This section will focus on the underlying bedrock formations of the state. In addition to discussion of the basic rock series present, the distribution of these various series will be examined. A review of a number of terms and definitions is also included.

2-2.1 Bedrock Formations

The bedrock formations are normally divided into three distinct groups. These consist of igneous rocks, sedimentary rocks, and metamorphic rocks.

2-2.1.1 Igneous Bedrock

The term “Igneous” is derived from the Latin word for fire. It is an appropriate term since all igneous rocks are formed from molten materials (magma) that solidified after cooling. Igneous rocks that formed deep below the surface of the earth as the magma forced its way into the crust are termed intrusive rocks. Common igneous intrusive rocks found in Wisconsin include granite, diorite, syenite, and gabbro. Rocks that formed from magma reaching the earth’s surface as lava flows, or other volcanic material, are termed extrusive rocks. Some of the most common extrusive rocks in the state are basalt, felsite, and rhyolite.

Mineral types and percentages are used to differentiate the types of igneous rocks, but this goes beyond the scope of this discussion. Igneous rocks have crystalline structures that range from very coarse to very fine, typically have high specific gravities, and tend to be very hard material. The most common igneous rock in Wisconsin is granite, but all of the listed rocks are present in significant amounts. Erosion and weathering of the igneous rocks and associated metamorphism provided the materials from which the sedimentary rocks were formed. In Wisconsin, igneous rocks are some of the oldest rocks, and are found near the surface in roughly the northern third of the state. They also extend under the southern portion of the state, but are buried by hundreds, to as much as several thousand, of feet of the younger sedimentary rocks.

2-2.1.2 Sedimentary Bedrock

Sedimentary rocks are those rocks formed through the deposition and solidification of sediment transported by water, ice or wind. A characteristic feature of sedimentary rocks is a layered structure known as bedding or stratification (AGI, 1972). The mineral portions of these rocks resulted from the erosion of rocks of earlier ages, while the organic portions originated from the accumulation of shells and skeletons of various marine creatures existing at the time of deposition. The wide spread distribution of water-lain sedimentary rocks in the state shows that Wisconsin was covered by oceans for many millions of years. The most common sedimentary rocks found in the state are sandstone, shale, and limestone/dolomite.

Sandstone is formed from the near-shore deposition of sand sized materials eroded from adjoining uplands and carried to the shore by water or wind. In Wisconsin, sandstones are composed primarily of quartz particles. Bedding is often visible in exposed rock faces which attests to the water borne origins of these rocks. The individual sand grains in the sandstone mass vary from coarse to fine, depending on the mechanics of deposition. Sandstone is formed when the individual grains are cemented together by silica and other minerals to form a coherent mass. However, variations in the type and degree of cementing agents cause sandstones to vary from hard, competent rock, to soft poorly cemented material. Sandstones are found in a broad arc across the northwestern and central parts of the state.

Shale is formed in a process similar to that of sandstone, but deposition occurred further away from the shore line and/or in deeper water. As a result, the individual grain size of the material is predominantly in the clay, and to a lesser extent silt, sized fraction. This gives the rock a fine grained appearance. However, at times the transition zone from sandstone to shale was gradual or uneven which resulted in shaley sandstones or sandy shales. In Wisconsin, shale tends to be a rather weak rock that weathers easily, making surface exposures of this rock uncommon. Shale is found in a narrow band in eastern Wisconsin, and in association with sandstone in western Wisconsin.

Limestone is termed a carbonate rock because of the high percentages of calcium carbonate found in its matrix. Limestone is formed in deeper water environments, from the accumulation of the shells and skeletal remains of sea creatures, along with the precipitation of calcium carbonate from the sea water. In Wisconsin, much of the rock originally deposited as limestone has been changed to dolomite (dolostone) by the gradual chemical replacement of calcium by water borne magnesium. (Shultz, 1986) Limestones and dolomites often contain fossils of some of the sea creatures that existed at the time of the rock formation. Fluctuating conditions during formation created shaley zones or layers in some of the carbonate rocks. However, most of the carbonate rocks tend to be dense, strong material, and are often used for construction. The carbonate rocks are widespread in a

broad arc extending across much of southern and eastern Wisconsin.

2-2.1.3 Metamorphic Bedrock

Metamorphic rocks are those derived from the alteration of existing rocks by heat and pressure over long periods of time. Igneous, sedimentary, and older metamorphic rocks can be altered by this process. The development of sufficient heat and pressure to create changes to the crystalline structure of the original rock can result from a number of conditions including earth crustal movement, pressure from increased overburden, and tectonic activity. The resultant metamorphic rocks often exhibit an increased competency and a more pronounced crystalline structure. Metamorphic rocks occur widely across the northern third of the state in complex associations with igneous rocks. However, there are also several significant exposures in southern Wisconsin including the Baraboo and the Waterloo quartzites. The most common metamorphic rocks found in Wisconsin are presented in Table 1.

