Ohio Geology

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THE GEOLOGY OF OHIO—THE PRECAMBRIAN

by Michael C. Hansen

In the 1790's, the land surface of Ohio constituted the frontier of America, beckoning the bold to explore this unknown territory. Two centuries later, the Ohio frontier lies thousands of feet beneath the now well-explored surface and consists of a complex of igneous, metamorphic, and sedimentary rocks formed so deep in the abyss of geologic time that it would have been beyond the realm of contemplation of our pioneer ancestors. The fundamental lure of exploration is, perhaps, similar for each generation—to see terra incognita for the first time and to discover hidden treasure. These frontier rocks, totally unknown to the pioneers and first geologists, and only now just beginning to be understood, belong to the geologic time interval called the Precambrian and represent the largest part of the geologic history of Ohio.

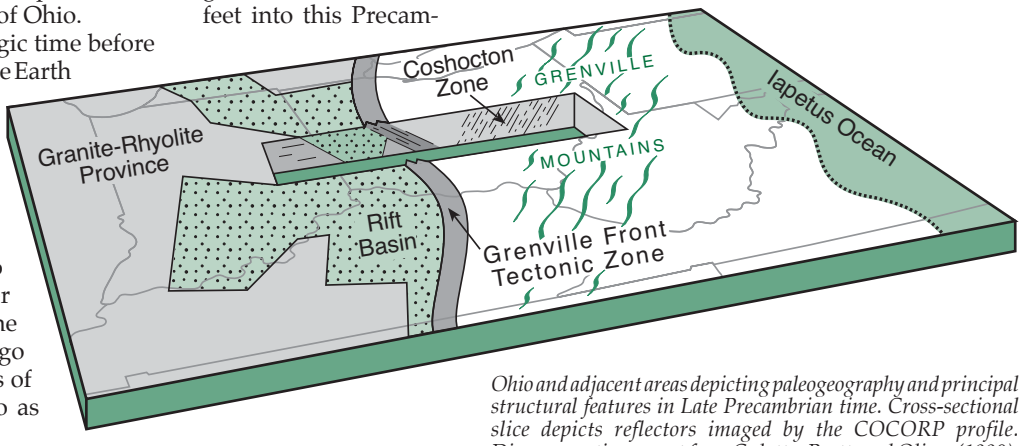
Precambrian time (all of geologic time before the Cambrian Period) began when the Earth became a solid entity about 4.5 billion years ago and ended when the Cambrian Period began, about 570 million years ago. "Precambrian" is actually an informal term used by geologists. This long period of time is now divided formally into two eons—the Archeozoic (greater than 2.5 billion years ago) and the Proterozoic (from 2.5 billion years ago to 570 million years ago). The rocks of the Archeozoic Eon are referred to as Archean rocks.

Despite the immense span of time represented by these rocks, the Precambrian is the most poorly known of the geologic subdivisions in Ohio, in part because Precambrian rocks are nowhere exposed in the state. They are deeply buried beneath younger Paleozoic rocks, at depths ranging from about 2,500 feet in western Ohio to more than 13,000 feet in southeastern Ohio. These rocks are collectively referred to by geologists as the "basement" because they form the foundation for the overlying Paleozoic sedimentary rocks. Drillers commonly refer to the Precambrian rocks as the "granite," in reference to a common rock type found below the Paleozoic rocks. Rocks representing the Archeozoic and most of the Proterozoic have not been found in Ohio and may or may not be present beneath later Proterozoic rocks. Ohio's Precambrian rocks appear to have formed in the late Precambrian, between about 1.5 billion and 800 million years ago.

Our knowledge of Precambrian rocks is derived from direct sampling of them through deep oil and gas wells or other boreholes or by indirect geophysical means such as aeromagnetic and gravity maps, reflection seismic lines, or study of earthquake waves. Geophysical techniques are comparatively new, and it has only been since the early 1980's that geophysical data have become widely available.

STUDY OF PRECAMBRIAN ROCKS IN OHIO

Intensive study of the surface and near-surface rocks of Ohio had been underway for nearly a century when the first sample of Precambrian crystalline rock was obtained in 1912 from the D. L. Norris well in Hancock County, near Findlay. At a depth of 2,770 feet the drill bit reached granite gneiss and continued for another 210 feet into this Precambrian rock. The Norris well seemed to confirm the 1890 prediction of third State Geologist Edward Orton that "The granite of Plymouth Rock underlies the continent."



Ohio and adjacent areas depicting paleogeography and principal structural features in Late Precambrian time. Cross-sectional slice depicts reflectors imaged by the COCORP profile. Diagrammatic concept from Culotta, Pratt, and Oliver (1990).

By 1932, only four more wells had reached the Precambrian basement, all of them in northwest Ohio where basement is shallowest, and all penetrating "red granitic gneiss." The information obtained from these wells led George D. Hubbard to suggest in a 1932 Ohio Journal of Science paper that the surface of the Precambrian rocks of Ohio was remarkably smooth and even, having slopes of only 2 to 10 feet per mile. He speculated that there must have been a great interval of erosion between the deposition of the granite and invasion of the Paleozoic seas.

