GEOLOGY OF WISCONSIN - OUTCROP DESCRIPTIONS

In 1976 the University of Wisconsin System - Central Administration provided special funding for the development of a field course on the Geology of Wisconsin. The initial descriptions were prepared by Professor G.L. La Berge (UW-Oshkosh) with the participation of Professors P.E. Myers (UW-Eau Claire), D.M. Mickelson (UW-Madison), and M.E. Ostrom (Geological and Natural History Survey, UW-Extension).

A major product of the development of this course is a series of over 100 descriptions of outcrops selected to illustrate various geologic formations, features, and characteristics in Wisconsin. Descriptions are loose-leaf, one to ten pages in length, including specific location with map at a scale of not less than one inch equals one mile, the geology usually with a photograph or sketch of the outcrop, a discussion of the significant geologic features, and a list of pertinent references. As additional outcrop descriptions are prepared, they will be added to the series.

An index of available descriptions is attached. The title of the outcrop is geographic, whereas the location is given to the appropriate section. For instance, Friendship Mound is catalogued as AD 17/ 6E/ 5, referring to Adams County (AD), T. 17 N. (17/), R. 6 E. (6E/), Section 5. Cost per outcrop is $1.00 each; the entire set can be purchased for $50.00. Please allow two weeks for processing and delivery. Inquiries should be directed to Map and Publication Sales Office, 608-263-7389.

When necessary to cite a particular description in the literature, we recommend the following citation (using Friendship Mound as an example):

Ostrom, M.E., 1978, Friendship Mound: Wisconsin Geological and Natural History Survey, Geology of Wisconsin Outcrop Description Series AD 17/6E/5, 2 p.

COUNTY ABBREVIATIONS

Adams	AD	Iron	IR	Portage	PT
Ashland	AS	Jackson	JA	Price	PR
Barron	BR	Jefferson	JE	Racine	RA
Bayfield	BA	Juneau	JU	Richland	RI
Brown	BN	Kenosha	KE	Rock	RO
Buffalo	BF	Kewaunee	KW	Rusk	RU
Calumet	CA	La Crosse	LC	St. Croix	SC
Chippewa	CH	Lafayette	LF	Sauk	SK
Clark	CK	Langlade	LA	Sawyer	SW
Columbia	CO	Lincoln	LN	Shawano	SH
Crawford	CR	Manitowoc	MN	Sheboygan	SB
Dane	DN	Marathon	MR	Taylor	TA
Dodge	DG	Marinette	MT	Trempealeau	TR
Door	DR	Marquette	MQ	Vernon	VE
Douglas	DS	Menominee	ME	Vilas	VI
Dunn	DU	Milwaukee	ML	Walworth	WW
Eau Claire	EC	Monroe	MO	Washburn	WB
Florence	FE	Oconto	OC	Washington	WN
Fond du Lac	FL	Oneida	ON	Waukesha	WK
Forest	FR	Outagamie	OU	Waupaca	WP
Grant	GR	Ozaukee	OZ	Waushara	WS
Green	GN	Pepin	PP	Winnebago	WI
Green Lake	GL	Pierce	PI	Wood	WD
Iowa	IW	Polk	PK		

Title	Location	Author	Geology
Upper Wis. Dells	AD 14/ 6E/ 28	J.W. Attig L. Clayton	Quaternary
Friendship Mound	AD 17/ 6E/ 5	M.E. Ostrom	Cambrian
Mt. Whittelsey	AS 44/ 2W/ 9a	G.L. La Berge	Precambrian
Mellen Gabbro	AS 45/ 2W/30	G.L. La Berge	Keweenawan
Mellen Granite	AS 45/ 2W/31	G.L. La Berge	Keweenawan
White River	AS 46/ 4W/ 6	M.E. Ostrom	Keweenawan
South Fish Creek	BA 47/ 5W/20	M.E. Ostrom	Keweenawan
Kittell Falls	BN 23/21E/32	M.E. Ostrom	Silurian, Ordovician
Yellow River at Cadott	CH 29/ 6W/31	P.E. Myers	Precambrian
Irvine Park	CH 29/ 8W/31	M.E. Ostrom	Cambrian, Precambrian
Tilden	CH 29/ 9W/ 7	M.E. Ostrom	Cambrian (Upper)
Jim Falls	CH 30/ 7W/30	P.E. Myers D.A. Maercklein	Precambrian (Middle)
Fisher River	CH 31/ 6W/ 4	P.E. Myers	Precambrian
Chippewa River at Cornell	CH 31/ 6W/18	P.E. Myers	Precambrian
Chippewa River at Holcombe Dam	CH 32/ 6W/28	P.E. Myers	Precambrian
Flambeau Ridge	CH 32/ 7W/ 1	P.E. Myers	Precambrian
Neillsville Mounds	CK 24/ 2W/ 4	P.E. Myers	Cambrian
Neillsville	CK 24/ 2W/10	P.E. Myers	Cambrian, Precambrian
Sidney	CK 24/ 2W/20	P.E. Myers	Precambrian
Cunningham Creek	CK 24/ 2W/26	P.E. Myers	Cambrian, Precambrian
Naedler Quarry Granton	CK 25/ 1W/35	P.E. Myers	Precambrian
Greenwood	CK 26/ 3W/ 3	P.E. Myers	Precambrian
South Fork of the Eau Claire River	CK 26/ 4W/ 1	P.E. Myers	Precambrian
Hay Creek Dam	CK 26/ 4W/26	P.E. Myers	Cambrian, Precambrian
South Fork of the Eau Claire River at Mead Dam	CK 27/ 3W/29	P.E. Myers	Precambrian
Prairie du Chien	CR 7/ 6W/29	M.E. Ostrom	Ordovician

Title	Location	Author	Geology
Marietta Valley	CR 8/ 3W/10	M.E. Ostrom	Cambrian
Easter Rock	CR 8/ 3W/21	M.E. Ostrom	Ordovician, Cambrian
Neda	DG 11/16E/ 1	G.L. La Berge	Silurian, Ordovician
Mt. Vernon	DN 5/ 7E/ 3	M.E. Ostrom	Ordovician
New Glarus North	DN 5/ 8E/36	M.E. Ostrom	Ordovician
Cross Plains West	DN 7/ 7E/ 4	I.E. Odom	Ordovician, Cambrian
Cross Plains East	DN 7/ 7E/11	I.E. Odom	Ordovician, Cambrian
Madison-Hoyt Park	DN 7/ 9E/20	I.E. Odom	Cambrian
Madison-Penn Park	DN 7/ 9E/35	I.E. Odom	Cambrian
Mazomanie Bluff (Schoolhouse)	DN 8/ 6E/16A	M.E. Ostrom	Ordovician
Mazomanie Bluff (Schoolhouse)	DN 8/ 6E/16B	I.E. Odom	Cambrian
Black Earth	DN 8/ 6E/23	M.E. Ostrom	Cambrian
Madison Mendota Station	DN 8/ 9E/26	I.E. Odom	Cambrian
Madison-Howard Johnson East	DN 8/10E/27	E.I. Odom	Ordovician, Cambrian
St. Croix River Overlook	DS 44/12W/36	D.M. Mickelson	Quaternary
Amnicon Falls State Park	DS 48/12W/29	G.L. La Berge	Keweenawan
North Fork of the Eau Claire River at Knight Pool	EC 26/ 5W/10	P.E. Myers	Precambriam
Eau Claire River at Confluence of North and South Forks	EC 26/ 5W/29	P.E. Myers	Precambrian
Rest Haven Gardens Town Road	EC 26/ 9W/ 2	M.E. Ostrom	Cambrian
Eau Claire River at Big Falls	EC 27/ 8W/13	M.L. Cummings P.E. Myers	Precambrian
Eau Claire River at Little Falls	EC 27/ 8W/19	P.E. Myers	Precambrian
Mt. Simon	EC 27/ 9W/ 8	M.E. Ostrom	Cambrian
Oakfield	FL 14/16E/23	G.L. La Berge	Ordovician
Panetti Stone Quarry, Hamilton	FL 14/17E/10	G.L. La Berge	Silurian
Dundee Mountain	FL 14/19E/25	D.M. Mickelson	Quaternary
Utley Rhyolite	GL 14/13E/36	G.L. La Berge	Precambrian

Title	Location	Author	Geology
Potosi Hill	GR 2/ 2W/ 7	M.E. Ostrom	Ordovician
Hoadley Hill	GR 2/ 2W/12	M.E. Ostrom	Ordovician, Cambrian
St. John Mine (Snake Cave)	GR 3/ 2E/34	M.G. Mudrey	Ordovician
Pigeon Creek	GR 4/ 3W/19	M.E. Ostrom	Ordovician
Bridgeport West	GR 6/ 6W/22	M.E. Ostrom	Ordovician
Wyalusing	GR 6/ 6W/31	M.E. Ostrom	Ordovician
Bear River (Powell Kyanite)	IR 42/ 4E/28A	G.L. La Berge	Precambrian
Copper Falls State Park	IR 45/ 2E/17	G.L. La Berge	Keweenawan
Oma Township	IR 45/ 2E/18	G.L. La Berge	Precambrian
Potato River	IR 46/ 1W/18	M.E. Ostrom	Precambrian
Hurley Overpass	IR 46/ 2E/14A	G.L. La Berge	Precambrian
Montreal Mine Dump	IR 46/ 2E/33	G.L. La Berge	Precambrian
Gile Flowage	IR 46/ 2E/34	G.L. La Berge	Precambrian
Montreal River	IR 47/ 1E/ 7	M.E. Ostrom	Precambrian (Keweenawan)
Blue Mounds	IW 6/ 5E/ 1	M.E. Ostrom	Silurian, Ordovician
Lone Rock South	IW 8/ 2E/13A	M.E. Ostrom	Cambrian
Lone Rock South	IW 8/ 2E/13B	I.E. Odom	Cambrian
Jackson County Iron Mine	JA 21/ 3W/15	D.G. Jones	Precambrian
Two Creeks North	KW 22/24E/35	D.M. Mickelson	Quaternary
Dill	LF 1/ 5E/12	M.E. Ostrom	Ordovician
Belmont Mound	LF 3/ 1E/ 3	M.E. Ostrom	Silurian
St. Francis Power Plant Site	ML 6/22E/23	D.M. Mickelson	Quaternary
Duveneck	MN 18/23E/24	D.M. Mickelson	Quaternary
Valders Quarry	MN 19/22E/32	D.M. Mickelson	Quaternary, Silurian
Manitowoc North	MN 19/24E/16	D.M. Mickelson	Quaternary
Point Beach State Forest	MN 20/25E/ 9	D.M. Mickelson	Quaternary
Two Rivers	MN 20/25E/31	D.M. Mickelson	Quaternary
Marathon City	MR 28/ 6E/18	P.E. Myers	Precambrian
Rib Mountain Southwest	MR 28/ 7E/19	P.E. Myers	Precambrian

Title	Location	Author	Geology
Athens County Park	MR 29/ 4E/6	G.L. La Berge	Precambrian
Rib River at Emory School	MR 29/ 5E/30	P.E. Myers	Precambrian
Artus Creek	MR 29/ 6E/29	G.L. La Berge	Precambrian
Wausau Employers Mutual Insuance Co.	MR 29/ 7E/27	P.E. Myers	Precambrian
Highland Grove School	MR 29/ 8E/29	G.L. La Berge	Precambrian
Brokaw East	MR 30/ 7E/34	G.L. La Berge	Precambrian
Garriety Hill	SB 14/20E/ 8	D.M. Mickelson	Quaternary
Parnell Lookout Tower	SB 14/20E/10a	D.M. Mickelson	Quaternary
Butler Lake	SB 14/20E/10b	D.M. Mickelson	Quaternary
Butler Lake North	SB 14/20E/20	D.M. Mickelson	Quaternary
Mink Creek	SB 14/20E/27	D.M. Mickelson	Quaternary
Greenbush Ski Run	SB 15/20E/22	D.M. Mickelson	Quaternary
Greenbush Kettle	SB 15/20E/27	D.M. Mickelson	Quaternary
Spring Green	SK 9/ 4E/30	I.E. Odom	Cambrian
Sauk Prairie	SK 10/ 6E/23	J.W. Attig L. Clayton	Quaternary
La Rue Quarry	SK 11/ 5E/22	B.A. Brown M.E. Ostrom	Cambrian, PE
East Bluff of Devil's Lake Gorge	SK 11/ 6E/24	J.W. Attig L. Clayon	Quaternary
Steinke Basin of Devil's Lake State Park	SK 11/ 7E/18	J.W. Attig L. Clayton	Quaternary
Parfrey's Glen	SK 11/ 7E/22	M.G. Mudrey S.A. Nichols	Quaternary
Upper Narrows & Van Hise Rock	SK 12/ 5E/28	B.A. Brown M.E. Ostrom	Cambrian, PE
Galesville	TR 19/ 8W/33	M.E. Ostrom	Cambrian
Decorah Peak	TR 19/ 8W/34	M.E. Ostrom	Cambrian
Arcadia South	TR 20/ 9W/ 9	M.E. Ostrom	Cambrian
Whitehall	TR 22/ 8W/12	M.E. Ostrom	Cambrian
Bruce Valley Quarry	TR 23/ 8W/ 9	M.E. Ostrom	Cambrian

Title	Location	Author	Geology
Strum North	TR 24/ 8W/18	M.E. Ostrom	Cambrian
Reads Creek	VE 12/ 4W/27	M.E. Ostrom	Ordovician
Coon Valley West	VE 14/ 6W/11	M.E. Ostrom	Cambrian
Valley Sand & Gravel Pit	WK 6/20E/ 5	D.M. Mickelson	Quaternary
Waukesha Lime & Stone Co. Pit	WK 7/19E/26	D.M. Mickelson	Quaternary

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Hamilton Mound	AD 20/ 6E/36	B.A. Brown	Precambrian
Irvine Park	CH 29/ 8W/31	M.E. Ostrom	Cambrian, Precambrian
Mt. Simon	EC 27/ 9W/ 8	M.E. Ostrom	Cambrian
Potosi Hill	GR 2/ 2W/ 7	M.E. Ostrom	Ordovician
Hoadley Hill	GR 2/ 2W/12	M.E. Ostrom	Ordovician, Cambrian
Arbutus Dam	JA 22/ 3W/ 3	R.S. Maass B.A. Brown	Precambrian
Skillett Creek	SK 11/ 6E/15	B.A. Brown	Precambrian
Arcadia South	TR 20/ 9W/ 9	M.E. Ostrom	Cambrian
Whitehall	TR 22/ 8W/12	M.E. Ostrom	Cambrian
Strum North	TR 24/ 8W/18	M.E. Ostrom	Cambrian

Out-of-State Outcrop Descriptions

Title	State	Location	Author	Geology
Mineral Creek	Iowa	Allamakee Co. 99/6W/23	M.E. Ostrom	Ordovician
Waukon Junction	Iowa	Allamakee Co. 96/3W/16	M.E. Ostrom	Ordovician
Wilmington	Minnesota	Houston Co. 101/6W/11	M.E. Ostrom	Ordovician

OUTCROP DESCRIPTIONS - ALPHABETICAL

Amnicon Falls State Park - DS 48/12W/29
Arbutus Dam - JA 22/3W/3
Arcadia South - TR 20/9W/9
Artus Creek - MR 29/6E/29
Athens County Park - MR 29/4E/16
Bear River (Powell Kyanite) - IR 42/4E/28A
Belmont Mound - LF 3/1E/3
Black Earth - DN 8/6E/23
Blue Mounds - IW 6/5E/1
Bridgeport West - GR 6/6W/22
Brokaw East - MR 30/8E/34
Bruce Valley Quarry - TR 23/8W/9
Butler Lake North - SB 14/20E/20
Butler Lake - SB 14/20E/10B
Chippewa River at Cornell - CH 31/6W/18
Coon Valley West - VE 14/6W/11
Cooper Falls State Park - IR 45/2E/17
Cross Plains East - DN 7/7E/11
Cross Plains West - DN 7/7E/4
Cunningham Creek - CK 24/2W/26
Decorah Peak - TR 19/8W/34
Dill - LF 1/5E/12
Dundee Mt - FL 14/19E/25
Duveneck - MN 18/23E/24
East Bluff of Devils Lake Gorge - SK 11/6E/24
Easter Rock - CR 8/3W/21
Eau Claire River at Confluence of N & S Forks - EC 26/5W/29
Eau Claire River at Little Falls - EC 26/8W/19
Eau Claire River at Big Falls - EC 26/8W/13
Fisher River - CH 31/6W/4
Flambeau Ridge - CH 32/7W/1
Friendship Mound - AD 17/6E/5
Galesville - TR 19/8W/33
Garriety Hill - SB 14/20E/8
Gile Flowage - IR 46/2E/34
Greenbush Kettle - SB 15/20E/27
Greenbush Ski Run - 15/20E/22
Greenwood - CK 26/3W/3
Hamilton Mound - AD 20/6E/36
Hay Creek Dam - CK 26/4W/26
Highland Grove School - MR 29/8E/29
Hoadley Hill - GR 2/2W/12
Hurley Overpass - IR 46/2E/14A
Irvine Park - CH 29/8W/31
Jackson Co Iron Mine - JA 21/3W/15
Jim Falls - Ch 30/7W/30
Kittell Falls - BN 23/21E/32
La Rue Quarry - SK 11/5E/22
Lone Rock South - IW 8/2E/13A
Lone Rock South - IW 8/2E/13B
Madison Mendota Station - DN 8/9E/26
Madison Howard Johnson East - DN 8/10E/27
Madison Penn Park - DN 7/9E/35
Madison Hoyt Park - DN 7/9E/20
Manitowoc North - MN 19/24E/16
Marathon City - MR 28/6E/18
Marietta Valley - CR 8/3W/10
Mazomanie Bluff Schoolhouse - DN 8/6E/16A
Mazomanie Bluff Schoolhouse - DN 8/6E/16B
Mellen Granite - AS 45/2W/31
Mellen Gabbro -AS 45/2W/30
Mink Creek - SB 14/20E/27
Montreal River - IR 47/1E/7
Montreal Mine Dump - IR 46/2E/33
Mt Whittelsey - As 44/2W/9A
Mt Simon - EC 27/9W/8
Mt Vernon - DN 5/7E/3
Naedler Quarry Granton - CK 25/1W/35
Neda - DG/11/16E/1
Neillsville Mounds - CK 24/2W/4
Neillsville - CK 24/2W/10
New Glarus North - Dn 5/8E/36
North Fork of the Eau Claire River at Knight - Pool EC 26/5W/10
Oakfield - FL 14/16E/23
Oma Township - IR 45/3E/18
Panetti Stone Quarry, Hamilton - FL 14/17E/19
Parfreys Glen - SK 11/73/22
Parnell Lookout Tower - SB 14/20E/10A
Pigeon creek - GR 4/3W/19
Point Beach State Forest - MN 20/25E/9
Potato River - IR 46/1W/18
Potosi Hill - GR 2/2W/7
Prairie Du Chien - CR 7/6W/29
Reads Creek - VE 12/4W/27
Rest Haven Gardens Town Rd - EC 26/9W/2
Rib River at Emory School - MR 29/5E/30
Rib Mountain Southwest - MR 28/7E/19
Sauk Prairie - SK 10/6E/23
Sidney - CK 24/2W/20
Skillett Creek - SK 11/6E/15
South Fork of Eau Claire River - CK 26/4W/1
South Fork of the Eau Claire River at Mead Dam - CK 27/3W/29
South Fish Creek - BA 47/5W/20
Spring Green - SK 9/4E/30
St John Mine (Snake Cave) - GR 3/2E/34
St Croix River Overlook - DS 44/12W/36
St Francis Power Plant Site - ML 6/22E/23
Steinke basin of Devils Lake - SK 11/7E/18
Strum North - TR 24/8W/18
Tilden - CH 29/9W/7
Two Rivers - MN 20/25E/31
Two Creeks North - KW 22/24E/35
Upper Wis Dells - AD 14/6E/28
Upper Narrows & Van Hise Rock - SK 12/5E/28
Utley Rhyolite - GL 14/13E/36
Valders Quarry - MN 19/22E/32
Valley Sand & Gravel Pit - WK 6/20E/5
Waukesha Lime & Stone Co Pit - WK 7/19E/26
Wausau Employers mutual Insurance Co - MR 29/7E/27
White River - AS 46/4W/6
Whitehall - TR 22/8W/12
Wyalusing - GR 6/6W/31
Yellow River at Cadott - Ch 29/6W/31

The Upper Wisconsin Dells

Location. The gorge of the Wisconsin River from the dam at the city of Wisconsin Dells northward for 6 km, in Juneau, Adams, Columbia, and Sauk Counties, sec. 28 and 33, T14N, R6E and sec. 3 and 4, T13N, R6E (Wisconsin Dells North, Wisconsin, Quadrangle 7.5-minute series, topographic, U.S. Geological Survey, 1975) (fig. 1). The gorge is most easily seen by boat. Boats can be rented in the Wisconsin Dells area, and tour boats travel the length of the gorge at frequent intervals during the tourist season.

Authors. Lee Clayton and John Attig, 1990.

Terminology. The word "dells" (or "dalles") has been used in Wisconsin for narrow rock-walled river gorges, many of which were cut during the drainage of glacial lakes. The name "Wisconsin Dells" (and the shortened form, "Dells") has been used at least three different ways: (1) the sandstone gorge of the Wisconsin River, consisting of the 6-km-long Upper Dells north of the Wisconsin Dells dam and the 4-km-long Lower Dells south of the dam (fig. 1), (2) the Wisconsin River gorge plus an ill-defined network of associated gorges such as Witches Gulch, Coldwater Canyon, the gorge around Blackhawk Island, and the gorge in Rocky Arbor State Park (all shown in fig. 1), and (3) the city of Wisconsin Dells (shown in lower right corner of fig. 1; formerly Kilbourn).

The Wisconsin River gorge. The width of the Wisconsin River gorge in the Upper Dells ranges from 15 m at The Narrows (the area shown near the middle of fig. 1) to 200 m south of Blackhawk Island and 0.7 km north of Witches Gulch. It is about 20 m deep (down to the water surface) in most places, but it was about 30 m deep before the Wisconsin Dells dam was built.

Before the Ice Age, the rivers of central Wisconsin flowed generally to the east-southeast. During the Wisconsin Glaciation (and perhaps during earlier glaciations as well), the Green Bay Lobe of the Laurentide Ice Sheet blocked the lower reaches of these rivers, forcing the drainage to shift southward along the edge of the glacier and establishing the course of the Wisconsin River as we see it today.