Table 1 – Bedrock and Parent Materials

Bedrock Type	Parent Material
Schist	Basalt, Gabbro
Gneiss	Granite
Greenstone	Basalt
Quartzite	Sandstone
Slate	Shale

2-2.2 Geologic History

2-2.2.1 Wisconsin Geologic Time

The geologic history of the earth is immense and spans approximately 4.6 billion years. The geologic time scale provides a relative system of chronological measurement relating rock layers (including rock types and sequences) to the timing of geologic events and relationships that have occurred during earth's history. This time scale is used by earth scientists throughout the world and is divided into standard eons, eras, periods and epochs. A generalized version of this time scale is presented for Wisconsin in Figure 1. This table relates representative rock units found in the state to the standardized time periods.

The bedrock series of Wisconsin are commonly divided into two groups, consisting of the Precambrian Era igneous and metamorphic series, and the Paleozoic Era sedimentary series.

Figure 1 - Wisconsin's Geologic Time Scale

Era	Period	Millions of Years Before Present (Ma)	Representative Rock Units in Wisconsin
Paleozoic	**Quaternary**	**2.0 - present**	**Glacial Deposits**
	Tertiary	65 – 2.0	*Missing*
	Cretaceous	144 - 65	*Missing*
	Jurassic	208 - 144	*Missing*
	Triassic	245 - 208	*Missing*
	Permian	286 - 245	*Missing*
	Pennsylvanian	329 - 286	*Missing*
	Mississippian	360 - 329	*Missing*
	Devonian	408 - 360	Limestone/shale from Milwaukee area
	Silurian	438 - 408	Limestones/dolomites from eastern 1/3 of WI
	Ordovician	505 - 438	Limestones/dolomites/ sandstone southern and eastern WI
	Cambrian	545 - 505	Sandstones central and southern WI
Precambrian Proterozoic	NA	2,500 - 545	1,000 – 1,200 Ma basalt, NW WI 1,400 – 1,500 NE WI granites (Wolf River) 1,400 – 1,750 (?) Ma quartzite e.g., Baraboo, Waterloo, Baron County areas. ~1,760 Ma Central WI granite and rhyolites
Precambrian Archean	NA	4,600 – 2,500	2,800 Ma gneiss Central and Northern WI (oldest rock in WI) 4,600 Ma Age of the earth

2-2.2.2 Bedrock Distribution and Age

The general distribution of the various rock types across the state can be seen by referring to Figure 2, entitled "Bedrock Geology of Wisconsin", prepared by the Wisconsin Geological and Natural History Survey (WGNHS). (http://wgnhs.uwex.edu/pubs/download_m067/)

The igneous and metamorphic rocks are the oldest in the state and fall into the Precambrian time period. The rocks range in age from approximately 1 billion years to about 2.8 billion years, and form the bedrock surface under most of the northern portion of the state. The great age of these rocks along with the effects of multiple stages of volcanism, erosion, deposition, and metamorphism make the interaction of these rocks very complex. They are considered to be part of the Canadian Shield, a large area of ancient rock units forming the core of the North American continent. The igneous and metamorphic rocks extend under southern Wisconsin but for the most part are covered by the younger sedimentary rocks. However, some exposures of Precambrian rocks do occur, most notably quartzite that forms the Baraboo bluffs in Sauk and Columbia Counties. Associated with the igneous and metamorphic Precambrian era is an area of sedimentary rocks extending out from the south shore of Lake Superior. These Lake Superior sandstones, shales, and conglomerates are thought to be of Precambrian age but somewhat younger than the other igneous and metamorphic rocks in this area. All of these sandstone, shale, and conglomerate deposits display a distinct reddish brown color.

The sedimentary rocks of southern Wisconsin form distinct layers covering the igneous and metamorphic basement rocks. They form a distinct pattern with the oldest rocks exposed to the north overlain by progressively younger rocks to the south and east. The oldest of the sedimentary rocks is a series of sandstones of Cambrian age. These are overlain by two distinct limestone sequences separated by a layer of sandstone followed by a layer of shale, all of Ordovician age. These sequences are overlain by Silurian age limestone extending across eastern Wisconsin. The uppermost rock unit is a small area of Devonian age shale and limestone located along the Lake Michigan shoreline in Milwaukee and Ozaukee counties. There are no rocks younger than Devonian age in Wisconsin even though these are present in adjoining states. While it is possible that some of the younger sedimentary rocks may have been deposited in Wisconsin, they have been removed by weathering and erosion.

