Sandstone aquifers

SANDSTONE AQUIFERS

Aquifers in sandstone are more widespread than those in all other kinds of consolidated rocks (**fig. 4**). Although the porosity of well-sorted, unconsolidated sand may be as high as 50 percent, the porosity of most sandstones is considerably less. During the process of conversion of sand into sandstone (lithification), compaction by the weight of overlying material reduces not only the volume of pore space as the sand grains become rearranged and more tightly packed, but also the interconnection between pores (permeability). The deposition of cementing materials such as calcite or silica between the sand grains further decreases porosity and permeability. Sandstones retain some primary porosity unless cementation has filled all the pores, but most of the porosity in these consolidated rocks consists of secondary openings such as joints, fractures, and bedding planes. Ground-water movement in sandstone aquifers primarily is along bedding planes, but the joints and fractures cut across bedding and provide avenues for the vertical movement of water between bedding planes.

Sandstone aquifers commonly grade laterally into fine-grained, low-permeability rocks such as shale or siltstone. Many sandstone aquifers are parts of complexly interbedded sequences of various types of sedimentary rocks. Folding and faulting of sandstones following lithification can greatly complicate the movement of water through these rocks. Despite all the above limitations, however, sandstone aquifers are highly productive in many places and provide large volumes of water for all uses.

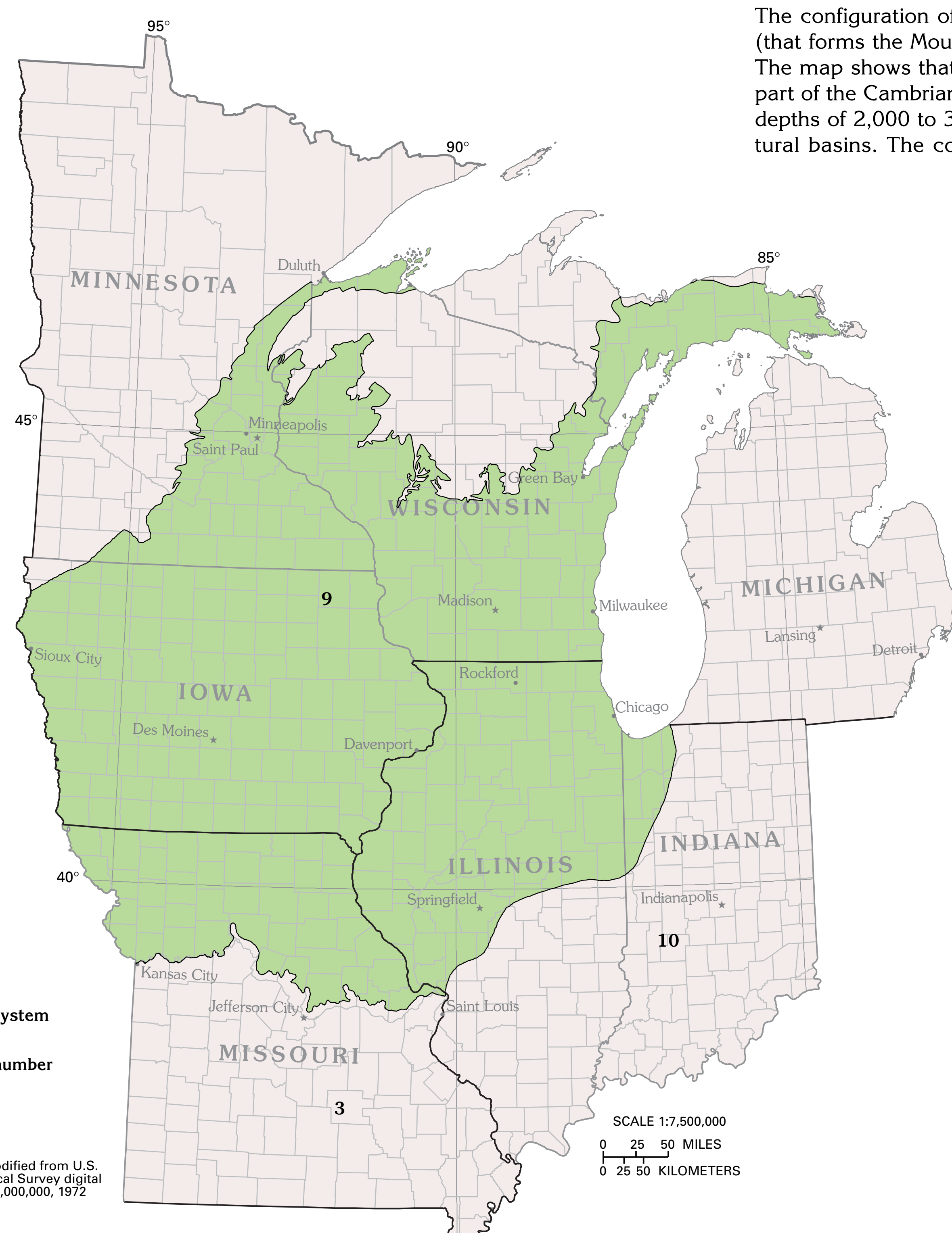
The Cambrian–Ordovician aquifer system in the north-central United States (**fig. 20**) is composed of large-scale, predominantly sandstone aquifers that extend over parts of seven States and three segments of the Atlas. The aquifer system consists of layered rocks that are deeply buried where they dip into large structural basins. It is a classic confined, or artesian, system and contains three aquifers (**fig. 21**). In descending order, these are the St. Peter–Prairie du Chien–Jordan aquifer (sandstone with some dolomite), the Ironton–Galesville aquifer (sandstone), and the Mount Simon aquifer (sandstone). The aquifers are named from the principal geologic formations that comprise them. Confining units of poorly permeable sandstone and dolomite separate the aquifers. Low-permeability shale and dolomite compose the Maquoketa confining unit that overlies the uppermost aquifer and is considered to be part of the aquifer system. Wells that penetrate the Cambrian–Ordovician aquifer system commonly are open to all three aquifers, which are collectively called the sandstone aquifer in many reports.

