks formed as the depth and shape of the ocean changed over a long period of time. The ocean disappeared from the area about 225 million years ago. In this ocean, many different types of sedimentary rocks formed in a wide variety of environments. Shales formed in deep water, sandstone along coastlines, and limestone and dolomite in warm shallow seas.

OBJECTIVES

After completing this activity, each student will be able to:

- Relate the hardness of rocks to topography and lake depth.
- Describe the topography of the Great Lakes area.
- Relate the pre-glacial drainage system to the present size and position of the Great Lakes.

Map 2. Areas of High Topography in the Great Lakes Basin.



Sources

Modified from "Topography of the Great Lakes," "Formation of the Great Lakes," and "The Erosion of Niagara Falls" by Dan Jax. In *Great Lakes in My World*. 1989. Lake Michigan Federation.

Earth Systems Understandings

This activity addresses ESU 1 (aesthetics and value), 4 (interactions), and 5 (change through time).

Materials

- Colored pencils.
- Water-based markers.
- Blank transparency sheet.
- Pen or pencil.
- Map 1, 2, 3, 4, and 5.

In the Great Lakes Basin, some of the hardest sedimentary rocks, called dolomite, formed at a time about 350 million years ago called the Silurian.

Question

What tourist attraction is found in the Silurian rock area? (Niagara Falls)

Answer to Procedure

1. It is Silurian rock, which is resistant to erosion and more resistant than the surrounding rock layers.
2. These islands are made of rock that resisted erosive processes while the rocks around them eroded away.
3. The peninsulas are made of Silurian rocks, which have withstood erosion from the action of the Lakes.
4. The rivers flowed the same way that the water flows through the lakes today.
5. Huron: Huronian River
Michigan: Laurentian River
Erie: Erigan River

Procedure

Different types of rocks resist erosion to different degrees. Hard rocks will erode slower (less) than softer rocks. In the Great Lakes Basin, some of the hardest sedimentary rocks, called dolomite, formed at a time about 350 million years ago called the Silurian.

Refer to Map 1 of the activity "How were sedimentary rocks in the Great Lakes basin formed?" This shows the distribution of rocks in the Great Lakes Basin. Use a blank transparency and water-based markers and trace the area of the Silurian age rocks from Map 1. Also use dotted lines to outline Lake Superior and Lake Ontario.

Map 2 included with this activity shows the areas that are generally higher in elevation than the areas right around them. Overlay your transparency on Map 2. Make sure the outlines of Lake Superior and Lake Ontario match.

An escarpment is a place where the slope of the land is very steep. In many cases it can be best described as a cliff.

1. Why does the Niagara Escarpment rise higher than the surrounding area?
2. Explain why the Manitoulin Islands in Lake Huron and the Lake Erie islands are islands.
3. Explain why the Bruce Peninsula in Ontario and Door County in Wisconsin "stick out" into their respective lakes.

Before the Great Lakes formed, the Great Lakes basin was occupied by a river with many tributaries (branches). The accompanying map shows what it may have been like.

4. How are the directions that the rivers flowed related to the shapes of the Great Lakes?
5. Which ancient rivers preceded the following:
   Lake Huron?
   Lake Michigan?
   Lake Erie?

The name "Laurentian" comes from the name for all of eastern Canada. It comes from the St. Lawrence River that drains the Great Lakes.

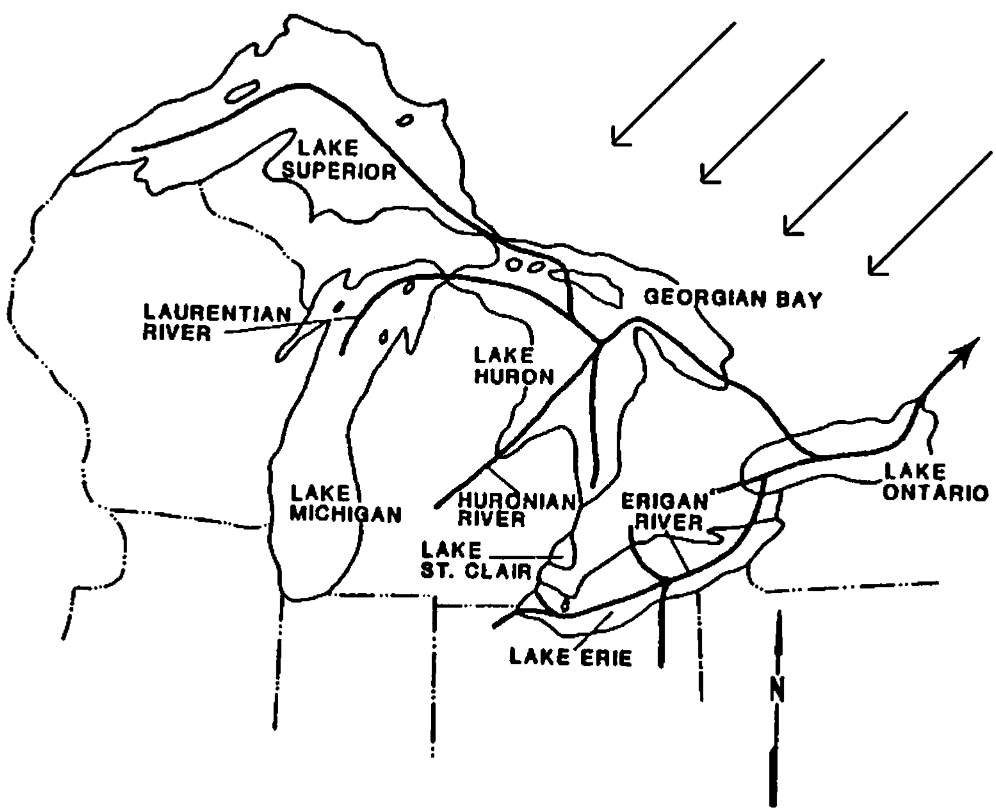
The large arrows at the top of Map 3 indicate the direction in which glaciers moved from near the present day Hudson Bay area. As the glacier moved through the area, it deepened and widened the river valleys. As the glacier retreated and melted, these low areas filled with water and became the Great Lakes.

Table1. Maximum Depths of the Great Lakes.

LAKE	MAXIMUM DEPTH
Huron	245 M (804 ft.)
Ontario	230 M (752 ft.)
Michigan	280 M (925 ft.)
Erie	63 M (211 ft.)
Superior	400 M (1333 ft.)

Using colored pencils and the information in Table 1, on Map 3, color in the lake with the greatest depth. Use a different color to shade in the shallowest lake. Label these two lakes the deepest and shallowest, respectively. Use a third color to shade in the other three lakes. They are all about the same depth.

Map 3. Preglacial River System in the Great Lakes Region.



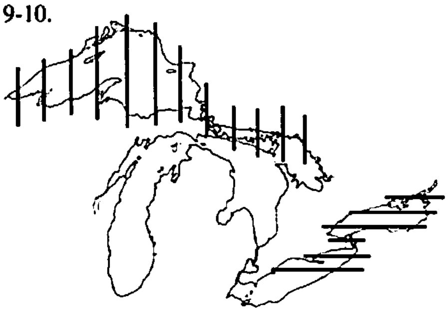
Source: Forsyth J. In *The Great Lake Erie*, 1993.

Answers

7. Lake Superior is the deepest and the northern-most lake.

8. Lake Erie is the shallowest and southernmost lake.

9-10.



11. It is the shallowest of the lakes because the glacier was thinner in the southern part near present day Lake Erie.

12. The softest rock is found in the eastern basin. This would most likely be the deepest part.

13. You might guess that Lake Erie was the deepest because it has the softest rock, but the glacier was also thinner in this region.

14. The glacier was thickest in the north. This allowed Lake Superior to be the deepest because ice weighed the land down more.

Technology Note

For Question 12, see the Great Lakes Forecasting System at http://superior.eng.ohio-state.edu/ for an image of water surface elevation of Lake Erie.

7. Is the deepest lake north or south of the other lakes ?

8. Is the shallowest lake north or south of the other lakes?

There are two main things that contributed to how deeply the lake basins were eroded by the glacier. One of these is the hardness of the rocks under the lakes. The hardest rocks are under Lake Superior and the northern half of Lake Huron.

9. Use your pencil or pen and draw vertical lines on Map 1 where the rocks are the hardest.

The softest rocks are under Lake Ontario and the eastern one-third of Lake Erie.

10. Draw in horizontal lines on Map 1 where the rocks are the softest.

The other thing that contributed to the depth of the lake basins was the thickness of the glacier. In general, the thicker the glacier, the more it erodes. The glacier was thicker nearer its source (Hudson Bay to the north) and was thinner toward its edge to the south. Use Map 1 and the above explanation to answer these questions.

11. Why is Lake Erie the shallowest of the Great Lakes?

12. What part of Lake Erie would you expect to be the deepest? Why?

13. If you thought that the hardness of the rock under each lake basin was the only factor that controlled the depth of the basin, which lake would you choose to be the deepest? This lake is not the deepest. Why not?

14. Lake Superior has some of the hardest rock in the region underneath it. Why is it the deepest?

Review Questions

1. How is the composition of a rock related to how quickly it will erode?

2. Identify four places in the Great Lakes area where the rocks are hard and so they rise above the rocks around them.

EXTENSIONS

Do you think there is a connection between geologic rock layers and other resources in a specific region? Observe maps 4 and 5 and answer the following questions.

1. Map 4 shows a representation of sources of iron ore and coal. Note their locations. From what you have learned about the rock types in the Great Lakes region, why do you think iron ore is plentiful here and not in other areas of the basin? Note on Map 5 which areas import and export iron ore. What area seems to be most dependent on iron ore imports?

2. Which areas export coal? Where is a large coal region located relative to the Great Lakes (Map 4)? Why might the coal be located here?

3. Use Map 5 to answer the following questions: What areas along the Great Lakes export grain? Where is the highest density of exports? Consider the rock layers you have studied. What kinds of rock layers predominate in this area? Why would grain grow better here than in other areas?

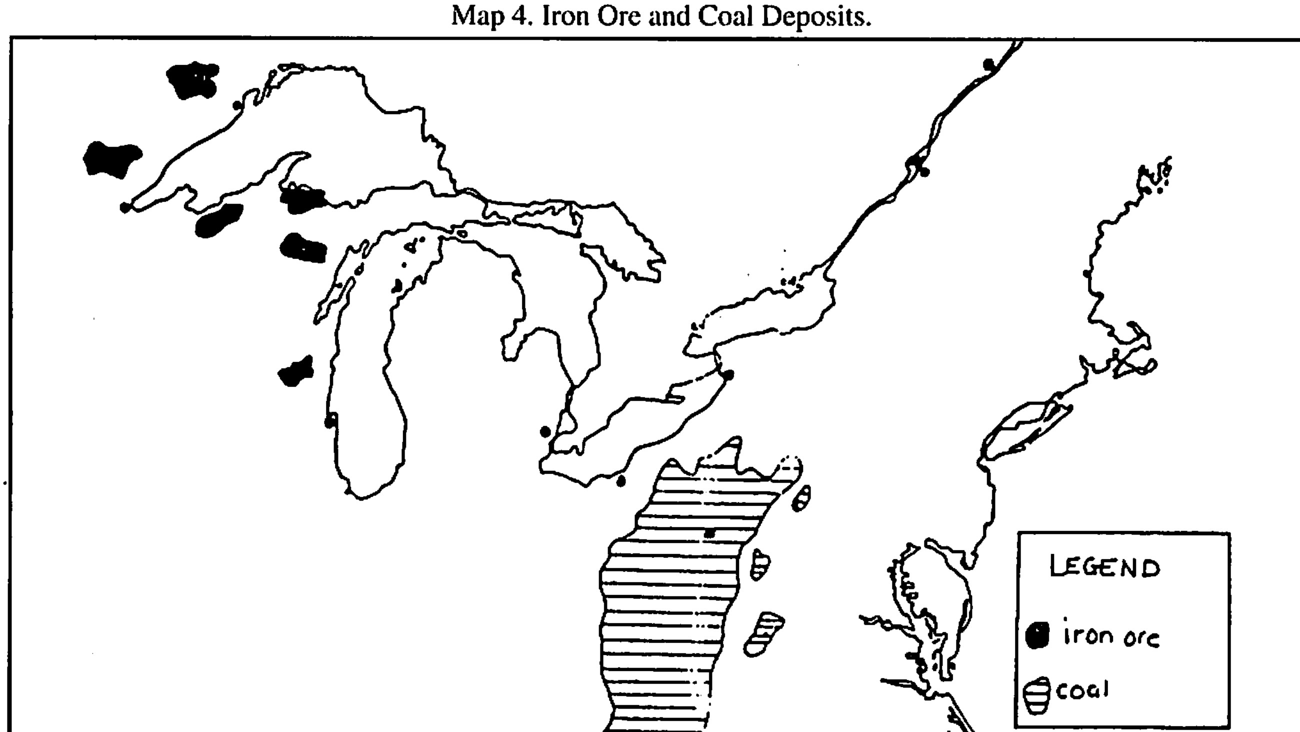
Ideas for Extension Activities

1. Students should recognize that this is an area of Pre-Cambrian rock. Iron ores are often associated with igneous rocks from which they can be commerically extracted. In sedimentary rocks, iron ores may exist but are not accessible. The Lake Erie basin displays several areas relying on imports. For more activities related to economic geology, use the shipping module.

2. Coals are associated with former swamps. The previous activity notes Pennsylvanian rock as being known for coal. It is found south of Lake Erie and in central Michigan.

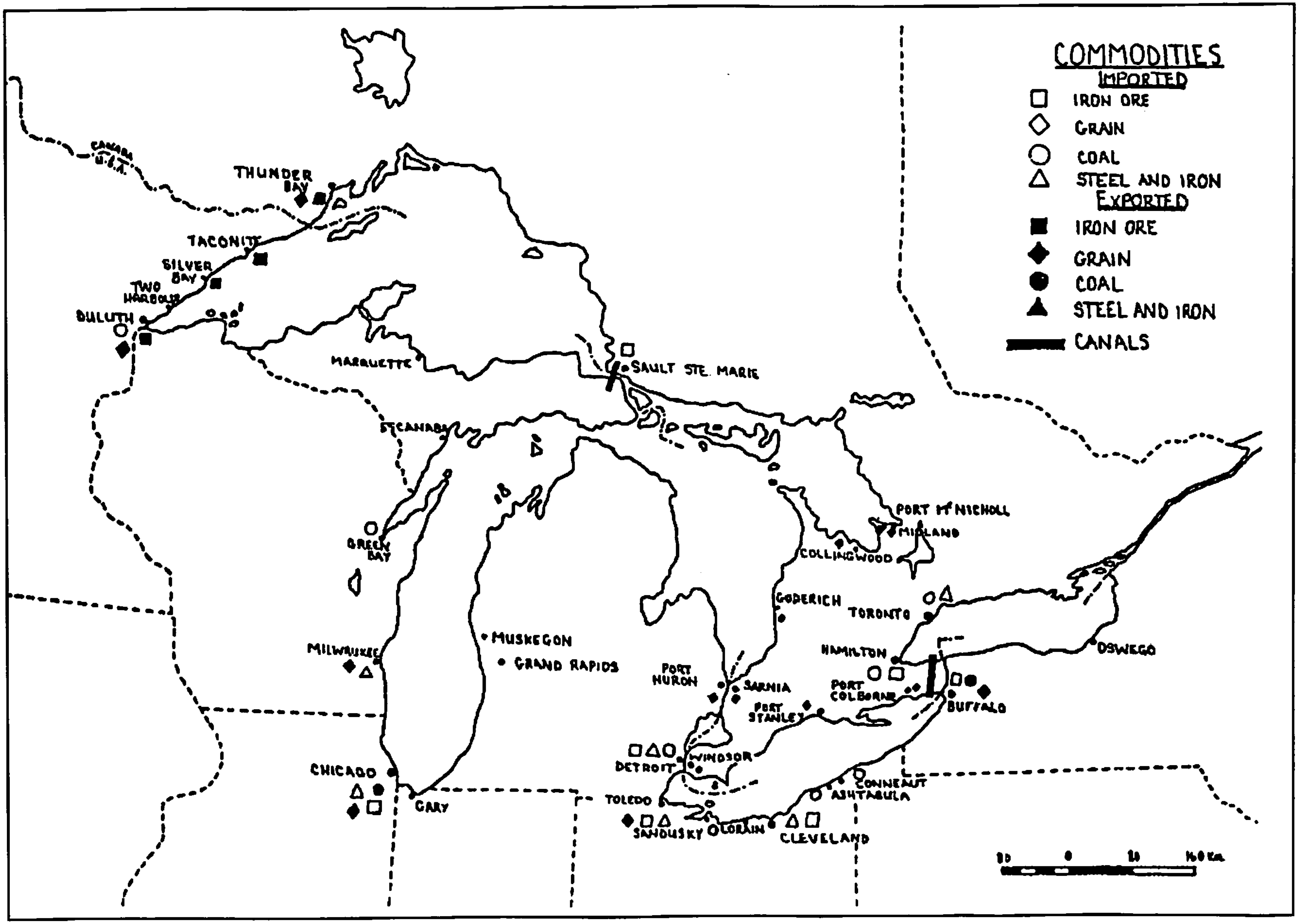
3. In shales, the basins of the Great Lakes formed. Also in shales lowlands are created that are more suited to grain production than are hilly areas where rock layers tend to be harder. The land shared by Lakes Erie, Huron, and Ontario has Devonian and Ordovician rock, which is known for shales. It is also an area with hard rock such as that forming the Niagara Escarpment.

Map 4. Iron Ore and Coal Deposits.



Source: *Discover the Five. A Great Lakes Investigation*, by Brent Dysart, Lynn McGuire and others. Waterloo County Separate School Board, Ontario.

Map 5. Major Commodities Shipped in the Great Lakes.



Source: *Discover the Five. A Great Lakes Investigation*, by Brent Dysart, Lynn McGuire and others. Waterloo County Separate School Board, Ontario.

APPLY WHAT YOU HAVE LEARNED: THE EROSION OF NIAGARA FALLS

The "Falls of the Niagara River" (Niagara Falls) formed when the glacier melted away from the Niagara Escarpment about 12,000 years ago. The water flowing in the Niagara River ran over the escarpment and formed the "Falls." Over the last 12,000 years the falls have not stayed in the same place. They have eroded upriver to their present position. Figure 1 is a cross-section (side view) and a top view of Niagara Falls and the rocks that are found there.

1. When the water flows over the falls and hits the bottom, which rocks will be eroded more, the hard ones or the soft ones?

2. Draw a cross-section to show what will happen to the cliff as the softer rock gets eroded faster than the harder rock.

3. As this continues, what will eventually happen to the harder rock on top?

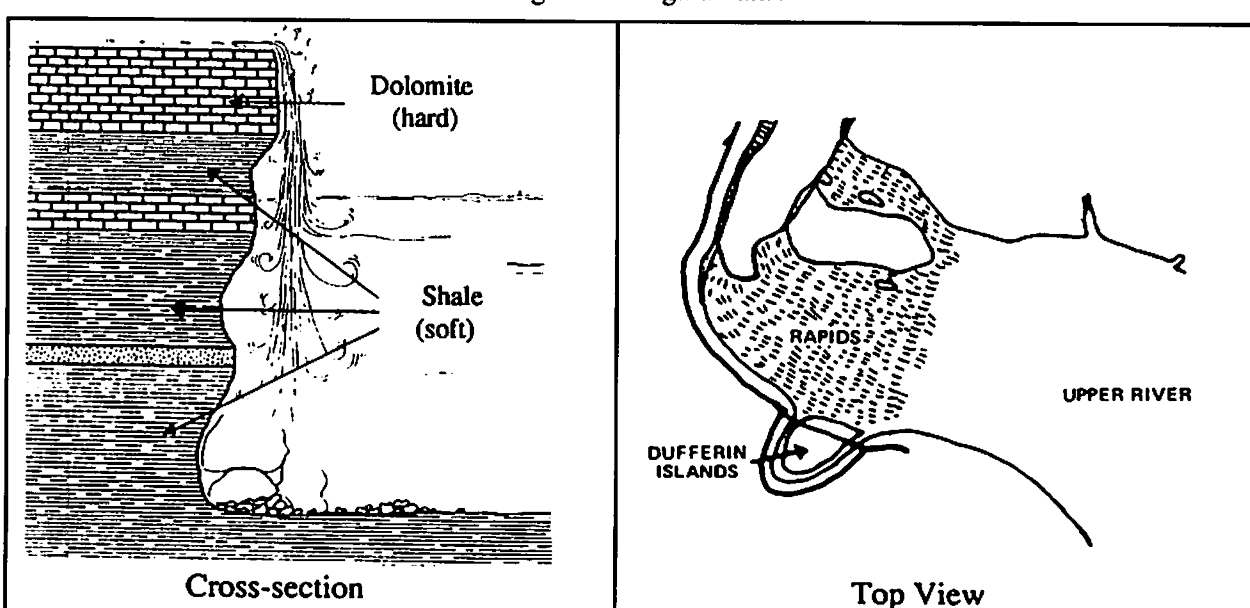
4. Over time, how will the position of the falls change?

5. The falls have moved about 11,250 m in 12,000 years. What is the average rate of movement per year?

Answers

5. The falls have moved an average of 0.94 meters/year.

Figure 1. Niagara Falls.



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Forsyth, Jane L., 1993. The Geological Setting of the Great Lakes, In *The Great Lake Erie. A Reference Text for Educators and Communicators*, Rosanne W. Fortner and Victor J. Mayer, Eds., Columbus: Ohio Sea Grant.

The Great Lakes Atlas. An Environmental Atlas and Resource Book. 1995. Jointly produced by Government of Canada and U.S. Environmental Protection Agency, 3rd ed.

What evidence of glaciation exists in the Great Lakes region?

Have you ever seen Lake Erie? Have you seen pictures of it? Maps? Does it change? Do you think the Great Lake nearest you has changed over time?

You may have seen or heard of waves on the lake destroying houses along the shore. These are certainly changes that can be seen. But does the lake change in size? Was it once bigger than it is today? Or has it moved? Although the lake may seem to be a permanent feature, it is not. All lakes are temporary. They exist for a few thousand years and then disappear. Will this happen to Lake Erie? To your Great Lake?

The Great Lakes Basin was once covered by the ice of continental glaciers. About 15,000 years ago the last ice melted to expose the lake basin. There have been minor advances and retreats of glaciers since then causing the level of the water in the lakes to rise and fall. How do scientists determine these past lake levels?

Objectives

When you have completed this activity you will be able to:

- Identify the evidence of ancient beach ridges.
- Become aware of the uses of ancient beach ridges today.

Source

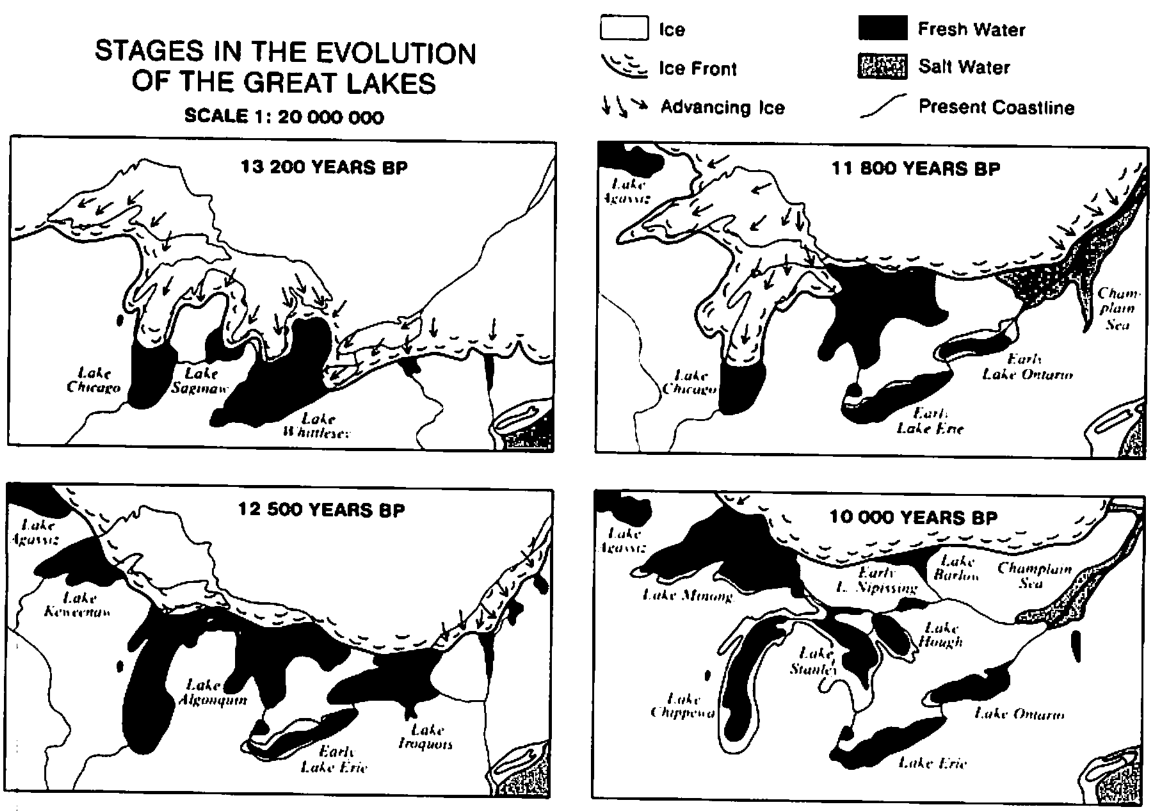
Modified from OEAGLS EP-3," Ancient Lake Shores" by James D. Comienski, Lakewood Public Schools, Ohio, and Victor J. Mayer, The Ohio State University.

Earth Systems Understandings

This activity examines evidence found in land features of past land and water interactions (ESU 4 and 5).

STAGES IN THE EVOLUTION OF THE GREAT LAKES

SCALE 1: 20 000 000



Teacher's Notes

Overview: In this investigation, students work with topographic maps and profiles to identify beach ridges in northern Ohio. They learn how to determine the ages of the ridges and how they were formed.

The questions are designed to lead the students to closely examine an area near Lake Erie to identify evidence of former Lake levels. They can apply this activity to their own area within the Great Lakes. Students can obtain maps from state divisions of geological survey.

Prerequisite Student Background: Students should be able to read a topographic map and construct a profile. They should also be somewhat familiar with the glacial history of the Great Lakes Region.

Note: Information to teachers is enclosed along the side so that teachers can cover this portion of the activity if photocopies are needed for classroom use.

Materials

- Topographic map – the Madison, Ohio quadrangle.
- Road map of Ohio
- Graph paper.
- Metric ruler.

One copy of each of the following should be posted in the classroom: An Ohio road map, copy of the map from the publication: The Beach Ridges of Northern Ohio (included within this activity on teacher pages).

Other USGS shoreline quadrangles can be obtained so that students can see more examples of ridges.

PART A

What evidence is there that the level of Lake Erie has changed?

OBJECTIVES

When you have completed this activity you will be able to:

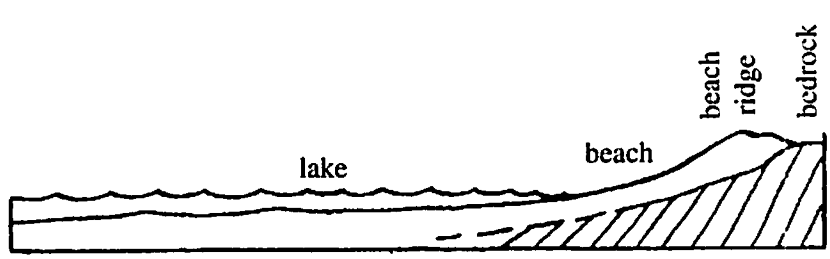
- Describe the evidence of past water levels of Lake Erie and other Great Lakes.
- Use topographic maps and topographic profiles to locate evidence of past water levels.
- Describe the processes by which ancient lakes changed size over time.

PROCEDURE

Most lakes are contained in basins and have flat, gently sloping floors. Wind causes waves, which in turn produce currents that act along the shores of lakes. These currents carry and deposit sand and form beaches. Perhaps you can remember swimming from a beach. If so, you know what the sand looks like and how it feels.