The distribution, nomenclature and classification of rock units of Wisconsin are best observed by referring to Figure 2 and Figure 3, "Bedrock Stratigraphic Units in Wisconsin" (http://wgnhs.uwex.edu/pubs/wofr200606sm/), both of which are published by the Wisconsin Geologic and Natural History Survey (WGNHS).

Figure 2 - Bedrock Geology of Wisconsin

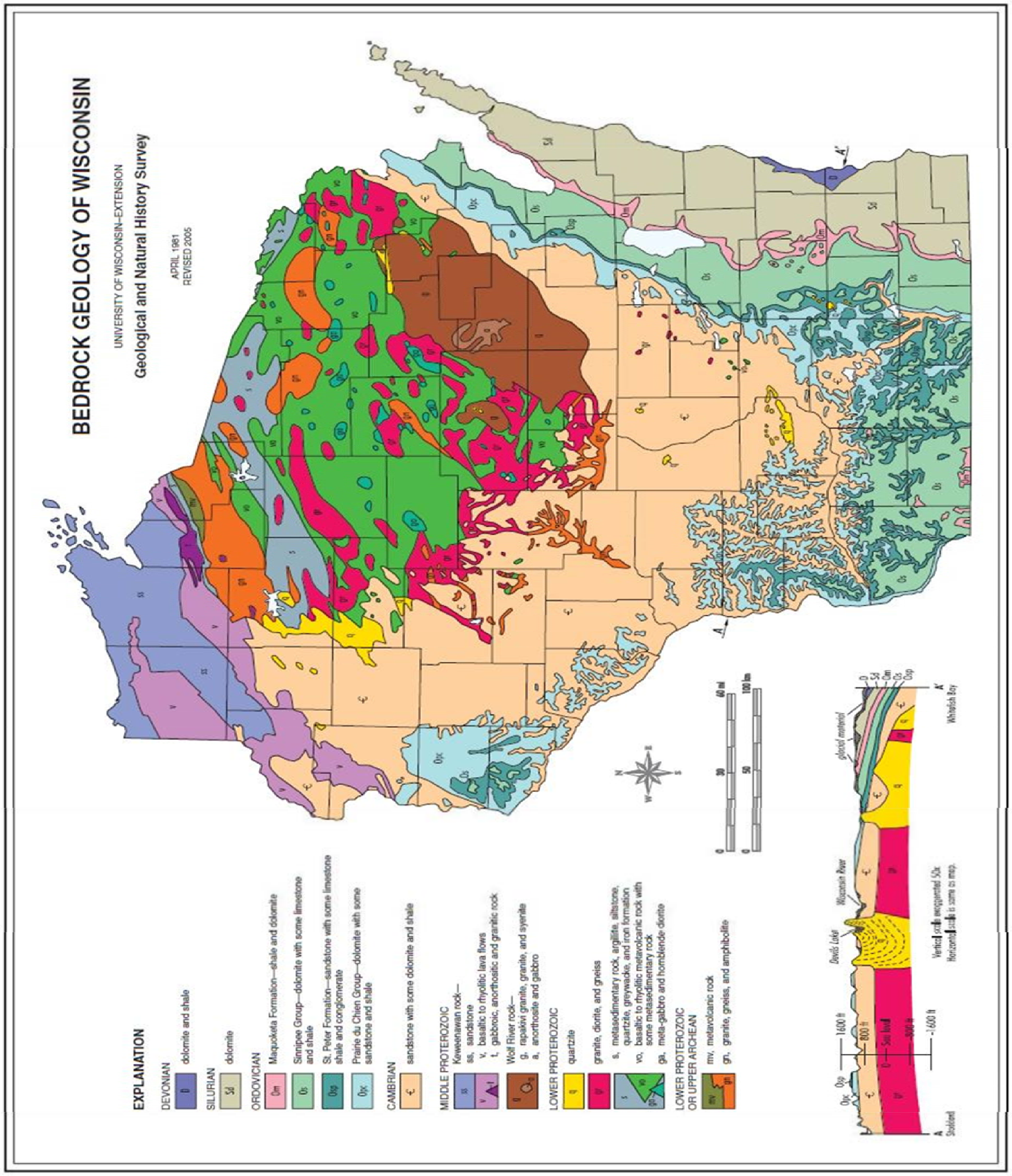
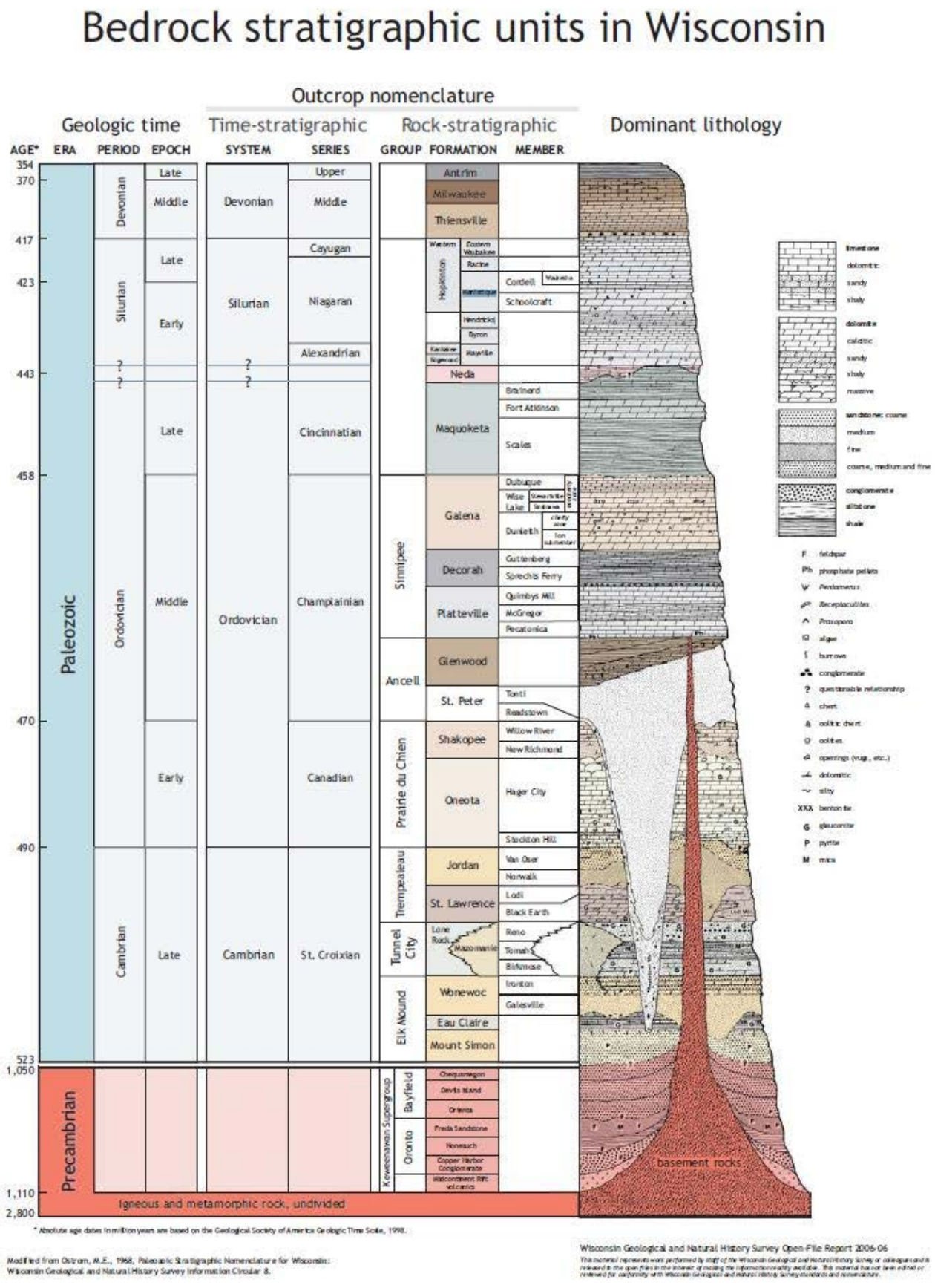


Figure 3 - Bedrock Stratigraphy



2-2.3 Karst

Karst refers to a landscape that develops on soluble bedrock and is characterized by closed depressions, sinkholes, voids and caves. In Wisconsin, karst features are typically associated with carbonate bedrock (limestones and dolomites) and are distributed across the western, southern and eastern portions of the state as illustrated in Figure 4 (https://wgnhs.uwex.edu/water-environment/karst-sinkholes/).

These features are formed when carbon dioxide (from the atmosphere and soil) is dissolved into rainwater and/or groundwater to form weak carbonic acid solutions. Groundwater containing these weak carbonic acid solutions works to slowly dissolve limestone and dolomite especially along joints and fractures in the rock. With enough time, these enlarged fractures and joints can become caves which in turn can produce sinkholes when the overlying soil collapses into a large void or cave. Voids, sinkholes and caves can become problematic when they occur around man-made structures such as roadways, bridges and culverts. Further assessment utilizing rock coring and/or geophysical methods (seismic refraction, and electro-magnetic methods) should be considered when conducting geotechnical investigations in the karst areas identified on Figure 4.

Figure 4 – Karst and Shallow Bedrock