GEOLOGIC FRAMEWORK

Geology, *topography*, and soils are major factors in determining the portion of precipitation which runs off the land to become surface water, as opposed to the portion which infiltrates into the soil and percolates through underlying materials to become ground water.

A generalized geologic timescale (fig. 6) illustrates the relationships of geologic periods and the rock types in Indiana associated with each period. During the Pleistocene Epoch (Ice Age), glacial lobes repeatedly entered Indiana. The glaciers entered the state from at least two directions: from the northeast out of the Lake Erie and Saginaw Bay Basins, and from the northwest out of the Lake Michigan Basin (fig. 7). In general, advancing glaciers scoured the land surface, while retreating glaciers left behind large deposits of *drift*. Erosion has subsequently modified the glacial deposits to produce existing landforms.

Glacial drift covers most of the Whitewater River Basin except for the southeastern portion. A complex series of glacial sediments has been deposited during repeated ice advances during both the older glacial periods and the most recent period, the Wisconsinan. (See fig. 7 for the approximate southernmost boundaries of the Wisconsinan and pre-Wisconsinan glaciations.)

The Wisconsinan glacial boundary, trending roughly northwest-southeast through Franklin and southwest Fayette Counties, divides the basin into two distinct portions (fig. 8). North of this glacial boundary, the bedrock is covered with variable but often thick layers of *lacustrine* clays, sands and gravels, and *tills*. The thickness of unconsolidated material is commonly 100 feet or more along the northern basin boundary.

Bedrock exposures north of the Wisconsinan boundary are rare, but in some areas of high bedrock, glacial meltwater and the larger post-glacial streams have cut their channels through the unconsolidated glacial materials and into bedrock. This is the case with the East Fork Whitewater River and its major tributaries. Bedrock exposures can be found as far north as the Richmond vicinity.

South of the Wisconsinan glacial boundary, thin layers of *residuum* and pre-Wisconsinan till overlie the bedrock surface. Bedrock exposures are common along valley walls. Depth to bedrock south of the Wisconsinan glacial boundary ranges from 5 to about 120 feet, as based on well drilling records. The thickest unconsolidated deposits are *alluvial* materials present in and along the Whitewater River valley.

ERAS	PERIODS	APPROXIMATE LENGTH IN YEARS	ROCK TYPES IN INDIANA
CENOZOIC	QUATERNARY (PLEISTOCENE EPOCH)	1 MILLION	Glacial drift: *till, gravel, sand, silt (including loess), clay, marl, and peat* *(Till and gravel contain boulders of many kinds of sedimentary, igneous, and metamorphic rocks)* Thickness 0-500 ft.
CENOZOIC	TERTIARY	60 MILLION	*Cherty gravels* *Sand and clay* — *Scattered deposits*
MESOZOIC	CRETACEOUS	70 MILLION	No deposits in Indiana
MESOZOIC	JURASSIC	35 MILLION	No deposits in Indiana
MESOZOIC	TRIASSIC	30 MILLION	No deposits in Indiana
PALEOZOIC	PERMIAN	25 MILLION	No deposits in Indiana
PALEOZOIC	PENNSYLVANIAN	20 MILLION	*Shale (including carbonaceous shale), mudstone, sandstone, coal, clay limestone, and conglomerate* 1,500 ft.
PALEOZOIC	MISSISSIPPIAN	20 MILLION	Upper Part: *alternating beds of shale, sandstone, and limestone* 500 ft.
			Middle Part: *limestone, dolomite; beds of chart and gypsum* 300 ft.
			Lower Part: *shale, mudstone, sandstone; and some limestone* 600 ft.
PALEOZOIC	DEVONIAN	60 MILLION	Upper Part: *carbonaceous shale* 100 ft.
			Lower Part: *limestone, dolomite; a few sandstone beds* 40-80 ft.
PALEOZOIC	SILURIAN	40 MILLION	*Dolomite, limestone, chert, siltstone, and shale* 100-300 ft.
PALEOZOIC	ORDOVICIAN	70 MILLION	*Shale, limestone and dolomite* 700 ft.
			Limestone, dolomite, and sandstone — Not exposed at the surface in Indiana
PALEOZOIC	CAMBRIAN	80 MILLION	*Sandstone and dolomite* — Not exposed at the surface in Indiana
PRECAMBRIAN ERAS		3 BILLION	*Granite, marble, gneiss, and other igneous and metamorphic rock types* — Not exposed at the surface in Indiana

