Ohio Geology

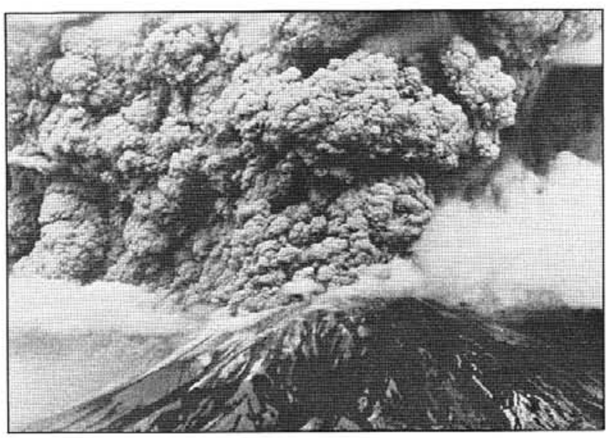
a quarterly publication of the Division of Geological Survey

VOLCANOES IN OHIO

by Gregory A. Schumacher

Volcanic eruptions are perhaps the most powerful and awesome of natural events, causing local death and destruction and, in some cases, worldwide climatic effects. The eruption of Krakatoa, an Indonesian volcano, in 1883 is estimated to have killed 35,000 people. The 1815 eruption of Tamboro, also in Indonesia, ejected so much volcanic ash into the atmosphere that the following year was known as the "year without a summer" or, colloquially, as "eighteen hundred and froze to death." Snow is reported to have fallen in Ohio during every month of the year in 1816 and there were widespread crop failures.

The recent and continuing eruption of Mount Pinatubo in the Philippines brings to mind the spectacular eruption of Mount St. Helens in 1980 in Washington. Few Americans will forget the photographs and videos of the dark, ominous clouds of volcanic ash which turned day into night over much of the Pacific Northwest, the Douglas fir trees broken off at their bases by the force of the blast, and the rivers of gray mud clogged by trees, houses, bridges, and vehicles.



The eruption of Mount St. Helens on May 18, 1980. Photo courtesy of Washington Division of Geology and Earth Resources.

Such events are fascinating to nearly everyone, but they occur today far from Ohio, mostly in the "ring of fire" surrounding the Pacific Ocean. There are no volcanoes visible in Ohio today. Ohio's age of volcanoes was during Precambrian time, from the beginning of the Earth about 4.5 billion years ago until the beginning of the Paleozoic Era about 600 million years ago. Today, Precambrian rocks in Ohio are buried beneath 2,500 to 15,000 feet of Paleozoic sedimentary rocks.

PRECAMBRIAN VOLCANIC ACTIVITY

Late in the Precambrian, Ohio was the site of a major continental collision (see *Ohio Geology,* Winter 1989) that squeezed and displaced rocks along a north-south linear belt (the Grenville Front) in west-central Ohio, forming a mountain range. This mountain range, known to geologists as the Grenville Mountains, had extensive volcanic activity associated with it, as evidenced by lava flows penetrated by some of the more than 150 boreholes that have reached Precambrian rocks in the state. These volcanic rocks are poorly known because so few samples of them are available. Geophysical maps such as the gravity and magnetic maps of Ohio (see *Ohio Geology,* Summer 1984) and the COCORP (Consortium for Continental Reflection Profiling) profile of the state (see *Ohio Geology,* Winter 1989) provide some insight into the configuration and distribution of Precambrian igneous and metamorphic rocks. Interestingly, the magnetic map of Ohio reveals a large circular structure along the Ohio-Indiana border in southwestern Ohio that some geologists have informally suggested may be a giant caldera from a Precambrian volcano.

PALEOZOIC VOLCANOES AND OHIO BENTONITES

In the early and middle portions of the Paleozoic Era, shallow tropical seas advanced and retreated across the area that is now Ohio and deposited a thick sequence of limestone, shale, and sandstone, thus deeply burying the worn-down remnants of the Grenville Mountains. Continental collision was still occurring, but by this time it was far to the east and south. Ohio's volcanic record during the Paleozoic consists of thin layers of volcanic ash which have been altered to a special type of clay known as a bentonite. These ash beds were altered to bentonites because the minerals in the ash, which formed under high temperature and pressure, are unstable in the low-temperature and low-pressure conditions at the Earth's surface. The volcanic minerals reacted with water to form the more stable clay minerals that characterize a bentonite. Geologists can sometimes recognize bentonite beds in an outcrop because the bentonites weather much more quickly than most other types of sedimentary rocks, thus forming a recessed area in profile. Bentonites also have a greasy feel when the material is rubbed between the fingers and, upon weathering, may have a diagnostic red-orange color.

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OHIO Department of Natural Resources

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FROM THE STATE GEOLOGIST . . . by Thomas M. Berg

LIVING WITH GEOLOGIC HAZARDS — ABIDING IN HARMONY WITH THE EARTH

While attending a 1978 geological symposium in England, I took a wonderful side trip to a place along the North Sea coast of southern Scotland called Siccar Point. There, 190 years before, Sir James Hall, Prof. John Playfair, and Dr. James Hutton—one of the founding fathers of the science of geology—visited the outcrop of the "great unconformity." What a terrific experience it was to stand on the same sedimentary rock exposures that Hutton, Hall, and Playfair stood upon as they marveled about the unimaginable dynamics of the Earth that were laid bare before them! At the Siccar, nearly vertical beds of hard graywacke sandstone (the "Silurian schistus" of Playfair) are overlain by gently dipping, softer beds of the Devonian Old Red Sandstone. With the sounds of the North Sea behind us, two other geologists and two small lads stood with me on those rocks while we read the words of John Playfair (*The Works of John Playfair,* 1822):

> On us who saw these phenomena for the first time, the impression made will not easily be forgotten .... We felt ourselves necessarily carried back to the time when the schistus on which we stood was yet at the bottom of the sea ... not yet disturbed by that immeasurable force which has burst asunder the solid pavement of the globe .... The mind seemed to grow giddy by looking so far into the abyss of time; and while we listened ... to the philosopher [Hutton] who was now unfolding to us the order and series of these wonderful events, we became sensible how much farther reason may sometimes go than imagination can venture to follow.