By 1962, 38 wells had reached Precambrian rocks in the state and the first inklings of the complexity of these rocks were beginning to emerge. Ohio Division of Geological Survey Report of Investigations 41, *Petrology of Precambrian rocks of*

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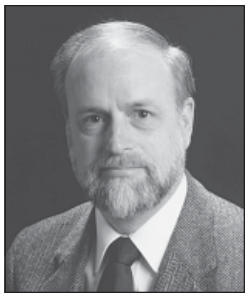

Thomas M. Berg, Division Chief and State Geologist

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From The State Geologist...

Thomas M. Berg

THE PEOPLE OF THE DIVISION OF GEOLOGICAL SURVEY: A PRICELESS RESOURCE FOR THE PEOPLE OF OHIO

Of all the resources available to an organization, the most valuable are the human resources.Without hesitation, I can say that this concept holds true for the Ohio Geological Survey. In March 1996, I will begin my eighth year with the Division. So far, these have been some of the most enjoyable years of my career—largely because of the outstanding public servants with whom I have the privilege of working.

The employees of the Geological Survey have diverse backgrounds, traditions, and experiences. Collectively, the present staff represent close to 350 years of high-school and college education. The collective experience of present full-time Survey staff working on Ohio geological programs totals 588 years. No other organization has that amount of education and experience dedicated to the geology of this state.

One interesting characteristic of state geological surveys is that there is usually low turnover; the majority of staff make a lifetime career working at the surveys. That is certainly true at the Ohio Survey. I often ask myself, "Why do they stay?" There are probably several answers to that question, but I think one important reason is that geological survey people are having fun. They are having fun making new discoveries about the geology of the state. They are enjoying seeing the work they do serve the citizens of the state. It is immensely satisfying to see a customer leave our office with a big smile, a load of maps and records, and lot of good advice needed to solve a difficult geological problem.

As required of state employees in Ohio, all staff members of the Division of Geological Survey have been trained in quality-service principles through the Governor's QStP (Quality Services through Partnership) Program. With this training, our staff have learned many problem-solving techniques and are already applying them to solve procedural and geological problems. QStP fosters customer-satisfaction and continuous-improvement attitudes. I am very proud of the people at the Ohio Geological Survey because they are dedicated to making the geosciences serve the public good. And they want to make that service of the highest quality!

With the current nationwide push to reduce government spending, the Ohio Geological Survey and most other state geological surveys have been striving to do more and more with less and less. "Downsizing" and "rightsizing" are popular buzzwords today. Yet the demands for high-quality geologic information do not "downsize" or diminish. Quite the opposite—the demands increase daily. A solution persistently offered by some policy-makers is to "privatize" and turn over the responsibility of government science agencies to private industry. What private geoscience firm would be able to collect all the information concerning the whole geologic framework of an entire state on a continuous basis, synthesize and interpret that information in an impartial and unbiased manner, integrate and compile all that three-dimensional spatial data into a variety of media for an audience ranging from grade-school children to scientists, engineers, professors, and legislators—all that, and not make a profit? The Ohio Geological Survey does just that!

The people of Ohio have a priceless resource in the people of the Ohio Geological Survey. The staff of the Survey provide Ohioans with a tremendous bargain. They are committed to excellence in public service and in making the geosciences serve the public good. An enormous amount of work remains to be done to establish the geologic framework of this state and describe how it affects our daily lives. The investigation of the Precambrian rocks of Ohio described by Mike Hansen in this issue of *Ohio Geology* is just one example. All of us at the Division look forward to continuing our tradition of quality service!

REVISED PUBLICATIONS LIST FOR EDUCATORS

The *List of educational resources of the Ohio Division of Geological Survey and sources of additional information* is in its third revision. The list includes educational resources of the Survey and of the Ohio Department of Natural Resources, plus other sources of information from federal agencies and private organizations, for kindergarten through college teachers, such as activity books, science books, catalogs, videos, workshops, and newsletters. Prices of materials are included; however, many of the resources are free. To obtain a free copy of the list contact the Geologic Records Center at 614-265-6576.

