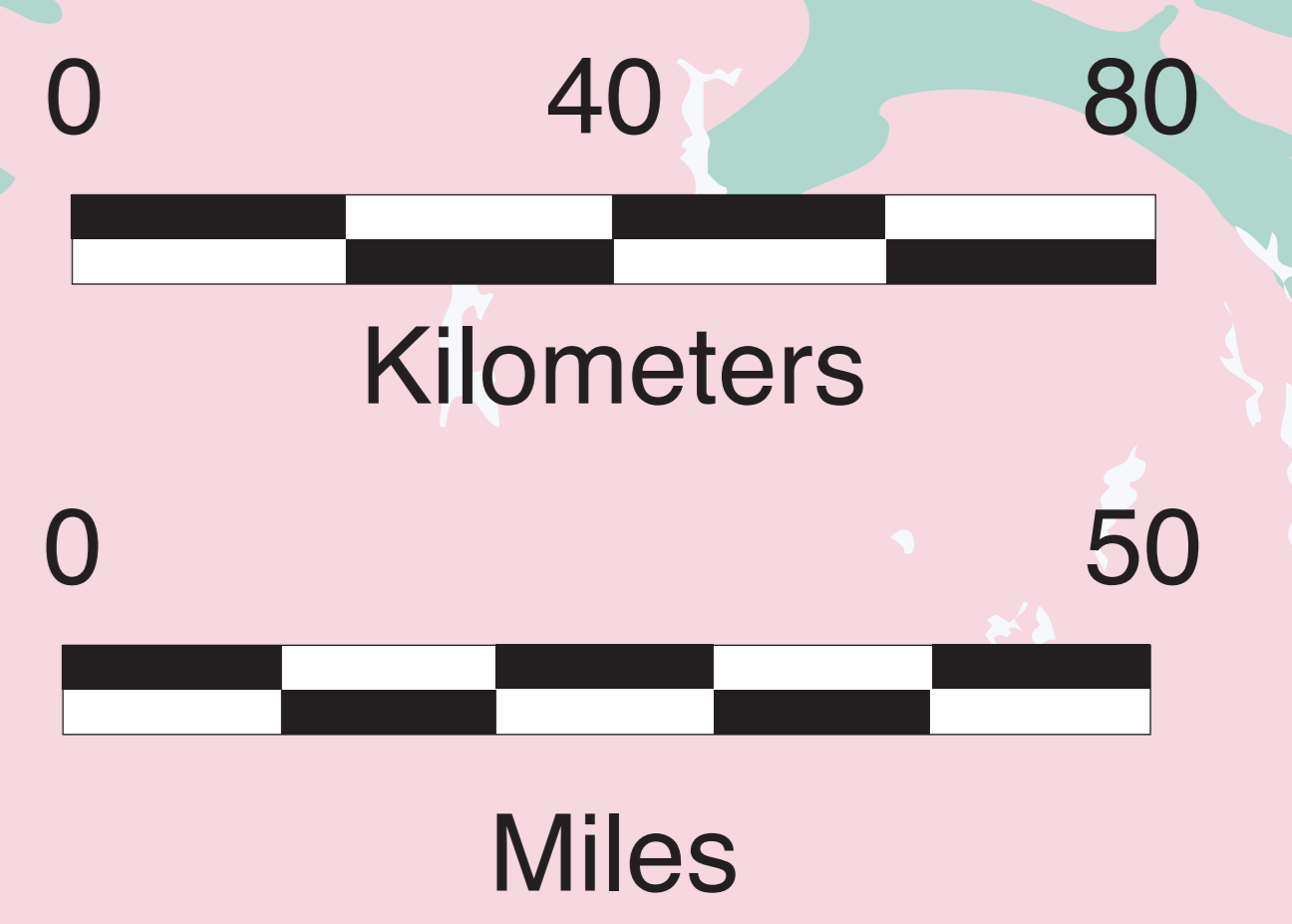