Hutton clearly perceived the immensity of mountain-building and erosional dynamics at the exposure of the great angular unconformity at the Siccar. Today, geologists still marvel at the dynamics of our planet, where whole continents have shifted thousands of miles about the globe for millions upon millions of years and have been rifted asunder or rammed into each other, forming huge mountain chains. Geologists who are used to thinking about such massive events are not surprised by earthquakes, volcanic eruptions, or immense landslides. These phenomena have been common throughout geologic time on our dynamic planet.

It is exceedingly important that all citizens become aware that indeed we do live on a dynamic planet that is in motion even though we may not perceive it. Human activities must be planned so that they are carried out in anticipation of small or large earth movements. With proper planning, loss of life and property can be avoided or minimized. We can live in harmony with our Earth if we utilize the maps that show the distribution of formations and structures that are associated with geologic hazards and plan to avoid or remedy them in our site designs.

Most readers of *Ohio Geology* will remember the commotion caused by the prediction of a December 1990 earthquake in the midcontinent. The prediction was scientifically untenable, but the human reaction was quite real. A series of major earthquakes did occur in the New Madrid, Missouri, region beginning on December 16, 1811, and continuing through February of 1812. At the first shock, chimneys were knocked over in Cincinnati. On February 7, more chimneys fell over and brick walls were split and ruptured. Shocks at Lebanon and Circleville in Ohio were violent enough to frighten people from their beds and out into the cold of winter. There were no skyscrapers and high-rise apartment complexes in Cincinnati in the early 1800's. There are many such structures now. Would they survive similar seismic shocks today? Little is known about exact recurrence intervals of midcontinent earthquakes, but even if such events occurred only every 200 or 300 years, they would still be considered quite common from the perspective of geologic time. Rather than being lulled into passive unconcern by the infrequency of major earthquakes in the midcontinent region, we should prepare now for a major seismic event that could occur within the next several decades. Research on seismic risk in Ohio is urgently needed, and mapping of geologic materials susceptible to failure during earthquakes is imperative.

Hamilton County, Ohio, has the most serious landslide problem of any county in the nation. Landslides are also a serious problem in Athens County and surrounding areas. On a recent field investigation in Guernsey County, I noted compelling evidence of prehistoric landslides. We should not be surprised by downslope movements of the land. Rather, we should expect such geologic events, gauge their potential using detailed geologic maps, and plan our use of the land to adequately address the hazard.

I doubt that a volcano would ever erupt in Ohio in our own time, but volcanic activity has affected the state in the geologic past, as described by Greg Schumacher in this issue of *Ohio Geology.* Ohioans who visit the west coast of the United States should not be surprised by an eruption such as occurred at Mount St. Helens in Washington. Volcanoes are not wild and unusual geologic events inflicted upon humanity as punishment for evil done. The eruption of Mount St. Helens was a moderate, volcanic side effect of the continuing collision between an oceanic crustal plate and a continental crustal plate—one diving beneath the other, melting to magma, and rising to the surface in an eruption. These common, everyday physical processes have been repeated again and again throughout geologic time. Volcanoes are a very serious hazard, but we can learn to live in harmony with them and avoid their areas of high risk. For example, U.S. Geological Survey geologists have already mapped the various risk areas on volcanoes such as Mount Rainier in Washington and Mount Hood in Oregon. We only need to use the maps and assure that our public policy-makers give full attention to them.

As I have described, there are geologic hazards in Ohio such as earthquakes and landslides. We also live with the hazards of coastal erosion along Lake Erie, sinkholes in limestone formations, radon emanating from black shales and some glacial deposits, subsidence caused by abandoned underground mines, and many others. The Ohio Division of Geological Survey is engaged in mapping and characterizing the bedrock and unconsolidated geologic formations that occur at the surface of the state. We are also engaged in mapping the deep subsurface formations and structures that can be examined only by drilling or

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geophysical surveys. As this research and mapping are carried out, our geologists identify and predict geological hazards that can take a serious toll on life and property.

We need to live in harmony with the Earth and not rail against it. But we cannot live harmoniously with natural systems that we do not understand. That is why the work of the U.S. Geological Survey and the state geological surveys is so critically important at this time in our history. Our government surveys are providing the essential understanding of geologic processes that planners and legislators need to make sound public policy. They are also providing essential geoscience information needed for the education of all citizens.

In an article in the May 1991 issue of *Geotimes,* Dr. Dallas L. Peck, Director of the U.S. Geological Survey, said: "The public does not understand the science of earthquake prediction, nor can the scientific community meet public expectations." While Dr. Peck urges continued research on natural hazards, he also emphasizes the need for earth scientists to communicate their research so that it can be readily utilized by citizens who are responsible for emergency planning: "We as earth scientists must be informative and forthcoming with the results of our research. But we must also be responsible in *how* that information is translated. We must learn to translate our science to meet public needs. Effective communication can help us all be better prepared when nature becomes the enemy. We can meet public expectations. We can deliver." I agree with Dr. Peck completely. We geologists need to let the public know what they can expect of us, and we need to communicate our science intelligibly to decision-makers. The Division of Geological Survey is committed to providing Ohioans with the best possible geologic information as quickly and as cost-effectively as possible. *We must live in harmony with the Earth.* Our legislators and public policy-makers should recognize this need as they judge the value of the Ohio Geological Survey.

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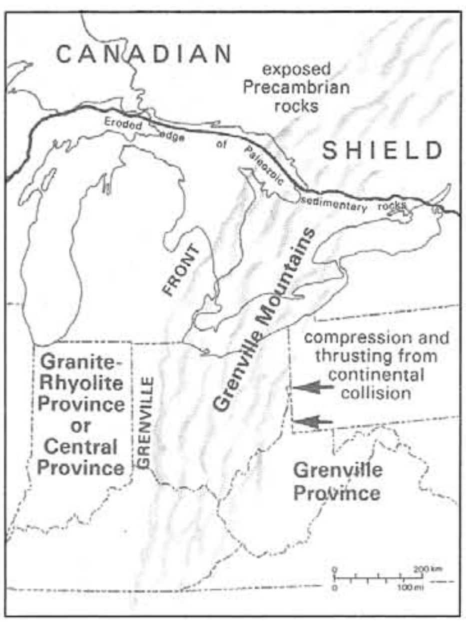
In many cases laboratory analyses are necessary to confirm the identification of a bentonite bed.