Figure 1 is a cross section (a side view) of a beach. Notice the flat floor of the lake, the gently sloping beach area itself, and a ridge at the top of the beach. This **beach ridge** is formed of sand thrown up by the action of waves.

Figure 1. Cross Section of a Beach.



Worksheet Questions

1. What is the contour interval of the map of the Madison area?

2. Examine the lower left portion of the topographic map. Compare the area immediately north of (above) the Penn Central Railroad with the area south (below) to the map's lower edge. How does the spacing of the contour lines in these areas differ?

3. What does the difference in the spacing of contour lines mean about the difference in topography in the two areas?

4. What evidence is there on the map that the lake once extended through the area north of the Penn Central Railroad?

5. Using graph paper, construct a topographic profile across North Ridge, Middle Ridge, and South Ridge. Start the northern end of your profile where Red Bird Road T-intersects with Chapel Road. The southern end should then be where South Bates Road intersects Interstate 90.

6. What difference between the three ridges does the profile reveal?

7. What do you think caused each of the three ridges?

Vertical Exaggeration
Vertical exaggeration is determined for the scales to which the profile is drawn. Graph 1 is a reduced image of a topographic profile originally drawn to a vertical scale of 1 inch = 50 feet and a horizontal scale of 1 inch = 2000 feet. The horizontal line would have to be extended 40 times or the vertical line compressed 40 times to make the scales the same. Therefore, we say the vertical exaggeration is 40:1 or 40x. To redraw the profile using a scale of 10:1, your vertical scale would have to be 1 inch = 200 feet. A profile with this scale will be harder for the students to graph but will give a more realistic look at the slope of the land.

A profile with vertical exaggeration of 10x is included as Graph 2.

Answers

1. 10 feet contour. This is located under the scale of the map.

2. North of (above) the Penn Central Railroad, the contour lines are farther apart than south of (below) the Penn Central Railroad.

3. Where contour lines are closer together, the area has more relief, or is "hillier." Where contour lines are farther apart, the slopes are gentle or nearly flat. Therefore, there is a change in topography between the two areas.

4. The area north of the Penn Central Railroad is flat, similar to the lake bottom in Figure 1. In addition, there are areas of swamps. There is evidence that the lake may once have extended over this area.

5. Be certain students use graph paper for the profile, and that they accurately record each contour line. You will need to provide additional copies of graph paper, because the profile will be about 34 cm long. If the profile is not done very carefully, the ridges may not be apparent on the profile.

6. The profile shows that the three ridges occur at different elevations.

7. Each one of these ridges is a beach ridge. They mark the previous beaches or boundaries of Lake Erie. They are built up by wave action as described in the explanation accompanying Figure 1.

Teacher's Note

A completed profile is included in Graph 1 with a vertical exaggeration of 40:1. This scale makes identification of the ridges easier, but greatly exaggerates the vertical, making the gently sloping "old lake" floor appear hilly. Here would be an excellent opportunity to discuss vertical exaggeration in more detail. Have your students redraw the profile using a vertical exaggeration of 10:1 and discuss the importance of considering scale when examining data.

8. Middle Ridge is not as prominent as the North or South Ridge. The lake's edge may not have been there long enough to build up a higher beach ridge. Middle Ridge may have been smoothed out by flooding during an increase in lake level.

9. North Ridge = 675 feet
   Middle Ridge = 695 feet
   South Ridge = 725 feet

10. North Ridge = Lake Warren
    Middle Ridge = Arkona
    South Ridge = Lake Whittlesey

11. There are 8 stages.

12. The oldest stage is 13,500 years before present.

13. Elevation indicates the lake stage.

14. Here the answers may vary because we are asking the students to "think." The actual cause was the retreat and readvance of glacial ice, opening up new lake drainage outlets and closing older ones (as described in "Background Information").

8. One of the ridges is not as prominent as the other two. What could be the reason for this difference?

9. Determine an "average" elevation for each of the three ridges.

10. Compare the elevations of the three ridges to the data in Table 1. What historical lake stage does each of the ridges represent? Label them on the profile.

A **stage** of the lake was a time when the lake level remained the same long enough to build a beach and a beach ridge.

11. How many stages has Lake Erie had? Refer to Table 1.

12. How old is the oldest stage?

13. What evidence do geologists use to tell what stage a ridge belongs to?

14. From what you have learned so far in the set of land/water interaction activities, what do you think could have caused the different stages of Lake Erie?

Could the hills you walk around near the lake that is closest to your home possibly be old beach ridges?

Table 1. Age and Elevation of Beach Ridges around Historic Stages of Present Lake Erie.

Years Before Present	Lake Stage	Elevation of Beach Ridge in feet
0	Erie	573
	Lundy (3 ridges)	620-640
12,700	Warren	690
	Wayne	660
12,800	Whittlesey	735
13,000	Arkona	690-710
	Maumee III	780
13,500	Maumee II	760

Glacial ice caused the variation in the levels of Lake Erie. As the glaciers retreated, they uncovered different outlets for the lake. These outlets were at successively lower elevations. When a new one was uncovered, the lake dropped fairly suddenly to a new level. Occasionally a glacier may have readvanced over an outlet, blocking it. In this case, the lake level rose once again, and the beach ridge was eroded by the higher lake. This may be the reason that Middle Ridge is so much lower than North and South Ridge.

REVIEW QUESTIONS

1. What evidence is there that indicates that Lake Erie has been larger than it is today? How do these features form?

2. What caused the level of water in Lake Erie to change?

EXTENSIONS

1. Do research on the career of limnologist. How would a limnologist apply the concepts of this activity? What training is required for such a career?

2. Would it be possible to find fossils from different years in the beach ridges? Would the fossils be different enough to indicate stages, or are the years in Table 1 relatively close from the perspective of geologic time?

3. Determine how much glacial evidence exists in your state. What topographic features might have been formed by glacial action? How are the state's soils, lakes, and other resources related to the action of ancient glaciers? Share your findings with the class.

Answers

1. Two ways are the following: a large, relatively flat area with several swamps and poor drainage, and ridges of sand and gravel (beach material) roughly paralleling the present shoreline. These ridges formed by wave action along the lake shore.

2. The level of water in Lake Erie fluctuated as the lake's outlet was changed by the retreats and readvances of glacial ice.

Background Information

Beach ridges are formed by storm waves, similar to the berms along the ocean beaches. An excellent source of background reading concerning their formation is *Waves and Beaches* by Willard Bascom; see the chapter on beaches. Each ridge represents an ancient beach formed along the shore of Lake Erie at a time in the past when the elevation of the lake was much higher than it is today. These higher lake levels were caused by the glacier damming the lake's outlet. As the ice front retreated, a series of newer and lower outlets were exposed, so the lake level lowered, changing the outlines of the lake and thus the beach patterns. Several times the ice readvanced, causing the lake level to rise and submerge the beach ridges made during a previous stage. The higher water would then scatter the materials making up the beach ridges and smooth them.

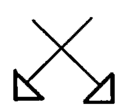
Materials

- Topographic map of the Madison, Ohio, area.
- Road map of Ohio.
- Map from *The Beach Ridges of Northern Ohio.*

Teacher's Notes

This activity leads the students to discover how people have made use of beach ridges. Evidences of changes in sea level are also discussed.

Answers to Procedure

1. North and South Ridges have a highway along their entire length. Middle Ridge also has a highway along most of its length.
2. The beach ridges were used as highways for a variety of reasons. The bedrock surface on each side of the ridges is covered by glacial till. These areas are generally swampy, due to low relief and poor drainage. Therefore, the buffalo in Ohio's early history chose the drier, better drained beach ridges for their trails. The Indians, hunting the buffalo, naturally followed the same trails. When the settlers moved into and across the state, they also followed these "established routes," as did the modern highway builders.
3. A sand pit, as indicated by 
4. There are two sandpits and a quarry along Middle Ridge and one gravel pit on South Ridge.
5. People are quarrying sand and gravel from the beach ridges for use in concrete for construction.
6. Middle Ridge cemetery is located here.
7. There is one cemetery on each of the North and South ridges and two cemeteries on Middle Ridge.

PART B

How have people used beach ridges?

OBJECTIVES

When you have completed this activity, you should be able to:

- Describe how people have made use of the beach ridges associated with Lake Erie.
- Describe some evidence of past changes in the water level of the oceans.

PROCEDURE

The beach ridges have been very useful to the inhabitants of northern Ohio. What are some of these uses?

1. Examine the three beach ridges on the Madison map. What human-constructed feature do they have in common?
2. Why do you think the beach ridges have been used for this purpose?
3. What type of human-constructed feature is located just southeast of North Perry and north of US Highway 20?
4. How many features similar to this do you find on Middle Ridge? On South Ridge?
5. What use of the ridges is implied by these features?
6. What type of human-constructed feature is located at 41°47'30"N, 81°02'30"W (just west of the pond)?
7. How many other features of this type can you find on the three ridges?
8. How many do you find that are NOT located on one of the three ridges?
9. Why do people prefer to locate these features on beach ridges?

10. Ask your teacher for a different map. How many beach ridges can you identify on this new map? (Try to obtain one perhaps from Lake Erie and one from another of the Great Lakes.)

11. What stages do they represent?

12. Which of the human-constructed features you identified in Steps 1 to 8 are found on the ridges on this map?

These beach ridges extend throughout northern Ohio. They indicate the location of the shoreline of the lake and the amount of area occupied by the lake at each of its stages. Your teacher will have a map of northern Ohio posted on the bulletin board. This map locates each of the beach ridges.

13. In an earlier part of this activity you learned that the people living in this area built many of their roads along the beach ridges. Using your road map and the map on the bulletin board, identify the major highways that have been built on beach ridges. Mark each of them on your road map. Label them with the name of the stage of the beach ridge.

14. List on your work sheet all of the uses people have made of beach ridges in the areas you have studied.

Answers

8. There are three cemeteries on this quadrangle that are not located on the ridges; two of these are on the glacial till forming the lake floor. The other one is in the hills to the south.

9. People tend to locate cemeteries in high areas where drainage is good and flooding is minimal.

10. Answers for this and subsequent questions will vary, depending upon which quadrangle the students have available. Possible quadrangles to use from Lake Erie are: Geneva, Perry, Mentor, and Eastlake, OH.

13. See the beach ridge background page.

14. Answers will vary but should include roads, cemeteries, and pits for obtaining construction material.

Teacher's Notes

Marine terraces are evidences of a higher sea level because they are formed by wave action. An example would be Palos Verdes Hills, California (photograph pg. 209; *Investigating the Earth*, 4th edition, 1987).

Perhaps you could discuss other evidences of sea level changes such as fossil ripple marks, seamounts, and fossilized sea life found in sedimentary rocks on land.

You have learned in this investigation that the movement of glaciers caused changes in the level of Lake Erie and that the beach ridges provide evidence of such changes in lake level. The oceans have also had different levels of water. Figure 2 illustrates some of the evidence of higher sea level (marine terraces) and lower sea level (wave-cut cliff).

Glaciation is also one of the causes of recent variations in sea level. As the glaciers have melted, the water returned to the sea, raising its level. Water locked up in the glacial ice has come from precipitation collected over the oceans. The removal of this water lowered the sea level greatly. If the present-day glaciers should melt, sea level would probably rise from 40 to 50 meters.

When sea level is lowered, the size of the continental shelf decreases, thereby decreasing the habitat of shelf-living organisms. Shorelines become broad, relatively flat areas. Land plants and animals can extend their ranges outwards. The climate of local areas may be affected by the change in its proximity to a large body of water.

Many scientists believe that increased amounts of greenhouse gases in the atmosphere will increase global temperature. This could result in an increase in sea level worldwide.

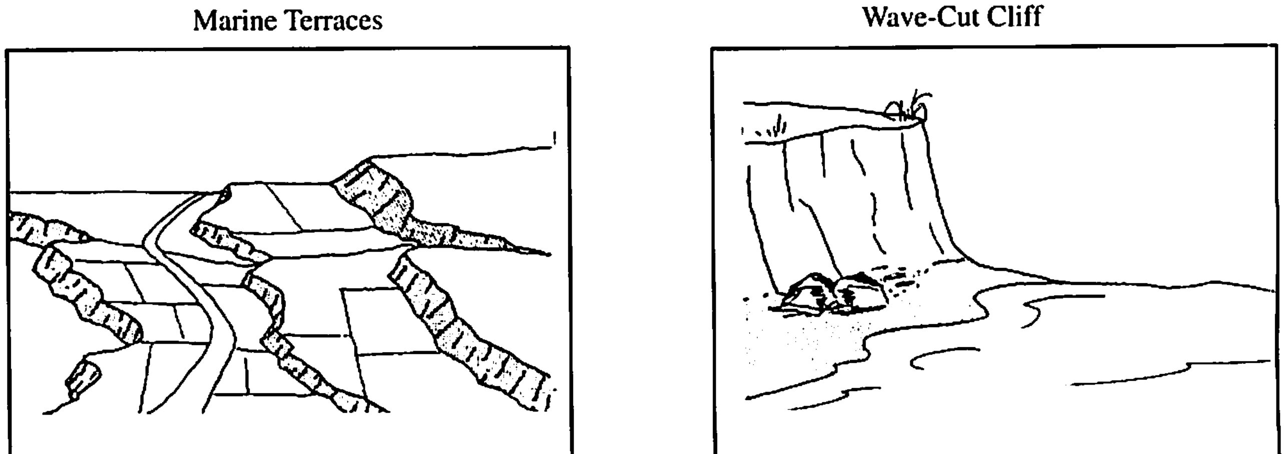
15. How would changing sea levels as a result of global warming affect habitats of marine animals and plants in coastal areas. What adaptations do you think organisms would need in order to live along the changing coastline?

16. What might be some economic impacts associated with changing sea levels? Discuss your ideas with the class.

Figure 2. Evidence of Sea Level Changes.

Marine Terraces

Wave-Cut Cliff



REVIEW QUESTIONS

1. Discuss three ways that people have used beach ridges.

2. Many types of fruit require well-drained soil. Why would beach ridges be good places for orchards?

Answers

1. People use beach ridges for highways, for cemeteries and as sources of sand and gravel.

2. The beach ridges and the immediate areas are composed largely of gravel covered with soil. The area is better drained and therefore provides an excellent location for orchards.

EXTENSION

Do research about your state for geologic features related to glacial evidence. Some of the following are examples of resources for your use.

- IL Geological Science Field Trips; for example, Livingston, La Salle and Vermilion Counties, which show various forms of glacial evidence. Also, Glacial Map of Illinois and other geologic maps.
- IN Department of Natural Resources Geological Survey state bedrock and glacial boundaries maps, generalized geologic map of IN.
- MI Department of Environmental Quality, Geological Survey Division, Map of Quaternary Geology.
- OH Department of Natural Resources, Division of Geological Survey, geologic map and cross section of Ohio.
- ON Ministry of Northern Development and Mines, Map of Geology and Principal Minerals of Ontario.
- PA Department of Environmental Protection, Topographic and Geological Survey, Glacial Deposits of Pennsylvania.
- WI University of WI Extension, Geological and Natural History Survey, Maps of Ice Age Deposits and Bedrock Geology.

Contact your state's Geological Survey Division or province's Ministry of Northern Development and Mines.

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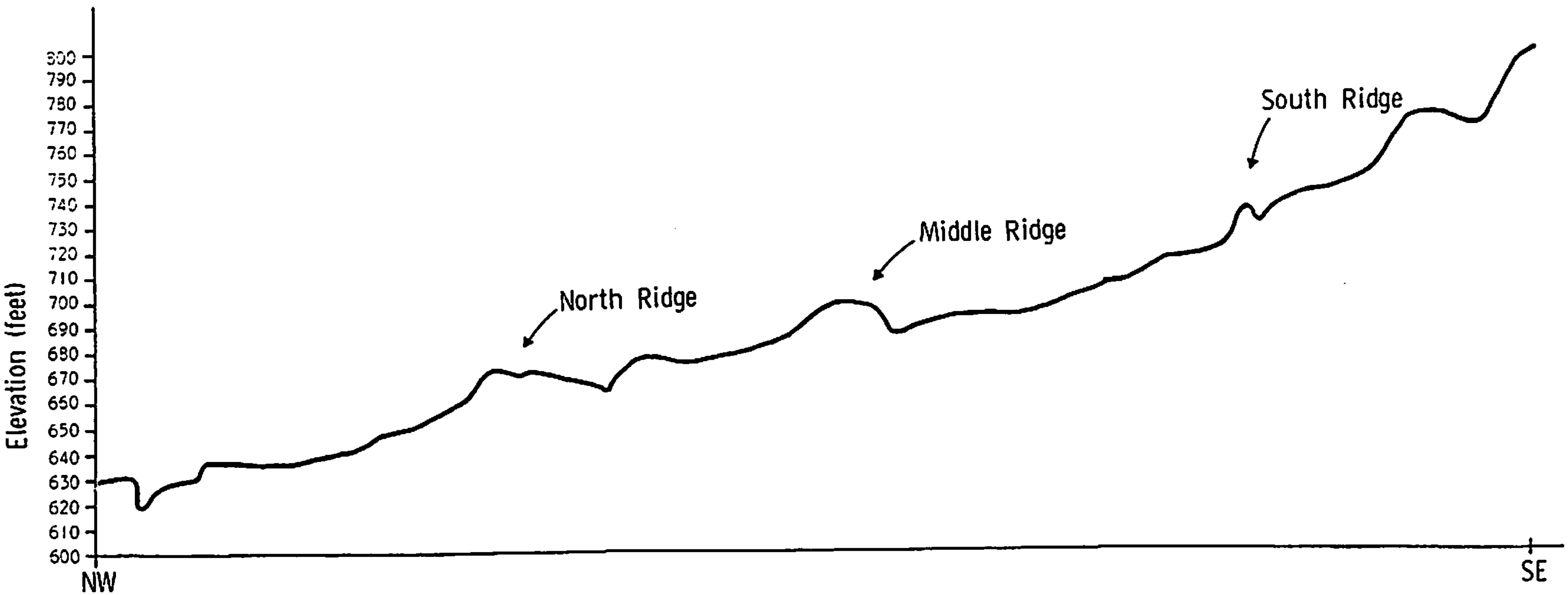
Hesser, Dale T. and Susan S. Leach, 1987. *Focus on Earth Science*. Charles E. Merrill Publishing Co., Columbus, Ohio, illus. 560 pp.

Graph 1.



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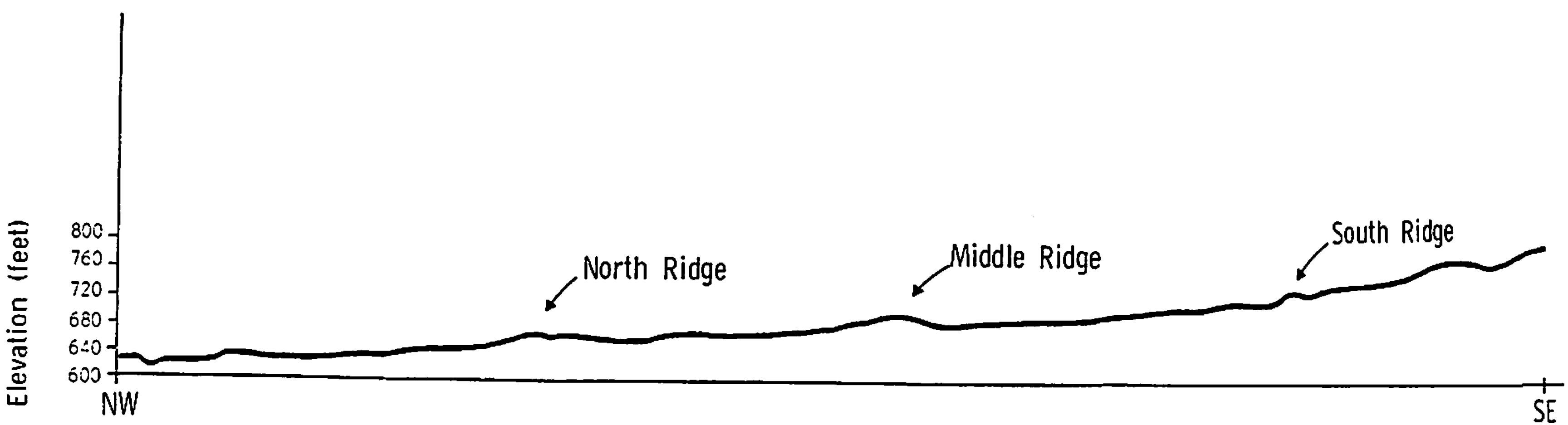
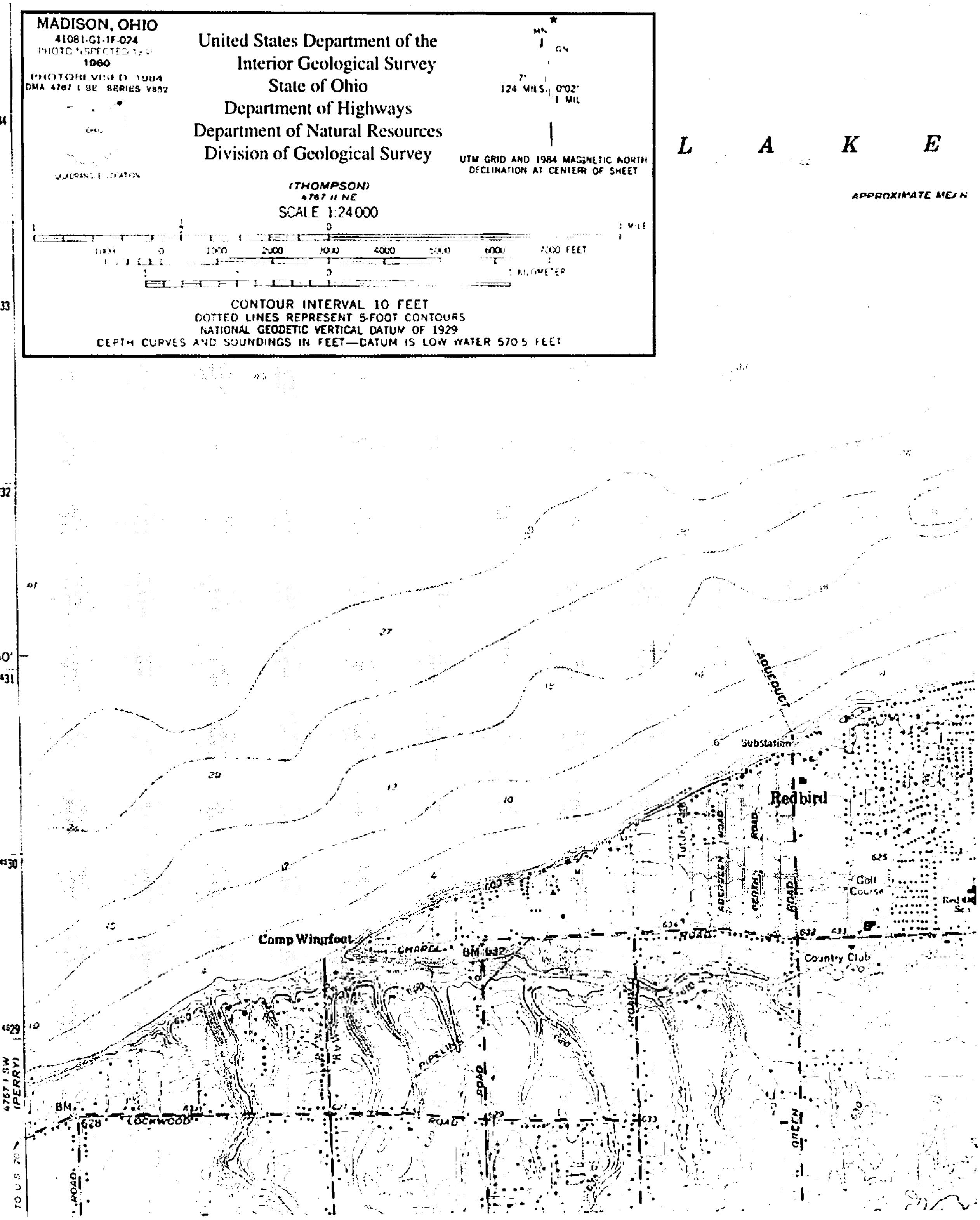
Graph 2.



