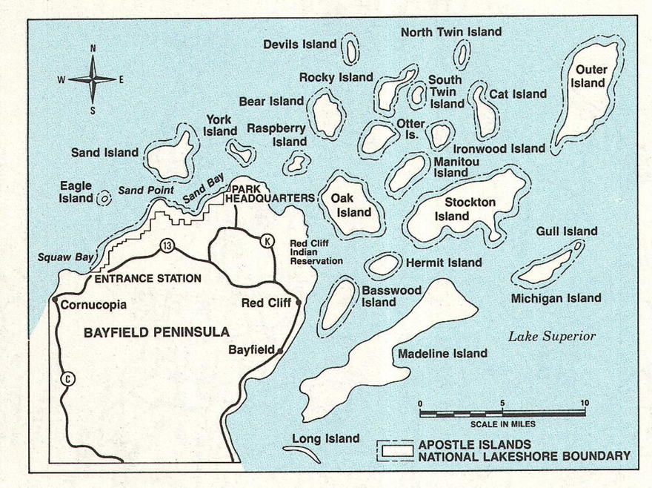


APOSTLE ISLANDS NATIONAL LAKESHORE, WISCONSIN

This is the traditional home of Longfellow's Hiawatha. The poem was based on Chippewa legends about a demigod, Manabozho, who became confused with the real Iroquoian Hiawatha. The islands are still wild and beautiful, although they were long inhabited by Indians and later by fishermen, lumbermen, and quarrymen. All are gone now and the islands support a growth of maple, aspen, and birch with scattered groves of pine and spruce. Eventually, 20 of the 22 islands off the tip of Bayfield Peninsula and 10 mi of the mainland shoreline will be included in the National Lakeshore. These glacier-created islands are still being assaulted by wind and water, forming striking patterns in stone. Stone arches have been hollowed out of sheer cliffs until some island shores resemble colonnaded cloisters. Sizable caverns extend in and under rock ledges. During storms, big waves slap into these caves, producing a thunderous boom. This booming caused the Indians to give Devils Island its name. On the north shore of this island is an excellent display of sculptured rock.

Sightseeing cruises leave Bayfield from June 15 to September 30. A camping shuttle departs daily at noon. Madeline Island, although not part of the National Lakeshore, is the site of one of the state's oldest settlements—La Pointe—which has a fine historical museum. Ferry service between Bayfield and La Pointe operates hourly from June 1 to September 30.

ICE AGE NATIONAL SCIENTIFIC RESERVE

The Reserve is in the National Park System (but administered by the Wisconsin Department of Natural Resources) and is designed to preserve the surviving glacial landforms. It consists of nine units throughout Wisconsin.

1. Kettle Moraine State Forest, about 17 mi (27.4 km) SE of Fond du Lac on SR67 off US45. The moraine was formed as the Green Bay and Michigan lobes of the glacier came together. Many kettle holes, or kettles, were formed when blocks of ice, buried in glacial debris, melted. The area also contains conical hills (kames) formed by material washed into holes in the ice, and the Parnell esker, a sinuous ridge formed by debris from water flowing under the ice.

2. Campbellsport Drumlin Unit, 6 mi (9.6 km) W of Kettle Moraine off SR67, is dotted with drumlins, which are elongated, rounded hills shaped by glacial movement. Existing roads through the area are County Trunks Y and V.

3. Sheboygan Marsh Unit, N of the Kettle Moraine on County Trunk P. The marsh was formed by sediments slowly filling glacial Lake Sheboygan.

4. Two Creeks Buried Forest Unit, on SR42, 2 mi (3.2 km) N of Manitowoc, still is not developed. It contains evidence of the advances and retreats of the Wisconsinan glaciers. Radiocarbon dating of an interglacial forest shows that it was living about 11,850 years ago.

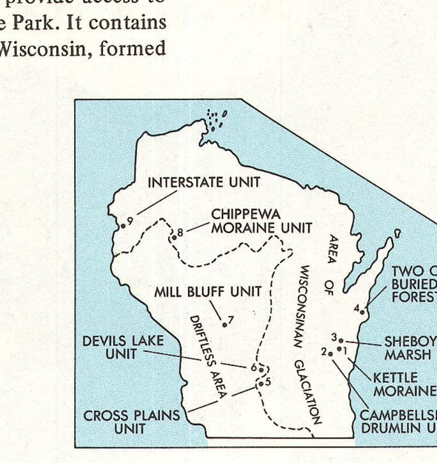
5. Cross Plains Unit, W of Madison, provides evidence of the glacier's farthest advance into the Driftless Area, where high bluffs, rugged cliffs, and well-drained river valleys prevail. The end moraine is thin and lies on bedrock. One glacial drainageway cut back under the glacier, leaving a deep gorge. Although the unit is still under private ownership, much can be seen by driving W from Madison on SR151; W on County Highway PD, Shady Oak Lane, and Timber Lane; then N to Cross Plains along Cleveland Road.