The volcanoes that produced Ohio's Paleozoic bentonites were probably located in what is now northern Georgia or Alabama in the early Paleozoic and in what are now the Middle Atlantic States during the middle Paleozoic. These volcanoes were probably part of a chain of islands similar to the Aleutian Islands of Alaska or the Philippines.

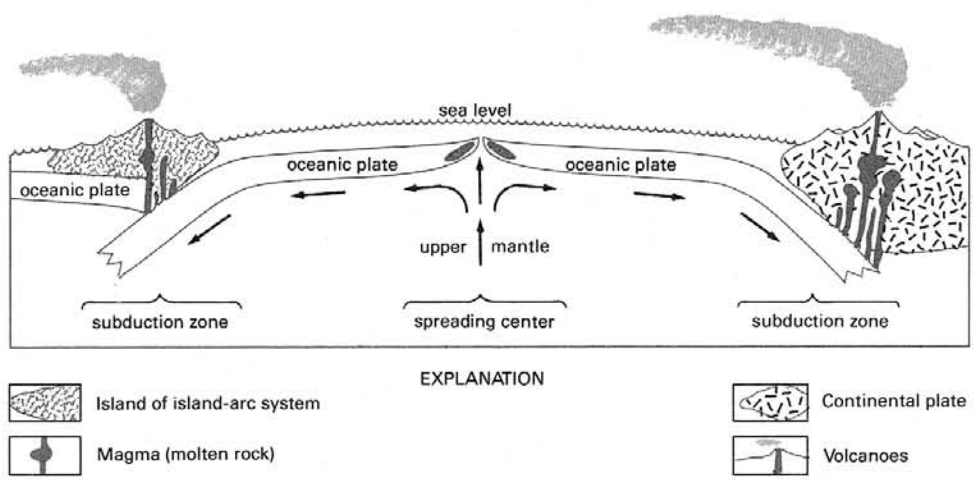


Probable extent of the Grenville Mountains (from Hansen, 1989).

Such arc-shaped chains of islands, called island-arc systems, form adjacent to deep oceanic trenches where heavy, less buoyant oceanic crust is being forced under lighter, more buoyant continental crust. These areas are known as subduction zones. As the oceanic crust is subducted, the rocks are subjected to high temperatures and pressures which cause the rock to melt. The molten rock, or magma, rises to form the volcanoes associated with island-arc systems. Most modern volcanoes are associated with subduction zones and it is probable that volcanoes of the past were also.

Subduction zones, island-arc systems, and extensive volcanism occurred at selected intervals in geologic time. At least a dozen major volcanic eruptions are recorded by bentonite beds in Middle Ordovician rocks in the subsurface of Ohio. Two of these Ordovician bentonite beds, the Deicke bentonite and the Millbrig bentonite, may represent some of the largest volcanic eruptions in the Earth's history. Drs. Stig Bergström (The Ohio State University), Warren Huff (University of Cincinnati), and Dennis Kolata (Illinois State Geological Survey) have traced these bentonite beds from the Mississippi River across eastern North America, throughout northern Europe, and into the eastern portion of the Soviet Union—roughly one-fourth of the Earth's surface during the Middle Ordovician. The volume of volcanic ash generated during these eruptions was about 5,000 times greater than the ash created by the eruption of Mount St. Helens in 1980. Volcanic eruptions of the magnitude of that represented by the Deicke and Millbrig bentonites would have catastropic effects on modern civilization. Apparently, the effects on Ordovician marine organisms were no less significant. Many marine species became extinct at the stratigraphic level at which these bentonites occur. It is probable that the huge volume of volcanic ash raining into the sea smothered many bottom-dwelling organisms and fouled the breathing and feeding apparatuses of others.

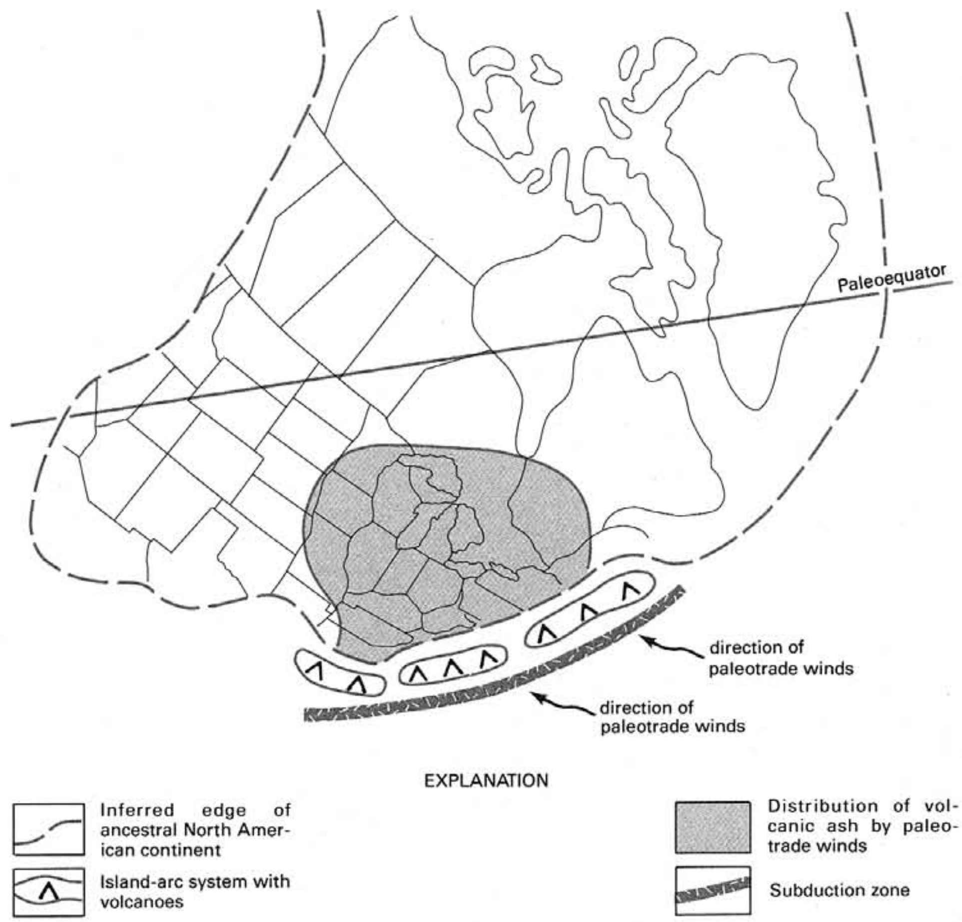
The Deicke and Millbrig bentonites were deposited in the first of two periods of intense Middle Ordovician volcanism. Five to 10 million years later, additional volcanic eruptions deposited widespread bentonites similar to the Deicke and