In preglacial time, the Upper Dells area was on the drainage divide between the Lemonweir River valley to the north and the Baraboo River valley to the south. During the height of the Wisconsin Glaciation, the glacier was a few kilometres east of the Upper Dells. At that time the Dells area was submerged under the water of glacial Lake Wisconsin, which formed when the central Wisconsin drainage was dammed by the glacier where it overrode the east end of the Baraboo Hills. Lake level in the Upper Dells area was at about 290 m (950 ft); only the highest hills shown on figure 1 were above water. The gorges in the Dells area were probably cut when glacial Lake Wisconsin drained catastrophically when its glacier dam failed.

Witches Gulch and Coldwater Canyon. Tour boats in the North Dells generally stop at two tributary gorges, Witches Gulch and Coldwater Canyon (fig. 1). They are a few tens of metres deep and only about 1 m wide in places. The gorges appears to be either a series of interconnected potholes or meander loops.

These and similar gorges on the east side of the Wisconsin River gorge could not have been cut by meltwater coming directly from the glacier, as has often been suggested, because any time the glacier was far enough west to send meltwater into this area, it was far enough west to cover the east end of the Baraboo Hills and dam glacial Lake Wisconsin, which completely covered the area of these gorges. Any time this area was exposed to subaerial erosion, the glacier margin had to have been far enough to the east that meltwater flowed southward along the margin east of the Baraboo Hills, completely missing the Dells area. It seems more likely that these gorges were cut by lake water rushing through the Dells area when glacial Lake Wisconsin catastrophically drained.

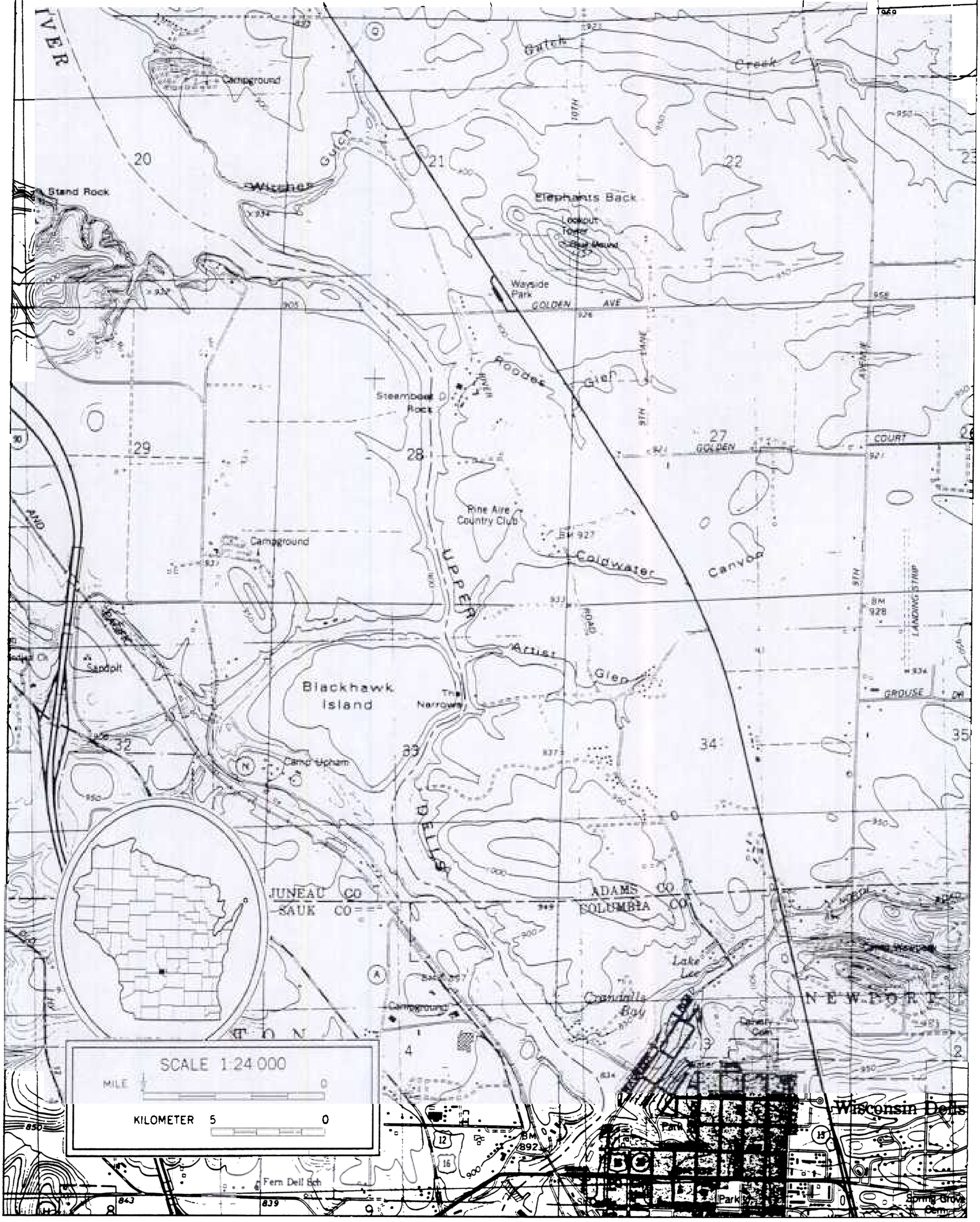

Figure 1. Location of the Upper Dells.

Blackhawk Island and the "Old Channel." The gorge around the west side of Blackhawk Island (fig. 1) has sometimes been called the "Old Channel." It is part of the Dells network of gorges. It joins the north end of the gorge in Rocky Arbor State Park (fig. 1), the south end of which joins Hulburt Creek gorge.

Stand Rock. Stand Rock (area shown in upper left corner of fig. 1) is generally the northernmost tour-boat stop in the Dells. It is a pinnacle of Elk Mound sandstone on the west wall of the Wisconsin River gorge.

Sandstone walls of the gorges. The walls of the Upper Dells gorges are composed of sandstone of the Elk Mound Group, deposited during the Late Cambrian Epoch. Elsewhere in southern Wisconsin, the Elk Mound Group is subdivided, from bottom to top, into the Mount Simon, Eau Claire, and Wonewoc Formations, but the distinction between these units is obscure in the Dells area. Twenhofel and others (1935, plate 151; Trowbridge, 1935, p. 135) considered the Upper Dells sandstone to be part of the Eau Claire Formation; Dott and others (1986) considered it to be part of the Galesville Member of the Wonewoc Formation; Clayton (1990) and Clayton and Attig (1990) considered it to be part of the Mount Simon Formation. The sandstone is poorly cemented and consists largely of unfossiliferous medium to fine quartz sand. The larger grains have undergone considerable rounding. Cross-bedding is conspicuous in the Dells; it is commonly high angled, trough shaped, and large scale, with the larger sets a few metres thick.

The sandstone in the Upper Dells has been studied by Fielder (1985) and Dott and others (1986). They concluded, on the basis of sedimentary structures (including adhesion-ripple bedding), that much of the sand was deposited in a coastal eolian environment.

References

Clayton, Lee, 1987, Pleistocene geology of Adams County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 59, 14 p.

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Clayton, Lee, and Attig, J.W., 1989, Glacial Lake Wisconsin: Geological Society of America Memoir 173, 80 p.

Clayton, Lee, and Attig, J.W., 1990, Geology of Sauk County, Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 67, 68 p.

Dott, R.H., Jr., Byers, C.W., Fielder, G.W., Stenzel, S.R., and Winfree, K.E., 1986, Aeolian to marine transition in Cambro-Ordovician cratonic sheet sandstones of northern Mississippi valley, U.S.A.: Sedimentology, vol. 33, p. 345-367.

Fielder, G.W., III, 1985, Lateral and vertical variation of depositional facies in the Cambrian Galesville sandstone, Wisconsin Dells: University of Wisconsin, Madison, Masters's thesis, 194 p.

Twenhofel, W.H., Raasch, G.O., and Thwaites, F.T., 1935, Cambrian strata of Wisconsin: Geological Society of America Bulletin, vol. 46, p. 1687-1744.

Trowbridge, A.C., ed., 1935, Guide book: Kansas Geological Society Ninth Annual Field Conference, 471 p.

Title: Friendship Mound

Location: Exposure in south end of Friendship Mound at north end of Friendship in the SW¼, NW¼, Sec. 5, T.17N., R.6E., Adams County (Adams 15-minute topographic quadrangle, 1961).

Author: M. E. Ostrom (modified from Twenhofel et. al, 1935)

Description: The relationships of the Mt. Simon, Eau Claire, and Wonewoc formation are shown. The Eau Claire Formation is thin or absent. Asthara (1969) showed the Mt. Simon Formation to contain significantly more feldspar than the Galesville Formation here as elsewhere.

Description follows:

CAMBRIAN SYSTEM
Tunnel City Group

Lone Rock Formation

Mazomanie Member (+71.0')

141.7' - 212.7'	+71.0'	Sandstone, yellow gray to light brown, coarse to medium-grained, well-sorted, cross-bedded, friable, abundant borings.

	34.0'	Covered.

Wonewoc Formation

Ironton Member (18.7')

141.7'	1.0'	Sandstone, brown, medium and coarse-grained, micaceous, appears reworked. Fossils present (trilobites and hyolithes).
136.2' - 140.7'	4.5'	Sandstone, light gray, coarse-grained, unbedded, burrows in lower part and glauconitic in upper part. Abundant Cenoraspis (trilobites) in middle portion.
130.0' - 136.2'	6.2'	Sandstone, light gray, mostly coarse-grained, poorly sorted, abundant burrows in upper 1.5'. Has symmetrical ripple marks.
122.0' - 130.0'	7.0'	Sandstone, light gray, coarse-grained, poorly sorted, steeply cross-bedded, silty laminae and pebbles of siltstone.

Galesville Member (52.0')

88.0' - 123.0'	35.0'	Sandstone, grayish white, medium-grained, mostly well-sorted, thick-bedded, cross-bedded. Symmetrical ripple marks in upper 15'.
71.0' 88.0'	17.0'	Sandstone, light gray, coarse and medium-grained, poorly sorted, silty.

Mt. Simon Formation (71.0')

70.5' 71.0'	0.5'	Sandstone, reddish brown, fine-grained, silty, some coarse grains, irregular thickness, limonite-cemented. May be Eau Claire Formation.
70.5'	70.5'	Sandstone, white to yellow brown, mostly coarse-grained, thick-bedded, massive appearance.

BASE OF EXPOSURE

Significance: This exposure illustrates thinning onto the Wisconsin arch. One can also examine the different directions of sediment transport between the Mt. Simon and Galesville.

What has happened to the Eau Claire Formation? How can you distinquish the Mt. Simon from the Galesville? What is the significance of cross-bedding? of ripple marks?

References: Raasch, 1935; Twenhofel et al, 1935; Ostrom, 1970.

Proterozoic quartzite at Hamilton Mound, central Wisconsin

B. A. Brown and J. K. Greenberg, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin 53705

LOCATION

The quarry at Hamilton Mound is in the NE¼,Sec.36,T.-20N.,R.6E., Coloma NW 7½-minute Quadrangle. It can be reached by turning east from Wisconsin 13 on Archer Drive, just north of Dorro Couche Lake, and proceeding about 4 mi (6 km) to a turnoff leading south into the quarry in the middle of Hamilton Mound. The turnoff from Wisconsin 13 is about 15 mi (24 km) south of Wisconsin Rapids (Fig. 1).

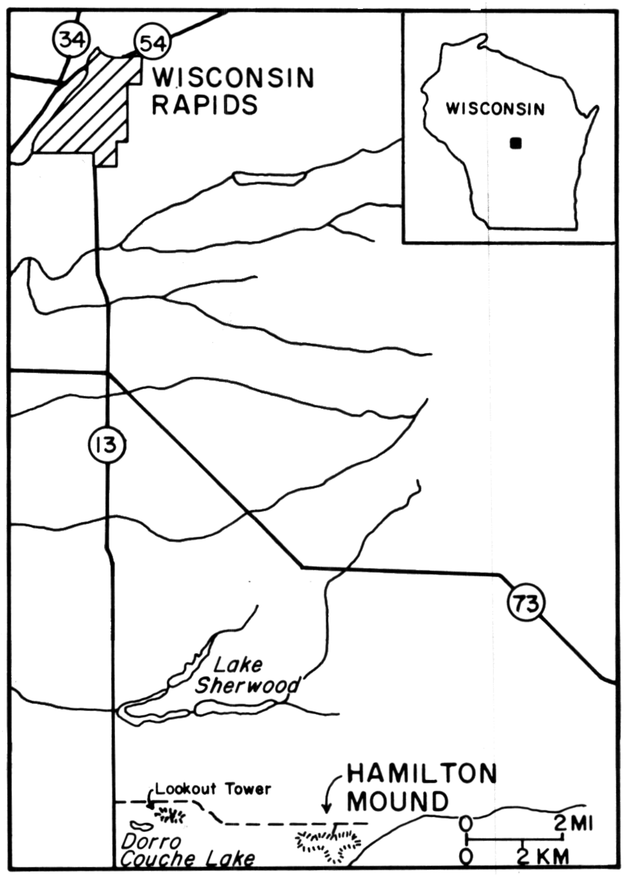

Figure 1. Location map.

SIGNIFICANCE

Hamilton Mound is an inlier of folded Proterozoic quartzite similar to the Baraboo Syncline and the Waterloo area exposures (Brown, 1986). The quartzite is exposed on a series of low hills; Upper Cambrian sandstone of the Elk Mound Group overlaps the quartzite and is exposed on the slopes. Hamilton Mound is a prominent feature on the flat sand plains of central Wisconsin. Sand dunes are scattered over the plain, which was a Quaternary lake bed. A quarry developed in the quartzite exposes a granite intrusive into the quartzite, and an unusual zone of contact metasomatism and alteration within the quartzite.

DESCRIPTION

The quartzite was originally a fine- to medium-grained quartz sand. Sericite and clays constitute from 1 or 2 percent to 25 percent of the rock, suggesting that the sandstone varied in content of clay (or feldspar?), which is now represented by mica or has been realtered to kaolin. Typical samples contain 5 to 10 percent sericite, 90 percent recrystallized quartz grains, and traces of hematite, chlorite, zircon, and other detrital minerals. Small feldspar grains (less than 1 mm) are common near the granite contact, and chlorite, zircon, sericite, and clay minerals are concentrated near the intrusion.

Primary sedimentary structures include bedding, cross-bedding, and, less commonly, ripple marks. Fine laminated units commonly are slumped and faulted, possibly due to tectonic as well as sedimentary deformation.

STRUCTURAL FEATURES

The macroscopic structure of the Hamilton Mound exposures was mapped by Ostrander (1931) who identified four major folds trending N75°W (Fig. 2). The roughly east-west axial trend is similar to that of the Baraboo Syncline and the Waterloo area. Other structures, including distortion of bedding, several sets of fracture cleavage, foliation, shear zones, and zones of breccia-tion are well developed in the area of the granitic intrusion (Fig. 3) and increase in intensity as the intrusive contact is approached. The intensity of deformation is evident in thin section (Fig. 4) where quartz grains become highly strained.

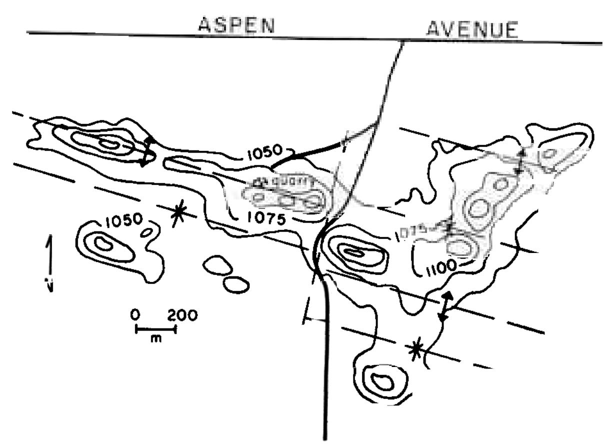

Figure 2. Major structures at Hamilton Mound (after Ostrander, 1931).

Figure 3. Excavation face at Hamilton Mound quarry showing steeply dipping beds in quartzite cut by nearly horizontal fracture cleavage.

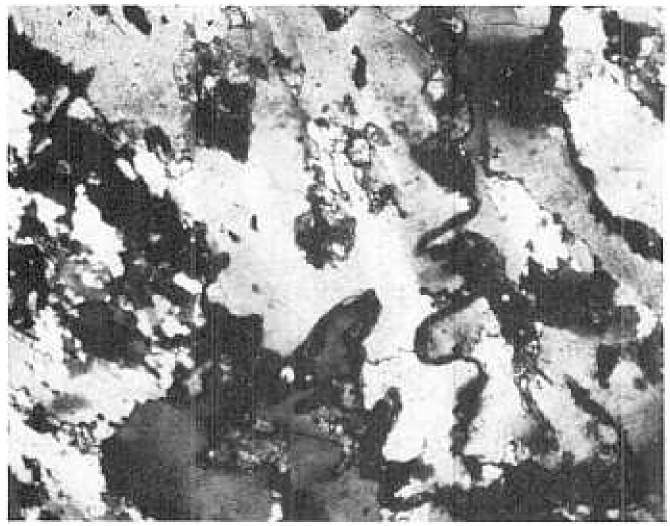

Figure 4. Micrograph of intensely deformed quartzite from near the intrusive contact. Note microstylolite developed between quartz grains. Long dimension is about 6 mm.

Important structural features are zones of quartzite breccia cemented by white vein quartz that extend upward from near the intrusive contact in the quarry. Similar brecciated zones are common in other areas where Baraboo interval quartzites are intruded by granitic rocks (Greenberg, 1986). Taylor and Montgomery (1986) observed porphyritic granitic fragments in the breccia zones, suggesting that they are late hydrothermal phenomena.

THE INTRUSIVE ROCKS

From the present extent of exposure, there is no certain way of knowing the original igneous character of the granitic intrusion at Hamilton Mound. Contaminated igneous material is of two types. The more original-appearing rock is exposed near the pit entrance, and contains bright red-orange phenocrysts (to 0.8 in; 2 cm in length) of potassium feldspar and plagioclase, colored by hematite inclusions. Some larger quartz grains also occur as clasts in a matrix of highly strained quartz (to 50 percent of total), chlorite, opaque minerals, and sericite (Fig. 5). Much of the sericite may have been derived from altered feldspars. Zircon is common. Larger inclusions in the granitic rock are composed of quartz, biotite, chlorite, and sericite. These inclusions are unlike the overlying quartzite and may be remnants of digested basement rocks. Chemical analyses of samples of the porphyritic granite are consistent with a granitic intrusion contaminated by mafic and aluminous material (Taylor and Montgomery, 1986). Initial U-Pb zircon data from the porphyritic granitic rock suggest 1760 Ma (W. R. Van Schmus, unpublished data) as a possible age. This age would further establish a link between Baraboo-interval sedimentation and 1760 Ma magmatism. Rb-Sr analyses (Taylor and Montgomery, 1986) indicate that whatever the original age, the granite at Hamilton Mound was isotopically reset at 1585 ± 30 Ma, an age overlapping the uncertainties of both the 1630 Ma regional disturbance and the 1500 Ma (Wolf River) episode of anorogenic magmatism.

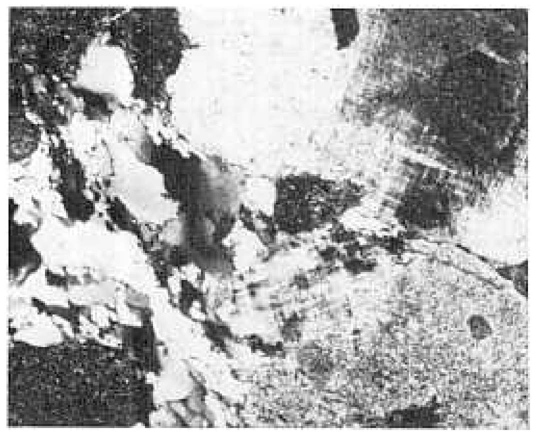

Figure 5. Micrograph of contaminated porphyritic granite. Note strained quartz and chlorite surrounding feldspar phenocrysts. Long dimension is about 8 mm.

At the west end of the quarry, quartzite and intrusive rocks appear to be very complexly mixed. The gray foliated rock exposed here ranges from a highly deformed micaceous quartzite into a very quartz-rich banded rock containing large amounts of fresh fine-grained feldspar (microcline and plagioclase), biotite, and less common hornblende near the granite. In this zone of transition or mixing, fine banding with the appearance of sedimentary laminations, becomes contorted and indistinguishable from tectonic foliation (Fig. 6). Enigmatic round inclusions (xe-

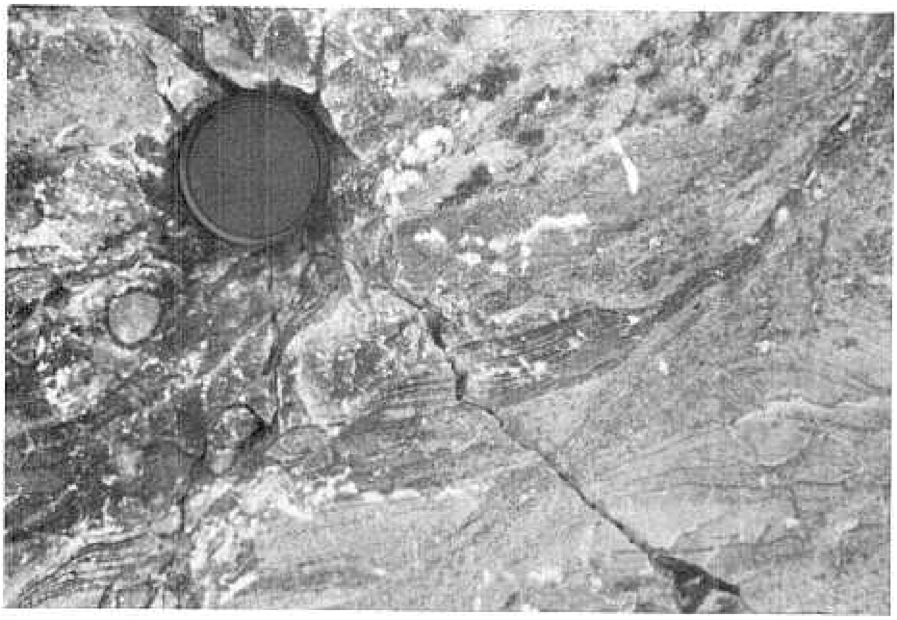

Figure 6. Distorted laminations and inclusions with reaction rims, from the quartzite-intrusion mixing zone at Hamilton Mound. Lens cap is 2 in (5 cm) in diameter.

