UNIVERSITY OF MINNESOTA

Minnesota Geological Survey

Minnesota at a Glance

Ancient tropical seas—Paleozoic history of Southeastern Minnesota

Imagine a sandy, tropical seashore extending across southern Minnesota—part of a vast, shallow sea that covers much of North America. The sandstone, shale and calcareous rock layers exposed across much of southeastern Minnesota (Figs. 1 and 2) are a geologic record of such conditions that existed hundreds of millions of years ago, during the Early Paleozoic.

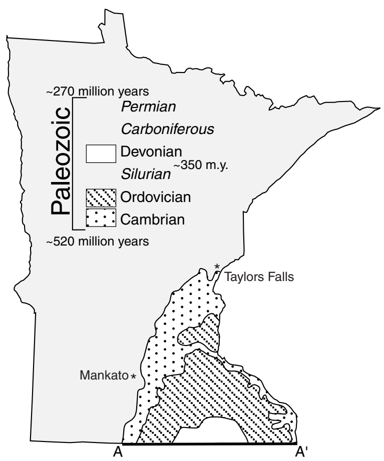

__Figure 1.__ Distribution of Paleozoic rocks in southeastern Minnesota. Line of cross section A-A' corresponds to Figure 2. Time periods shown in italics are not represented by rocks in Minnesota.

Although many people are not aware of the geologic history of the Paleozoic bedrock in Minnesota, the rocks are familiar to anyone who has travelled in southeastern Minnesota. The bluffs along the St. Croix, Minnesota and Mississippi rivers, and their tributaries, are composed of layers of Paleozoic-aged rock such as the St. Peter Sandstone and the Prairie du Chien Group (Fig. 2). Paleozoic rocks lie beneath glacial deposits across much of southeastern Minnesota, from as far north as Taylors Falls, southwest to Mankato (Fig. 1). They extend southward into Iowa and eastward into Wisconsin.

To understand the detailed history of the bedrock in southeastern Minnesota, you need only be familiar with the processes of deposition and erosion. Paleozoic bedrock layers are sedimentary in origin. They are composed of particles of pre-existing rocks or minerals, or are precipitated by biogenic or chemical processes. Deposition is the accumulation of particles into layers, or beds. Small grains are dropped by wind or settle in water to form sandstone and shale. Elements such as calcium, magnesium, and iron, precipitate from seawater to form limestone or dolostone.

Different rocks reflect the environmental conditions present at the time the original sediments were deposited. For example, where sand was scarce, carbonate minerals, chemically precipitated from seawater, and carbonate shells of marine organisms accumulated to form limestone.

Erosion is the natural process whereby water, wind, or ice breaks down rocks and soil and shapes the land. Weathering can be chemical, as when water dissolves limestone, or mechanical, as when wind blows away the soil or glaciers scour the landscape.