Schematic diagram illustrating the formation of volcanoes in island-arc systems or along continental margins.

Millbrig bentonites. Recently, Survey geologists Gregory Schumacher and Richard Carlton discovered seven bentonites deposited during this second episode of intense volcanism. This volcanic episode started and ended with massive eruptions separated by a period of quiescence. The lower four bentonites are known as the Westboro bentonite zone and are separated by 40 feet of nonvolcanic rocks from the upper three bentonites, known as the Bear Creek bentonite zone.

Like the volcanic ash deposited by the recent eruption of Mount Pinatubo, the volcanic ash of the Westboro and Bear Creek bentonite zones apparently was subjected to the destructive forces of hurricanes (called cyclones in the Pacific Ocean area). The series of hurricanes which have struck the Philippines have produced massive mudflows in the thick volcanic ash. In the sea, the beds of volcanic ash have been eroded by currents, mixed with normal-marine sediments, and redeposited. A similar process likely acted upon the original volcanic ash of the Westboro and Bear Creek bentonite zones, producing bentonites which are difficult to distinguish from the adjacent nonvolcanic rocks.



Middle Ordovician paleogeography illustrating the interaction between paleotrade winds and distribution of volcanic ash beds.

Bentonites deposited during the middle part of the Devonian Period have a similar distribution to those of Ordovician age. These bentonites are present in the Columbus and Delaware Limestones, which are exposed in central Ohio. One of these bentonites, the Tioga bentonite, is widely distributed in Devonian rocks in the eastern half of North America.

Era	Period	Major volcanic deposits
Paleozoic	Pennsylvanian and Permian	volcanic ash beds (?)
	Mississippian	
	Devonian	Tioga bentonite
	Silurian	
	Ordovician	Bear Creek bentonite zone Westboro bentonite zone Deicke and Millbrig bentonites
	Cambrian	
Precambrian		lava flows ash beds volcanoes

Ohio's major volcanic deposits through geologic time.

Volcanic ash beds also have been reported from rocks of the Pennsylvanian Period in Kentucky, Tennessee, Virginia, and West Virginia. Currently, geologists from the Ohio Survey and the U.S. Geological Survey are working to identify these ash beds in Ohio.

To explain the wide distribution of bentonite beds deposited during the Paleozoic Era requires knowledge of the paleogeography. During this time in Earth history the shapes and positions of the continents were greatly different than today. For example, during the Middle Ordovician the ancestral North American continent was in tropical latitudes—Ohio was at about 20° to 25° south latitude, or about the position of southern Brazil today. At this latitude, paleotrade winds would have blown from the southeast to the northwest, carrying volcanic ash northwestward towards the Paleoequator and across what is now the North American continent. A similar scenario applies to the bentonites and volcanic ash beds present in Devonian and Pennsylvanian rocks.

Bentonites are of more than academic interest. Certain clay minerals in bentonites will expand to many times their original volume by absorbing large quantities of water. This property makes these clays very useful in the oil and gas industry and the water-softening industry. In particular, bentonite is used to thicken oil-well drilling muds to plug pore spaces in the walls of boreholes. Most bentonite used in the United States is mined from numerous thin beds in rocks of Mesozoic and Cenozoic age in the western part of the country. No Ohio bentonites are mined commercially.

FURTHER READING

Hansen, M. C., 1989, "How the world was made"—The COCORP traverse of Ohio: *Ohio Geology*, Winter 1989, p. 1-4.

Schumacher, G. A., and Carlton, R. W., 1991, Impure K-bentonite beds from the Lexington Limestone and the Point Pleasant Formation (Middle Ordovician) of northern Kentucky and southwestern Ohio: Southeastern Geology, v. 32, no. 2, p. 1-23.

Tarbuck, E. J., and Lutgens, F. K., 1984, The Earth: an introduction to physical geology: Charles E. Merrill Publishing Company, 594 p.

Witzke, B. J., 1990, Palaeoclimatic constraints for Palaeozoic palaeolatitudes of Laurentia and Euramerica, in McKerrow, W. S., and Scotese, C. R., eds., Palaeozoic palaeogeography and biogeography: London Geological Society Memoir No. 12, p. 57-73.

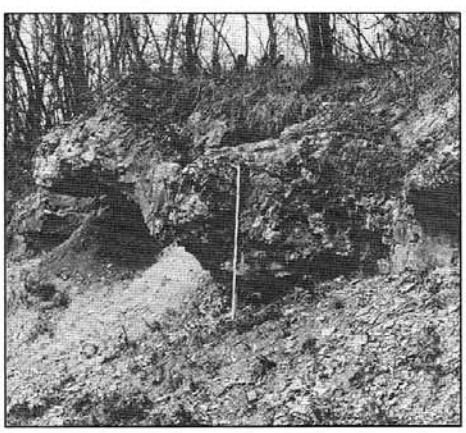
STATE GEOLOGIC SYMBOLS

A state symbol, whether it be a flower, bird, rock, mineral, or fossil, is meant to represent something important, colorful, or typical that presumably draws attention to a state. Birds, trees, and flowers have long been designated as state symbols, but it has only been in more recent decades that geologic symbols such as rocks, gems, minerals, and fossils have received acclaim in many states. Currently, 42 states have at least one geologic state symbol (see accompanying table). Two states, California and Massachusetts, have four official geologic symbols—gem, mineral, rock, and fossil.

