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Meredith E. Ostrom, State Geologist and Director

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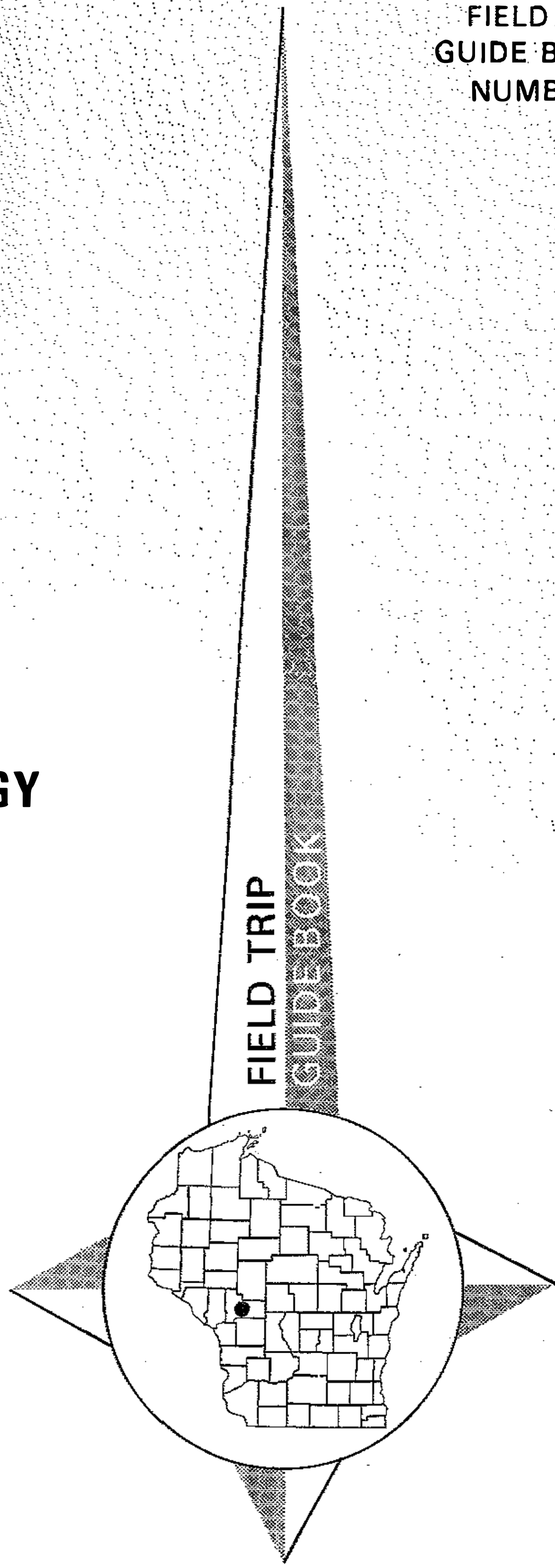
THREE BILLION YEARS OF GEOLOGY

ARCHEAN, PROTEROZOIC, PALEOZOIC AND PLEISTOCENE GEOLOGY OF THE BLACK RIVER VALLEY



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Field Trip Guide Book
Number 9

University of Wisconsin-Extension
GEOLOGICAL AND NATURAL HISTORY SURVEY
Meredith E. Ostrom, State Geologist and Director

THREE BILLION YEARS OF GEOLOGY: A FIELD TRIP THROUGH THE ARCHEAN, PROTEROZOIC, PALEOZOIC AND PLESITOCENE GEOLOGY OF THE BLACK RIVER FALLS AREA OF WISCONSIN

Discussion, Geological Stop Descriptions and Roadlog

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Edited by B.A. Brown

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PREFACE

The Wisconsin Geological and Natural History Survey is pleased to host the 47th Annual Tri-State Field Conference. The Black River Falls area is an ideal location because, in addition to its scenic beauty, it contains abundant exposure of rocks which record parts of a nearly 3 billion year geologic history. This guidebook is intended to provide an introduction to this history. The road log and geological stops provide a sampling of the important rock units. For those who wish to return and see more, descriptions of eight supplemental localities are included.

We hope that this conference will live up to the long tradition of Tri-State, and provide both an educational field experience for undergraduates, and the opportunity for advanced students and professionals to discuss the many problems posed by the rocks of this region.

ACKNOWLEDGMENTS

Sincere thanks are extended to all of the individuals and organizations who have helped to plan and conduct this conference. Thanks to the contributors to the guidebook who are listed as authors, and to Jeff Greenberg, Irene Lippelt and Kathie Zwettler who provided editorial assistance. Special thanks are due to Rose Scott, who typed the manuscript. Illustrations were prepared by M.L. Czechanski and Jon Zuiker. Logistics were handled by Mike Mudrey and Monika Thompson. Irene Lippelt managed conference registration. Dinner Saturday night was provided by M.L. Czechanski, I. Lippelt, K. Zwettler and assistants. Mike Mudrey, Jeff Greenberg, Ron Hennings, and Randy Maass served as trip leaders.

Special thanks are due to Vern Metzger of the Jackson County Iron Co. for entertaining and enlightening us after the dinner. We thank the many people of the Black River Falls area whose cooperation made this conference possible, especially the staff of the Jackson County Fairgrounds, and the Black River Falls area Chamber of Commerce.

HISTORY OF THE PRECAMBRIAN AND PALEOZOIC ROCKS

by Bruce A. Brown

INTRODUCTION

The Black River Falls area contains exposures of rocks which range in age from early Precambrian to Upper Cambrian. Several cycles of tectonism are evident in these rocks. The earliest tectonic activity occurred in the Archean, around 2800 m.y. ago. The region was later the site of intense deformation and intrusive activity during the Penokean orogeny 1850 m.y. ago. Following the Penokean event, the region was covered by sandstones, shales and cherty sediments deposited between two anorogenic magmatic episodes, which occurred 1760 and 1500 m.y. ago. The last Precambrian tectonic activity to affect this region occurred about 1100 m.y. ago with the development of the Keweenawan midcontinent rift system. The only evidence of this event is the scattered occurrence of undeformed diabase dikes of probable Keweenawan age.

The Cambrian rocks record a history of periodic marine transgression and regression in early Paleozoic times. The distinctive erosional landforms and the fluvial deposits along the Black River illustrate the history of this part of the Driftless Area during the Pleistocene.

The following text is intended to serve as a brief inroduction to the geology of the Black River Falls area, and to establish a regional perspective in which to view the rocks and relationships illustrated by the nine stops and eight supplemental localities which follow.

PRECAMBRIAN ROCKS

The Precambrian rocks of Wisconsin (fig. 1) have been divided into four terranes based on their ages and tectonic settings (Greenberg and Brown, 1983b). From north to south these are: (1) the Keweenawan rocks, which consist of basaltic flows and interbedded clastic sediments, deposited in a major rift system about 1100 m.y. ago. (2) The northern Penokean terrane, a region characterized by clastic sedimentary rocks and bimodal tholeiitic volcanic rocks, which were deposited on the southern margin of the Archean Superior Craton approximately 1850-1900 m.y. ago. The Archean basement, up to 3500 m.y. old, is exposed in the cores of a series of gneiss domes which were emplaced into this terrane during the Penokean orogeny. (3) The Penokean volcanic belt--this terrane is separated from the northern Penokean terrane by a major structural discontinuity, the Niagara tectonic zone. The Penokean volcanic belt consists of basaltic and andesitic volcanic rocks, with lesser felsic volcanic rocks and sediments, which formed in an island arc and basin-type environment at about 1850 m.y. ago. This terrane has been extensively intruded by calc-alkaline plutonic rocks and large gneissic batholiths, which are about 1850 m.y. old. In contrast to the northern Penokean terrane, the Penokean volcanic belt did not develop on Archean basement but represents new crust that was accreted onto the southern edge of the Archean Craton during the Penokean orogeny (Greenberg and Brown, 1983b). (4) The southern Archean terrane. The origin of this terrane, which occurs to the south and west of the Penokean volcanic belt, is somewhat enigmatic. Gneisses in the Stevens Point area (Linwood) at Pittsville, and in the Black River Valley (Hatfield, Stop 9) have been dated by Van Schmus (1980) as 2800 m.y. old (fig. 2). This terrane, like the northern Penokean terrane and the Penokean volcanic belt,

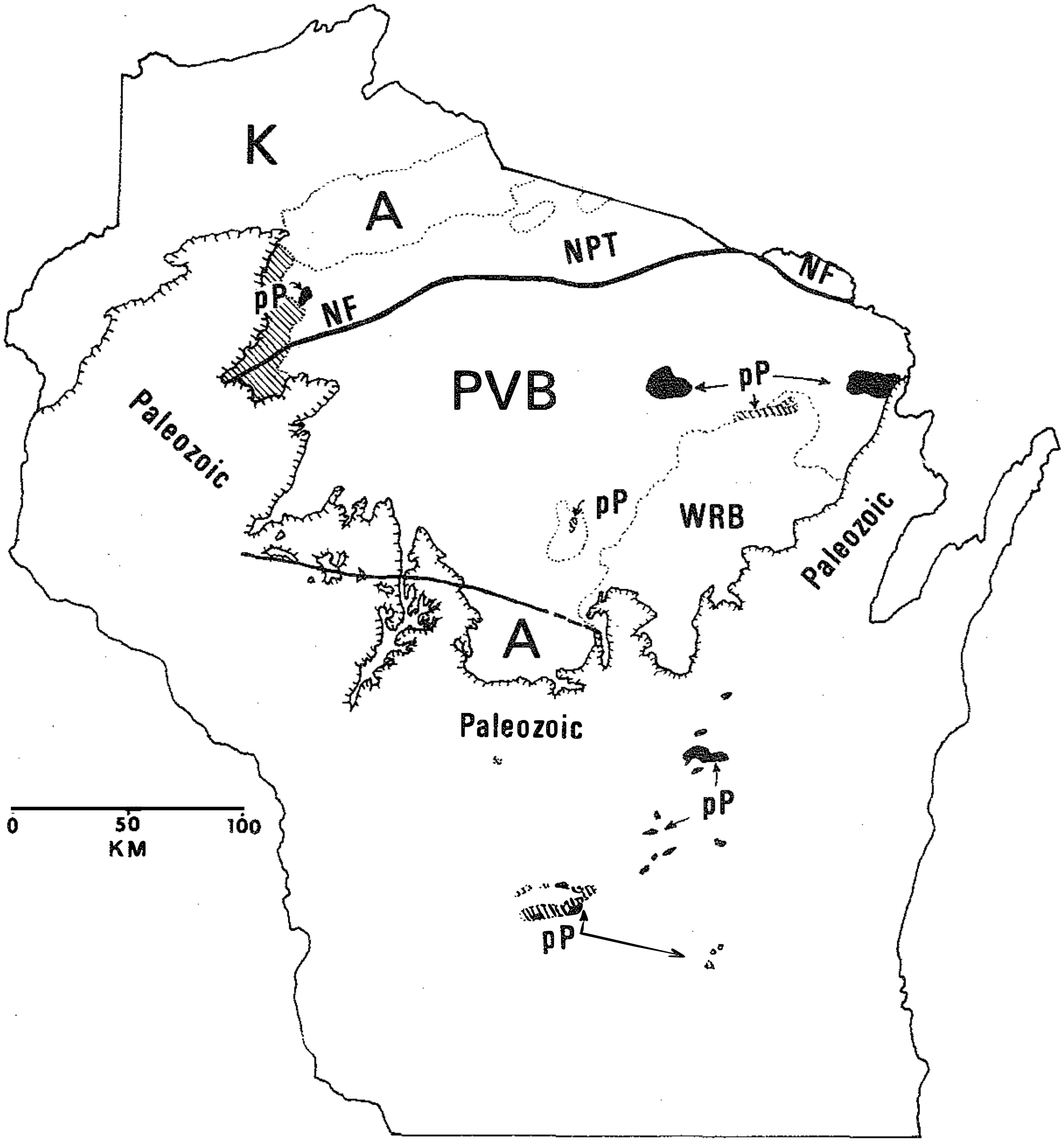


Figure 1.--Major tectonic terranes in Wisconsin. Map modified from the page-size bedrock geology map of Wisconsin (Wisconsin Geological and Natural History Survey, 1981). K, Keweenawan terrane; A, Archean terranes; NPT, northern Penokean terrane; PVB, Penokean volcanic belt (southern terrane); NF, Niagara fault; WRB, Wolf River batholith; pP, post-Penokean; 1,760-m.y.-old magmatic rocks in black; quartzites cross-hatched.

was intensely deformed, and was intruded by granitic rocks during the Penokean orogeny. The lack of any reported Archean rocks in the subsurface of southern Wisconsin and Illinois (Van Schmus and Bickford, 1981) poses important questions as to the origin of these rocks. One possibility is that they represent crust rifted off of the Archean craton to the north prior to the Penokean orogeny. Another is that they represent a microcontinental mass accreted along with rocks of the Penokean volcanic belt during the Penokean orogeny (Van Schmus and Bickford, 1981).

Archean Rocks

The Archean rocks of the Black River valley belong to the southern Archean terrane. Most of the dated Archean rocks of this terrane consist of banded gneiss, migmatitic gneiss and migmatite. The protoliths of these rocks are uncertain, but were probably volcanic and plutonic rocks. Archean metapelitic gneisses and gneisses or schists of obvious sedimentary origin are not known in this region. Identifiable Archean plutons are rare, the only reported example is an augen gneiss at Neillsville, north of Black River Falls. This rock was probably derived from a syenite protolith which crystallized about 2535 m.y. ago (Maass and Van Schmus, 1980).

The Archean gneisses underwent intense deformation and amphibolite facies metamorphism during the Penokean orogeny. This helped to further obscure their original nature and Archean tectonic history (Maass and Van Schmus, 1980; Maass, 1983). Most of the tectonic structures visible in these rocks have been attributed to the Penokean deformation (see Stop 9 description).

Archean (?) Rocks

An important group of rocks, exposed in the Black River Valley, are of uncertain age. These rocks may either be part of an Archean supracrustal sequence, or they may be Penokean supracrustal rocks equivalent in age to the rocks of the Penokean volcanic belt. This group includes the iron formation (Stop 6, Supplemental Locality E), siliceous schists which form the hanging wall of the iron deposits, mafic amphibolites which occur in the footwall of the deposit, siliceous feruginous sediments, and minor quartzites (Locality D) and metavolcanic rocks known only from drill core collected during mineral exploration in the areas of Hatfield and Merrillan.

The potentially Archean units pose an important question in the interpretation of the Precambrian tectonic history of the region, and of the entire southern Archean terrane. If these rocks are of Archean age, they imply the existence of a heretofore unrecognized supracrustal sequence. The only rocks of comparable age and lithology in Wisconsin would be the greenstones of Archean age exposed in the Hurley area, in the northern Penokean terrane. If these rocks are Proterozoic, and about 1850 m.y. old, they could be equivalent to the volcanic and sedimentary rocks deposited on an Archean basement in the northern Penokean terrane. Jones (1978) has suggested that the iron formation at the Jackson Co. Iron Mine (see Locality E description) is more comparable to the iron formations which occur in the Archean greenstone sequences of the Superior Province than to the Proterozoic Lake Superior type. Amphibolitic rocks from the footwall of the iron deposit are currently being dated by the neodymium-samarium technique, and we will hopefully have an answer to this question in the near future.

Lower Proterozoic Rocks

The only rocks of known lower Proterozoic age in the area of Black River Falls are granites (Maass and Van Schmus, 1980). The granite at Stop 7 and a similar granite which outcrops at the northern end of Lake Arbutus crystallized 1840 ± 20 m.y. ago (fig. 3). Both of these plutons appear to be undeformed. No lineation or foliation, typical of Penokean syntectonic granites, is visible in hand specimen or thin section. In thin section, both granites show evidence of minor deformation in the form of recrystallization, particularly of quartz. Both plutons consist of medium-grained red granite with subequal amounts of quartz, alkali feldspar, normally zoned plagioclase (An 25-33), and minor chlorite or biotite. These granites were emplaced into the Archean gneisses late in the Penokean orogeny.

Lower to Middle Proterozoic Rocks

The quartzite exposed at Stop 5 is unlike any other Archean or Early Proterozoic rock of the region. The only rocks of comparable composition and texture are fine-grained, cherty quartzites which belong to the sequence of clastic rocks and chemical sediments deposited in the anorogenic interval which followed the Penokean orogeny. This sequence includes the well-known Baraboo and related quartzites. The interval began with rhyolitic volcanism and deposition of thick sequences of quartzites about 1760 m.y. ago (Greenberg and Brown, 1983a). The interval ended with the emplacement of the alkalic granitic rocks of the Wolf River batholith in central Wisconsin (fig. 1) about 1500 m.y. ago.

The rocks at Stop 5 are tentatively correlated with similar rocks assigned to this sequence in central Wisconsin. Their lithologic similarity to these rocks, and the fact that they do not appear to have undergone the intense Penokean deformation and metamorphism that is characteristic of the Archean and Penokean rocks support this correlation.

PALEOZOIC ROCKS

The Paleozoic section in the Black River Falls area consists of the Mt. Simon Formation, Eau Claire Formation, Wonewoc Formation, and the Lone Rock Formation of the Tunnel City Group. These rocks all belong to the Upper Cambrian St. Croixan Series (fig. 4).