The graph portrays a 10x exaggeration. The original graph had a horizontal scale of 1 inch equals 2000 feet and a vertical scale of 1 inch equals 200 feet. The original is shown here at a reduced size.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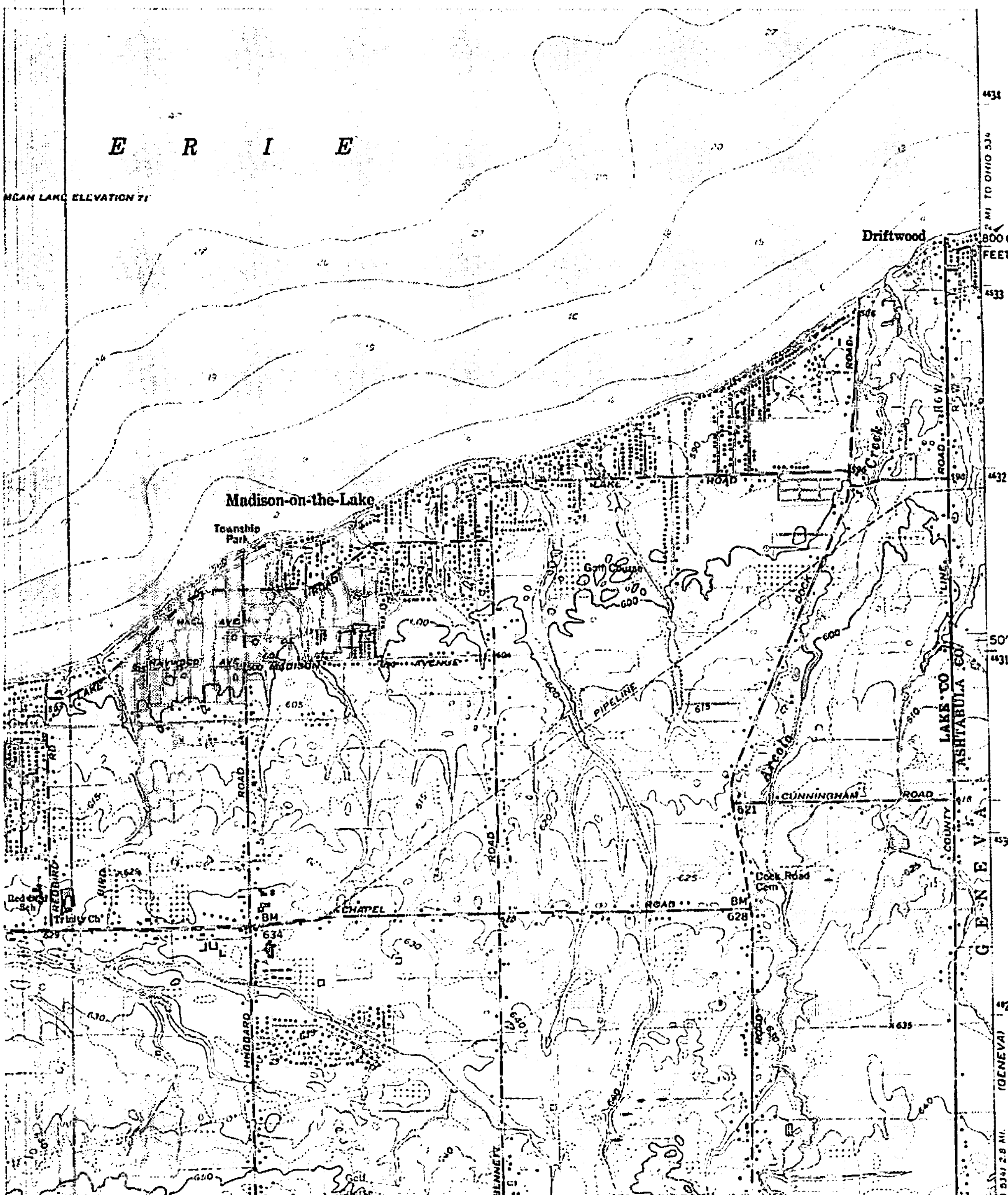
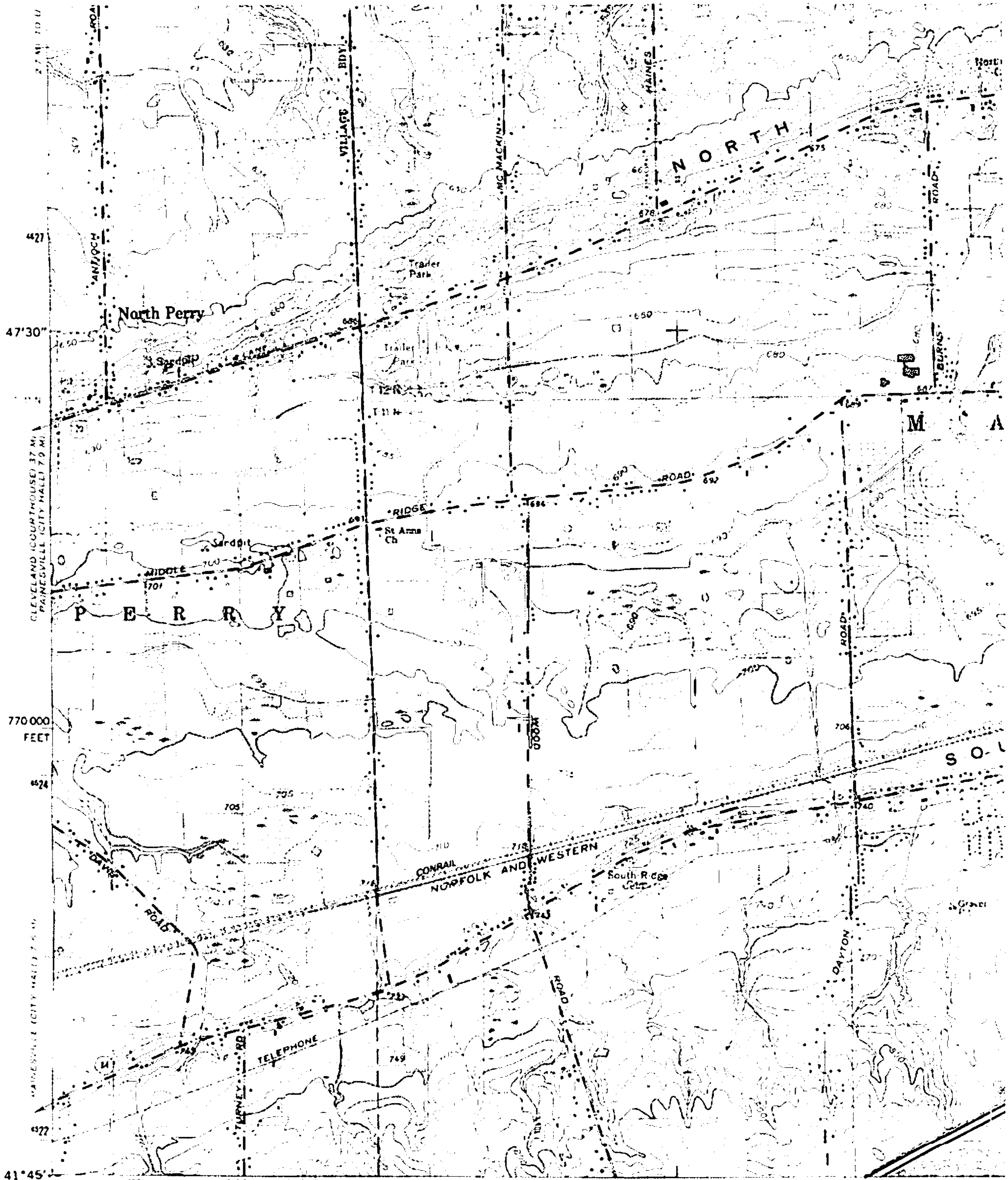
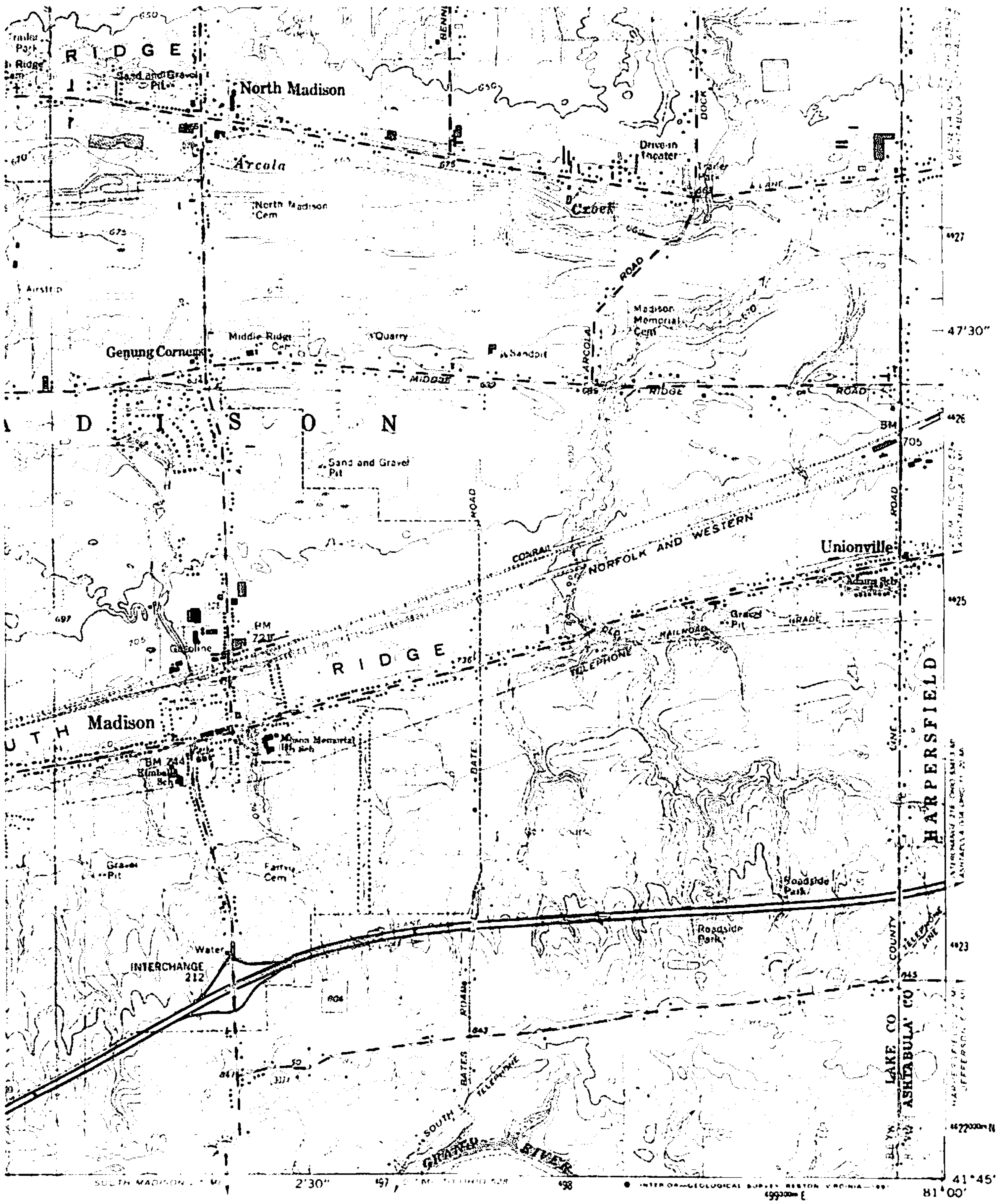
United States Department of the Interior Geological Survey
State of Ohio
Department of Highways
Department of Natural Resources
Division of Geological Survey
UTM GRID AND 1984 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
(THOMPSON)
4767 II NE
SCALE 1:24 000
CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS LOW WATER 570.5 FEET
L A K E
APPROXIMATE MEAN
AQUEDUCT
Substation
Redbird
Golf Course
Country Club
CHAPEL
LOCKWOOD
ROAD
PIPELINE
GREEN
4767 I SW (PERRY)
50'


E R I E
Madison-on-the-Lake
Township Park
Driftwood
800 000 FEET
Golf Course
PIPELINE
CUNNINGHAM
ROAD
CHAPEL
Cook Road Cem
Trinity Ch
HUBBARD
BENNETT
LAKE CO
ASHTABULA CO
COUNTY LINE ROAD
GENEVA
Creek
BM
634
628
621
50'

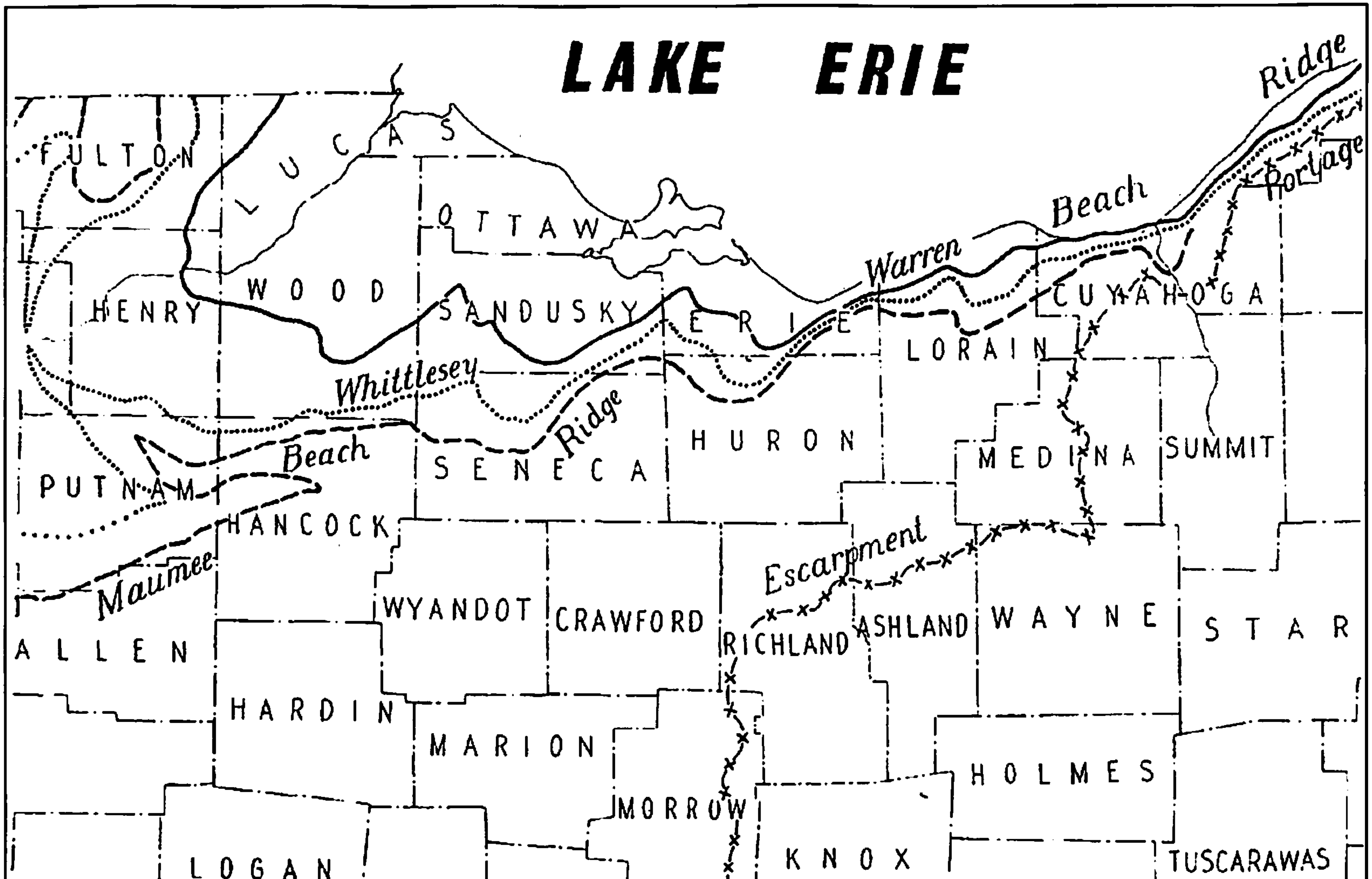

North Perry
NORTH
PERRY
M A
S O
Trailer Park
St Anns Ch
South Ridge
VILLAGE BDY
MC MACKIN
HAINES
ANTIOCH ROAD
BURNS ROAD
RIDGE ROAD
MIDDLE
DAYTON
WOOD
TURNEY RD
TELEPHONE
CONRAIL
NORFOLK AND WESTERN
CLEVELAND (COURTHOUSE) 37 MI
PAINESVILLE (CITY HALL) 7.9 MI
47'30"
770 000 FEET
41°45'
81°07'30"
2 380 000 FEET
R 7 W
R 6 W



RIDGE
North Madison
Arcola
North Madison Cem
Drive-in Theater
Creek
Airstrip
Madison Memorial Cem
Middle Ridge Cem
Quarry
Sandpit
Genung Corners
MIDDLE
RIDGE
ROAD
ARCOLA
MADISON
Sand and Gravel Pit
ROAD
CONRAIL
NORFOLK AND WESTERN
Unionville
RIDGE
Gasoline
Madison
Gravel Pit
Farris Cem
Roadside Park
Water
INTERCHANGE 212
BATES
ROAD
SOUTH
GRAND RIVER
LAKE CO
ASHTABULA CO
HARPERSFIELD
COUNTY
LINE
47'30"
41°45'
81°00'
2'30"

Background Page: Some beach ridges around historic stages of present Lake Erie.

Source of Art: Ohio Sea Grant Manual for Stone Lab



What evidence of glaciation and geologic processes can be found on Great Lakes beaches?

What kinds of substances make up the Great Lakes shoreline? What makes up the sediment? What do we walk on as we stroll along the beach? This activity investigates the characteristics of different pebbles and rock pieces along Great Lakes shores.

You will be examining data from different sections of a Great Lakes shoreline to study composition of beach sediments. Follow the guidelines to organize the data, analyze it, and provide some interpretations.

OBJECTIVES

When you have completed this activity, you should be able to:

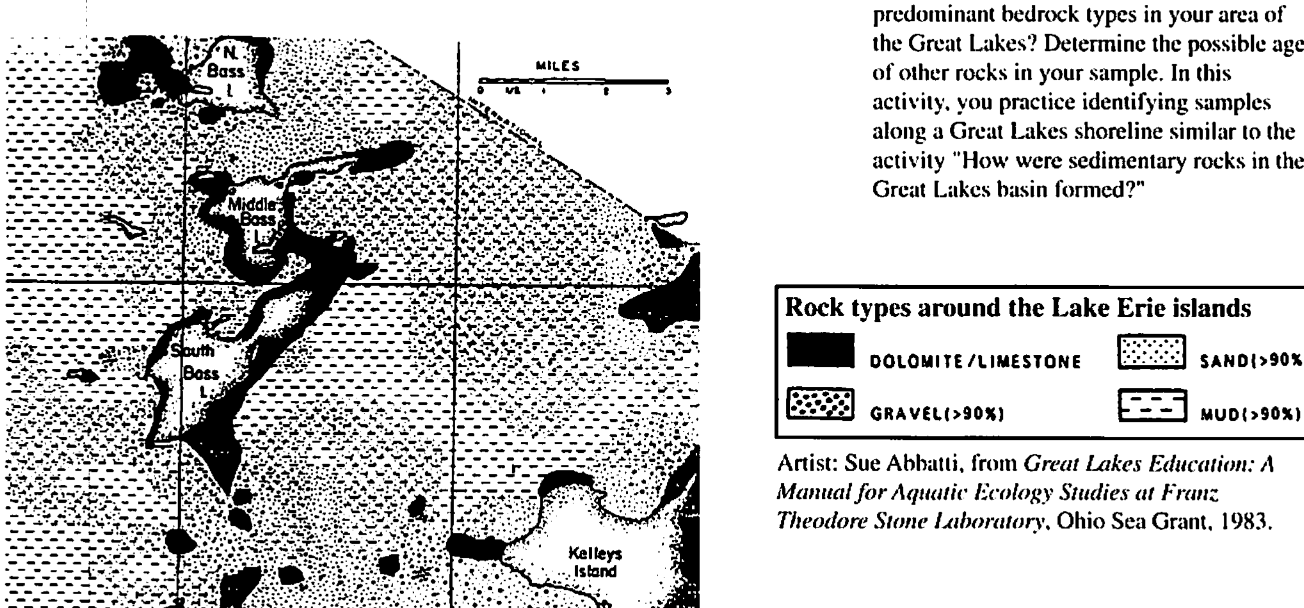
- Distinguish between general types of rocks found on a Great Lakes beach.
- Analyze factors that might determine rock types at a specific location.
- Explore options for presenting data.

PROCEDURE

Work in groups to cover as many different areas of the shoreline as possible.

Collect Samples

1. Data Collection: You will collect samples from different areas of shoreline. Locate each of your sampling stations on a map of the lake. Note which direction the shore faces at that site.



Artist: Sue Abbatti, from *Great Lakes Education: A Manual for Aquatic Ecology Studies at Franz Theodore Stone Laboratory*, Ohio Sea Grant, 1983.

Source

"Coastal Geology Study," Earth Systems Education Program, The Ohio State University.

Earth Systems Understandings

This activity uses ESU 3 (science methods and technology), ESU 4 (to investigate evidence of natural interactions), and ESU 5 (change through time).

Materials

- Hand lens.
- Geologist's hammer.
- Graph paper.
- Dilute HCl.
- Pencil, ruler, paper.

Student Review

In what ages of rock are limestone and dolostone found? What are the ages of predominant bedrock types in your area of the Great Lakes? Determine the possible age of other rocks in your sample. In this activity, you practice identifying samples along a Great Lakes shoreline similar to the activity "How were sedimentary rocks in the Great Lakes basin formed?"

Teacher's Note

An easy way to sample a beach is to randomly select a spot on the rocky shore to sit down, facing the water, and reach down to your sides with both hands. Gather all the pebbles you can hold in two hands and test them for types. The number collected is a good relative size measure.

Student Observations

Observe the location of larger and smaller pebbles relative to the water's edge. For an example of how larger and smaller sediments settle at different rates, see the demonstration in the activity "How were sedimentary rocks in the Great Lakes basin formed?"

You may observe quartz along the dunes of the lakes. Quartz is more resistant to weathering than other rocks.

Answers

4. It may be challenging to identify types of rocks. You may want to become familiar with the local rocks typical to your specific area before trying to identify them in the field. Refer to the activity "How were sedimentary rocks in the Great Lakes basin formed?" for examples of rocks and for geologic evidence that may suggest the kinds of rocks present at a specific site. A conglomerate will consist of several different kinds of pebbles cemented together, and crystalline rocks may sometimes display different types of minerals in one pebble.

5. This is especially important in the Lake Erie island region, where some islands are limestone and some are dolostone.

2. Decide on a sampling technique that will yield a good representation of the kinds of rocks present. Determine what you think is the best way to achieve a good distribution of samples from different areas.

3. Divide into groups so that different sections of the beach can be examined and collect pebbles from different areas of the shoreline. Note and record the wave action at your sample site. If you took more than one pebble sample at each station, indicate the position of samples on the map.

Analyze Samples

4. Which pebbles in your sample appear to be homogeneous, or made of the same material throughout the sample? Which types of pebbles consist of many different pieces of rock cemented together? Are there pebbles in which you notice a repeating pattern? How many of each kind do you have in the sample?

5. Break each pebble with a blunt hammer and drop a small amount of dilute HCl on the fresh surface. If the pebble is limestone, it will fizz vigorously. If dolostone, it will fizz very slowly. Other types of rocks will not fizz. Count how many original pebbles you had before breaking them that are dolostone and limestone; decide which others are crystalline, conglomerate, etc. Use your pebble count for the next step.

Graph the data

6. As a class, plot the number of rocks of given types in each sample based on categories in the included table (conglomerate, limestone, dolostone, and crystalline – igneous and metamorphic – rocks, etc.). Use a single bar divided proportionally by the number of pebbles in the sample or another technique as appropriate. If you selected a sample with many large pebbles, you will have a short bar; and if your sample contained various small pebbles, it will be a taller bar. You will get an idea of the size of pebbles, in each beach sample from your graph. If you did more than one sediment sample at a site, use the sample nearest the water's edge for a graph.

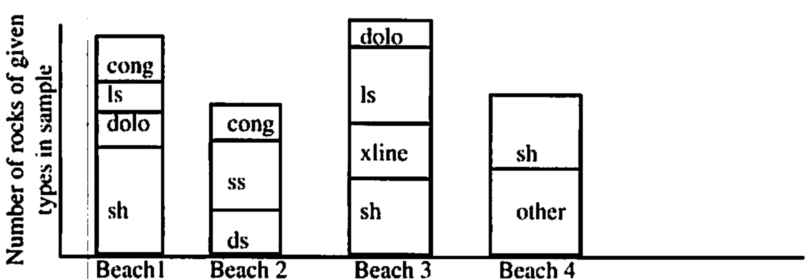
7. Are there any fossils in your collection? Ask local experts for help in identifying them or use a key to try to name the fossils you have found.

8. Is there other glacial evidence relating to topography in the sample area? Draw or describe the topography you notice,

for example the shape of the landscape that might suggest the action of glaciers in the past, or the presence and orientation of glacial grooves or striations. Are there glacial erratics present in the local bedrock? Which pebbles in your sample may have been carried by glaciers to the site? (Hint: Which pebbles appear different than the native bedrock?)

9. Develop a report that includes:
   a. Data collection methods.
   b. Methods used to analyze rock samples.
   c. Description of any patterns you see in the data, both for glacial direction, rock types and size.
   d. Possible explanation for any patterns you see.
   e. Justification of those explanations. What other information do you have that leads you to choose one explanation over another? What other information do you need to see if your explanation is valid?

One way to graph:



In your discussion, consider data that would provide information about island bedrock, direction of wind, effect of wind, etc. Explain why there would be differences in rock size on the same beach, on a different beach nearby, no obvious beach materials on some shores, etc.

REVIEW QUESTIONS

1. Why are glaciers able to transport rock and sediment long distances? How can you tell when looking at a section of beach if pebbles came from glacial deposits?

2. Based on this and previous activities, what are the major ways we distinguish rock types – sedimentary, igneous, etc.? What are the different ways rocks form?

3. How does the action of water on beaches affect beach composition and morphology? Is it possible that these beach characteristics could change seasonally?

Answers

8. Ideally, students should find an area such as an outcropping where they can view the bedrock beneath the soil layer for glacial deposits. An erratic is a rounded rock that does not match the local bedrock and perhaps was deposited by glaciers.

Glaciers are able to keep sediments suspended over long distances and time periods. Also glaciers grind rocks, and there may be evidence of this on the surface of larger rock pieces or rocky beach walls. Rocks carried in by glaciers may be different from the native bedrock. Gathering data from more than one beach is ideal for this exercise.

Teacher's Note

Ideally, this activity would be conducted on several beach areas accessible by the classroom. Students collect a variety of specimens from as many different areas as possible.

Alternatively, collect the beach pebbles yourself and bring in enough for the class to analyze, or develop a simulated data set.

The movement of water causes various effects on rock walls and beaches. Water can increase changes in rocks by freezing and expanding; thus, changes in seasons will have an effect on beaches.

Table 1. Characteristics of Rock Samples.

Date: Site:

Morphology of beach (slope, width, etc.):

Pebble count

Type	cong	ss	sh	ls	dolo	xline	other
Number							
% of total							

Notes (on size, and shape of pebbles, etc.):

Key: cong (conglomerate), ss (sandstone), sh (shale), ls (limestone), xline (crystalline – igneous and metamorphic).

EXTENSIONS

1. What is a petrologist? a geomorphologist? Why might such careers be important in the Great Lakes region?

2. Accurately weigh a few pieces of limestone and record the weights. Take a cold carbonated drink and place the weighed pieces of limestone in it. Cap the drink tightly and place it in the refrigerator. After a few days remove and dry the limestone chips. Reweigh them to see if their mass has changed. If it has changed, test the carbonated drink for calcium ions by adding some saturated ammonium oxalate solution. A milky white precipitate denotes the presence of calcium in the drink. Add ammonium oxalate to a fresh carbonated drink to see if a reaction takes place without the presence of limestone pieces.

3. Freeze pebbles in water in a milk carton. After it is frozen, remove the bottom of the milk carton. Drag the exposed surface over different materials such as wood, compacted clay, and plastic. This simulates the action of a glacier. Record the effects you see. Observe the scouring effects as you add force to the motion across surfaces.

REFERENCES

Earth Science Curriculum Project, American Geological Institute, William H. Matthews, et. al. 1987. *Investigating the Earth*, 4th ed. Boston: Houghton Mifflin Company, illus. 560 pp. See teacher's guide and text.

Ramsey, William L., et. al. 1989. *Modern Earth Science*. Austin, Texas: Holt, Rinehart and Winston Inc., 592 pp.

Additional Method

Each group will receive an assortment of beach samples. Identify them and predict where they came from, based on six possible Great Lakes sites. You can construct a composite graph of the different samples. Examine your samples to see if there are individual rocks that do not appear to belong to the group, as they could be glacial erratics. After you determine where your group sample was found, discuss how the sample groups differ throughout the Great Lakes region.

The following are recommendations for sample groups:
1. 4 basalt, 2 rhyolite, 2 granite, 1 limestone, 1 quartz, 1 shale.
2. 1 granite, 3 limestone, 3 shale, 1 basalt, 2 dolostone.
3. 3 dolostone, 1 granite, 2 shale, 2 limestone, 2 sandstone.
4. 4 sandstone, 1 basalt, 1 rhyolite, 1 limestone, 2 granite, 1 shale, 1 dolostone, 1 quartz.
5. 4 dolostone, 4 shale, 1 granite, 1 sandstone.
6. 3-4 sandstone, 3 shale, 1 limestone, 1 dolostone, 1 basalt.

Geographic Locations

1. Lake Superior, north shore.
2. Lake Erie, south shore and islands.
3. Lake Michigan, Door County.
4. Lake Superior, south shore.
5. Niagara Falls.
6. Lake Ontario, south shore.

Part B

Where do land and water meet?

There are different shore deposits around each of the Great Lakes. Understanding the differences between deposits accounts for the various features along the shoreline.

Objectives

In this activity you will:

- Observe the shore deposits of the Great Lakes region for evidence of ancient processes.
- Consider the nature of shore deposits that permits the existence of wetlands or other features.
- Describe reasons why topography and the nature of shorelines varies throughout the Great Lakes region.

Procedure

The coastline of the Great Lakes contains various types of shore deposits. The deposits vary in their erodibility. Shorelines consist of rock, clay, and sand as well as unique transitional environments such as wetlands.

Source

"Coastal Processes on the Great Lakes," by Charles Carter in *The Great Lake Erie*, Ohio Sea Grant Education Program. Students will need to refer to the map of shoreline deposits included with the activity "What causes the shoreline to erode?" in this module.

Answers

1. Huron and Superior have rock along their northern shores. Around Michigan, Erie, and Ontario there is a good deal of clay and sand.
2. Wetlands are noticed quite readily in the western areas of Lakes Erie, Michigan and Huron. They also occur at other smaller sites.
3. The northern rocks along Huron and Superior (part of the Canadian Shield) are metamorphic and igneous. They are resistant while the southern rock shorelines contain more sedimentary rocks prone to erosion.
4. Rock, clay, sand. Students may provide an explanation based on particle size, where clay is fine compact sediments, and sand has a larger particle size and is less compact. Rock may contain limestone and dolostone, which are very hard. Such rocks are cemented sediments formed over long periods of time.
5. In addition to carving out the basins, glaciers deposited clay and other sediments and formed coastlines. Meltwater from glaciers created ice-dammed lakes that formed lakeshores. The movement of glaciers affected the topography of a region. The load carried by glaciers was added to native bedrock, changing the nature of coastal bluffs and beaches.
6. Elevation and shoreline composition are related. Wetlands occur near the lake level, and rock cliffs rise higher than the lake level. Less resistant shorelines will erode away more quickly than resistant rock; thus, elevations will vary.
7. Lake levels affect the shape and nature of the shoreline. Lake levels also affect the rate of erosion. When lake levels are low, waves break further offshore, but when levels are high, even small waves can have an effect on the shore.