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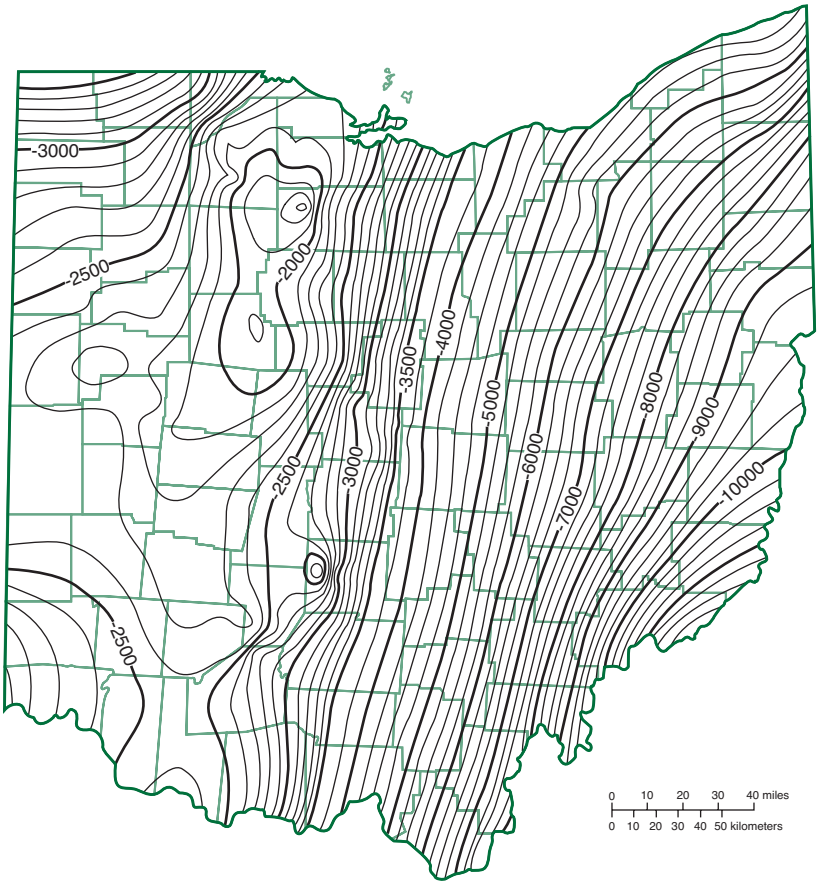
Ohio, by G. R. McCormick (1961), gave a lithologic description of well cuttings taken from Precambrian rocks in 24 wells. Report of Investigations 44, *Precambrian in Ohio and adjoining areas*, by C. H. Summerson (1962), gave the first detailed overview of lithologic differences and interpretations of Ohio's basement. These reports and a 1960 paper in the Journal of Geology by M. N. Bass provided the first clear evidence that the Precambrian basement of Ohio was complex.

Bass presented the results of radioisotopic dating of samples from four wells—three in Fayette County and one in West Virginia—and a lithologic analysis of 14 Ohio wells that reached Precambrian rocks. He reported that wells east of a north-south line in west-central Ohio encountered high-grade metamorphic rocks consisting mostly of schists and gneisses. West of this line, the rocks consist of unmetamorphosed fine-grained volcanics and granitic rocks. The samples subjected to radioisotopic dating (rubidium-strontium method), all of which were from wells in metamorphic rocks, yielded ages of between 870 and 980 million years ago. From this information, Bass concluded that the north-south boundary in west-central Ohio was the southward extension of the Grenville Front, which is exposed in the Canadian Shield. The Grenville Front is an orogenic (mountain building) boundary between metamorphosed, faulted rocks and unmetamorphosed, undisturbed rocks.

By 1967, 94 wells had reached the Precambrian in Ohio, permitting Gordon L. Owens, in Report of Investigations 64, *The Precambrian surface of Ohio*, to construct a paleotopographic map of the Precambrian surface. Owens' map had a contour interval of 100 feet and was more detailed than Summerson's 1962 map, which had a contour interval of 500 feet. Both maps showed the same general configuration of the basement surface—a broad platform (known as the Indiana-Ohio Platform or Cincinnati Arch) in western Ohio and a southeast-sloping surface in eastern Ohio dipping into the Appalachian Basin.

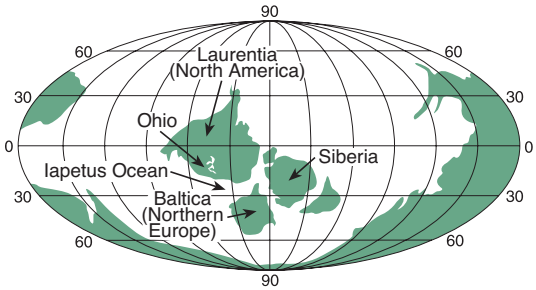
Although wells that reached the Precambrian basement continued to be drilled at a slow but steady rate, little new understanding of the geologic history of the Precambrian geology of Ohio developed during nearly the next two decades. Beginning about the mid-1980's, acquisition and interpretation of new geophysical data revolutionized our concepts about the Precambrian of Ohio and adjacent areas and, for the first time, presented a coherent picture of long-ago geologic events that had been frustratingly hidden for so long. Within the period from 1985 to 1995, we gained more understanding about the Precambrian of Ohio than had been obtained in the previous 15 decades.

In 1956, the Division of Geological Survey had published a gravity map of Ohio (Report of Investigations 30), compiled by W. A. Heiskanen and U. A. Uotila. This map depicted a complex and provocative series of anomalies, particularly in western Ohio, but there was little understanding at the time of the relationship of these anomalies to the Precambrian history of the state.



Precambrian surface of Ohio as determined from deep-well data. Contour interval is variable. Elevations are in feet below sea level (datum). Western Ohio is dominated by the broad Indiana-Ohio Platform (Cincinnati Arch). The edge of the platform drops off steeply to the east into the Appalachian Basin. Modified from Lucius and Von Frese (1988).