Mt. Simon Formation

The Mt. Simon Formation is the basal unit of the Upper Cambrian, and consists predominantly of quartz sandstone, with minor shale and local conglomerate beds. The Mt. Simon is characterized by thick beds of well to poorly sorted, clean, friable, medium- to fine-grained sandstone. Near the base, or near Precambrian highs, very coarse sand, granules, and pebble- to cobble-sized fragments are common. The Mt. Simon is commonly cross bedded. Mineralogically, the Mt. Simon consists predominantly of quartz, but feldspar content may reach 20 percent locally. Common heavy minerals include magnetite, ilmenite, leucoxene, zircon, tourmaline and garnet. Fossils are rare to absent. The upper part of the Mt. Simon shows evidence of reworking, and consists of laterally persistent beds of medium to coarse sandstone inter-

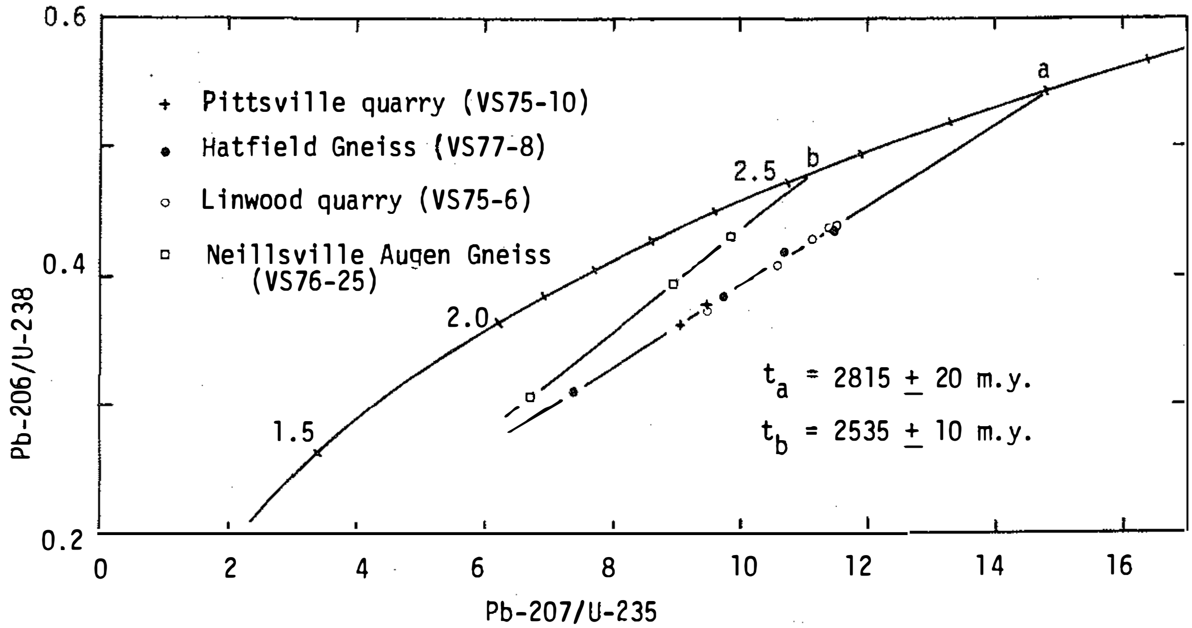


Figure 2.--U-Pb plot of data for zircon fractions from Archean rocks in central Wisconsin (Van Schmus and Anderson, 1977; DuBois and Van Schmus, 1978; Van Schmus, unpub.). The Hatfield Gneiss is from near Stop 9. The ages given are for least-squares fits to the data. From Maass and Van Schmus (1980).

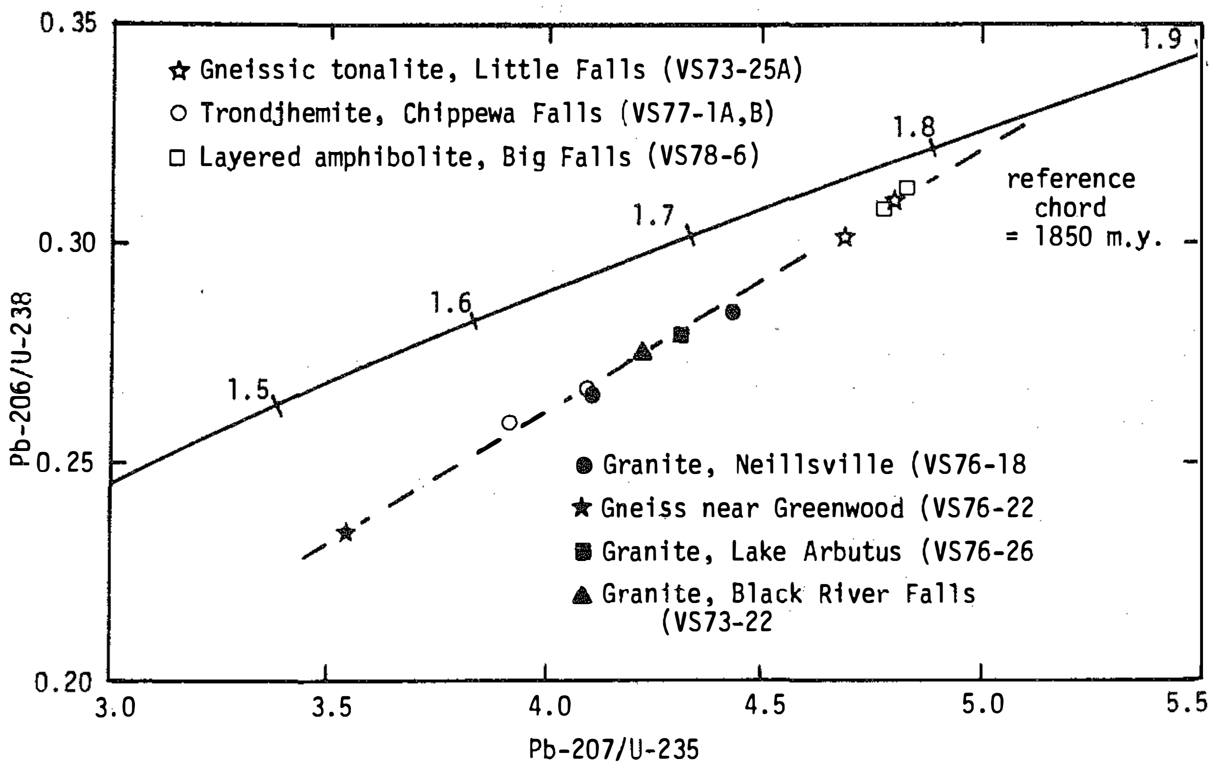


Figure 3.--U-Pb plot of data for zircon fractions from Penokean plutonic and gneissic rocks in the western part of central Wisconsin (Van Schmus, 1980, unpub.). Note that the Neillsville Granite appears to be distinctly older than the main suite of samples. From Maass and Van Schmus (1980).

System	Series	Group	Formation	Member
Devonian	Upper		Kenwood	
	Middle		Milwaukee	
			Thiensville	
			Lake Church	
Silurian	Cayugan		Waubakee	
	Niagaran		Racine	
			Manistique	
			Hendricks	
			Byron	
	Alexandrian		Mayville	
Ordovician	Cincinnatian		Neda	
			Maquoketa	
	Champlainian	Sinnipee	Galena	
			Decorah	
			Platteville	
			St. Peter	Glenwood
				Tonti
				Readstown
	Canadian	Prairie du Chien	Shakopee	Willow River
				New Richmond
			Oneota	
Cambrian	St. Croixan	Trempealeau	Jordan	Coon Valley
				Sunset Point
				Van Oser
				Norwalk
			St. Lawrence	Lodi
				Black Earth
		Tunnel City	Lone Rock	Reno
			Mazomanie	Tomah
				Birkmose
		Elk Mound	Wonewoc	Ironton
				Galesville
			Bonneterre	
			Eau Claire	
			Mt. Simon	

Figure 4.--Geologic column of Paleozoic rocks in Wisconsin. From Ostrom (1978).

bedded with poorly sorted material ranging in size from clay to granules. Thin shaly partings and rip-ups occur in this upper reworked zone which is commonly 12 to 18 m thick.

Eau Claire Formation

The Upper Mt. Simon is overlain by the Eau Claire Formation. The Eau Claire is commonly fine-grained, thin bedded, locally shaly, and contains glauconite and abundant fossils. Cross bedding is common; and ripple marks are locally abundant. Beds of intraclasts are common and consist mainly of sandstone clasts in a matrix of fine sand, silt, clay and glauconite, often cemented with carbonate. Fossils in the Eau Claire include brachiopods, trilobite molds and casts, and burrows and trails. The contact between the Eau Claire and the upper part of the Mt. Simon is conformable, and marked by an abrupt change to finer average grain size. Mineralogically the Eau Claire consists of quartz and feldspar with clay present as coatings on sand grains, glauconite pellets, thin shaly partings, or shale beds up to 3 m thick.

Wonewoc Formation

The top of the Eau Claire is marked by an erosional unconformity. The overlying Galesville Member of the Wonewoc Formation is a quartz arenite similar to the Mt. Simon. The Galesville consists predominantly of medium to fine, clean, well-sorted quartz sand, generally without the feldspar content and coarse pebbly beds typical of the Mt. Simon. Thick beds and cross bedding are common in the Galesville as in the lower part of the Mt. Simon. Fossils are rare to absent.

The Galesville grades upward into the Ironton Member. This unit is similar to the upper part of the Mt. Simon in that it shows evidence of reworking. The Ironton is characterized by thinner, more laterally persistent beds, poorly sorted silty beds, and local intraformational conglomerates. Fossils in the Ironton consist predominantly of burrows and trails, and locally of brachiopod shells and trilobite fragments.

Tunnel City Group

The Wonewoc is overlain conformably by the shaly glauconitic sandstones of the Lone Rock Formation of the Tunnel City Group. The Lone Rock is in many respects similar to the Eau Claire, consisting of medium- to thin-bedded, medium- to fine-grained cross-laminated sandstone, interbedded with shale beds which range from several millimetres to 3 metres thick. The Lone Rock in this area is typically very glauconitic, giving the characteristic green color to many beds. Fossils are common in the Lone Rock, consisting of trails, burrows, and brachiopod and trilobite fragments.

ENVIRONMENT OF DEPOSITION

Ostrom (1978) has proposed that the Cambrian and Ordovician rocks of western Wisconsin represent cyclic repetition of four distinct lithofacies, each of which originated in a distinct sedimentary environment (fig. 5). The cycles began with deposition of a quartz arenite (Mt. Simon, Galesville) followed by a reworked quartz sandstone (upper Mt. Simon, Ironton), shaly sandstone (Eau Claire, Lone Rock) and end with a biogenic carbonate (Bonneterre, St. Lawrence). The carbonate units are not exposed in the Black River Falls area. Dolomitic shaly sandstone which may represent the Bonneterre is known only in the subsurface of extreme southern Wisconsin. The St. Lawrence Formation occurs at higher elevations 10 to 15 km to the south of Black River Falls, and may have been removed from the area by erosion. The sandstones at Stops 1 thru 4 represent parts of the lower two of five cycles proposed by Ostrom (1978).

The regional significance of these cycles is shown in figure 6. The Mt. Simon Formation is the basal unit of the sequence, deposited during a marine transgression which submerged the Precambrian surface during Upper Cambrian time. Ostrom (1978) interpreted the Lower Mt. Simon quartz arenites and conglomerates to be deposits formed in the littoral zone. The upper part of the Mt. Simon represents reworking of the quartz arenites on a nondepositional shelf seaward of the littoral zone. The Eau Claire was deposited further offshore on the depositional shelf. Carbonate, represented by the Bonneterre Formation, was deposited further offshore. The carbonate facies is only known in the subsurface in extreme southern Wisconsin. Regression and erosion took place at the end of the first cycle resulting in an erosional unconformity at

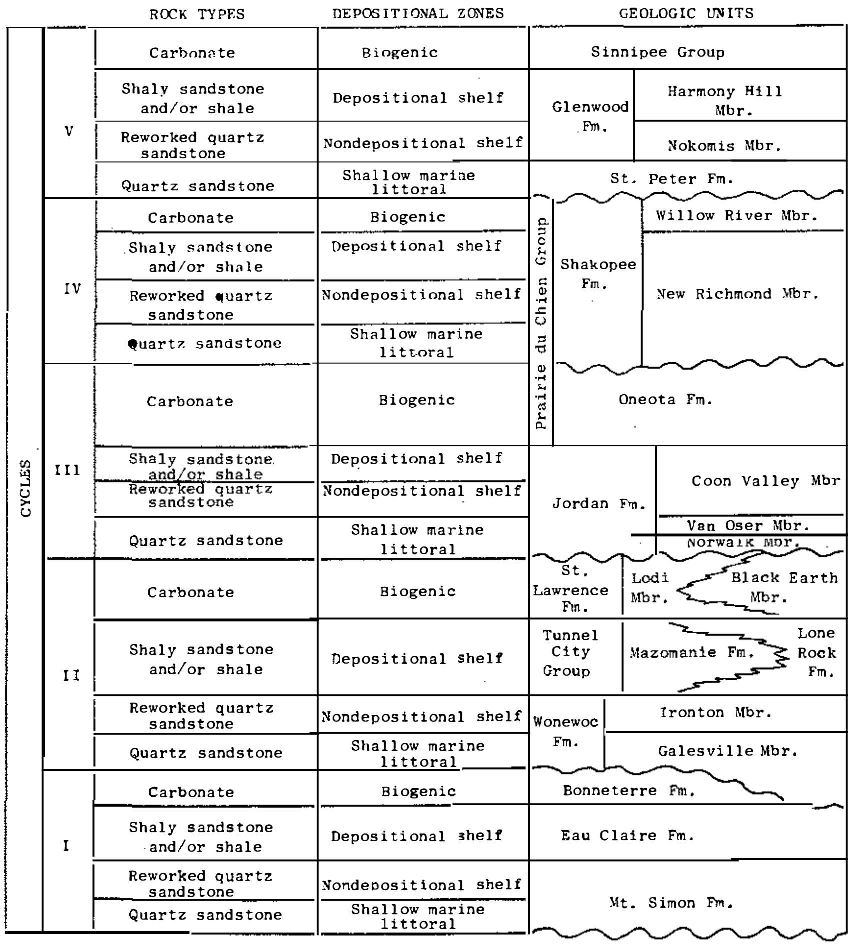


Figure 5.--Cycles of sedimentation in Upper Cambrian and Lower and Middle Ordovician in Wisconsin. From Ostrom (1978).

the top of the Eau Claire. A second transgression, the beginning of the second cycle, is represented by the quartz arenite of the Galesville. The second cycle ended with carbonate deposition in the St. Lawrence Formation, which may have been deposited as far north as the Black River Falls area, and has since been removed by erosion.

PRE-PLEISTOCENE GEOLOGIC HISTORY

The earliest geologic events recorded in the rocks of the Black River Falls area occurred nearly 3 billion years ago with the formation of the volcanic and plutonic protoliths of the Archean gneisses. It is uncertain whether the sequence of supracrustal rocks, which includes the iron formations, is of Archean age or is of Penokean age (1850 m.y.), the lateral equivalent of volcanic and sedimentary rocks exposed in northern and central Wisconsin and upper Michigan. In any event, these rocks and the older gneisses were deformed, metamorphosed, and intruded by granitic plutons during the Penokean orogeny. After the Penokean orogeny, much of the region was covered by a blanket of quartzite, argillite, and siliceous sediments similar in lithology to the Lower Paleozoic rocks.

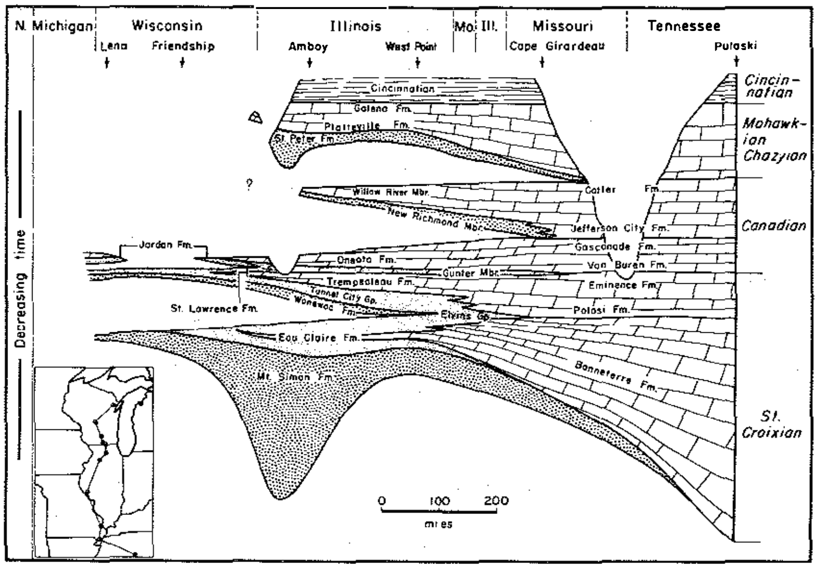


Figure 6.--North-south generalized cross section showing relationships of pre-Cincinnatian Paleozoic strata from Lena, Wisconsin to Pulaski, Tenn. Vertical scale is much exagerated and is intended to show relative thickness, inferring a general time relationship. Section is approximately 1900 km long. From Ostrom (1978).

There is little evidence of Precambrian tectonic activity after about 1600 m.y. ago. This time interval is represented only by local emplacement of Keweenawan diabase dikes about 1 billion years ago. There is no record of activity between 1 billion years ago and the beginning of the Late Cambrian, about 525 million years ago. This was presumably a period of erosion in which the relatively flat Precambrian surface was formed over which the Cambrian seas later advanced.

The Cambrian rocks represent two cycles of marine transgression and regression. The distribution of lithofacies in the Cambrian sediments suggests that transgression progressed from south to north, probably in response to periodic epeirogenic uplift of the Precambrian shield in northern and central Wisconsin. Known as the Wisconsin arch or Wisconsin dome, this terrane was a positive feature throughout much of the Paleozoic.

PLEISTOCENE HISTORY
OF THE
BLACK RIVER FALLS AREA

by Lee Clayton and Fred Madison

INTRODUCTION

Black River Falls is near the northern edge of the Driftless Area (fig. 7). The Chippewa Lobe of the ice sheet reached a point 80 km north of Black River Falls during the last part of the Wisconsin Glaciation. An ice sheet nearly reached the field-trip area, about 25 km northeast of Black River Falls, probably during an earlier glaciation (fig. 8).

The area west of Black River Falls has the rugged topography that is characteristic of the Driftless Area. To the east of Black River Falls, in an area roughly corresponding to eastern Jackson County (area A of fig. 7; fig 8), the topography is much less rugged. This area has been considered to be a different physiographic area from the Driftless Area, but it is sometimes considered to be part of the Driftless Area because there is little or no evidence that the area was glaciated. This area is characterized by sand flats.