Examine the shoreline map of the activity, "What causes the shoreline to erode?" and answer the following questions:

1. In what ways do types of shore deposits vary among the Great Lakes?
2. Where are wetlands located?
3. How do the rocks differ between the northern and southern parts of the basin?
4. Place shoreline sediments in order of least resistant to most resistant. What determines how well the material making up a shoreline can resist erosion?
5. How did the glaciers contribute to the shape and composition of shorelines?
6. How do coastal elevations contribute to shoreline features?
7. Think about the changes in lake levels over seasons. How would lake levels affect the shoreline?

Examining shoreline deposits and understanding the relationship between shorelines and erosion rates involves various factors. This investigation involved a few of them. On your next visit to the Great Lake nearest you, observe the changes on the shoreline from day to day. How are the changes different from seasonal changes? yearly changes? Note the shoreline protection devices in place (if any). What is your prediction of what the shoreline will look like in the future?

References

U.S. Army Corps of Engineers Low Cost Shore Protection Publications On-Line, http://sparky.nce.usace.army.mil/shore.protection/lcsphmpg.html. Web addresses sometimes change. Do a word search using shoreline related topics if necessary.

Land and Water Interactions Today

The major natural forces affecting the shoreline today are wind, waves, and currents. These forces both wear away and build up shorelines. People can modify these forces and redirect them, but we will never totally control them.

The wind is the principal generator of waves. The longer and stronger the wind blows and the greater distance, or **fetch**, over which it blows, the larger and more powerful the waves will be.

Waves have significant effects on shorelines. Often during storms, their energy can carry beach sands lakeward, erode cliffs and banks, and damage or carry away human-made structures. During calm periods, waves move offshore sand onto the beaches, building them up.

Currents – streams of moving water within a body of water – are another major force affecting the shoreline. Perhaps the most important current causing the shoreline to change is **longshore current**, which is generated by waves as they strike the coast at an angle. A longshore current runs parallel to the shoreline and varies in speed and direction with the angle of waves and their energy. It often transports large quantities of sand along the beach. This transportation is known as **littoral drift**.

If there is an abundant supply of sediment, as from eroding cliffs or sediment-laden streams flowing into the lake, the littoral drift will deposit sediment wherever its speed is reduced. When sediment is scarce, the littoral drift will carry sand away from the beaches, causing erosion.

Because wind and waves determine the directions and amount of littoral drift, there may be an overall or **net** sand movement in the lake, such as in Lake Erie, where it is from west to east.

Shoreline Processes

The following are selected readings from Charles Carter's "Coastal Processes on the Great Lakes" in *The Great Lake Erie*: The coastal zone, on both the Great Lakes and the oceans, is the dynamic interface between the waves and the land. On the Great Lakes this is the zone that can change from tranquil to turbulent in a matter of hours (if not minutes), and the zone for which major historic changes can be documented. Moreover this is a zone of crucial importance to electrical power, commercial navigation, recreation, shoreline development and environmental interests. Almost without exception, the naturally occurring physical processes that take place in this zone have a profound effect on these activities and systems.

The lakeshore deposits consist largely of rock, clay, sand, and wetlands. The rock is exposed along the north shores of Lake Superior and Lake Huron (Georgian Bay and North Channel) and at scattered locations on the other lakes. The rock along Superior and Huron is part of a vast complex of erosion-resistant igneous and metamorphic rocks known as the Canadian shield, whereas the rocks exposed along Lakes Erie and Ontario to the south consist of less resistant Paleozoic sedimentary rocks.

The clay, with intervening stretches of rock, sand, and wetlands, is exposed along most of the remainder of the shore. For the most part it was deposited by or in association with the Pleistocene glaciers and glacier-dammed lakes. The rock is most resistant to erosion, followed by clay and then sand as the least resistant.

The wetlands occur commonly along Green Bay off Lake Michigan, along Saginaw Bay off Lake Huron, and at the west end of Lake Erie. The wetlands may be associated with narrow strips of sand known as barrier beaches. The relief (the elevation of the shore deposits above the lake) of the lakeshore ranges from essentially zero along the wetland shores to nearly 800 feet along Lake Superior's north shore.

The beaches, which are so important as a barrier to wave erosion, are as variable as the relief and the nature of the shore deposits. For example, wide, sandy beaches characterize the eastern shore of Lake Michigan; narrow, discontinuous beaches characterize the south shore of Lake Erie; and pocket, cobble beaches characterize the north shore of Lake Superior.

The nature of the shore material, like the amount of wave energy reaching the shore, has a major effect on erosion. Rock for the most part is quite resistant to erosion and usually erodes at less than one foot per year Clay-rich glacial drift (debris transported by or away from a glacier) on the other hand usually erodes at 2-3 ft/yr but may erode much more rapidly.

People, as they have done in so many other natural systems, have had a major impact on shore processes, particularly shore erosion. Human effects on erosion along the Great Lakes shore are caused in two ways: by harbor structures, and by shore protection structures. The shore protection structures that have had the most effect are groins and seawalls. Groins act as small jetties in that they block and/or divert the longshore transport of sand. In so doing they lead to the formation of a wider beach on one side of the structure, which is the basic purpose of a groin, but again, a narrower beach on the other side of the structure. Frequently, the apparent necessity for the construction of the groins has been created by the jetties built updrift. These have contributed to narrower beaches and thus the need for shore protection.

Carter, Charles H. 1993. Coastal Processes on the Great Lakes. In *The Great Lake Erie*. Edited by Rosanne W. Fortner and Victor J. Mayer. Ohio Sea Grant Education Program. Columbus, OH: Ohio Sea Grant Publications, The Ohio State University.

What causes the shoreline to erode?

Shorelines along the Great Lakes vary in the nature of their sediments and erodibility. Natural causes of erosion include waves, currents, and effects of wind and storms on shoreline processes. We can simulate the processes of shoreline erosion for an understanding of the ongoing changes that occur in coastal areas.

OBJECTIVES

When you have completed this investigation you will be able to:

- List major natural forces of erosion along the lake shore.
- Describe how the rate of erosion differs with different materials.

PROCEDURE

In teams of three, follow the procedure below.

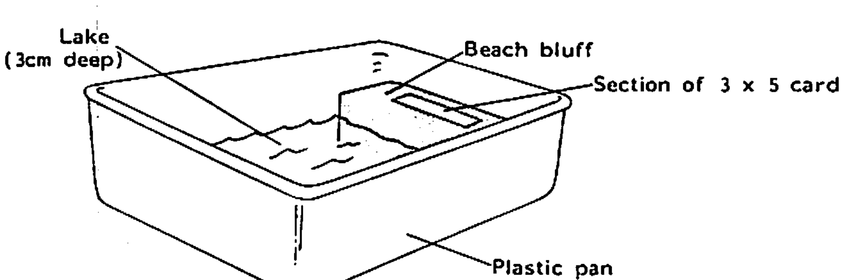
A. In the end of one of the plastic pans, place three handfuls of wet sand.

B. Using a piece of board, mash the sand up against the end of the pan and flatten the top. Make this "beach bluff" about as wide as it is high.

C. Repeat Steps A and B with a second pan, building a beach bluff made of wet soil.

D. In one end of the third pan make a stack of rock pieces that will represent a rocky shoreline about the same size as the other bluffs.

Figure 1. Shoreline Model.



Source

Modified from OEAGLS EP-7, "Coastal Processes and Erosion," by Beth A. Kennedy, Newark Public Schools, Ohio, and Rosanne W. Fortner, Ohio Sea Grant Education Program, The Ohio State University.

Earth Systems Understandings

This activity explores ESU 4 and 5 (the impact of land and water interactions on shorelines over time). Extensions address stewardship of coastal resources using ESU 2 and 3 (scientific methods and planning). Using ESU 6 students can consider how coastal processes relate to Earth's position in a larger universe.

Materials

Divide the class into teams of three, giving each team the appropriate materials. Each lab team should be supplied with

- Three rectangular plastic dishpans or plastic shoe boxes.
- One piece of board (2 x 4 or plank) as long as the width of the dishpan's floor.
- One piece of board half as long as the width of the pan.
- About 1 liter of sand per team.
- 1 liter of potting soil per team.
- Several pieces of rock 5-10 cm long.
- 3 x 5 note card cut in three long strips.
- Ruler to measure wave heights.
- Access to a supply of water.
- Each student will need a pencil or pen for recording data and answering questions.

Teacher's Overview

Students examine how shoreline geology affects the rate and amount of erosion that occurs along the edges of oceans or lakes. They conduct an experiment comparing the stability of three geologically different beach bluffs as they are attacked by waves.

In recording data, it is suggested that the number and height of waves be recorded only once for each shore type, when the bluff collapses.

Additional Method

Students can use a fan to generate wind and produce waves, simulating actual conditions on a lake.

Suggested Approach

To help cut down on the amount of equipment needed, the activity could be done in large groups or by a single group of students acting as demonstrators. Stress that the water used in Step E be poured in slowly; otherwise beach bluffs may begin to collapse before waves are generated.

Be sure to provide an appropriate place to dispose of the muddied water, preferably outdoors away from the school building.

You should now have three "beach bluffs" of various types and sizes of material. The three pans represent lakes.

E. Hold the pieces of board up against the sand bluff to protect it while you slowly add water to the empty end of the pan. Create a lake about 1-1.5 cm deep. Remove the board gently when the lake water is still.

F. Repeat Step E to create lakes in front of the soil and rock bluffs.

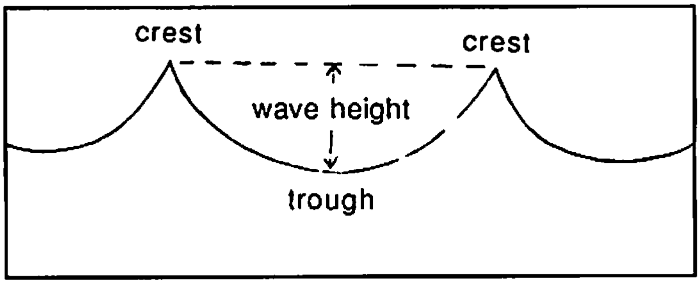
G. Gently place a strip of note card flat on top of each bluff.

H. You are now ready to act as the wind, making waves and causing erosion on the shoreline. Using a ruler or the pieces of board, make waves that move toward the beach bluff from the opposite end of the lake. Start gently, counting the number of waves you produce. Then gradually increase the strength of your waves as if the wind were becoming stronger. Record what happens to the beach bluffs as you repeat this process in each lake. Put your information in a Data Table that shows the number of waves before bluff collapse, size of waves, and effects on the bluff for each type of shore material.

I. When the section of note card slips toward the water, your bluff has collapsed. If collapse has not occurred after 100 waves, stop and record your observations of the bluff's condition. Put this information in the Data Table.

NOTE: To estimate the height of waves, find the distance from the top (crest) of the wave to the lowest part (trough) of the wave. Do not measure from the bottom of the "lake" basin unless the bottom is actually exposed as the wave passes by. Refer to Figure 2.

Figure 2. Determining Wave Height.



Answer the following questions based on your results.

1. Which beach bluff is the least stable (collapsed first)?

2. Which beach bluff is the most stable (withstood the most waves)?

Some beach bluffs around the Great Lakes shore are actually made of sand and some of clay similar to the soil bluff you constructed. The rocky bluffs of the lake shore may be of limestone or a soft shale.

3. What type of beach bluff would you choose if you were building a cottage on the shoreline? Why?

4. Map 1 shows Lake Erie's shoreline. Cover the top half of the page. Based on what you have discovered about how different materials erode, answer the following questions using the lower map provided.

   a. Put X's on the sections of shoreline that are probably made of rock.

   b. Put O's on the sections of shoreline that are probably made of sandy material.

(You do not have to cover the shoreline with either X's or O's. The shape of the shore may not give you any clues about the type of material it has.)

Uncover the top half of the page and check your predictions using the map of shoreline deposits.

5. Some points of land sticking out into the lake may be made of sand. What process is probably responsible for carrying the sand and depositing it there? (You may need to reread the introduction at the beginning of this activity.)

Answers

1. The sand bluff is the least stable. The small and fairly uniform grain size produces a permeable surface that is quickly penetrated and disrupted by the water. On the board, record wave heights and number of waves from different lab teams. Note that higher waves erode the bluff more quickly (fewer waves are needed).

2. The rock beach is the most stable because of the resistant nature of the rocks. Students may want to discuss which types of rocks would be more resistant to erosion. An interesting experiment could be designed by the class using small rock polishers (tumblers) loaded with different kinds of local rocks and processed simultaneously for the same number of days. Students should choose rocks depending on the lake region of study. Comparing the mass of rocks before and after the erosion would indicate which rock types were more resistant. However, you should mention that shale, though a rock, is quite erodible and would not be a good site for construction.

3. When erodible characteristics are considered, students should choose the rocky bluff as a building site. However, you should mention that shale, though a rock, is quite erodible and would not be as good a site for construction. At the end of the activity are transparency masters for use in illustrating the types of shorelands and beaches around the Great Lakes and a discussion of the possible uses made of these areas. Students who have completed the activity should be able to identify areas of potential erosion problems using the outline maps.

4. See the accompanying map for approximate locations of sandy and rocky shorelines. Student maps should be accepted if an attempt has been made to label shoreline sections. Points of land projecting into the lake are often labeled "X" by students, and cut away sections of shore may be labeled "O." A discussion of students' responses and the transparencies can lead to consideration of Question 5.

Lake Erie's Pelee Island is an interesting case in point. The island is rocky, but has a spit at its southern tip. Changes in the direction of the longshore current cause the spit to curve eastward at some times and westward at others. People sailing on the lake have referred to Pelee island as "the island that wags its tail."

6. How could you tell from their appearance which points of land might be sandy instead of rocky?

Erosion of coastal areas, as you have seen, occurs at different rates depending upon the material making up the shoreline. The same processes act upon the ocean as upon large lakes. Some of the coast of England, for example, has been worn back more than 3 km since the time of the Romans. The shore of Cape Cod retreats at the rate of 25 to 150 cm each year. These coasts are composed of relatively weak material, but the same process takes place more slowly in the hardest rock.

7. On the map on your work sheet, draw your prediction of how the Lake Erie shoreline will be shaped 100 years from now if the present rates of erosion and deposition continue. Select another of the Great Lakes and repeat steps 4-7 using the lake outline provided.

Answers

5. The lake's longshore current, or littoral drift, is responsible for creating many of the points of land projecting into the lake. The "spits," as they are called, are made of sediments carried from other areas. The current direction produced by the prevailing winds determines which way a spit curves.

6. The points of land that form smooth curves out into the lake are generally sandy. Those with ragged or angular shapes usually have a rock base. The two lakeward projections surrounding the mouth of Sandusky Bay illustrate these differences. The Marblehead area to the west of the bay is limestone, and Cedar Point to the east is a sandy deposit.

7. In predicting future shoreline characteristics, it is hoped that students will apply what they have learned about coastal processes. Answers will vary, and the differences between predictions can furnish material for class discussion of erosion and deposition rates, the future of lake shore property, and how the shore could be protected. An outline map of all lakes is found at the back of this volume. Enlarge sections as needed.

REVIEW QUESTIONS

1. Explain how natural forces cause erosion along the Great Lakes. How do you think human actions contribute to coastal changes?

2. What types of shore materials erode faster? Slower?

3. Use a concept map to illustrate the present day land/water interactions along the Great Lakes coastline showing relationships between the factors involved in coastal processes.

EXTENSIONS

1. Do research to locate the largest cities along the Great Lakes. Also determine where the population densities are the greatest. Begin your search with GLIN on the Internet, or with the Great Lakes Atlas. What effect would these factors have on erosion rates along the shores?

2. How should decisions be made about potential shoreline uses and devices designed for shoreline protection? What interests should be considered in the decision-making process? What would you do if you could decide on the best way to use a section of shoreline? Draw a picture of what it would look like.

3. Extend your thinking to construct a concept map relating this activity with the position and action of Earth in space, i.e., the effect of the rotation of the Earth on wind generation, the seasons and their influence on storms, temperature, and coastal processes. Work in teams to create ideas to share with the class.

Teacher's Page

Example of student data table:

	Number of Waves	Height of Waves	Effects on Bluff
SANDY BLUFF			
SOIL BLUFF			
ROCKY BLUFF			

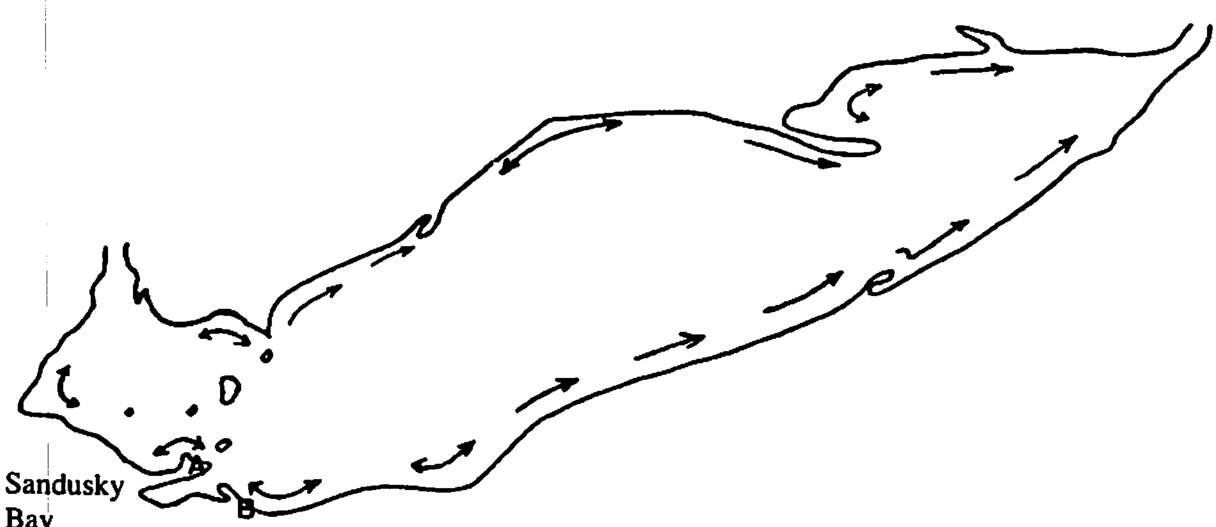
Figure 1. Comparison of Lake Erie Coastline Features.

Figure 1 shows how the rocky and sandy bluffs look in cross section. Rocky areas are generally steep and angular, while sandy bluffs have a gentle slope. The cross sections shown were taken at areas marked A and B on Figure 2.

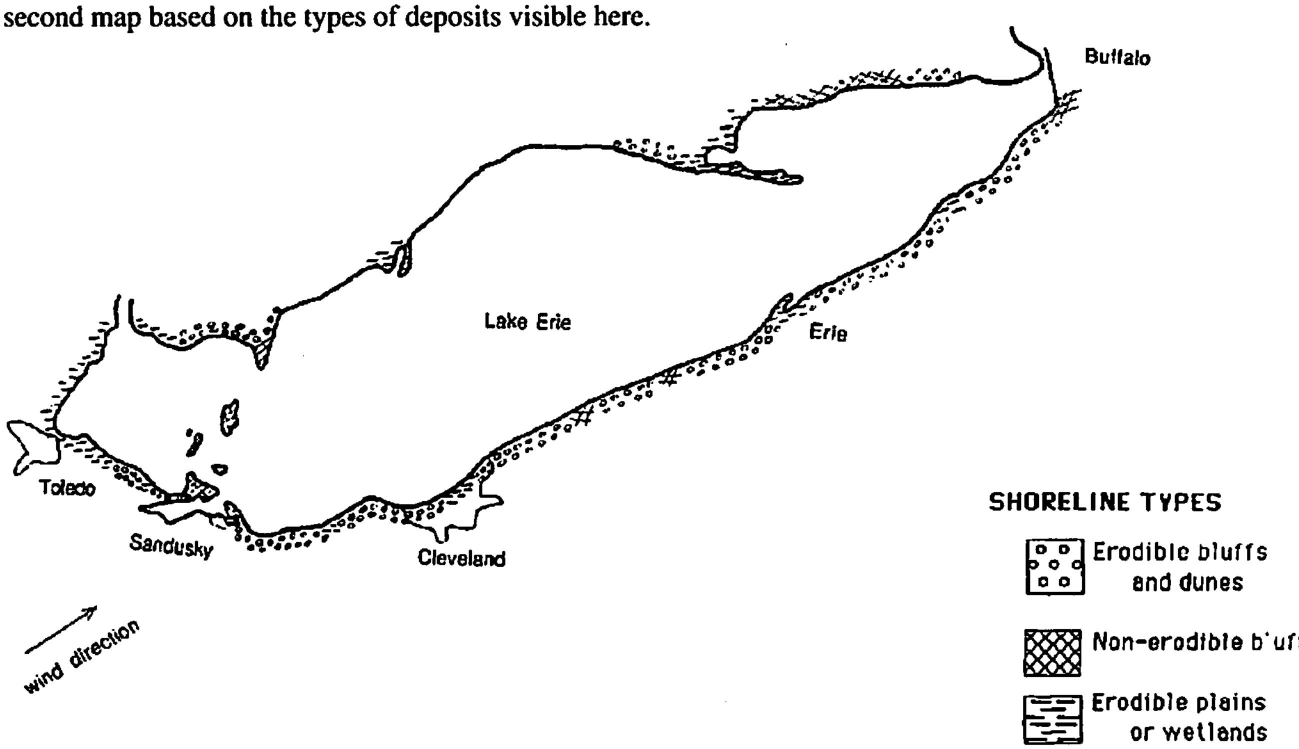
A. Rocky bluff profile (Eastern end of Marblehead).

B. Sandy bluff profile (West of Huron, Ohio).

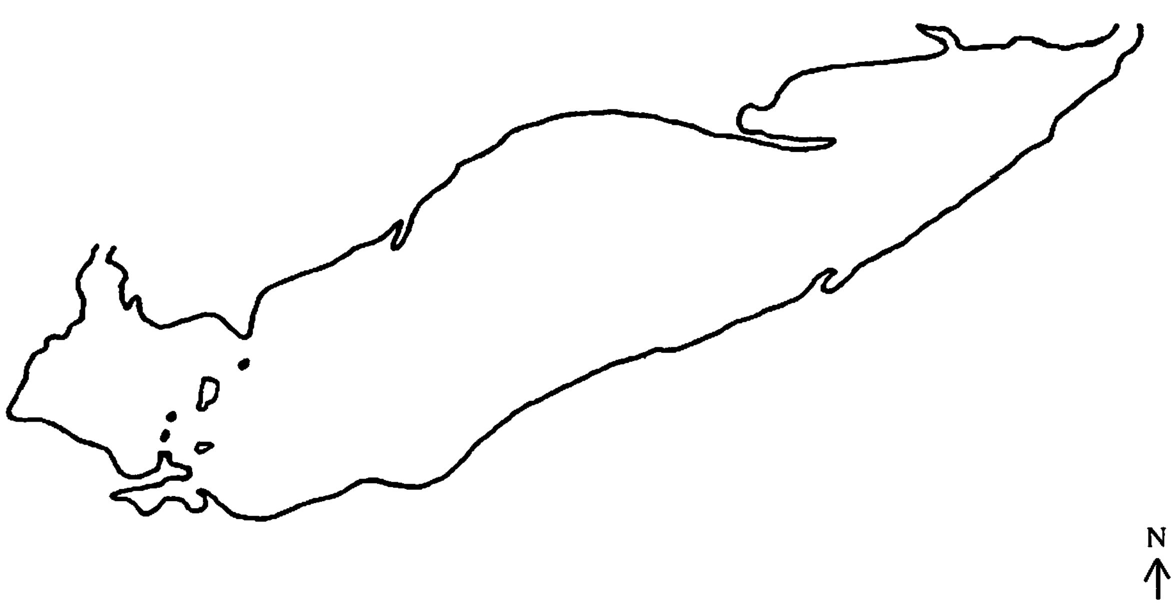
Figure 2. Net Direction of Littoral Transport, and Curvature of Spits in Lake Erie.



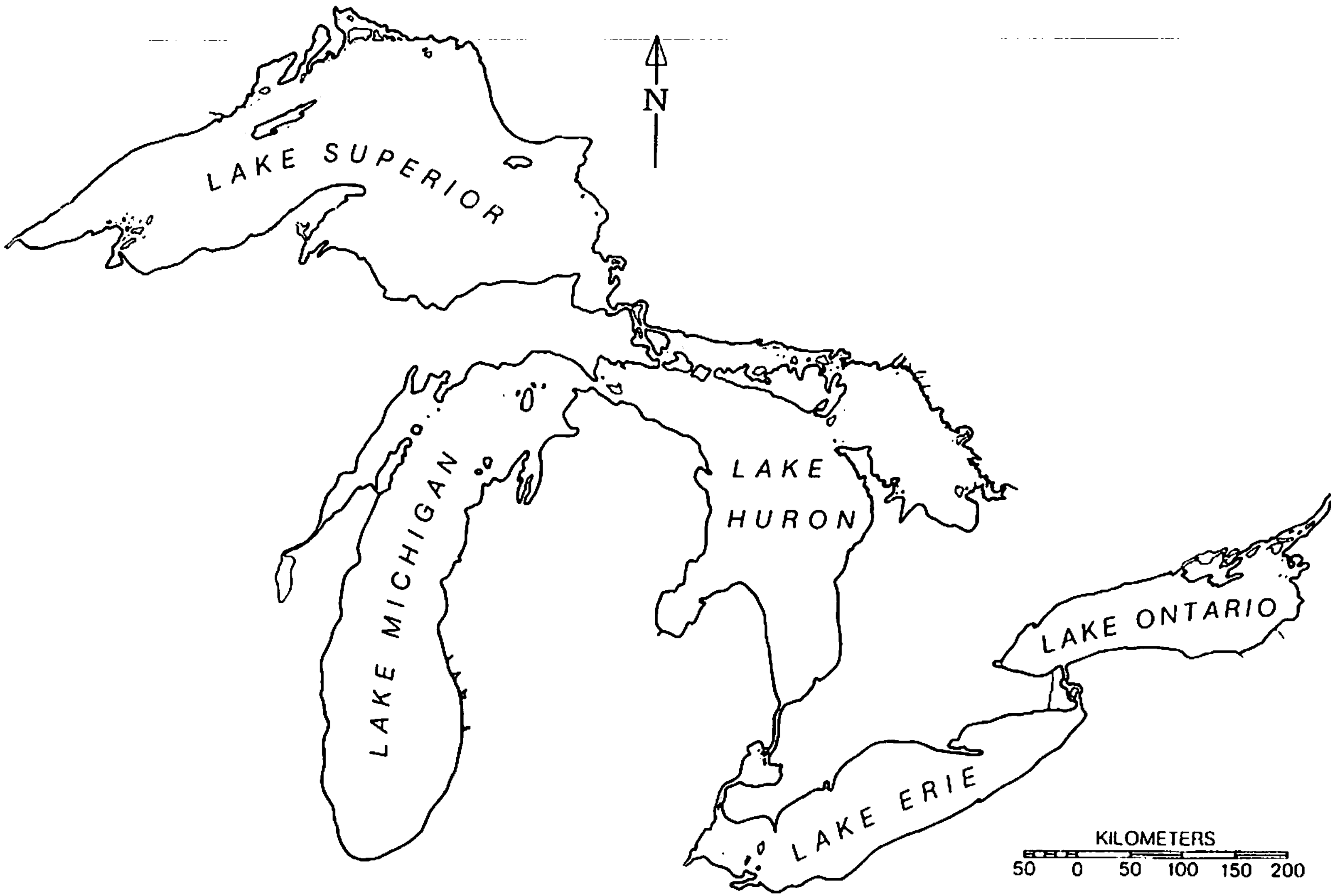
Map 1. Lake Erie Shoreline.
Below are the shoreline types surrounding Lake Erie. Make your prediction of the future shoreline on the second map based on the types of deposits visible here.