It was not until 1984, when the U.S. Geological Survey, in cooperation with the Ohio Geological Survey, published gravity and aeromagnetic maps of Ohio (see *Ohio Geology*, Summer 1984), that the current understanding of the Precambrian geology of Ohio began to emerge. A deep, east-west reflection seismic profile across Ohio completed in late 1987, as part of the nationwide COCORP (**Co**nsortium for **Co**ntinental **R**eflection **P**rofiling) project, revealed new details of the state's crust that allowed a meaningful interpretation of the basement (see *Ohio Geology*, Fall 1987 and Winter 1989). These investigations, along with the Survey's fortuitous discovery of a thick sequence of Precambrian sedimentary rocks in a core hole in Warren County (see *Ohio Geology*, Summer 1989), spurred the formation of an industry-supported consortium composed of the Ohio, Indiana, and Kentucky Geological Surveys that was known as the Cincinnati Arch Consortium (CAC). This team assembled and analyzed all available data on Precambrian rocks and structure in the tri-state area and in 1992 issued a summary report (Ohio Geological Survey Information Circular 57) that outlined an interpretation of the remarkable events in the geologic development of the Precambrian basement of Ohio, particularly the formation of a feature interpreted to be a rift basin in western Ohio and adjacent areas.

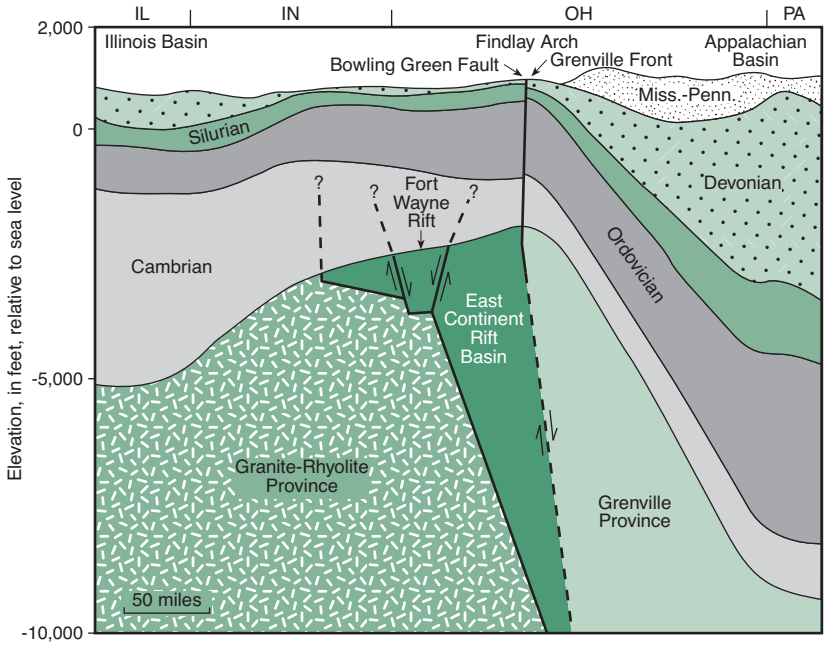


Continental configuration during the latest Precambrian. Modified from Scotese and McKerrow (1990, in *McKerrow, W. S., and Scotese, C. R., Palaeozoic palaeogeography and biogeography: Geological Society Memoir 12, p. 5).*

PRECAMBRIAN GEOLOGY OF OHIO—THE CURRENT VIEW

The North American craton—an area of ancient, rigid, stable rocks—is really a conglomeration of continental plates or microcontinents that have been fused together by a series of collisions that resulted in deformation of the rocks in mountain-building events (orogenies). These blocks of ancient rock were assembled in the Early Proterozoic into the progenitor of the North American continent, known as Laurentia. A large number of radioisotopic dates has permitted geologists to ascertain the ages of these continental blocks and the time of their accretion to the North American protocontinent. In general, older rocks (>2.5 billion years) are in the central, Canadian portion of the continent, and progressively younger belts of rocks form the continental perimeter.

Known Precambrian history of Ohio began with the emplacement of a vast, horizontal, 7-mile-thick layered sheet of granite and rhyolite beneath western Ohio and neighboring states to the west.



East-west cross section depicting Precambrian rocks and structures and overlying Paleozoic rocks from the Illinois Basin to the Appalachian Basin. Vertical exaggeration 165X. Modified from a diagram by Dr. E. Scott Bair, The Ohio State University.

This emplacement has been attributed to an uprising in the Earth's mantle known as a superswell. Radioisotopic dating suggests that this event took place between about 1.4 and 1.5 billion years ago, forming what we call the Granite-Rhyolite Province.

Continued continental doming of the superswell caused the crust beneath western Ohio, Indiana, and Kentucky to extend and split (rifting), resulting in major faulting and consequent downdropping to form a complex rift basin, now known as the East Continent Rift Basin. Molten basalt flowed upward as erosion began to fill the basin with clastic sediment, perhaps as much as 20,000 feet thick in some places. This extensive clastic deposit is known as the Middle Run Formation. About 1 billion years ago, doming ceased and the rift became a failed or aborted rift, bringing rifting, volcanic activity, and basin filling to an end.

The East Continent Rift Basin is similar in configuration and age to an extensive arcuate system of rifts that extends from Nebraska and Iowa northward to the Lake Superior region and then southward into Michigan. These rifts, known as Keweenawan rifts and named for exposures of these rocks on the Keweenaw Peninsula of Michigan, may be continuous in the subsurface with the East Continent Rift Basin.