The rocks of the aquifer system are exposed in large areas of northern Wisconsin and eastern Minnesota, adjacent to the Wisconsin Dome, a topographic high on crystalline Precambrian rocks. From this high area, the rocks slope southward into the Forest City Basin in southwestern Iowa and northwestern Missouri, southeastward into the Illinois Basin in southern Illinois, and eastward toward the Michigan Basin, a circular low area centered on the Lower Peninsula of Michigan. The configuration of the top of the Mount Simon sandstone (that forms the Mount Simon aquifer) is shown in **figure 22**. The map shows that this aquifer, which represents the lower part of the Cambrian–Ordovician aquifer system, is buried to depths of 2,000 to 3,500 feet below sea level in these structural basins. The configuration of the tops of the overlying Ironton–Galesville and St. Peter–Prairie du Chien–Jordan aquifers are similar to that of the Mount Simon aquifer. The deeply buried parts of the aquifer system contain saline water.

Regionally, water in the Cambrian–Ordovician aquifer system moves from topographically high recharge areas, where the aquifers crop out or are buried to shallow depths, eastward and southeastward toward the Michigan and Illinois Basins. A map of the 1980 potentiometric surface of the St. Peter–Prairie du Chien–Jordan aquifer (**fig. 23**) shows this general direction of movement. The map also shows that water moves subregionally toward major streams, such as the Mississippi and the Wisconsin Rivers, and toward major withdrawal centers, such as those at Chicago, Illinois, and Green Bay and Milwaukee, Wisconsin. In and near aquifer outcrop areas, water moves along short flow paths toward small streams. Movement of water in the underlying Ironton–Galesville and Mount Simon aquifers is similar to that in the St. Peter–Prairie du Chien–Jordan aquifer. Before development, all the water moved either toward surface streams where it discharged as base flow, or downgradient, toward the structural basins, into deeply buried parts of the aquifer where it discharged by upward leakage into shallower aquifers.

One of the most dramatic effects of ground-water withdrawals known in the United States is shown in **figure 24**. Withdrawals from the Cambrian–Ordovician aquifer system, primarily for industrial use in Milwaukee, Wisconsin, and Chicago, Illinois, caused declines in water levels of more than 375 feet in Milwaukee and more than 800 feet in Chicago from 1864 to 1980. Many of the wells in the Chicago–Milwaukee area obtain water from all three aquifers of the aquifer system, and the water-level decline map, accordingly, is a composite map that shows the effects of withdrawals on the entire system. The declines extended outward for more than 70 miles from the pumping centers in 1980. Movement of water in the aquifers was changed from the natural flow direction (eastward toward the Michigan Basin) to radial flow toward the pumping centers. Beginning in the early 1980's, withdrawals from the Cambrian–Ordovician aquifer system decreased as some users switched to Lake Michigan as a source of supply. Water levels in the aquifer system had begun to rise by 1985 as a result of the decreased withdrawals.

Figure 20. The Cambrian–Ordovician aquifer system, which consists of predominantly sandstone aquifers separated by poorly permeable confining units, extends over a large part of the north-central United States.