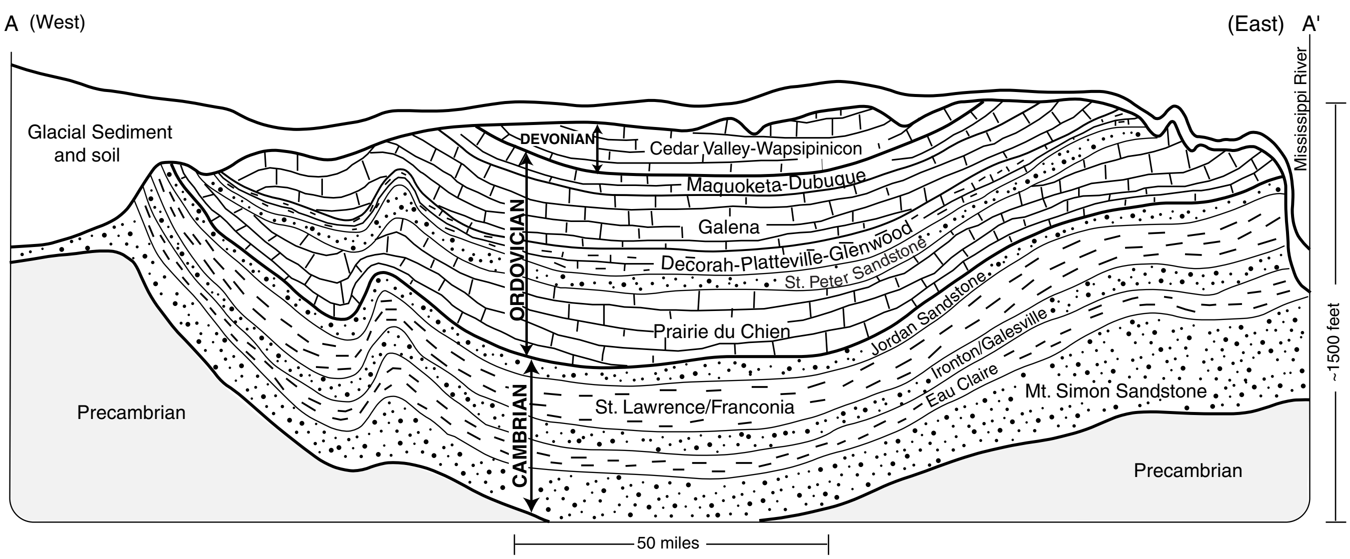

__Figure 2__. Cross section of bedrock from west to east across southeastern Minnesota. The bedrock consists of sedimentary rock layers composed of sandstone, shale, and carbonate rocks such as limestone. Location of cross section is shown on Figure 1.

DEPOSITION OF PALEOZOIC ROCKS

The General Setting

In earliest Paleozoic time, North America was on the equator, and Minnesota was a low-lying, mostly flat area. Although the climate was probably tropical, land plants had not yet evolved so the land surface was barren except for some primitive algae and bacteria. Sea level began to rise much higher than it is today, and eventually most of North America was covered by the ocean. As a result, about 520 million years ago, southern Minnesota, Wisconsin, and Iowa became a shallow sea with islands at Baraboo, Wisconsin, in southwestern Minnesota, and near Taylors Falls (Fig. 3). The sea was bordered on the northeast side by higher ground called the Wisconsin Dome. Over the next 200 million years, sediments eroded from highlands to the north accumulated in more or less flat layers in this sea. These sediments were later buried and cemented eventually forming the layers of bedrock. Fossils contained in this bedrock record life that existed in this ancient sea. They are described in detail in Minnesota at a Glance: Fossil Collecting in the Twin Cities area.

If you examine the bedrock exposed in quarry walls, road cuts or steep hillsides in southeastern Minnesota, you can see that it consists of more than one kind of rock—sandstone, shale, dolostone, and limestone (Fig. 2). The coarsest sandstone layers are composed almost entirely of quartz grains, a mineral rich in silica—similar in composition to window glass. Other layers are mostly limestone or dolostone—an altered limestone made up of calcium, magnesium and carbon dioxide. Still other layers are mostly shale, or a mixture of fine-grained sand, shale and carbonate rock. Geologists have assigned names to these individual rock layers. The names are from places where the rocks are, or were at one time, well exposed. For example, the Jordan Sandstone is named for the city of Jordan, Minnesota; and the St. Peter Sandstone, for the St. Peter (now Minnesota) River near Fort Snelling.

The Paleozoic rock layers are more than 1,500 feet thick in some places, and were deposited over a span of some 200 million years during the three geologic time periods known as the Cambrian, Ordovician, and Devonian (Figs. 1 and 2). The manner in which they were deposited varied through time, and is described in greater detail in two parts: 1) Late Cambrian to Late Ordovician time—when the rock layers were deposited as part of a texturally graded shelf; and 2) Late Ordovician and Devonian time—when the depositional environment was dominated by carbonate.

Deposition in a texturally graded shelf

To best envision what southeastern Minnesota may have looked like in the Cambrian and most of the Ordovician, picture the sandy coast of the Gulf of Mexico, but with a barren, mostly lifeless land surface. Sediments deposited in Minnesota at this time consisted mostly of sand, silt and clay-sized particles that were carried by streams from the Wisconsin Dome to the shoreline. Shallow ocean currents subsequently sorted and deposited these sediments forming a "texturally graded shelf" (Fig. 4). The coarsest sand was laid down in a shallow marine environment known as the shoreface. The shoreface includes the beach and shallow water nearshore where oceanic currents were relatively strong. At the same time, finer sand, silt and clay-sized particles carried seaward by storm currents were deposited in deeper water on the offshore shelf. In the deeper parts of the offshore shelf, hundreds of miles from the shoreface, silt and clay-sized particles and carbonate grains slowly settled out of suspension.