At the time of rifting, it appears that eastern Ohio marked the edge of the North American protocontinent. Between about 990 and 880 million years ago a continent to the east collided with North America, resulting in extensive crustal compression and development of a mountain range that geologists call the Grenville Mountains. What is thought to be the zone of continental collision, known as a suture zone, is located in eastern Ohio, where it was first discovered as a deep, broad zone of west-dipping reflectors on the 1987 COCORP profile. This zone has been called the Coshocton Zone because it was first noted across Coshocton County.

As these continents collided along a 3,000-mile-long line, perhaps stretching from Sweden to Mexico, rocks were folded, twisted, metamorphosed, and thrust westward across part of the rift zone in western Ohio. This north-south-oriented, 30-mile-wide zone of east-dipping, imbricated thrust slices is called the Grenville Front Tectonic Zone and marks the westward limit of the Grenville Mountains. The Grenville Front in western Ohio sharply demarcates relatively undisturbed 1.5-billion-year-old granitic rocks to the west from 800- to 900-million-year-old, greatly disturbed metamorphic rocks to the east.

Alternatively, some geologists have suggested that the apparent rift basin may be a basin that was downwarped in front of the Grenville Mountains, a structure known as a foreland basin, or it may represent extensive, previously unknown sedimentary rocks that were deposited in conjunction with the igneous rocks of the Granite-Rhyolite Province. They suggest that faulting occurred after formation of the Grenville Mountains.

After the Grenville Mountains were formed, a 300-million-year-long period of deep erosion oc-

curred during the Late Precambrian. During this time the landscape was reduced to a gently rolling surface and the Grenville Mountains were carved away, exposing their roots of high-grade metamorphic rocks. It is probable that even the upper part of the rift-basin sedimentary rocks were removed at this time. At some time during this interval, extensive strike-slip faulting occurred.

The close of the Precambrian is marked by the transgression of Cambrian seas across this geologically complex but topographically simple surface, formed by multiple events during more than a billion years of time. This topographic surface and its structural configuration would subtly influence subsequent geologic history forevermore.