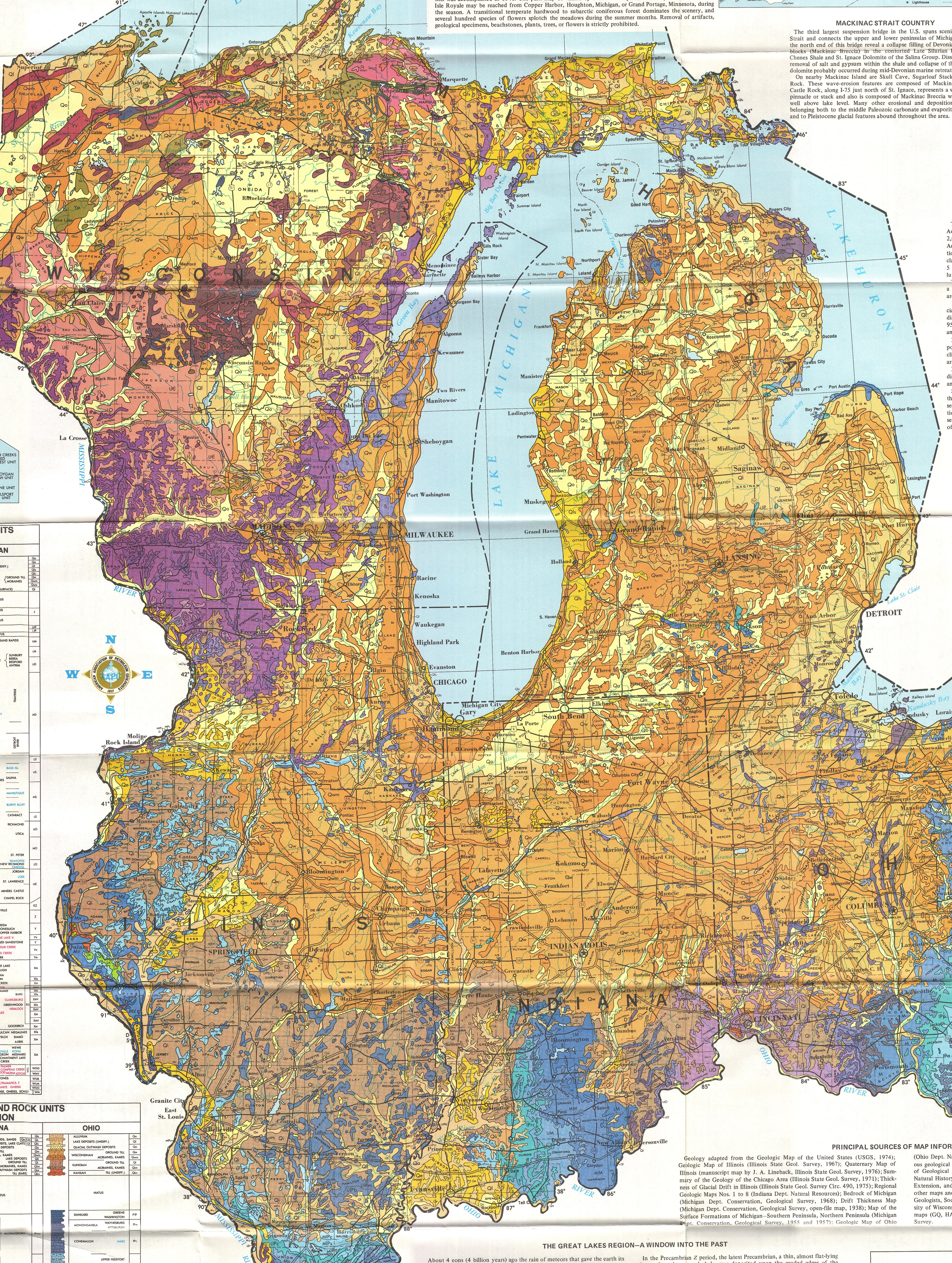
6. Devils Lake Unit, 3½ mi (5.6 km) S of Baraboo on US123, is a State Park noted for spectacular scenery. A gorge over 1,100 ft (335 m) deep was cut by the preglacial Wisconsin River and later dammed by the Green Bay lobe. Thus Devils Lake basin was formed and later was filled with water and over 325 ft (99 m) of glacial debris.

7. Mill Bluff Unit; US12 and US16 exits from I-90-94 provide access to County Trunk W, the unit's main road. The unit is a State Park. It contains sandstone buttes which once were islands in glacial Lake Wisconsin, formed when the Wisconsin River was dammed by the Green Bay lobe.

8. Chippewa Moraine Unit. 6 mi (9.6 km) N of Bloomer on SR40, then E on County Trunk M. This area was formed by the Chippewa glacial lobe, which was slowed by the northern Wisconsin highlands. The stagnant or "dead ice" moraine formed crevasses that later were filled with debris to create ridges. Also present are kettle lakes; large elevated inwash plains; and a large, fertile outwash plain.

9. Interstate Unit, 62 mi (99 km) NE of Minneapolis via I-34 and US8, is located in Interstate Park. It is an area of ancient lava flows, large water-formed potholes, and the scenic gorge of the St. Croix River, which once was a drainageway of glacial Lake Duluth. The Lake of the Dalles is believed once to have been a gigantic whirlpool.