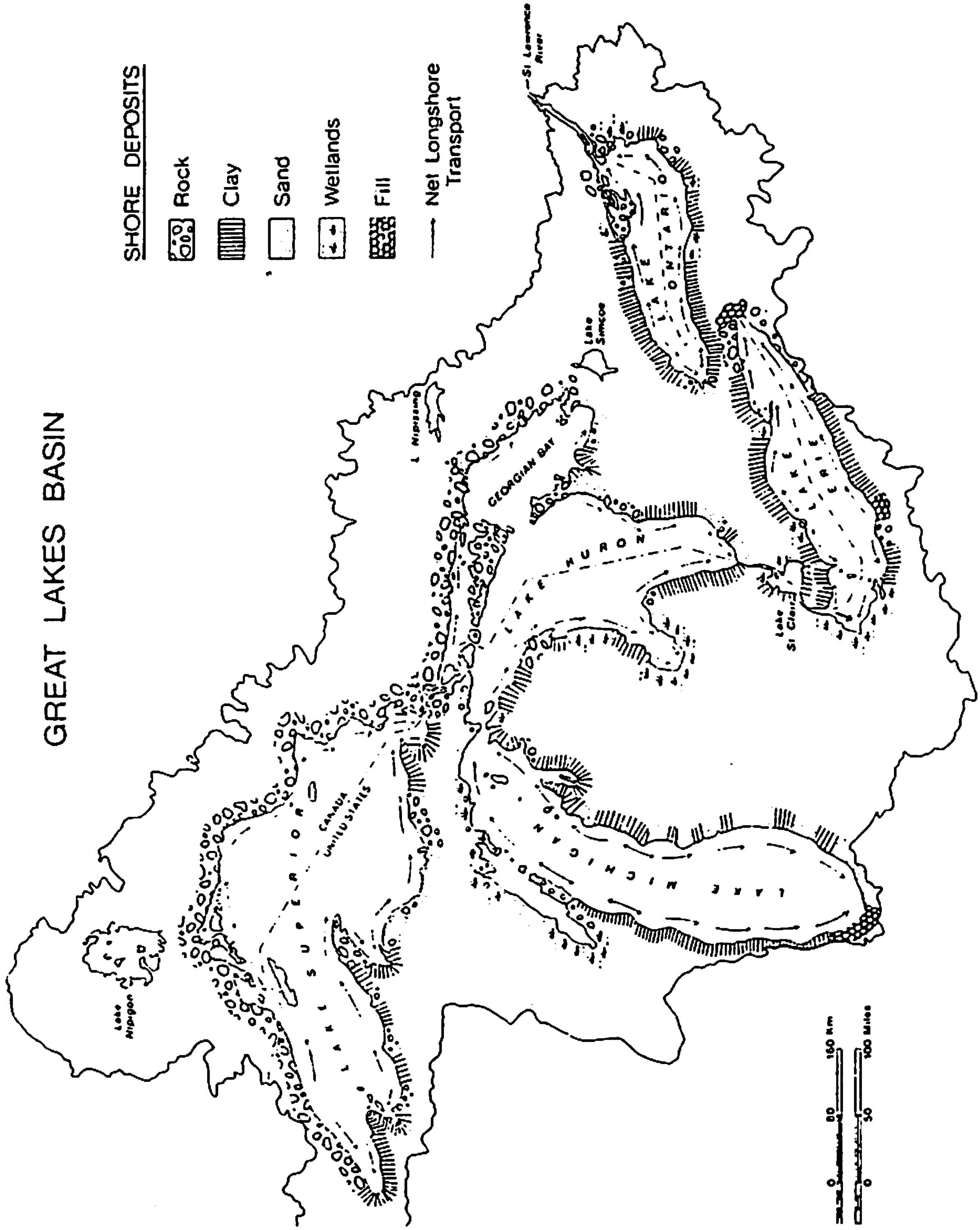
Predicted Shoreline of Lake Erie 100 Years From Now (Present Shape Given).



Map 2. Great Lakes Outline Map.



Map 3. Shoreline Deposits of the Great Lakes Region.



Source: Carter, Charles. 1993. *The Great Lake Erie.*

Can erosion be stopped?

The shores of the Great Lakes are subject to the attack of winds, waves, longshore currents, ice, and floating debris. Winds having an average velocity of more than 40 km per hour and lasting from 6 to 10 hours are capable of creating waves from 2 to 3 m high on many portions of the Great Lakes. Some shoreline areas suffer damage from smaller waves as well as from the larger ones.

The possibilities for erosion along ocean shorelines are even greater. For instance, at Minot's Ledge in Massachusetts, waves from severe storms destroyed a lighthouse several times during its construction. In 1851, when the lighthouse was finally completed, waves brought the entire structure crumbling into the sea, killing its two keepers and leaving little evidence that the lighthouse had ever been there.

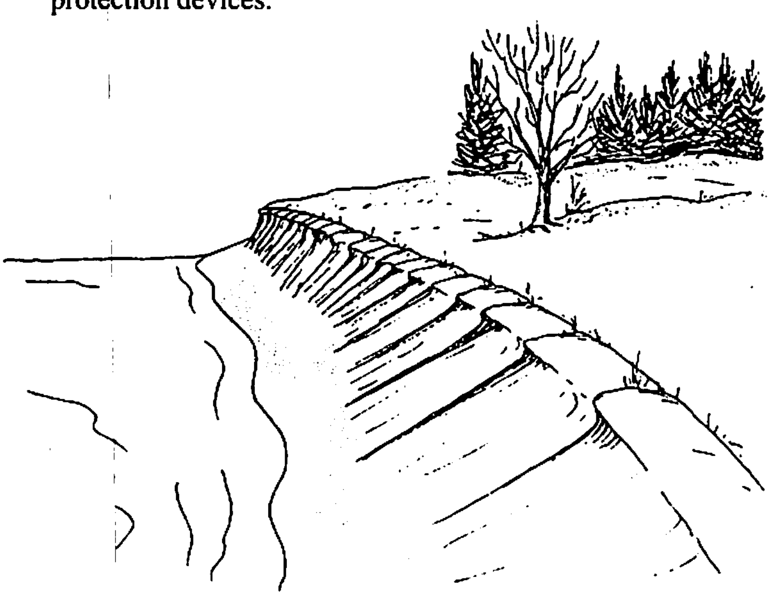
Over 80 percent of Lake Erie's erodible shoreline is privately owned. Therefore, many land owners protect their shorelines. Methods of erosion prevention involve attempts to keep the force of the waves away from the bluffs. Nature protects shorelines by building sand beaches where the waves can break and use up their energy before reaching the bluffs. People can construct devices that duplicate the effectiveness of natural sand beaches.

Erosion cannot be permanently stopped, but construction of the proper devices can slow erosion. What are the devices available to the homeowner and to coastal communities in general?

OBJECTIVES

When you have completed this activity, you should be able to:

- Explain the purposes of the three major categories of shoreline protection devices.
- Consider their effectiveness in preventing erosion.
- Observe differences in the shoreline simulation model from "What causes the shoreline to erode?" by adding shoreline protection devices.



Source

Modified from OEAGLS EP-7, "Coastal Processes and Erosion," by Beth A. Kennedy, Newark Public Schools, Ohio, and Rosanne W. Fortner, The Ohio State University, Ohio Sea Grant Education Program.

Earth System Understandings

This activity addresses ESU 2 (how people decide to best protect shorelines), ESU 3 (using different devices and methods), ESU 4 (Dealing with coastal interactions), ESU 5 (changes in the shoreline over time), and ESU 7 (important decisions made by coastal landowners that sometimes require the expertise of others).

Materials

- Those used in the activity "What causes the shoreline to erode?"
- 2 x 4 board equal to half the width of the lake pan.

Teacher's Note

Using descriptions of the three major types of shoreline protection devices, students should be able to label diagrams of these devices, as shown on the following pages. It may be necessary to review with students the meanings of the terms "parallel" and "perpendicular."

Answers

1. A	4. C	7. A
2. A	5. B	8. A
3. B	6. C	

Procedure Notes

A. An example is a sea wall.
B. Groins are an example of this method.
C. An example of this is a breakwater of piled stone.

Students should find that the sea wall type of device is more effective than the breakwater design in reducing bluff erosion.

Teacher's Notes

The introduction to this activity indicates to students that erosion is a personal problem to coastal land owners. There are ways to redirect the natural forces at work on the shoreline so that the rate of erosion can be slowed.

Part 1 is best done individually or by teams of two to three students. More students may work together on Part 2 of this activity.

This activity deals with methods of slowing the rate of shoreline erosion. Three types of shoreline protection structures and their purposes are discussed. The students examine illustrations of several structures and label them for the type of protection device they represent. Two of the devices are tested in a laboratory experiment similar to the activity "What causes the shoreline to erode?"

PROCEDURE

You will become familiar with various shore protection devices and test their effectiveness with a shoreline simulation.

Part 1

A description of each of the three major methods of shore protection follows. After reading each description, carefully examine the diagrams located at the end of this activity. Label each diagram by letter (A, B, C) according to the method of shore protection that each one shows.

A. One method of shore protection involves the use of concrete, wood, or steel structures built directly against and parallel to the shore. These structures are designed to help keep currents and waves from reaching the erodible shoreline. Some of these structures also serve as docking facilities.

B. A second method of beach protection is the construction of a device perpendicular to the shore and connected to it. This device traps the sand moving with the littoral drift. A beach is formed on the side of the device facing into the current, which is excellent protection against shore erosion.

C. The third method of shore protection is an offshore structure. It usually consists of fairly large stones that are piled away from but parallel to the coastline. The wall of stone reduces wave attack on the shoreline, much as a natural sand bar would.

Part 2

Now you can test the effectiveness of some of these shoreline protection devices:

A. Rebuild the sand bluff at one end of a plastic pan used in the activity "What causes the shoreline to erode?"

B. Put a short section of 2 x 4 firmly up against the bluff to act as a seawall.

C. Repeat the wave-making activity from "What causes the shoreline to erode?" Record the condition of the bluff after 5 waves and again after 10 waves. Put this information in a data table on your work sheet.

D. Repeat Step A above. This time, place the short 2 x 4 in the center of the basin to form a breakwater about 5 cm from the sandy bluff.

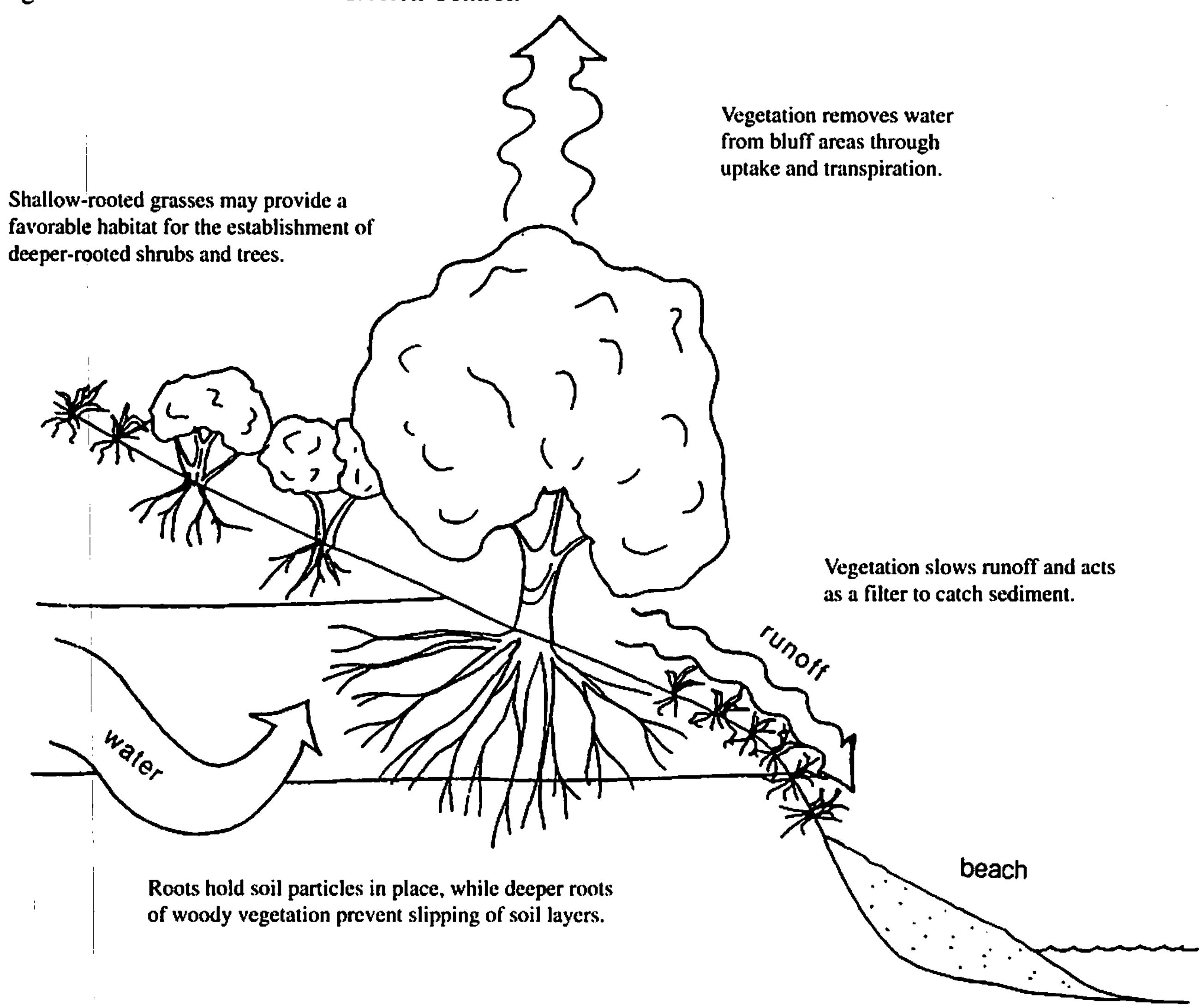
E. Make some waves again, and record what happens to the bluff after 5 waves and after 10 waves.

As you may have observed, the water within your reconstructed sand bluff may have weakened it before wave erosion began. Groundwater and surface streams do the same thing on real lake shores. For this reason, trees, grasses, and shrubs are sometimes planted to go along with some other shore protection device. The life processes of plants remove ground water, the roots hold soil in place, and beach grasses trap sediment to actually help build the beach (Figure 1).

Suggested method

While one group conducts the activity "What causes the shoreline to erode?," a second group can complete this activity. Groups should compare their data to see how the presence of shoreline protection devices affects the results.

Figure 1. The Role of Plants in Erosion Control.



In recent years there has been growing concern about the uncontrolled construction of shore protection devices such as groins, sea walls, and revetments. Many people interested in maintaining and improving the environment are concerned about the placement of multiple protection devices along stretches of the shoreline. Evidence strongly indicates that groins speed up erosion in nearby areas and that seawalls cause shore loss and water turbidity. Some argue, "What harm does a single 50-foot or 100-foot seawall do to the environment?" There are many miles of protective devices added to our shoreline every year, yet the erosive energy of the Great Lakes waves still remains. Its effect is something to be considered, even with protective devices added along the shore.

Answer

F. There are advantages and disadvantages to each of the construction alternatives for shoreline protection. Construction costs, maintenance problems, and beach changes associated with some devices make them unsuitable for use by private landowners. Legal responsibilities to owners of adjoining land may also be factors in determining which shoreline protection method is used.

F. What is the long-term and the cumulative effect of these structures?

Review Questions

1. Briefly describe the three major methods or categories of shoreline protection devices and discuss how they work to protect the shore.

2. If you had a beach cottage, which type of device would you build to protect your section of shoreline? Explain your choice.

3. Would it be advisable to construct shore protection devices along all sections of the Great Lakes shoreline? Would it be possible? Explain.

If further investigation about effects of shore protection devices is desired, you may wish to use a stream table. Studies of the effect of groins in trapping sediment, filling in of sediments behind breakwaters, and formation of spits can be made using the guidelines of a reference such as Fisher Scientific's *Stream Table Laboratory Manual*. This can be ordered (product # S451391) from Fisher, 485 S. Frontage Rd., Burr Ridge, IL 60521. Phone: 1-800-955-1177. You may want to investigate their Internet site: http://www.fisher1.com/.

Extensions

1. Assume you own a waterfront home being threatened by erosion. Make a list of questions you should try to answer before you attempt to control the erosion. Then identify the professions of the people you would consult to find answers. Remember that there are legal, economic, and social issues involved in the problem, not just science and engineering.

2. Who should be involved in decisions about whether or not to use protection devices on public beaches or on privately owned beaches? Select one Great Lake and do research on how states and provinces coordinate coastal planning efforts that may encompass several geographic regions?

3. Global change is predicted to lower water levels in the Great Lakes. How would erosion concerns change with the advent of global climate change? If storm events were to increase as predicted, do you think this would offset possible improvement in coastal areas with lowered water levels?

REFERENCES

Bascom, Willard. 1980 revised and updated. *Waves and Beaches: the dynamics of the ocean surface*. Garden City, NY: Anchor Press, 366 pp.

Carter, Charles H., et. al. 1987 *Living with the Lake Erie Shore*. Durham: Duke University Press. Sponsored by the National Audubon Society. As a reference book on coastal processes, it includes relevant photographs and diagrams.

Sanko, Peter. *Shoreline Protection Guide for Property Owners*. Albany, NY: New York Sea Grant Advisory Service.

Shoreline Erosion: Questions and Answers. Ann Arbor, Michigan: Michigan Sea Grant. MICHU-SG-85-511.

Stream Table Laboratory Manual. Fisher Educational Materials, 485 S. Frontage Rd., Burr Ridge, IL 60521.

Understanding, Living With & Controlling Shoreline Erosion: A Guidebook for Shoreline Property Owners. 1995. Doug Fuller, Water Quality Technician. Tip of the Mitt Watershed Council. Project funded by a grant from the U.S. EPA through the Great Lakes Commission's Great Lakes Basin Program for Soil Erosion and Sediment Control.

Copies can be obtained for the cost of postage from Tip of the Mitt Watershed Council, P.O. Box 300, Conway, MI 49722. Phone: (616)347-1181

USACE. *Low Cost Shore Protection: A Property Owner's Guide*. This publication focuses on structures used to slow erosion. Guides are also available for government officials, engineers, and contractors.

To obtain reports, mail request to: John G. Housley, Section 54 Program, U.S. Army Corps of Engineers, USACE (DAEN-CWP-F), Washington D.C. 20314

Additional Notes

"Positive measures to control erosion depend on the type of shore in need of protection and the way you want to use the property. Marshes are best served by protecting the existing vegetation and restricting traffic. Beaches may be protected or enhanced by filling or by constructing retaining sills, breakwaters, or groin fields. Accelerated beach erosion usually associated with bulkhead and seawall construction make these measures most suitable for areas where the shore uses (such as boating) require deeper water or where steep bluffs are already severely threatened. Revetments protect sloping backshore areas and have a somewhat less erosive effect on the existing beach." (U.S.ACE, 1996)

U.S.ACE Addresses

U.S. coasts of Lakes Superior, Huron, and Michigan (Lake Michigan coasts of WI, MI, and IN only), and U.S. Coast of Lake St. Clair: U.S. Army Engineer District, Detroit
Attention: NCEED-L
P.O. Box 1027
Detroit, MI 48231
(313)226-6791

Lake Michigan Coast of Illinois
U.S. Army Engineer District, Chicago
Attention: NCCPE-HS
219 South Dearborn Street
Chicago, IL 60604
(312)353-0789

U.S. Coasts of Lakes Erie and Ontario
U.S. Army Engineer District, Buffalo
Attention: NCBED-DC
1776 Niagara Street
Buffalo, NY 14207
(716)876-5454 ext. 2230

Teacher's Notes

You might introduce the investigation by using the film, *The Beach: A River of Sand*, from the AGI Earth Science Series, available through Encyclopedia Britannica Films, Inc. 425 North Michigan Avenue, Chicago, Illinois 60611. The film can serve as an excellent introduction or conclusion to this activity. It illustrates how beaches are built and destroyed by waves, how longshore transport functions, and how groins and breakwaters affect the shoreline. The film effectively illustrates the development and effects of longshore currents on shorelines, and some of the problems created by harbors and other features that interrupt the littoral drift.

Locate the U.S. Army Corps Divisions in the Great Lakes on-line. Explore activities of the district nearest you: Buffalo, Chicago, Detroit, Rock Island, and St. Paul.

U.S.ACE Low Cost Shore Protection Publications On-line
http://sparky.nce.usace.army.mil/shore.protection/lcsphmpg.html
Investigate different methods of low cost shore protection such as:

Erosion	Vegetation	Beach Fill	Perched Beaches
Breakwaters	Groins	Revetments	Bulkheads
Seawall	Combination Methods	Considerations	Information

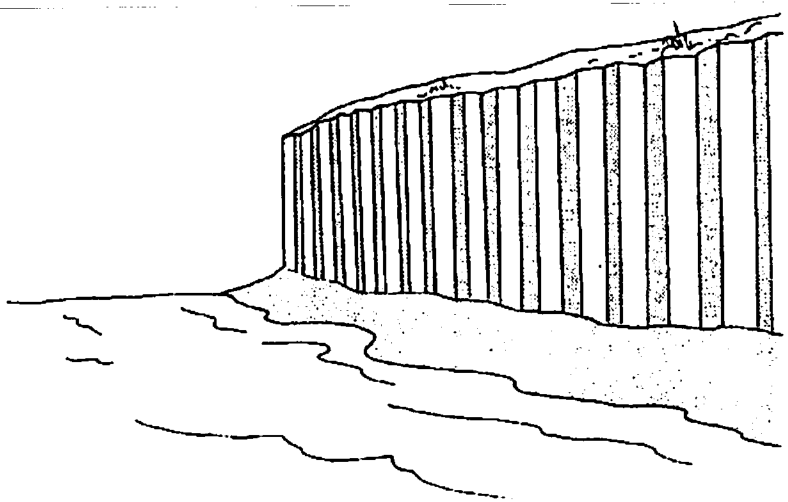
Vegetation and Its Role in Reducing Great Lakes Shoreline Erosion: A Guide for Property Owners. Ann Arbor, MI: Michigan Sea Grant. MICHU-SG-88-700.

Name ____________________

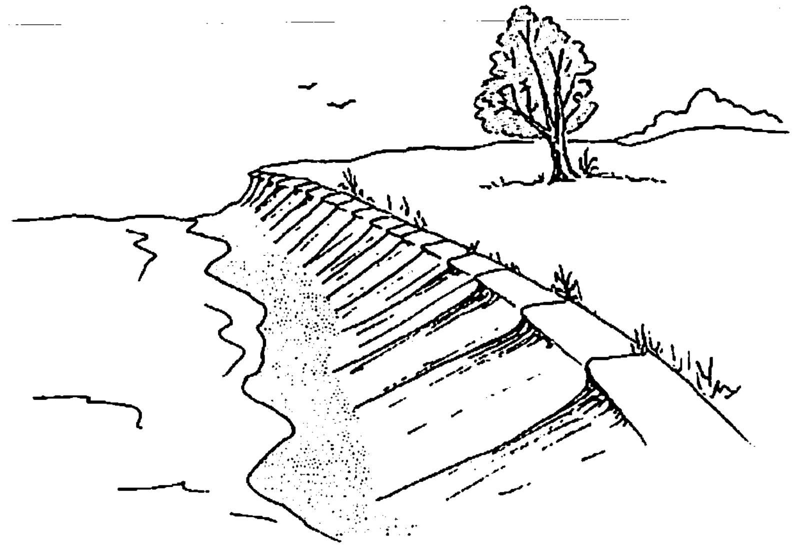
Can erosion be stopped?
Worksheet

Effects on Bluff

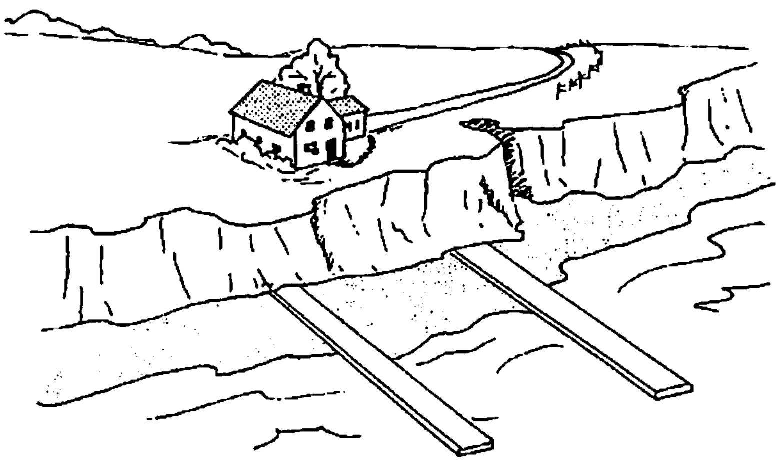
	Number of Waves	Behind Seawall	Unprotected
Seawall Effects	5		
	10		
		Behind Breakwater	Unprotected
Breakwater Effects	5		
	10		



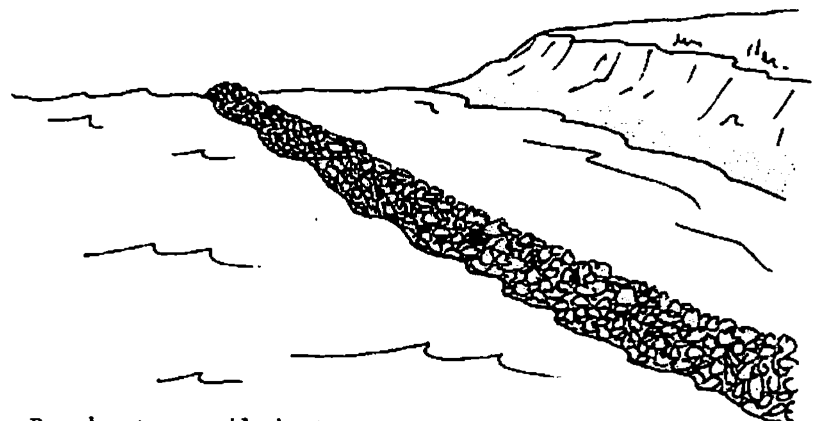
Sea Wall: sheet pile



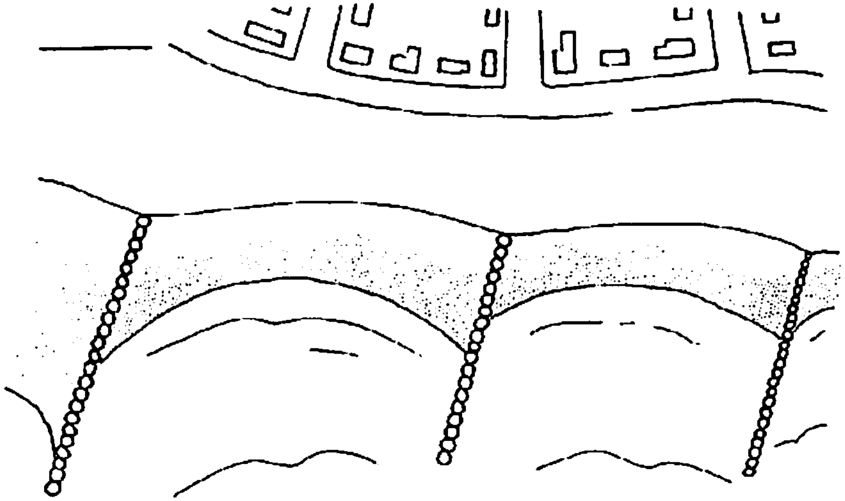
Sea Wall: cement



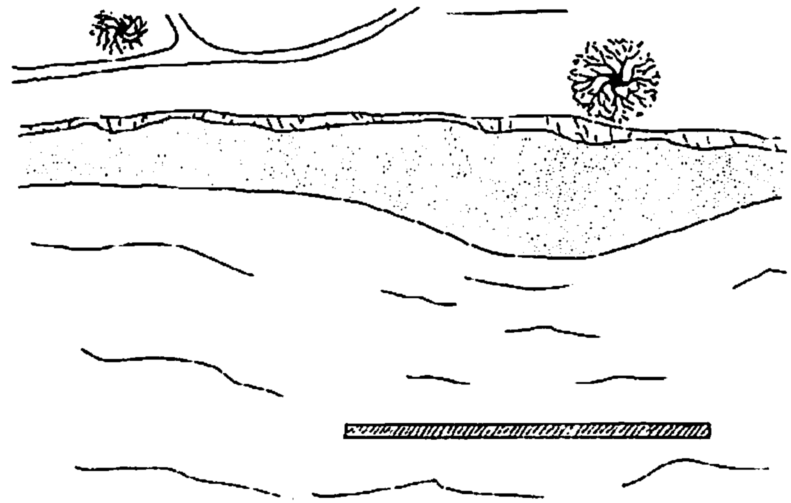
Groin: cement



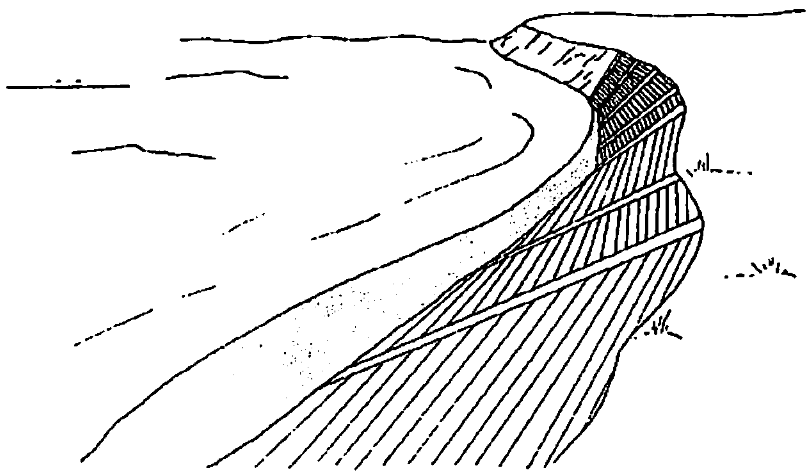
Breakwater: piled stone



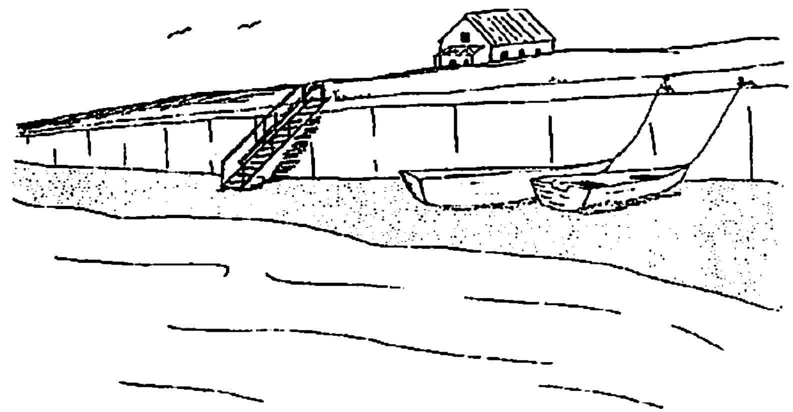
Groins: sheet pile



Breakwater: steel pile



Stepped Revetment



Sea Wall: Concrete

How fast can a shoreline change?