EXPLANATION

Cambrian-Ordovician aquifer system

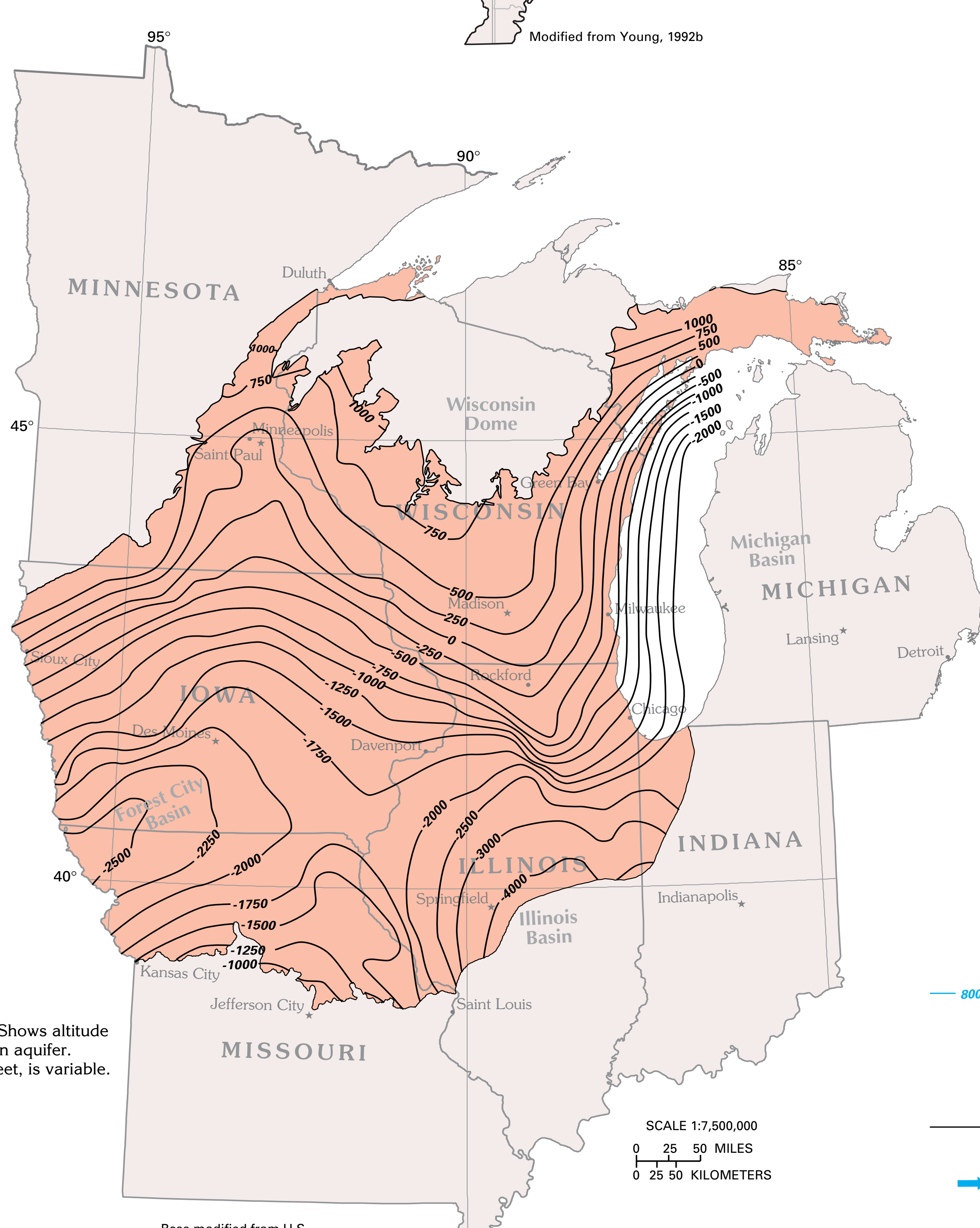
9 Atlas segment boundary and number

Figure 21. The three aquifers of the Cambrian–Ordovician aquifer system are separated by confining units. The Maquoketa confining unit at the top of the system creates artesian conditions wherever it is present.

Geologic nomenclature	Principal lithology	Hydrogeologic nomenclature	
Ordovician	Shale and dolomite	Maquoketa confining unit	Cambrian–Ordovician aquifer system
	Dolomite		
	Shaly dolomite		
	Sandstone	St. Peter–Prarie du Chien–Jordan aquifer	
	Dolomite and sandstone		
Cambrian	Dolomite and fine-grained sandstone	St. Lawrence-Franconia confining unit	
	Sandstone	Ironton–Galesville aquifer	
	Shaly sandstone	Eau Claire confining unit	
Precambrian	Sandstone	Mount Simon aquifer	

Modified from Olcott, 1992

Figure 22. The top of the Mount Simon aquifer slopes from high areas near the Wisconsin Dome downward into the Michigan, Illinois, and Forest City Basins. The tops of the overlying Ironton–Galesville and St. Peter–Prairie du Chien–Jordan aquifers have the same general shape.