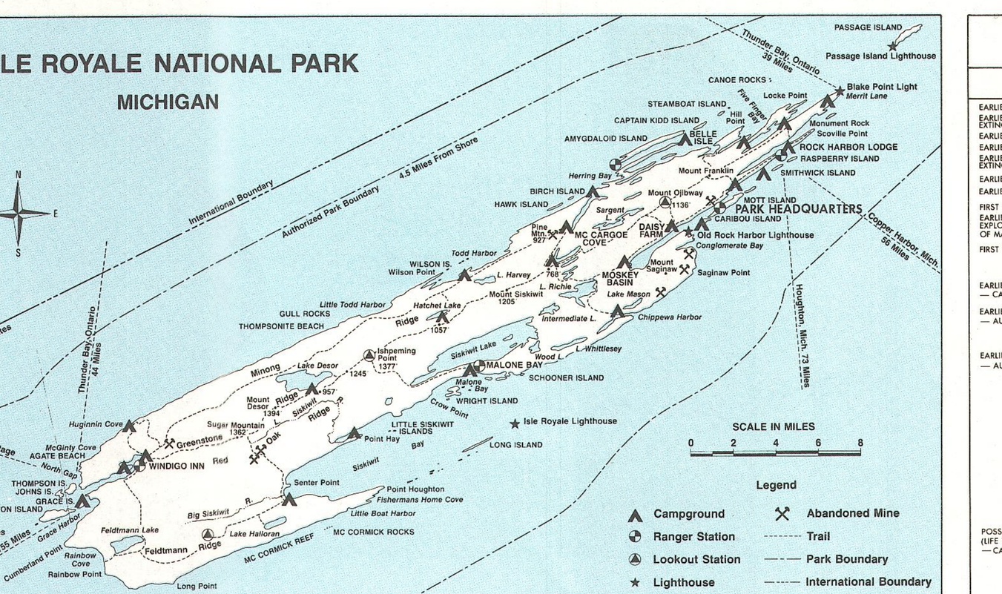


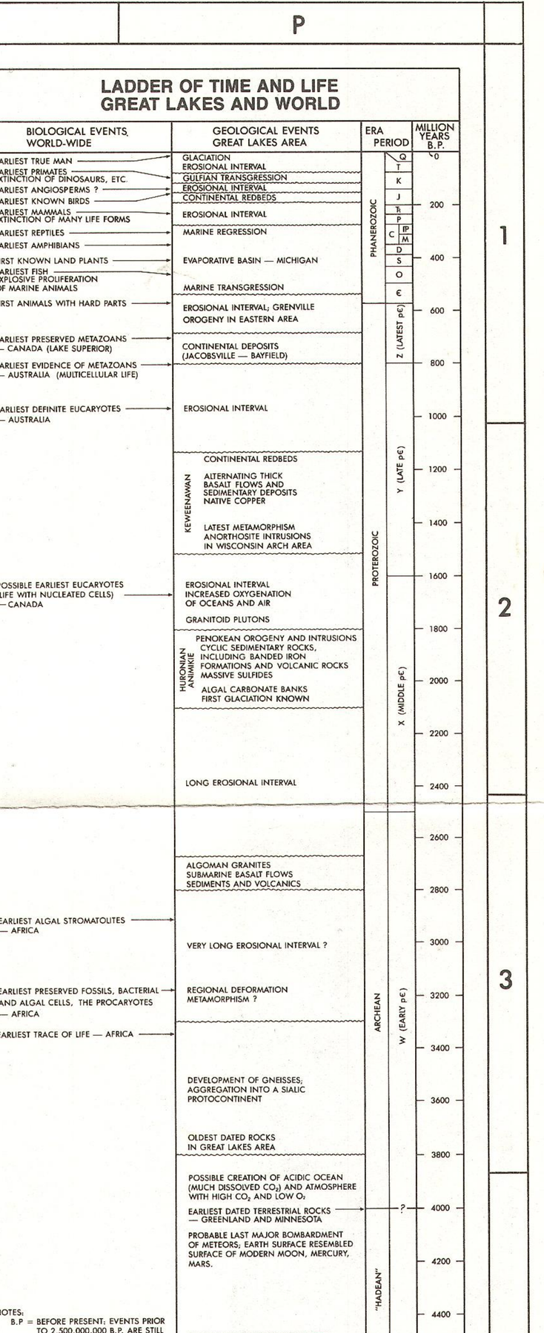
ISLE ROYALE

Isle Royale, 5-8 mi wide by 45 mi long (8-13 by 72 km), is the largest island in a lake within the United States. It was created by volcanoes, ice, and water. Much of the island is ribbed by great basaltic flows that intermittently poured out over river-deposited sands and gravels more than 1 b.y. ago (late Precambrian). Millions of years later these layers were downfolded to form the trough now partly occupied by Lake Superior. Isle Royale is on the northwest rim of this great geological trough. This downfolding was the last of the great crustal movements in the area, as the crustal movements migrated to the edge of the receding continental margin. As the land expanded in area and both the land and the sun cooled, great ice sheets formed in northern Canada and moved southward to gouge out basins and smooth the exposed rock layers. Rocks of some areas were more resistant to the glaciation than those of others. As the last glacier melted away, Isle Royale, which had been covered by water during earlier interglacial periods, protruded as an emerald above the level of the meltwater that became the modern Lake Superior. The rock beds on the island slope southeast into the lake basin. The softer rocks have been eroded to form valleys extending the full length of the island. The valleys are separated by the hard basalt ridges, such as Greenstone Ridge, backbone of the island. Lakes occupy basins hollowed out by the glaciers.

Indians mined copper on Isle Royale long before the white men came. The old pits have been excavated by archaeologists. The Indians who occupied the island when the French arrived (and gave it its name) knew nothing about the old mines. After the United States gained jurisdiction over the island in 1783, it remained Chippewa territory until 1843, when the tribe ceded it to the United States. Prospectors and lumbermen cleared much of the land, and copper was mined again until 1899, when the deposits became too depleted for commercial mining. By that time the island was becoming a tourist attraction.

Albert Stoll, Jr., a Detroit newspaperman, spearheaded the movement to make Isle Royal a National Park; this was accomplished in 1940. The park may be visited by boat or float plane from May 15 to October 20. Isle Royale may be reached from Copper Harbor, Houghton, Michigan, or Grand Portage, Minnesota, during the season. A transitional temperate hardwood to subarctic coniferous forest dominates the scenery, and several hundred species of flowers splotch the meadows during the summer months. Removal of artifacts, geological specimens, beachstones, plants, trees, or flowers is strictly prohibited.





MACKINAC STRAIT COUNTRY

The third largest suspension bridge in the U.S. spans scenic Mackinac Strait and connects the upper and lower peninsulas of Michigan. Cuts at the north end of this bridge reveal a collapse filling of Devonian dolomite blocks (Mackinac Breccia) in the contorted Late Silurian Pointe Aux Chenes Shale and St. Ignace Dolomite of the Salina Group. Dissolution and removal of salt and gypsum within the shale and collapse of the overlying dolomite probably occurred during mid-Devonian marine retreat and uplift.