Figure 6. Generalized geologic timescale
(From Wayne, 1958b)

TOPOGRAPHY AND SOILS

The Whitewater River Basin includes two contrasting physiographic regions. The northern third lies within the Tipton Till Plain, and the southern two-thirds is in the Dearborn Upland (fig. 9). The Tipton Till Plain has nearly flat to gently rolling topography characterized by slightly modified *ground moraine* and

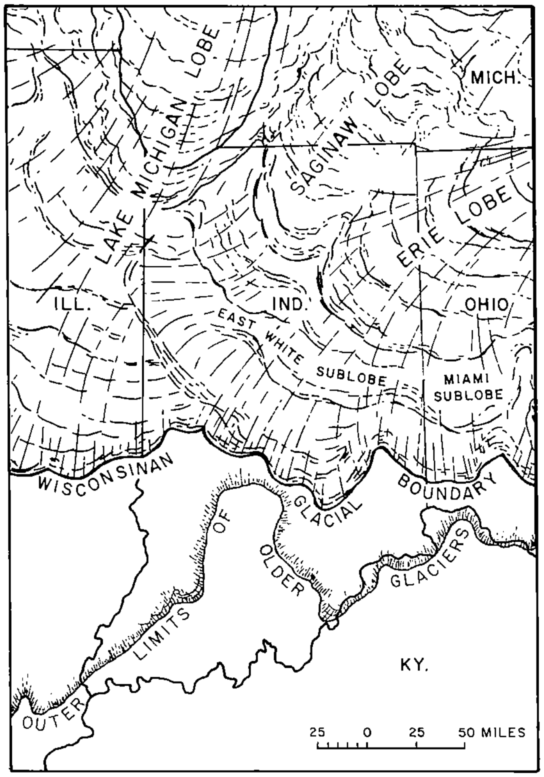

Figure 7. Extent of major ice lobes during Wisconsinan time in Indiana
(Modified from Wayne, 1965)

poorly developed *end moraines* formed by glaciation during Wisconsinan time. Wide stream valleys containing *valley-train* deposits of *outwash* are common.

The boundary between the Tipton Till Plain and the Dearborn Upland is gradational. As the drift thins near the Tipton Till Plain's southern margin, bedrock features become more apparent. The boundary placement shown on fig. 9 is within the transitional zone.

The rugged Dearborn Upland is dominated by slopes. Relatively little bottom land is present along the streams, and much of the upland surface has been *dissected*. The higher elevations are covered by glacial drift, which is much thinner south of the margin of Wisconsinan deposition (fig. 8), where only pre-Wisconsinan glacial deposits are present. Even these pre-Wisconsinan deposits are absent from the extreme southeastern part of the Whitewater Basin where bedrock is covered with thin residuum.

Evolution of Whitewater drainage patterns on the Tipton Till Plain is almost exclusively a post-glacial event, and bedrock topography has had little effect on drainage development. In contrast, drainage patterns