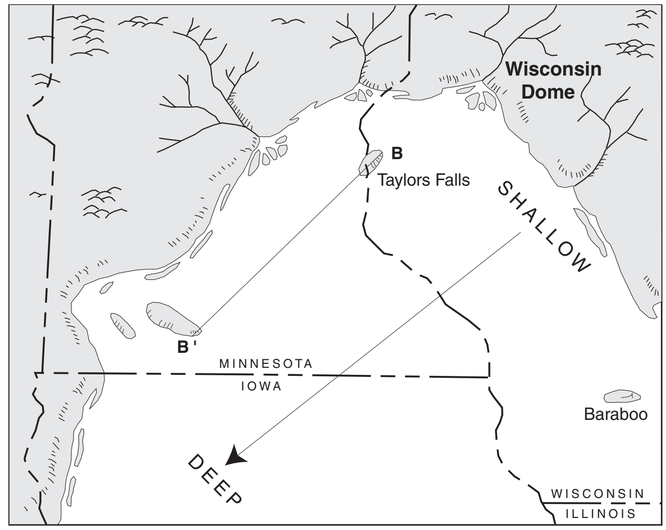

Figure 3. Paleogeographic map of southern Minnesota and adjacent states in early Paleozoic time when a shallow sea covered much of North America. At times when sea level was much higher than shown here, most of the state was covered with water. At other times, sea level was much lower and all of Minnesota was dry land. Line of cross section B-B' corresponds to Figure 4 (from Runkel, A.C., 1996, MGS Educational Series 9).

The different layers of Paleozoic rocks that stretch across southeastern Minnesota were formed when sea level, and therefore the depth of the ocean, changed through time (Figs. 5 and 6). Large changes in sea level led to drastic changes in the position of the sandy shoreface, moving it off of the Wisconsin Dome, and back and forth across southeastern Minnesota. Each time the shoreface passed across southeastern Minnesota, it left behind sandy deposits. The Mt. Simon Sandstone, the oldest Paleozoic formation, was deposited during the initial Cambrian flooding of Minnesota during which the shoreface migrated northward as southeastern Minnesota was covered with water. The younger Ironton/ Galesville and Jordan sandstones were deposited during subsequent major sea level changes. When sea level fell, the sandy shoreface retreated southward into Iowa, leaving behind a "trail" of quartz sand (Figs. 5 and 6). When sea level rose again, the shoreface moved northward across Minnesota, also leaving behind a trail of sand. The last major shoreface sandstone accumulation is represented by the Ordovician St. Peter Sandstone. The St. Peter was deposited during a slow rise in sea level that followed an extended period of low sea level and erosion across much of Minnesota.

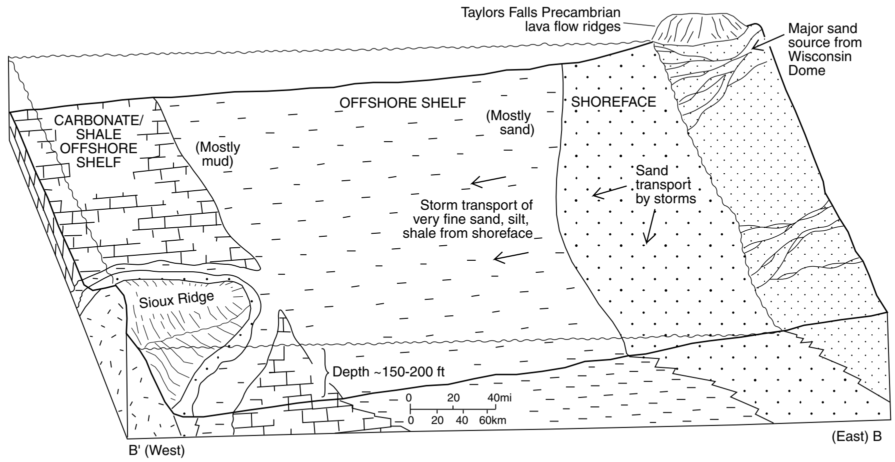

***Figure 4**. Conceptual model depicting the shallow ocean conditions known as a "texturally graded shelf" that existed during much of the Early Paleozoic in southeastern Minnesota. Sand, silt and clay-sized particles were transported by rivers to the shoreline. Frequent storms sorted the sediment so that the coarsest particles were deposited in the shoreface where currents were strong, and finer particles were carried seaward where they settled out in quieter, deeper water. Calcareous particles accumulated far from the shoreline. The different kinds of sedimentary particles eventually became sandstone, shale and limestone (modified from Runkel and others, 1998, GSA Bulletin, v. 110, p. 188-210).*

When sea level was relatively high, the sandy shoreface was on higher ground to the northeast outside of Minnesota (e.g., Fig. 6). At these times, most of southeastern Minnesota was a large offshore shelf under relatively deep water where clay, silt and fine sand accumulated. Such offshore shelf deposits form the layers now called the Eau Claire and Franconia formations. Even higher sea level and deeper water led to offshore conditions where only silt, clay and carbonate particles accumulated. The layers called the St. Lawrence, Glenwood and Decorah formations are composed of variable proportions of shale, siltstone and carbonate sediments deposited in such a setting. When the sea was at its highest levels, nearly all of Minnesota and surrounding areas were flooded, and carbonate deposition occurred in the deep water that covered southeastern Minnesota. The part of the Prairie du Chien Group, the Platteville Formation, and the Galena Group were deposited in such very deep water. At about the same time, the small patch of Paleozoic rocks in northwestern Minnesota was also deposited. The Galena Group represents the last deposit of the "texturally graded shelf" system.