Figure 7. Excavation face at Hamilton Mound quarry showing quartzite blocks in Cambrian sandstone overlying quartzite. Sandstone beds become more regular and flaggy to the right of the photo. Quartzite bluff is to left. Horizontal dimension is about 33 ft (10 m).

noliths?) of mafic material with reaction rims occur in the mixed zone. U-Pb analyses by W. R. Van Schmus (unpublished data) determined an age for the zircon crystals from this mixed zone as 2500 Ma. One interpretation is that these zircons and inclusions in the magma represent basement assimilated and brought up from below. Another possibility is that the Hamilton Mound quartzite contains detrital zircons derived from eroded Archean basement.

All thin sections of quartzite and intrusive rock collected from within or near the mixed zone have the high-strain deformational fabric associated with the quartzite-intrusion contact. Unusually strain-free grains, feldspar and biotite in particular, appear to be late magmatic (metasomatic?) phases that grew during or after deformation. Rare dikelets of granitic rock containing tourmaline are also known to postdate deformation (Taylor and Montgomery, 1986; Greenberg, 1986). These observations, along with the extensive brecciation, suggest both a forceful intrusion and a substantial chemical interaction between magma and overlying quartzite.

A definite influence of granitic intrusion on the quartzite is color alteration. Although Hamilton Mound quartzite away from the intrusion is characteristically pink-red (as seen on the ridge southeast of the quarry ridge), quartzite in proximity to the granitic rock is distinctly greenish. The color change is probably explained by the reduction of iron in hematite during heating. Similar color variations can be seen at Necedah and in the contact zone of the Baxter Hollow Granite at Baraboo (Greenberg, 1986).

SANDSTONE

A thin cap of sandstone sits atop poorly exposed quartzite along one wall of the quarry. This sandstone, like most other exposures in the area, is correlated with the Upper Cambrian Elk Mound Group. The sands are interpreted as having been deposited on a topographic high of the eroded Precambrian rocks.

Just above the quartzite, the sandstone is very poorly sorted with alternating beds of rubbly conglomerate and finer sand beds (Fig. 7). The rubbly conglomerate contains large angular blocks (to 3 ft; 1 m across) of quartzite. Away from the unconformity, the beds become thinner, with better sorting and flaggy parting.

The Cambrian sediments at Hamilton Mound may have been storm deposits like those which have been described in the Baraboo area by Dalziel and Dott (1970). The Hamilton Mound inlier probably stood above sea level as small islands or stacks during deposition of the flanking sandstone.

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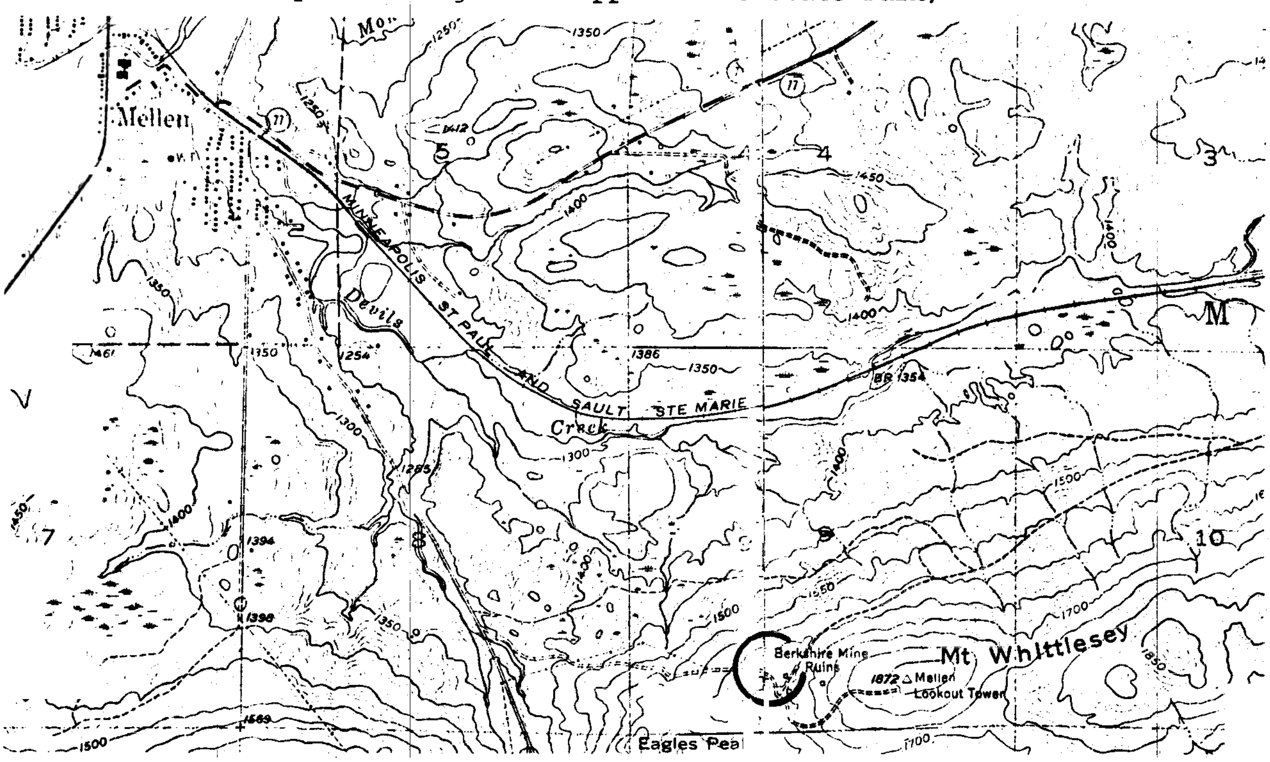
Taylor, S. M., and Montgomery, C. W., 1986, Petrology, geochemistry, and Rb-Sr systematics of the porphyritic granite at Hamilton Mound, Wisconsin, *in* Greenberg, J. K., and Brown, B. A., eds., Proterozoic Baraboo interval in Wisconsin: Geoscience Wisconsin, v. 10, p. 85–95.

Title: Ironwood Iron-formation

Location: Mt. Whittelsey (Berkshire Mine Ruins), SE¼, SW¼, Sec. 9, T.44N., R.2W. (Mt. Whittelsey 7½ Min. Quad.) Ashland County (Get key from Ranger at Copper Falls State Park)



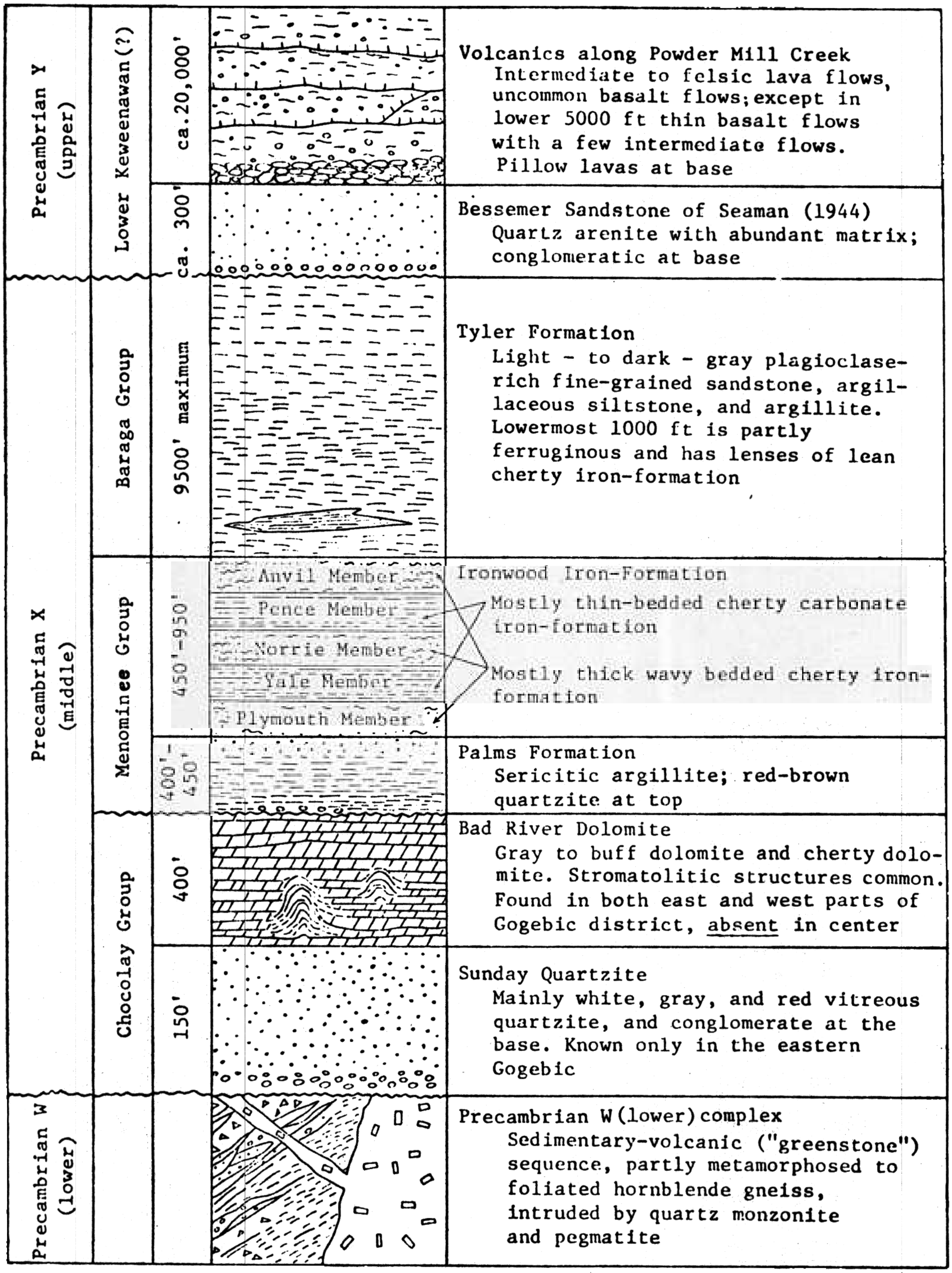
Author: Gene L. LaBerge

Description: This outcrop is man-made. The area was cleared off in connection with proposed mining operations on the hill. This is one of the best exposures of Middle Precambrian iron-formation in the entire Lake Superior region, and is a representative example of the rock type.

The iron-formation is composed of roughly equal portions of chert (SiO_2) and iron minerals with distinct segregation of the components into layers. Chert-rich layers range in thickness from less than 1 cm to several cm, and iron-rich layers are approximately the same thickness Note the highly irregular contacts between iron-rich and chert-rich layers at some levels and much smoother contacts in others.

Texturally, the iron formation is quite variable, and has features very comparable to post-Precambrian limestones. Some layers are composed of sand-size "granules" of chert and/or iron minerals set in a chert matrix. The "granules" are actually fragments of iron-formation and thus are called intra-clasts. Other layers are finely laminated and composed of silt size grains of chert and/or iron minerals.

Mineralogically, iron-formations consist of chert and one or more iron minerals: siderite ($FeCO_3$); iron silicates (minnesotaite, stilpnomelane, greenalite or grunerite); magnetite, hematite, and goethite.



Generalized stratigraphic section in central and western Gogebic district

From Schmidt & Hubbard, 1972.

Significance: The Ironwood Formation is typical of the Middle Precambrian iron formations in the Lake Superior region. It is similar to, and is believed to have been continuous with the iron formations on the Mesabi and Gunflint ranges on the north shore of Lake Superior. Thus, it represents a blanket-like deposit up to 800 feet thick that covered perhaps 20,000 square miles. It is underlain and overlain by typical detrital sediments (the Palms and Tyler Formations respectively) (Aldrich, 1929; Schmidt and Hubbard, 1972) and appears to interfinger with a thick volcanic pile (the Emperor Volcanics) (Hendrix, 1960) east of Wakefield, Michigan, yet the iron formation itself is almost completely devoid of detrital materials. How does this occur? Is iron-formation deposited so rapidly that clastic influx is insignificant? Or is it deposited during a period of extreme quiescence when no clastics are added to the basin.

Iron-formations are common throughout the world in rocks older than about 1800 m.y., but are virtually unknown in younger sequences. This may reflect a major change in the evolution of the earth's atmosphere and hydrosphere about 1800 m.y. ago.

Iron-formations are chemical (biochemical) precipitates, yet the mechanism of precipitation and nature and composition of the original material has been debated for more than a hundred years. The reason for this is that iron minerals respond to changes in Eh and pH of their environment. For example, hematite and goethite are most stable in an oxidizing environment while siderite and pyrite are most stable in a reducing environment. If the environment changes the iron minerals will also change. Therefore, the iron minerals present in these rocks today reflect the oxidation potential of the depositional environment, the diagenetic environment, the metamorphic environment and the weathering environment, and deciding when a particular mineral formed is at best difficult.

Many geologists now believe that iron-formations are largely biochemical precipitates with the iron being precipitated as a by-product of oxygen-producing photosynthetic organisms. The silica may also be largely organically precipitated.

References:

Aldrich, H. R., 1929, The Geology of the Gogebic Iron Range of Wisconsin: Wis. Geol. Nat. Hist. Survey Bull. 71, 279 p.

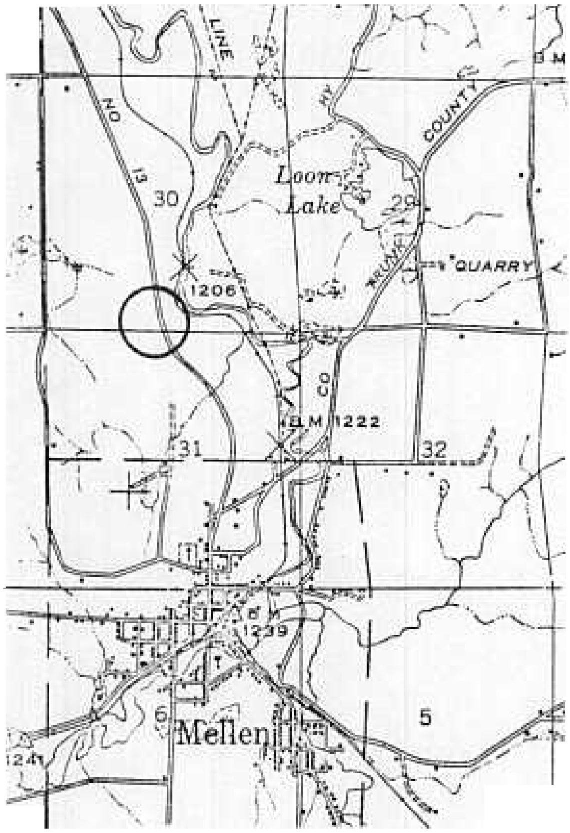
Hendrix, T. E., 1960, "Structural History of the East Gogebic," Unpublished Ph.D. Thesis, Univ. of Wis.

Schmidt, R. G., and Hubbard, H. A., 1972, Penokean Orogeny in the Central and Western Gogebic Region, Michigan and Wisconsin: Field Trip A, 18th Annual Institute on Lake Superior Geology, Houghton, Mich.

Title: Mellen Gabbro

Location: Exposures along the east side of Hwy. 13 in SE¼, SE¼, SW¼, Sec. 30, T.45N., R.2W. Ashland County, (Mellen planimetric quadrangle.)

Author: Gene L. LaBerge

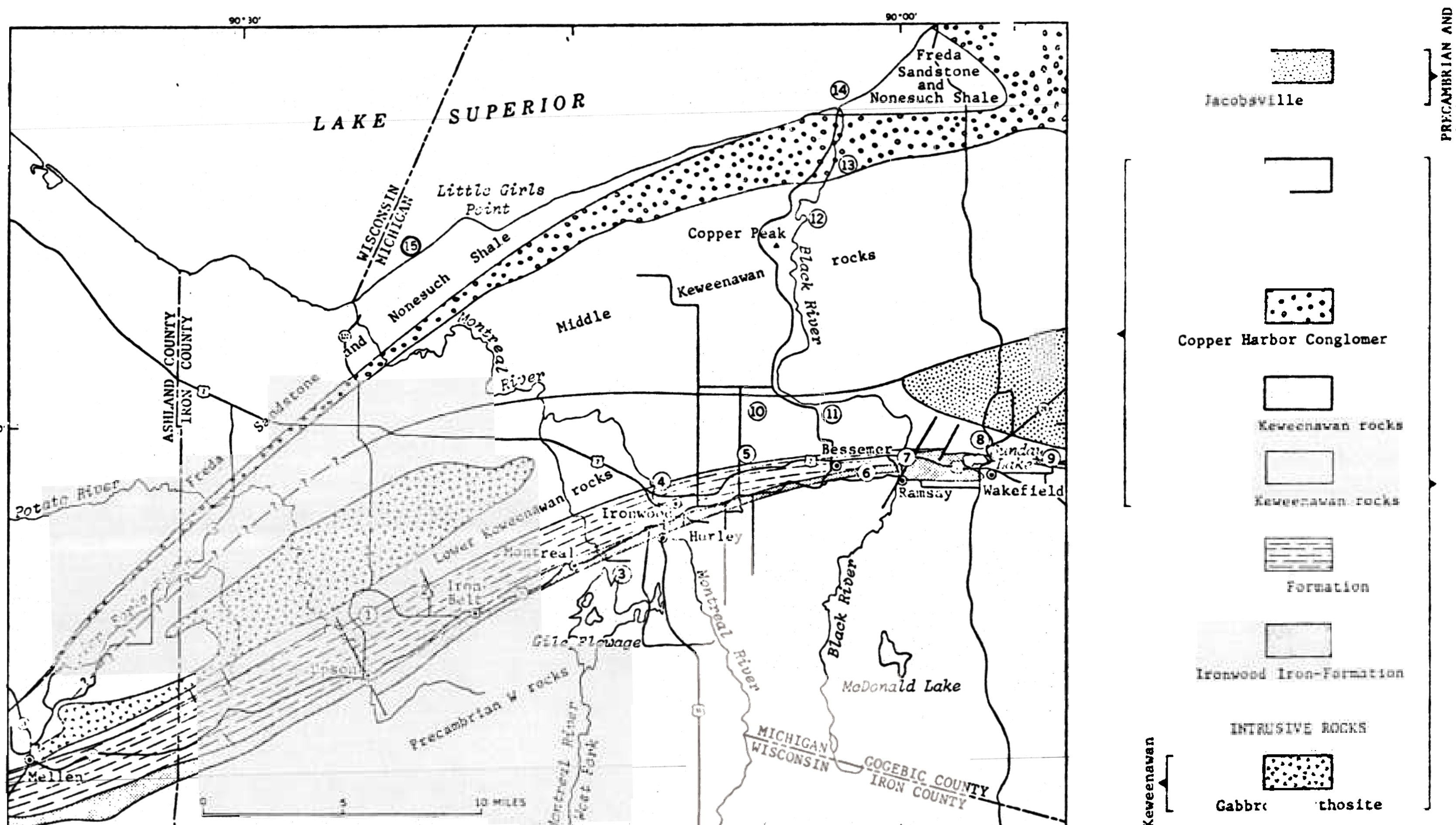


Description: The Mellen Gabbro is a large sill-like mass nearly 60 miles long. The Mellen granite divides the intrusion into two segments. The Mineral Lake intrusion is west of here -- west of the Mellen granite. The eastern complex exposed here is about 35 miles long and up to five miles thick. It was intruded near the base of the Keweenawan lava flows, approximately along the unconformity between the Keweenawan and the older Precambrian rocks.

Tabet and Mangham (in press) concluded that the eastern half of the Mellen complex was formed by three separate intrusions of basaltic magma. Each intrusive phase crystallized with an olivine-rich base and a plagioclase-rich top before intrusion of the next overlying sequence. Fractional crystallization and convection currents produced rhythmic layering in the olivine-rich basal portions (olivine gabbros and troctolites). The layered gabbro exposed in the outcrops here is part of the olivine-rich basal parts of one of the intrusions.

An anorthositic gabbro phase of the intrusion has been quarried about a mile east of here. Rock from these quarries have been marketed as "black granite," some of which was used in the construction of the "Eternal Flame" monument to J. F. Kennedy.

Significance: The Mellen Gabbro and associated lava flows and granite represent the last known igneous event in the Lake Superior region. The lava flows and associated sediments are believed to have formed in an opening rift that extended from Lake Superior southwestward at least to Oklahoma (Craddock, 1972). Igneous activity along the rift took place from about 1250 to 950 million years ago, and deposition of sedimentary rocks continued for an unknown length of time thereafter, forming the sandstones along the south shore of Lake Superior.



General geology and field trip stops, central and Gogebic
Geology in Wisconsin in part from Aldrich (1929)

From Schmidt & Hubbard, 1972

The compositional layering in the gabbro was probably nearly horizontal at the time of formation. Why? Using this assumption, Tabet and Mangham (in press) show that the lava flows were dipping only 10°-15° north at the time the gabbro was intruded. Radiometric age on the gabbro is approximately 1,000 m.y., and this must represent an early stage in the tilting of the south limb of the Lake Superior Syncline. As the central part of the syncline subsided, northward-flowing streams kept it largely filled with sandstones eroded from the surrounding highlands (Hamblin, 1961).

An extensive contact metamorphic aureole is present around the gabbro produced by the heat given off by the cooling magma. Metamorphic effects are most noticeable in the slates, graywackes, and iron-formations to the south, but the basalts into which the magma intruded are also highly metamorphosed near the gabbro. The metamorphism of the iron-formation increased the grain size and developed iron-amphiboles which inhibited the development of natural orebodies in this part of the Gogebic Range, but this increase in grain size and development of magnetite has rendered the iron-formation suitable for beneficiation as a taconite ore.