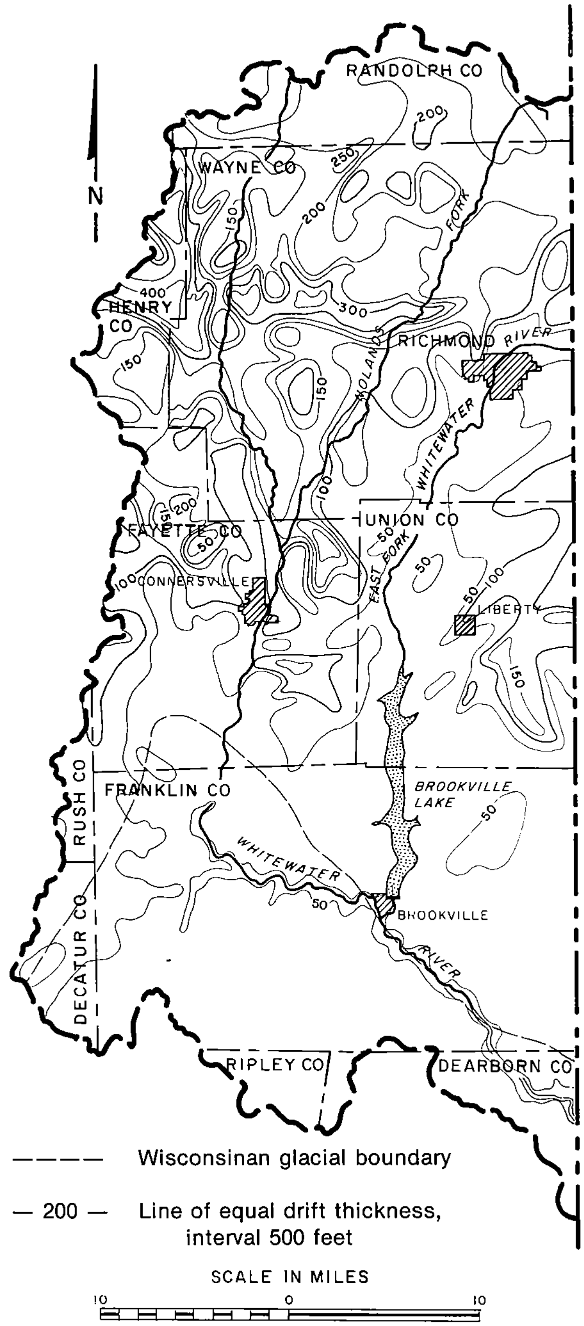

Figure 8. Drift thickness
(Modified from Gray, 1983)

in the southern part of the basin were less obviously rearranged by glaciation, and most of the dissection of bedrock predates the latest (Wisconsinan) glaciation in the basin.

Surface elevations often exceed 1,200 feet m.s.l. (mean sea level) in southeast Randolph and northeast

