

General Geology of Michigan

Michigan is unique among the states in that it is divided into two areas geographically, the Northern and Southern Peninsulas, and in that, to a considerable degree, these two geographical provinces are geologically separate and distinct. This geological dichotomy is not absolute, inasmuch as the eastern part of the Northern Peninsula is geologically similar to parts of the Southern Peninsula. The western part of the Northern Peninsula is underlain by rocks of Precambrian and Cambrian age. In contrast, underlying rocks of the eastern Northern Peninsula and the entire Southern Peninsula are younger (Ordovician to Pennsylvanian) in age.

In addition to this broad split, Michigan geology also is characterized by a major horizontal break-bedrock geology vs. surficial geology. Much of the state is veneered by deposits of Pleistocene age, the results of glacial and glaciofluvial depositional processes. These sediments are unconsolidated tills, gravels, sands, silts, and clays. They effectively mask much of the bedrock geology, particularly in the Southern Peninsula.

With a few exceptions, the spectacular metallic mineral deposits for which Michigan is justly famous occur in rocks of Precambrian age. The younger Paleozoic rocks are by no means devoid of mineral deposits or occurrences, but their variety is smaller and their mineral assemblages are more severely restricted. Only a very few inconsequential mineral occurrences appear in the Pleistocene blanket.

Precambrian Geologic History

The Precambrian involves 85 to 90% of all geologic time. The oldest radiogenic date presently recorded for Precambrian rocks is ca 3900 million years, and it is estimated that the earth originated 4000 to 5000 million years ago. The Precambrian thus begins at some yet undetermined time between 4500 and 3800 million years ago and extends to 500 million years ago - the age of the oldest Paleozoic (Cambrian) sediments.

For this enormous span of time the rock record is incomplete and, indeed, within many areas, only fragmentary. Much has happened to Precambrian rocks both within Precambrian and within Phanerozoic (post-Precambrian) time. Within Michigan, the oldest Precambrian rocks have been subjected to at least three major periods of crustal deformation and mountain building and to at least three or four additional minor or local deformational episodes. In many cases these crustal crumplings were accompanied by the intrusion of molten masses of granitoid igneous rocks emplaced deep within the crust and subsequently unveiled by uplift and erosion. Periods of volcanism (at least four) produced lava and pyroclastic rocks, chiefly of basaltic composition and accompanied by dikes of diabase and gabbro.

Metamorphism of varying degrees of intensity accompanied many of the disturbances and transformed sedimentary,

intrusive igneous, and volcanic rocks into their metamorphic equivalents. Thus basalt became greenstone; granite became granitic gneiss; sandstone was converted to quartzite; limestone to marble; and shale became slate or mica schist. The youngest Precambrian rocks, such as those of the Keweenaw Period on the Keweenaw Peninsula, have not been metamorphosed and have remained largely unchanged as basalts, sandstones, and conglomerates. Even these nonmetamorphosed rocks, however, have been tilted, folded, and faulted. Because of the enormous length of Precambrian time and the complexity and multiplicity of its major geological events, the Precambrian rocks of the Northern Peninsula of Michigan are exceedingly diverse, being represented by such groups as:

Igneous Rocks: Intrusive, extrusive

Sedimentary Rocks: Clastic, chemical, biochemical

Metamorphic Rocks: Meta-intrusive igneous rocks, meta-volcanics, meta-sediments

Most of the Northern Peninsula is underlain by rocks of Precambrian age - the southern extension of the megatectonic-petrologic unit called the Canadian Shield. Essentially all of the state's metallic mineral resources (iron, copper, copper sulfides, silver, etc.) occur in rocks of Precambrian age and, indeed, were formed in Precambrian time.

To acquire some degree of understanding of the nature and interrelations of Michigan's metallic mineral deposits requires some knowledge of the Precambrian geological history. This section outlines that history, encompassing a period of time of at least 3500 my.

Beginning in the early 1960's modern studies of the major iron and copper districts in the Lake Superior region were completed, resulting in much new information on the geology and geochronology of its Precambrian rocks. This information can now be synthesized into a relatively detailed age classification of the Precambrian of the Northern Peninsula.

We also know something about the Precambrian buried to great depths in the Southern Peninsula.

In 1976 the McClure-Sparks 1-8 borehole was drilled into Precambrian rocks in the center of the Michigan basin (T10N, R2W near Ithaca, Gratiot County). Beneath the Cambrian Mt. Simon sandstone Precambrian red clastic sedimentary rocks; sandstone, siltstone, shale; were encountered. In these redbeds igneous rock units were transected at two intervals: the first from 4970-4998 m and the second from 5252 m to the bottom of the hole at 5324 M. (These depths are referenced to the elevation above sea level of the top of the hole, which is at 232 m.) Rocks from this borehole, tabbed the Michigan Basin Deep Drill Hole (MDH) have been intensely studied.