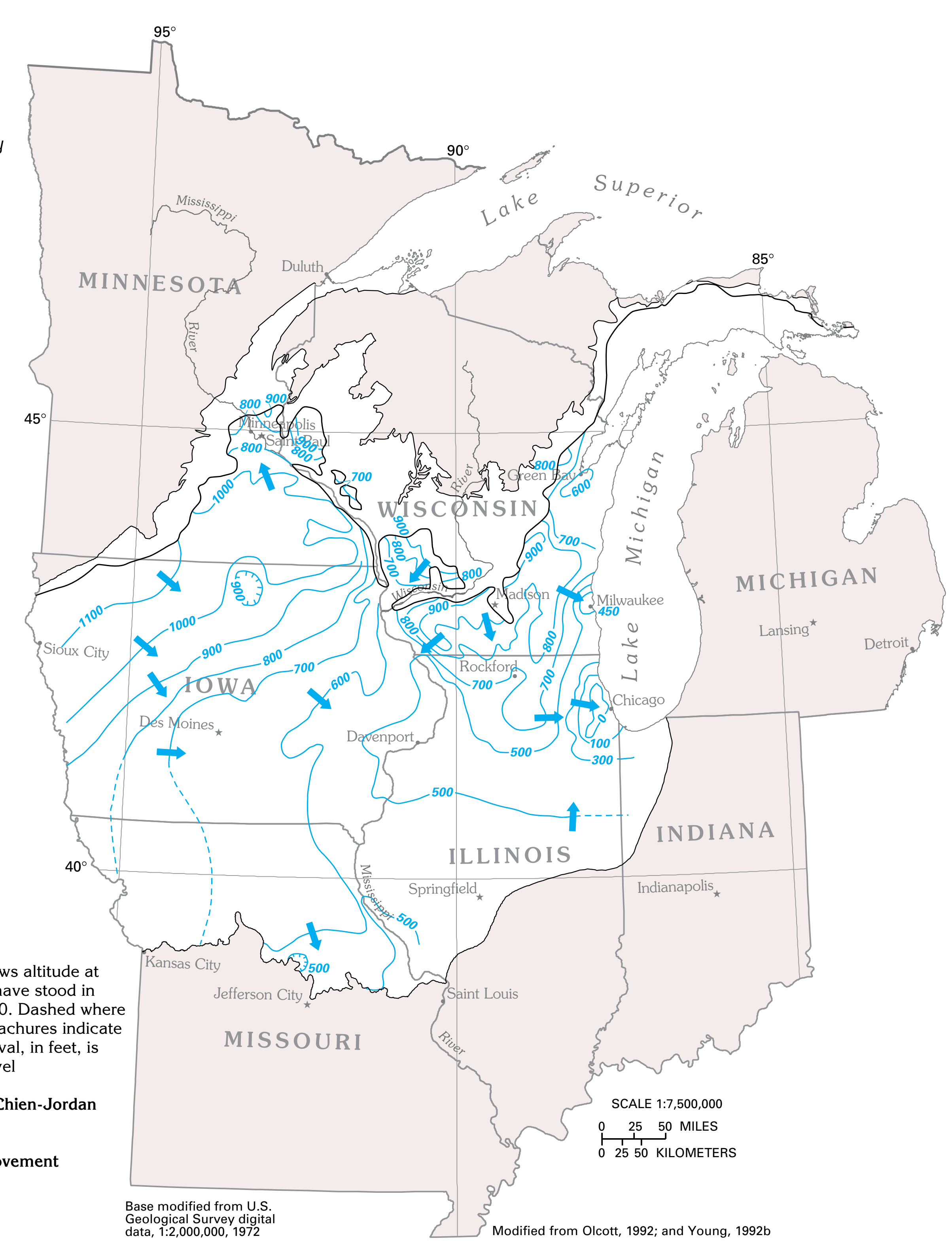


EXPLANATION

Mount Simon aquifer

-250 Top-of aquifer contour—Shows altitude of top of Mount Simon aquifer. Contour interval, in feet, is variable. Datum is sea level

Figure 23. Water in the St. Peter–Prairie du Chien–Jordan aquifer moves from aquifer outcrop areas regionally toward the Michigan and Illinois Basins, subregionally toward large rivers and major pumping centers, and locally toward smaller streams.



EXPLANATION

800 Potentiometric contour—Shows altitude at which water-level would have stood in tightly cased wells in 1980. Dashed where approximately located. Hachures indicate depression. Contour interval, in feet, is variable. Datum is sea level

Limit of St. Peter-Prairie du Chien-Jordan aquifer

Direction of ground-water movement