On nearby Mackinac Island are Skull Cave, Sugarloaf Stack, and Arch Rock. These wave-erosion features are composed of Mackinac Breccia. Castle Rock, along I-75 just north of St. Ignace, represents a wave-eroded pinnacle or stack and also is composed of Mackinac Breccia which is now well above lake level. Many other erosional and depositional features belonging both to the middle Paleozoic carbonate and evaporite sequences and to Pleistocene glacial features abound throughout the area.

SERPENT MOUND STATE MEMORIAL

The Great Serpent Mound, 4 mi (6.4 km) NW of Locust Grove in Adams County, Ohio, is an effigy of a serpent constructed 1,500 to 2,000 years ago by prehistoric Indians, probably of the Ohio Valley Adena culture. It is thought to have had religious significance. Excavations show that the serpent was traced on the ground with stones and clay, then built up with baskets of earth. It is ¼ mi (0.4 km) long, 3 to 5 ft (0.9-1.5 m) high, and 15 to 20 ft (4.6-6.1 m) wide. It has 7 convolutions, 3 coils in the tail, and an open mouth.

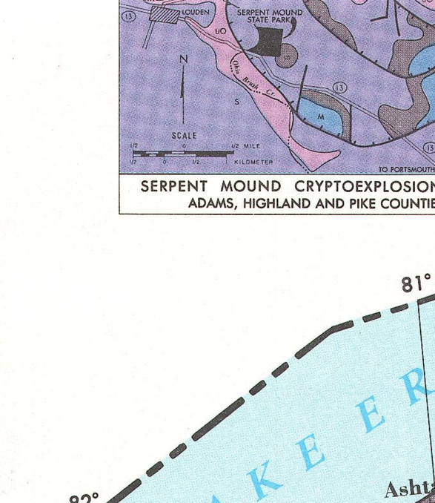
The ridge along Brush Creek on which the serpent was constructed is a cryptoexplosion structure which forms an elongate circle with an area of 16 sq mi (41 km²). It can be divided into three units:

1. A circular central area of uplifted and faulted Silurian and Ordovician rocks folded sharply into seven radiating anticlines. The greatest diameter of the central area is 3 mi (4.8 km), and minimum uplift is 950 ft (290 m). Faults separate the anticlines on the west and north and form six grabens on the south and east. Shatter cones are present.

2. A depressed outer ring of downfolded beds with curving axes exposing Mississippian rocks. This structure is bordered by faults, an anticline on the NE border, a horst along the N border and two unfaulted areas on the E and W sides.

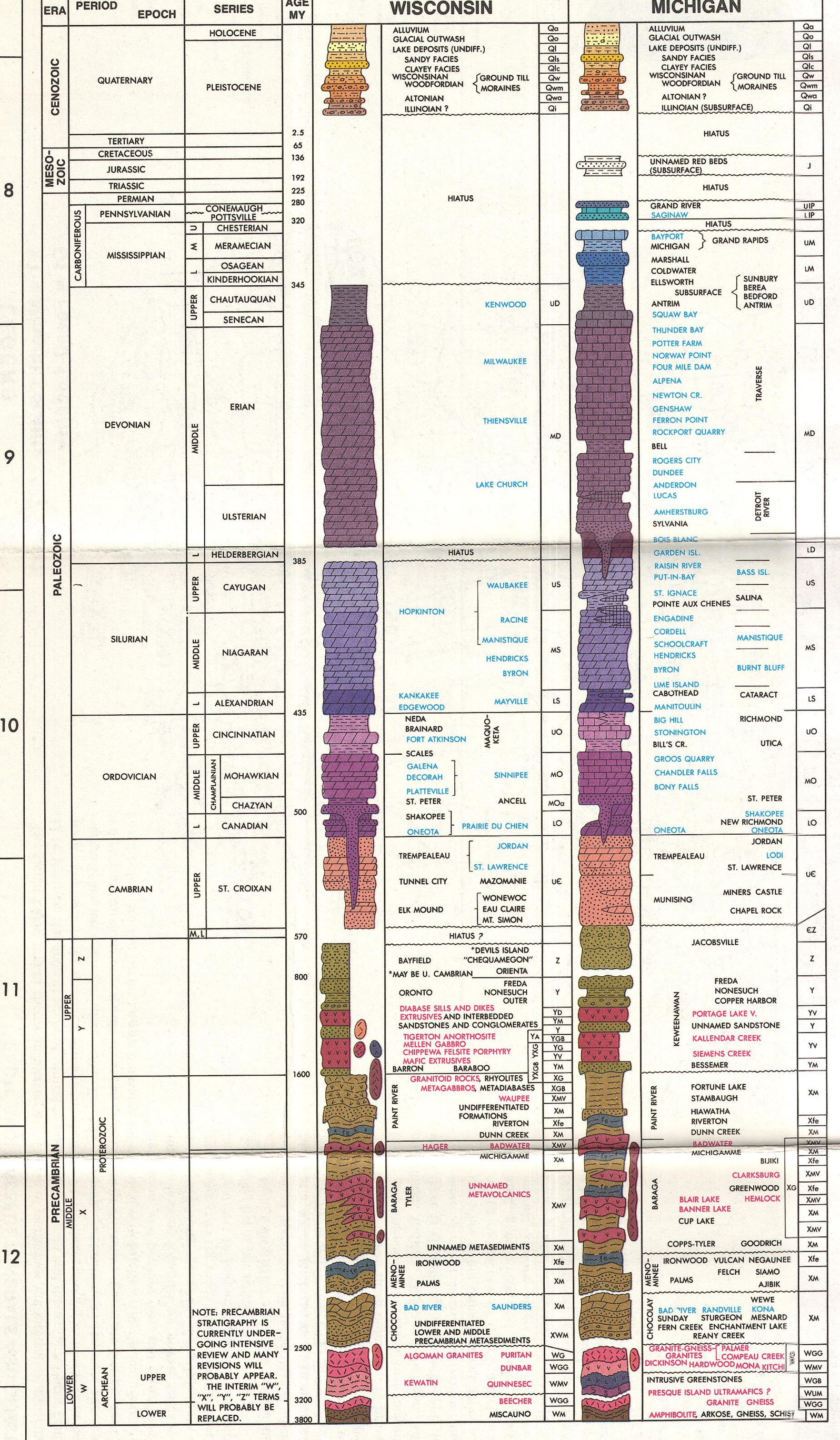
3. An intermediate ring of folded and faulted beds with less vertical displacement than the central or outer areas. Three prominent domes and a 3-mi (4.8 km) fault are the major features.