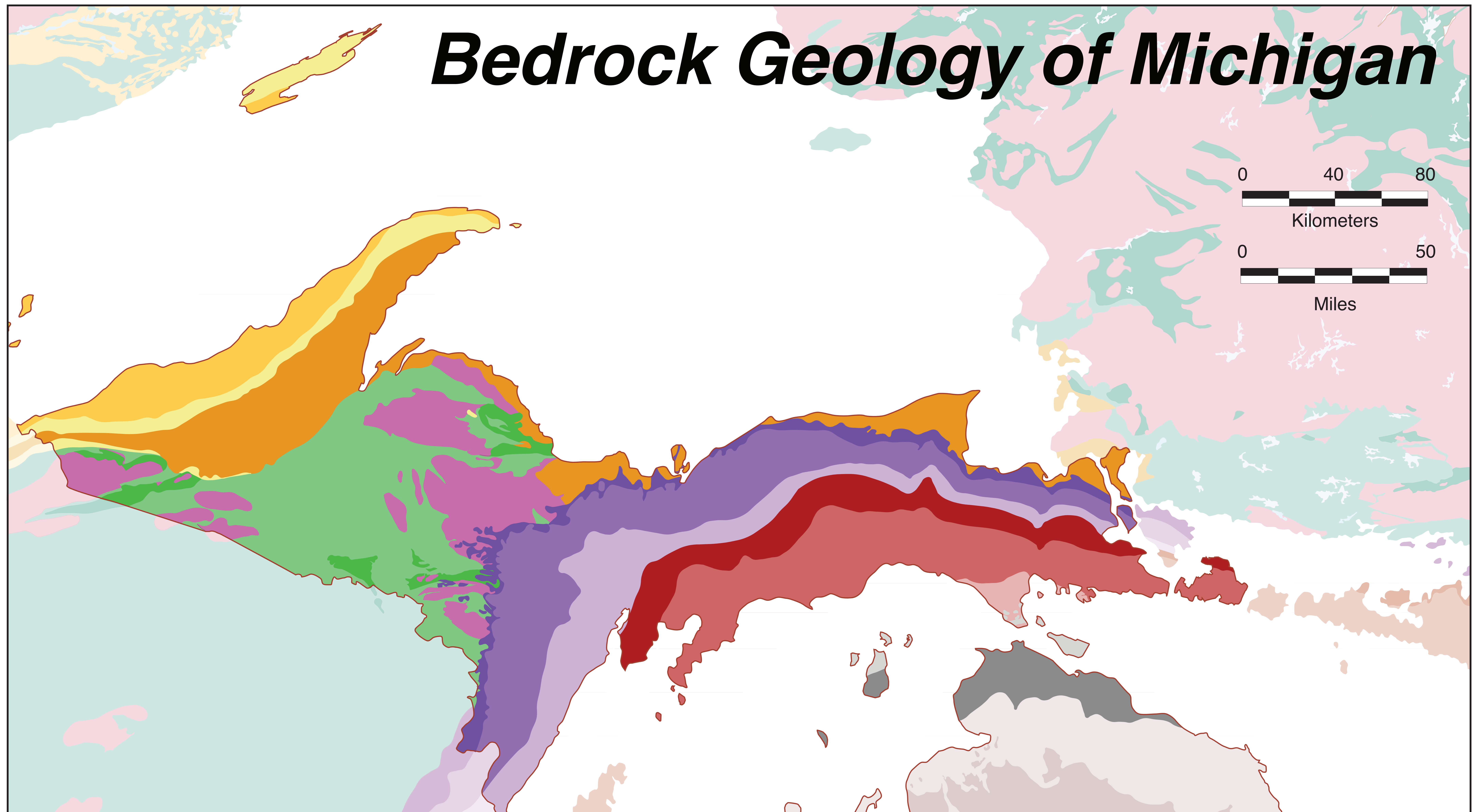