There is no universal, uniform categorization of these geologic symbols from state to state. Florida and Michigan have state stones that are fossil corals. Mississippi, Texas, and Washington list petrified wood as their official stone, rock, and gem, respectively. Montana has both an official gem (Yogo sapphire) and an official gemstone (moss agate). Nevada is unique in having an official metal, silver, as a state symbol. New Jersey's state fossil and rock have unofficial status, as does Florida's state fossil.

Of the 27 states with fossils as symbols, 15 are vertebrates (eight dinosaurs or reptiles, five mammals, and two fish), eight are invertebrates, and four are plants. Among the primary categories of state symbols, fossils and gemstones are the most common (27 states for each category), followed by rock or stone (21 states), and mineral (13 states).

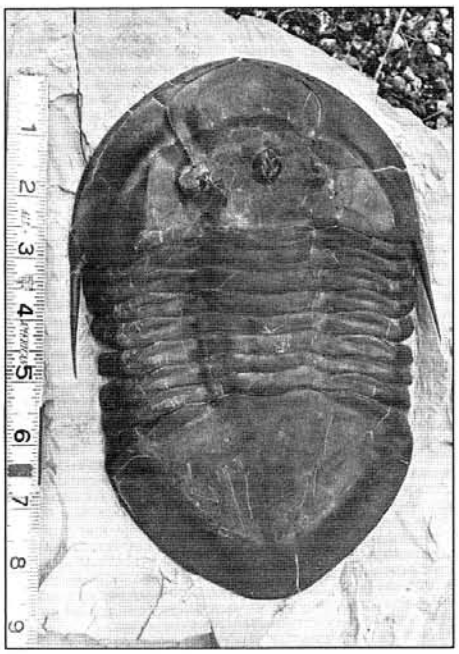
Ohio has two official state geologic symbols—flint, named the official gemstone in 1965, and an Ordovician trilobite, *Isotelus,* named the official fossil in 1985. Each symbol represents the State of Ohio well.



Outcrop of Vanport flint on Flint Ridge, Muskingum County.

Ohio is not particularly noted for a wide variety of gemstones, so the selection of flint was relatively easy. Although flint may seem to be a somewhat pedestrian symbol for the state, such is not the case. Ohio flint, particularly the Vanport flint from Flint Ridge in Licking and Muskingum Counties and the Upper Mercer flint (sometimes called the Nellie blue flint) from Coshocton County, are highly desired by lapidarists throughout the country because of their varied and intricate color patterns. Exquisite jewelry is fashioned from Ohio flint.

Flint was of vital importance to Ohio's prehistoric peoples who utilized this rock as a raw material for tools such as knives, scrapers, drills, and projectile points. Indeed, Ohio flint was important not only to American Indians living in the state but also to tribes throughout a wide area of the eastern United States. Tools and artifacts constructed from Flint Ridge flint have been found from Kansas City to the Atlantic coast and as far south as Louisiana.



Isotelus, *Ohio's official state fossil.*

In contrast to gems, Ohio has abundant and varied fossils. Choosing a state fossil would not necessarily be an easy proposition if all candidates were considered. A Middle Devonian trilobite, *Phacops rana,* and a Devonian arthrodire fish, *Dunkleosteus,* were suggested as candidates for the state fossil of Ohio. However, a large and spectacular Ordovician trilobite, *Isotelus,* was the favorite of Dayton-area school children who initiated and promoted the legislation to establish a state fossil in 1985 (see *Ohio Geology,* Summer 1985).

Should Ohio have additional geologic symbols? Possible categories include a state mineral, a state rock, and possibly a state vertebrate fossil (*Isotelus* is actually the official invertebrate fossil). Considerations for a state mineral include calcite, fluorite, celestite, and pyrite. Considerations for a state rock might include a cliff-forming unit such as the Black Hand sandstone that provides the spectacular scenery in the Hocking Hills and Mohican areas, or perhaps an industrial mineral of present or past importance such as limestone or the Berea Sandstone. A prime candidate for a state vertebrate fossil would be *Dunkleosteus,* the formidable Devonian arthrodire fish known from spectacular fossils in the Cleveland Shale Member of the Ohio Shale in northern Ohio. Or perhaps the mastodon, a common fossil in sediments of the Pleistocene Ice Age that blanket two-thirds of the state, would be a worthy representative.

ITEMS COMMEMORATING OHIO'S GEOLOGIC SYMBOLS

The Survey offers several items to commemorate Ohio's official geologic symbols. Lapel pins or tie tacks made of polished Flint Ridge flint are available for $1.81, including tax and mailing. Each pin is unique in shape and color and was crafted by Russell Bowman of Toledo, a lapidarist well known for his Ohio flint jewelry. Please specify either lapel pin or tie tack so that the appropriate clasp can be included. A 3½ x 5 inch postcard depicting flint is available free of charge (single copies) from the Survey.

Isotelus commemorative items include a 3-inch long paperweight and beltbuckle in brass finish ($6.54 each), and a lapel pin or tie tack in either brass or pewter finish ($1.81 each). A 4 x 6 inch postcard with a full-color photograph of an exceptional *Isotelus* specimen is available for $0.25 each.

It is unlikely that serious consideration will be given to any of these additional categories in the near future, unless a groundswell of support would emerge. Of course, the designation of new state symbols is of low priority among the issues we face, but they do give us a sense of pride about something unique or spectacular in our chosen geographical area.