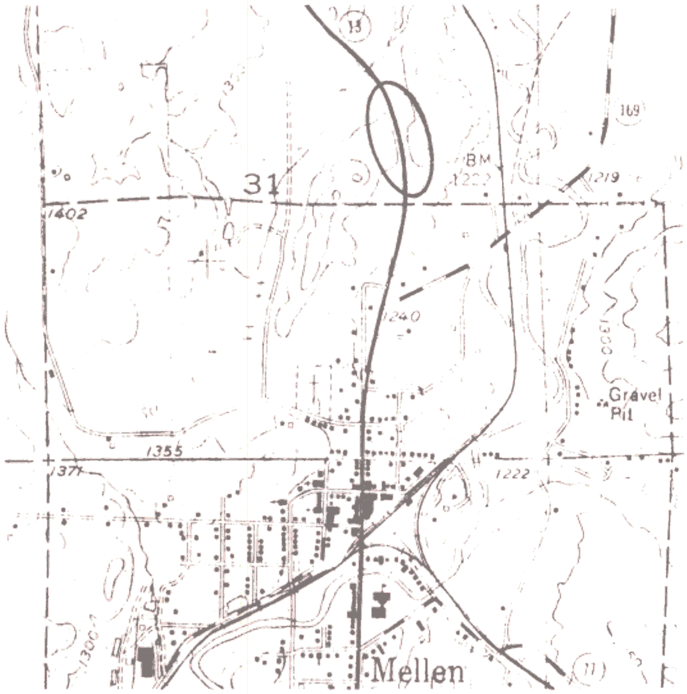
References:

Craddock, J., 1972, "Late Precambrian: Regional Geologic Setting": in Geology of Minnesota: A Centennial Volume, edited by Sims and Morey, Minn. Geol. Survey, pp. 281-291.

Tabet, D. E., and Mangham, J. R., (in press), The Geology of the Eastern Mellen Intrusive Complex, Wisconsin, Geoscience Wisconsin, Wis. Geol. Nat. Hist. Survey.

Title: The Mellen "Granite"

Location: West side of Wis. Hwy. 13, NE¼, SW¼, NE¼, Sec. 31, T.45N., R.2W
Mellen 7.5 Minute Quadrangle, Ashland Co.

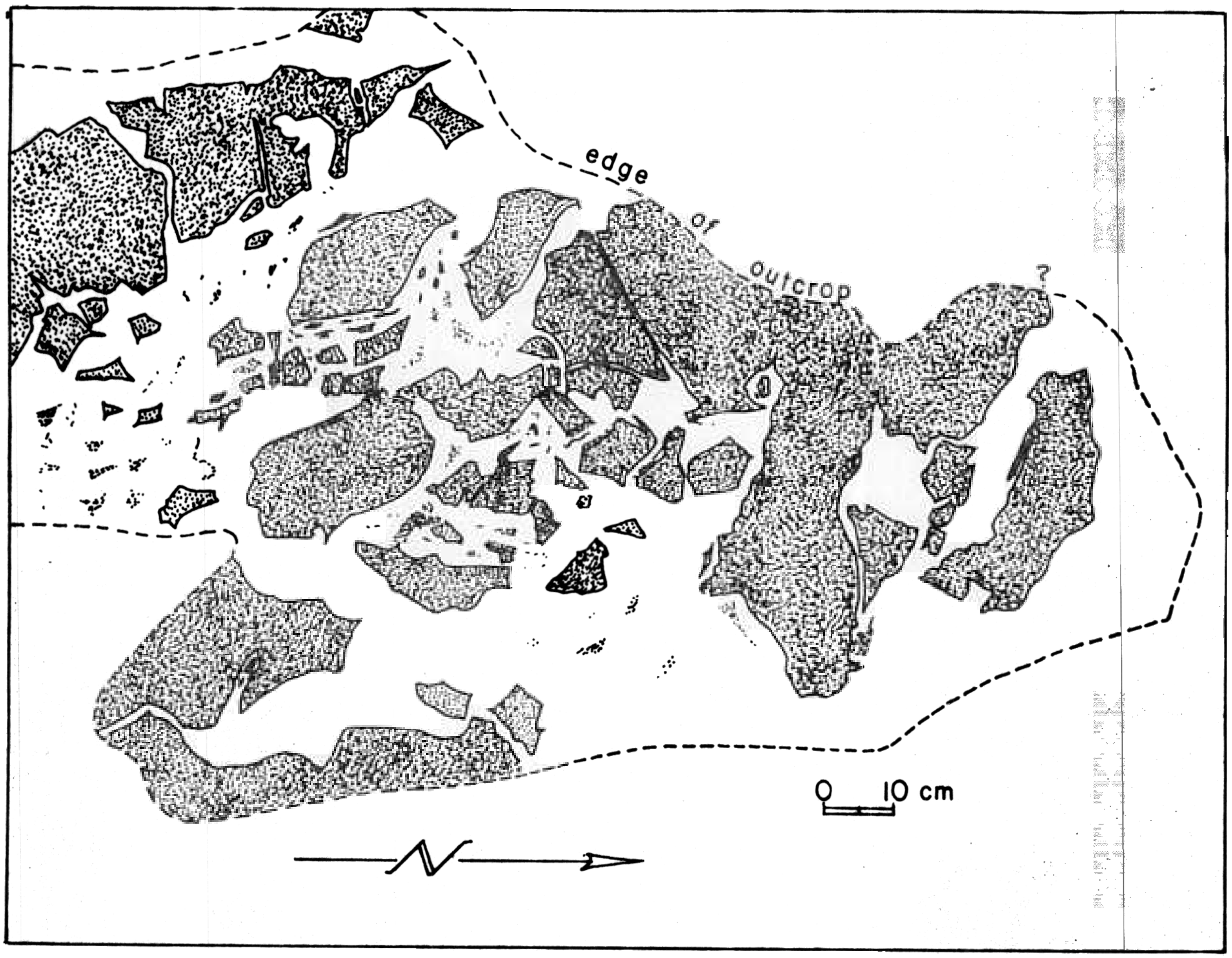


Author: Gene L. LaBerge

Description: This exposure is an excellent example of an intrusion breccia, with the light gray granodiorite containing numerous angular blocks (xenoliths) of darker gabbro and basalt. Breccias of this type are a result of magmatic stoping, wherein the rising magma cracks the overlying rocks, and magma is squeezed into the cracks, opening them wider. Finally, the opening cracks free large blocks of the overlying rock that fall into the rising intrusion. Xenolith rich portions such as we see here are typical of the border zones of intrusions.

The variety of lithologies in the xenoliths indicates mixing by flow during intrusion, which also produces alignment of the xenoliths. As shown in the sketch, some of the gabbroic xenoliths are extensively veined by the granite, suggesting that they were being segmented at the time the granite solidified. Some segmentation of the xenoliths probably occurred prior to incorporation in the magma. Further fragmentation may occur by attenuation of the fragments during flow of the highly viscous magma.

The exposure also illustrates differential weathering. The granitic rock stands about 1.5 cm higher than the gabbro, indicating that the mafic rocks here are more susceptible to chemical weathering. Note that there is no glacial polish, or pavement on this outcrop, yet about a half a mile south of here there are excellent glacial grooves and polish on outcrops of the Mellen Gabbro. The question arises, is the weathering here a post-glacial phenomenon? Or was there no glacial polish here originally? If the weathering is post glacial, then we have an opportunity to determine the rate of differential weathering since the ice receded from here some 9,000 years ago.



Sketch of intrusion breccia of the Mellen "Granite." White is granodiorite, dark blocks are gabbro and basalt. Note alignment and segmentation of blocks. (Sketch by P. E. Myers, UW-Eau Claire.)

Significance: The Mellen Granite is intrusive into the Mellen Gabbro and to some extent into the Keweenawan basalts that enclose the gabbro. Similar granodioritic intrusions are present south of Amnicon Falls near Superior (Mengel, 1969) and form extensive units called "redrock" associated with the Duluth Complex in Minnesota. Thus, the granodioritic intrusions are relatively widespread and are spatially related to gabbroic intrusions.

Radiometric age dating indicates that the granodiorite was intruded about 950 million years ago (Mengel, 1969), and thus represents the youngest known igneous event in the Lake Superior region. Although it is younger than, and intrudes the Mellen Gabbro, its close spatial relationship to the gabbro indicates that both magmas must have followed the same path to their present site. It is likely that the granodiorite is a late stage differentiate of the same parent magma that formed the Mellen Gabbro.

Mangham and Tabet (1978) conclude that the Mellen Gabbro was intruded during the early stages of folding of the Lake Superior Syncline. Since the Mellen Granite was intruded sometine after the gabbro body, it follows that it must have been intruded later in the deformational history. Thus, we may infer that the formation of the Lake Superior Syncline was well under way by 950 million years ago.

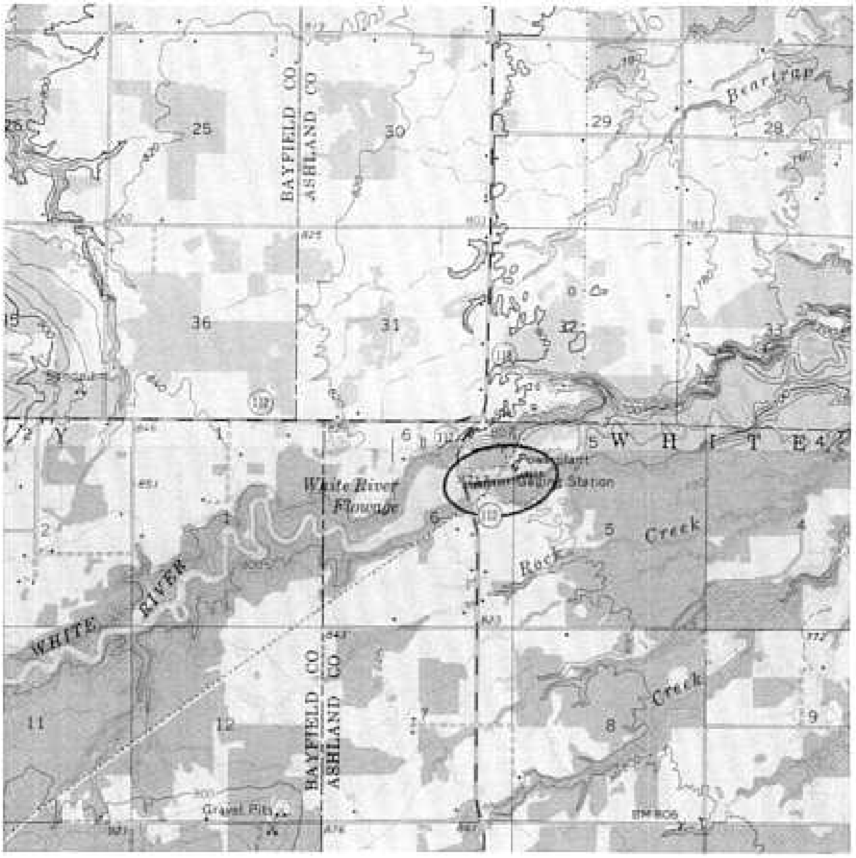
References:

Mengel, J. T. Jr., 1970, Geology of the Western Lake Superior Region: Geology Dept., UW-Superior.

Tabet, D. E. and Mangham, J. R., (in press), Geology of the Eastern Mellen Intrusive Complex, Wisconsin: Geoscience Wisconsin, Wis. Geol. Nat. Hist. Survey.

Title: White River

Location: Exposures in banks and bed of White River below reservoir dam and on both sides of bridge on Highway 112 about 4.3 miles south of Ashland in NE$\frac{1}{4}$, Sec. 6, T.46N., R.4W., Ashland County (Marengo 15-minute topographic quadrangle 1967).



Author: M. E. Ostrom (modified from Myers, 1971)

Description: Exposures of gently-dipping Freda Sandstone Formation. The Freda Sandstone is the upper formation of the Oronto Group of the "Lake Superior Sandstone" which is called the Upper Keweenawan Series. In ascending order the Upper Keweenawan consists of the Outer Conglomerate, the Nonesuch Shale, and the Freda Sandstone which in this area has an estimated total thickness of 12,000 feet (Thwaites, 1912). A description of strata exposed downstream from the dam is:

PRECAMBRIAN SYSTEM

Keweenawan Series

Oronto Group

Freda Sandstone Formation (+8.0 feet)

6.5' - 8.0'	1.5'	Sandstone, pebbly; basal contact sharp; appears to be cross-bedded, feldspathic, poorly sorted.
4.5' - 6.5'	2.0'	Siltstone, grayish red; well cemented; birdseye leaching.
0.0' - 4.5'	4.5'	Sandstone, grayish red locally leached light olive gray, medium grained, with interbeds of siltstone. Mudcracks having lengths up to 3"; width of crack 2 mm.

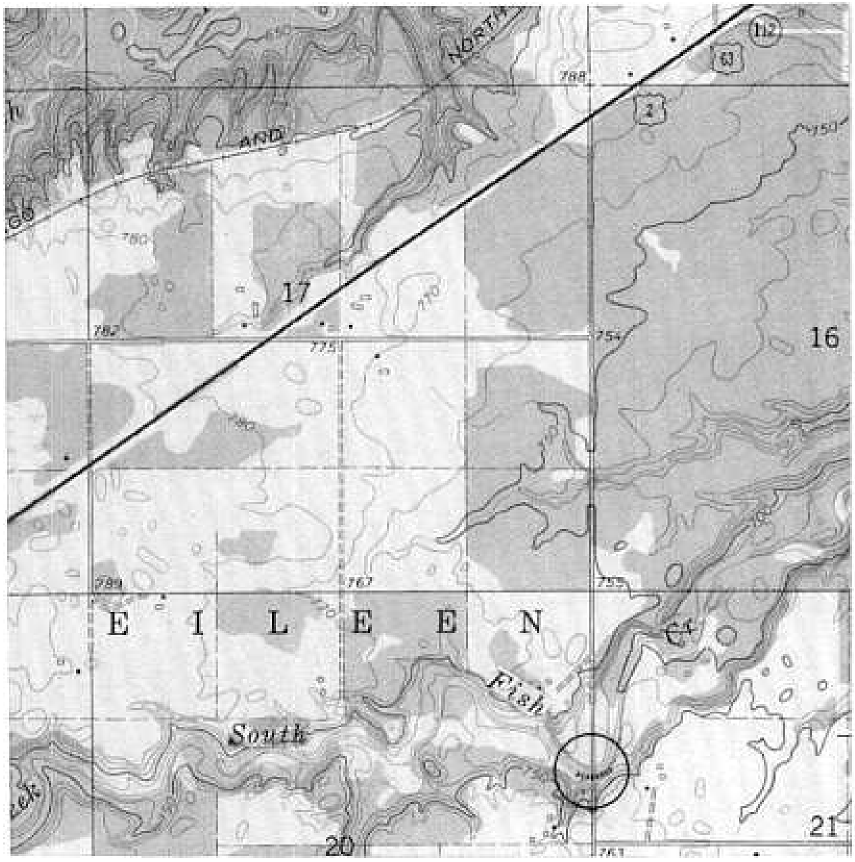
Significance: Although only 8 feet of a very thick formation is present it can be used for interpretation of both environmental, historical, and structural interpretation.

Examine lithology and mineralogy. What do they signify? What sedimentary structures can you identify? What do they signify? Measure dip and strike of the beds. What do these mean in terms of structural history? What is the origin of the red color? What caused the bleached areas?

References: Thwaites, 1912; Myers, 1971.

Title: South Fish Creek

Location: Exposures in banks of South Fish Creek beneath bridge on north-south secondary road 1.2 miles south of U. S. Highway 2 on the east line of the SE$\frac{1}{4}$, SE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 20, T.47N., R.5W., Bayfield County (Moquah 7.5 minute topographic quadrangle, 1964).



Author: M. E. Ostrom (modified from Myers, 1971)

Description: Exposures of steeply-dipping Freda Sandstone exhibit the lithologic and mineralogic character of the formation. A description of the strata downstream from the bridge is:

PRECAMBRIAN SYSTEM

Keweenawan Series

Oronto Group

Freda Sandstone Formation (11.0 feet)

11.0' Sandstone, grayish red to reddish brown, uniformly fine-grained, hard, cross-bedded with parting lineation. Much leaching. Penecontenporaneous deformation. Current ripple marks found in float.

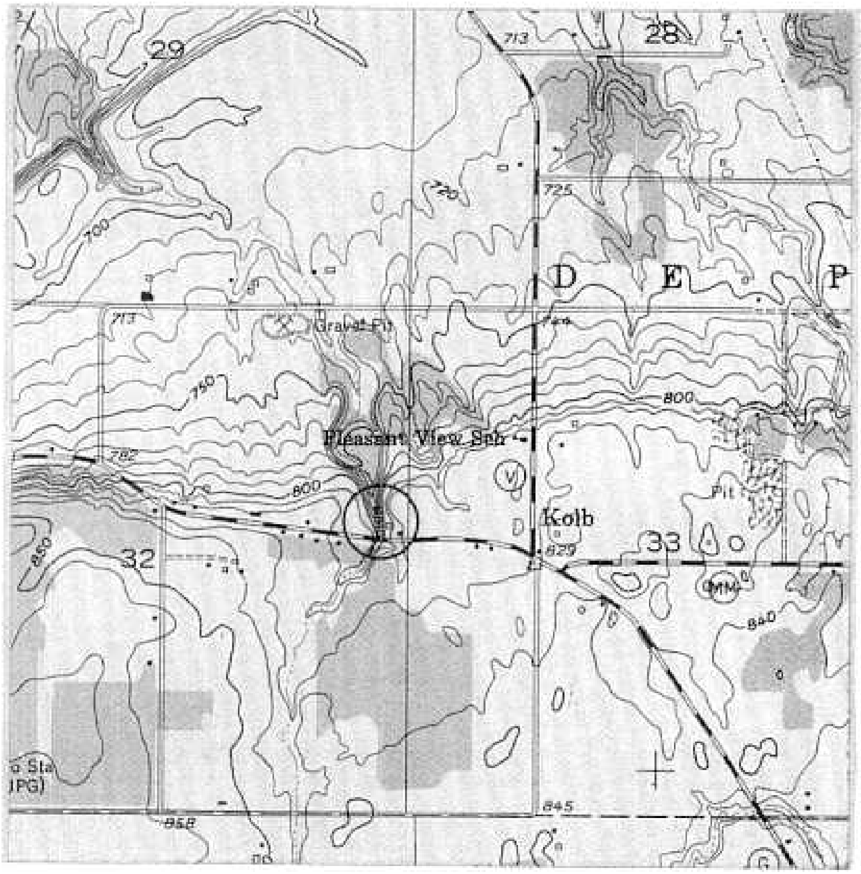
BASE OF EXPOSURE

Significance: Provides evidence of environmental, geologic and structural history. Examine lithology and mineralogy. What do they signify? What direction is the top of the beds? Measure dip and strike of beds. What do these mean in terms of structural history? From what direction did the sand come? What is the origin of the red color?

References: Thwaites, 1912; Myers, 1971.

Title: Kittell Falls

Location: Natural falls at the north side of County Highway "G" and 0.4 miles west of junction with County Highway "V", "MM", and "G" in the SE¼, NE¼, Sec. 32, T.23N., R.21E., Brown County (Bellevue 7.5-minute topographic quadrangle, 1970).



Author: M. E. Ostrom (modified from Rosenzweig, 1951)

Description: Exposure of Maquoketa Shale, Neda "Iron Ore" Formation, and Silurian dolomite.

Very little data is available on the distribution of the Neda Formation in this area. It is considered to be discontinuous and to occur in lenses. It was at one time mined near Iron Ridge in Dodge County where it is over 50 feet thick in places. Its high phosphorous content makes it undesirable for mining today. None of the wells around the outcrop shows any ore. An outcrop 1½ miles east also fails to show any ore. It is therefore assumed that the lense is of small extent.

A shallow channel sample was taken and analyzed by Inland Steel, with the following results:

Iron	P	Si	Mn	Al	S	CaO	MgO	Loss
21.68	.880	17.00	.11	5.86	.988	10.65	5.44	17.00

There are two main hypothesis concerning the origin of the ore:

(1) One theory holds that carbonate sediments were replaced long after deposition by iron oxides. Apparently there is not enough supporting evidence for this theory.

(2) A second theory, advanced by Hawley and Bevan (1934), postulates that the iron was deposited from a colloidal state as ferric hydroxide and hydrated aluminosilicates and the iron compound was later partially dehydrated. Description follows:

SILURIAN SYSTEM

Mayville Dolomite (+30.0')

37.9'	23.0'	Dolomite and dolomitic limestone, light yellowish gray, thin-to-medium to fine-crystalline, medium-bedded (1" to 18"). Some chert in lower part. Based contact even and sharp.
13.4' - 14.9'	1.5'	Dolomite, green gray, finely crystalline, dense. Lenticular with undulating base.
13.4'	0.1'	Shale, ferroginous, variegated

ORDOVICIAN SYSTEM

<u>Neda Formation</u> (5.3')

13.3'	1.2'	Dolomite, blue green, very finely-crystalline, with abundant pyrite. Some oolites, especially in lower part.
12.1'	2.5'	Iron ore, oolitic, dark reddish brown. Oolites are flattened parallel to bedding. Clay pebbles up to 2 inches in diameter are present. Shale partings present and most abundant in lower part.
9.4' 9.6'	0.2'	Shale, dark bluish gray, calcareous.
8.0' 9.4'	1.4'	Shale, brown, abundant oolites along bedding planes. Oolites increase upward. Some shiny 2-inch pebbles of shale and large oolite structures. Fossils were collected 1.5 feet above base by Savage and Ross ( ). Abundant pyrite near top.

ORDOVICIAN SYSTEM

Maquoketa Shale (8.0')

8.0'	8.0'	Shale, gray green, calcareous, hard, thinly-laminated in beds 3 inches to 8 inches thick with "yeast-like" fracture.