Deposition in carbonate dominated systems

Depositional conditions during the latest Ordovician and Devonian were dominated by calcareous sediments at all water depths. Sand was largely absent, even in the shallowest water environments at this time, indicating that Minnesota may have been very low-lying, and perhaps much of its surface was covered with newly evolved vegetation. Such conditions inhibited erosion across the Wisconsin Dome and nearly eliminated the supply of sand to the shoreline.

The latest part of the Ordovician Period came to a close with the deposition of the Dubuque and Maquokada formations (Fig. 2), which together record a change from deep water deposition to shallow tidal-flat deposition as sea level fell and the shoreline retreated out of Minnesota. At tidal flat is a broad shoreline area where limy muds accumulated as water advanced and retreated during high and low tide cycles.

After a long period of erosion during Silurian and Early Devonian time, the seas returned to Minnesota in the Middle Devonian. Sea level was relatively low, and the shoreline remained at or near extreme south-central Minnesota, rarely if ever extending as far north as the Twin Cities area. The Cedar Valley and Wapsipinicon groups were deposited at this time (Figs. 1 and 2). Conditions were similar to those in latest Ordovician time—shallow water deposition dominated by carbonate sediments. Communities of shelled organisms, such as corals, locally built up into tropical reefs.

POST DEVONIAN HISTORY

There are no rocks in Minnesota representing the remainder of the Paleozoic Era and much of the early Mesozoic (350 to 100 million years ago [see Minnesota at a Glance: Geologic Time]). For most of this time, the region was above sea level, and the land surface was eroded by wind and water. The sea never became high enough for the shoreline to advance further north than Iowa. The sea returned to Minnesota for the last time about 100 million years ago during the Cretaceous Period, a time when dinosaurs roamed the Earth. Deposits laid down at this time are common beneath the surface of southwestern Minnesota, but in southeastern Minnesota, only thin, patchy remnants of Cretaceous strata are present.

EROSION OF PALEOZOIC ROCKS

Paleozoic rock formations are no longer the continuous layers they were when they were first laid down in the ocean. Instead, they have been eroded in places by relatively recent geologic activities, particularly during the Ice Age that began about two million years ago. At times, glaciers covered much of the state (see Minnesota at a Glance: Quaternary Glacial Geology). The Paleozoic bedrock of southeastern Minnesota was deeply eroded when large amounts of water from melting glaciers to the north caused the ancient Mississippi, St. Croix, and Minnesota rivers and their tributaries to erode more deeply into their valleys. Thus, the bluffs you see today along the