SAND FLATS OF EASTERN JACKSON COUNTY

The lowest sand flats along the Black River are fluvial terraces. Most contain sand or gravelly sand deposited by melt water from the Chippewa Lobe or from proglacial Lake Wisconsin (figs. 7 and 8). Immediately above the terraces are broad sand flats that slope down from the surrounding low hills (fig. 8).

The history of the sand flats of eastern Jackson County is largely unknown. The sand flats are now inactive and formed at an earlier time, presumably when the climate was different from that of today, perhaps during a periglacial climate.

As far as we know, no one has studied the sand, but it is presumably fluvial because the surfaces are shaped like alluvial fans or pediments. Judging by the location of outcrops of pre-Pleistocene rock in the area, the sand is only a few metres thick in many areas, indicating that the surfaces are pediments rather than alluvial fans. The sand was derived from the Cambrian formations at the heads of the pediments. A thin layer of wind-blown sand caps the surfaces in most places, and low dunes are present in some areas. Sand-blasted pebbles and cobbles of chert commonly occur under the wind-blown sand.

The sand flats seem to be restricted to areas of thin Cambrian rock, generally the Mt. Simon Formation, and also perhaps to areas with only a Precambrian weathering mantle overlying Precambrian rock. The sand flats continue across the drainage divide between the Black River basin and the basin of proglacial Lake Wisconsin (fig. 8); they are as wide as 2 km where they cross the divide. To the east of the divide they merge with similar sand flats on the plain of Lake Wisconsin (fig. 8).

Figure 7.--Location of field-trip area at the northern edge of the Driftless Area. A: The unglaciated (?) area of eastern Jackson County, characterized by periglacial (?) pediments; sometimes considered part of the Driftless Area. B: The unglaciated (?) area of proglacial Lake Wisconsin and proglacial fluvial plain.

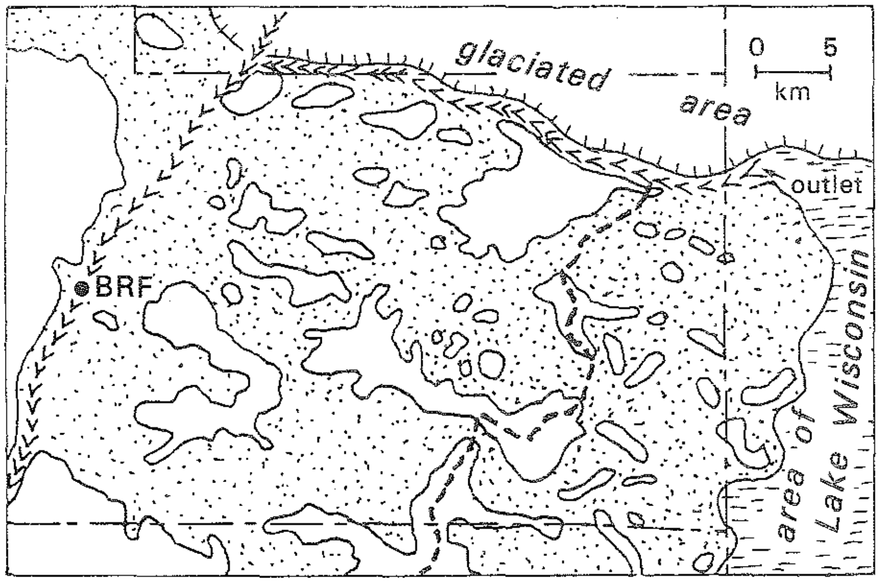


Figure 8.--Approximate distribution of sand flats of eastern Jackson County, which may be periglacial pediments (dotted area). Dashed line is drainage divide. Arrow heads indicate melt-water flow during Wisconsin Glaciation, down the Black River from the Chippewa Lobe to the north and down the East Fork Black River from the outlet of Lake Wisconsin. The area immediately north of the East Fork Black River was glaciated, probably in pre-Wisconsin time. BRF = Black River Falls.

In most areas, the water table is near the surface of the sand flats, and much of the flats is covered with peat bogs (described below). The groundwater is held up by clayey layers in the Mt. Simon Formation, by the weathering mantle on top of the Precambrian rock, and by the Precambrian rock, which is generally only slightly permeable. If there was permafrost in the area during glaciation or if there was more recharge on the surrounding hills, the water table would have been higher in the hills. The sand flats may be restricted to these settings because groundwater sapping at the bases of the hills caused the pediments to laterally expand when the water table was slightly higher during glaciation.

WAS THE AREA GLACIATED?

Mickelson and others (1982) reviewed the evidence for the glaciation of the Driftless Area and concluded that there is no convincing evidence for glaciation, although the exact extent of glaciation is obscure around some of the boundaries of the Driftless Area. In figure 8, the limit of glaciation is shown along the East Fork Black River, but it may have been farther north. No evidence of glaciation south of the East Fork Black River is known. Scattered pebbles and cobbles from northern Wisconsin have been observed, but they are more likely lag from Cenozoic or Mesozoic fluvial deposits (such as the Windrow gravel) than from an eroded till sheet. If the area south of the East Fork Black River was glaciated, Lake Wisconsin (if it existed then) spilled westward at higher levels south of the East Fork Black River outlet, where the sand flats are shown crossing the divide in figure 8.

LAKE WISCONSIN

Lake Wisconsin occupied much of Juneau, Adams, and Wood Counties (fig. 7) during the last part of the Wisconsin Glaciation. The Wisconsin River valley was dammed when the Green Bay Lobe covered the east end of the Baraboo Range. Through most of its history, the outlet of Lake Wisconsin was the East Fork Black River (fig. 8), which joins the Black River on the east side of Lake Arbutus, near the northern end of the field trip route. The outlet river was about 0.7 km wide and more than 5 m deep. Many of the outcrops of Precambrian rock in the field trip area are on the sides or bottom of the spillway channel.

PEAT

Much of the sand flat area is covered with varying thicknesses of histic (organic) materials. Characteristically, a metre or so of sphagnum peat overlies reed-sedge peat or woody peat. Near Millston in southeastern Jackson County, there are several active sphagnum harvesting operations. Only the upper part of the mass is harvested, which allows it to regenerate, and so the resource is not depleted.

If this area (fig. 8) was, in fact, not glaciated then these bogs might contain interesting paleoclimatic and paleobotanic information. Bogs in the glaciated part of the state typically contain evidence of botanical change from about 10,000 B.P. to the present. If this surface is much older than Pleistocene, then perhaps the pollen record will provide insights into the vegetation of the area before 10,000 B.P.

Many workers have also suggested that the Driftless Area was, during glacial periods, the repository for plants that then served to revegetate the rest of the state following the disappearance of ice. Because of the location of these bogs between the glaciated and unglaciated parts of the state, their pollen record might reveal the evolution of late Pleistocene vegetational patterns.

CRANBERRIES

The sand flats (fig. 8) are dotted with cranberry bogs. Wisconsin is now the leading cranberry-producing state in the nation, with a 1982 yield of 1,300,000 barrels from about 28 km^2. The cranberry is an evergreen that requires very wet soil and very acid soils ($pH < 4.5$). The bogs of Jackson, Juneau, Wood, and Monroe Counties are ideal.

Abundant water is essential for cranberry production for reasons other than maintaining soil moisture. When bog temperatures drop below freezing in early fall, plants are sprayed with a fine mist to prevent freezing. For harvest, the bogs are flooded and the berries are knocked off the plants with a mechanized beater. The berries, which float, are then drawn off with the water that was used to flood the bogs. Before winter, the bogs are flooded incrementally to freeze the plants and, in effect, to put them in the deep freeze for the winter to prevent desiccation.

IRON ORE RESOURCES AND THEIR DEVELOPMENT IN THE BLACK RIVER FALLS AREA

by Thomas J. Evans

What is now the Jackson County area in west-central Wisconsin has long been known for the presence of low-grade iron mineralization (25-35 percent Fe) associated with Precambrian-age metamorphic rocks exposed along the Black River. The iron deposits were known as far back as 1839, nine years before Wisconsin became a state. In 1856 a blast furnace was constructed along the east bank of the Black River, less than two miles from the Black River Falls community. This early operation was short-lived, but was the forerunner of the York Iron Company's blast furnace operations initiated in 1882. Within ten years, this second iron producer moved on as market competition from Minnesota's Mesabi District proved too much to handle. Little else happened, beyond some exploration in the World War I years, until 1939 when Inland Steel started land acquisition and preliminary exploration activities. After a few years, Inland's efforts, which included construction of an adit to obtain a bulk sample for metallurgical testing, were put on hold until 1961 when advances in low-grade iron ore (taconite) technology renewed hope for development of these lean ores.

With exploration continuing, Inland sought improved tax treatment by the state--an effort led largely by interests associated with the dying (and now dead) Gogebic iron range in the Hurley-Montreal area of Iron County in northern Wisconsin. The tax break came in June, 1967 and one month later bids were let for construction of the Jackson County Iron Company (JCIC) Black River Falls mine-mill operation. The first shipment of taconite pellets by this wholly-owned subsidiary of Inland Steel was made in November, 1969.

The JCIC operation is designed to produce about 750,000 long tons of taconite pellets annually. These pellets are hauled by unit train to Inland's Indiana Harbor steel mills in East Chicago, Indiana (456 km to the southeast). The iron ore is mined and hauled from the 130-acre open pit to the pelletizing plant several thousand feet away. Ore tailings are slurried to the 320-acre tailings basin. Waste rock is placed on nearby waste-rock dumps.

[Details of the JCIC operation--ore, waste rock, tailings handling, pellet production, environmental controls, and on-going reclamation practices--will be presented by Mr. Vern Metzger, operations superintendent for Jackson County Iron Co., on Saturday evening.]

Having been started in the late 1960s, the JCIC operation was "grandfathered", that is, exempt from many of the rapidly evolving, comprehensive metallic-mining regulations that were the focus of legislative activity in the 1970s. As a consequence, the JCIC mining permit was issued in early 1981, following a two-day hearing on its application in January. Unfortunately, the prospect of continuing mine development over the next 10 years ran head-on against the plummeting demand for steel products in the recent recession. The slack in demand resulted in the shutdown of JCIC on April 9, 1982 and the layoff of over 250 employees. Since that time, efforts have been made to keep the mine in a "ready" status to resume mining, but the prospects for resumption of pellet production continue to become dimmer and dimmer. Today, the future of JCIC's Black River Falls mine, the only active metal mine in Wisconsin, remains much in doubt. The mine-mill complex represents what modern metal mining can be--an environmentally sound development of commercially important mineral resources--but the vagaries of national and international economics will determine the course for JCIC and the Black River Falls community irrespective of the mineral heritage of the Precambrian metamorphic rocks which we'll see on this field trip.

REFERENCES CITED

DuBois, J.F., and Van Schmus, W.R., 1978, Petrology and geochronology of Archean gneiss in the Lake Arbutus area, west central Wisconsin, (abs.): 24th Institute on Lake Superior Geology, Milwaukee, p. 11.

Greenberg, J.K., and Brown, B.A., 1983a, Middle Proterozoic to Cambrian Rocks in Central Wisconsin: Anorogenic sedimentary and igneous activity, Field Trip Guidebook 8, Wisconsin Geological and Natural History Survey, Madison, 50 p.

Greenberg, J.K., and Brown, B.A., 1983b, Lower Proterozoic volcanic rocks and their setting in the southern Lake Superior district: in Medaris, L.G., (ed.) Early Proterozoic geology of the Great Lakes region, Geological Society of America Memoir 160, p. 67-83.

Jones, D.G., 1978, Geology of the iron formation and associated rocks of the Jackson County Iron Mine, Jackson County, Wisconsin: Unpub. M.S. thesis, Univerity of Wisconsin-Madison, Madison, 117 p.

Klemic, H., and J.M. Ohlson, 1973, Guidebook to the geology and mineral deposits of the central part of Jackson County and part of Clark County, Wisconsin: Prepared for the 19th Institute on Lake Superior Geology, Wisconsin Geological and Natural History Survey, Madison, 27 p.

Maass, R.S., 1983, Early Proterozoic tectonic style in central Wisconsin: in Medaris, L.G., (ed.) Early Proterozoic geology of the Great Lakes region, Geological Society of America Memoir 160, p. 85-96.

Maass, R.S., and Van Schmus, W.R., 1980, Precambrian Tectonic History of the Black River Valley: Field guide prepared for the 26th Institute on Lake Superior Geology, University of Wisconsin-Eau Claire, Eau Claire, Wisconsin, 43 p.

Mickelson, D.M., Knox, J.C., and Clayton, Lee, 1982, Glaciation of the Driftless Area: an evaluation of the evidence: Wisconsin Geological and Natural History Survey Field Trip Guide Book 5, p. 155-169.

Ostrom, M.E., 1978, Stratigraphic Relationships of Lower Paleozoic Rocks of Wisconsin, in Lithostratigraphy, Petrology, and Sedimentology of Late Cambrian-Early Ordovician rocks near Madison, Wisconsin, Field Trip Guide Book Number 3, Wisconsin Geological and Natural History Survey, Madison, p. 3-22.

Van Schmus, W.R., 1980, Chronology of igneous rocks associated with the Penokean orogeny in Wisconsin: Geological Society of America Special Paper 182, p. 159-168.

Van Schmus, W.R., and Anderson, J.L., 1977, Gneiss and migmatite of Archean Age in the Precambrian Basement of central Wisconsin: Geology, v. 5, p. 45-48.

Van Schmus, W.R., and Bickford, M.E., 1981, Proterozoic chronology and evolution of the midcontinent region; North America, in Kroner, A., (ed.) Precambrian Plate-tectonics; Amsterdam, Elsevier, p. 261-296.

GEOLOGIC ROADLOG - DAY 1

--Mileage is cumulative, with increments between entries in parentheses.

Miles	
0 (0.6)	Entrance to Jackson Co. fairgrounds, located on Hwy. 54 at the southwest edge of Black River Falls. Turn left on 54 to County Hwy. C.
0.6 (0.7)	Turn right on C. Bedrock is Cambrian Mt. Simon Formation, probably covered by thin fluvial sands up to the crest of the hill.
1.3 (0.4)	Junction with Co. Hwy. P, go straight on C. Mt. Simon Formation exposed in cuts and ditches.
1.7 (0.1)	Cross Kenyon Creek. Sandstones of the Mt. Simon Formation exposed in banks.
1.8 (0.4)	Turn left on Moss Hill Road.
2.2 (0.4)	STOP 1. Exposure of Mt. Simon and Eau Claire Formations. Road cut on east side of Moss Hill Road.
2.6 (0.5)	Return to intersection of Moss Hill Road and County C. Turn right on C.
3.1 (0.8)	Junction with County Hwy. P, turn left on P.
3.9 (0.5)	Turn right on Kenyon Creek Road.
4.4 (0.3)	Fine sandstones of the Eau Claire underlie fields on right.
4.7 (0.1)	Turn right on East Kenyon Creek Road.
4.8 (0.3)	Turn left on East Kenyon Creek Road.
5.1 (0.2)	Log house on right. This is the type of house built by the early residents of this region. Many fine examples are still standing, although many have been modified or covered by clapboard siding at a later time.
5.3 (0.3)	Jog to right, then left.
5.6 (0.8)	Sandstones of the Galesville Member of the Wonewoc Formation cap the higher hills to the right.
6.4 (0.3)	Junction with Town Creek Road, turn right.

6.7 (0.4) Travelling on top of Eau Claire surface near the base of the formation.

7.1 (0.1) Junction with Hwy. 27, turn left on 27.

7.2 (1.7) Cut along I-94 on right is in the upper Mt. Simon Formation.

8.9 (2.0) STOP 2. Exposure of Wonewoc Formation (Galesville and Ironton Members) in road cut on Hwy. 27 and I-94.

Turn around and proceed east on Hwy. 27 to County F.

10.9 (0.5) Turn left on County F and cross under I-94.

11.4 (1.4) Good exposure of Mt. Simon Formation in road cut on right.

12.8 (0.7) Road cut in Wonewoc.

13.5 (0.2) Wonewoc exposed in road cut on left, exposure continues for next .5 mile. Tunnel City Group (Lone Rock Formation) caps high hills to left.

13.7 (1.3) Wonewoc exposed in cut at crest of hill. Farms below are on the Eau Claire.

15.0 (1.8) Turn right on Oak Grove Road. Wonewoc exposed on small hill to west of intersection. Ridge in distance ahead is capped by Lone Rock. Farms to right and left are underlain by Eau Claire.

16.8 (0.7) Curve to right.

17.5 (0.1) At the top of hill, a small unimproved road branches off to the left in front of a house. Follow this road to the left along the ridge top to STOP 3. The Lone Rock Formation of Tunnel City Group is exposed in small quarries labeled on the topographic map as shale pits. After this stop, follow road to radio tower at top of hill, turn around and return to Oak Grove Road.

17.6 (1.9) Wonewoc is exposed in road cuts down steep hill.

19.5 (0.1) Follow fork to left.

19.6 (0.6) Junction with East Snow Creek Road, turn left.

20.2 (0.3) Junction with Kenny Road. Continue north on East Snow Creek Road.

20.5 (0.2) Road cut on crest of small hill contains Wonewoc-Eau Claire contact. This is the wavellite occurrence in the Eau Claire Formation described by Klemic. (see Supplemental Locality G.)

20.7 (0.3) Road cut in Wonewoc (Galesville Member on left).

21.0 (0.1) Road cut in Galesville.

21.1 (0.2) Fork in road. Follow Gilbert Road to right.

21.3 (0.8) The large hill directly ahead in the distance is Bruce Mound, located east of the town of Merrillan. The prominent cliffs are Wonewoc. The mound is capped by the Lone Rock Formation of Tunnel City Group.

22.1 (0.2) Junction with Hwy. 12, turn left.

22.3 (1.3) Road cut exposes Mt. Simon Formation.

23.6 (0.8) Turn right on Garage Road.

24.4 (0.1) Cross Halls Creek. Bluffs of lower Mt. Simon Formation are visible downstream along creek. Creek bed is close to contact of Precambrian in this area. Precambrian rocks are largely schists and gneisses, probably derived from Archean or Proterozoic volcanic and sedimentary rocks. These rocks are exposed at the canoe landing where Halls Creek enters the Black River.