BASE OF EXPOSURE

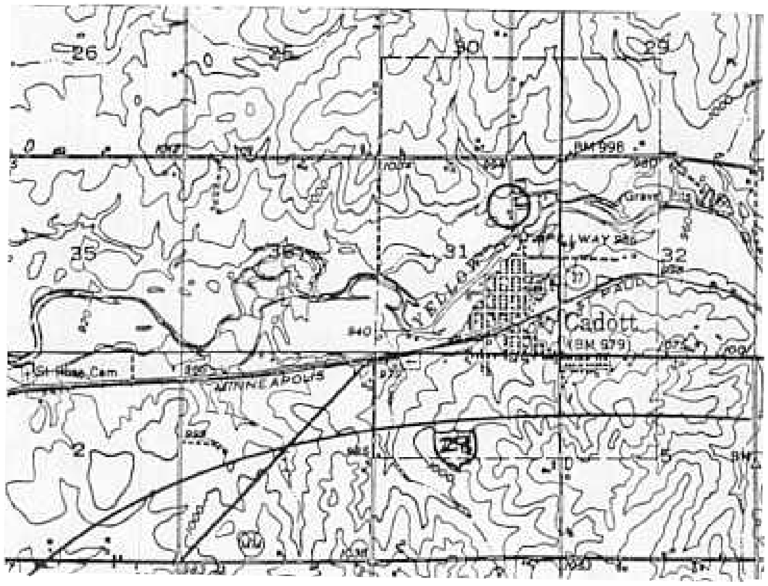
Significance: Exposure illustrates lithology and constant relationships of the Maquoketa, Neda, and Mayville Formations and, in the Neda, an ore of iron referred to as "flax-seed".

How is the Neda related to the Maquoketa? Contact? Lithology? Minerology? Fossils? Bedding at sedimentary structures? How is the Neda related to the Mayville? Explain the flattened oolites. What was the environment of deposition of each of the formations and what is your evidence?

References: Savage and Ross, 1916; Hawley and Bevan, 1934; Rosenzweig, 1951.

TITLE:

LOCATION: SW 1/4, NE 1/4, Sec 31, T 29 N, R 6 W, Cadott 15' Quadrangle



AUTHOR

DATE:

Faintly foliated hornblende-biotite tonalite complexly veined by leucocratic aplite and pegmatite is strongly folded, faulted, and locally detached and rotated as xenoliths in lighter-colored biotite tonalite. Foliation in the younger tonalite encloses the more mafic xenoliths. An older cataclastic foliation (N10-20°W) is cut by a second cataclastic foliation at N65-75°W. Gneissic hornblende tonalite is the predominant rock type for 3.2 kilometers upstream. Further up the Yellow River the tonalite contains screens and/or pendants of metamorphosed pyroxene gabbro with a strong west-northwest stronctural grain.

DESCRIPTION:

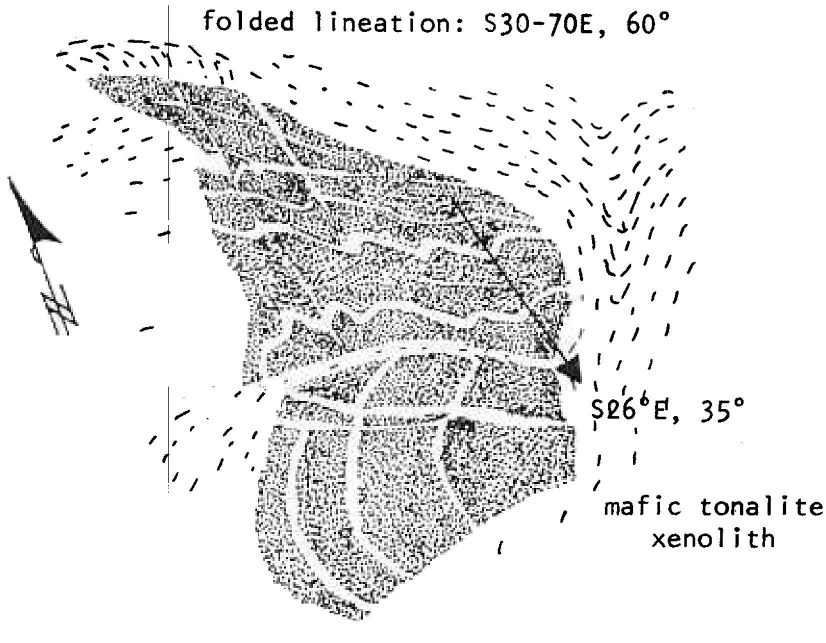


Figure 1 -- Xenolith of veined and folded hornblende tonalite in gneissic felsic tonalite

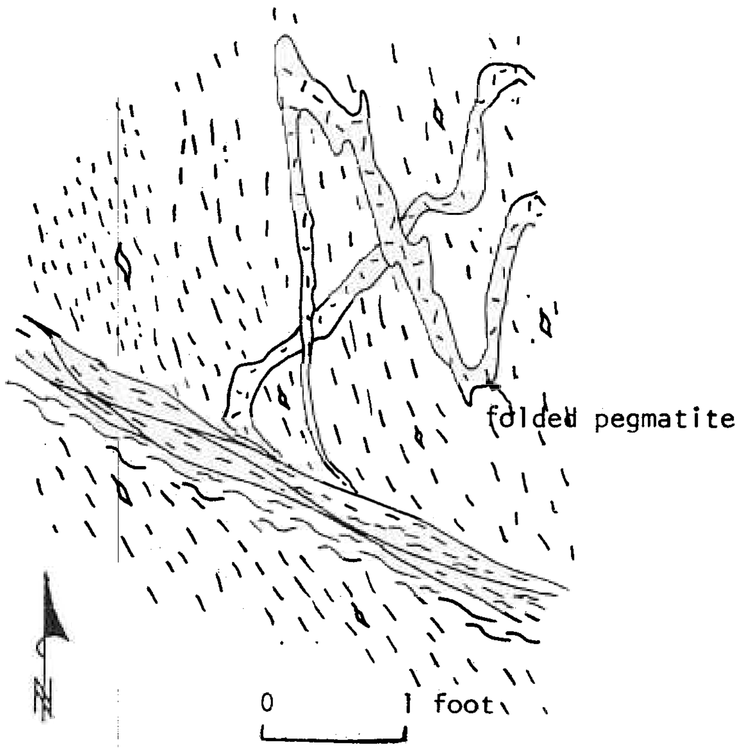
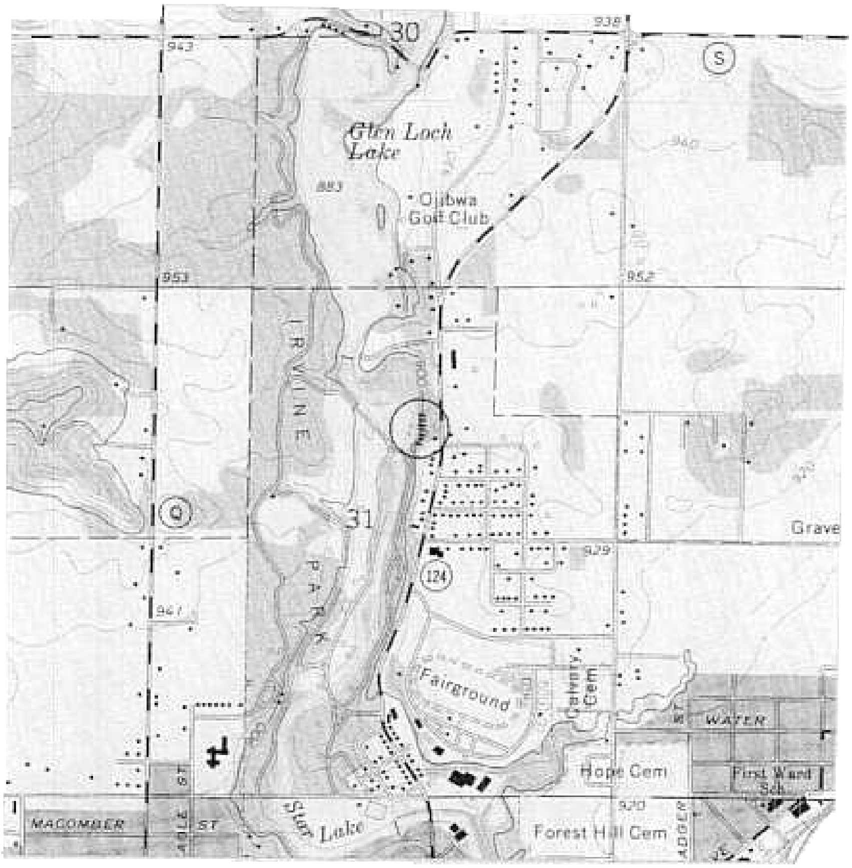


Figure 2 -- Two ages of cataclastic foliation in biotite tonalite with axial planes of folded pegmatite veinlets parallel to older cataclastic foliation. The second cataclastic foliation is mylonitic.

Location: Stream cut in east bank of Duncan Creek just north of first bridge south of Glen Lock dam in Irvine Park near north city limits of Chippewa Falls in the NW¼, SW¼, NE¼, Sec. 31, T.29N., R.8W., Chippewa County (Chippewa Falls, 7½-minute topographic quadrangle, 1972). Exposure can be reached by foot path from northeast side of bridge northward for about 100 yards.



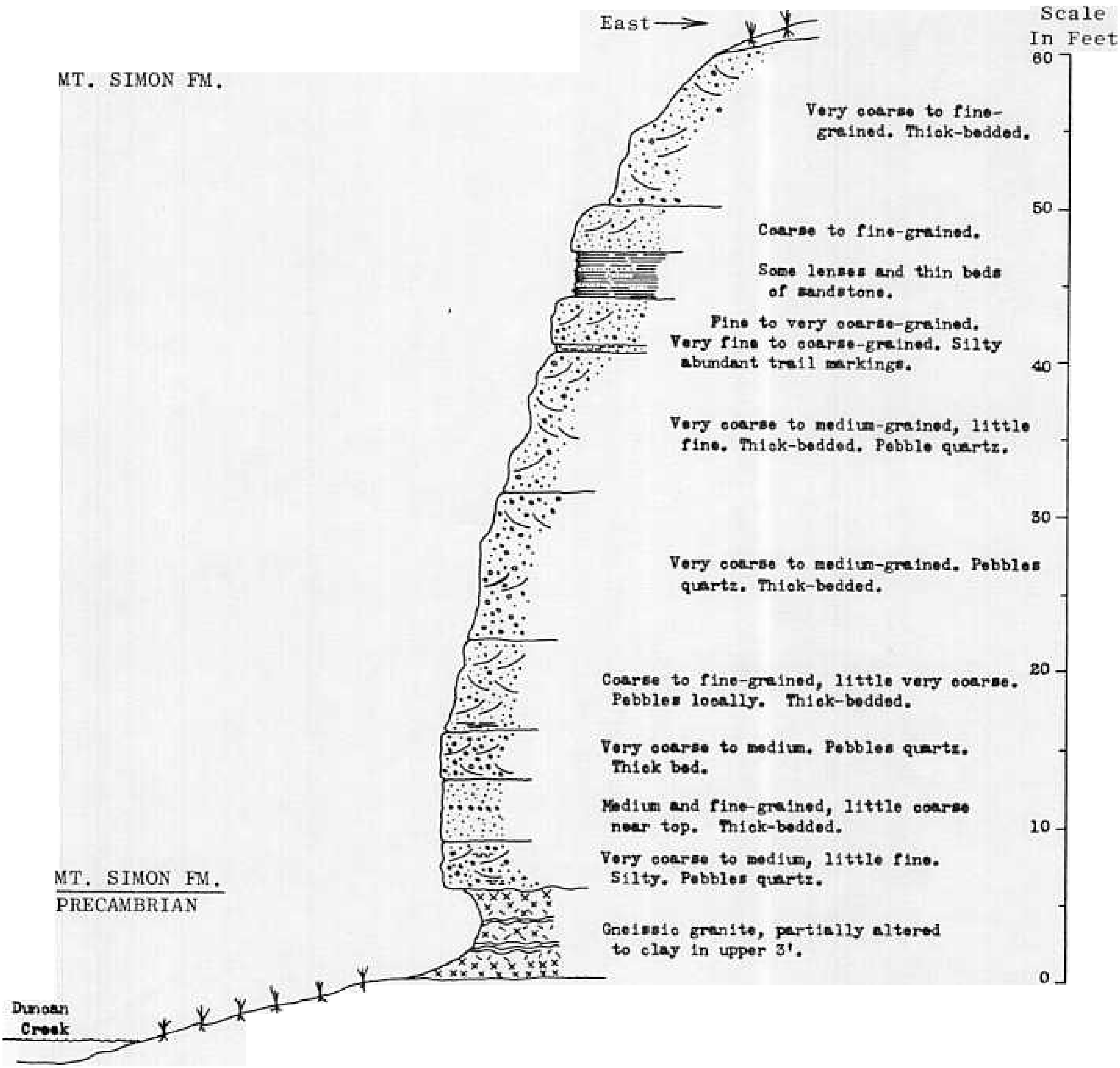
Author: M. E. Ostrom (modified from Ostrom, 1970)

Description: The Mt. Simon Sandstone, presumably the oldest Cambrian formation in Wisconsin, here rests unconformably on weathered Precambrian gneissic granite. This relationship with the Precambrian persists throughout the Paleozoic area of the state except that rock type and altered condition of the Precambrian vary.

Lack of data prevents construction of a coherent "buried" Precambrian geologic map, however drill cuttings reveal that a wide variety of igneous and metamorphic rock types occur beneath the Paleozoic cover. Among the rocks reported are granite, diorite, quartzite, gneiss, schist, iron formation, rhyolite, basalt, slate, shale, and greenstone.

The Mt. Simon Sandstone is believed to have been deposited in a shallow marine nearshore environment by an advancing sea which migrated from southeast to northwest over a weathered and eroded Precambrian rock surface (Ostrom, 1964a).

IRVIN PARK OUTCROP
NW¼,SW¼,NE¼,Sec.31,T.29N.,R.8W.



The areal extent of such deposits in the Gulf of Mexico today is limited to the length of the shoreline and a maximum width of about 20 miles. The Cambrian and Ordovician sandstones are believed to be a result of spreading out shallow nearshore marine deposits as blankets during transgression (Ostrom, 1964a). For example, Calvert (1962) shows that the Mt. Simon or its equivalent the Erwin Sandstone, overlaps to the northwest from Tennessee to Wisconsin, that it was deposited during a period of transgression, and that its age is Early Cambrian in Tennessee and Late Cambrian in Wisconsin.

The Mt. Simon has been considered predominantly a quartz sandstone with minor shale, siltstone, and fine conglomerate and minor feldspar (Crowley and Thiel, 1940; Potter and Pryor, 1960). However, in 1968 a study sponsored by the Wisconsin Geological Survey and used as a PhD dissertation by Virendra Asthana revealed that the feldspar content of the Mt. Simon Sandstone averages 18% of which 81% is potash feldspar, 10% is plagioclase feldspar and 9% is microcline. The range in feldspar content reported is from 2.85% to 40.07%. Asthana reports that all of the microcline and plagioclase grains are detrital as are a part of the potash feldspar grains. Authigenic orthoclase is very common but occurs as rhombic overgrowths on detrital grains. On this basis it appears that the Mt. Simon contains far more feldspar than has been previously noted which fact helps to distinquish it from other Upper Cambrian and Ordovician sandstones in Wisconsin.

The source of the Cambrian sands has long been an enigma. Without going into a lengthy discussion of the various hypotheses involving weathering and long transport of eroded Precambrian rocks to produce a relatively clean quartz sand it should be pointed out that there is a ready source available, namely quartzites of Precambrian age. Distribution of the Baraboo Quartzite today is probably the result of a combination of factors including local and regional variations in intensity of metamorphism disintegration, and erosion. It has been noted (Ostrom, 1966) that the Baraboo Quartzite disintegrates by some natural process to yield already rounded monocrystalline quartz sand grains and that this and similar quartzites may have been a major source of sand found in Cambrian and Ordovician rocks of the region. In a quarry located near North Freedom, Wisconsin, steeply tilted beds of quartzite, weathered in the upper few feet, are overlain by flat-lying beds of the Galesville Sandstone. Here weathering of the quartzite released rounded quartz grains which went to make up the Galesville Sandstone; an example of a Cambrian beach deposit. Other quartzites exhibit similar disintegration, namely the Rib Hill and Barron in Wisconsin and the Sioux in Minnesota (Austin, 1969). The fact that these quartzites are extensive, thick, and weather to yield already rounded quartz grains suggests that they may have been a major source of sand supplied to Cambrian and Ordovician seas.

Significance: This exposure illustrates the Precambrian/Paleozoic unconformity in Wisconsin and the character of the initial Paleozoic deposits. Consideration should be given to geologic events which occurred in the time represented by the unconformity.

On the basis of what has been seen and discussed at previous stops how much time is represented by the unconformity? What geologic events occurred during this time? What evidence do you have at this and previous stops for these events? On the basis of sedimentary features and mineralogy, what was the source of Mt. Simon Formation sediments at this stop?

References: Thwaites, 1935; Crowley and Thiel, 1940; Potter and Pryor, 1960 Calvert, 1962; Ostrom, 1964 and 1966; Asthana, 1968; Austin, 1969.

Title: Tilden, Wisconsin -- contact of Mount Simon and Eau Claire Formations (Upper Cambrian)

Location: Section in roadcut on both sides of Chippewa County Highway F, 0.8 mile north of its intersection with Chippewa County Highway B in the SE corner NE1/4 NE1/4 sec. 7, T.29N., R.9W., Chippewa County (Como Creek, Wisconsin, quadrangle, 7.5-minute series, topographic, U.S. Geological Survey, 1975) (fig. 1).

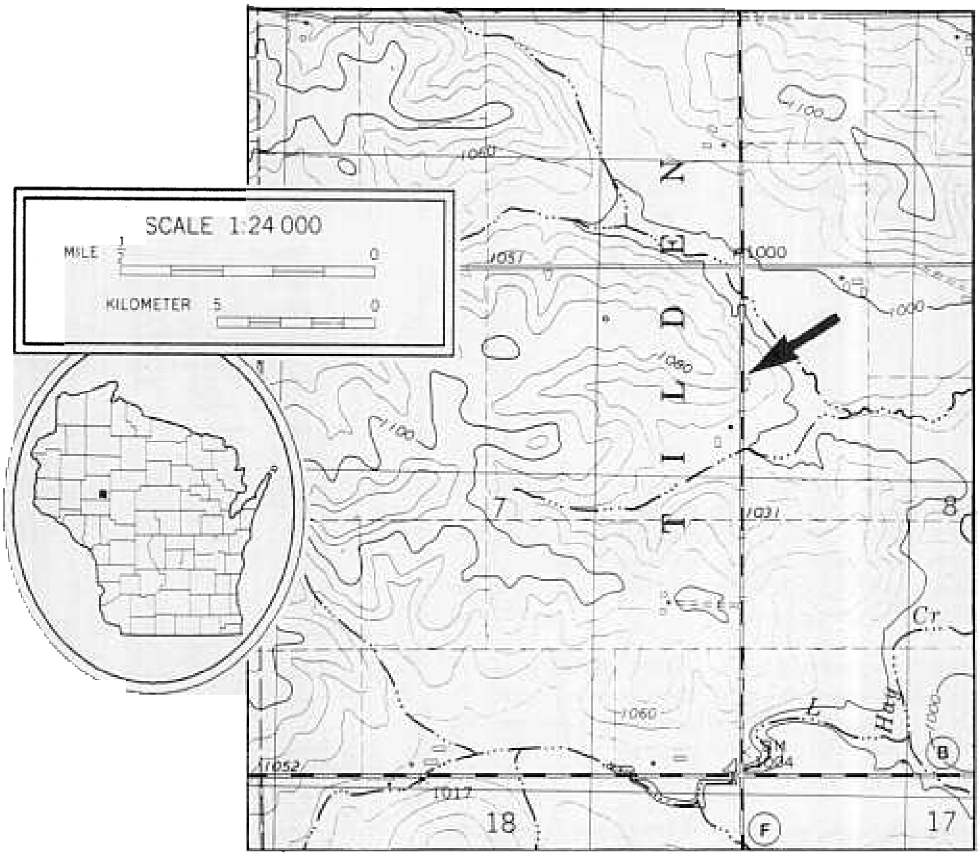


Figure 1. Location of roadcut near Tilden, Wisconsin, showing contact of Mount Simon and Eau Claire Formations.

Author: M.E. Ostrom, 1988

Significance: This exposure illustrates the contact of the Mount Simon Formation with the Eau Claire Formation. The proximity of this exposure to others of these formations in the vicinity of Chippewa Falls and Eau Claire is helpful for understanding stratigraphic and contact relationships in the area.

Description: This is one of the better exposures in Wisconsin of the contact between the Mount Simon and Eau Claire Formations. Although only 5 ft of Mount Simon is visible, its contact with the Eau Claire is exposed over a distance of 100 ft (figs. 2 and 3).

The Eau Claire Formation is distinguished from the Mount Simon by its generally finer grain size and thinner bedding and by the presence of abundant clay in thin shale beds and along partings. Glauco-

Eau Claire Formation (18.8 ft [5.7 m] exposed)

Sandstone, light yellowish brown and light yellowish gray, thick-bedded, inaccessible (top of west side of cut) (4 ft) [1.2 m]

Sandstone, light gray and light yellowish brown, interbedded with pale green clay partings, thin-bedded, inaccessible (10 ft) [3.1 m]

Sandstone, light yellowish brown mottled yellowish brown, very fine and fine grained, trace of glauconite, some gray clay on bed partings, thin-bedded, unevenly bedded. Some beds silty. Medium sand grains in lower 1 in. of some beds. Some limonite stain along beds; appears to be concentrated in bottom of beds. Few small reddish brown (0.25 in. to 0.5 in.) pods of fine and medium sand grains in limonite cement. Clay partings up to 1 in. (3 ft) [0.9 m]

Shale, gray to light yellowish brown and light brown, and silty, interbedded with very fine silty sandstone with some medium sand. Brachiopod fossils (black traces) especially noticeable in sandstone. Very thin-bedded with discontinuous limonite enrichment in basal few inches (1 ft) [0.3 m]

Shale, dark gray, interbedded with sandstone, very fine to fine grained, fossiliferous (black brachiopod traces), unevenly bedded. Ratio of shale to sandstone approximately 1:1. Limonite enrichment in bottom 1 in. (0.8 ft) [0.2 m]

Mount Simon Formation (5 ft [1.5 m] exposed)

Sandstone, light yellowish gray and light yellowish brown, coarse and medium grained with some fine, thick-bedded (single bed), cross-bedded, with abundant white phosphatic brachiopods. Limonite enrichment irregular and discontinuous (3 ft) [2.7 m]

Sandstone, light yellowish gray to light yellowish brown to reddish brown, fine and very fine grained, some siltstone and gray shale partings (1 ft) [0.3 m]

Sandstone, light gray, very fine grained and silty with gray shale partings and some limonite enrichment (1 ft) [0.3 m]

Base of exposure at road level (elevation estimated from topographic map is 1040 ft).