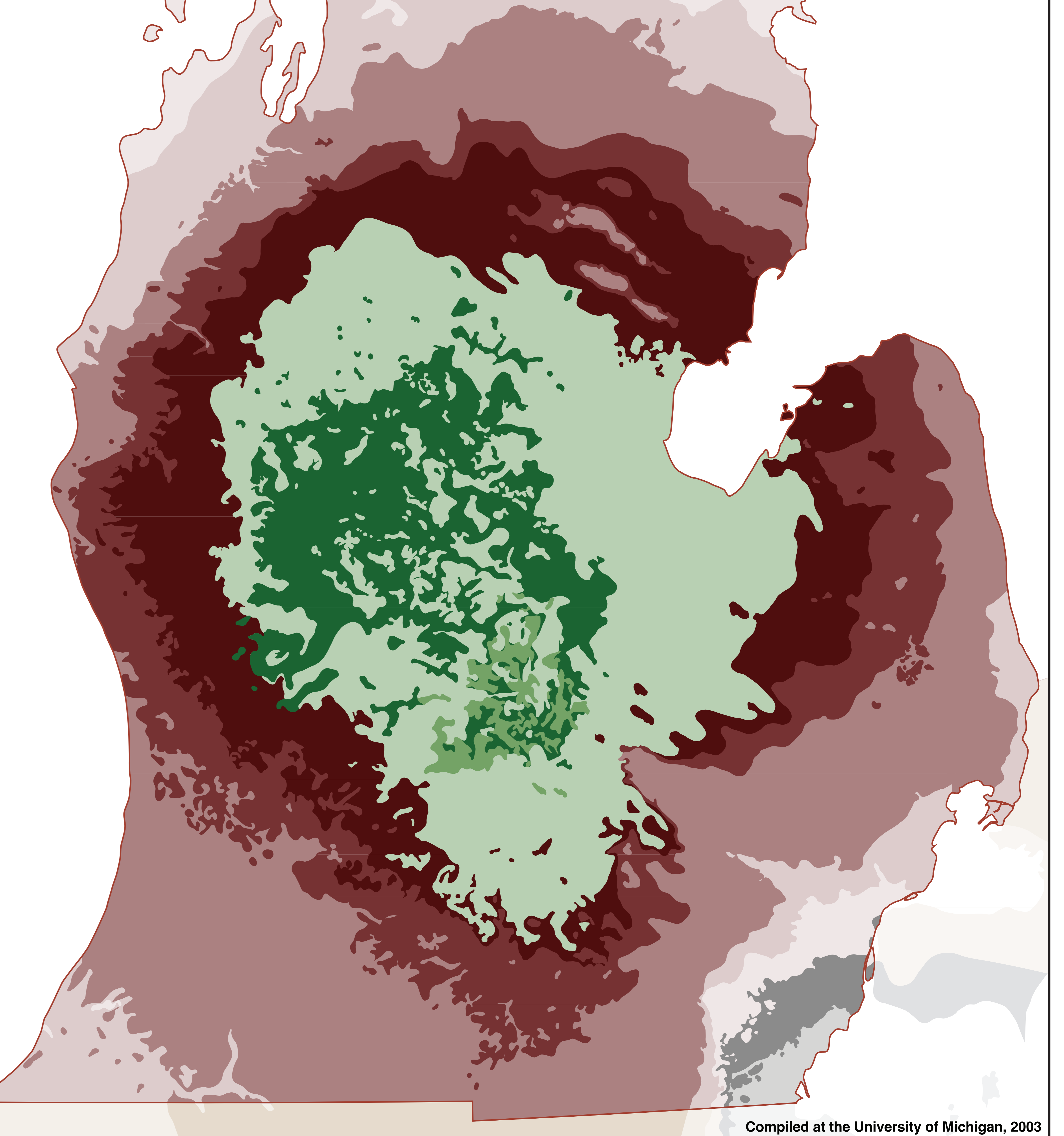