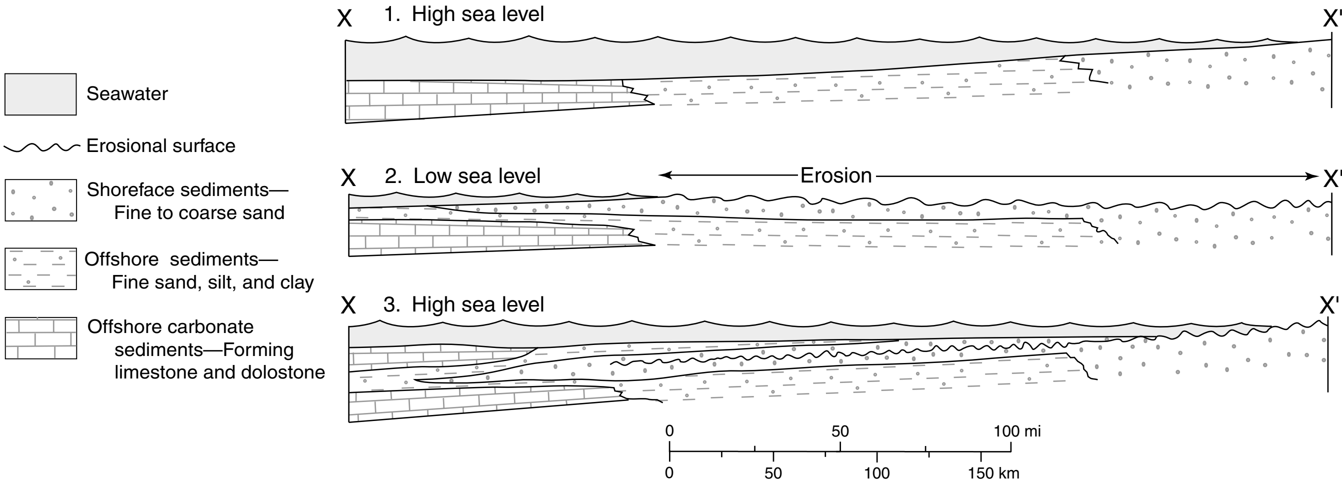

Figure 5. *Profiles of shallow ocean conditions during the Early Paleozoic that depict how a widespread layer of sediment is formed during changes in sea level. The layer of sand formed in this example eventually is lithified to become a sandstone bedrock formation (from Mossler, J.H., 2000, MGS Rept. of Inv. 50).*

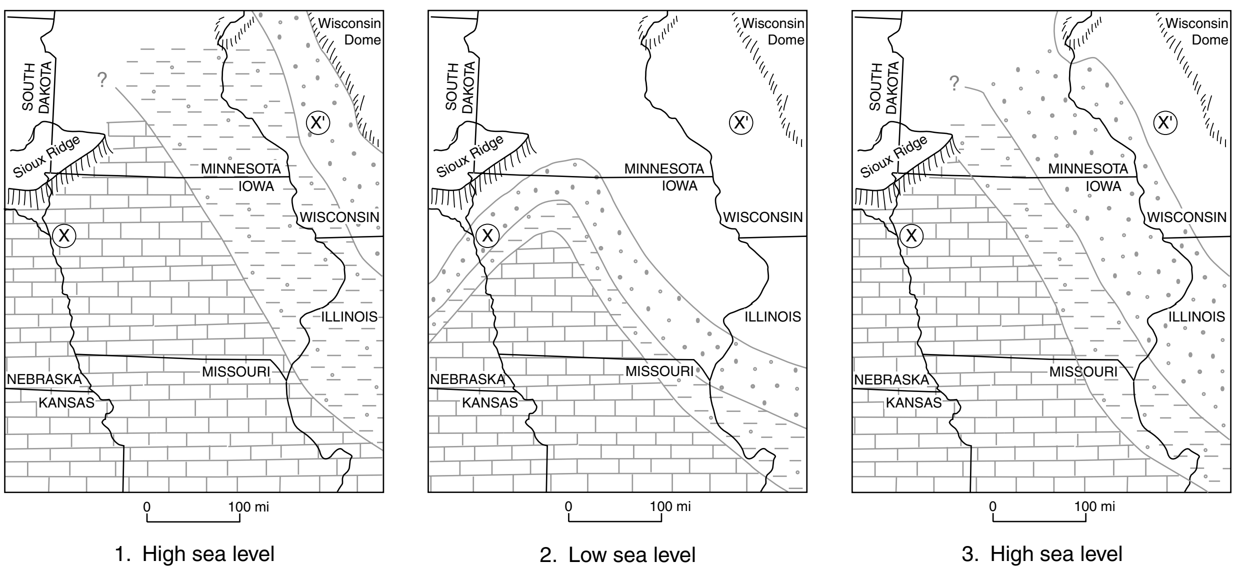

Figure 6. *An aerial view of the sediments that accumulated in the shallow ocean that covered much of southeastern Minnesota and adjacent areas in the Early Paleozoic. Compare to Figure 5 and note how changes in sea level result in a shifting of the kinds of sedimentary particles that are deposited (from Mossler, J.H., 2000, MGS Rept. of Inv. 50).*

major rivers in southeastern Minnesota are not mountains as early explorers thought. Instead, they are more or less horizontal layers of Paleozoic rocks that have been carved by streams over tens of thousands of years (Fig. 2). Relatively soft formations, like the Jordan Sandstone, are easily eroded and commonly form the valley floors. Harder, more resistant rocks, like the Oneota Dolomite and Platteville Formation, stand as cliffs along the valley walls.

The next time you drive through southeastern Minnesota, take note of the varied rock formations exposed in the river bluffs and along the side of the road. Remember that these rocks record what the world was like hundreds of millions of years ago when a shallow tropical sea existed in right here in Minnesota and across much of central North America.

Minnesota at a Glance is produced by the Minnesota Geological Survey—University of Minnesota, 2642 University Avenue, St. Paul, MN 55114; (612) 627-4780; www.geo.umn.edu/mgs
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