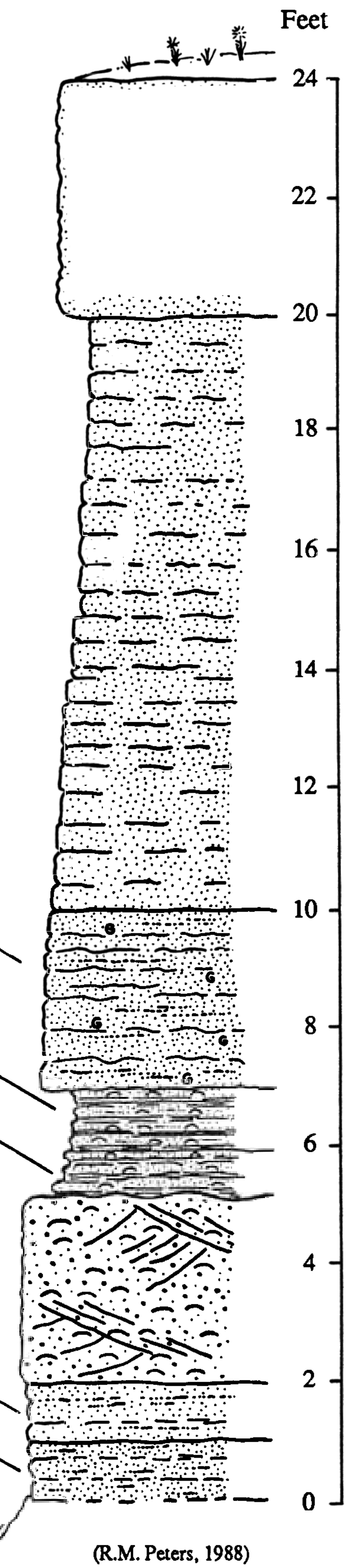


Figure 2. Stratigraphic section of Eau Claire and Mount Simon Formations.

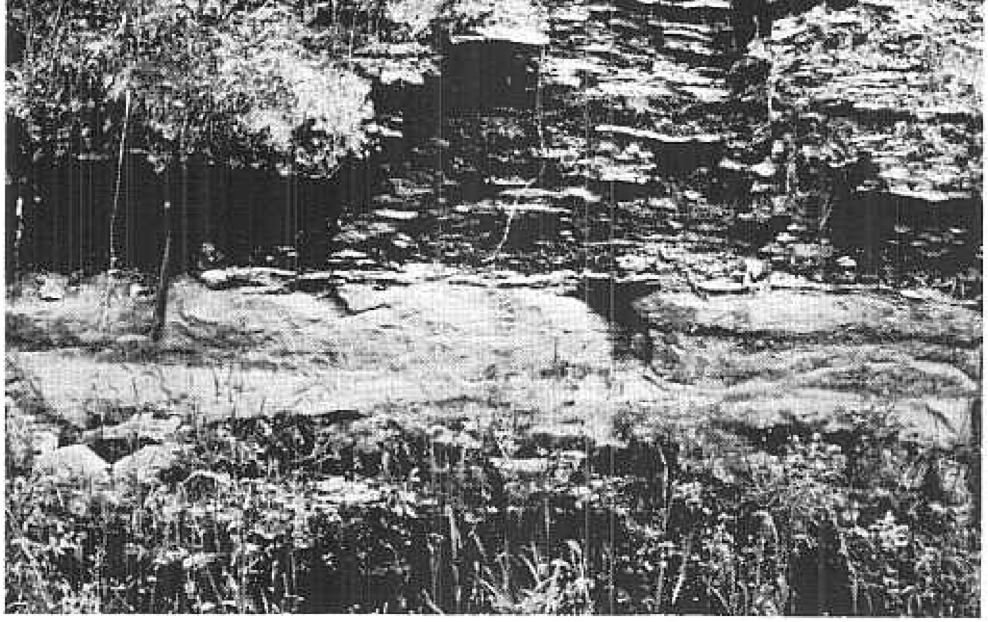


Figure 3. Contact of Mount Simon sandstone with overlying Eau Claire shaley sandstone at east side of County Highway F (hammer handle is 14 in. long).

nite and trilobites are common in places. The Eau Claire in this exposure is within the *Cedaria* faunal zone. The lower few inches to 1 ft is commonly limonite-enriched. At the contact, about 4 ft above road level, the Mount Simon consists of cross-bedded, coarse- and medium-grained sandstone in a single thick bed, with abundant phosphatic brachiopod shells. Limonite enrichment is more or less present in this bed but tends to be more prevalent in the upper 6 in. The Mount Simon is overlain by the Eau Claire Formation, which consists of about equal amounts of dark gray shale interbeddded with brownish gray silty, very fine-grained sandstone that contains abundant brachiopod fossils (black traces) and trail markings. Limonite enrichment is in the bottom few inches. Bedding is uneven.

A similar relationship can be seen at the Rest Haven Gardens exposure on Old Town Hall Road, an east-west asphalt road 0.8 mile west of the junction of Eau Claire County Highway IA with U.S. Highway 53, south of the city of Eau Claire on the north line of the NW1/4 SE1/4 sec. 2, T.26N., R.9W., Eau Claire County (Ostrom, 1978a). Although more than 20 ft of each formation is exposed here, the contact of the Mount Simon with the Eau Claire is poorly exposed.

The Eau Claire Formation at the Tilden outcrop consists of 14.8 ft of the lower "shaley beds" overlain by the "lower thin-bedded unit" of Morrison (1968). Morrison describes the shaley beds as "shaley sandstone and shale, very fine and fine-grained, and very thin-bedded, individual beds often indistinct and seldom over 3 in. thick. Abundant fossils and track markings. About 15 ft thick." The overlying lower thin-bedded unit consists of "sandstone, fine and very fine-grained, mixed thin and thick beds, thin beds regular and distinct, glauconitic, high clay content, mica common. Abundant fossils and trail markings. About 20 ft thick."

The Eau Claire Formation is exposed in other roadcuts along County Highway F both north and south of this exposure. An expecially good exposure of some of the overlying units is in a semi-active quarry located 1 mile east of this exposure at the east side of Quarry Road, 0.4 mile north of its junction with County Highway B.

Ostrom (1970) interprets the section exposed in this outcrop to represent a transgressive transition from prevailing high-energy shallow, near-shore marine deposits of the Mount Simon Formation to prevailing lower energy, more offshore marine deposits of the Eau Claire Formation. This interpretation is suggested by the change from coarse sand grains, thick beds, few to no fossils, and no to minor clay

The following exposures in this vicinity are helpful to understanding stratigraphic relationships and lithologies of the Upper Cambrian rocks:

Irving Park: Precambrian/Paleozoic unconformity at Chippewa Falls (Ostrom, 1978b; 1987a), CH 29N/08W/31;

Mount Simon: Mount Simon Formation at Eau Claire (Ostrom, 1978c; 1987b), EC 27N/09W/08;

Strum: Eau Claire Formation at Strum (Ostrom, 1978d; 1987c), TR 24N/08W/18.

References

Morrison, B.C., 1968, Stratigraphy of the Eau Claire Formation of west-central Wisconsin: Madison, University of Wisconsin, Master's thesis, 41 p.

Ostrom, M.E., 1970, Field trip guidebook for Cambrian-Ordovician geology of western Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 11, 131 p.

_____, 1978a, Rest Haven Gardens Town Road: Wisconsin Geological and Natural History Survey Outcrop Description EC 26/09W/02.

_____, 1978b, Irvine Park: Precambrian/Paleozoic unconformity at Chippewa Falls, Wisconsin: Wisconsin Geological and Natural History Survey Outcrop Description CH 29N/08W/31.

_____, 1978c, Mt. Simon: Mt. Simon Formation at Eau Claire, Wisconsin: Wisconsin Geological and Natural History Survey Outcrop Description EC 27N/09W/08.

_____, 1978d, Strum: Eau Claire formation at Strum, Wisconsin: Wisconsin Geological and Natural History Survey Outcrop Description TR 24N/08W/18.

_____, 1987a, Precambrian/Paleozoic unconformity at Chippewa Falls, Wisconsin: Geological Society of America Centennial Field Guide Volume 3, North-Central Section, Outcrop Description Number 42, p. 177-178.

_____, 1987b, The Mount Simon Formation at Eau Claire, Wisconsin: Geological Society of America Centennial Field Guide Volume 3, North-Central Section, Outcrop Description Number 43, p. 179-182.

_____, 1987c, Late Cambrian Eau Claire Formation at Strum, Wisconsin: Geological Society of America Centennial Field Guide Volume 3, North-Central Section, Outcrop Description Number 44, p. 183-184.

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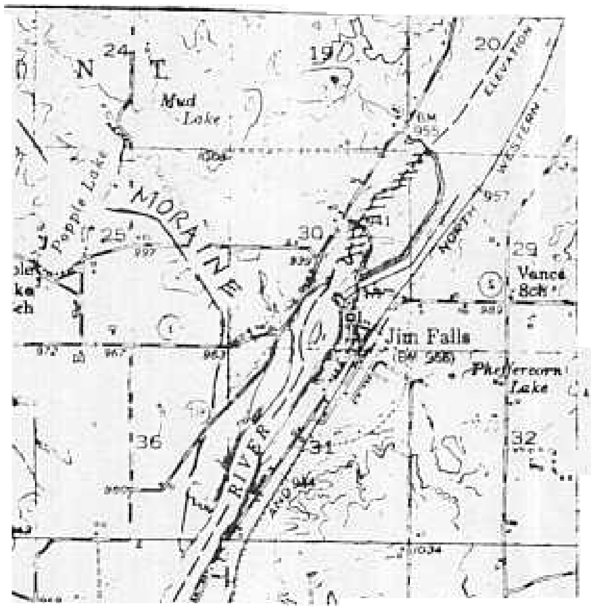
Geological and Natural History Survey
Ronald Hennings, Acting Director and State Geologist
3817 Mineral Point Road, Madison, Wisconsin 53705

TITLE: Amphibolites and Granites at Jim Falls

LOCATION: E 1/2 Sec. 30, T 30 N, R 7 W, Jim Falls, Bloomer 15' Quadrangle



AUTHORS: Paul E. Myers, UW - Eau Claire and Douglas R. Maercklein, Texaco, Midland, TX 79701

DATE: September, 1974, Revised January, 1978

SUMMARY OF FEATURES:

Banded amphibolites, probably derived from mafic volcanics and associated sediments, were intruded by granites of diverse composition and their cogenetic pegmatites in Middle(?) Precambrian time. Subsequent cataclasis, deformation, and metamorphism produced a highly deformed system of tectonically interlensing rock units showing only partial preservation of older structures. Prevailing regional structural grain is ENE. Late Precambrian jointing and diabase dike intrusion (1100 - 900 m.y.?) followed prolonged erosion.

DESCRIPTION:

Garnetiferous hornblende gneiss and schist with folded, high-amplitude isoclines (Fig. 1) and persistent ENE strike and steep dip are cut subconcordantly by granitic rocks ranging in composition from leuco-tonalite to granite. Pegmatite dike intrusion occurred at several stages of "granite" intrusion. The older granitic rocks are foliated and locally mylonitized. Shearing and boudinage of pegmatite stringers transposed them into oblique concordance with lamination in the enclosing rocks (Fig. 5). A rough correlation can be made between relative age and concordance of veinlets.

At location A, thinly laminated amphibolite was intruded by granite so that lenticular slices of the amphibolite were dragged en echelon away from the wall (Fig. 6). The coarse granite pegmatite intruded under stress contains en echelon (gash) fractures which are filled with quartz. The amphibolite-granite contact is sheared and cataclastically blended. The cataclastic zone appears to have been granitized. The effects of cataclasis are not easily seen here because shearing occurred almost concordantly: that is, granite intrusion was guided by lamination in the amphibolites, and subsequent shearing was localized along these contacts.

Small scale folds at Location C (Fig. 1) plunge gently east. These are folded high-angle (F-1) isoclines. Older, F-1 isoclines are best seen in amphibolite at Location B. Stream erosion nearly parallel to fold axial planes produced an unusual wood-like grain on the outcrop.

The aeromagnetic map (Fig. 7) shows a V-shaped area of low magnetic contrast opening eastward from Jim Falls. North of this "V", elongate ridges of high magnetic contrast suggest close-spaced interlenticulation of amphibolite and subordinate granite. A magnetic high extends ESE from Jim Falls: this is also probably produced by an amphibolite septum. A prominent magnetic "ridge" crosses the former one, and may represent a dike or fault. Faults of this trend are unusual in the Jim Falls area.

The chronology at Jim Falls is approximately as follows: (1) basaltic volcanism and associated sedimentation (archean?) (2) folding and regional metamorphism converting the volcanics and sediments to amphibolites, (3) late tectonic cataclasis forming ultramylonite, (4) faulting and brittle deformation, (5) successive intrusion of at least four granitic magmas with episodes of intervening cataclasis (folded mylonite xenoliths occur in some of the younger intrusives), (5) prolonged erosion, and (6) Late Precambrian jointing and diabase dike intrusion. (This sequence is modified from Maercklein, 1974, p. 16-20.) As at Big Falls (Eau Claire River) at least three distinct deformational episodes can be seen in these rocks.

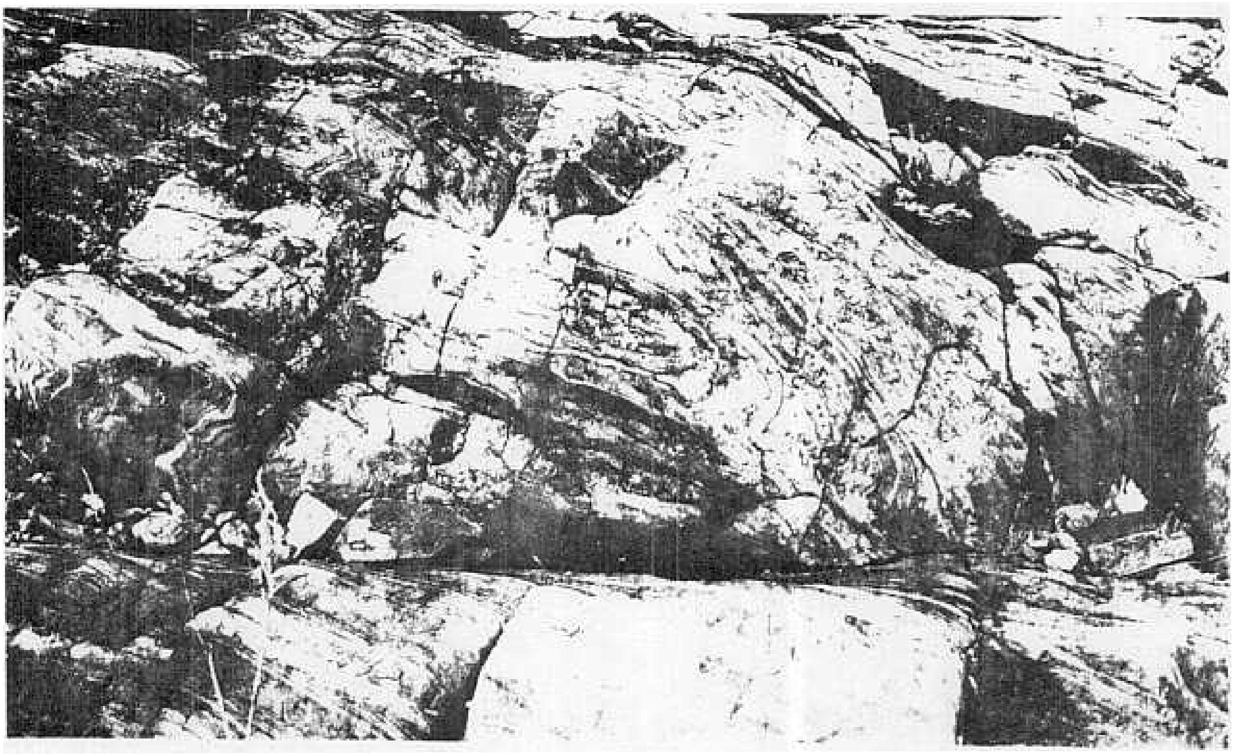


Figure -- Folded isoclines in thinly laminated amphibolite at Location C. Drag folding and brecciation can be seen on some fold limbs. These are F-2 folds. F-1 isoclinal fold hinges can be found in a few places on this outcrop.

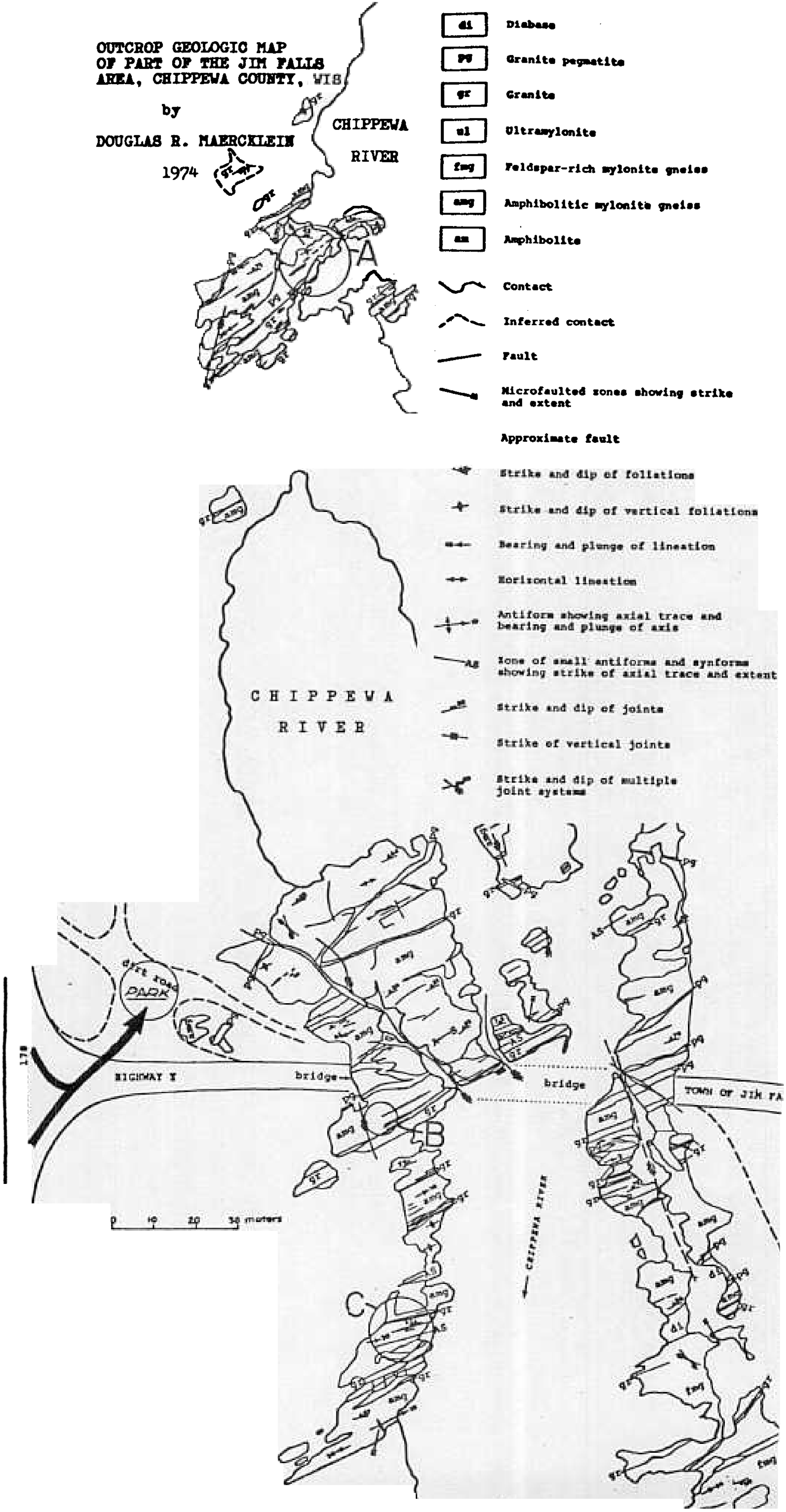


Figure 2 -- Generalized geological outcrop map of Jim Falls Wide lines are contacts; broken lines are inferred contacts.

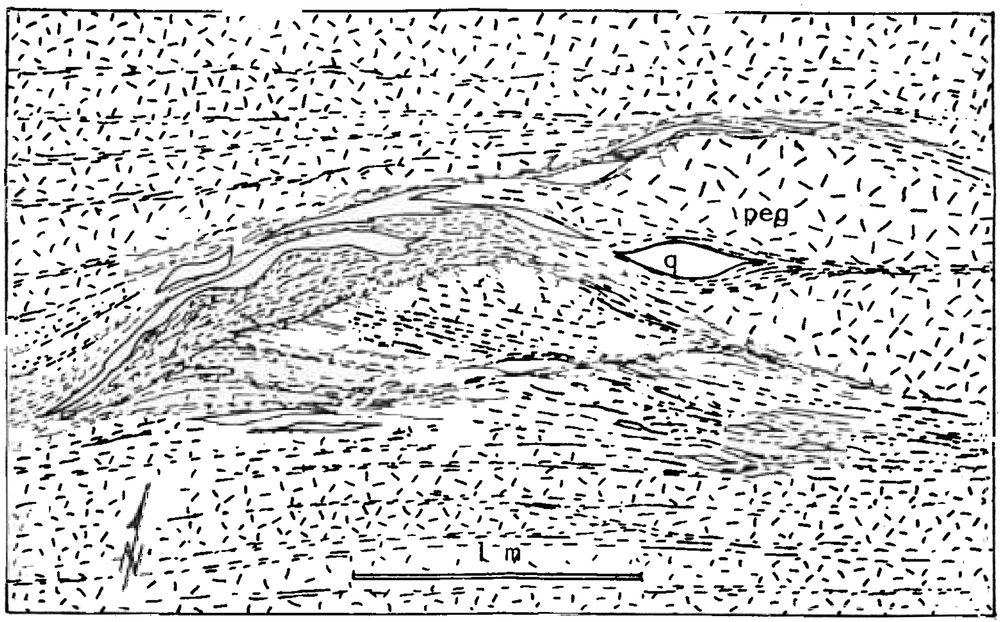


Figure 3 -- Interlensing shear cutting granite pegmatite at Location A. Lenticular white areas are quartz, which tends to be locallized along surfaces of major slippage.