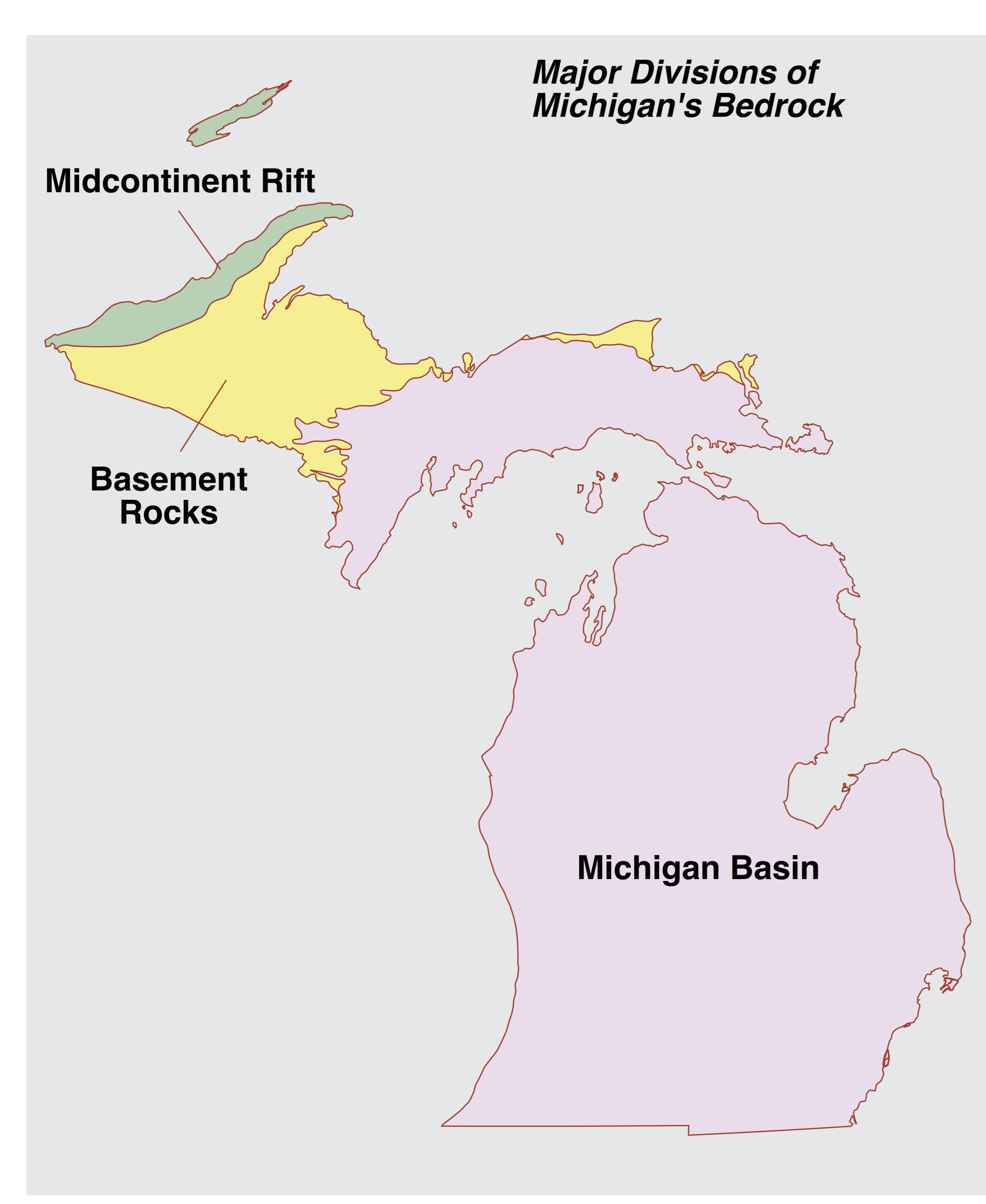
Bedrock Geology of Michigan



MICHIGAN BASIN	Jurassic	286 Ma	Red Beds
	Pennsylvanian		Grand River Formation
		325 Ma	Saginaw Formation
	Mississippian		Bayport Limestone and Michigan Formation
			Marshall Formation
		360 Ma	Coldwater/Sunbury/Berea Shale
			Ellsworth and Antrim Shales
	Devonian		Traverse Group and Dundee Limestone
			Detroit River Group and Sylvania Sandstone
	Silurian	410 Ma	Bois Blanc and Garden Island Formations
		Bass Island Formation and Salina Group	
440 Ma		Niagara-Clinton Formations	
Ordovician		Cincinnati Shales	
		Trenton Group	
MIDCONTINENT RIFT	Cambrian	505 Ma	Black River and Prairie du Chien Groups
			Munising Group and Mt. Simon Sandstone
	Late Proterozoic	544 Ma	Jacobsville Sandstone
BASEMENT ROCKS	Early - Middle Proterozoic	1000 Ma	Oronto Group
			Portage Lake Lavas
	1700 Ma	Marquette Supergroup and Related Units	
	Late Archean	2500 Ma	Metavolcanic and Metasedimentary Rocks
Early Archean	3500 Ma	Granite and Granite Gneiss	



Compiled at the University of Michigan, 2003



BASEMENT ROCKS

The oldest rocks in Michigan are Archean-age igneous and metamorphic rocks that are exposed around Marquette and to the southwest around Watersmeet. Rocks around Watersmeet include Early Archean granite and granite gneiss that is about 3.6 billion years old. These rocks, which are among the oldest in North America, appear to be remains of some of the first continents that formed on Earth. They are overlain and surrounded by Late Archean rocks that are about 2.5 billion years old. Most of the Late Archean rocks are metamorphosed remains of ancient island arcs that formed in the seas that surrounded the Watersmeet continents, and they consist of volcanic rock and sediment that was eroded from them. At the end of Archean time, the Early Archean Watersmeet continents and Late Archean island arcs collided to form larger, more stable continents.

The presence of large continents changed the nature of sedimentation and volcanism and resulted in deposition of the Marquette Supergroup and related rocks. These sequences consist of sedimentary and volcanic rocks that were deposited on top of the submerged Late Archean continent during Early to Middle Proterozoic time, from about 2.5 to 1.8 billion years ago. They were deposited in a series of basins that formed as the Late Archean continent began to break apart.