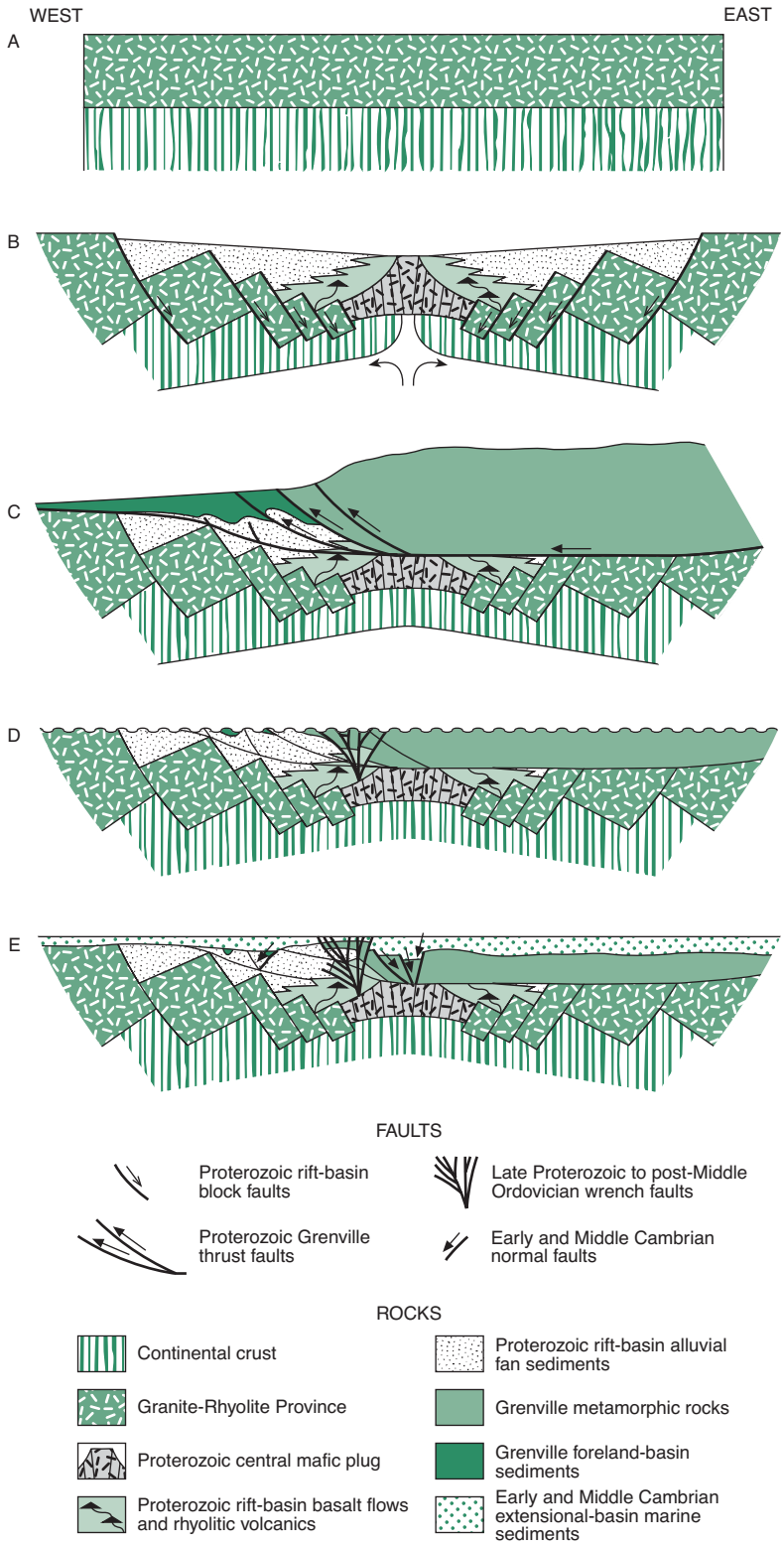
ECONOMIC AND ENVIRONMENTAL INFLUENCE OF PRECAMBRIAN ROCKS

At the present time, no minerals are produced directly from Precambrian rocks in Ohio. There is a potential for petroleum and natural gas to be present in economic quantities in Precambrian sedimentary rocks. Limited sampling of the upper part of rift-basin sedimentary rocks in western Ohio has yielded discouraging results in regard to hydrocarbons because the porosity and permeability of these rocks are very low. However, much exploration remains to be done. More importantly, topographically high areas and periodic reactivation of faults and other Precambrian structures have influenced the deposition of overlying Paleozoic sedimentary rocks, creating both structural and stratigraphic traps for significant accumulations of hydrocarbons. Strong evidence also has begun to emerge that many coal beds in late Paleozoic Pennsylvanian rocks in eastern Ohio were deposited on structurally upthrown blocks that were reactivated along faults formed in the Precambrian.

The economic potential of metallic ores, particularly sulfides of lead and zinc, also remains unevaluated. Small amounts of sulfide mineralization occur in carbonate rocks of northwestern Ohio and other areas of the state. It is probable that these occurrences represent deposition by fluids derived from Precambrian rocks.

The mild to moderate-sized earthquakes that periodically strike Ohio were poorly understood until recent years, when the structure of Precambrian rocks began to emerge. Ohio had traditionally been considered to be a state with simple geologic structure based on the fact that only a very few faults were exposed at the surface in nearly flat-lying to gently dipping rocks. There was little realization that the underlying Precambrian rocks are complexly faulted and that many of these faults have undergone periodic reactivation during several intervals of geologic time, including the present. Perhaps the best-known fault in Ohio is the Bowling Green Fault, a north-south-oriented reverse fault that coincides with the Grenville Front Tectonic Zone. This fault is known at the surface only from quarry and stream exposures near Waterville in Wood County, but it can be traced extensively in the subsurface.

It has now become obvious that some of these



Development of the East Continent Rift Basin in western Ohio. ***A****, Emplacement of granitic igneous rocks about 1.5 billion years ago.* ***B****, Rifting of the crust by spreading about 1 billion years ago. The basin was filled by a thick sequence of sediments and lava flows.* ***C****, Formation of the Grenville Mountains between about 990 and 880 million years ago. Continental collision in eastern Ohio thrust Grenville rocks westward over the rift zone in a series of thrust sheets. The western limit of thrusting is known as the Grenville Front.* ***D****, Leveling of the mountains by erosion; wrench faulting.* ***E****, Transgression of the first of the Paleozoic seas about 570 million years ago and burial of the leveled Precambrian surface beneath a thick sequence of sedimentary rocks. Modified from Drahovzal and others (1992).*

Precambrian faults are still capable of movement and are periodically reactivated by stresses within the North American plate. The most seismically active area of the state, in Shelby and Auglaize Counties in the western Ohio, is now known to be associated with a segment of the East Continent Rift Basin that has been termed the Fort Wayne or Anna-Champaign Rift. It is still poorly understood as to why this portion of the rift is active and other portions appear to be stable. Increased knowledge of the Precambrian basement rocks may one day enable us to estimate the location, frequency, and maximum size of earthquakes in certain areas of the state. Such knowledge will have wide-reaching implications for building codes; zoning regulations; siting of critical facilities such as schools, hospitals, and utilities; and insurance on homes and businesses.

This brief summary of the Precambrian geology of Ohio is, perhaps, just the beginning of the story. To return to our opening analogy of the pioneer exploration and settlement of Ohio, we have accomplished little more than sending scouts into the Precambrian geological frontier. They have returned with exciting reports of what they have seen, although different scouting parties have slightly different interpretations of what they have seen. Much scouting and investigation remains to be done.

ACKNOWLEDGMENTS

We thank Lawrence H. Wickstrom of the Survey and E. Scott Bair of The Ohio State University for assistance with this article.

FURTHER READING

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Lisa Van Doren named 1995 Survey Employee of the Year

Lisa Van Doren

Lisa Van Doren, a cartographer in the Cartography and Editing Group, was the recipient of the 1995 Employee of the Year award for the Division of Geological Survey. The award was presented to Lisa by Division Chief and State Geologist Thomas M. Berg at the annual staff Christmas luncheon. The selection of the Employee of the Year is made by a committee of peers from nominations submitted by Survey staff.