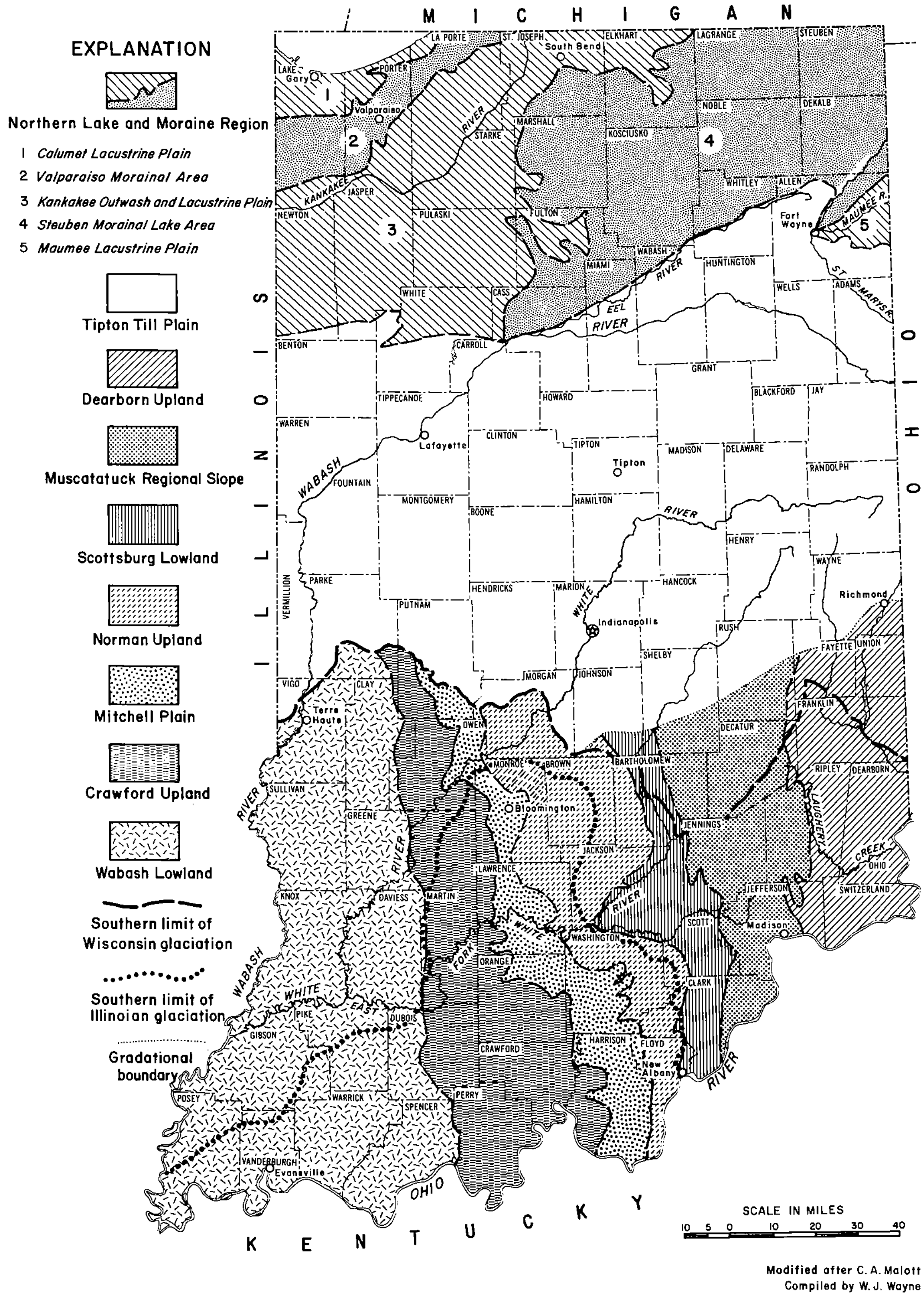

Figure 9. Physiographic regions in Indiana

Wayne Counties along the crest of the Knightstown Moraine (see fig. 11). The highest elevation in Indiana (approximately 1260 feet m.s.l.) is found within the Whitewater Basin in extreme northeastern Wayne County. The lowest elevation in the basin, which occurs where the Whitewater River leaves Indiana, is approximately 500 feet m.s.l. Maximum local relief occurs in southeast Franklin County, where bedrock ridges can rise more than 400 feet above the Whitewater River.

Soils in the Whitewater River Basin are closely related to geologic parent materials and topographic characteristics. *Loamy*, silty, and clayey soils are common in the northern two-thirds of the basin, according to maps by the Soil Conservation Service (1971, 1982). In these northern areas, soil parent materials consist of thin to moderately thick *loess* over loamy Wisconsinan glacial till. Representative soil associations include the Miami, Crosby, and Brookston in northern areas of the basin, and the Miami, Russell, Ragsdale, and Fincastle in central regions (app. 3).

Wisconsinan outwash and alluvial deposits constituting stream *terraces* and floodplains typically undergo *weathering* to form loamy, well-drained soils. Representative soil associations nearest the basin's major streams include the Fox, Ockley, Genesee, and Eel (app. 3).

Silty soils with *fragipans* occupy the rolling upland areas in the southwest part of the basin, primarily in western Franklin County. Soil parent materials consist of loess of variable thickness over weathered pre-Wisconsinan glacial till. Representative soil associations include the Cincinnati and Rossmoyne (app. 3).

Along valley sides of the Whitewater River and its major tributaries in Franklin County, shallow, stony, or clayey soils predominate. Parent materials are discontinuous loess over weathered Ordovician limestone and shale. Representative soil associations include the Fairmount, Eden, and Switzerland (app. 3).

SURFICIAL GEOLOGY

Four terrains, characterized by variations in surficial materials and the nature of potential aquifers, can be recognized in the Whitewater Basin (fig. 10; table 3). These include: (1) bedrock covered by a generally thin veneer of residuum and/or *colluvium*; (2) dissected pre-Wisconsinan tills; (3) Wisconsinan tills; and (4) valley-train deposits.

The far southeastern part of the basin consists of Ordovician bedrock covered by residual soils, colluvial debris, and loess (terrain 1; fig. 10). Thickness of this cover is variable, but in only a few places does it exceed 10 feet. The cover consists mainly of oxidized clay-rich soils that locally contain weathered fragments of the underlying parent rock. Sand and gravel deposits that have significant potential as *aquifers* are not present within this material. Areas of residual soils occur mainly in Dearborn County near the mouth of the Whitewater River, but small areas also occur along the margins of the valleys of the Whitewater River and its tributaries in Franklin, Union, and Wayne Counties.