Following breakup of the continents, the ocean closed again when a land mass known as the Wisconsin Terrain moved northward and collided with the southern margin of the Archean continent and its Proterozoic sedimentary cover. This took place about 1.7 billion years ago and formed the Penokean Mountain Range. The deeply eroded roots of the Penokean Range are exposed throughout the Upper Peninsula and adjacent regions.

The Archean rocks contain deposits of copper and zinc that formed in hot springs on the ocean floor, and deposits of gold that formed as water was expelled from rocks undergoing deformation and metamorphism. The Early Proterozoic rocks contain large deposits of uranium-bearing gravels and iron-rich sediment (banded iron formation), which provide evidence that early Earth's atmosphere lacked abundant oxygen.

Penokean Mountain Range

MIDCONTINENT RIFT

The Midcontinent Rift formed when North America began to pull apart about 1 billion years ago. As the crust pulled apart, a rift valley formed and magma flowed up from Earth's mantle onto the surface to form the Portage Lake Lavas. As rifting and eruption of the lavas slowed, rivers flowed into the rift and deposited clastic sediments, including the Copper Harbor Conglomerate, Nonesuch Shale and Freda Sandstone, which make up the Oronto Group. The last sediments to form, the Jacobsville Sandstone, were deposited from rivers that spread over a large area after the rift was completely covered by the earlier sediments. Most of the water that filled the rift appears to have been fresh suggesting that the rift did not reach the ocean at the edge of the North American continent.

The Midcontinent Rift is an arcuate zone that extends northward from Iowa through the Lake Superior region and then turns southward through the Lower Peninsula of Michigan. Throughout most of this area, rocks of the rift are covered by younger Paleozoic sedimentary rocks, including those of the Michigan Basin. Rocks of the Midcontinent Rift are exposed at the surface only around Lake Superior.

Rocks of the Midcontinent Rift have been an important source of copper and silver, particularly in the Keweenaw Peninsula and the Porcupine Mountains. Much of the copper and silver was in the metallic state and did not have to be smelted for use, making it especially valuable. Many of the miners who came to the Upper Peninsula originally were from the ancient tin mines of Cornwall, England. They brought with them the tradition of a meat-potato pie, the pastie, which is still popular in Michigan.

The Midcontinent Rift is among the world's best examples of a failed attempt at continental breakup from plate movement. A complete breakup leads to the formation of an ocean that gradually separates continental segments, such as today's Atlantic Ocean, but the Midcontinent Rift did not split North America into two continents. Instead, it became a "failed rift" and provides rock exposures that tell us much about the early stages of rift formation in continents.

Midcontinent Rift

MICHIGAN BASIN

The Michigan Basin contains sedimentary rocks that were deposited in a circular depression that formed in Earth's crust during Paleozoic time, between about 544 and 286 million years ago. During most of this period, Michigan was flooded by the sea. Rivers that flowed into this basin deposited clastic sedimentary rocks, such as the Mt. Simon and Sylvania Sandstones and the Antrim Shale. When the supply of sediments was low, extensive reefs of coral and other organisms formed the Niagara Formation and Traverse Group and seawater evaporated to leave thick accumulations of gypsum and salt in the Salina and Detroit River Groups. These sediments gradually lithified to form rocks, which have been divided into the formations and groups shown on the map.

The resulting sediment-filled basin has a bowl-shaped form and reaches a maximum thickness of about 15,000 feet beneath Midland. The oldest formations reach the surface around the margins of the Michigan Basin and are buried at great depth in the central part of the basin, whereas the younger formations are near the surface in the center of the basin. Beneath these Michigan Basin sediments are older rocks of the Midcontinent Rift and Archean and Proterozoic basement rocks.

The Michigan Basin is an important source of crude oil, natural gas, salt, gypsum, and limestone, as well as brines containing bromine, magnesium and other elements that are the basis for much of the chemical industry in the state.

The Michigan Basin is the best known example of an "intracontinental basin", an unusual feature in the context of global plate tectonics. Whereas most sedimentary basins form on the margins of continents, the Michigan Basin formed well away from the margin. The formation of a sedimentary basin with up to 5 kilometers of sediment in a bowl-shaped depression on the continental interior requires a special geologic history. The Midcontinent Rift underlies the Michigan Basin and reactivation of the Midcontinent Rift during Paleozoic time might have caused subsidence that formed the basin. Activity deeper in the mantle and far-field stress effects, possibly related to formation of the Appalachian Mountains, may have contributed to this reactivation.

Basement Rocks **Midcontinent Rift**

Cross-section of Michigan Basin