Lisa received the award for her skill and mastery of the Survey's Macintosh desk-top publishing system and her efficiency in typesetting, design, and layout of Survey publications. Her innovative designs have prompted many compliments from the Survey's constituency. She is responsible for the new format of *Ohio Geology* as well as other recent Survey publications. Staff members are continually amazed at Lisa's speed and efficiency in producing camera-ready copy for publications, illustrations for presentations, and graphics for displays used at technical meetings or popular exhibitions such as the Ohio State Fair. She also curates the Survey's extensive collection of photographs.

Lisa is from Wooster, Ohio, and came to the Survey in 1984 after receiving a bachelor's degree in geography from Wittenberg University. During this time she has been involved with nearly all aspects of production of Survey publications and maps and has witnessed the transformation of these procedures from labor-intensive, hands-on fabrication to advanced computer processes. Indeed, Lisa has been a leader in the computerization of Survey maps and publications.

Collecting Smokey Bear memorabilia and Legos are some of Lisa's hobbies, and she is a key player on the Division's softball team. Lisa also enjoys working with her own Macintosh computer at home.

1996 Teachers workshops

1996 OHIO'S MINERAL INDUSTRIES AND THE ENVIRONMENT

The "Ohio's Mineral Industries & the Environment—North" teachers workshop will be based in Akron and held July 8-12, 1996. The "Ohio's Mineral Industries & the Environment—South" teachers workshop will be based in Columbus and held July 22-26, 1996. Both workshops are designed to familiarize participants with the geology of Ohio, the importance of Ohio's mineral industries, and how environmental protection is compatible with mining. Graduate or undergraduate college credit is available through the University of Akron. For more information contact Sherry Weisgarber, ODNR, Division of Geological Survey, 4383 Fountain Square Dr., Columbus, OH 43224-1362, telephone 614-265-6588; or Dr. Roger Bain, Department of Geology, University of Akron, Akron, OH 44325-4101, telephone 216-972-7659.

Geologic maps of Ohio available on World Wide Web

Dr. Annabelle Foos, Associate Professor of Geology at the University of Akron, has adapted modified versions of page-size geologic maps of Ohio for the World Wide Web. The maps include bedrock geology, glacial geology, physiographic provinces, soils, ground-water resources, and a bedrock cross section. The Internet address of the maps is: *http://www.uakron.edu/geology/ohmaps.html*.

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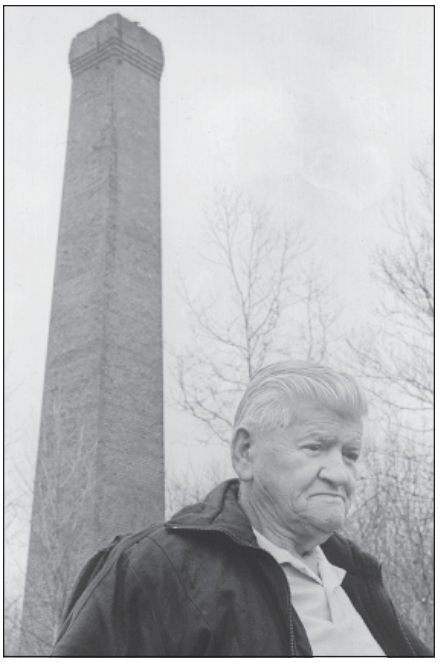
MILLFIELD MINE DISASTER CORRECTION

The Division of Geological Survey recently learned that Sigmund Kozma, Athens, is the lone living survivor of the methane explosion at the Sunday Creek Coal Company No. 6 mine at Millfield, Athens County (see *Ohio Geology*, Fall 1995). This explosion on November 5, 1930, took the lives of 82 men. In an article in the Athens News (December 4, 1995, p. 7), Kozma stated "We were loading a coal car and we felt the pressure (much like diving) and then it was released. All you could hear was the force of air (in your ears). There was no (sound of an) explosion . . . . There were four men in our group (of 13) that were badly injured. The force of the explosion hit them and rolled them . . . . As long as we had good air we would have lived. We followed where the (good) air was (leading us)." Three hours after the explosion, Kozma and the rest of his group made it out of the mine.



Sigmund Kozma in front of the power-plant chimney at the Millfield mine. Photo courtesy of the Athens News.

Price reduced on Digital Chart and Map Series

In our continuing effort to better serve our customers, the Division of Geological Survey has reduced the cost of computer-generated maps and charts in the Digital Chart and Map Series (DCMS) from $10 each to $5 each. Please add $2 handling charge to all mail orders and $0.29 cents tax to orders shipped to Ohio addresses.