The southwestern part of Franklin County is underlain by loess-covered tills of pre-Wisconsinan age (terrain 2; fig. 10). At least four till units, separated by stratified sediments, organic silts, or *paleosols* have been identified in northern Franklin County (Gooding, 1963, 1966). These deposits have traditionally been considered to be Illinoian in age, but recent work in Decatur County (N. K. Bleuer, unpubl.) suggests that the drifts are significantly older. The loess, of Wisconsinan age and older, overlies a paleosol developed on loamy to pebbly silts.

The unconsolidated deposits in terrain 2 normally do not exceed 50 feet in thickness, and form a gently rolling land surface except where dissected by stream valleys of the Whitewater system. Beds of sand and gravel, normally less than 5 feet thick, occur within the glacial material. The lateral extent and degree of interconnection of these beds are unknown at this time. Because the sands and gravels are thin, their potential as aquifers is limited.

Most of the northern two-thirds of the basin is covered by tills of Wisconsinan age (terrain 3; fig. 10) that overlie older till units. The southern boundary of Wisconsinan deposits extends through Decatur, Fayette, and Franklin Counties (fig. 10). The boundary has a V-shaped configuration, opening to the south, that may reflect the juncture of the *terminal moraines* of the East White Sublobe moving from the west and the Miami Sublobe moving from the east (fig. 7).

The Wisconsinan margin on the west side of the basin is marked by the massive Shelbyville *Moraine* (fig. 11) rising as much as 70 feet above the older, more level plain to the south. The Wisconsinan margin is discontinuous and less conspicuous on the east side of the basin where it is cut by tributaries of the Whitewater River. The surface of the Shelbyville Moraine is mildly *hummocky* and marked by numerous closed depressions.

The Knightstown Moraine (fig. 11) forms the drainage divide between the Whitewater River Basin

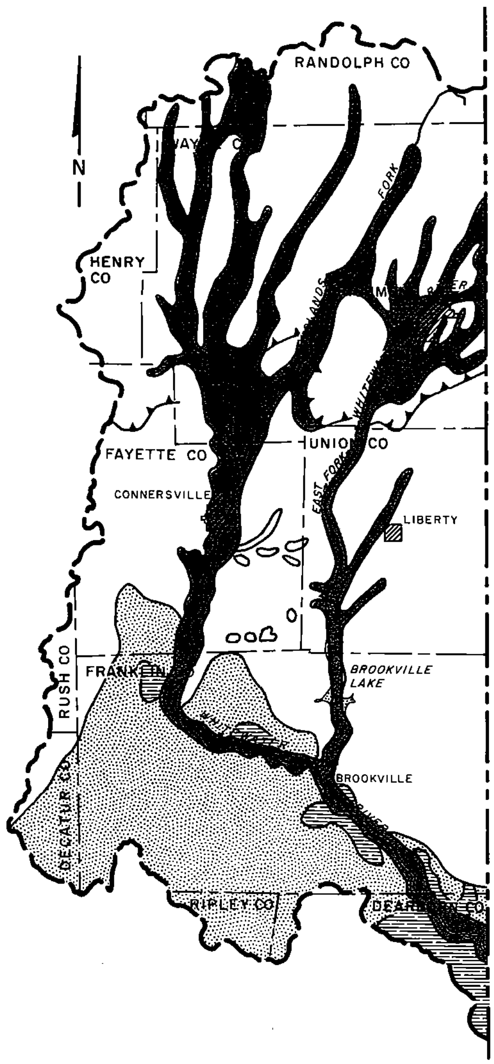

Figure 10. Surficial geology
(Modified from Wayne, 1958a)

Table 3. Types of unconsolidated surficial materials

Map region[1]	Name	Dominant material	Accessory materials	Nature of aquifers
1	Residuum/colluvium	Oxidized loam to clay	——	Minimal
2	Pre-Wisconsinan tills	Oxidized pebbly loam	Sand and gravel, silt (loess)	Thin beds (~1 ft) of unknown lateral extent
3	Wisconsinan till	Pebbly loam	Sand and gravel, clay	Moderately thick beds (~10 ft) of unknown lateral extent
4	Valley train	Sand and gravel	Pebbly loam, clay	Linear sand bodies commonly in excess of 10 ft thick

[1]Numbered map regions are shown in fig. 10.

to the south and the White River system to the north. The moraine is conspicuously bouldery in a manner similar to the boulder belt derived from the Miami Sublobe in Ohio.