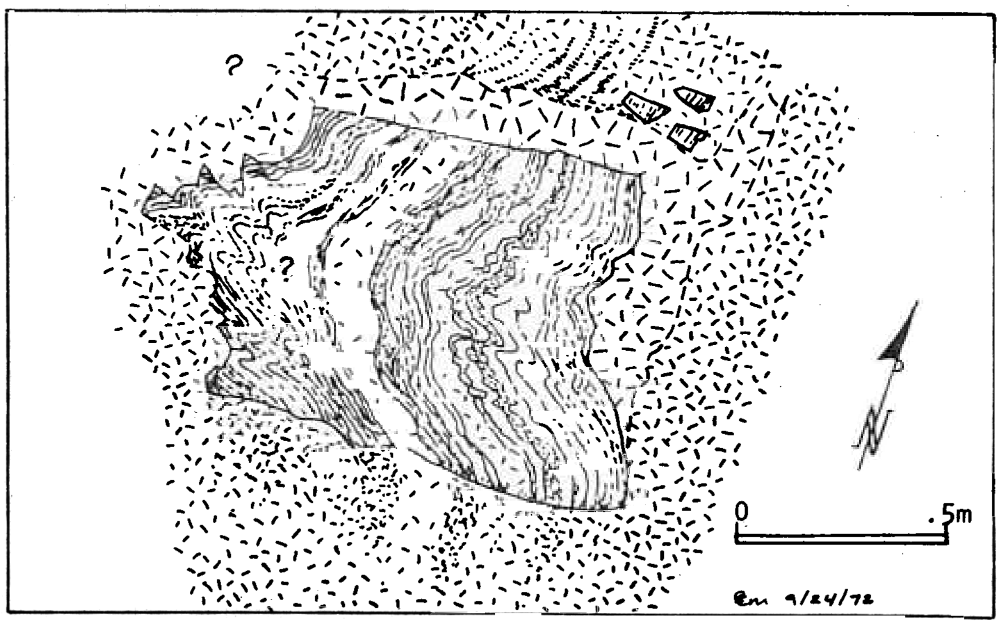
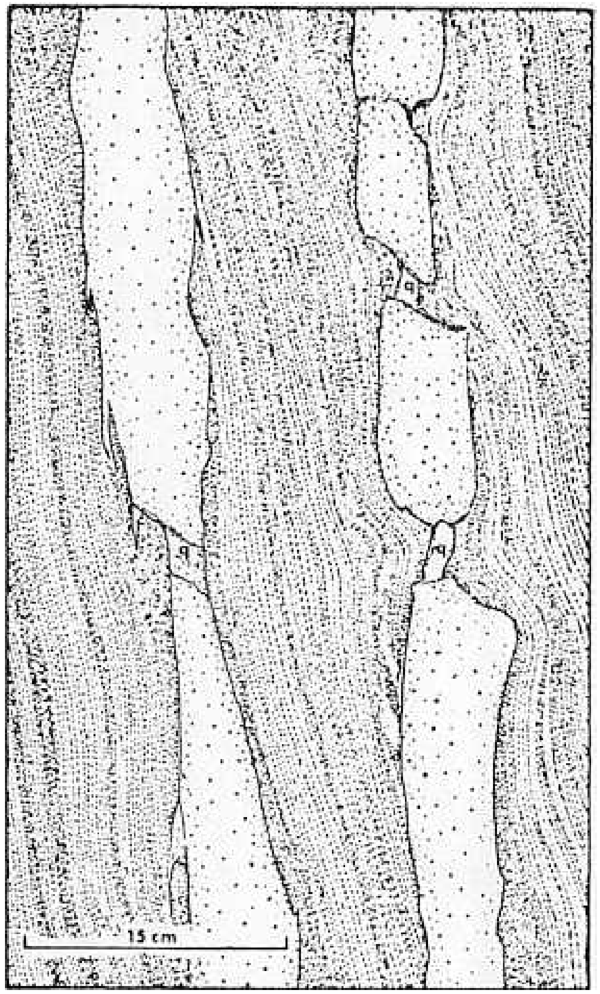


Figure 4 -- Partially granitized amphibolite xenoliths in biotite granite. Contact locally discordant. Biotite-rich bands extend into the granite from the xenolith. Location, halfway between dam and bridge on west side of river.



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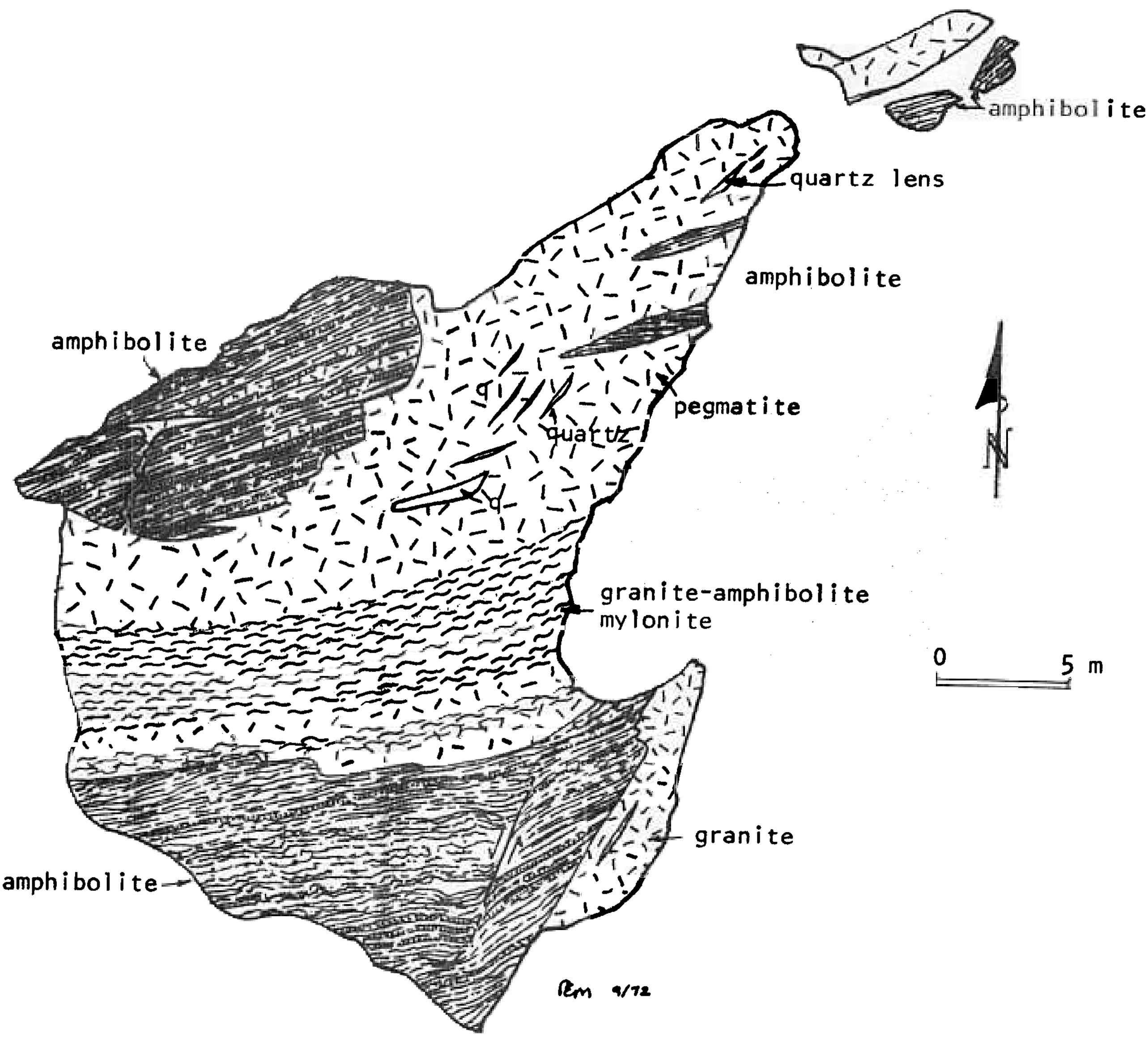


Figure 6 -- Detailed geologic map showing sheared intrusive contact of "granite" in thinly banded amphibolite. Lenses of amphibolite were carried away from the wall by the granite. En echelon fractures were filled by quartz during contraction of the pegmatite. Location (A)

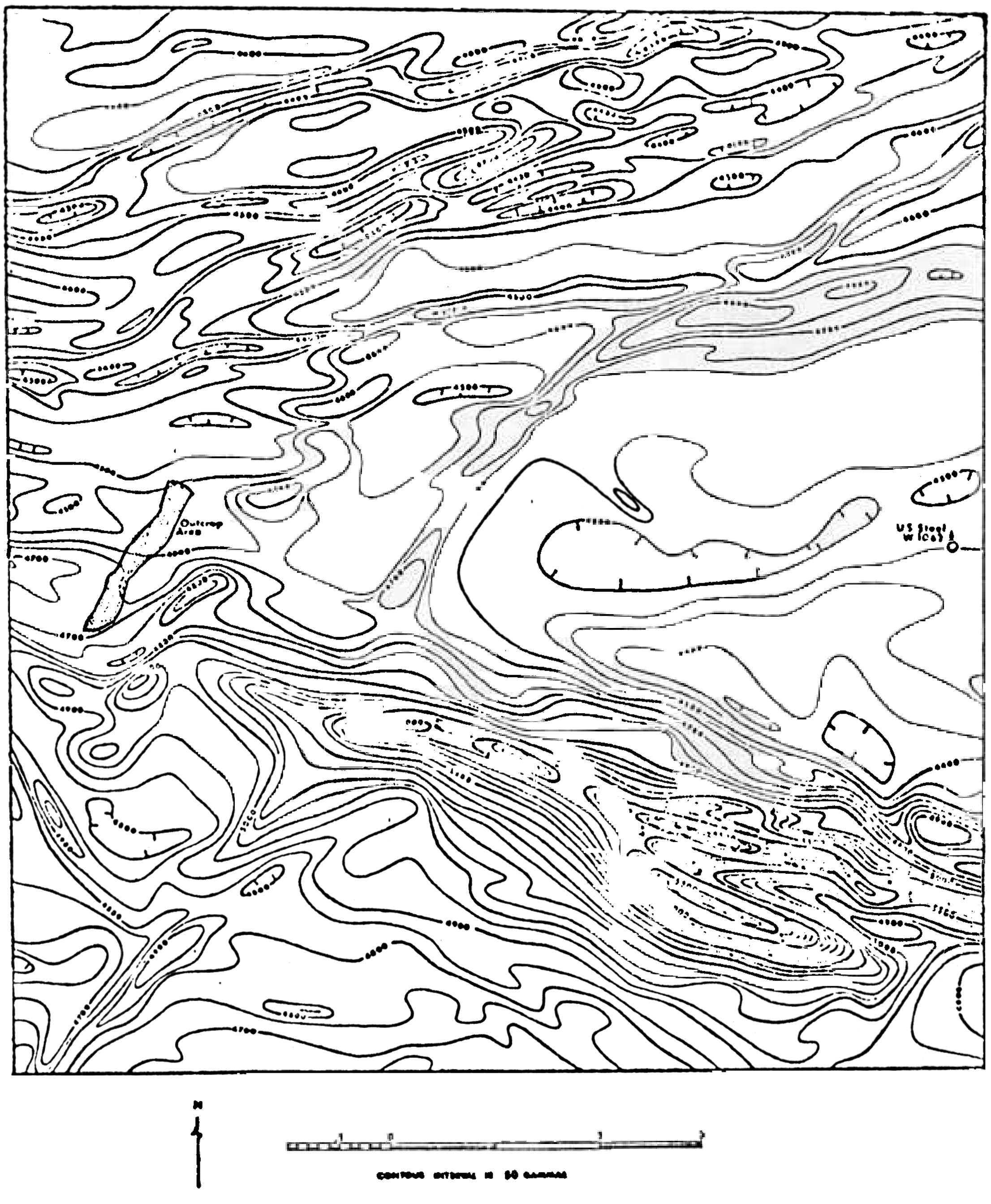
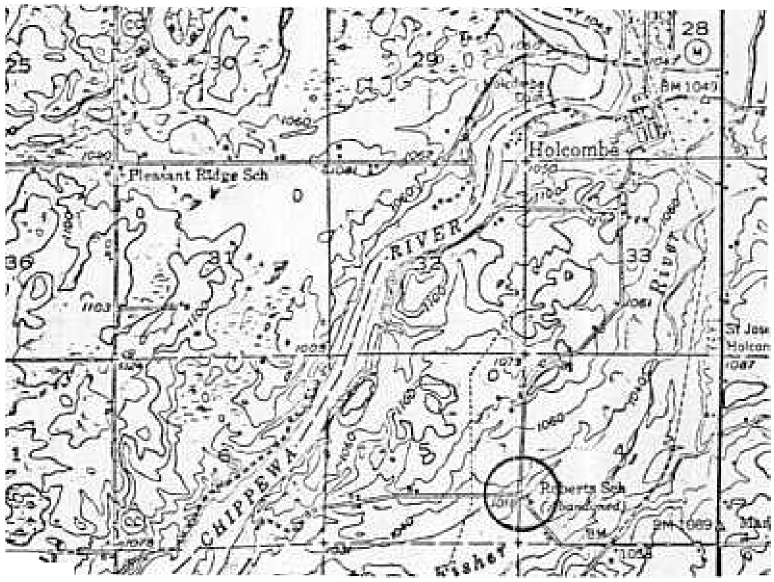


Figure 7 -- Aeromagnetic map of Jim Falls area adapted from an aeromagnetic survey by U.S. Steel, 1974. Exposures at Jim Falls are shown by stippled area near left margin.

TITLE: Fisher River Breccia

LOCATION: NW 1/4, SW 1/4, Sec. 4, T.31N., R.6W, Chippwa County, Cornel 15' quadrangle



AUTHOR: P. E. Myers, UW-Eau Claire

DATE: September 1974

SUMMARY OF FEATURES:

This unusual breccia contains many rock types not seen elsewhere in this region. The poorly sorted, subangular to subrounded fragments are mainly of massive, schistose and gneissic greenstone, hornblende gabbro, metapyroxenite, anorthosite(?) and granite. The breccia grades southeast across strike into a sheared granitic rock. The origin of the breccia is in question.

DESCRIPTION:

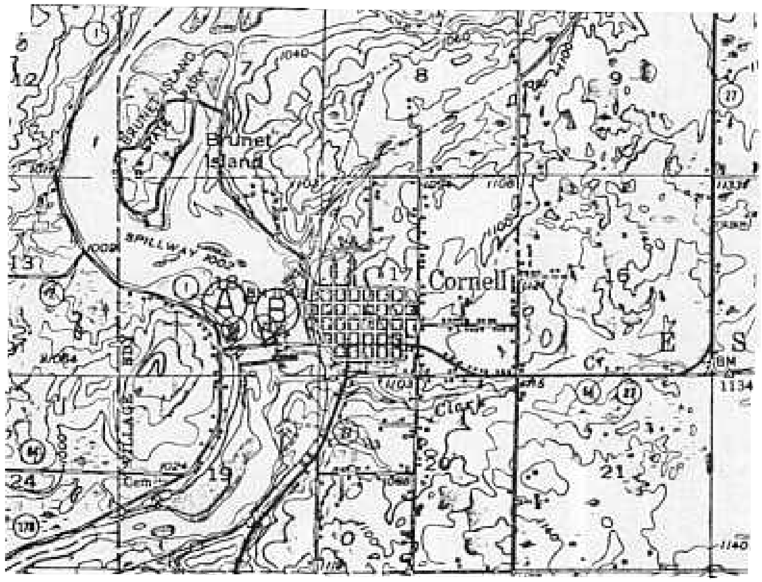
Poorly sorted, subangular to rounded clasts in this heterolithic breccia are dominantly mafic rock types, including basaltic greenstone, hornblende gabbro, pyroxenite(?) and anorthosite(?). Subordinate granitic clasts are found. The fine-grained feldspar-biotite-quartz matrix is of remarkably small volume. Many of the rocks in this breccia do not crop out in this area, but they are abundant in nearby glacial deposits--a factor indicating that a high proportion of the region north of here is underlain by mafic igneous rocks. Biotite appears to have been formed after emplacement of the breccia as evidenced by the widespread occurrence of biotite in clasts originally containing other mafic minerals.

Outcrops of cataclastic biotite granite(?) gneiss along Fisher River about 0.5 km south of here and in outcrops about 250 m WSW of here contain no such clasts. Fine-grained hornblende tonalite(?) intruded by much coarser hornblende tonalite(?) crops out just northwest of Fisher River bridge 0.5 km southeast of here. Banding in the coarse quartz diorite trends E-W vertical. Both rocks are lineated, probably as a result of shearing. Leucogranite pegmatite veins in these rocks have been segmented and displaced along cataclastic foliation. A late, massive leucogranite (low % dark minerals) is not sheared. Is the breccia a tectonic breccia? Is it a clastic dike like those of the Sudbury District, Ontario? Is it a tillite?

Figure 1. Roadside outcrop of heterolithic breccia showing wide variety of rock components. Scale is 15 cm long.

TITLE: Cornell Flaser Gneiss and Amphibolite

LOCATION: A, SE 1/4, NE 1/4, Sec. 18, T.31N., R.6W., west side of Hwy. 64 bridge
B, SW 1/4, NE 1/4, Sec. 18, T.31N., R.6W., east side of Hwy. 64 bridge



AUTHOR: P.E. Myers, UW-Eau Claire

DATE: September 1974

SUMMARY OF FEATURES:

Flaser gneiss composed of mica, quartz, feldspar and sparse garnets is tectonically interlensed with thinly laminated fine-grained banded garnet amphibolite. Although granite, which became the flaser gneiss, was probably intruded into the amphibolite, its contact today is a shear zone.

DESCRIPTION--FLASER GNEISS, Loc. A

Garnetiferous, biotite flaser gneiss (Fig. 1) near water level at the northwest corner of the Cornell bridge is composed of coarse lenses of zoned feldspar in a micaceous mylonitic matrix. This rock contains more biotite and less garnet than flaser gneiss at Locality B. "Penetrative" deformation and cataclasis normally involve several stages of differential grain fracture, displacement, and ablation. The rock from which this gneiss formed was probably a coarse-textured biotite quartz monzonite. Each component mineral in a granitic rock behaves differently under shearing stress.

Stage 1--Protomylonite

Early strain is expressed as progressive microscopic crushing of minerals, first at corners, then on edges, and last on faces. The lens is an equilibrium form at all scales. Quartz is easily fractured and accumulates with fragmented feldspar as an insulating film of crushed rock or "mylonite" encasing relict feldspar lenses or "porphyroclasts". Such a rock is characterized by a faint foliation and ovoid shape of feldspars. Primary textures are still conspicuous.

Stage 2--Flaser Gneiss

With continued deformation, relict feldspar lenses become decidedly lensoidal (Fig. 2). Primary mica is reoiriented along interlensing slip planes, and the rock becomes conspicuously foliated. New mica may begin to crysallize at this stage. The proportion of mylonite to surviving grains increases while relict feldspar lenses become thinned by ablation. Crenulation or microfolding or residual rock lenses is common at this stage. "Tectonic xenoliths" or lenticular fragments of non-mylonitized rock are carried along in the flowing granular mass. Drag folds and ptygmatic folds show differential movement and turbulence. Most of the displacement becomes localized along thin, interlensing zones of slippage (Fig. 2).

Stage 3--Ultramylonite

Reduction of relict rock and mineral lenses by ablation may ultimately result in a thinly laminated, flinty ultramylonite, or in crystallization of new feldspar. Relict feldspar lenses become mantled by new feldspar. Reversed zoning is common. The rock at this stage becomes a blastomylonite. The point at which feldspar regrowth begins varies even from one part of an outcrop to another.

Reaction rates accelerate with: (1) increased surface area in accumulating mylonite. (2) frictional heat. and (3) pressure of mobilized water.

Anhedral form of the garnets and absence of deformation around them indicate their late-kinematic age. Fresh garnet is a relatively rare mineral in rocks of the Eau Claire region. Large, relict garnets at Big Falls are altered to hornblende. With rocks that have been deformed and metamorphosed at least three times, it becomes difficult to discriminate between surviving "relict" minerals and those produced during later metamorphism.

Foliation and compositional layering in rocks at Cornell strike N80°E to N80°W. These same structural elements at Fisher River 4 km northeast of here trend N40°-50°E, a factor taken to indicate a major flexure in the rocks north of Cornell.

GARNET AMPHIBOLITE, Loc. B

Laminated garnet amphibolite at Location B is representative of the "Cornell amphibolite" which crops out almost continuously for 4 km down the Chippewa River. Banding in the amphibolite is cur by lenticular segments of granite and quartz veinlets. The nearly vertical banding is

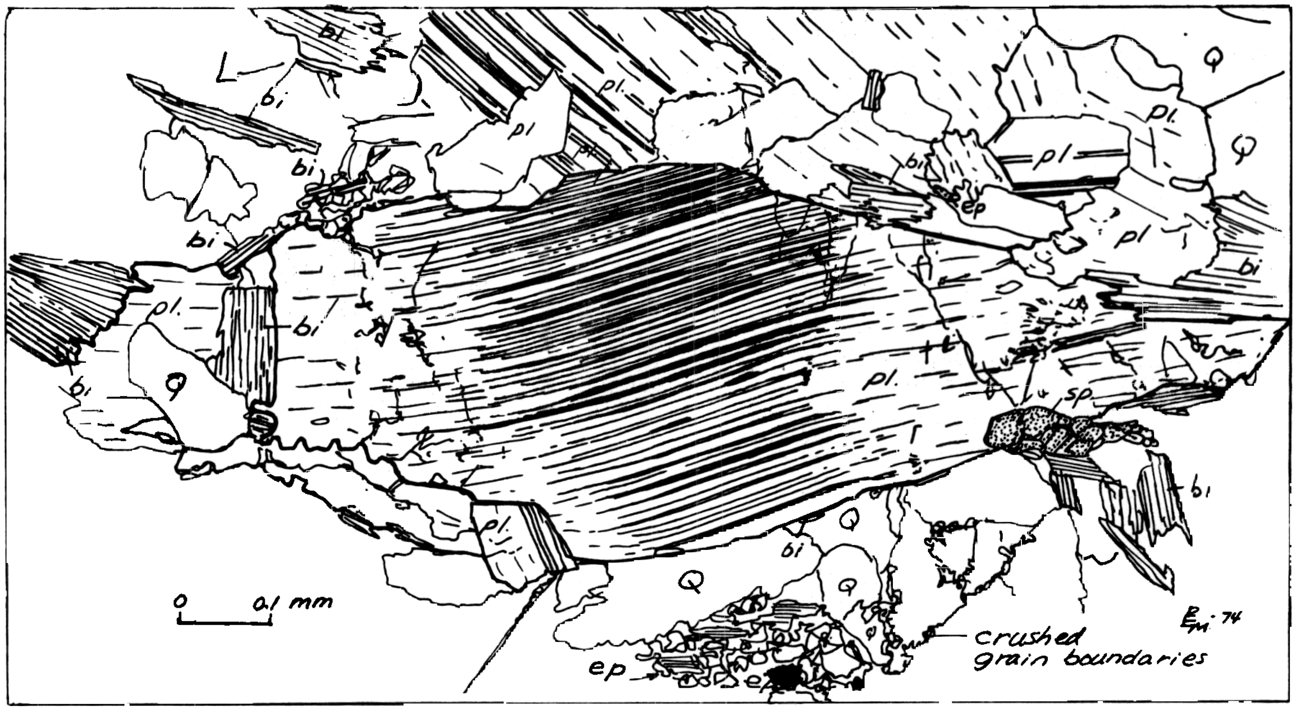


Figure 2 -- Bent and lenticulated plagioclase in feldspathic orthogneiss from Hamilton Falls. Biotite shows spatial affinity for slip planes enveloping the plagioclase lens. Some plagioclase grains show destruction of albite twinning owing to small-scale disordering of crystal lattices.