24.5 (0.4) <u>STOP 4</u>. Junction with Flood Road. New cut for the eastern approach to the bridge over Halls Creek exposes shaly beds of the Mt. Simon Formation. Coarse sandstone typical of lower part of Mt. Simon is exposed in cut bank on east side of Flood Road.

Continue north on Flood Road.

24.9 (2.0) Turn right on Evergreen Road. Wetlands in this area are probably caused by a perched water table on top of shaly beds in Mt. Simon Formation.

26.9 (1.2) Junction County E, turn left on E.

28.1 (0.6) Enter Hatfield.

28.7 (0.5) Junction with County K, turn left.

29.2 (0.3) Junction with J (Clark-Jackson Co. line), turn right on J.

29.5 (0.4) J turns north, go straight ahead into Russell Park on shore of Lake Arbutus. Lunch Stop.

29.9 (0.2) Leave Russell Park, proceed west on J.

30.1 (0.6) Junction K, turn left on K.

30.7 (0.4) Junction K and E, downtown Hatfield, proceed straight ahead on K.

31.1 (0.2) Cross Hatfield Canal. This canal provides water from Lake Arbutus dam to a powerplant about 5 km down the Black River. This canal is cut into sandstones of the Mt. Simon Formation and was considered quite an engineering feat when built in the early 1900s.

31.3 (0.1) Bridge over the Black River. The Mt. Simon-Precambrian unconformity is at about road level, but not exposed. Archean Hatfield gneiss is well exposed under the bridge and in river bed, which is a deep gorge in this area. Cut on left before the bridge is in the lower Mt. Simon.

31.4 (2.1) Clay School Road on left. Continue on K. Mt. Simon Formation is exposed in backslope of ditches along K.

33.5 (0.7) Precambrian rocks, predominantly gneisses of Archean age, are exposed in bed of Morrison Creek (see Supplemental Locality C). Banks of creek consist of sandstone of the lower Mt. Simon.

34.2 (1.2) Exposure of Mt. Simon on east side of road.

35.4 (0.7) Follow K to right, Mt. Simon is exposed in backslope of ditches.

36.1 (1.1) Shaly Mt. Simon exposed in ditch on right. Note swampy area for next .5 kilometre. This is probably caused by a perched water table on top of shaly Mt. Simon bed.

37.2 (0.1) Dangerous S curve and narrow bridge! Bridge crosses Dickey Creek. Mt. Simon is exposed in creek banks.

37.3 (0.4) Fork in road, follow K to left.

37.7 (0.4) End of K. Junction with 54, turn left on 54.

38.1 (2.8) Winnebago Indian council grounds on left. We are driving up the Mt. Simon pediment surface toward the east. Lakes and cranberry bogs in this area probably represent the perched water table over shaly Mt. Simon.

40.9 (0.8) Turn right on Spangler-Wildcat Road.

41.7 (2.4) Turn left on Battle Point Road. Continue 2.4 miles to quarry on left.

44.1 (2.8) STOP 5. Exposure of "Quartzite" of Klemic and Ohlson (1973). This rock is probably a cherty quartzite correlative with rocks of post-Penokean age exposed in central Wisconsin, although age is uncertain.

Turn around and retrace route on Battle Point Road.

46.9 (0.7) Junction of Spangler-Wildcat Road, turn right.

47.6 (3.3) Junction with Hwy. 54, turn left.

50.9 (1.0) Junction with K, continue west on 54.

51.9 (1.1) Indian village on right.

53.0 (0.9) Junction with Mission Road, make sharp right turn, then go left at fork in road.

53.9 (0.3) Turn left on West Bottom Road.

54.2 (0.1) Turn right on Levis Creek Road

54.3 (0.7) STOP 6. Exposure of Precambrian Iron Formation on small hill to south of road. Mt. Simon sandstone locally caps and flanks this mound, which is one of several mounds consisting of iron formation in the immediate area. Iron Mound, a similar hill to the southeast, is the site of the Jackson County Iron Company mine and pellet plant (see Supplemental Locality E).

Continue west on Levis Creek Road.

55.0 (0.8) Bear to left at "Y" intersection and follow Levis Creek Road.

55.8 (0.4) "T" intersection, turn right.

56.2 (0.5) Pass under I-94, Pleistocene terrace sands are exposed to the left and right.

56.7 Enter Black River Falls, continue straight ahead.
(0.3)

57.0 STOP 7. Granite exposure at Black River Falls power dam. An excel-
(0.2) lent exposure of 1850 m.y.- old red granite occurs in river bed below dam.

Park to left in lot provided for boat launch ramp. After stop, proceed straight ahead past old bridge abutment and up hill.

57.2 Junction hwys. 12-27 and 54. Go straight ahead on 12-27.
(0.2)

57.4 Enter Brockway, a suburb of Black River Falls.
(0.3)

57.7 Junction 12 and 27, continue straight ahead on 27.
(0.7)

58.4 Turn left on 7th Street.
(0.2)

58.6 Alluvial sands are exposed along road.
(0.8)

59.4 STOP 8. Castle Mound. Follow flagged trail up east end of mound for
(1.0) overview of geomorphic features and to examine outcrops of silica-cemented quartzite developed locally within Wonewoc sandstones. (see also Supplemental Locality F for further information on these rocks.)

Turn around and return to Hwy. 27.

60.4 Junction Hwy. 27, turn right to Junction Hwy. 54.
(1.2)

61.6 Junction Hwys. 12-27-54, go left on 54 and cross Black River. Con-
(1.1) tinue straight through town on 54 to Jackson County fairground.

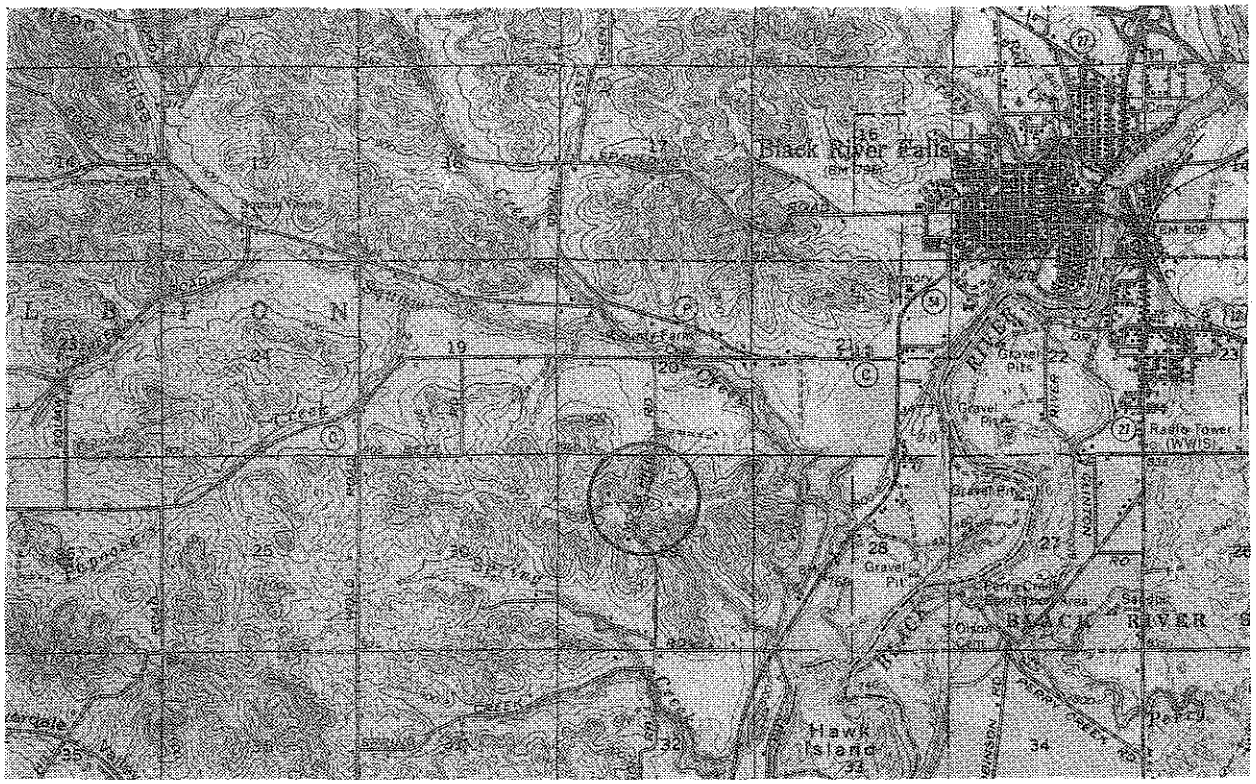
62.7 End of trip. Jackson Co. fairgrounds.

Note: There is no road log for Day 2. We will meet at 8:00 a.m. at the Arrowhead Lodge parking lot at the junction of Hwy. 54 and I-94, and proceed to STOP 9.

GEOLOGIC STOP DESCRIPTIONS

STOP 1

Title: Mt. Simon and Eau Claire Formations, Moss Hill Road Cut



Location: NW¼ sec. 29, T. 21 N., R. 4 W. Black River Falls 15-minute topographic quadrangle. Road cut on east side of Moss Hill Road.

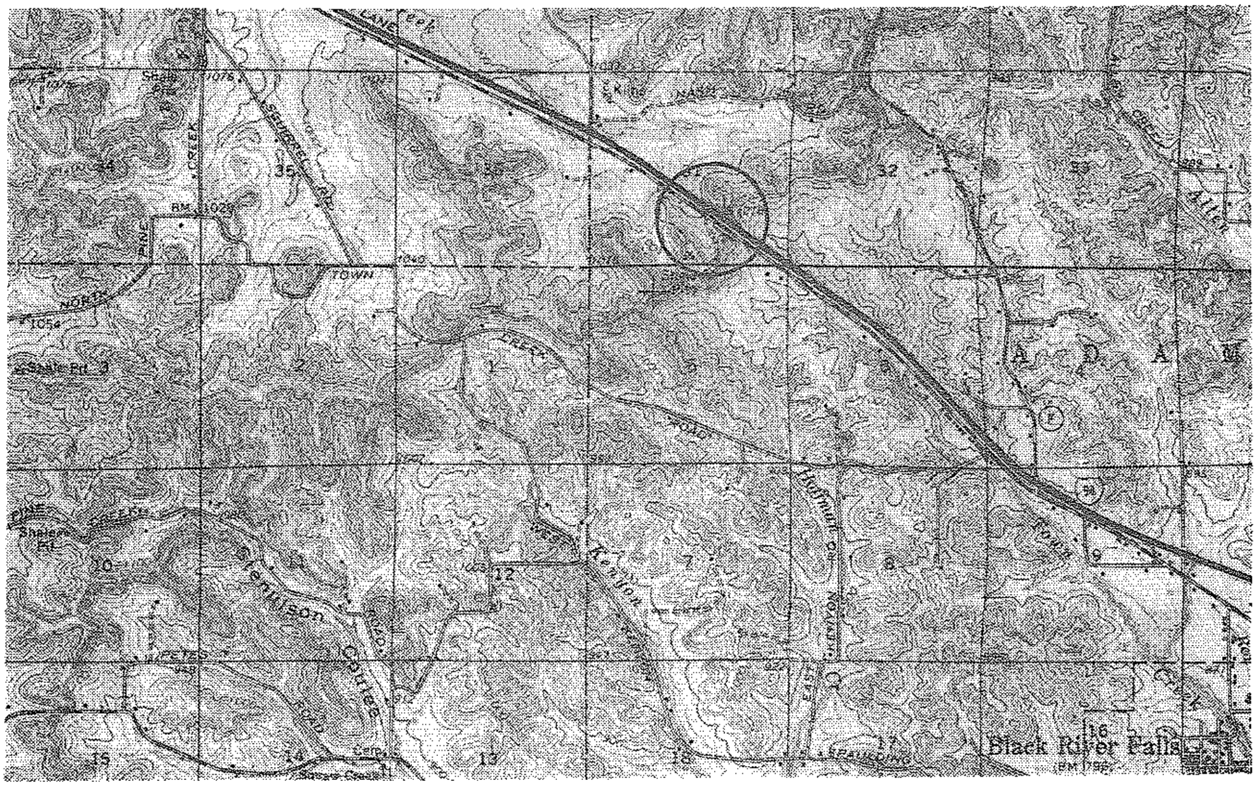
Author: B.A. Brown (1983)

This cut exposes beds of the upper part of the Mt. Simon Formation and the lower part of the Eau Claire Formation. Beds exposed in the lower part of the cut are about 50 m above the base of the Mt. Simon. These rocks consist of medium bedded, poorly cemented, medium- to fine-grained, pale gray to buff quartz sandstone. Coarser beds are commonly cross laminated. Thin shaly partings and partings stained by iron oxide occur throughout the exposure. Alternating beds of coarse quartzose sandstone and poorly sorted sandstone with clasts ranging from granule to clay-size produce the characteristic ledge and reentrant weathering on the cut face. This feature, and the lateral persistence of individual beds are characteristic of the upper Mt. Simon in this region. Ostrom (1978) considers the upper 15 m of the Mt. Simon to be a reworked quartz arenite formed in a nondepositional shelf environment. Quartz arenites, which originated as littoral zone deposits, were periodically reworked in this environment by wave action during storms.

The Eau Claire Formation overlies the Mt. Simon at an approximate elevation of 940 feet above sea level. The contact is covered, and the beds of the Eau Claire are poorly exposed in a bank on the east side of the road. The Eau Claire consists of thin beds of fine- to very fine-grained shaly sandstone with shaly partings and thin shale interbeds. Rocks at this exposure contain glauconite and abundant fossils, primarily small white phosphatic brachiopods. The thin flaggy bedding and abundant fossils characterize the Eau Claire in this area. Ostrom (1978) interpreted the Eau Claire to represent the finer material which accumulated on a depositional shelf seaward of the littoral and reworked facies represented by the Mt. Simon.

STOP 2

Title: Highway 27/I-94 roadcut: Wonewoc Formation



Location: NW¼SE¼ sec. 31, T. 22 N., R. 5 W. Black River Falls 15-minute topographic quadrangle.

Author: B.A. Brown (1983)

The Wonewoc Formation is well exposed in roadcuts on the south side of Hwy. 27 and on the north side of I-94. More than 30 m of the Wonewoc are visible in the face of the large cut to the north. The base of the formation, where the Galesville Member unconformably overlies the Eau Claire, is below road level, at an approximate elevation of 1040 feet (317 m). The top of the Ironton Member is near elevation 1210 feet (369 m), approximately at the top of the exposed rock face in the north cut. The gradational transition between the Galesville and the overlying Ironton occurs at about the level of the second bench from the top of the I-94 cut.

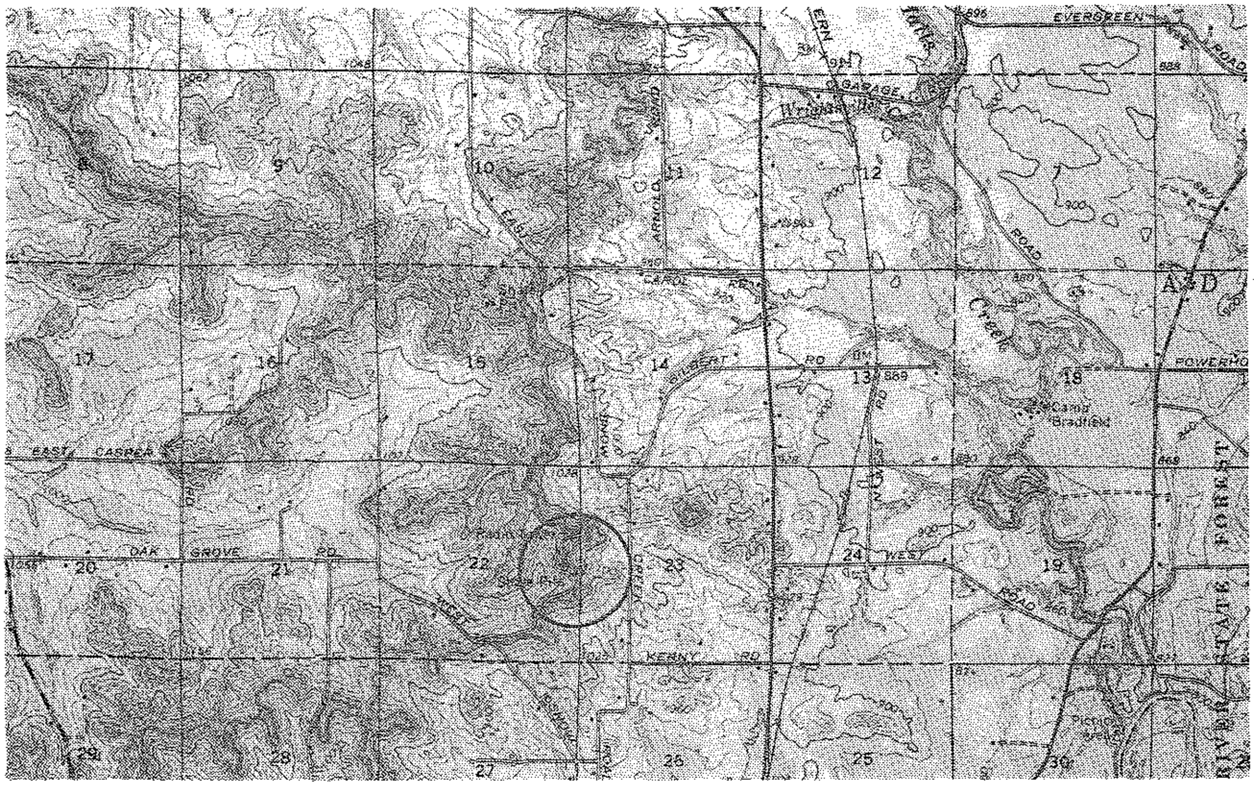
The Galesville Member consists of clean medium- to fine-grained quartz sandstone. Beds are commonly thick, and large-scale cross bedding and channels are visible on the I-94 cut face. The Galesville is characteristically a cliff-forming unit in this region, in spite of its friability.