Several tills of Wisconsinan age have been identified in the Whitewater River Basin (Gooding, 1963, 1966, 1975). The tills can be distinguished on the basis of interlayered, stratified sediments, especially organic silt beds, which apparently were deposited during ice retreats.

Two late Wisconsinan tills, the Shelbyville and Fayette Tills, record two glacial advances to the Wisconsinan margin at about 21,000 and 20,000 years before present, respectively. In southeast Fayette and eastern Franklin County, the Fayette Till overlies a paleosol that is the subsurface continuation of the soil developed on the older drifts south of the Wisconsinan margin. In the northern part of Union County, however, the Fayette Till is separated from the paleosol by numerous other till units. These units have been interpreted as early Wisconsinan in age, but this cannot be proved in the absence of a regional, physically defined *stratigraphy*.

Some of the till units of terrain 3 may have regional significance, and laterally extensive aquifers may occur where tills are separated by sand and gravel beds. Other tills, however, are probably of local significance only, and interbedded sands and gravels would be of limited lateral extent. Of more significance, however, is the fact that Wisconsinan till units as well as multiple older till units occur together in a complex vertical succession commonly no thicker than 60 feet.

Sand and gravel beds within the Wisconsinan tills are normally less than 10 feet thick. These beds are significantly thicker than sand and gravel beds in older till units, which suggests greater lateral extent and more potential as aquifers. In addition, because two or more such beds commonly are stacked within a till sequence, the total thickness of potential aquifers in a given area is increased.

The thickest deposits of sand and gravel in the basin occur as valley-train deposits within the valleys of the Whitewater River and its tributaries, especially the East Fork Whitewater River (terrain 4; fig. 10). Valley-train deposits north of the Wisconsinan terminal moraine probably originated as intra-ice drainageways and apparently formed during the same period of time as the surrounding till. These deposits consist of poorly sorted sand and gravel *intercalated* with till beds of variable thickness and lateral extent. The uppermost unit of the deposits within the valleys most commonly is a till bed that may be as much as 15 feet thick near the margins of the valleys and in their upper reaches.

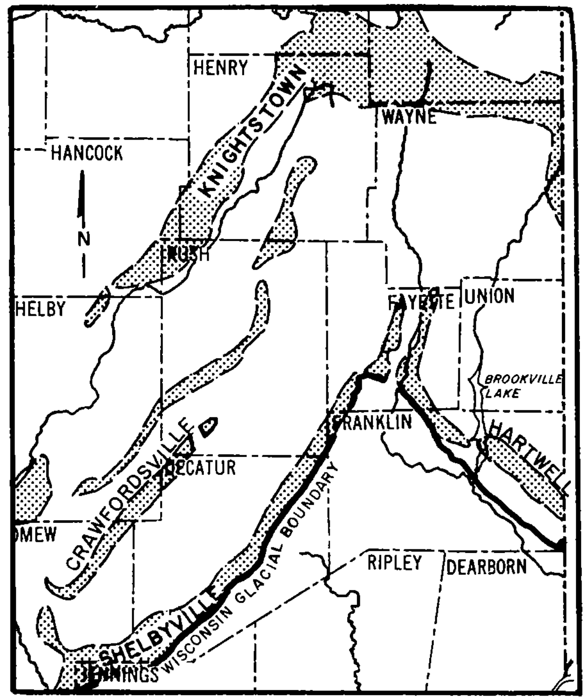

Figure 11. Glacial moraines
(Modified from Wayne, 1965)

Valley-train deposits south of the Wisconsinan terminal moraine are finer grained and better sorted, and occur in more consistent vertical sequences than those to the north. Sand and gravel units are much thicker, and they contain no till beds. Although lacustrine silts and clays occur in these deposits, the degree to which they affect aquifer properties is not known.