Shoreline and bluff erosion has been identified by shoreline residents as a critical problem along some parts of the Great Lakes. Land losses of up to 10 feet per year have been estimated for some areas. Property damage totals millions of dollars. Land loss and property damage are caused by the conflict between natural forces and human activity along the shoreline.

Ohio's Lake Erie shoreline consists of wetlands, low bluffs, and gently sloping shore in the western one-third of the state and glacial till and soft shale bluffs in the eastern two-thirds of the state. The rate of shore erosion is affected by the kind of land and rock materials and the use of protective structures.

Objectives

When you have completed this investigation, you will be able to:

- Recognize some shoreline features on aerial photos.
- Observe changes in a shoreline over time.
- Observe the effects of shoreline devices on rates of erosion.

Materials

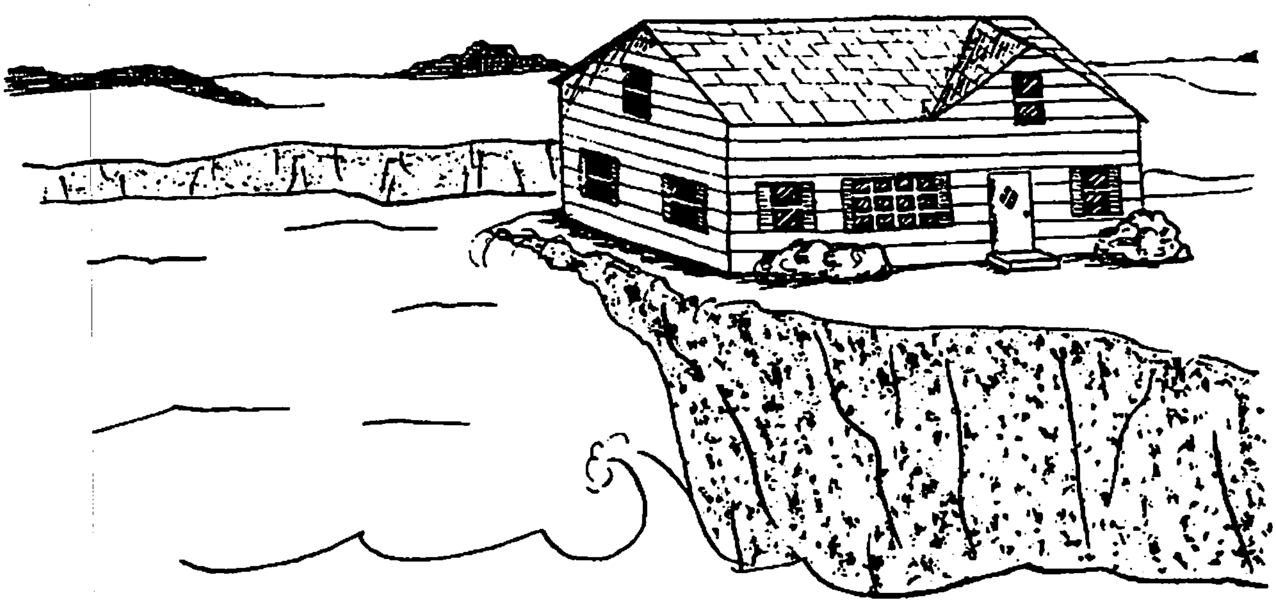
- Ruler.
- Tracing paper.
- Pencil and colored pencils.
- Paper clips.
- Aerial photos of Painesville Township Park.

Source

Modified from OEAGLS EP-6, "Erosion along the Great Lakes," by Beth A. Kennedy, Newark Public Schools, and Victor J. Mayer, The Ohio State University.

Earth Systems Understandings

This activity considers the effects of erosion protection devices on shorelines, ESU 2 (stewardship) and ESU 3 (science methods and technology) and ESU 4 and 5 (analyzes observable changes resulting from coastal processes over time).



Suggested Approach

You might introduce the investigation by using the film, *The Beach: A River of Sand*, from the AGI Earth Science Series, available through Encyclopedia Britannica Films, Inc. 425 North Michigan Avenue, Chicago, Illinois 60611. The film effectively illustrates the development and effects of longshore currents on shorelines, and some of the problems created by harbors and other features that interrupt the littoral drift.

For those schools along one of the Great Lakes, a field trip would be an effective follow-up to the investigation (i.e., Carter, 1973, describes locations along Lake Erie where the effect of erosion processes can be observed).

Answers

1. Students should observe the groins at the center of the photo, the sand beaches to the west, and the slumping bluffs to the east of the groins.

2. In the second photo, the beach has largely disappeared, and the bluffs have retreated southward. A part of the highway has been removed as well as several buildings.

3. Additional erosion has taken place, as noticed for example in the area to the east of the groins.

4. There are six rather prominent groins. In the 1954 photo, students may see several other small structures built out from the beach. These may be small groins or perhaps piers. Of the three largest groins, one has become very faint in the 1973 photo. Other groins seem to have disappeared. They have been submerged by the higher lake level. The general level of the lake increased over the decade from 1960 to when the 1973 photo was taken. This is the major reason that the beach is not as wide and that the groins seem less prominent. In the 1981 photo, two groins are recognizable with the other appearing faint.

PROCEDURE

You will be studying a portion of the Lake Erie shoreline in Lake County, Ohio. You will determine how fast erosion has occurred in the area and how much sand and clay has been removed by the waves and currents of the lake.

You will be using photographs taken from an airplane flying over the area at three different times, one in 1954, one in 1973, and again in 1981. The photos represent the same area of the shoreline. When using the photos, be sure that the large area of water (Lake Erie) is at the top of each photo. Then it will be oriented just like a map. The top will be north; the left side of the photo, west; and the right side, east.

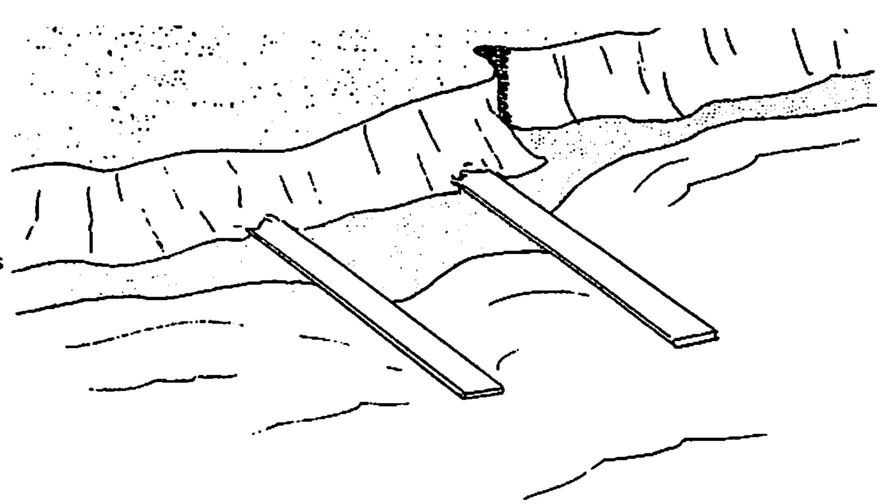
1. Examine the 1954 photo. Describe the shoreline.

2. Now examine the 1973 photo. How has the shoreline changed? What features have been destroyed?

3. View the third photo from 1981. What changes do you see?

You should have noticed some straight objects jutting out into the water in the west central part of the photos. These are **groins**. They are structures designed to protect the shoreline by trapping sand.

4. How many groins are there in the 1954 photo? In the 1973 and 1981 photos?



5. Cover the 1954 photo with a sheet of tracing paper and secure it with paper clips.

6. Starting 1 inch in from the left border of the photo, draw 8 parallel N-S lines at one-inch intervals. Label the lines A through H starting at the left line.

7. Using a pencil, trace the base of the bluff on the paper. Label this line "1954."

8. Now draw in and label the groins.

9. Outline two or three major road intersections. These will help you to position the paper on the other photo.

10. Now place the tracing paper on the 1973 photo. Match the road intersections.

11. Using a different colored pencil, trace in the base of the bluff. Label this line "1973." Draw in and label the groins.

12. Notice that you have two different shorelines. Lightly shade in the area between the two shorelines.

13. Why are there two different shorelines?

14. What does the shaded area between the two shorelines represent?

15. What differences do you note between the area of shoreline east of the groins and that to the west of the groins?

16. What caused these differences?

17. Repeat the same procedure with the 1981 photo, comparing it to the 1973 photo. Note that the time elapsed between the 1954 and 1973 photos is more that twice that between 1973-1981. Observe the rates of erosion to see if there is a related relationship to time, i.e., did twice as much erosion take place between the first two photos as between the latter two? How can you tell?

Answers

5. The base of the bluff is used as an indicator of the position of the shoreline. The beach itself varies considerably in size because of normal processes such as longshore currents and periodic changes in lake level. It, therefore, is not a good indicator of the position of the shoreline.

6. For questions 6-12, see Appendix A. The scales of the two photos are not exactly the same. Therefore, students will not be able to get a perfect match on road intersections. But they can match close enough to get a good idea of the changes that have occurred to the shoreline.

13. The two shorelines are the result of erosion processes and the consequent retreat of the shoreline to the south. ONE CAUTION; LINE A WILL CROSS A CLAY PIT. On the 1973 photo, clay has been removed to the beach. Therefore, there is a broad white stretch on the photo. Students may interpret this as cliff recession.

14. The shaded area represents land removed by erosion.

15. A greater amount of erosion has taken place to the east. Because of the presence of the clay pit, students may not arrive at this conclusion. You should discuss this with them.

16. The groins protected the portion of the shoreline they were connected to. The new beaches, once formed, provide a place for waves to expend their energy. This energy is not used to erode the upland areas; consequently, the recession rate of the shoreline is considerably reduced. Beyond the groins on the downcurrent side, currents will pick up a new load of sediment, and there will be more erosion than occurring upstream of the groins.

Between 1954 and 1973, a portion of the shoreline eroded away. Between 1973 and 1981, an additional amount was removed. Shore erosion occurs through the combined effects of waves and currents. Waves, especially during storms, will attack the bluffs along the shore, causing them to collapse. Currents moving along the shore will pick up the sediments and carry them away. These currents flow in a predominant direction. Any obstruction will trap the sediment carried by the currents on its upcurrent side (the side from which the current is coming). On the downcurrent side of the obstruction, the currents will pick up a new load of sediment. Because of these processes, the groins slow down erosion upstream and cause additional erosion downstream.

18. In what direction do the currents along this section of the shore move?

Answer

18. Groins will cause deposition on their upcurrent side, and increased erosion on the downcurrent side. Therefore, it appears that the predominant direction of the longshore currents is from west to east.

You have heard that "energy can neither be created nor destroyed." As wave energy is taken in by the shoreline, the shore deposits are changed. Energy is transformed from the wave to the shore.

EXTENSIONS

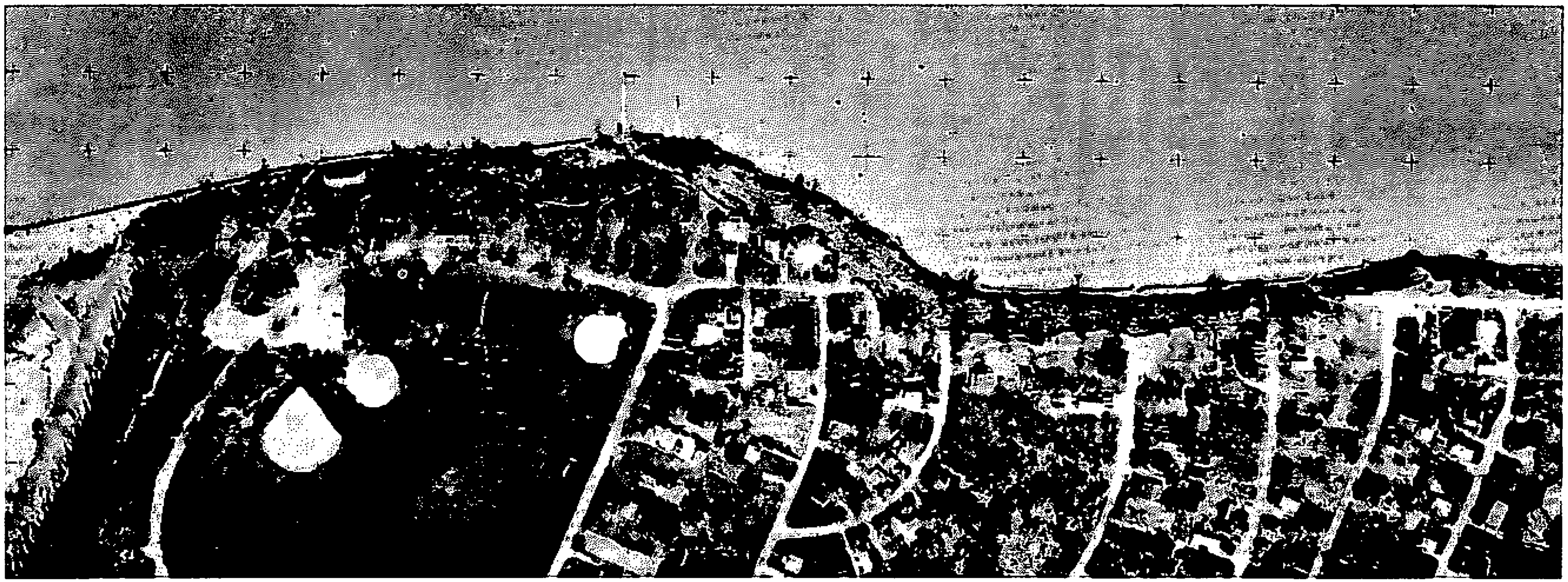
1. How do you think lake shoreline erosion is different from inland erosion, as into a stream or river? Which do you think is more costly in economic terms? Which is more critical in environmental terms? How could erosion affect water quality and activities along a shoreline such as fishing and swimming? Offer a discussion of different perspectives to support your answer.

2. Refer to the activity "How well do you know the Great Lakes?" Determine the density of population per Great Lakes shorelines. On which lake would you assume population density to have the most impact regarding erosion? On which the least?

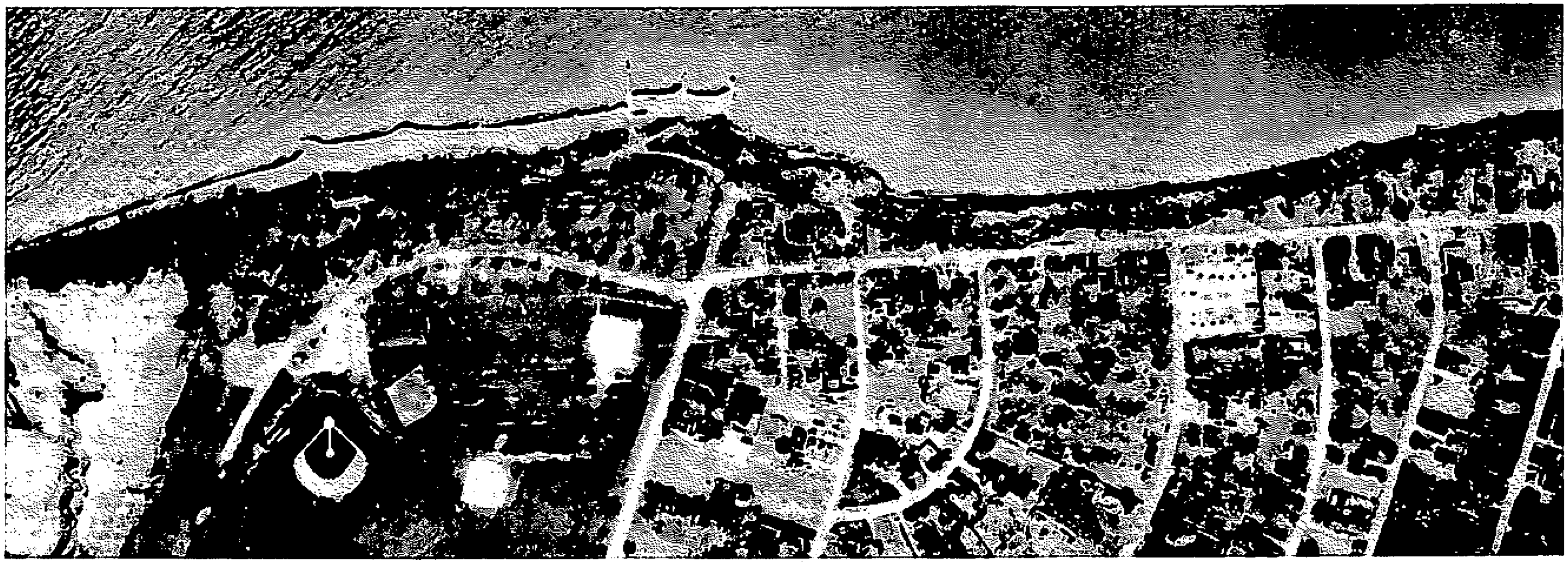
Teacher's Note

For the second extension activity, refer to the Great Lakes Atlas for land use and erosion maps. Note the erosion of shoreline areas near large cities.

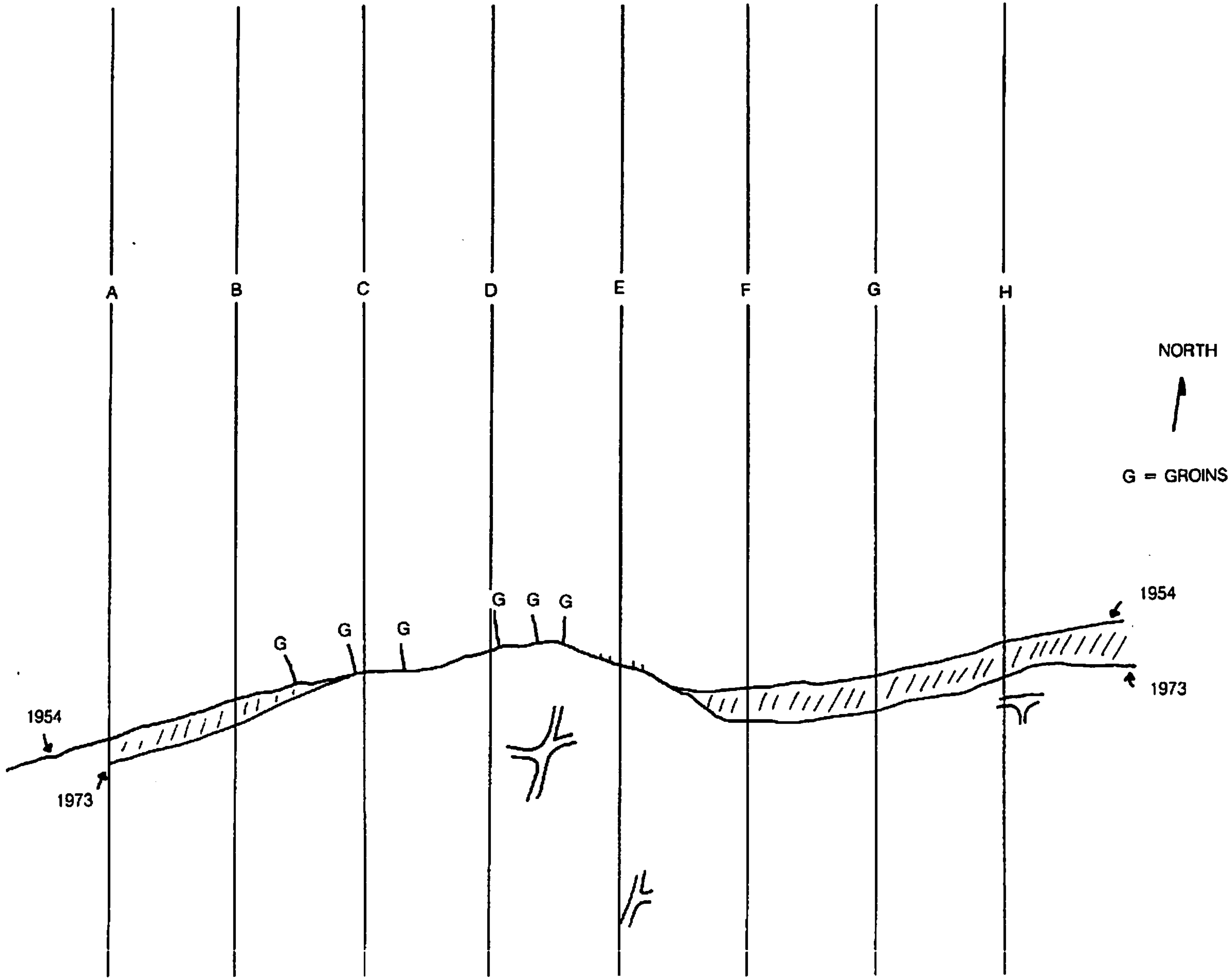
Painesville, 1973



Painesville, 1954



Appendix A.
Teacher's Page: Example of student comparison of 1954 and 1973 photos.



11

How much land has been lost?

We might wonder exactly how much land is lost with erosion. It is easier to see surface changes than to perceive actual amounts in terms of volume. Analytical techniques allow us to calculate the amount of land lost through erosion.

OBJECTIVES

You will use aerial photos to:

- Calculate the amount of material eroded from a portion of shoreline.
- Estimate an average rate of recession for a section of shoreline.
- Consider possible economic effects associated with changing shorelines.

PROCEDURE

In this investigation, you will actually calculate the amount of land surface lost to erosion and the volume of material that made up that land. You will measure the change from 1954-73 and then 1973-81.

1. Use your map of the three shorelines from the activity "How fast can a shoreline change?" and begin with the years 1954 and 1973. With the following scale measure the distance between the two shorelines along each of the lines A through H. Enter your measurements in Line Q of the worksheet.

0 — 400

1 inch = 400 feet

2. Lines A through D are west of the groins. Average the distances for these four lines and enter them in line R. Now determine the average distance between shorelines for the remaining four lines and enter it in the worksheet.

You are now ready to determine the **recession rate** for this section of shorelines. The recession rate is the average distance the shoreline has been eroded away per year.

3. Divide each average distance in Line R by 19 years, the length of time between the taking of the two photos for 1954 and 1973. For the difference between 1973 and 1981, divide by 8. Enter in line S.

Source

Modified from OEAGLS EP-6, "Erosion along the Great Lakes," by Beth A. Kennedy, Newark Public Schools, Ohio, and Victor J. Mayer, The Ohio State University.

Earth Systems Understandings

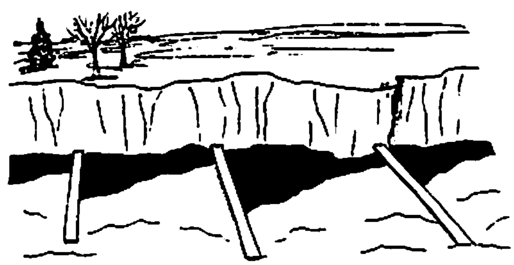
This activity uses scientific methods to calculate the amount of land lost by erosion. It addresses ESU 2 (stewardship), 3 (science methods and technology), 4 (interactions), and 5 (change through time).

Materials

- The chart traced from the photos in the activity "How fast can a shoreline change? (Appendix A)
- Graph paper (10 squares per inch).
- Topographic map of Perry, Ohio.

Answers

1-3. See Appendix A, completed worksheet. Use the top of the bluff line, which gives you a more accurate idea of the recession rate.



4. Which part of the shoreline, western or eastern, has a higher recession rate? Describe what this means. Where would you prefer to own shoreline property?

5. Place your map over the piece of graph paper provided by your teacher. Locate the easternmost of the two prominent groins appearing on the 1973 photo. Count the number of squares in the shaded area to the east of the groin and enter in line T. Also, count the number of squares to the west of the groin and enter on line T.

6. Each square represents 160 square feet of surface area. Calculate the total surface area eroded away and enter in line U.

To determine the total volume of material removed, you will need to know its depth as well as its surface area. The depth of material will be roughly equivalent to the average height of the bluffs. To determine this, you will need a copy of the Perry, Ohio, quadrangle.

7. Determine the area of a typical lot on the air photo. Divide that into the value on line U. This is the number of lots or yards that have been removed.

8. Locate Painesville-on-the Lake. This is the same area represented on the air photos. Note that the contour lines are closely spaced along the shore at Painesville-on-the-Lake. They represent the bluffs. The highest close-spaced contour represents the top of the bluff.

9. Determine the elevation of the lake. Record it on your worksheet.

10. Determine the elevation of the bluff just west of Hardy Road.

Subtract the elevation of the lake from that of the bluff and enter the difference on line V of the worksheet.

11. Now determine the elevation of the bluff to the east of Hardy Road.

Answers

4. The eastern part has the higher recession rate. This means that the bluffs retreat southward more rapidly in this area. The best place to own shoreline property would be behind the groins, because that is where the recession rate is the least. Again, students might not get the expected results because of the presence of the clay pit (refer to question 13 in the activity "How fast can a shoreline change?").

5. Students will have to use their judgment in counting the squares. It is easiest if they align the shoreline with a line of the graph paper.

6. See Appendix B.

9. On the 1992 revised map, the approximate mean lake elevation is 571 feet.

10. To the west of Hardy Road, the contour lines at the top of the bluff are confusing. However, it appears that the elevation of the top of the bluff is 610 or 620 feet. The answers your students give on lines V and W will vary according to the elevation that they select for the bluffs.

11. The elevation is 600 feet.

Subtract the elevation of the lake and enter the difference on Line V.

12. Calculate the total volume of material removed by erosion by multiplying the average height of the bluffs times the total surface area removed. Enter in Line W.