The Ironton Member is similar to the upper Mt. Simon in texture and bed form. Beds are thinner and more persistent than in the Galesville, and the alternation of coarser sandstone beds with poorly sorted beds produces the characteristic ledge and reentrant weathering. The Galesville, like the lower part of the Mt. Simon, has been interpreted by Ostrom (1978) to represent littoral zone deposition, while the Ironton is a reworked quartz arenite similar to the upper part of the Mt. Simon.

The Wonewoc is overlain by the basal beds of the Lone Rock Formation of the Tunnel City Group near the top of the hill above the Hwy. 27 cut. A small unimproved road leads to the top of the hill, where thin-bedded, fine- to medium-grained, glauconitic sandstone typical of the Lone Rock is exposed in the floor of a shale pit.

STOP 3

Title: Shale Pits in Lone Rock Formation



Location: NE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 22, T. 22 N., R. 4 W. Black River Falls 15-minute topographic quadrangle.

Author: B.A. Brown (1983)

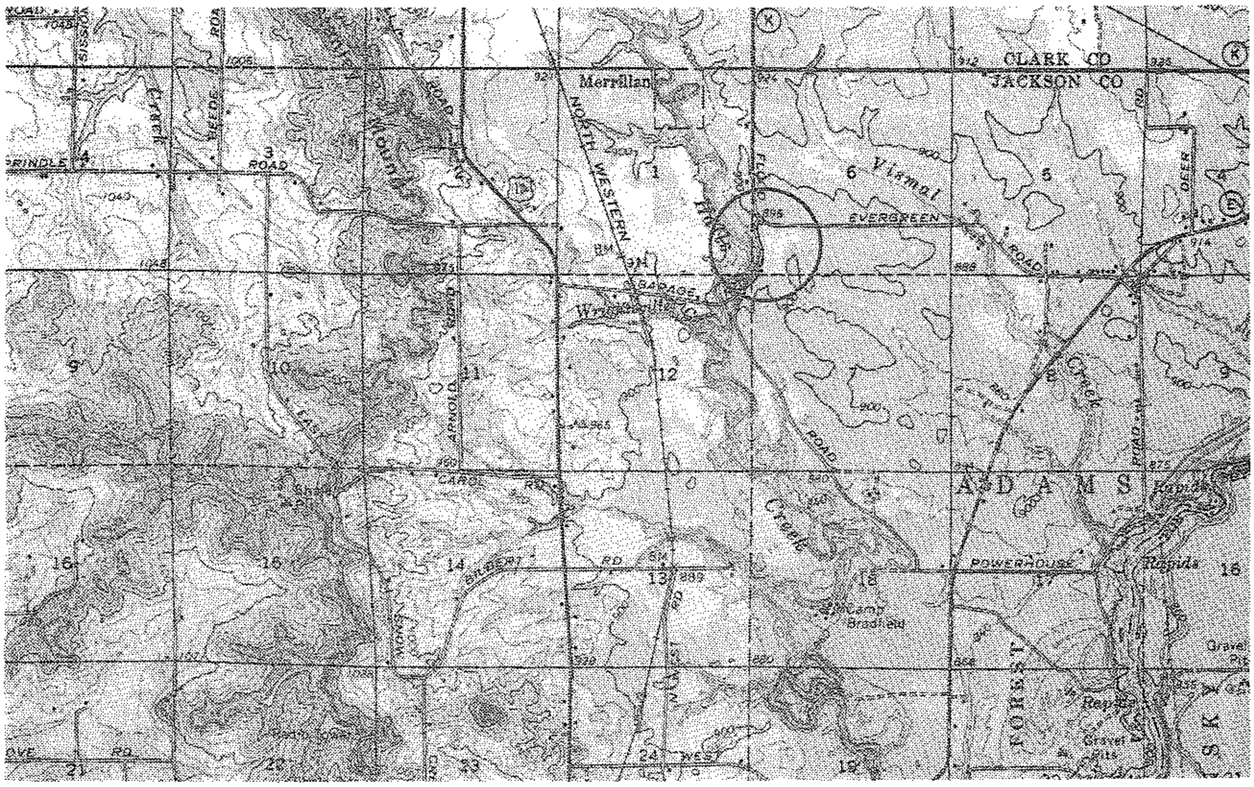
Several small shale pits are developed in the Lone Rock Formation of the Tunnel City Group along the dirt road leading up to a radio tower on the crest of the ridge which forms the Paleozoic escarpment on the west side of the Black River. The formation consists of light brown to buff, thick to thin bedded, medium- to fine-grained sandstone interbedded with thin shales. The Lone Rock typically contains glauconite, often in sufficient quantity that some beds and partings are grass green in color. Fossils, including trails, burrows, brachiopod shells and occasional trilobite fragments are common in the fine-grained beds.

The environment of deposition of the Lone Rock was similar to that of the Eau Claire. Ostrom (1978) considers the Lone Rock to represent the offshore depositional shelf deposits of the second depositional cycle of the Cambrian-Ordovician sequence in Wisconsin.

Shale pits such as this one are developed on the tops of most of the ridges and hills where the Lone Rock is exposed. The medium to coarse grain size, and lack of fine material characteristic of the Mt. Simon and Wonewoc make them unsuitable for road construction. The higher content of fine sand and clay-size material in the Lone Rock makes it an ideal, and often the only available, material which will compact sufficiently to be used as surfacing material for dirt roads.

STOP 4

Title: Exposure of shaly beds in Mt. Simon Formation, Halls Creek



Location: NE¼NE¼ sec. 12, T. 22 N., R. 4 W. Black River Falls 15-minute topographic quadrangle.

Author: B.A. Brown (1983)

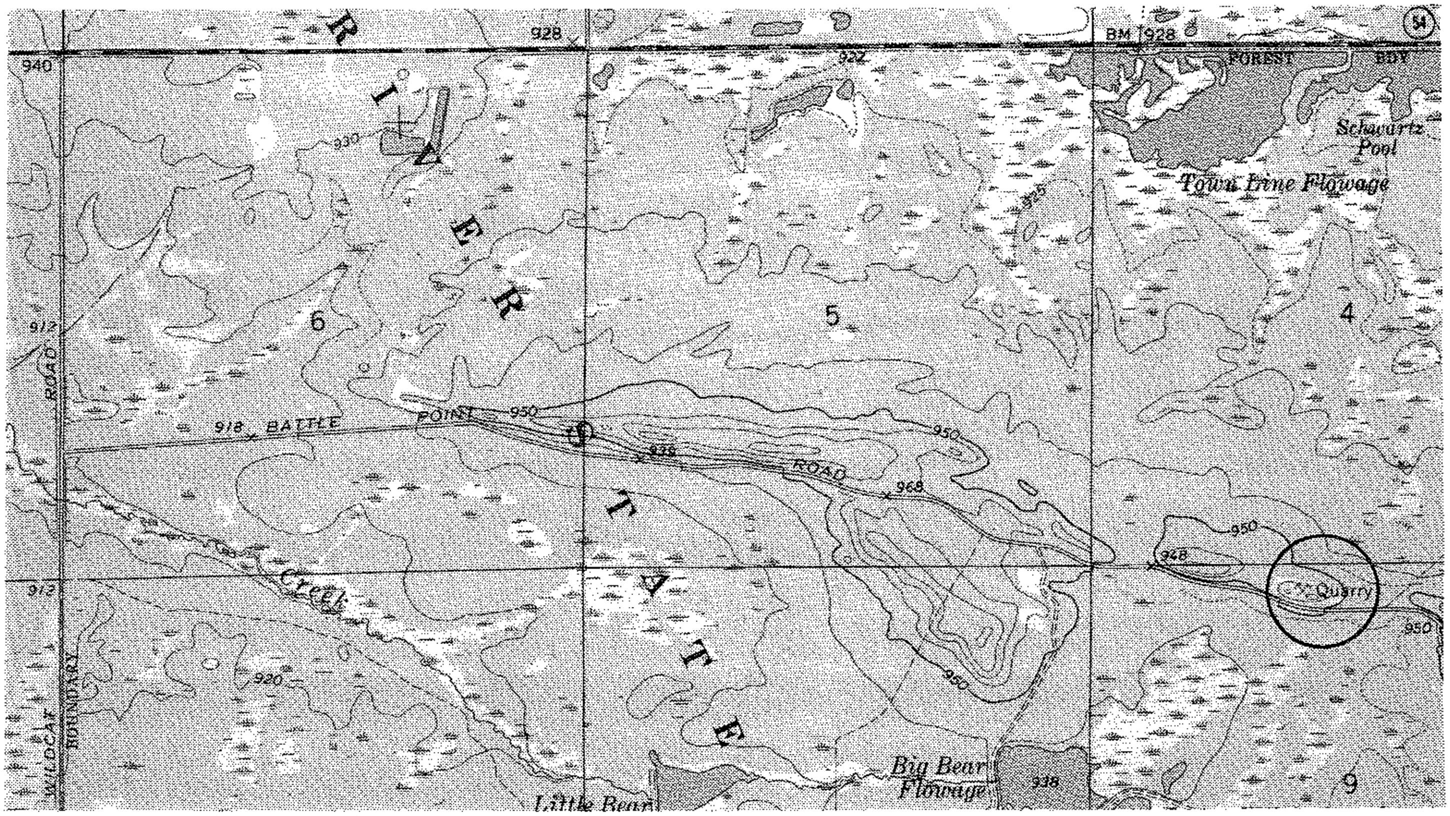
The road cut for the eastern approach to the bridge over Halls Creek exposes shaly beds of the lower part of the Mt. Simon Formation. The rocks consist of 5 to 10 cm thick beds of red and green shale alternating with 5 to 10 cm thick beds of fine, micaceous sandstone. These beds are overlain by thin, cross-laminated beds of medium to coarse sandstone, more typical of the lower Mt. Simon. The coarser sandstone is exposed on the east side of Flood Road at the intersection with Garage Road.

These shaly beds in the Mt. Simon are widespread in the area east of Black River Falls. Although this facies of the Mt. Simon has not previously been widely recognized or studied, recent work has shown that it is widely distributed in eastern Jackson County. A test hole drilled by the Wisconsin Geological Survey encountered 20 m of alternating sandstone and red and green shale in the area of City Point.

These shaly beds may have a significant influence on the hydrogeology of the region. A perched water table held up by these impermeable clay-shale layers in the otherwise permeable Mt. Simon is probably in part responsible for the extensive wetlands east of the Black River. These wetlands are of economic importance as peat deposits and for development as cranberry bogs.

STOP 5

Title: Battle Point Road Quartzite Quarry



Location: NW¼ sec. 9, T. 21 N., R. 2 W. Hatfield Southwest 7½-minute topographic quadrangle.

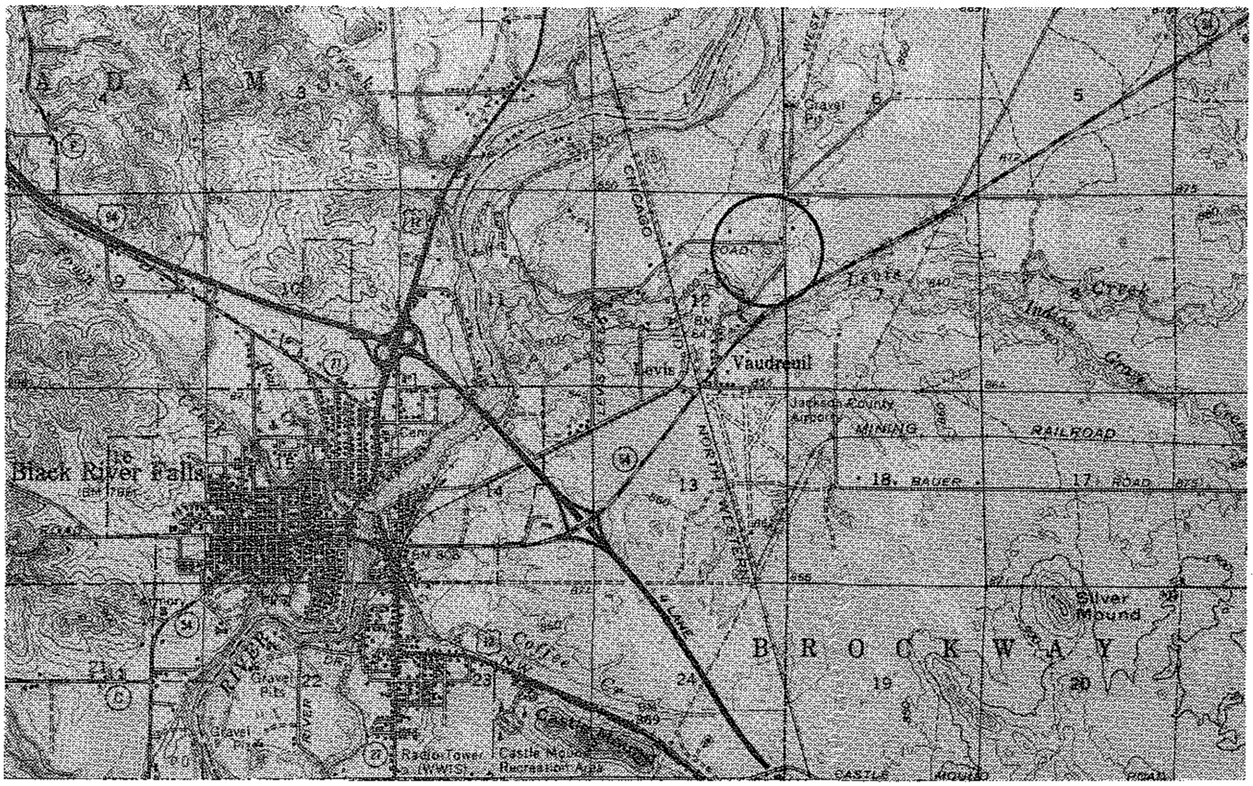
Author: B.A. Brown (1983)

This small quarry is developed on a basement high consisting of Precambrian quartzite. The outcrop is flanked by Mt. Simon sandstone, which locally contains clasts of the cherty quartzite.

The quartzite is difficult to characterize because it is highly brecciated and extensively veined with white quartz. No primary structures which would give clues to the original nature of the rock are visisble, except for the suggestion of crude bedding trending east-west across the exposure. This rock is different in appearance from the quartzose sediments associated with the iron formation in that it lacks the characteristic fine lamination and is not as ferruginous. In thin section it consists of a fine aggregate of quartz grains, similar in texture to metacherts exposed to the northeast in Wood County (Greenberg and Brown, 1983a). The textural similarity, and the apparent lack of deformation and metamorphism characteristic of the older rocks suggest that these rocks may be correlative with other sedimentary rocks deposited during the anorogenic period (1760-1500 m.y. ago) which followed the Penokean orogeny.

STOP 6

Title: Precambrian Iron Formation, Levis Creek Road



Location: NE¼ sec. 12, T. 21 N., R. 4 W. Black River Falls 15-minute topographic quadrangle.

Author: B.A. Brown (1983)

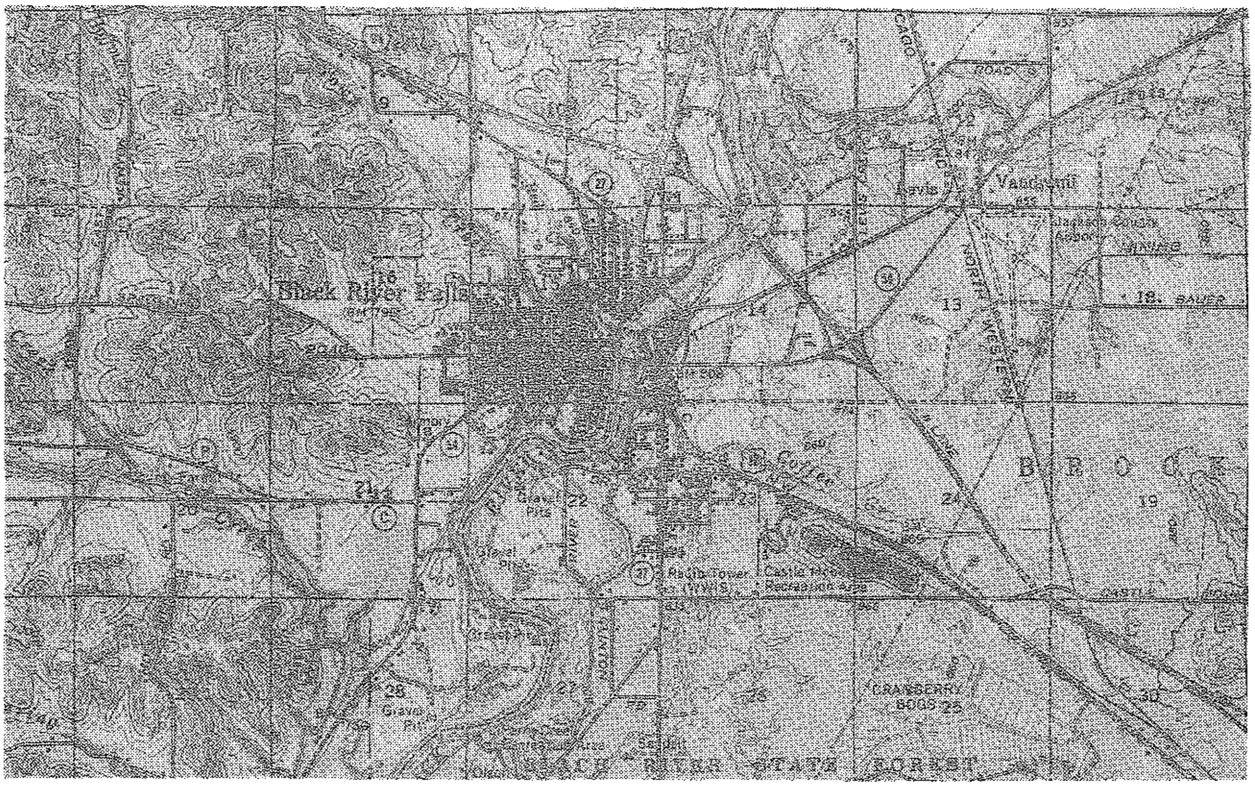
Precambrian Iron Formation is exposed on a small hill near the junction of Levis Creek Road and West Bottom Road. Several other prominent hills in this area, including Iron Mound--the site of the Jackson County Iron Mine, consist of similar iron formation. These outcrops are typical of the exposures which were found by early iron prospectors in the 19th Century. All of these represent resistant highs on the Precambrian bedrock surface, which were later surrounded and covered by Mt. Simon Formation. On the flanks of these mounds, coarse pebbles of the iron formation are commonly seen in the adjacent sandstone beds.