Sphalerite and related zinc minerals are found along fault zones throughout the structure, both as replacements and as breccia filling. A sequence of events involving three episodes of faulting and mineralization tends to suggest that this structure was formed as a result of a series of gas explosions—probably resulting from deep resurgent boiling of a crystallizing melt—rather than meteorite impact.

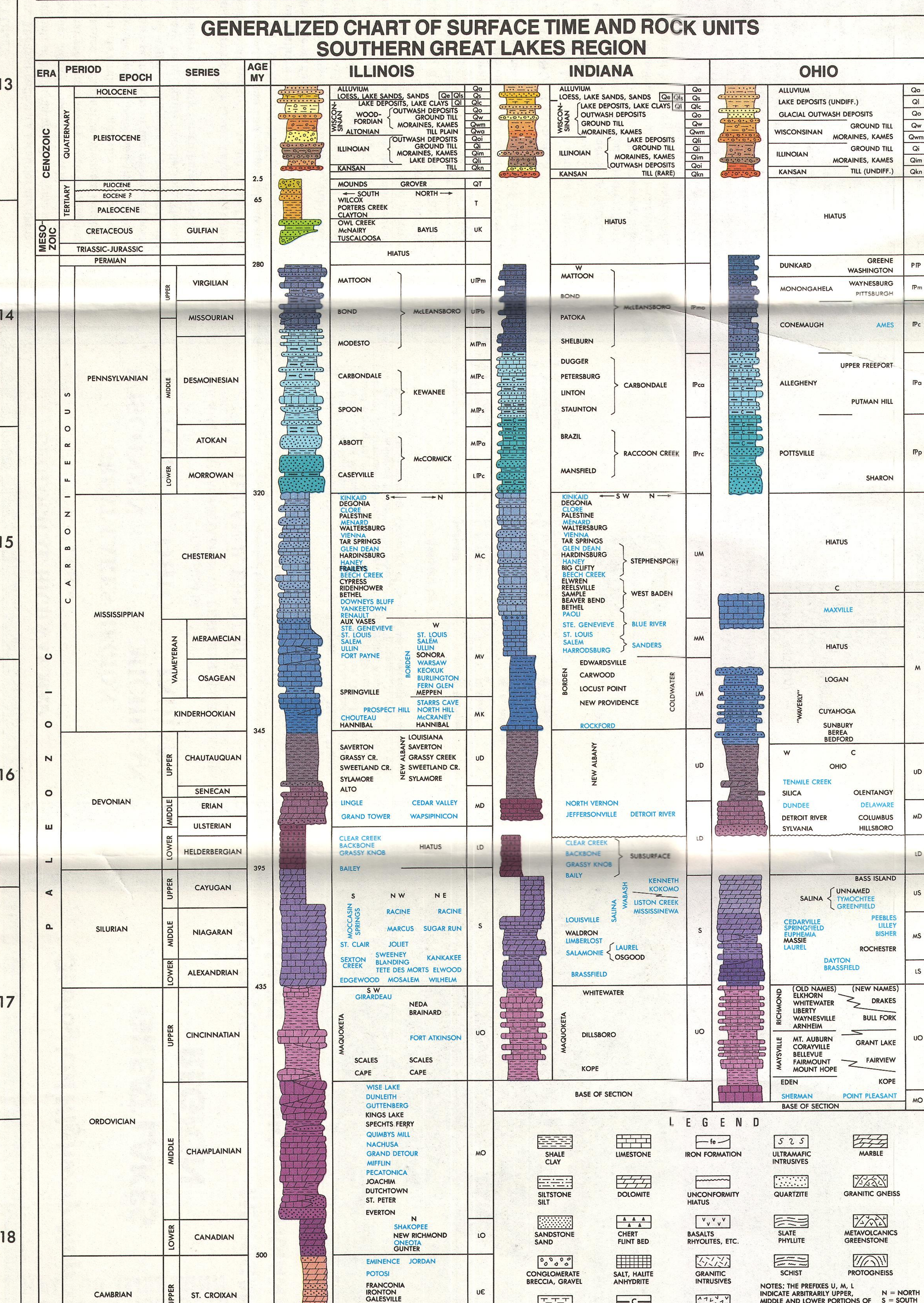


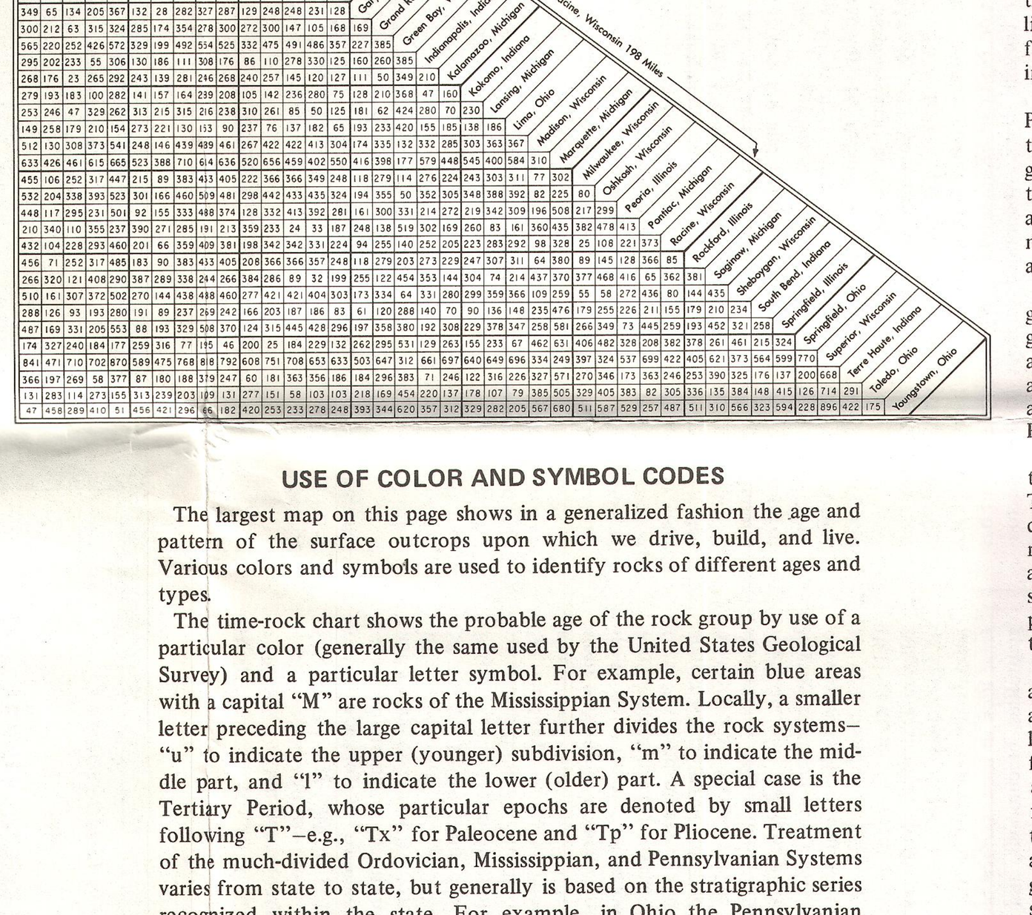
SERPENT MOUND CRYPTOEXPLOSION STRUCTURE
ADAMS, HIGHLAND AND PIKE COUNTIES, OHIO

GENERALIZED CHART OF SURFACE TIME AND ROCK UNITS NORTHERN GREAT LAKES REGION



GENERALIZED CHART OF SURFACE TIME AND ROCK UNITS SOUTHERN GREAT LAKES REGION





PRINCIPAL SOURCES OF MAP INFORMATION

Geology adapted from the Geologic Map of the United States (USGS, 1974); Geologic Map of Illinois (Illinois State Geol. Survey, 1967); Quaternary Map of Illinois (manuscript map by J. A. Lineback, Illinois State Geol. Survey, 1976); Summary of the Geology of the Chicago Area (Illinois State Geol. Survey, 1971); Thickness of Glacial Drift in Illinois (Illinois State Geol. Survey Circ. 490, 1975); Regional Geologic Maps Nos. 1 to 8 (Indiana Dept. Natural Resources); Bedrock of Michigan (Michigan Dept. Conservation, Geological Survey, 1968); Drift Thickness Map (Michigan Dept. Conservation, Geological Survey, open-file map, 1938); Map of the Surface Formations of Michigan—Southern Peninsula, Northern Peninsula (Michigan Dept. Conservation, Geological Survey, 1955 and 1957); Geologic Map of Ohio (Ohio Dept. Natural Resources, Div. of Geological Survey, 1920, repr. 1965); numerous geological reports and maps of the Ohio Geological Survey and the Ohio Division of Geological Survey; Geologic Map of Wisconsin (revised; Wisconsin Geol. and Natural History Survey, 1949); Depth to Bedrock in Wisconsin (Univ. of