BEDROCK GEOLOGY

The Whitewater River Basin sits along the crest of the Cincinnati Arch, a major geologic structure in the Midwest (fig. 12). Hence, younger rocks at the bedrock surface occur along the margins of the Whitewater Basin and older rocks occur in the center. Rocks at the basin margin to the west, north, and north-

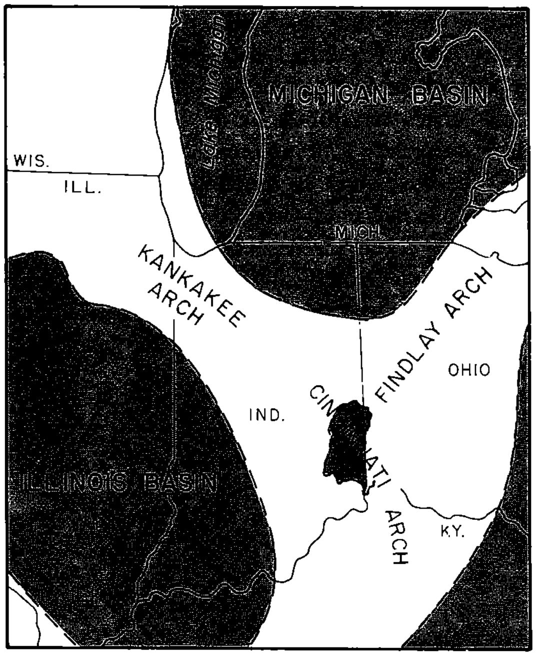

Figure 12. Regional geologic structure

east are of Silurian age (fig. 13). The large central area of the basin is underlain by Ordovician rocks, the oldest of which are limited to a small downstream area of the basin (fig. 13). Table 4 summarizes the characteristics of exposed Silurian and Ordovician rock units, while app. 4 describes the units in more detail.

Still older Ordovician and Cambrian rocks are present in the subsurface above the basement complex of *igneous* and *metamorphic* rocks. A brief description of these rocks is included in app. 5, but the likelihood of successfully developing water wells in them is considered small.

The highest bedrock elevation in the Whitewater River Basin exceeds 1050 feet m.s.l. and occurs in the northeast portion of the basin near the Wayne-Randolph county line (pl. 1). Despite its elevation, this bedrock high is buried by more than 100 feet of glacial deposits. The lowest elevation of the bedrock surface as based on drilling records is approximately 440 feet m.s.l. and occurs in Dearborn County where the Whitewater River valley leaves Indiana (pl. 1).

Table 4. Characteristics of exposed stratigraphic units

		Unit	Thickness (feet)	Description
Silurian System		Salamonie Dolomite	40	Gray and tan cherty limestone, argillaceous in lower part to south
		Brassfield Limestone	0 - 18	Yellowish-brown, salmon or gray, medium- to coarse-grained fossiliferous limestone
Ordovician System	Maquoketa Group	Whitewater Formation	90	Upper part - argillaceous fossiliferous limestone interbedded with calcareous shale; Saluda Dolomite Member (lower part) - varicolored fine-grained dolomite that includes a thin coralline zone
		Dillsboro Formation	300	Thin-bedded fossiliferous limestone alternating with calcareous shale
		Kope Formation	250 - 550	Bluish- to brownish-gray shale including about 5 percent discontinuous beds of fossiliferous limestone

Perhaps the most interesting feature of the bedrock surface is the large *buried valley* in western Wayne County and eastern Henry County. This valley, now filled with 200-300 feet of glacial sediment, appears to have been the major pre-glacial drainageway in the northern basin area. Originally carrying a northwest-flowing stream, the valley was blocked by ice and filled with glacial drift. After glacial retreat, the modern south-flowing drainage was established on this depositional surface.

Most wells in the northern parts of the basin are completed in the glacial materials overlying the bedrock surface. Depth to bedrock data is therefore sparse and the bedrock surface cannot be depicted in detail as it is in southern areas of the basin. The lack of bedrock data is especially acute in areas of the deeply buried valley because most wells encounter water-bearing zones above bedrock. Therefore, the buried valley is defined largely on the basis of seismic data provided by the Indiana Geological Survey rather than on well data. Deep drilling would help define this and other buried valleys in northern parts of the basin.