The iron formation consists of alternating thin beds of chert and magnetite. In weathered exposures such as this one, magnetite is commonly weathered to hydrous iron oxides. The iron formation is interbedded with garnet-bearing amphibolites, which probably originated as mafic volcanic rocks, and andalusite-bearing siliceous biotite schists, which probably were originally sediments (see Supplemental Locality E).

The iron formation strikes west-northwest and dips about 70° to the southwest. This, and the other knobs of iron formation lie on a prominent east-west trending magnetic anomaly which can be traced several kilometres to the east and west. Jones (1978) considered the Jackson County iron formations to be more typical of the Algoma type, common to the Archean granite greenstone terranes, rather than the Proterozoic iron ores of the Lake Superior region.

STOP 7

Title: Black River Falls Granite



Location: NE¼SE¼ sec. 15, T. 21 N., R. 4 W. Black River Falls 15-minute topographic quadrangle. Outcrop occurs along river downstream from dam and north of State Highway 54.

Author: B.A. Brown (1983)

The granite at Black River Falls is a typical, largely undeformed, late-tectonic Penokean granite that is intrusive into the Archean gneiss complex. The granite crops out below a power generating dam in the center of Black River Falls. The pink, medium-grained biotite granite consists of nearly equal amounts of quartz, alkali feldspar, and normally zoned andesine-oligoclase (An 25-33). Biotite comprises approximately 5 percent of the unit, and retrograde chlorite derived from biotite constitutes another 1 percent. Trace minerals include sphene, allanite, and epidote.

The feldspars, which often exhibit nearly euhedral outlines, range from 1 to 4 mm. The alkali feldspars consist of both microcline and perthite, with microcline dominating. Granulated and recrystallized quartz grains, from 0.1 to 1 mm, have been derived from quartz grains which were originally as large as 2 mm. Anhedral to subhedral biotite is often partially or completely replaced by chlorite. Selective sericitization of the feldspars has resulted in extensively altered plagioclase, moderately altered perthite, and nearly unaltered microcline.

On both the mesoscopic and microscopic scales, the granite at Black River Falls appears unfoliated and unlineated, despite microscopic textures such as granulation of quartz, which indicate that it has been deformed and recrystallized. This unit was probably emplaced during the late stages of Penokean deformation.

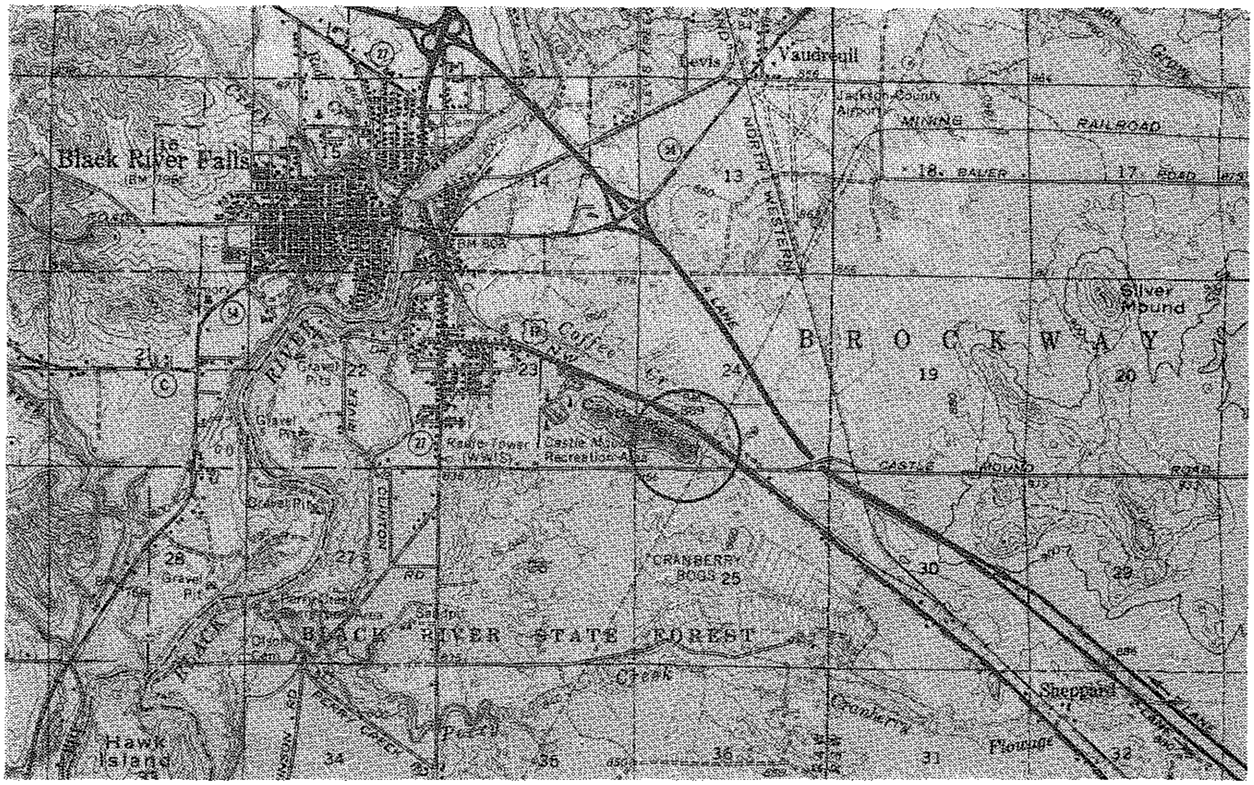
U-Pb analyses on two zircon fractions (Van Schmus, 1980) confirm that the Black River Falls granite is a Penokean granite and, like the granite exposed to the north of Lake Arbutus, is about 1840 $\pm$ 20 m.y. old.

Except for a small exposure of banded gneiss several hundred metres downstream (Supplemental Locality B), this is the southernmost outcrop of Precambrian rocks along the Black River. The character of the Black River changes markedly at this point. Below Black River Falls, the river meanders through a broad valley floored largely by Mt. Simon Formation, until it reaches the Mississippi near La Crosse. Above Black River Falls, the channel is narrow and floored by Precambrian rocks. River flow above Black River Falls is quite variable and subject to sudden increases common in response to rains in the upper drainage basin.

A flood in the early 1900s washed out an earlier dam and destroyed much of the low-lying parts of Black River Falls, including much of the present business district.

STOP 8

Title: Castle Mound



Location: SW¼ sec. 24, T. 21 N., R. 4 W. Black River Falls 15-minute topographic quadrangle.

Author: B.A. Brown (1983)

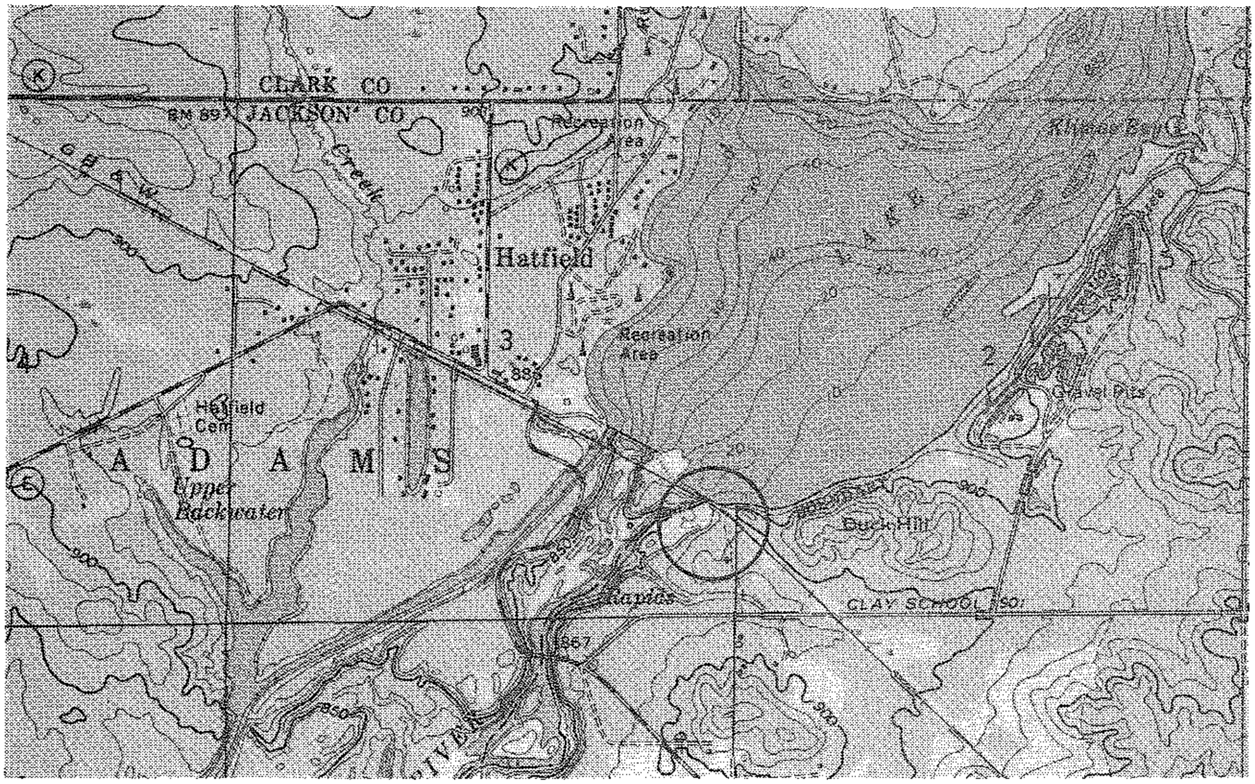
Castle Mound is an elongate ridge capped by the Galesville Member of the Wonewoc Formation. The Mt. Simon Formation forms the base of the ridge up to an elevation of about 995 feet (306 m), but is largely covered by talus. The Eau Claire Formation occurs from 995 to 1025 feet (306 - 315 m) in elevation, and is also largely talus covered. Fragments of Eau Claire found on the slopes commonly contain abundant small white phosphatic brachiopods and a noticeable amount of glauconite.

The Wonewoc is locally cemented by silica, making it a particularly resistant caprock. This cemented material is a very hard gray quartzite, similar to that which caps Silver Mound, a prominent hill to the northwest between Hixton and Alma Center (see Supplemental Locality F).

The eastern end of Castle Mound provides a panoramic view of the Black River valley. A pediment surface developed on the Mt. Simon Formation stretches eastward toward the divide which separates the Black River basin from the basin of glacial Lake Wisconsin. This surface is dotted with hills which are erosional remnants of Paleozoic rocks, such as Saddle Mound to the northeast (Supplemental Locality H). The higher hills are typically capped by the Lone Rock Formation. The lowlands are largely wetlands, which have been extensively developed for cranberry culture, such as the bog complex visible to the southeast of Castle Mound.

STOP 9

Title: Hatfield Gneiss, Lake Arbutus Dam



Location: SE¼ sec. 3, T. 22 N., R. 3 W. Hatfield 7½-minute topographic quadrangle. Outcrop along the Black River below the eastern half of Arbutus Dam. Approach is on 0.3 km long gravel road that intersects Clay School Road 0.2 km west of the Green Bay and Western RR tracks. Additional outcrop occurs for 1 km downstream from dam.

Authors: W.R. Van Schmus and R.S. Maass (1980)

Summary: The main outcrop area immediately below the dam is one of the largest, if not the largest, outcrop of Archean rocks in Wisconsin. The principal unit is the Hatfield gneiss, an interlayered sequence of quartzo-feldspathic gneisses and minor amphibolite. The rocks are interpreted as a metavolcanic sequence that was formed 2815 m.y. ago and deformed at least twice, with the latest deformation and metamorphism occuring during the Penokean orogeny, 1850 m.y. ago. Post-deformational cross-cutting mafic dikes are also present at this locality.

The principal unit exposed (fig. 9) is the Hatfield gneiss, an interlayered sequence of granitic to tonalitic gneiss with concordant layers of amphibolite. Over much of the outcrop the layers are 0.1 to 3 cm thick, pink to gray, quartzo-feldspathic gneiss. In some parts the layers are thicker,

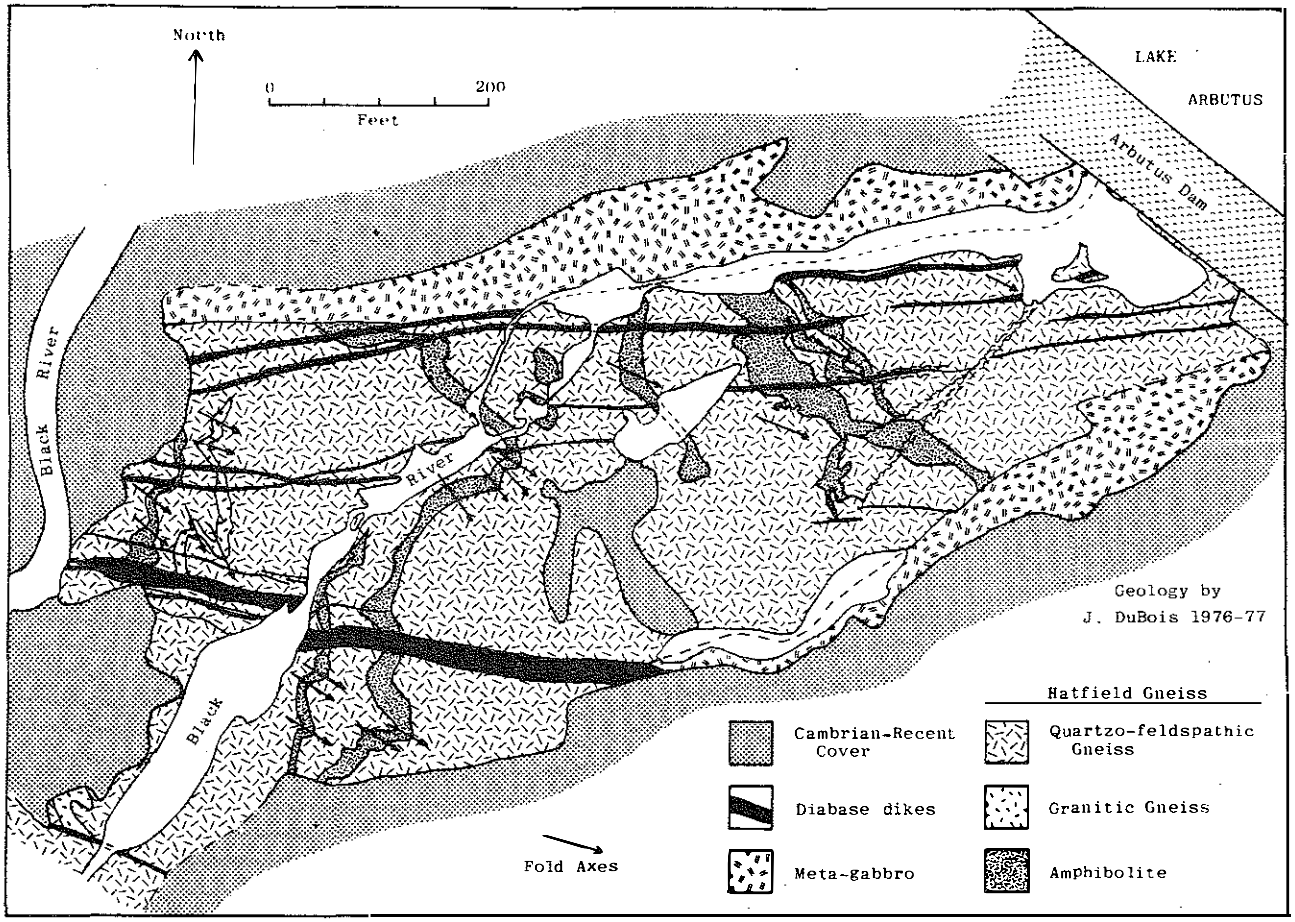


Figure 9.--Geologic map of Archean bedrock exposed south of Arbutus Dam.

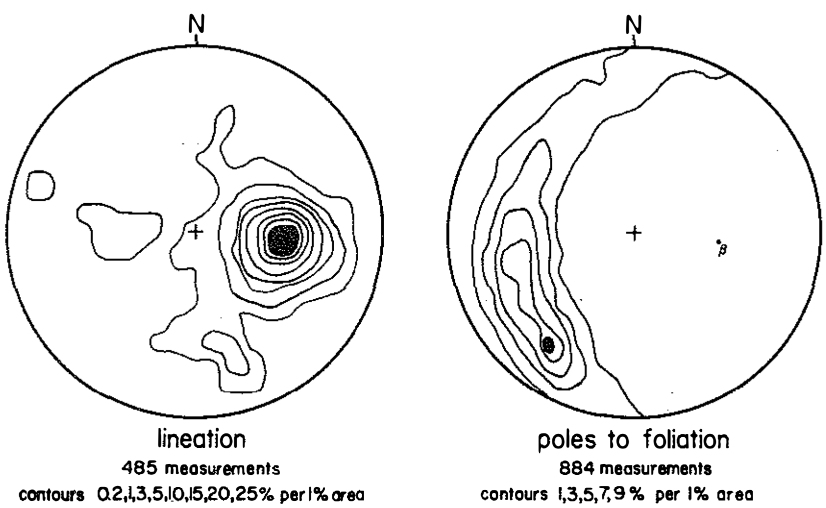


Figure 10.--(Maass and Van Schmus, 1980, fig. 11.). Lower hemisphere stereographic projections of structures in the Hatfield gneiss. (left) Lineations defined by fold axes, crenulations, and mineral elongations. The mean orientation of the lineations is S. 84° E. with a plunge of 51° ESE. (right) Plot of poles to foliation yields a mean for β trending S. 84° E. with a plunge of 52° ESE, virtually identical to the mean orientation for the lineations.

approaching several metres of massive gneiss. Folding and foliation are best displayed in the thinner-banded portions. The quartzo-feldspathic gneiss has a granoblastic texture and consists of equal amounts of quartz, plagioclase, and microcline. Mafic minerals represent less than 10 percent in most instances. Normative abundances based on bulk chemical analyses show that the amount of quartz is approximately constant and that plagioclase/orthoclase ratios vary from about 1:1 (adamellite) to primarily plagioclase (tonalite).