13. Determine the volume of your classroom. Divide this value into the value on Line W. The result will be the number of volumes equal to your classroom removed by erosion.

14. Determine the average yearly loss of material by dividing the total volume removed by 19 or 8 years as appropriate. Enter on Line X.

15. Repeat the procedure for 1973-1981.

From this investigation, you have learned that a portion of the Great Lakes shoreline, specifically on Lake Erie, is retreating southward at a fairly rapid rate. It may surprise you to find out that this is occurring throughout the lake.

What evidence of erosion can you find on your section of the Great Lakes?

The rate of recession will vary according to the hardness of the materials. Near Marblehead in Lake Erie, for example, the rate is barely noticeable. Marblehead has limestone exposed in the bluffs along the lake. The shoreline on the northern side of Lake Erie is retreating at a more rapid rate than in the Perry area, but northward. In a sense, then, Lake Erie is getting bigger. What happens to all the material that has eroded? Most of it eventually ends up filling in the deeper basins of the lake.

Lake shorelines are not the only shores that erode. The seacoast also erodes. The same processes, wind, and currents are involved, and the same protective structures are used. As you have seen, groins are effective in treating some local problems on a temporary basis. Although they do not offer a permanent solution to erosion problems, they may provide the extra time needed for other measures to be taken.

EXTENSION

Observe the following shoreline changes of Racine County, Wisconsin on Lake Michigan. Determine a method to measure the amount of shoreline removed by erosion.

Answer

12. See Appendix B.

The following paragraph from Willard Bascom's *Waves and Beaches* describes how groins may be helpful in preventing seacoast erosion.

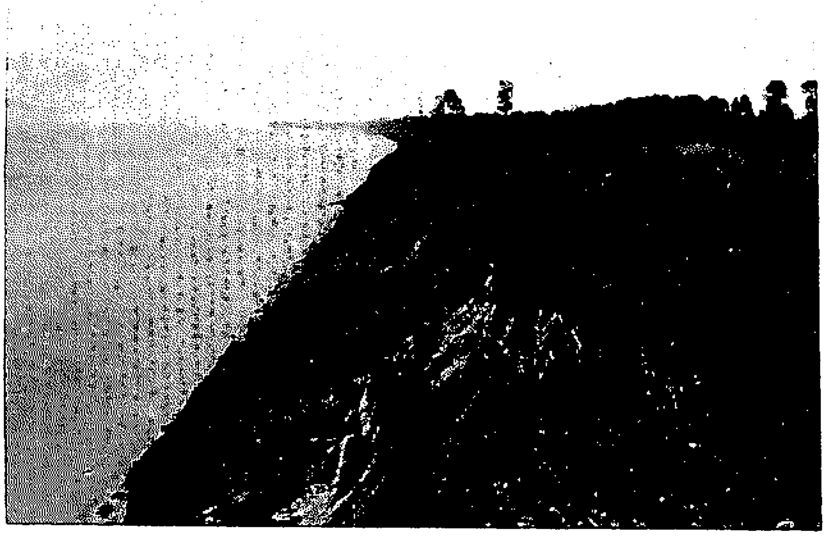
There is an instance in which a ship saved a lighthouse, instead of vice-versa. In 1883, the Cape Henlopen light on the Delaware coast was in imminent danger of being undermined by the sea. The high-water mark reached around the base and various emergency protective actions were being considered. Then, in a storm the Minnie Hunter was driven ashore, grounding about 500 feet north of the lighthouse. The wrecked ship immediately acted as a groin which dammed the coastal flow of sand and replaced the beach in front of the light so that the structure survived for many more years.

Site 2D-North 12/3/81

4/1/82

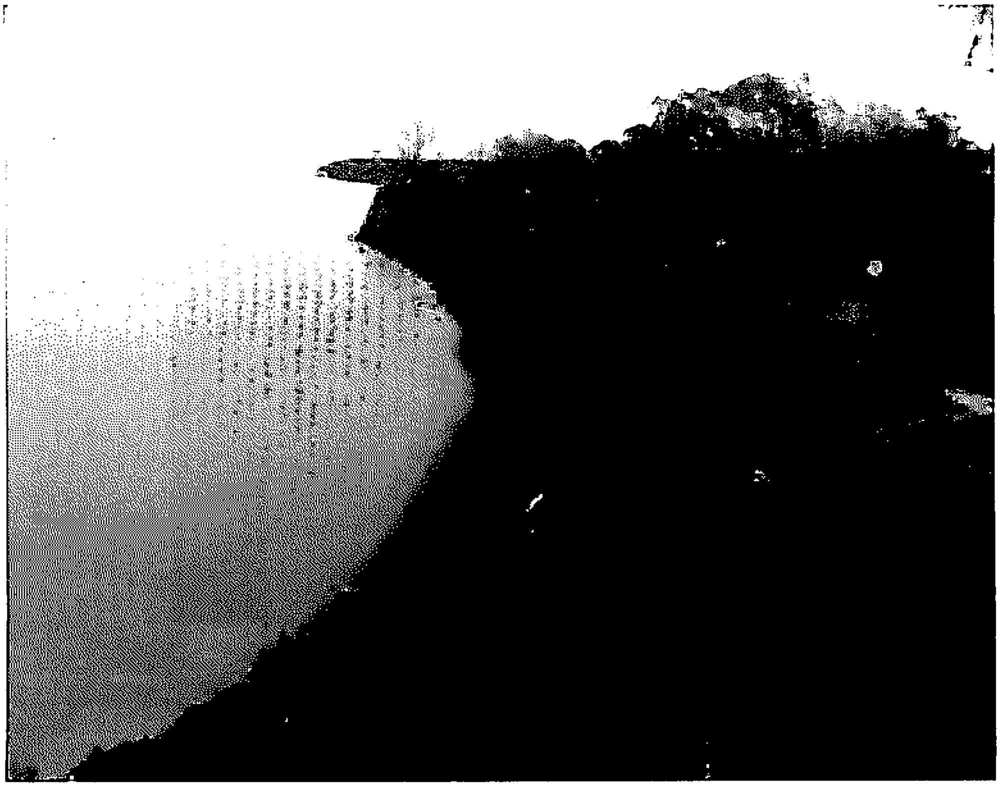
Site 2D – North: "Note the large slump that is broken into three major pieces in photo 12/3/81. . . Photo 4/1/82 shows the remains of the slump failure. It is evident that the supporting soil of the slump block partially disintegrated, resulting in the downward movement of the slump. Also note the development of bluff overhang above the slump in photo 4/1/82. This overhang is not significant in photo 12/03/81. The remaining loose soil material above the slump is a remnant of the supporting soil structure before crumbling away resulting in bluff overhang. . . (T)he scalloped shaped bluff edge in photo 12/3/81 is becoming more bowl-shaped in photo 4/1/82 Several slump events ranging from 4 feet by 2 feet to 75 feet by 10 feet have been observed at this location. In general, the bluff slope shown in photo 4/1/82 is becoming steeper." (Racine County Coast Watch Program Final Report, 1982, p. 85)

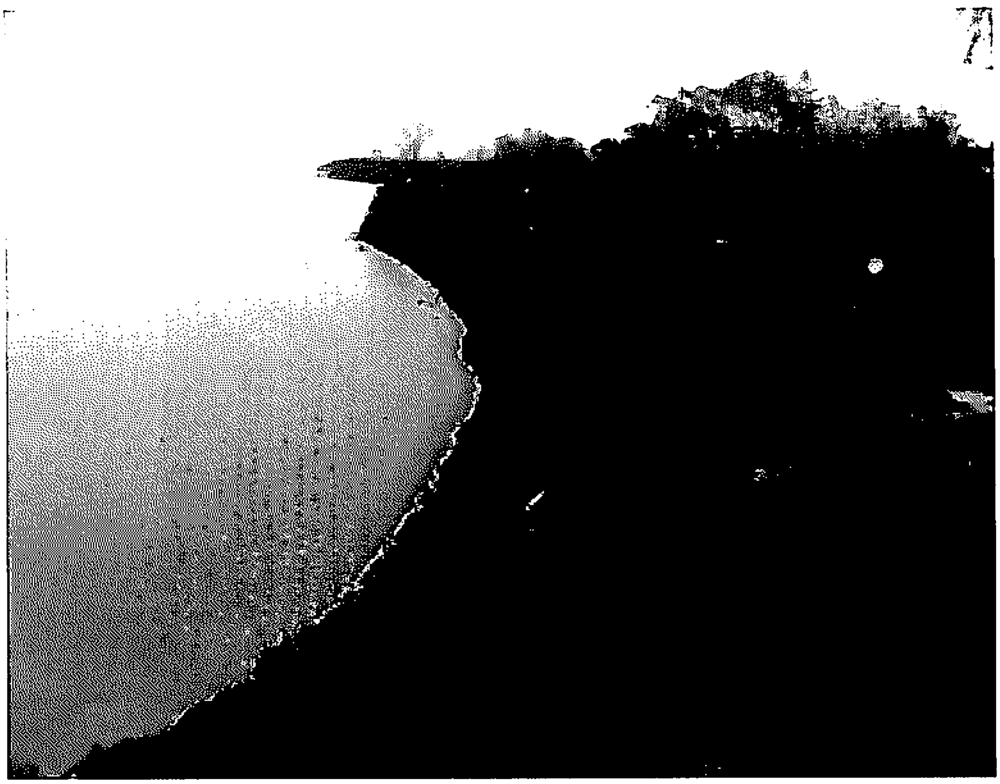
Site 1C-South 8/1/80



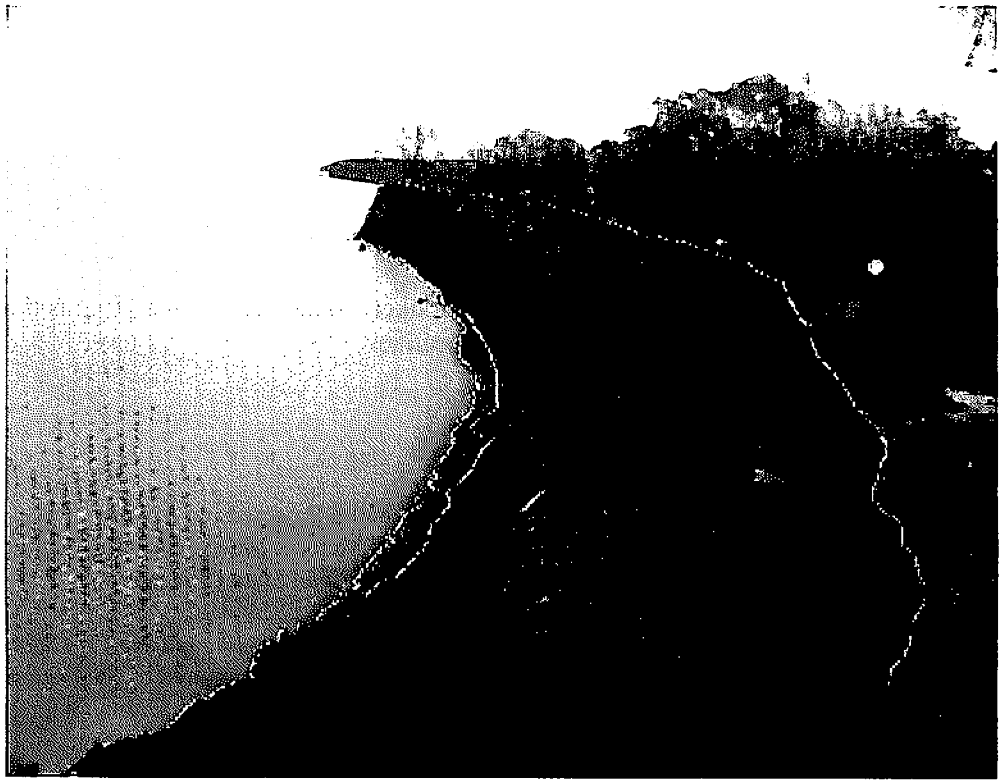
5-14-82

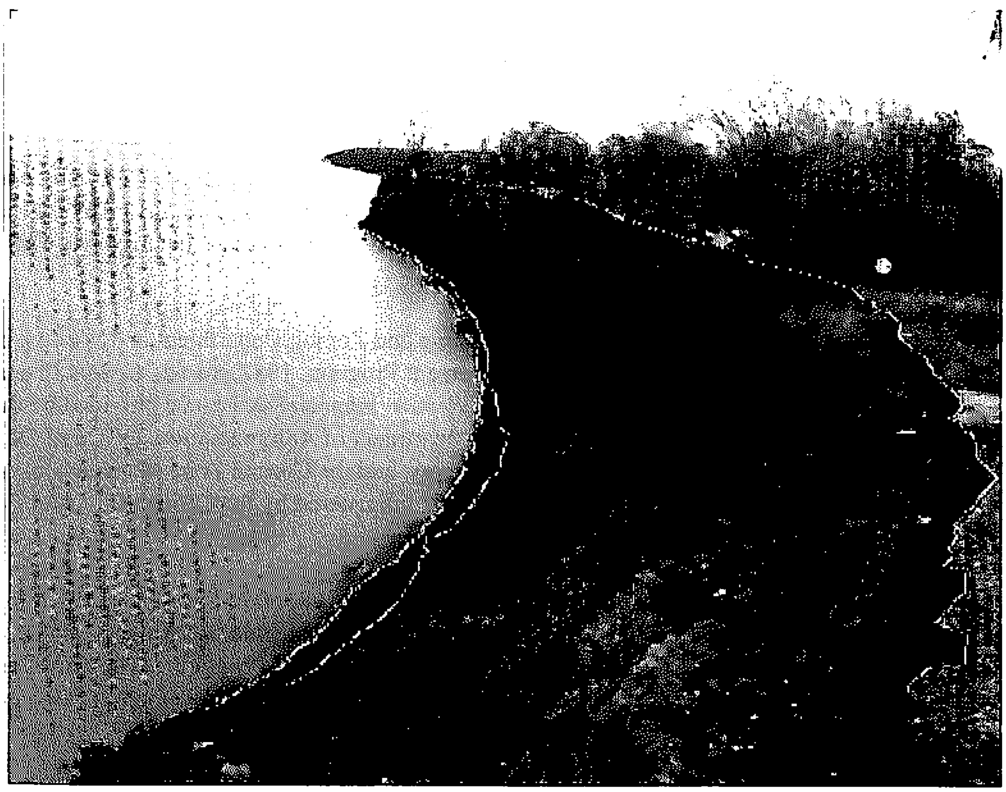
Site 1C – South: "Photo 8/1/80 shows that the bluff edge was "scalloped" shaped and the bluff slope was steep. This site is subjected to wave attack that erodes the solid material from the bluff toe. . . . Photo 5/14/82 shows large slumps that detached from the bluff edge and slid down the bluff face. Recorded observations indicated that slump pieces vary greatly in size and range from 1 x 1 foot to 50+ feet long and 12 feet wide. The bluff edge has changed from the scalloped shaped to a bowl-shaped retreat. . . . The major slumps occurred over a 4-month time period in 1982." (Racine County Coast Watch Program Final Report, 1982, p. 83)





The above photographs are examples of remote video monitoring of the shorelines you have examined in this activity. Investigate more images of Lake Erie and at other sites by exploring the Internet address http://stimpy.er.usgs.gov.





Additional Suggestion: A similar "video" can be designed with a site near your school. Find a place where you can observe shoreline changes or sand bar movement or stream level changes. Take photographs at successive times over several months. Display the photographs on a poster or digitize them to make a movie.

Additional Background Information

The techniques used in this activity to determine the rate of recession and the amount of materials lost through beach processes are adapted from the techniques used by professional geologists.

Painesville (on-the-Lake) is located along the shore of the central basin of Lake Erie. Here the prevailing southwesterly winds have a fetch (straight-line distance crossing a body of water) over the lake and, therefore, cause longshore currents that have a net easterly movement. In the western part of the Lake Erie Basin, however, such as in the area of Sandusky, these winds at the shore blow only from over the land, and there is little if any fetch. The occasional northeasterly storms, then, are the major cause of longshore currents, especially because of the long fetch that they have over the lake. As a result, the net movement of longshore currents on the southern shore in the western basin is in a westerly direction.

Review Questions

1. Describe how you would determine the recession rate of a section of the Atlantic Coast?

2. How would you determine the amount of material removed from a section of the Atlantic coast?

3. Describe what is likely to happen when a groin is built along a section of shoreline.

References

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Carter, Charles H., et. al. 1987. *Living with the Lake Erie Shore.* Durham: Duke University Press. Sponsored by the National Audubon Society. This is a reference book with photographs, diagrams, and relevant information about coastal processes, shoreline protection, and coastal zone management.

Carter, C.H. and W.S. Haras. 1985. Great Lakes. In: E.C. Bird and M.L. Schwarz, eds., *The world's coastline.* New York: Van Nostrand Reinhold.

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U.S. Army Corps of Engineers. 1981. *Low Cost Shore Protection: A Property Owner's Guide.* Philadephia, PA: Rogers, Golden and Halpern, Inc. Contact: Section 54 Program, U.S. Army Corps of Engineers, USACE (DAEN-CWP-F), Washington D.C. 20314

Worksheet

Names in Group:

Shoreline Changes 1954-73

	West A	B	C	D	East E	F	G	H
Q: Distance								
R: Average Distance Q/4								
S: Recession Rate R/19								
T: Squares								
U: Surface Area T x 160 sq ft								
V: Cliff Height								
W: Volume U x V								
X: Yearly Loss W/19 yr								

Shoreline Changes 1973-81

	West A	B	C	D	East E	F	G	H
Q: Distance								
R: Average Distance Q/4								
S: Recession Rate R/8								
T: Squares								
U: Surface Area T x 160 sq ft								
V: Cliff Height								
W: Volume U x V								
X: Yearly Loss W/19 yr								

Appendix B. Completed worksheet example.

	West A B C D	East E F G H
Q: Distance	90 ft + 75 ft + 0 + 0 = 165 ft	0 + 100 ft + 120 ft +125 ft = 345 ft
R: Average Distance Q/4	41.25 ft	86.25 ft
S: Recession Rate R/19	2.2 ft/yr	4.5 ft/yr
T: Squares	25	90
U: Surface Area T x 160 sq ft	4,000 sq ft	14,400 sq ft
V: Cliff Height	40 or 50 ft	30 ft
W: Volume U x V	160,000 cu ft	432,000 cu ft
X: Yearly Loss W/19 yr	8,421 cu ft/yr	22,737 cu ft/yr

What natural wonders of the Great Lakes relate to land and water interactions?

Like the ancient world around the Mediterranean Sea with its Seven Wonders, the Great Lakes are home to many amazing places and things. Included with this activity are descriptions of Seven Natural Wonders. There is one group for each of the five lakes. While these lists were constructed after examining many books and magazines and after visiting many places around the lakes, they are nonetheless subjective. The wonders vary in size; some are clearly defined places, while others are general areas. They also vary in accessibility. The Great Lakes boast many interesting natural locations. Students will work in groups to examine some of these sites.

Objectives

Students will work in groups to:

- Become familiar with some natural places of interest in the Great Lakes.
- Consider the criteria a person or group would use in selecting a place to visit.
- Make group decisions through discussion and consensus.

Procedure

1. Divide into five client groups and five expert groups, one for each of the Lakes. Each person should belong to one of each type of group.

2. Each expert group takes the role of a travel agency. The group comes to a consensus about how best to market their Lake, by learning more about a specific natural area, designing a Lake tour package, brochure, etc. and deciding how to present their ideas to the class and/or to client groups.

3. They can find additional information throughout this set of activities to describe the natural area more fully, i.e., how geologic time and glaciers helped to produce Kelleys Island Glacial Grooves and Niagara Falls. The library and tourist guides will also have additional information.

4. Students relate the natural area selected to the previous activities. How does this area relate to shoreline processes, geologic change, and ongoing interactions between land and water?

5. The expert groups decide which vacation spots they would recommend for families, for school groups, or for individuals. You may want to select one approach but mention how your recommendations would change based on the clientele.

Source

Adapted from Ohio Sea Grant Education materials.

Earth Systems Understandings

This activity focuses on ESU 1 and 2 (the formation of unique sites and features of interest) and ESU 4 and 5 (that result from natural processes acting on Earth systems over time). Sites of interest are related ESU 7 (careers and hobbies that affect the use and management of resources and to the careers of those in tourism support industries).

Materials

- Vacation guides available from AAA and other travel agencies. Also check with the local Department of Natural Resources and Divisions of Travel and Tourism.

Suggestion

Each travel agent group could have a name such as "Lake Huron Travel Agency."

Online resources: www.city.com has information that cities are using to attract industry and visitors to their areas.

Water has no hands,
But what does it hold,
Pieces of rock
Centuries old.

Moving and shaking,
Mountains creating,
Earth from her nest
Explodes with unrest.

Water responds,
Forms lakes and ponds,
Bringing debris
Beneath the Sea.

Forming new places
Basins and Faces
Until things again
Are at rest in the end.

Then change that's new
Brings movement through
History's door
Land and Water meeting once more.

Hint for Extension

Possible items for discusssion are fences around natural features, lookout points, and boardwalks over wetlands.

Did you know that coastal resources can be recreational resources? The Great Lakes Circle tour has been promoted as an attraction for those who wish to travel the coastline and visit sites along the way.

Source of Photographs

Visualizing the Great Lakes: Images of a Region. Minnesota Sea Grant and U.S. EPA Great Lakes National Program Office.

6. The travel agent groups design a skit – Why visit this specific Lake of the five Great Lakes? What could a person or group do if he/she decided to tour the perimeter of the lake for a one or two week vacation? What is a "must-see' site on the Lake?

7. After each expert group has given a skit on a specific lake, individuals from the expert groups return to their client groups. Each expert presents a package, for example a brochure or flyer, to the client groups regarding the attributes of the natural area that would warrant a trip there. Members of the expert groups state their cases for each of their respective travel agencies.

8. Client groups take an inventory of people's interests in the group and select a Great Lake by consensus of their members. Each client group shares its perceptions with the class.

> The Great Lakes are constantly moving, changing, evolving. Have you seen beautiful scenes on your trips throughout the Great Lakes? Do they inspire artistic images in your mind, such as a picture you have seen or a song you have heard? Have you witnessed memorable scenes in the lake nearest you? Perhaps you have a favorite site in the Great Lakes region. What makes it interesting?

EXTENSIONS

1. From the natural areas you have examined and the concepts of change learned in the activity set, how do you think recreation activities affect land/water interactions? Think of boating, lakeside resorts, public beaches, walking on outcroppings, etc. What would you suggest as ways of resolving interests among different recreation uses while preventing erosion along coastlines?

2. What mechanisms would you suggest to permit tourism activities in some of the natural areas of this activity while minimizing negative impacts on the resources?

REFERENCES

See tourism guides, state recreation publications, AAA, and other travel organizations for resource material.

Lake Superior

Agawa Rock (Ontario): The only human-made site of the Great Lake Wonders, Agawa Rock carries a collection of pictographs. Thought to be 200-600 years old, the rock paintings were created by Ojibway warriors, who considered the site sacred.

Apostle Islands (Wisconsin): Twenty-one islands and 2,500 acres of the Bayfield Peninsula make up this unit of the National Lakeshore system. Sea caves and gigantic rookeries are but two of the pleasing characteristics of the reserve.

Isle Royale (Michigan): The largest island in Lake Superior, Isle Royale is located in the middle of the lake, closer to Minnesota and Ontario than mainland Michigan. This is true wilderness: no roads, and only about 16,000 human visitors each year. The island, and its 200 or so surrounding islets, is a National Park.

Minnesota and Wisconsin Points (Minnesota and Wisconsin): Together these two are the world's longest rivermouth sandbar; Minnesota Point is more than 8 miles long and Wisconsin Point, about 2. They also mark the westernmost extent of the Great Lakes.

Ouimet Canyon (Ontario): While in most places glaciation is a slow process, on rare occasions ice has caused sudden changes in terrain. Ouimet Canyon is one such place. A great quantity of meltwater broke through an ice dam during a glacial retreat. The force hit a rock fault with such power that it nearly instantly blasted a 2-mile long, 350-feet-deep, 500-feet-wide canyon.

Painted Rocks (Michigan): Encompassing 42-miles of lakeshore cliffs, Painted Rocks rise up to 200 feet from Superior's waters. The colors come from the action of water on the ores in the rocks. Also here is Miner's Castle, a place where a waterfall drops directly into the lake.

Witch Tree (Minnesota): Clinging precariously to life for more than 300 years on boulders at the lake's edge that are pummeled by storm waves, the Witch Tree is an excellent example of an organism's ability to adapt and survive. The Chippewa Indians consider the tree sacred.

Isle Royale

Lake Michigan

Door Peninsula (Wisconsin): The westernmost extension of the Niagara Escarpment forms this peninsula into Lake Michigan. Rock outcrops are common and just north of the tip of the Door is Washington Island. The passage between the two landmasses was named Porte des Morts (Death's Door) because of its treacherous sailing conditions caused by shoals, rocky bluffs, and strong currents.

Indiana Dunes National Lakeshore (Indiana): A complex ecosystem that is preserved within the Chicago metropolitan area. The 13,000 acre reserve (that's small compared to most National Park Service units) has the third highest biodiversity of any national park.

Oconto Marsh (Wisconsin): More than half of the wetlands around the shores of the Great Lakes have been destroyed. This is one of the largest remaining systems, at more than 4,000 acres.
Hint: In a wetland, a unique kind of land and water interaction takes place.

Sleeping Bear Dune (Michigan): Jutting up out of Lake Michigan at a 45-degree angle, this dune rises almost 400 feet. Lake Michigan's eastern shore is the sandiest of all the Great Lakes, and this is one of its highest spots. This dune is part of Sleeping Bear Dune's National Lakeshore.

Valley of the Giants (Michigan): On South Manitou Island, 8 miles west of Pyramid Point, a grove of white cedars grows. At 110 feet, they are the largest of this coniferous species in the world. South Manitou is part of Sleeping Bear Dunes National Lakeshore.

Volo Bog (Illinois): An outstanding example of a bog wetland has survived in the northern reaches of metropolitan Chicago. Unusual plants include marsh marigolds and several species of orchid. The bog is an Illinois State Natural Area.

Warren Woods (Michigan): A few miles from the sand dunes of Lake Michigan's southeastern shore, this is a 480-acre stand of virgin beech-maple forest. The trees allow one but a mere glimpse into what was the most common ecosystem along the southern Great Lakes until European settlement.

Sleeping Bear Dune

Lake Huron

Bois Blanc Island (Michigan): One of thousands of islands in Lake Huron, Bois Blanc is incredible for the contrast it offers to its smaller neighbor, Mackinac Island. Whereas Mackinac gets hundreds of thousands of visitors to its Grand Hotel and has dozens of fudge shops, Bois Blanc is mostly wooded and uncrowded by humans.
Hint: A good choice for people who want to have a quiet vacation.

Flowerpot Island (Ontario): Off the tip of the Bruce Peninsula, water and wind have combined to erode the dolomite of this part of the Niagara escarpment. The result is 30-foot tall cylinders that resemble giant flowerpots. These formations are part of Canada's Fathom Five National Marine Park.

Kirkwood Giant Pine (Ontario): At 162 feet, this white pine tree is the tallest in Ontario. It is located about 3 miles north of the shoreline.