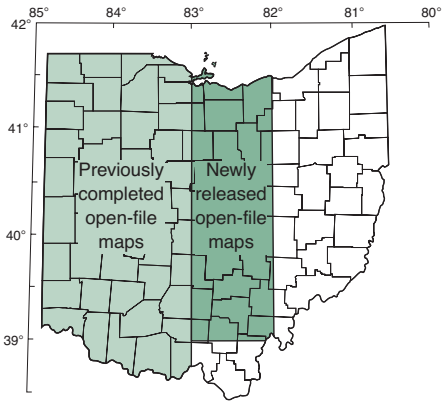
OHIO SURVEY WORLD WIDE WEB SITE

The Division of Geological Survey has established a team to develop a home page from which information on Ohio geology and the Division's products and services can be accessed on the Internet. We solicit suggestions from our readers on what information would be most useful at our Web site. Please contact us by phone or regular mail or e-mail at *mike.hansen@dnr.ohio.gov* and give us your thoughts.

Phase Three bedrock mapping completed

The Bedrock Geology Mapping Group has completed bedrock-geology, bedrock-topography, and structure-contour maps for 164 7.5-minute quadrangles in north-central, central, and south-central Ohio. The area includes rocks of Silurian, Devonian, Mississippian, and Pennsylvanian age. In some areas, these rocks have a considerably different areal distribution than that shown on the 1920 1:500,000-scale bedrock map of Ohio.

This area represents the third phase of a four-phase program by the Division to remap the bedrock geology of the state. Survey geologists have completed bedrock-geology, bedrock-topography, and structure-contour maps for most quadrangles in western Ohio west of 82° west longitude. The Ironton 30 x 60 minute quadrangle is being mapped by the U.S. Geological Survey. These maps are on open file and are available for purchase as paper copies reproduced from inked mylars. Several different structure-contour maps may be available for each quadrangle. Cost is $4.00 per map plus sales tax and handling. Please contact the Geologic Records Center at 614-265-6576 for ordering information.



HANDS-ON EARTH SCIENCE No. 7

by Richard Hansgen
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TWO SCALE MODELS OF THE EARTH-MOON SYSTEM

Given the diameters of the Earth and the Moon and the distance between the two bodies, students can construct a scale model of the Earth-Moon system which will prove very useful in their classroom. The following activity is written in an inquiry mode and should be presented to students as a set of activities and questions. Answers for the instructors are provided in *italics* in brackets.

Diameter of the Earth	=	12,800 km
Diameter of the Moon	=	3,500 km
Mean distance from Earth to Moon	=	385,000 km

MODEL I

First, calculate to the nearest whole number how many times larger the Earth (its linear diameter) is than the Moon. [*4*]

If we choose a basketball (diameter of approximately 25 cm) to represent the Earth, what size ball would represent the Moon? [*~6 cm, a tennis ball. For any scale model, the Earth must be four times larger than the Moon.*]

We now have our system to scale with respect to size. Next we scale for distance. To the nearest whole number, how many Earths can fit between the Earth and the Moon? [*30*] This is a fascinating answer. Does it surprise you? Did you think it should be smaller or greater?

According to our above scale, how many basketballs must fit between the Earth and the Moon? [*30. For any scale model, the Moon must be 30 "Earths" from the Earth.*]

Now obtain a long piece of heavy string. Using our scale, how long should the string be to represent the distance between the Earth and the Moon? [*30 x 25 cm = 750 cm = 7.5 meters*]

With masking tape, attach one end of the string to the "Earth" and the other end to the "Moon." You now have a very flexible Earth-Moon model which is to scale for both size and distance—the Earth and Moon in your classroom!

With this model, how far away would the sun be, in units of our Earth-Moon distance? Hint: the Earth-Sun distance is 150,000,000 km. [*400*] If we took our model outside into the street, how far away would the sun be in meters? [*400 x 7.5 meters = 3,000 meters = 3 km*] This exercise should provide the students some food for thought as to the immense size and vast emptiness of our solar system!

MODEL II

The second model is less flexible than the one above but has the advantage of clearly simulating both solar and lunar eclipses.

Let the Earth be represented by a 10-cm styrofoam ball. What size styrofoam ball should represent the Moon? [*2.5 cm. Remember, our scaling factor for size is 4.*]

What is the Earth-to-Moon distance with our new scale? [*30 x 10 cm = 300 cm = 3 meters. Remember, our scaling factor for distance is 30.*] Go to your local lumber yard and have them cut an inexpensive 1-inch x 1-inch board whose length correctly represents this Earth-Moon distance.

Attach the larger ball (the Earth) to one end of the board with glue or large rubber bands. Place the smaller ball (the Moon) at the other end. However, in order to keep the shadow of the Moon distinct from the shadow of the board, raise the smaller ball above the surface of the board by attaching it to a nail or a stiff wire. A bent paper clip works well.

Armed with this model (and it is an armful), take your class outside on a sunny day and demonstrate eclipses. It really works! You will discover that the "Moon" will be completely covered by the "Earth's" umbra as you simulate a lunar eclipse just as in the actual event, but during your "solar" eclipse only a portion of the "Earth's" surface will fall into the "Moon's" total shadow. Again, this is what actually happens. Our model illustrates nicely why one must live within that narrow zone of totality in order to experience a total solar eclipse! The strip of totality is generally about 241 km wide, which explains why most people have never seen a total solar eclipse.

NOTE: Contact Sherry Weisgarber at 614-265-6588 if you are interested in submitting a hands-on activity for this column.

Scale diagram showing the styrofoam balls and board for model II.

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