The amphibolite is interlayered with the quartzo-feldspathic gneiss and consists primarily of hornblende with about 20 percent epidote. The amphibolite has been deformed along with the rest of the gneiss and is interpreted as originally concordant. The entire assemblage is interpreted as having formed from an interlayered sequence of volcanic flows, pyroclastic rocks, or sills (DuBois and Van Schmus, 1978). The major metamorphism currently recorded by the rocks is amphibolite facies. Relict pyroxene has been found in some of the quartzo-feldspathic gneiss samples, suggesting either primary volcanic pyroxene or an earlier, higher-grade period of metamorphism.

The Hatfield gneiss has been subjected to an isoclinal folding event (F_1) which produced an axial planar foliation parallel to the layering, except in fold hinges where the foliation transects the layering. The foliation was then tightly to openly folded during F_2 deformation; the axial planes of these folds are at high angles to the foliation. F_1 folds are rarely visible, but F_2 folds are conspicuous wherever the banding is readily apparent.

Lineations (fold axes, crenulations, mineral lineations) and foliations were measured in the gneiss along a 0.6 km long stretch of the river. Poles to foliation define a β axis which is essentially identical to the orientation of the main grouping of the linear structural elements (fig. 10). Fold axes, when plotted separately, fall into the two groups in the southeast quadrant of the stereonet, with the vast majority plotting in the main group.

A group of F_1 fold axes in the core of a large tight F_2 fold were plotted separately from the rest of the linear structural elements. The folding in this vicinity is highly complex, resulting in numerous and diverse interference patterns from the folding of F_1 axes. The axes of these F_1 folds plot in all four quadrants of the stereonet with plunges ranging from horizontal to vertical. Girdles which would indicate a later simple folding pattern of the F_1 axes do not exist, and the interference patterns are therefore believed to be the result of inhomogeneous deformation in the core of the F_2 fold.

Although F_2 deformation is inhomogeneous in this relatively small area of the outcrop, the outcrop as a whole exhibits homogeneous deformation, as demonstrated by the tight distribution of 94.5 percent of the linear structural elements. F_1 fold axes are never exposed in 3 dimensions (except in the anomalous area just discussed), thus their trend and plunge are unknown. The age of F_1 folding is unclear, but F_2 folding is probably Penokean.

Zircon has been separated from a tonalitic layer of the gneiss on the west bank of the Black River, about 1 km downstream from the dam. The zircons are brown, euhedral crystals with normal igneous zoning and no signs of significant overgrowths or relict cores. U-Pb analyses on several fractions show that this unit is essentially the same age (2815 $\pm$ 20 m.y. old) as other Archean gneisses in central Wisconsin. This age is interpreted as the time of crystallization (volcanism) of the protolith of the Hatfield gneiss. Rb-Sr analyses from several samples collected in the area of Stop 9 and further downstream do not plot coherently on an isochron diagram, indicating partial resetting during subsequent metamorphism. However, there are no indications of crustal history older than 2800 Ma.

SUPPLEMENTAL LOCALITIES

The following are additional localities of geologic interest in the Black River Falls area.

Precambrian Rocks

LOCALITY A: Gneiss, Powerhouse on Black River below Lake Arbutus Dam

LOCATION: NW¼ sec. 16, and SE¼ sec. 9, T. 22 N., R. 3 W. Black River Falls 15-minute topographic quadrangle, Jackson County. Semi-continuous exposure occurs on both banks of the Black River for approximately 1.5 km upstream of the powerhouse.

AUTHOR: R.S. Maass (1980)

DESCRIPTION: This is an excellent exposure of Archean gneisses and presumed early Proterozoic andesitic and dacitic dikes, plus a gabbro of unknown age. Layering in the gneisses ranges from thin to massive and composition ranges from granite to diorite, with tonalite to granodiorite predominant. Many of the layers are augen gneisses containing feldspar porphyroclasts, averaging 1 cm in size, but also containing quartz porphyroclasts. The gneisses have been intruded by andesitic to dacitic dikes which have been deformed and recrystallized. Some of the dikes are porphyritic. A gabbro unit near the powerhouse is weakly foliated, but the origin of the foliation is unclear. The gneisses have been metamorphosed to amphibolite facies, but it cannot be ascertained at what grade the crosscutting dikes were recrystallized.

Isoclinal F_1 folding produced an axial planar foliation in the gneisses striking N. 45° W. and dipping vertically which is relatively consistent in orientation in the downstream three-quarters of the exposure. Tight F_2 folds become progressively more common and disharmonic toward the upstream end of the outcrop.

LOCALITY B: Gneiss and tonalite, Black River Falls

LOCATION: NE¼NE¼ sec. 22, T. 21 N., R. 4 W. Black River Falls 15-minute topographic quadrangle, Jackson County. East bank of the Black River, 0.3 km west of U.S. Hwy. 12. Dirt path starting near sharp bend in road leads to outcrop.

AUTHOR: R.S. Maass (1980)

DESCRIPTION: The gneiss is banded and consists of quartz, plagioclase, alkali feldspar, biotite, hornblende, chlorite, and epidote. Thin to thick layering in the gneiss varies from compositional extremes of quartzo-feldspathic bands containing as much as 40 percent alkali feldspar to bands consisting entirely of hornblende, plagioclase, and minor quartz. The gneiss has been intruded by fine-grained diorite and diabase dikes which have been metamorphosed to amphibolite facies and by a fine-grained lineated tonalite which was probably subjected to the same grade of metamorphism. Age relationships among the intrusive units have not been established due to lack of suitable field relationships. Isoclinal F_1 folding produced an axial planar foliation which has been openly to tightly folded during the F_2 phase of the Penokean deformation.

F_2 fold axes in the gneiss, statistically defined β from a stereographic plot of poles to foliation, and mineral lineations in the intrusive units are essentially colinear, trending southeasterly and plunging between 50° and 75°.

LOCALITY C: Gneiss at Morrison Creek

LOCATION: NE corner sec. 22, T. 22 N., R. 3 W. Hatfield 7½-minute topographic quadrangle, Jackson County. Outcrop occurs in bed of Morrison Creek, downstream from County Hwy. K bridge.

AUTHORS: W.R. Van Schmus and R.S. Maass (1980)

DESCRIPTION: The unit is a pink, fine-grained quartzo-feldspathic gneiss that is similar to much of the gneiss along the Black River downstream from Arbutus Dam. Rb-Sr analyses of samples of gneiss from Morrison Creek do not define a good isochron, but they appear to be less disturbed than those from near Arbutus Dam, and are consistent with an age of 2,800 Ma for the gneiss. Chemical alteration during Penokean metamorphism was less severe here than at Arbutus Dam. The gneiss does have a pronounced foliation, with a general strike of N. 16° W. and a dip of 78° E.

LOCALITY D: Precambrian siliceous sediments, Silver Mound (Not to be confused with Locality F)

LOCATION: NE¼NW¼ sec. 20, T. 21 N., R. 3 W. Black River Falls 15-minute topographic quadrangle, Jackson County. Follow a dirt road from Bauer Road to reach Silver Mound.

AUTHOR: R.S. Maass (1980)

DESCRIPTION: The quartzite at Silver Mound is white, nearly pure, and strongly lineated. It is poorly exposed, occurring mostly as loose blocks on top of, and along the sides of, the mound. It is believed to have formed from chert beds associated with the Archean (?) volcanic rocks and iron formations of the region.

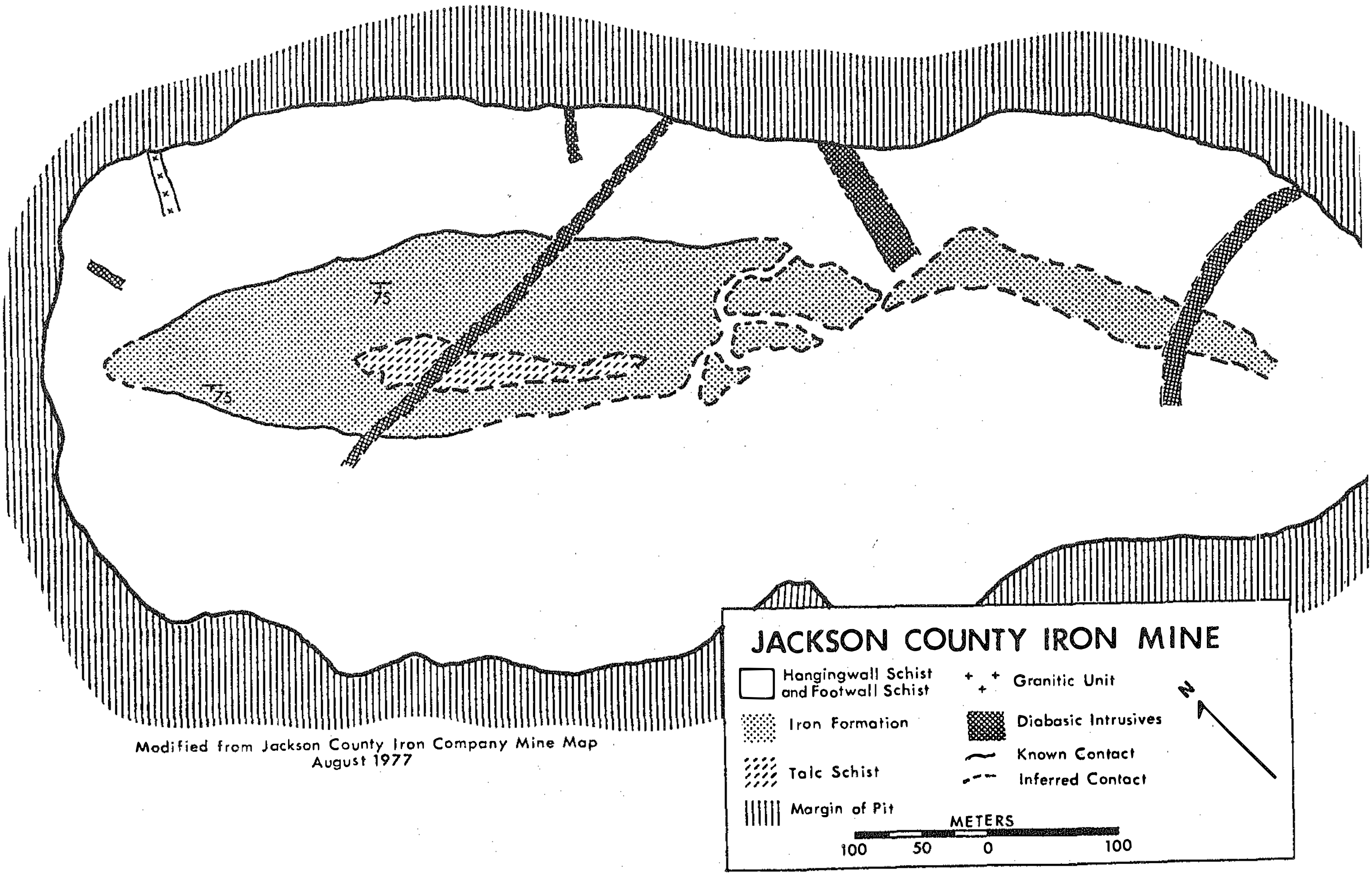
LOCALITY E: Jackson County Iron Mine

LOCATION: SE¼ sec. 15, T. 21 N., R. 3 W. Hatfield SW 7½-minute topographic quadrangle.

AUTHOR: David G. Jones (1977)

SUMMARY OF FEATURES

Precambrian iron formation, possibly Archean in age, crops out as low isolated mounds in Jackson County, Wisconsin. The Jackson County Iron Company owns and operates an open pit taconite mine and plant on the largest of these mounds. The iron formation is compositionally banded and composed primarily of quartz-biotite-garnet schist that has been highly weathered southwest of the ore body. An elongate zone of nearly pure talc schist is located near the center of the ore body.



Modified from Jackson County Iron Company Mine Map
August 1977

Figure 11.

Outcrop patterns, minor structures, and geophysical data suggest that the rocks of the area have been isoclinally folded about nearly vertical fold axes. The rocks have been metamorphosed to the lower amphibolite facies, and textural evidence indicates that they have been deformed and recrystallized.

The Precambrian rocks are unconformably overlain by Upper Cambrian conglomerate and sandstone.

INTRODUCTION:

The Jackson County Iron Mine, located near Black River Falls, Wisconsin, is an open pit taconite operation which produces about 750,000 tons of pellets per year. The ore body is a lens-shaped body 915 metres in maximum length within the mine and 150 metres in maximum width. The ore mineral is magnetite, and the grade of the iron formation usually varies between 20-50 percent, the average being 35 percent magnetite. Weathering has oxidized the iron formation to hematite, and the depth of oxidation seems to be controlled by the amount of fracturing in the rock. The iron formation strikes approximately northwest-southeast, and dips 70-75 degrees southwest and has undergone penetrative deformation. A highly sheared and recrystallized schist surrounds the iron formation. The lower or footwall schist is composed predominantly of quartz, biotite, chlorite, and garnet. Near the surface the upper or hangingwall schist is a soft, crumbly quartz-biotite-sericite schist, but at depth it resembles the footwall schist. A zone of talc schist is situated within the iron formation near the central portion of the pit and may have been structurally emplaced.

Within the Black River Falls area, local deposits of iron formation rise above the surrounding area in the form of low hills or knobs. Besides the site of the current operation there are three other potentially economic deposits. Ground magnetic surveys best delineate the location of the iron formation in the area.

DESCRIPTION OF ROCK UNITS:

Footwall Schist: This unit is a dark colored, highly foliated siliceous schist. It is structurally situated directly northeast of the iron formation (see map) and is in sharp contact with the iron formation. The mineral assemblages within the schist are:

1. quartz-biotite-plagioclase-garnet
2. quartz-biotite-muscovite-chlorite-andalusite
3. quartz-biotite-muscovite-garnet-staurolite-chlorite-plagioclase

Modal variations in quartz and biotite are obvious in hand sample, and compositional banding of quartz-rich and biotite-rich layers is evident locally. The banding parallels foliation and is, in places, intensely folded.

Texturally, the footwall schist is extremely variable, ranging from a highly foliated coarse-grained schist to a fine-grained, nearly granular rock within a few metres. The mineral assemblage, however, is constant.

Hangingwall Schist: The weathered rock which occurs along the southwest side and around the northwest end of the iron formation is called the hangingwall schist (fig. 11). The schist is composed primarily of quartz, biotite, and sericite. The depth of the weathered zone within the hangingwall schist seems to increase to the northwest and varies between 6 metres and 50 metres. Weathering is apparently controlled by a fracture pattern that locally increased the permeability of the rock.

Drill cores through the hangingwall schist exhibit a gradual decrease of weathering and clay content with depth until the unweathered schist is reached. The mineralogic assemblage and textural characteristics of this unweathered material are strikingly similar to those of the footwall schist. Even in thin section, no distinction can be made between the hangingwall and footwall schists.

Iron Formation: The iron formation is a highly deformed unit composed almost entirely of the following minerals:

quartz	ferroactinolite
magnetite	Ca-rich hornblende (hastingsite)
cummingtonite-grunerite	sphene
biotite	apatite
garnet	pyrite
calcite	

Compositional banding of the magnetite and quartz is prominent. The quartz bands range from a few millimetres to nearly a metre in thickness. This variation in thickness is in part structurally controlled. Some bands are formed of the assemblage garnet-amphibole-quartz. These bands may be distinct, having sharp contacts with the surrounding magnetite and containing very coarse-grained, reddish-brown garnet, or they may be zones of fine-grained pink garnets and chlorite. Band thickness varies from 0.5-5.0 cm. The garnet-amphibole-quartz assemblage also occurs as elongate pods up to 15 cm long. Other mineralogic assemblages exhibit compositional banding which contributes to the overall banded character of the iron formation. Some of the mineral assemblages are:

1. quartz-ferroactinolite-grunerite-magnetite
2. magnetite-grunerite-quartz-calcite
3. quartz-biotite-cummingtonite-magnetite
4. quartz-magnetite-ferroactinolite-hastingsite
5. quartz-grunerite-hastingsite-magnetite
6. quartz-magnetite-garnet-ferroactinolite-calcite-potassium feldspar
7. quartz-garnet-biotite-hastingsite

Garnets commonly appear in the iron formation as isolated prophyroblasts rimmed with either Ca-rich hornblende and biotite or pure Ca-rich hornblende which appears to replace the garnets. These porphyroblasts vary from a few millimetres to 3.0 cm in diameter. The amount of dark green Ca-rich hornblende can vary from a thin rim to a total replacement of the garnets. The crystal form of the original prophyroblasts decreases with increased replacement of garnets. Many of the prophyroblasts are ellipsoidal in cross-section with long axes parallel to foliation.

Another rock type found sporadically within iron formation is dark green, non-foliated to poorly-foliated amphibolite. Amphibolites are apparently concordant with the foliation in the iron formation and vary in thickness from 0.5 metres to 3 or 4 metres. They are usually in sharp contact with the iron formation. Again the mineralogy is extremely variable. The assemblages present include:

1. biotite-hastingsite-epidote-potassium feldspar
2. talc-grunerite-biotite-chlorite
3. grunerite-hastingsite-magnetite
4. biotite-hastingsite-scapolite-epidote

One striking characteristic of the amphibolites is that most of them display a distinctly splotchy texture owing to the presence of spherical aggregates of chlorite and/or Ca-rich hornblende surrounded by polygonized biotite. Dark green amphibolite layers are also found within the talc schist horizon and sometimes within the hangingwall and footwall schists.

Drill cores show zones of schist, texturally and mineralogically similar to the footwall schist, locally interlayered with the iron formation. Whether the schist layers are primary or structurally emplaced is not known.