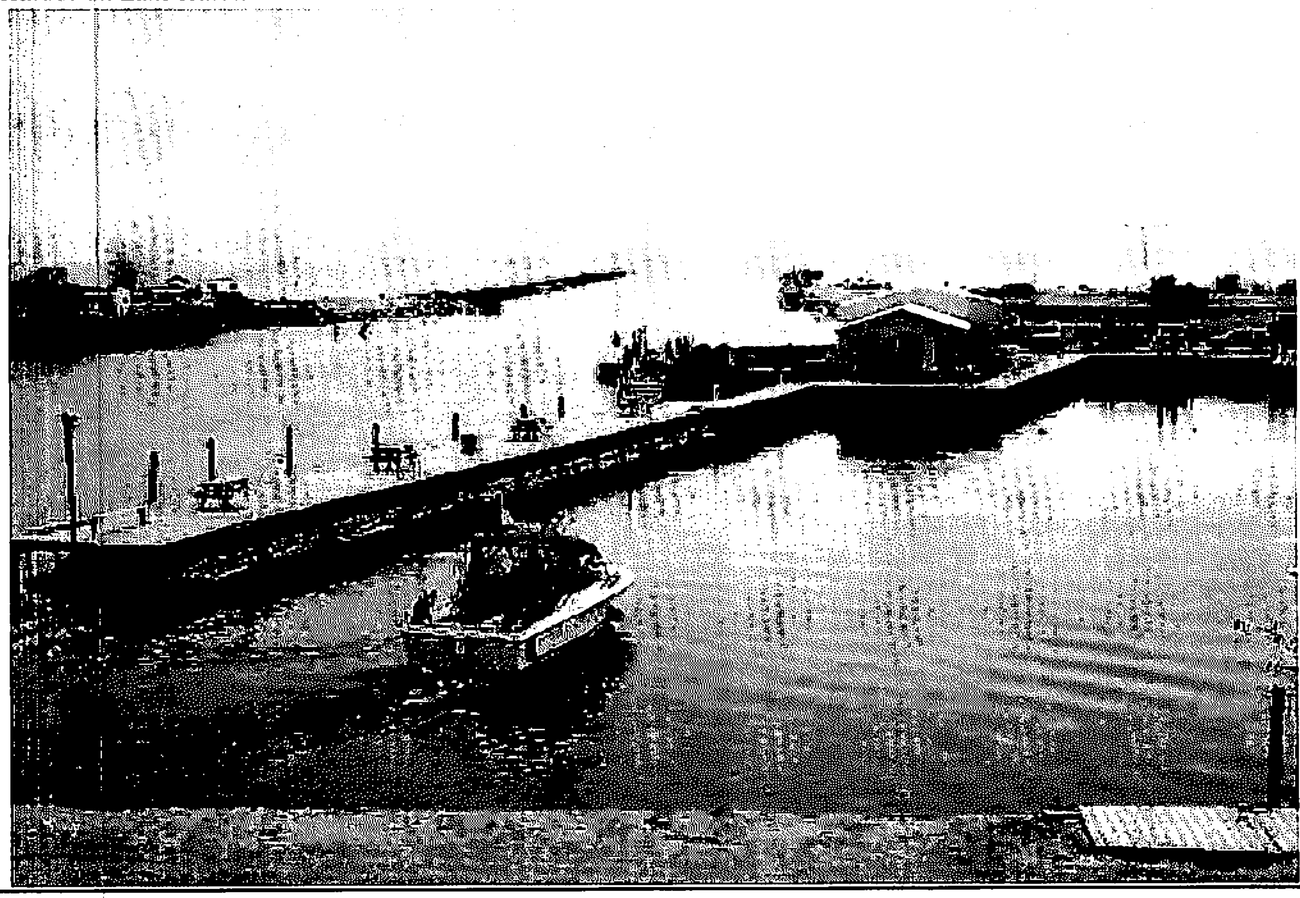
Manitoulin Island (Ontario): This is the largest freshwater island in the world. Geologically the island is part of the Niagara Escarpment. The bedrock here is Silurian and Ordovician in age.
Hint: Do the rock types of the Niagara Escarpment explain why the island has resisted erosion and remained and island?

Rock Glen (Ontario): A fossil bed along the Ausable River at Arkona contains specimens as old as 350 million years. The site is operated by a local service organization as a conservation area.

St. Clair River Delta (Michigan and Ontario): The outflow of Lake Huron is the St. Clair River and it is only about 75 miles long. Nonetheless, it empties into Lake St. Clair through the largest delta system in the Great Lake region. Although the Michigan portion of the delta has been somewhat urbanized, the Ontario segment remains in a less developed state.

Thirty Thousand Islands (Ontario): Stretching along the northeastern shore of Georgian Bay, hundreds (if not 30,000) islands dot the coast. Fifty-nine of them have been set aside as Georgian Bay Islands National Park.

Harbor on Lake Huron



Lake Erie

Kelleys Island Glacial Grooves (Ohio): Carved by mile-thick glaciers, these grooves are 300 feet long and 15 feet deep. Multitudes of fossils from the Devonian sea, from which the Columbus Limestone was formed, can be seen. The site is an Ohio State Park. A group could rent bikes at the dock and ride there for an afternoon outing.
Hint: This would be a good site to discuss the movement of the glaciers that eventually carved out the basin of the Great Lakes. Think about how long a mile is, such as the distance from home to school, and discuss the size of the glaciers from that perspective.

Lake Erie Snow Belt (Ohio, Pennsylvania, New York): Winter storms tracking over Lake Erie pick up a lot of moisture. Reaching land and being pushed up by the Portage Escarpment causes them to redeposit the water as snow. Buffalo, New York, is well known for heavy snowfall. There are ski areas in the snow belt, too. Average annual amounts can top 100 inches.
Hint: Consider how changes in topography affect the hydrologic cycle.

Long Point (Ontario): Longshore drift has constructed this 20-mile long sand spit out into the deepest part of Lake Erie. The point features sandy beaches on the south; high dunes, some forest and grassland at the height of land; and extensive marshes on its north side. By deflecting the water's motion, the formation also creates a swirling area of lake surface that rarely freezes in winter. Some of the point is administered as an Ontario Provincial Park.

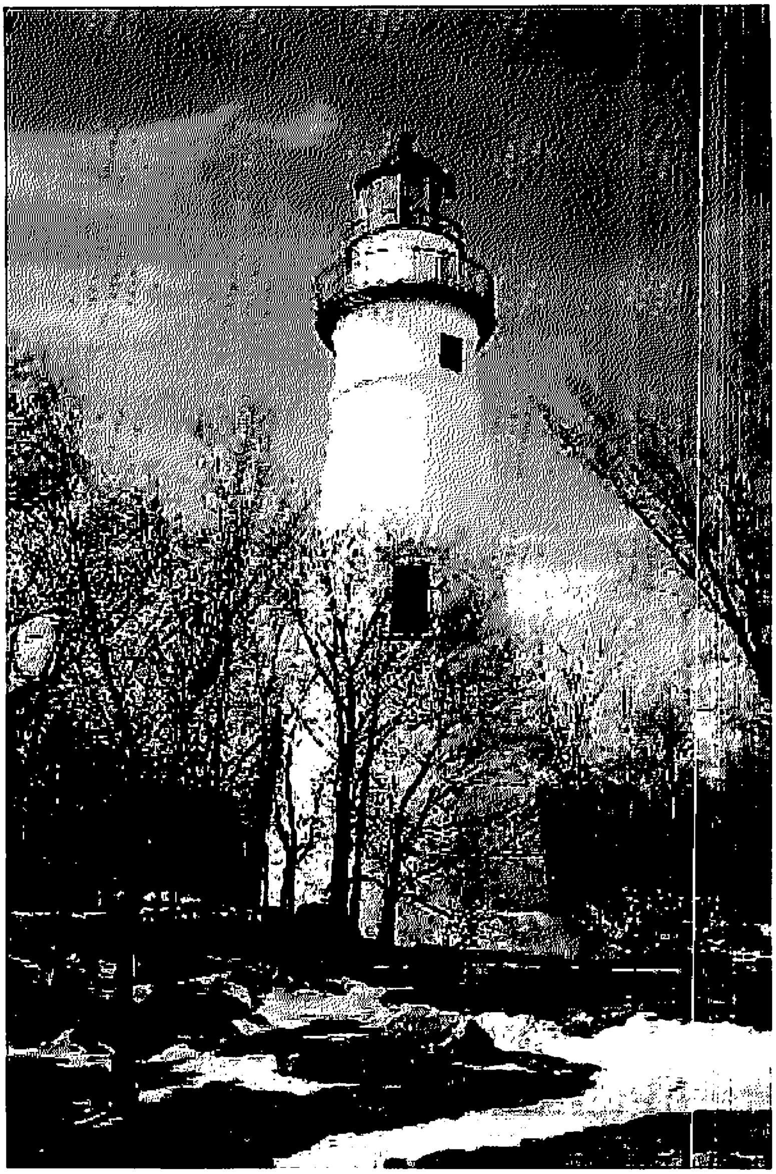
Oak Openings (Ohio): Sand dunes are found scattered through wet oak forests and prairies inland from the lake's southwestern extreme. The dunes mark ancient shorelines of the glacial lakes that preceded modern Lake Erie. The habitat formed by the sand as it is slowly encroached upon by forest is an oak opening. Oak Openings Metropark of the Toledo Area Metropolitan Park District is the best site to see oak openings.
Hint: This site would go well with Ancient Shores as a reference so people could understand why other shorelines have existed in Lake Erie's history.

Old Woman Creek Estuary (Ohio): At the most southerly extent of the Great Lakes, Old Woman Creek Estuary is composed of a barrier beach beyond which a stream mouth has been flooded. The wetland is bordered by forest. The community has more than 300 species of plants and animals. Old Woman Creek was the first established National Estuarine Sanctuary on the Great Lakes.
Hint: This wetland site is an example of a unique land/water interaction where an estuary removes nutrients from water entering Lake Erie.

Point Pelee (Ontario): A sand spit built by longshore drifts on top of a glacial moraine, Point Pelee protrudes more than 8 miles south into Lake Erie from the northern shore. Migrating birds of more than 100 species use the spit as a haven, making it their last stop before crossing the lake heading south and landfall on the way north. The area is a Canadian National Park.
Hint: This site would be good for bird watchers.

Western Basin Islands and Reefs (Ohio and Ontario): Resistant Silurian Dolomites and Devonian Limestone withstood glaciation, becoming an archipelago in the Western Basin. Ohio counts 17 islands and Ontario, eight. Those outcrops that were worn down just enough to be below the lake surface became reefs, where fish congregate, attracting boats of fishers.

Marblehead: The oldest operating lighthouse on the Great Lakes.



Lake Ontario

Bay of Quinte (Ontario): The closest thing to a fjord on the Great Lakes, the Bay of Quinte reaches about 70 serpentine miles around Prince Edward County, yet it is never more than a mile or two wide.

Chimney Bluff State Park (New York): Sandstone pillars jut above Lake Ontario's southern shore. While their dimensions can't match structures of the upper lakes, these bluffs are the highest along the southern shore of Ontario.
Hint: The lower lakes may be more comfortable year round compared to the cold in the northern areas during the winter.

Frontenac Provincial Park (Ontario): This park marks the southern extreme of the Canadian Shield complex of Pre-Cambrian rock. As this vast geologic area is so important in determining the character of Lakes Huron and Superior, it is interesting to note that it reaches to within about 15 miles of Lake Ontario.
Hint: The activity "How were sedimentary rocks in the Great Lakes Basin formed?" relates to this location of interest in considering ages of geologic time.

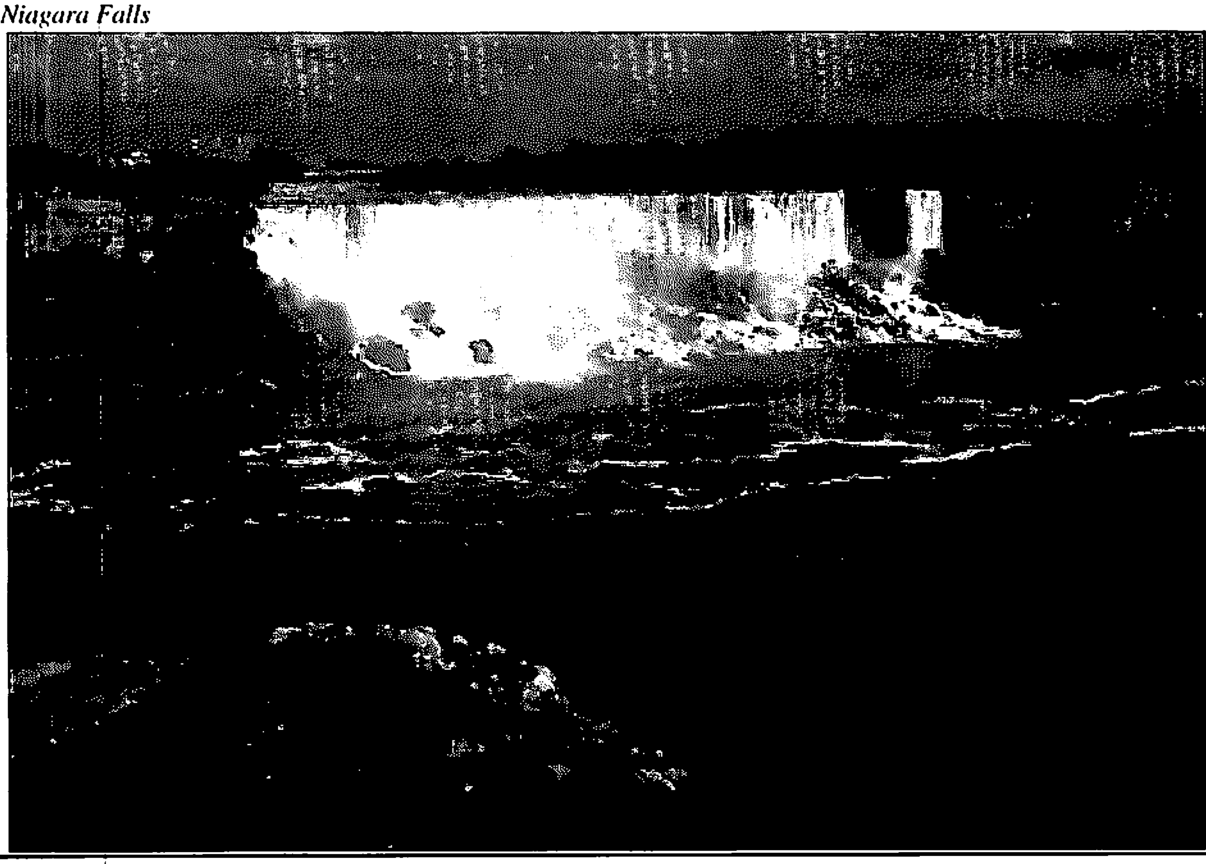
Lake on the Mountain (Ontario): This small clear lake sits about 200 feet above Ontario's surface. It is like thousands of other small lakes in Ontario, except for the legend about is source: the Lake on the Mountain is said to be fed by underground springs direct from Niagara Falls. Can this be true?

Niagara Falls (New York and Ontario): Over its 32-mile run, the Niagara River drops 326 feet. Half of this is the plunge over Niagara Falls. The falls are actually three streams of water – American, Bridal Veil, and Horseshoe. Horseshoe Falls, on the Canadian side, carries approximately 95 percent of the river flow. The waterfalls tumble over dolomite and wear away the softer underlying shale.

Niagara Gorge (New York and Ontario): Below the falls, the Niagara courses through a gorge that has been cut by the river more than 6 miles into the Niagara Escarpment. Niagara Falls continues to lengthen the gorge by about 3.5 feet per year. A gigantic whirlpool can be seen in the gorge 4 miles below the falls.

Thousand Islands (New York and Ontario): As water exits Lake Ontario and collects into the St. Lawrence Seaway, it flows around hundreds of islands. Many parks are present, and boat tours traverse the area.

Niagara Falls



How can a concept map represent land and water interactions?

What are some creative ways to demonstrate what you have learned? A concept map provides both the means for creativity and for expressing relationships between the components of land-water interaction.

OBJECTIVE

- You will be able to illustrate relationships between topics learned in this set of activities.

See: Special Supplement on Assessment. March, 1992. *Science Scope*. This issue provides additional information on concept mapping.

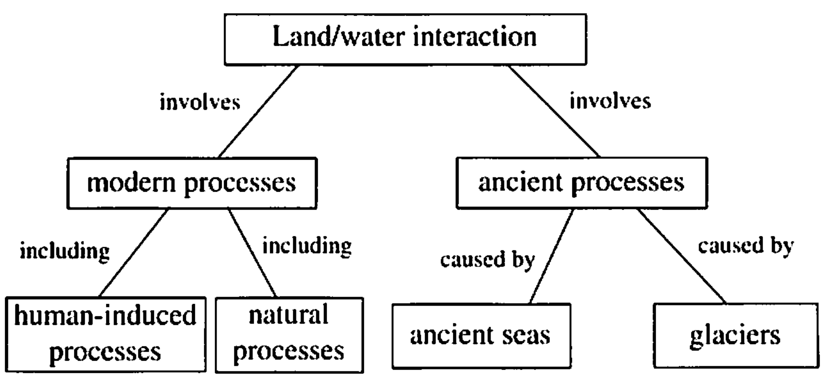
PROCEDURE

Construct a concept map using the most important topics that you have gained from this set of activities. Keep in mind how processes you have studied are interrelated and how one affects another. Begin with what you think are the broadest concepts and expand downward toward the more specific concepts. Some topics may connect to more than one idea. Use your imagination and add some of your own ideas.

Include the following concepts and add additional ones that you think are important:

Land-water interaction, coastal erosion, shoreline protective device, erosion rate, shoreline changes, rock layers, glaciers, ancient seas, sedimentary, sediments, igneous/metamorphic, time, ancient rivers, subterranean forces, erodibility of rock, storms, natural processes, human-induced processes, natural features, mineral deposits, population distribution, recreation sites, Devonian, Silurian, Precambrian, etc., your own additional concepts.

An example of a starting arrangement is shown here:



Framework for Earth Systems Education

UNDERSTANDING #1: Earth is unique, a planet of rare beauty and great value.

- The beauty and value of Earth are expressed by and for people of all cultures through literature and the arts.
- Human appreciation of Earth is enhanced by a better understanding of its subsystems.
- Humans manifest their appreciation of Earth through their responsible behavior and stewardship of its subsystems.

UNDERSTANDING #2: Human activities, collective and individual, conscious and inadvertent, affect Earth systems.

- Earth is vulnerable, and its resources are limited and susceptible to overuse or misuse.
- Continued population growth accelerates the depletion of natural resources and destruction of the environment, including other species.
- When considering the use of natural resources, humans first need to rethink their lifestyle, then reduce consumption, then reuse and recycle.
- Byproducts of industrialization pollute the air, land, and water, and the effects may be global as well as near the source.
- The better we understand Earth, the better we can manage our resources and reduce our impact on the environment worldwide.

UNDERSTANDING #3: The development of scientific thinking and technology increases our ability to understand and utilize Earth and space.

- Biologists, chemists, and physicists, as well as scientists from the Earth and space science disciplines, use a variety of methods in their study of Earth systems.
- Direct observation, simple tools, and modern technology are used to create, test, and modify models and theories that represent, explain, and predict changes in the Earth system.
- Historical, descriptive, and empirical studies are important methods of learning about Earth and space.
- Scientific study may lead to technological advances.
- Regardless of sophistication, technology cannot be expected to solve all of our problems.
- The use of technology may have benefits as well as unintended side effects.

UNDERSTANDING #4: The Earth system is composed of the interacting subsystems of water, rock, ice, air, and life.

- The subsystems are continually changing through natural processes and cycles.
- Forces, motions, and energy transformations drive the interactions within and between the subsystems.
- The Sun is the major external source of energy that drives most system and subsystem interactions at or near the Earth's surface.
- Each component of the Earth's system has characteristic properties, structure, and composition, which may be changed by interactions of subsystems.
- Plate tectonics is a theory that explains how internal forces and energy cause continual changes within Earth and on its surface.
- Weathering, erosion, and deposition continuously reshape the surface of the Earth.
- The presence of life affects the characteristics of other systems.

UNDERSTANDING #5: Earth is more than 4 billion years old, and its subsystems are continually evolving.

- Earth's cycles and natural processes take place over time intervals ranging from fractions of seconds to billions of years.
- Materials making up Earth have been recycled many times.
- Fossils provide the evidence that life has evolved interactively with Earth through geologic time.
- Evolution is a theory that explains how life has changed through time.

UNDERSTANDING #6: Earth is a small subsystem of a Solar system within the vast and ancient universe.

- All material in the universe, including living organisms, appears to be composed of the same elements and to behave according to the same physical principles.
- All bodies in space, including Earth, are influenced by forces acting throughout the solar system and the universe.
- Nine planets, including Earth, revolve around the Sun in nearly circular orbits.
- Earth is a small planet, third from the Sun in the only system of planets definitely known to exist.
- The position and motions of Earth with respect to the Sun and Moon determine seasons, climates, and tidal changes.
- The rotation of Earth on its axis determines day and night.

UNDERSTANDING #7: There are many people with careers and interests that involve study of Earth's origin, processes, and evolution.

- Teachers, scientists, and technicians who study Earth are employed by businesses, industries, government agencies, public and private institutions, and as independent contractors.
- Careers in the sciences that study Earth may include sample and data collection in the field and analyses and experiments in the laboratory.
- Scientists from many cultures throughout the world cooperate and collaborate using oral, written, and electronic means of communication.
- Some scientists and technicians who study Earth use their specialized understanding to locate resources or predict changes in Earth systems.
- Many people pursue avocations related to planet Earth processes and materials.

The development of this framework started in 1988 with a conference of educators and scientists and culminated in the Program for Leadership in Earth Systems Education. It is intended for use in the development of integrated science curricula. The framework represents the efforts of some 200 teachers and scientists. Support was received from the National Science Foundation, The Ohio State University, and the University of Northern Colorado.

For further information on Earth Systems Education, contact the Earth Systems Education Program Office, 2021 Coffey Road, The Ohio State University, Columbus, OH 43210.

Ohio Sea Grant Education Program

The Ohio Sea Grant Education Program has focused on the development of curriculum materials to enhance the quality of science education, the infusion of these materials into the classroom, and teacher training. Materials developed emphasize real-world issues including, most recently, the impact of global climate change on the region.

Earth Systems -
Education Activities for Great Lakes Schools (ES-EAGLS)

ES-EAGLS are designed to take a concept or idea from the existing school curriculum and develop it in a Great Lakes context, using teaching approaches and materials appropriate for students in middle and high school. The activities are characterized by subject matter compatibility with existing curriculum topics, short activities lasting from one to three classes, minimal preparation time, minimal equipment needs, standard page size for easy duplication, suggested extension activities for further information or creative expression, teachability demonstrated by use in classrooms, and content accuracy assured by critical reviewers.

Each title costs $8.00

Land & Water Interactions in the Great Lakes EP-082
Great Lakes Climate & Water Movement................EP-083
Great Lakes Shipping EP-084
Life in the Great Lakes EP-085
Great Lakes Environmental Issues EP-086

The Great Lakes Solution Seeker

This compact disk will help educators teach their students about the Great Lakes by providing online or simulated Internet connections to comprehensive data sources, resources, graphics, and activities. The data and activities work best on Macintosh system 7.0 or higher. Most sections are also usable with Windows 95. EP-081 *$10.00*

Global Change in the Great Lakes

Ten scenarios (2-4 pp. each) and an introduction explain climate models and are packaged in a file folder. The scenarios describe the scientific community's prevailing interpretations of what may happen to the Great Lakes region in the face of global warming but are written in terms the general public can understand. The scenarios explore water resources, biological diversity, shipping, agriculture, airborne circulation of toxins, estuaries, eutrophication, recreation, fisheries, and forests. EP-078 *$6.00*

Great Lakes instructional material for the changing earth system. Provides integrative activities on global change to educators and decision-makers and must be purchased with EP-078 (above). Printing donated by Brunswick Marine. Cost includes EP-078 and additional postage charge. EP-080 *$9.00*

Summary of the global change scenarios (above) for the Great Lakes region, 2 pp. FS-057 *free*

Oceanic Education Activities for Great Lakes Schools (OEAGLS)

OEAGLS (pronounced "eagles") were developed from 1985 to 1991 for students in middle school grades. The ES-EAGLS (see above) are modifications of OEAGLS. Refer to that series description. Each OEAGLS title consists of a student workbook and a teacher guide.

Each title costs $3.00

Yellow Perch in Lake Erie EP-009
Shipping on the Great Lakes EP-013
Geography of The Great Lakes EP-014
Ohio Canals EP-015
The Great Lakes Triangle EP-017
Knowing the Ropes EP-018
We have Met the Enemy..EP-021
It's Everyone's Sea: Or is it? EP-022
A Great Lakes Vacation EP-024
Storm Surges EP-025

OEAGLets

Three activities provide students in primary grades with activities relevant to Lake Erie. The activities apply to all primary subject areas. *Each title costs $5.00*

Lake Erie - Take a Bow EP-031
Build a Fish to Scale EP-032
A Day in the Life of a Fish EP-033

Additional Educational Materials

Holling C. Holling's *Paddle-to-the-Sea* published by Houghton Mifflin Company. 28 pp. EP-076/B *$10.00*

Supplemental curriculum activities to accompany Holling C. Holling's Paddle-to-the-Sea. 168 pp. of activities for grades 3-6: science, social studies. EP-076 *$10.00*

The great Lake Erie. Sixteen experts present different facets of the importance of the Great Lakes to North America and the world. Written in 1987 and reprinted by Ohio Sea Grant in 1993. 148 pp. EP-079 *$10.00*

The Ohio Sea Grant Education Program: Development, Implementation, Evaluation. EP-075 *$8.00*

Abstracts of research in marine and aquatic education: 1975-1990. Brief review of the topics addressed in marine and aquatic education research, including knowledge and attitude testing of various groups, models of program evaluation, and comparisons of impact of education techniques. 24 pp. EP-077 *$2.00*

Costs cover publication, postage, and handling.
Make payment payable to The Ohio State University in U.S. dollars. Mail your request and payment to:
Ohio Sea Grant Publications, The Ohio State University, 1314 Kinnear Road, Columbus, OH 43212-1194.
Phone 614/292-8949 or e-mail (cruickshank.3@osu.edu) if you have any questions or would like to place a large order.

Other ES-EAGLS

Great Lakes Climate and Water Movement

Water Movement

- How does water move in the Great Lakes basin?
- How long does it take water to flow through the Great Lakes?

Temperature and Climate

- What happens to heat energy reaching the Great Lakes?
- What causes the land-sea breeze?
- How do the Great Lakes affect temperature?
- How is weather influenced by the Great Lakes?

Lake Levels and Storms

What causes storm surges?

- How do storm surges affect water levels on Lake Erie?
- How do the levels of the Great Lakes change?
- What would be the result of regulating the level of one of the Great Lakes?

Seasons on the Great Lakes

- How do the Great Lakes change through the seasons?
- How does stratification affect water quality?
- What factors impact ice coverage on the Great Lakes?

Great Lakes Shipping

Great Lakes Shipping

- What products are carried on the Great Lakes?
- What is the most economical form of transportation?
- Which transportation method uses the least energy?

World Connection

- Where go the boats?
- How do ships go from one lake to another

Language

- How have ships and sailing influenced our language?

Great Lakes Triangle

- What is the Great Lakes Triangle?
- How can disappearances within the Triangle be explained?
- What happened aboard the *Edmund Fitzgerald*?

Canals

- How were early canal routes determined?
- How did the canals affect Ohio?

Life in the Great Lakes

Organisms in the Lakes

- How does a dichotomous key work?
- What are the characteristics of some Great Lakes fish?
- How do fish get their names?
- How are shorebirds adapted for feeding?
- What do scientists know about invader species of the Great Lakes?

Ecological Relationships

- Who can harvest a walleye?
- What does a biomass pyramid tell us?
- What is a food web?
- What factors affect the size of a natural population? (A Great Lakes fish example)
- How can a natural fish population be managed?

Estuary Values and Changes

- What is the role of plants in an estuary?
- How does the estuary serve as a nursery?

Great Lakes Environmental Issues

Resources and Reactions

- How big is a crowd?
- Who owns the resources of the Great Lakes?
- How (environmentally) insulting can we get?
- How skillfully can you read science articles?

Toxins in the Great Lakes?

- How much is one part per million?
- Which fish can we eat?
- How should the public heath be protected?
- How do toxins move through the food chain?
- How big is the problem of airborne toxins?
- Where do all the toxins go? (internal view)
- Where do all the toxins go? (external view)
- Could we live without chlorine in the Great Lakes?

Watershed and Basins Issues

- What can we learn about water quality in a river?
- What happens when nutrients enter a lake?
- What is the status of the Great Lakes Areas of Concern?

Oil Pollution

- Where does oil pollution come from?
- How can an oil spill be cleaned up?
- How does an oil spill affect living things?
- What if . . .? (a Great Lakes investigation)

Sea Grant
Ohio Sea Grant College Program

1314 Kinnear Road
Columbus, OH 43212-1194
614/292-8949
Fax 614/292-4364

http://www-ohiosg.osc.edu/OhioSeagrant