STATE GEMS, MINERALS, ROCKS, STONES, METALS, AND FOSSILS

(from State Geologists Journal, 1990)

Alabama: Mineral - hematite; Rock - marble; Fossil - Eocene whale, *Basilosaurus cetoides* (Owen)
Alaska: Gemstone - jade; Mineral - gold; Fossil - mammoth, *Mammuthus primigenius*
Arizona: Gem - turquoise; Fossil - petrified wood, *Araucarioxylon arizonicum*
Arkansas: Gem - diamond; Mineral - quartz crystal; Rock - bauxite
California: Gem - benitoite; Mineral - gold; Rock - serpentine; Fossil - sabertooth cat, *Smilodon californicus*
Colorado: Fossil - dinosaur, *Stegosaurus;* Gem - aquamarine
Connecticut: Gem - garnet
Delaware: Mineral - sillimanite
Florida: Fossil - Eocene heart urchin, *Eupatagus antillarum* (unofficial); Gem - moonstone; Stone - agatized coral
Georgia: Fossil - shark's teeth; Mineral - staurolite; Gemstone - quartz crystal
Idaho: Gemstone - star garnet
Illinois: Mineral - fluorite
Iowa: Rock - geode

Louisiana: Gemstone - agate; Fossil - petrified palm wood
Maine: Mineral - tourmaline; Fossil - Devonian plant, *Pertica quadrifaria*
Maryland: Fossil - Miocene snail, *Ecphora quadricostata*
Massachusetts: Gem - rhodonite; Mineral - babingtonite; Rock - conglomerate; Fossil - dinosaur tracks
Michigan: Stone - Petoskey stone (Devonian coral, *Hexagonaria);* Gem - chlorastrolite
Minnesota: Stone - Lake Superior agate
Mississippi: Stone - petrified wood; Fossil - prehistoric whale
Missouri: Mineral - galena; Rock - mozarkite; Fossil - crinoid
Montana: Gem - Yogo sapphire; Gemstone - moss agate; Fossil - *Maiasaurus*
Nebraska: Fossil - mammoth, *Mammuthus;* Rock - prairie agate; Gem - blue chalcedony
Nevada: Fossil - marine reptile, *Ichthyosaurus;* Metal - silver
New Jersey: Fossil - *Hadrosaurus foulkii* (unofficial); Rock - Stockton Sandstone (unofficial)
New Mexico: Gem - turquoise; Fossil - dinosaur, *Coelophysis*
New York: Gem - garnet; Fossil - eurypterid, *Eurypteris remipes*
North Carolina: Precious stone - emerald; Rock - granite; Shell - Scotch bonnet
North Dakota: Fossil - teredo petrified wood
Ohio: Gemstone - flint; Fossil - trilobite, *Isotelus*
Oklahoma: Rock - rose rock (barite rose)
Oregon: Gemstone - sunstone (gem feldspar); Rock - thunderegg (agate-filled nodule)
Pennsylvania: trilobite, *Phacops rana*
Rhode Island: Mineral - bowenite; Rock - cumberlandite
South Carolina: Gemstone - amethyst; Stone - blue granite
South Dakota: Gemstone - Fairburn agate; Mineral - rose quartz; Fossil - dinosaur, *Triceratops prorsus*
Tennessee: Gemstone - river pearl; Rocks - limestone and agate
Texas: Gemstone - topaz; Rock - fossilized palm wood
Utah: Gem - topaz; Fossil - dinosaur, *Allosaurus fragilis*
Washington: Gem - petrified wood
Wisconsin: Mineral - galena; Rock - Wausau red granite; Fossil - trilobite, *Calymene celebra*
Wyoming: Gem - jade; Fossil - fish, *Knightia*

ODNR HISTORY BOOK AVAILABLE

The Ohio Department of Natural Resources has released *A legacy of stewardship: the Ohio Department of Natural Resources, 1949-1989.* This 280-page softbound book not only chronicles the 40-year history of the Department of Natural Resources as a legislatively authorized state agency but also traces the long history of several divisions that were in existence prior to creation of the Department.

The history of the Division of Geological Survey, the oldest ODNR division and indeed the oldest legislatively authorized natural resources agency in the state, is the first chapter in the section on divisions. This 14-page chapter was authored by Michael C. Hansen, Senior Geologist with the Division of Geological Survey, and Ralph J. Bernhagen, former State Geologist of Ohio (1958-1968). Twenty-one photos and maps illustrate this chapter. In addition, a full-page color reproduction of John Strong Newberry's first official geologic map (1870) of the state is included in the book.

The history book contains 26 chapters authored by past and present employees of the Department of Natural Resources. Each chapter is profusely illustrated by historical photos. Many chapters contain insights and recollections by authors who were directly involved with the programs, policies, and decisions that now form a rich history of the protection and management of Ohio's natural resources. Dr. Charles King, Executive Director of the Ohio Biological Survey of The Ohio State University, served as editor of the volume and did an admirable job in editing and organizing a complex and diverse text. Daniel Atzenhoefer, a 54-year employee of ODNR and its predecessor in the Department of Agriculture, initiated and organized the project at the direction of former ODNR Director Joseph J. Sommer.

This volume provides a detailed and rich overview of Ohio's natural resources and the people and organizations who have been responsible for protecting and developing these resources throughout much of the state's history. *A legacy of stewardship: the Ohio Department of Natural Resources, 1949-1989,* is available from the ODNR Publications Center, 4383 Fountain Square Drive, Columbus, OH 43224-1362 for $18.11, which includes tax and mailing.

NEW MADRID EARTHQUAKE BOOK REPRINTED

The Center for Earthquake Studies at Southeast Missouri State University has reprinted a facsimile version of Myron L. Fuller's 1912 U.S. Geological Survey Bulletin 494, *The New Madrid earthquake.* Although Fuller's work was published a century after the 1811-1812 series of earthquakes at New Madrid, Missouri, the report is a detailed documentation of historical accounts throughout the felt area and records the geologic changes on the landscape wrought by these earthquakes.

The New Madrid earthquakes were the largest ever to occur in historic times in the continental United States. Some of the shocks were of sufficient intensity to topple chimneys in Cincinnati. The late Dr. Otto Nuttli of St. Louis University determined that during a five-month period in 1811-1812 there were five quakes with Richter magnitudes greater than 8.0, 15 quakes between 6.7 and 7.7, 35 quakes of about 5.9, 65 quakes of about 5.3, 89 quakes of about 5.0, and 1,800 quakes in the range of 3.0-4.5 magnitude. Three quakes with magnitudes between 8.0 and 8.6 occurred on December 16, 1811, and in February 1812, a quake occurred with a magnitude of about 8.8.