The compositional banding in the iron formation provides an excellent means of viewing the minor structures in the rock. The structural style is more complex than initially evident. Parallel banding is the most conspicuous structural feature of the iron formation and probably represents transposed primary bedding parallel to foliation. Tight, small-scale, isoclinal folding occurs in some of these layers. The limbs of the minor folds have commonly been thinned while the hinge areas are thickened, rotated, and detached. Amphiboles within amphibole-rich layers define a lineation parallel to the axes of the minor isoclinal folds. The relationship between the folds and the straight banding is not everywhere apparent. In a few areas in the northeast wall of the pit, however, minor isoclinal folds can be found in place. Fold axes plunge 70-75 degrees in a southwesterly direction and are parallel to the lineations defined by the amphiboles. In such places it is apparent that the parallel and the highly deformed bands represent the limbs and hinges, respectively, of isoclinal folds. Quartz boudins of all sizes up to a metre in thickness occur in the iron formation. These boudins represent both isolated fold hinges and thickened, separated portions of fold limbs.

Two, or posssibly three, sets of broad, open folds have been overprinted onto the isoclinal folds. The broad, open folds can only be seen within the iron formation in the northeast wall of the pit.

Drilling indicates that the iron formation continues at depth in approximately the same attitude. The bottom of the ore body has not been located. Magnetic data show that locally the iron formation pinches out rapidly to the northwest but pinches and swells for about a mile to the southeast of the present pit.

The local outcrop pattern of the iron formation (fig. 11) indicates a distinct thickening and thinning. Presumably, this represents large-scale boudinage with nearly vertical axes, and is a result of the same deformation which produced the small-scale penetrative structures.

<u>Talc Schist</u>: A zone of talc schist is located within the iron formation in the eastern portion of the mine (see map). The long axis of the talc zone is about 200 metres long and is parallel to the structural grain of the iron formation. At its widest portion the talc schist approaches 50 metres. For

the most part, the talc schist is coarse-grained and nearly pure. One striking assemblage within the talc schist is composed of garnet prophyroblasts rimmed with cummingtonite and biotite associated with long (1.5 cm) prismatic blades of andalusite. The talc schist contains variable amounts of magnetite, which increases in abundance toward the contact with the iron formation. Pyrite appears to be concentrated in the iron formation and in a chlorite-biotite-talc schist, both located near the edge of the talc schist zone, but pyrite is not found in the nearly pure talc schist. Near the southwest side of the talc schist zone, partially chloritized garnets weather out of a biotite-chlorite-talc-garnet schist and are found as small green nodules at the surface. Other mineral assemblages that occur locally within the talc zone or at the contact between the talc zone and the iron formation are:

1. talc-cummingtonite
2. quartz-biotite-talc-magnetite
3. talc-hastingsite-biotite-magnetite-apatite
4. talc-garnet-andalusite-cummingtonite

The talc is too incompetent and the outcrop too limited for structural determinations, but some of the nearly pure talc does exhibit well developed crenulations.

Other Rock Units: On the upper bench, at the northwest end of the mine, a zone of granitic material crops out. The contacts of this zone and the footwall schist are sharp and parallel with the foliation in the footwall schist. From the far side of the mine the granite is conspicuous as a narrow white vertical band in the dark footwall schist. The granite is highly deformed, with large augen (1 cm) of K-feldspar embedded in a matrix of predominantly quartz and K-feldspar. The recrystallized texture and concordant nature indicate emplacement prior to regional metamorphism and deformation.

Five diabase dikes ranging in size from 2 metres to approximately 20 m in thickness transect the mine in various orientations. The largest of the five displays a coarse-grained center and fine-grained margins. There is no evidence of any chemical alteration of the adjacent rock due to these dikes.

UNCONFORMITY:

Overlying the Precambrian rocks are Upper Cambrian sandstones. The contact is unconformable, and immediately above the undulating Precambrian surface is a conglomerate containing clasts of angular to subangular hematitic iron formation in a matrix of well sorted and well rounded, coarse-grained, quartz sand. The hematitic clasts range up to nearly 2 metres in diameter. The conglomerate grades rapidly upward into poorly indurated Upper Cambrian sandstone, which thickens locally to the southeast and in places contains thin clay partings.

CONCLUSION:

The outcrop pattern suggests that large-scale boudinage of competent iron formation within incompetent schist is a dominant structural feature. The iron formation appears to have been isoclinally folded about a nearly vertical axis. Small-scale structures within the iron formation which support this hypothesis include isolated and rotated fold hinges, mineral lineations, and the predominance of parallel, compositional bands.

The mineralogic and textural similarities between the footwall schist and the unweathered portion of the hangingwall schist suggest that the two schists are a single folded stratigraphic unit.

The accompanying map of the mine illustrates that the major part of the ore body is the partially detached hinge of an isoclinal fold. One line of evidence which supports this interpretation is that magnetic surveys do not indicate that the ore body extends to the northwest beyond the zone of talc schist. The disjointed northeast limb of the major fold, however, seems to continue to the southeast in what appears to be a slightly offset segment of the iron formation which has a more northerly trend.

LOCALITY F: Eau Claire Sandstone and Wonewoc Formation of Ostrom (1966)

LOCATION: SW¼ sec. 35, T. 23 N., R. 5 W. Black River Falls 15-minute quadrangle. At Silver Mound north of Hwy. 95 between Alma Center and Hixton, and in the field on the southwest of Silver Mound.

AUTHORS: H. Klemic and J.M. Ohlson (1973)

DESCRIPTION: Fossiliferous and glauconitic sandstone beds of the Eau Claire Sandstone are well exposed in a small excavation on a promenence in the field southwest of Silver Mound, and loose fossiliferous Eau Claire occurs at an altitude of 1025 feet (312 m) on the southern tip of Silver Mound near the highway.

Silver Mound is an important archeological locality. The mound is capped by the Wonewoc Formation. The lower part of the formation is largely concealed. The upper most 100 feet (30 m) or so of beds, however, is thoroughly cemented by silica, and the rock is a brittle quartzite. This rock was extensively used by prehistoric Indians for the manufacture of tools and weapons. Artifacts are numerous in the fields surrounding the southern part of Silver Mound, and artifacts and whitish flakes of quartzite from this locality are widespread in Jackson County.

Similar quartzite occurs in lesser amounts on a ridge several kilometres northwest of Silver Mound. The source of the silica that cemented the sandstone and the conditions under which it was deposited in the formation of the quartzite in this almost isolated occurrence require an explanation. There is no lack of silica in the Upper Cambrian strata of this general area, but most of it is in the relatively inert form of quartz sand. Therefore, some local chemical environment that differed from the general conditions must have made silica available in solution. Perhaps the chemical environment of the fossiliferous beds, particularly of the coquina layers, may have been the source of the silica. As previously described, the quartz sand grains in contact with the phosphatic brachiopod shells have partially dissolved into hemispherical forms having their flat surfaces against the shell surfaces. The chemical environment that produced this result in the Eau Claire and the Lone Rock, both of which are fossiliferous and contain phosphatic brachiopods, would have made available large quantities of silica in solution. Such silica-bearing waters percolating from the fossiliferous Lone Rock Formation may have deposited the silica cement in the Wonewoc Formation at Silver Mound.

Small zones of silicified sandstone a few centimetres thick, in the Mount Simon Sandstone near its contact with the Eau Claire Sandstone have been noted in several places in Jackson County.

LOCALITY G: Wavellite occurrence in the Eau Claire Formation

LOCATION: SW¼ sec. 23, T. 22 N., R. 4 W. Black River Falls 15-minute quadrangle. Roadcut on East Snow Creek Road.

AUTHORS: H. Klemic and J.M. Ohlson (1973)

DESCRIPTION: Wavellite ($Al_3(PO_4)_2(OH)_3 \cdot 5H_2O$) occurs as thin botryoidal crusts, small spherical masses, and as cement in the sandstone at this outcrop and at several other places where the Eau Claire is exposed in this general area. The source of the phosphorus is believed to have been phosphatic fossil material such as the phosphatic brachiopod shells in the Eau Claire Sandstone.

The Wonewoc Formation which crops out on the west side of the road is weakly cemented, very porous and permeable sandstone. It is coarser in grain size than the underlying rock and is thoroughly leached. The Wonewoc-Eau Claire contact zone is favorable for the development of a perched water table in places where shale or clay is abundant in the Eau Claire.

Wavellite probably occurs in many places in Wisconsin where the Eau Claire Sandstone is present and where conditions for movement of ground water were comparable to those in this area. In addition, similar conditions for occurrences of wavellite in association with the Lone Rock Formation may exist. Wavellite, however, may be readily overlooked, particularly in cases where it contains surficial stains of iron oxides.

LOCALITY H: Saddle Mound, north of Wisconsin Highway 54.

LOCATION: NE¼ sec. 33, T. 22 N., R. 1 W. Hatfield SE, 7½-minute topographic quadrangle.

AUTHORS: H. Klemic and J.M. Ohlson (1973)

DESCRIPTION: The crest of the mound at the lookout tower is capped by about 15 metres of the Lone Rock Formation. Glauconitic sandstone is well exposed in a small abandoned quarry near the foot of the tower, and Ostrom's (1966) Birkmose Member of the Lone Rock Formation is exposed near the guard rail east of the tower.

The Wonewoc Formation is well exposed on the steep southern slopes of the mound. Minor amounts of weathered fossiliferous sandstone, probably of the Eau Claire Formation, can be found on the spur on the northwestern side of the mound near an altitude of 1100 to 1130 feet (335 to 344 m). Most of the Eau Claire, however, is concealed by debris from the overlying formations, and some of the loose fossiliferous rock on the lower slopes is talus from the Lone Rock Formation.

The view of the surrounding countryside of the driftless area is excellent from the abandoned fire tower, and well worth the climb.

LOCALITY I: Belle Mound scenic overlook.

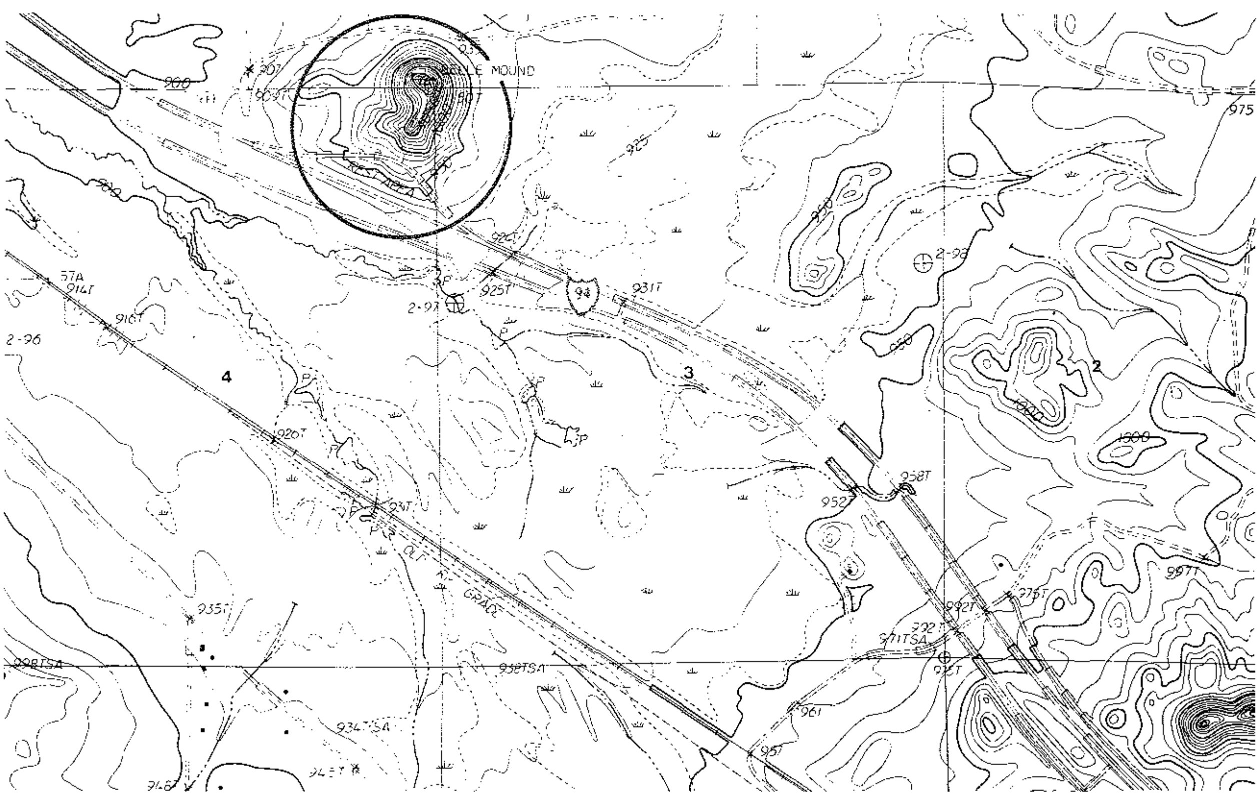
LOCATION: NE¼NE¼ sec. 4, T. 20 N., R. 3 W. Millston 7½-minute topographic quadrangle. Turn off northbound I-94 at "Scenic View" sign near milepost 123.

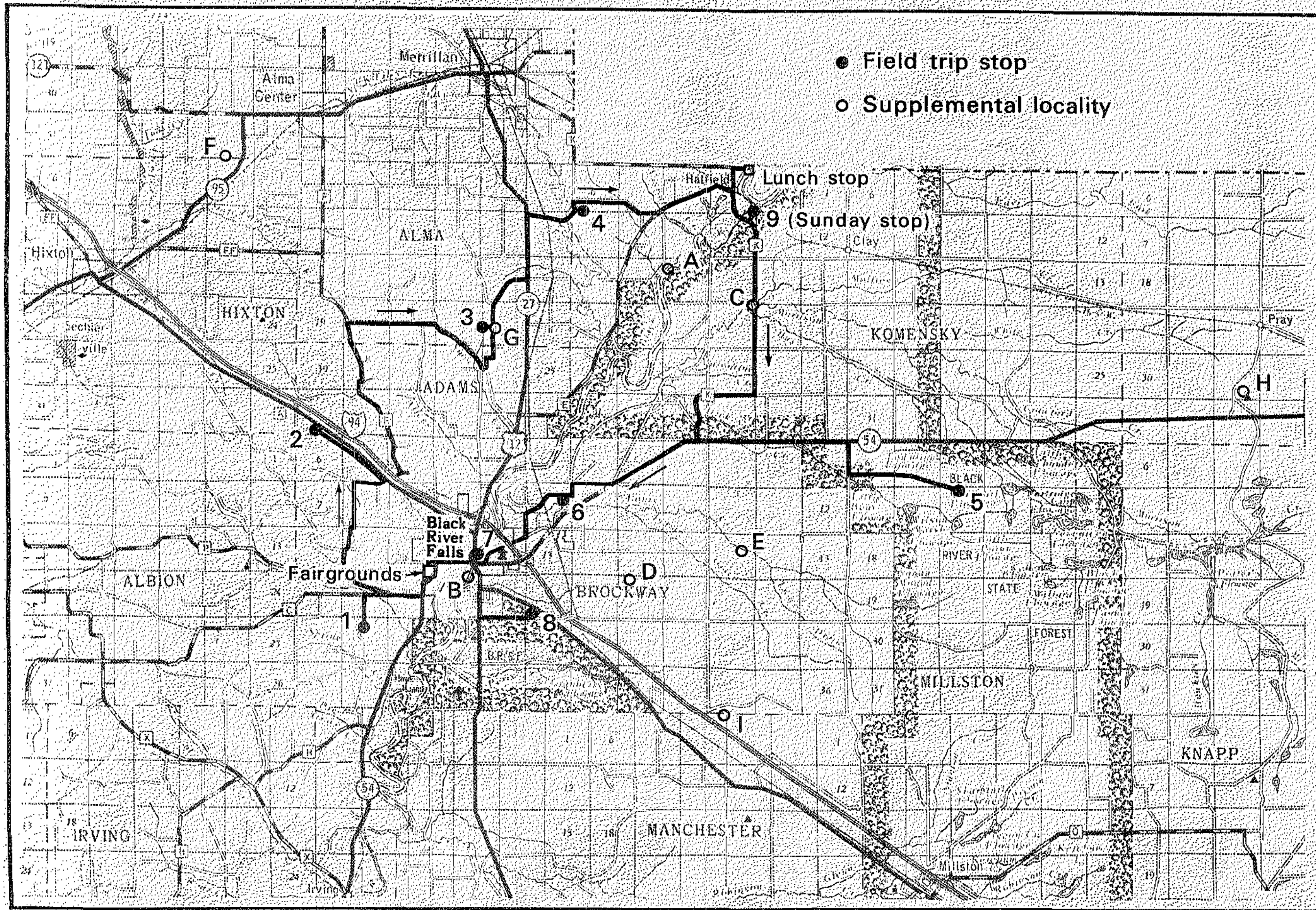
AUTHOR: B.A. Brown (1983)

DESCRIPTION: Belle Mound is an erosional remnant capped by sandstone of the Wonewoc Formation. The top of the mound is at elevation 1154 feet (352 m), about 77 m above the surrounding plain. The erosional surface below is developed on the Mt. Simon Formation which, along with the Eau Claire Formation, is covered by talus on the lower slopes. Medium- to coarse-grained quartz sandstone of the Wonewoc is exposed on the upper slopes and at the summit. The sandstone is heavily cemented by iron oxide.

The mound provides an excellent view of the surrounding terrane. The pit and dumps of the Jackson County Iron Company mine are visible to the northwest. Several of the small hills beyond the mine workings consist of Precambrian bedrock. Hills to the south and east are capped by Tunnel City Group. The wetlands which cover much of the surrouding plain are probably caused by a perched water table on shaly beds in the Mt. Simon.

It is a long climb to the top, but the view of the typical driftless area landscape is worth the effort.





● Field trip stop
○ Supplemental locality
Lunch stop
9 (Sunday stop)
Black River Falls
Fairgrounds
Merrillan
Alma Center
Hatfield
Hixton
Clay
Pray
Millston
Irving
ALMA
HIXTON
ADAMS
ALBION
BROCKWAY
KOMENSKY
BLACK RIVER STATE FOREST
MILLSTON
KNAPP
MANCHESTER
IRVING