Wisconsin—Extension, and Wisconsin Geol. and Natural History Survey, 1973); plus numerous other maps and publications of the state surveys, American Association of Petroleum Geologists, Society of Economic Geologists, Geological Society of America, University of Wisconsin, and Michigan Technological University, and the bulletins, circulars, maps (GQ, HA, I, and MF series), and professional papers of the U.S. Geological Survey.

THE GREAT LAKES REGION—A WINDOW INTO THE PAST

About 4 eons (4 billion years) ago the rain of meteors that gave the earth its fiery birth and its substance dwindled to occasional showers, and the cooling, steamy atmosphere precipitated to form large bodies of water. Within the evolving crust and mantle, heat from disintegrating radioactive minerals, and also from gravitational differentiation, melted extensive rock masses which led to volcanic eruptions onto the surface and to release of more water vapor, chlorine, nitrogen, sulfur, and carbon dioxide to the air. The resultant heavy, acid rains carried particulate and soluble materials into the ever-deepening and expanding seas. These sediments and volcanic ejecta accumulated to many miles of thickness and later were uplifted, intensely folded and faulted, and intruded by molten granitic magmas and metamorphosed to schists and gneisses by heat and pressure. This is the postulated cataclysmic beginning of the Great Lakes story, which was about 3.2 to 4 b.y. ago.

A long erosional hiatus followed before the sea rose and covered the area. Fault rifting, perhaps comparable to modern seafloor spreading, occurred, and thousands of feet of basaltic lavas poured out upon the ocean floor. Rhyolitic lavas, pyroclastics, and then graywacke sediments covered the basalt flows, and in turn were invaded and metamorphosed by the Algoman granitic intrusions of the late Archean (Precambrian *W*) about 2.7 b.y. ago.