The two bodies of igneous rock belong to the basalt-gabbro clans which have been transformed by metamorphism of the greenschist facies. The upper unit is an assemblage of albite-chlorite-calcite-epidote with minor sphene, spinel, bornite, digenite, and native copper. The original pyrogenic minerals, probably labradorite and clinopyroxene, have been completely altered, but the primary igneous texture has been preserved. The rock apparently is an altered diabase.

The lower unit consists mainly of albite-epidote-(tremolite)-actinolite-chlorite with relict clinopyroxene and minor quartz, K-feldspar, sphene, anatase, magnetite, ilmenite, pyrite and chalcopyrite. Stakes (1978) also reports prehnite. Of the original pyrogenic assemblage (labradorite, olivine, and titanite) only the last and ilmenite remain in fresh relicts. In addition to the pseudomorphic alterations of calcic plagioclase, olivine, and glass, the rock is transected by veinlets of: 1) epidote-actinolite, 2) chlorite-actinolite, 3) serpentine-chlorite-epidote and 4) albite-quartz-actinolite-pyrite. This rock corresponds texturally and mineralogically to the well-defined ophitic, basaltic flow rock of the Portage Lake Lava Series of the Keweenaw Peninsula, though somewhat finer grained.

Paleozoic Geologic History

The Paleozoic Era in Michigan is represented by rocks that underlie the entire Southern Peninsula and the eastern part of the Northern Peninsula. Beginning about 500 million years ago and ending about 370 million years later, this era is represented by a wide variety of strictly sedimentary rocks that were deposited in the Cambrian, Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian Periods, aggregating about 14,000 feet in thickness. Together, formations of these periods form a huge regional structure called the Michigan Basin, which approximates a stack of shallow nested spoons whose long axis trends north-south. At the center of the basin, just west of Saginaw Bay, near the geographic midpoint of the Southern Peninsula, are exposed the youngest rocks of the sequence, which here are underlain by nearly 2.5 miles of successively older layers above the Precambrian floor. Outward in all directions those units at or near the surface become progressively older, forming irregularly circular bands that dip at very gentle angles (average, 60 ft. per mile) inward to the nadir of the basin. Although locally disturbed by minor folding and faulting, the rocks of this entire stratigraphic column have neither been metamorphosed nor subjected to igneous intrusion or volcanism. Hence they have remained sedimentary rocks, modified only by weathering and by the action of ground waters and trapped environmental (connate) waters. Since outcrops are scarce in the Southern Peninsula, owing to the depositional veneer of glacially derived material, much of our information on these rocks has been obtained from wells and drill holes. Most of the Paleozoic rocks were deposited as marine sediments. Exceptions are the oldest: the Jacobsville Sandstone (Cambrian), a stream and lake deposit; and many of the youngest (Pennsylvanian), which include sandstones

(stream-channels), shales (floodplains), and coals (swamps).

The Paleozoic rocks of Michigan do not represent a completely continuous record of Paleozoic sedimentation. At several times uplift interrupted the general sinking of the basin and erosion, or at least nondeposition, characterized that particular time interval. Thus, the stratigraphic sequence contains time gaps (unconformities), some local and some regional, e. g., in the Early Ordovician, the Early Devonian, and the Late Mississippian Periods. Types of rocks in the Paleozoic of Michigan include:

Cambrian: shale, sandstone, hematitic sandstone, conglomerate

Ordovician: sandstone, glauconitic sandstone, dolomitic sandstone, shale, sandy dolomite, dolomitic limestone, shaly limestone, cherty limestone

Silurian: limestone, reef limestone, dolomite, shale, evaporites (rock salt, rock gypsum, rock anhydrite, potash-salt rocks)

Devonian: sandstone, shale, black shale, limestone, reef limestone, cherty limestone, dolomite, evaporites (rock salt, rock gypsum, rock anhydrite), solution breccia

Mississippian: shale, siltstone, silty sandstone, sandstone, hematitic sandstone, conglomerate, limestone, dolomite, evaporites (rock gypsum)

Pennsylvanian: sandstone, siltstone, shale, red shale, underclays, coal, limestone

Post-Pennsylvanian / Pleistocene Geologic History

The post-Pennsylvanian geological record for Michigan is divisible into two main parts: 1) "The lost interval" (Dorr and Eschman, 1970), a nearly unrepresented period of time between the end of the Pennsylvanian and the youngest Pleistocene glaciation, and 2) the Pleistocene glacial epoch. Missing are rocks of the youngest Paleozoic Period (Permian), nearly all of the Mesozoic Era (Triassic, Jurassic, and Cretaceous), and all of the Cenozoic, save for the youngest--the Pleistocene. A small area near the middle of the Michigan Basin contains "red beds" (entirely under glacial cover) of sandstone, shale, and minor limestone and gypsum, which have been dated as youngest Jurassic on the basis of fossil plant spores. The complete Pleistocene Epoch involved four major glacial periods, but only deposits from the youngest, the Wisconsinan, are represented as surficial deposits in Michigan. They consist of unconsolidated, nonstratified clastic sediments dumped directly from continental glaciers (drift), and unconsolidated stratified gravels, sands, and clays deposited by glacial streams and in glacial lakes (glaciofluvial deposits).

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