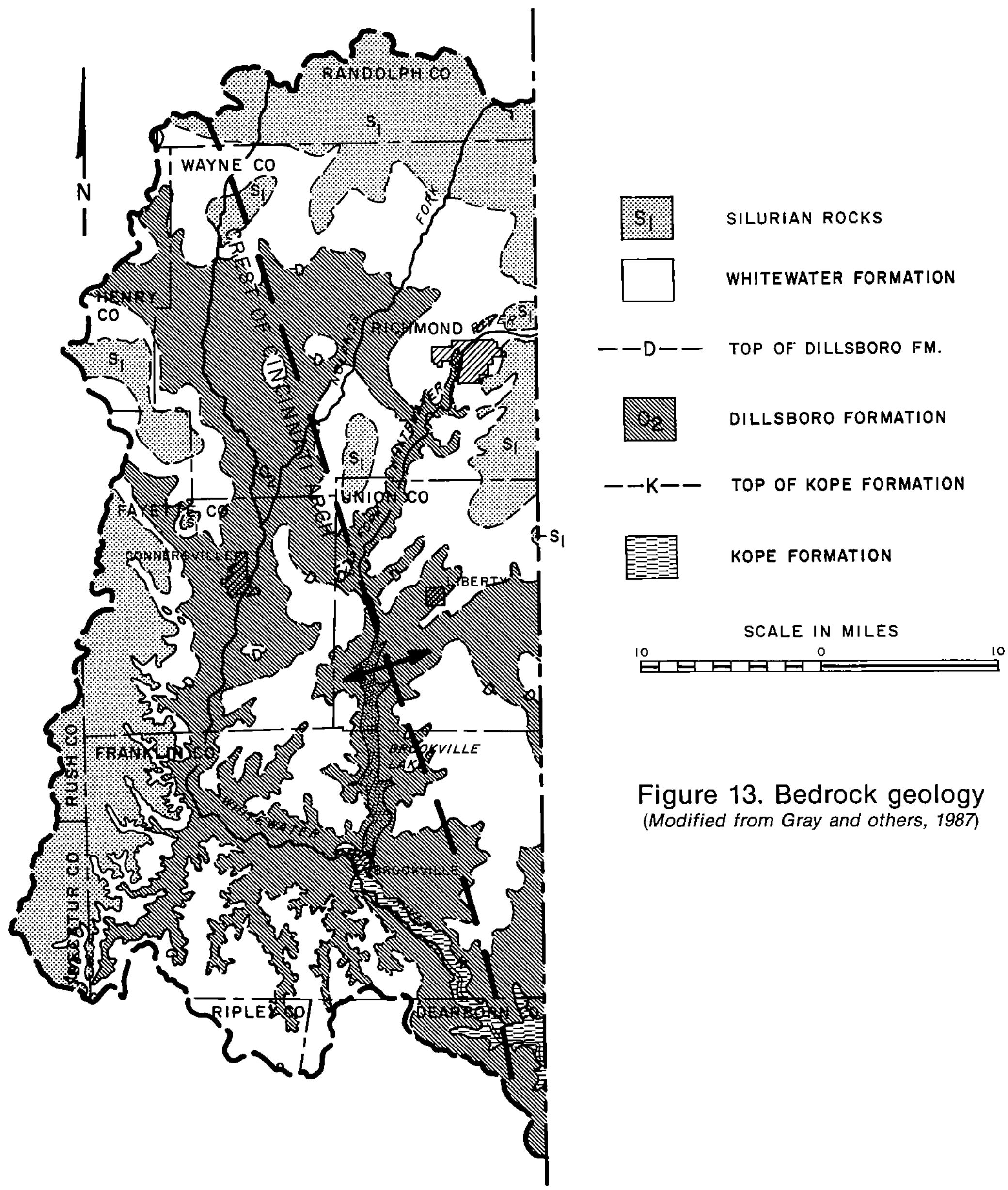

Figure 13. Bedrock geology
(Modified from Gray and others, 1987)