Another long erosional interval of about 600 m.y. (equal to the entire Phanerozoic–Cambrian to Holocene) ensued. Continents had evolved, but their shapes would be unfamiliar to modern geographers. Volcanoes had outgassed vast amounts of water, nitrogen, sulfur, and especially carbon dioxide—the gas of life for most early organisms, including the plants, which appeared about 3.2 b.y. ago. The earth was cooling, but was still too hot for complex multicellular organisms. Oxygen isotopes suggest oceanic temperatures of about 170°F (77°C), but high-latitude highlands were probably much colder.

About 2.1 b.y. ago the polar ice sheets expanded to form the first known glacial deposits on earth, the Huronian tillites. Rising sea levels caused these glacial beds to be buried below increasingly marine deposits of shore sands; algal carbonate banks; iron-rich claystones and cherts; and basinal muds, silts, and graywackes. The great Proterozoic Era was under way and persisted for almost 2 eons (2 b.y.). Its major divisions are now arbitrarily referred to as Precambrian *X*, *Y*, and *Z*, in order of time.

Precambrian *X* (middle Precambrian) is famous for its banded iron formations, which make possible the steel sinews of our technological civilization. The bands consist of carbonates, silicates, and oxides of iron deposited in reducing seas (low in dissolved oxygen) and derived from iron-rich igneous terrains exposed to a wet carbon dioxide atmosphere. These conditions ended about 1.8 b.y. ago owing to the increase of oxygen in the environment. Shale, sandstone, and volcanic rocks formed the bulk of the depositional sequence, piling up to about a 5-mi (8 km) thickness in some areas. Orogenies interrupted this long depositional period and caused intrusion of the Penokean granites.

The late Precambrian (*Y* and *Z*), beginning about 1.6 b.y. ago, lasted 1 b.y. and was a time of changeover from a carbon dioxide to a nitrogen-oxygen atmosphere, and from asexual, budding, unicellular, primitive aquatic plant life to a varied, complex, multicellular animal and plant population with differentiation into male and female organisms. The initial deposits were sand and gravel, which later alternated with the great Keweenawan basaltic lava flows that accumulated to a thickness of almost 40,000 ft (12 km). Some of these flows and associated conglomerates are rich in native copper, perhaps as a result of the reducing atmosphere. In central Wisconsin, anorthosites and granites invaded the older rocks. Anorthosite is unusual calcium-rich and silica-poor igneous rock believed to have issued from the mantle during a period of unusual worldwide crustal stress about 1 to 1.7 b.y. ago. In the eastern Ohio part of the map region, these rocks were metamorphosed during the Grenville orogeny, which occurred about 950 m.y. ago. Tidal stress from a near lunar approach is one interesting explanation of the worldwide cataclysmic event. Volcanism ceased, and conglomerate, shale, and sandstone covered the volcanics; these, in turn, were gently folded and eroded. The younger sediments show increasing signs of oxidation, revealing that atmospheric oxygen was gradually building up from the photosynthesis processes of the proliferating plant communities. Other evidence indicates that many organisms were evolving complex organelles in their cells for oxygen utilization, and, as a result, some unicellular plants were becoming more animal-like in mobility and irritability.

In the Precambrian *Z* period, the latest Precambrian, a thin, almost flat-lying sheet of sandstone and shale was deposited upon the eroded edges of the older rocks. The continents were greatly expanded, almost to their present dimensions. During the approximately 200 m.y. of Precambrian *Z* time, a most remarkable transformation of marine life occurred. Decreasing oceanic temperature and the increased atmospheric oxygen enabled life to become more multicellular, more diversified, and more mobile. Segmented worms, jellyfishes, and sponges anticipated the evolutionary explosion of life in the immediately following Early Cambrian. At the close of the Precambrian the earth was already 4 b.y. old, and only 600 m.y., or 12% of earth time, remained until the Holocene.

The sea began its return in the Early Cambrian from the edges of the continent, reaching the Great Lakes area about 50 m.y. later and spreading sands over the eroded Precambrian *Z* and older deposits. The succeeding Ordovician through Mississippian Periods produced extensive limestone deposits which record an abundant subtropical life in the shallow seas. These limestones and associated dolomite deposits represent a tremendous withdrawal of atmospheric carbon dioxide and its partial biological replacement by oxygen. Photodissociation of this oxygen in the upper atmosphere produced an ozone layer which screened harmful ultraviolet light from the surface, enabling life to live on dry land, beginning sometime in the Silurian.

The Early Silurian produced the great accumulation of Niagaran Dolomite with an abundance of reefs, some as much as 400 ft (122 m) thick. The reef rocks have been highly productive of natural gas. During the Late Silurian, the Michigan basin, which had begun to form in the Middle Ordovician, became partly enclosed as a result of subsidence, and the tremendous salt deposits (Salina Formation) accumulated. The volume of the Silurian salt is estimated to be 7,210 cu mi (66 trillion tons). In Middle Devonian time, the Detroit River Group, which includes dolomite, anhydrite, and salt, was deposited. It is estimated to have a salt volume of 543 cu mi (5 trillion tons). Evaporites also were deposited in Late Mississippian time. Gypsum production from the Michigan Formation of this age is very significant.

During the Pennsylvanian, the sea began its multicyclic retreat from the Great Lakes area. Swamp forests of tree ferns, giant mosses, scouring rushes, and primitive conifers formed thick, peaty bogs that were repeatedly buried below marine inundations to form, in time, precious coal reserves.