The recurrence of such a series of earthquakes would have major consequences for much of the Midwest, including parts of Ohio. Fuller's report provides documentation of the severity of the 1811-1812 New Madrid events.

This volume is available for $10.95, which includes shipping, from: Center for Earthquake Studies, Southeast Missouri State University, One University Plaza, Cape Girardeau, MO 63701-4799.

1989 REPORT ON OHIO MINERAL INDUSTRIES

The 1989 *Report on Ohio mineral industries,* compiled by Survey geologist and mineral statistician Sherry Weisgarber Lopez, is now available from the Division of Geological Survey. The report provides production, sales, and employment statistics for all Ohio mineral industries, including coal, limestone/dolomite, sand/gravel, sandstone/conglomerate, clay, shale, gypsum, salt, and peat, plus production and value statistics for oil and gas. In addition, the mining activities of each mineral industry are briefly reviewed. Alphabetical and by-county directories of coal and industrial-mineral mine operators are included, as is a map of the locations of reporting producing coal mines and all industrial-mineral mines in 1989.

The 1989 report contains three articles of interest. The staff of the National Lime & Stone Company prepared an article on the problems of opening a new limestone quarry and plant. Survey geologist Richard W. Carlton authored an article on the U.S. Geological Survey's National Coal Resources Data System. The Ohio's Mineral Industries Teachers Workshop is the subject of an article by Ms. Lopez.

Copies of the *1989 Report on Ohio mineral industries* are available from the Survey for $6.54, including tax and mailing. The map is also available separately for $1.81, including tax and mailing.

CORE-USE POLICY

The Ohio Geological Survey desires to make its core samples more easily accessible for legitimate scientific research by qualified individuals and organizations. At the same time, the Ohio Geological Survey has a responsibility to permanently preserve a portion of all core which is held in the Survey core repository. In order to achieve a balance of these two goals, the following core-use policy has been established.

The Geological Survey highly recommends that core be examined *at the Survey core repository.* When macroscopic sample examination is not sufficient, a few thin-section billets may be provided. If (1) many samples are requested, (2) destructive testing is involved, or (3) the core is to be examined off-site, a formal request must be submitted.

Requests to borrow or use core samples should be submitted to:

Mr. Garry E. Yates
Samples and Records
Division of Geological Survey
4383 Fountain Square Drive
Columbus, Ohio 43224-1362
(614) 265-6581

1) Requests should consist of a letter describing the project, the procedure of study, and the duration of the project. It is recommended that appropriate Survey geologists

be consulted during the development of a request.

2) The request must be specific as to which cores are required and the amount of sampling necessary. Sampling of cores should be kept to the minimum.
3) All costs related to handling or transporting core material shall be borne by the borrower. If cores are to be split, this will be done on Survey premises unless other arrangements are approved. Extensive Survey time for processing core may necessitate a charge.
4) Cores and samples remain the property of the Division of Geological Survey. Thin sections, polished sections, sample residues, etc. made from sampled portions of the cores shall be returned to the Survey at the conclusion of the project to become part of its permanent library for the benefit of the public.
5) Each core generally shall be on loan for a period of no longer than 45 days. In the event a returned core is determined to have been damaged, improperly handled or sampled, or is otherwise in poor condition, the borrower will forfeit the privilege of borrowing other materials from the core library.
6) Cores of unconsolidated materials (glacial and lacustrine), outcrop samples, grab samples, well cuttings, and other samples held by the Geological Survey also are available for use, subject to the provision of this policy.
7) Final sampling arrangements shall be set forth in a letter of agreement from the Chief of the Division of Geological Survey and acknowledged by the borrower.
8) Copies of data and reports must be supplied to the Division of Geological Survey. All data must be made public through independent publication and/or placed on open file at the Survey. The Division of Geological Survey should be properly acknowledged in any publication resulting from the inspection and/or analysis of samples held by the Survey.

NEW GEOLOGIC QUADRANGLE MAPS RELEASED

The following open-file quadrangle-scale (1:24,000) maps are now available as part of the Survey's statewide mapping program. Blueline copies of these maps are $5.48 per map, which includes tax and mailing. Add $1.00 per order for unfolded copies mailed in a tube. Please order by quadrangle name and map title. An index to topographic quadrangle maps in Ohio is available at no charge from the Survey. Please consult previous issues of *Ohio Geology* for a listing of previously released quadrangles.

Greenhills (Hamilton Co. portion only) bedrock geology; bedrock topography; structure contours on base of Fairview Formation; structure contours on base of Miamitown Shale and Grant Lake Formation; structure contours on base of Mount Auburn Member of Grant Lake Formation and isopach contours of Miamitown Shale; structure contours on base of Waynesville/Arnheim undifferentiated and Corryville Member of Grant Lake Formation.

Mason *(Butler, Clermont, Hamilton, and Warren Cos.)* bedrock geology; bedrock topography; structure contours on base of Fairview Formation and Grant Lake Formation; structure contours on base of Corryville Member and Mount Auburn Member of Grant Lake Formation; structure contours on base of Miamitown Shale and Arnheim/Waynesville undifferentiated.

Newport (Ohio portion only) *(Hamilton Co.)* bedrock geology; bedrock topography; structure contours on base of Kope and Fairview Formations; structure contours on base of Bellevue and Corryville Members of Grant Lake Formation.

1991 MATHER MEDAL DINNER

The Mather Medal of the Division of Geological Survey recognizes a geologist who has made significant contributions to the understanding of Ohio's geology. Past medalists are Myron T. Sturgeon, George W. White, Richard P. Goldthwait, and Jane L. Forsyth. At the time of this printing, the Mather Medal Committee had not yet selected the 1991 recipient. However, this year's presentation dinner has again been scheduled in conjunction with the Bownocker Lectures sponsored by the Department of Geological Sciences at The Ohio State University (this year's lecturer is Adolf Seilacher). The Mather Medal dinner will be at 6:00 p.m., Monday, October 14, 1991, at the OSU Faculty Club. For more information or to receive a reservation form, please contact Scott Brockman at 614-265-6473.