The Permian left some redbeds in the southeastern Ohio area. Triassic rocks are completely missing, but a thin remnant of Jurassic redbeds is known from the subsurface of Michigan. Cretaceous and Tertiary deposits are barely represented in southern Illinois. All of these probably are mere remnants of once more extensive deposits. These remnants testify to the growing continentality of central North America. The culmination—about 1 m.y. ago—was the four or more glacial episodes whose southward-expanding ice sheets covered almost the entire Great Lakes area. Today, in what probably is an interglacial interval, the soil produced by the glacial debris left by the ice sheet is very fertile and a source of great agricultural wealth. Furthermore, the abundant sands and gravels are worth millions of dollars to the construction industry.

Tangible records of all these ancient events can be seen in bedrock outcrops throughout the Great Lakes area. Geologists of the state and federal surveys and the regional universities have cooperated generously with the compiler to depict more faithfully the prevailing concepts about the geology of the area. In many areas where Pleistocene deposits are extensive, the few scattered outcrops of older rocks are purposely emphasized to alert the map reader to search for these important glimpses of a remote past. The compiler hopes that this map will serve another important need, which is to show the interplay between the ancient bedrock configurations and the overriding Pleistocene ice sheets.

This map is dedicated to the pioneer geologists and prospectors of the Great Lake region of more than a century ago. These vigorous and knowledgeable men, many of whom became famous in their mature years, wrote eloquently and precisely about the natural resources of this area, including its people. They testified to the fact that the West was not so much won by the man with the gun as by the man with the pick and shovel, the map, and the notebook, who with his intelligence and tenacity made the wilderness a source of new wealth and industry. Fortunately, geologists are continuing this tradition with new tools and insights.

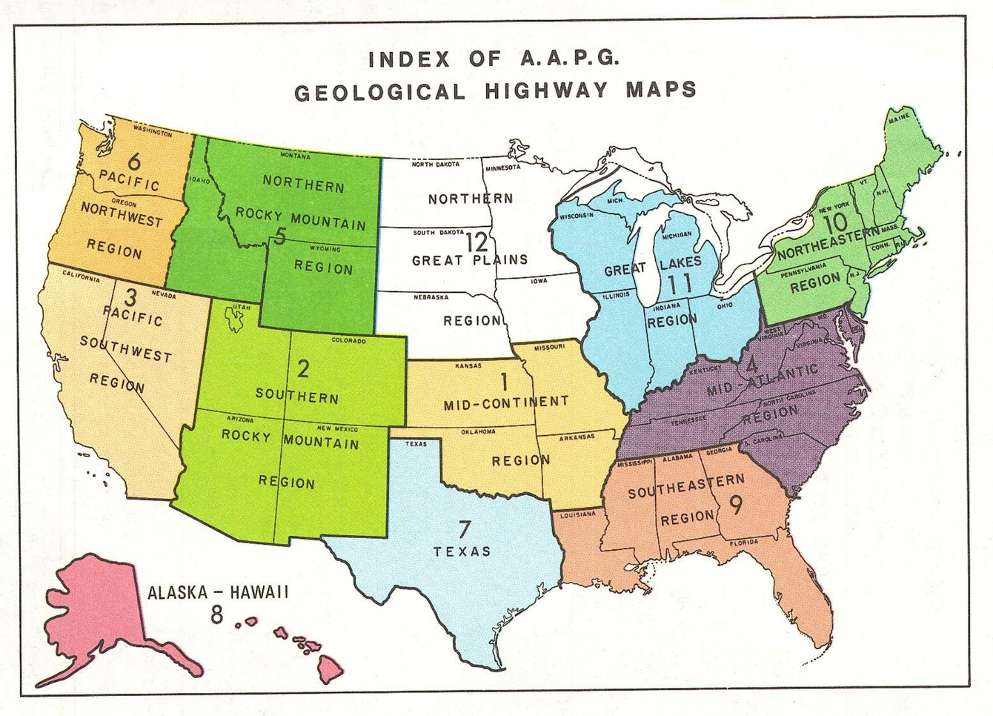
USE OF COLOR AND SYMBOL CODES

The largest map on this page shows in a generalized fashion the age and pattern of the surface outcrops upon which we drive, build, and live. Various colors and symbols are used to identify rocks of different ages and types.

The time-rock chart shows the probable age of the rock group by use of a particular color (generally the same used by the United States Geological Survey) and a particular letter symbol. For example, certain blue areas with a capital "M" are rocks of the Mississippian System. Locally, a smaller letter preceding the large capital letter further divides the rock systems—"u" to indicate the upper (younger) subdivision, "m" to indicate the middle part, and "l" to indicate the lower (older) part. A special case is the Tertiary Period, whose particular epochs are denoted by small letters following "T"—e.g., "Tx" for Paleocene and "Tp" for Pliocene. Treatment of the much-divided Ordovician, Mississippian, and Pennsylvanian Systems varies from state to state, but generally is based on the stratigraphic series recognized within the state. For example, in Ohio the Pennsylvanian System is divided into "Pp," "Pa," "Pc," and "Pm," respectively, for the Pottsville, Allegheny, Conemaugh, and Monongahela successions.

Other letter symbols are added for special types of rocks—"M" for metamorphic or altered rocks, "V" for volcanic or extrusive rocks, "G" for intrusive granite rocks, and "UM" for ultramafic or serpentine-type rocks.

For the complex Precambrian succession, the symbols currently used by the U.S. Geological Survey are employed, such as W for the lower Precambrian, X for the middle Precambrian, and Y for the upper Precambrian. This interim terminology is one of convenience which some day will be replaced by more formal terminology.



MAP NO. 11
UNITED STATES GEOLOGICAL HIGHWAY MAP SERIES

Geological Highway Map OF THE GREAT LAKES REGION

WISCONSIN ILLINOIS | **INDIANA** | **MICHIGAN OHIO**

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