GEOLOGICAL MATERIALS FOR EDUCATORS

The Division of Geological Survey distributes a wide variety of publications and other educational materials that are of use to educators at all levels. Most of these items are nontechnical and can be used directly by students or by teachers as background materials. A full list of these items, including technical reports, can be found in the Division of Geological Survey *List of publications,* which is available at no charge. An abbreviated list of Survey publications, *Educational materials of interest to teachers, students, and hobbyists,* describes only those in-print items of direct interest to most teachers and is also available at no charge.

Educationally oriented publications include some bulletins, reports of investigations, and information circulars, guidebooks, educational leaflets, postcards, maps, and reprints of papers originally published elsewhere. Additional items include rock and mineral kits, poster sets, and a film (16 mm or VHS format) about the geology of Ohio. Educating Ohio's citizens about the geology of their state has long been an important objective of the Division of Geological Survey. We continue to develop new publications and materials that help us accomplish this objective.

GEOLOGIC POSTCARDS AVAILABLE

The Survey now has available two new full-color geologic postcards that depict the bedrock geologic map and the map of glacial deposits of Ohio, respectively. The postcard of the bedrock map is a new, more attractive version of the one previously offered. It shows the distribution of the six geologic systems exposed at the surface in the state and the glacial boundary and includes an east-west cross section of the state's bedrock. The postcard of glacial deposits shows the distribution of Kansan, Illinoian, and Wisconsinan glacial sediments. Wisconsinan deposits are divided into end moraine, ground moraine, lake deposits, and kames and eskers.

In addition to the bedrock and glacial postcards, Survey postcards depict, in full color, Ohio's two official geologic symbols—*Isotelus,* the state fossil, and flint, the state gemstone. Any of these postcards provides a unique way to communicate with friends and colleagues. The bedrock, glacial, and *Isotelus* postcards are all 4 x

6 inches and are available from the Survey for $0.25 each; the flint postcard is 3½ x 5 inches and is available at no charge. Please include Ohio sales tax of 5¾ percent plus $0.75 mailing charge for orders of $3.00 or less. Contact the Survey for mailing charges on larger orders.

VOLUNTEERS FOR OHIO GEOSCIENCE

With continually increasing demands for geologic information, the Geological Survey welcomes part-time volunteers to assist us in our investigations of the geology of Ohio. Volunteers may include high school students, earth science teachers, retirees, and others interested in contributing to the development of a better understanding of Ohio's geology and mineral resources. Volunteers would be used on an as-needed basis for assistance with miscellaneous tasks or for specific projects or investigations.

Although there are no financial rewards for such volunteer activities, the program offers a unique opportunity for individuals to participate in worthwhile and interesting scientific activities and be recognized for their work. If you have an interest in Volunteers for Ohio Geoscience, please contact Thomas M. Berg, Chief, Division of Geological Survey at 614-265-6576.

QUARTERLY MINERAL SALES, JANUARY—FEBRUARY—MARCH 1991

compiled by Sherry L. Weisgarber

Commodity	Tonnage sold this quarter[1]	Number of mines reporting sales[1]	Value of tonnage sold[1] (dollars)
Coal	7,616,500	153	$213,051,214
Limestone/dolomite[2]	6,741,517	106[3]	26,605,124
Sand and gravel[2]	4,176,116	183[3]	13,152,932
Salt	1,278,215	5[4]	21,183,018
Sandstone/conglomerate[2]	327,360	20[3]	5,683,667
Clay[2]	112,403	14[3]	319,326
Shale[2]	236,587	17[3]	409,581
Gypsum[2]	48,480	1	460,560
Peat	4,047	2[3]	62,114

[1]These figures are preliminary and subject to change.
[2]*Tonnage sold* and *Value of tonnage sold* include material used for captive purposes. *Number of mines reporting sales* includes mines producing material for captive use only.
[3]Includes some mines which are producing multiple commodities.
[4]Includes solution mining.

QUARTERLY MINERAL SALES, APRIL—MAY—JUNE 1991

compiled by Sherry L. Weisgarber

Commodity	Tonnage sold this quarter[1]	Number of mines reporting sales[1]	Value of tonnage sold[1] (dollars)
Coal	7,377,600	144	$209,072,027
Limestone/dolomite[2]	12,681,823	104[3]	47,276,697
Sand and gravel[2]	9,989,530	201[3]	34,744,500
Salt	539,803	5[4]	6,517,086
Sandstone/conglomerate[2]	381,201	14[3]	6,871,327
Clay[2]	266,979	24[3]	606,293
Shale[2]	278,316	21[3]	495,911
Gypsum[2]	43,106	1	409,507
Peat	6,770	3[3]	102,499

[1]These figures are preliminary and subject to change.
[2]*Tonnage sold* and *Value of tonnage sold* include material used for captive purposes. *Number of mines reporting sales* includes mines producing material for captive use only.
[3]Includes some mines which are producing multiple commodities.
[4]Includes solution mining.

GEOFACTS SERIES

The Survey has begun a new informational series, known as *GeoFacts*. These one-page, 8½ x 11 inch sheets have holes punched for filing in a three-ring notebook. The first in the series, *GeoFacts No. 1*, compiled by Suzan E. Jervey, is titled *Obtaining maps and charts* and lists various types of maps and charts commonly used by individuals involved with Ohio's natural resources. Included are addresses and phone numbers of organizations that distribute maps not available from the Ohio Department of Natural Resources.

Additional titles are in preparation for the *GeoFacts* series and will be announced in *Ohio Geology* as they are released. Single copies of the *GeoFacts* sheets are available from the Survey at no charge.

EDITOR'S NOTE

Multiple, unavoidable delays have necessitated that, in the interest of timeliness, we combine the summer and fall issues of *Ohio Geology*. It is our intent that future issues of *Ohio Geology* will appear in a timely manner.

Ohio Department of Natural Resources
Division of Geological Survey
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Columbus, Ohio 43224-1362

OHIO DEPARTMENT OF NATURAL RESOURCES DIVISION OF GEOLOGICAL SURVEY

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