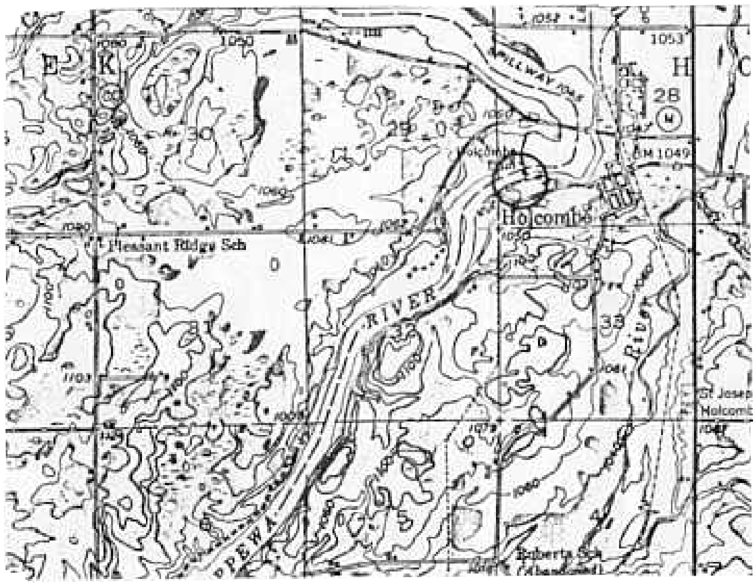
thinly interlensing in 3 dimensions, and strikes N80°E to N80°W. Small, isoclinal folds plunge at low angles in the plane of compositional banding. Garnets in the amphibolite tend to be randomly clustered and have ragged borders. No evidence of garnet porphyroblast rotation was seen. The distribution of garnet clusters shows little relation to banding or fold morphology. The garnets appear to have formed after most of the particulate flowage of the rocks, as evidenced by the good preservation of garnet crystal apophyses in the amphibolite.

Coarse, garnetiferous felsic flaser gneiss and sheared pegmatite are in contact with amphibolite in this outcrops. Granite commonly intrudes amphibolite at other locations (Jim Falls). Intrusive relations of most granite bodies in the area are obliterated by shear displacement and partial recrystallization. The occurrence of garnet in the flaser gneiss indicates that both rocks were metamorphosed after tectonic imbrication.

Figure 2 -- Flaser gneiss from Loc. A
Relict feldspar lensoids are enclosed
in a matrix of micaceous mylonite.

TITLE: Gneissic amphibolite, hornblende diorite, and felsic dikes of the Holcombe Dam area

LOCATION: Holcombe Dam, SW 1/4, Sec. 28, T.32N., R.6W., Chippewa County, Cornell 15' quadrangle



AUTHOR: P.E. Myers, UW-Eau Claire

DATE: September 1974, January]978

SUMMARY OF FEATURES:

Gneissic amphibolite with basaltic inclusions was intruded by anatectic(?) hornblende diorite and later converted to schist along a shear zone exposed at the south end of the dam. After prolonged erosion, these rocks were intruded at shallow depth by granite dikes and later segmented by a system of ENE-trending faults.

DESCRIPTION:

Dark gray, medium-grained amphibolite and metalamprophyre(?) probably derived from mafic volcanics and/or intrusives, cintains lenticular inclusions and drag folds indicating flowage. The amphibolite is intruded with sharp contact by medium-grained hornblende diorite(?). The diorite contains inclusions of the amphibolite as well as relatively non-metamorphosed basalt. Migmititic-gneissic lamination in the amphibolite trends N80°W, 75°N. The diorite is locally flow-lineated. The diorite magma may have been formed by partial melting of the amphibolite at depth. South of Chippewa River below Holcombe Dam, mafic mylonitic biotite-chlorite schist probably formed by shearing of the amphibolite and diorite, has foliation which trends N60°E, 80°S. Crinkle folds plunge N60°W at 40°.

Several NNW-trending chloritized biotite granite dikes with chlorite and biotite along chilled margins can be seen along the N65°E, 68°N fault on the outcrop just below the NW retaining wall. The dikes have fine-grained, flinty marings--a good indication of shallow, Late Precambrian intrusion. These dikes are segmented by numerous steep, N60°W trending right lateral faults (NE side SE). The felsic dikes are pyritic with hematite replacement.

Figure 1. Fault offsets of felsic dikes. The dike strikes about north-south and is about 0.5 m wide.

TITLE: The Flambeau Quartzite

LOCATION: Flambeau Ridge, sections 1, 2, 11, and 12, T.32N., R.7W., and sec. 6, T.32N., R.6W., Chippewa County

AUTHOR: P. E. Myers, UW-Eau Claire

DATE: September 1974 from field reconnaissance, July 1974

SUMMARY OF FEATURES:

The Flambeau Quartzite contains numerous beds of rounded quartz pebbles and smaller, angular clasts of more locally-derived slaty iron formation. Cross bedding and ripple marks indicate shallow-water deposition. The quartzite is thrown into a tight, west-northwest-plunging syncline. Contact and structural relations of the unit are obscured by glacial drift. Erratics on the ridge summit indicate that ice passed over it.

DESCRIPTION:

LITHOLOGY AND PROVENANCE

Rounded, white quartz pebbles with a maximum diameter of about 12 cm. are mixed with angular to subangular, smaller clasts of slaty iron formation. Many of the conglomerate beds are only one pebble layer thick. Conglomerate in the lowest visible part of the formation (Loc. C) is rich in angular iron formation clasts and shaly, feldspathic matrix. With dimunition in relative abundance of iron formation clasts creates a question about the mechanism of deposition. The relative angularity of the iron formation clasts suggests a nearby source. The quartz pebbles may have been reworked. More work is needed on this problem.

A spectacular outcrop of the quartzite can be seen at Loc. B, where a 6-meter bed of conglomerate overlies cross-bedded, purple quartzite and granule metaconglomerate. The outcrop has slabbed off along bedding in these units.

STRUCTURE

Cross bedding provided a reliable top-indicator in most outcrops. Available field data indicate that the quartzite is tightly folded into a syncline which plunges steeply west-northwest. Most of Flambeau Ridge is an exposure of the south limb of this fold.

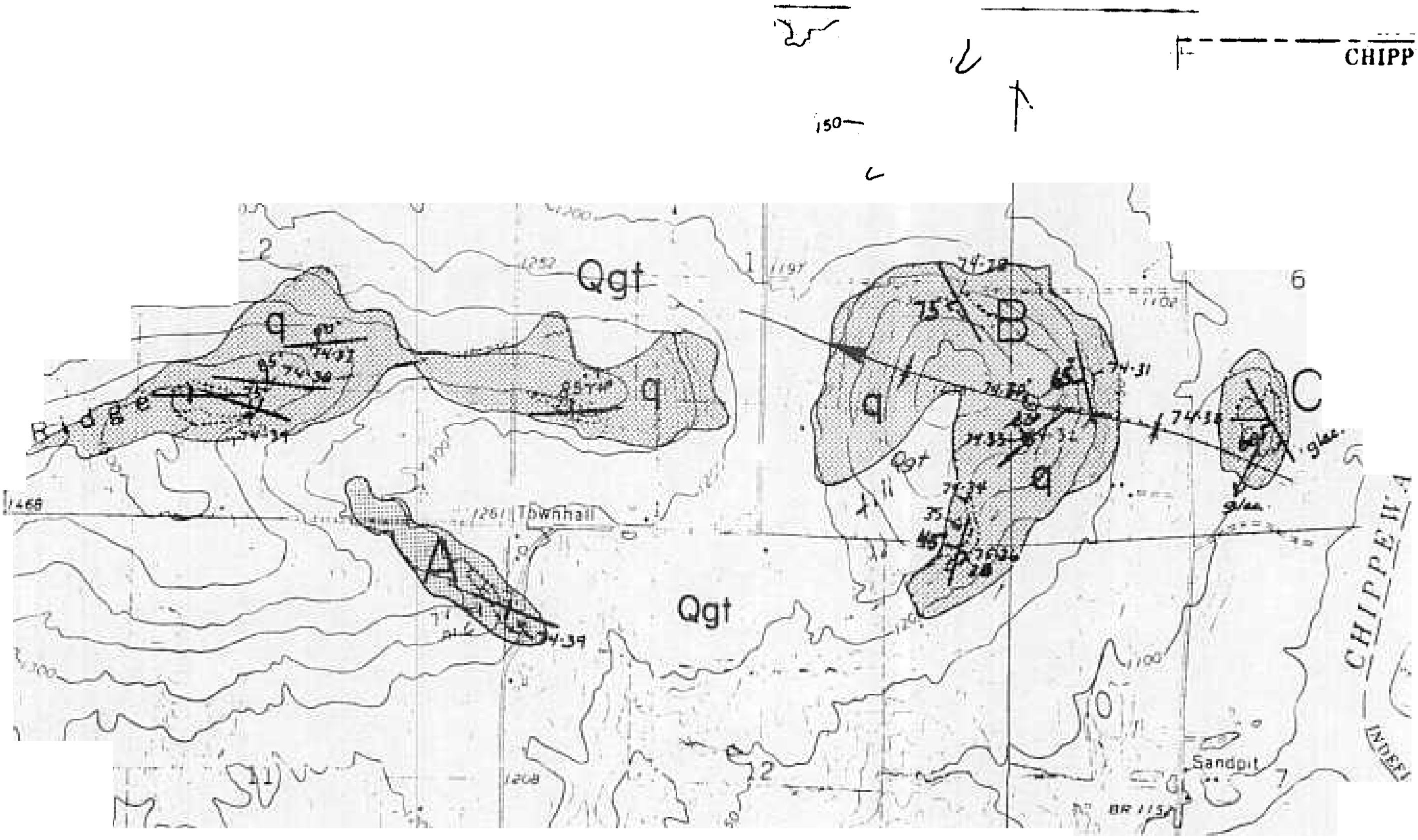


Figure -- Geologic map of Flambeau Ridge showing locations of major geologic interest (A, B, and C).

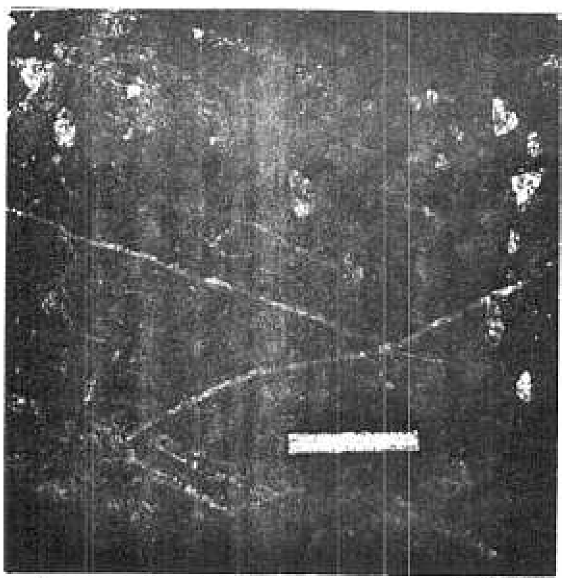


Figure 2 -- Flambeau quartzite metaconglomerate at Location A. Note stratification and dark clasts of banded iron formation.

TITLE: Neilsville Mounds - Geologic History

LOCATION: SE /4, NE 1/4 Sec. 4, T 24 N, R 2 W, Neillsville 15' quadrangle

AUTHOR: P.E. Myers, UW - Eau Claire

DATE: January, 1978

SUMMARY OF FEATURES:

Quartzitic, Late Cambrian sandstone ridges and knobs in the outer part of Central Wisconsin's Precambrian "dome" owe their topographic prominence to very subtle differences in resistance to erosion, due at least in part to silicification. While displaying excellent preservation of such primary features as cross-bedding, ripple marks, fossils, and worm burrows, the sandstone was converted without metamorphism or deformation to quartzite, which breaks with conchoidal fracture across component grains. Microscopic study has shown that clastic grains have grown to incorporate silica cement in optical continuity. Boundaries between friable and indurated sandstone are sharp, but irregularly trending within the sandstone.

The quartzite ridges commonly show conspicuous north-south and east-west elongation, roughly parallel with pervasive joint sets in the region. A buried, south-facing fault scarp just north of Granton is in remarkably close alignment with Neillsville Mounds. This suggests that groundwater rising along a fault silicified the sandstone on the upthrown side. The silicified sandstone then became the prominence we see today because of its relative resistence to erosion.

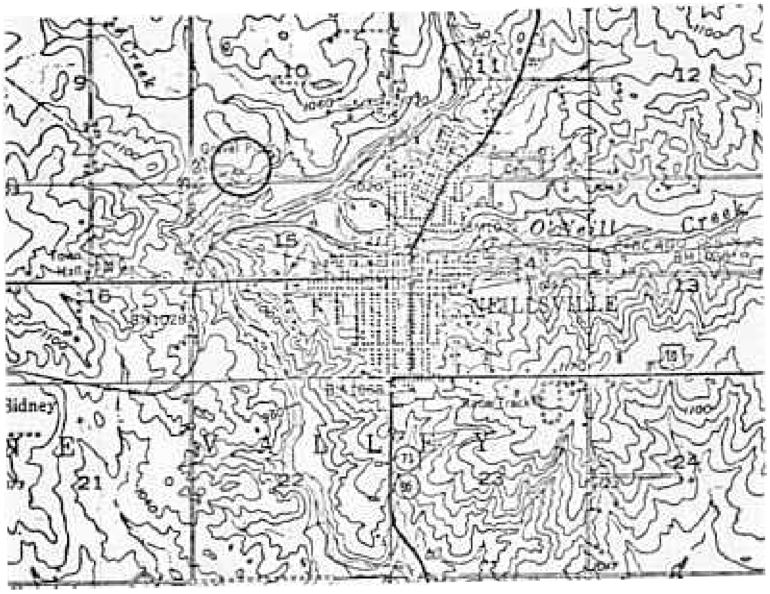
Pinnacle rocks, some of them more than over 5 meters high line the summit of the ridge here. It is suggested that these indicate that the summit of the Neillsville Mounds was not overtopped by Wisconsin glaciers. Till and erratics can be seen on the north slope of the ridge only 200 meters from its summit. The suggestion is that the ice was deflected westward around the ridge and stopped along the line of the moraine along U.S. 10 about 4.5 km southwest of here.

Several important questions remain unanswered here:

1. When and how was the Mt. Simon Sandstone silicified here?
2. Was the ridge a nunatak at glacial maximum? If so, where are the glacial deposits on the east side - in the valley of Black River?

____: Spheroidal Weathering - Neillsville, Granite (?)

LOCATION: SE 1/4, SW 1/4, Sec. 10, T 24 N, R 2 W, Neillsville 15' quadrangle



AUTHOR: P. E. Myers, UW - Eau Claire

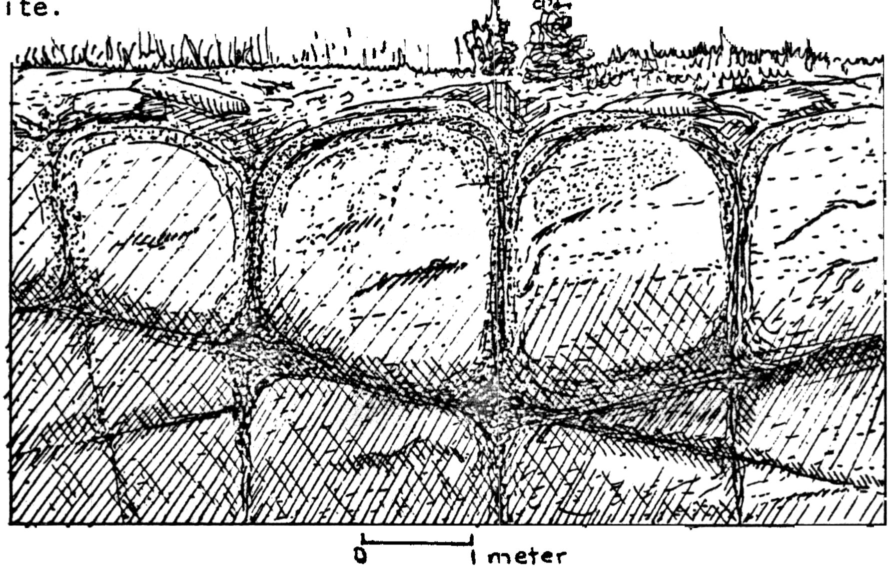
DATE: January, 1978

SUMMARY OF FEATURES:

Spheroidally weathered, coarse-grained, gneissic biotite granite(?) is quarried here for road construction materials. Foliation (N40°W, 35°SW) has had no obvious effect on development of residual spheroids up to four meters in diameter. The zone of spheroidal weathering is about 5 meters thick as exposed in this quarry. The largest spheroids have two and even three concentric exfoliation rinds, which spall off in large concavo-convex slabs. The most intensely weathered granite(?) at the top of the outcrop spalls as thin, lenticular chips 5-10 cm in diameter. Downward diminution in extent of exfoliation can be readily seen here. The spheroids developed by sequential weathering of first corners, then edges, then faces of joint blocks (Figure 1).

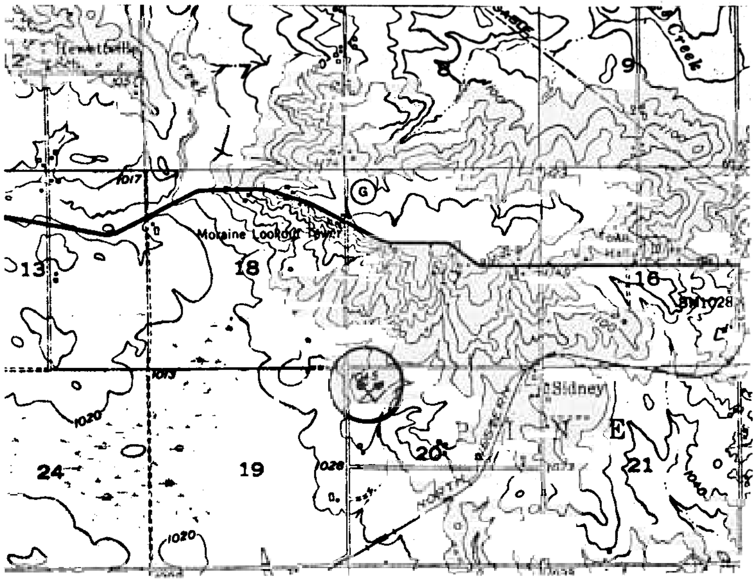
Specimens of fresh granite(?) are medium gray and are composed of quartz, sodic plagioclase, K-feldspar, and brown biotite, which occurs in small, lenticular clusters. Based on study of mineral grains only, the rock is tentatively classified as an adamellite.

Figure



TITLE: Age of Spheroidal Weathering in Precambrian "Granite"

LOCATION NW 1/4, NW 1/4, Sec. 20, T 24 N, R 2 W, Neillsville 15' quadrangle



AUTHOR: P. E. Myers, UW - Eau Claire

DATE: January, 1978

SUMMARY OF FEATURES:

Sheared and spheroidally weathered "granite" containing xenolithic sheets and lenses of biotite-chlorite schist is overlain by Late Cambrian Mt. Simon Sandstone and then by red-brown boulder till in a small quarry. The unconformity is unique in displaying depositional features indicating that the Mt. Simon Sandstone was deposited on a granitic surface which was already spheroidal weathered. Some geologists argue that weathering at the Precambrian-Cambrian interface has occurred in much more recent time as groundwaters tend to flow along it.

The "granite" (probably adamellite or trondhjemite) is composed of feldspar, quartz and biotite, most of which has been chloritized. Schlieren and lenticular xenoliths of chloritized mica schist are strongly folded: they probably represent fragments of older Precambrian (archean?) metasediments which were rafted up during "granite" intrusion. The fresh "granite" is gray: the pervasive pink color of its weathered counterpart was produced by chemical weathering of abundant pyrite.

Basal Mt. Simon Sandstone here consists of a thin, discontinuous layer of coarse sand overlain by 0.5 meter bed of sandy shale, which was probably derived locally from clays formed on the weathered "granite" and deposited in slack waters between exposed spheroids during Late Cambrian transgression. Overlying sandstone is of more "normal" Mt. Simon lithology. (See Figure 1 and 2)

The glacial deposits overlying Mt. Simon Sandstone at this locality is a red-brown sandy boulder till with a maximum exposed thickness of 7 meters. It is interesting that this till sheet lies 1.2 kilometers south of the moraine along U.S. 10. What is the significance of this spatial relationship?

Observe the "granite" closely: take careful notes, make sketches, take samples for comparison with granitic rocks elsewhere in the Neillsville area. How does the "granite" here compare with the "Neillsville granite"?

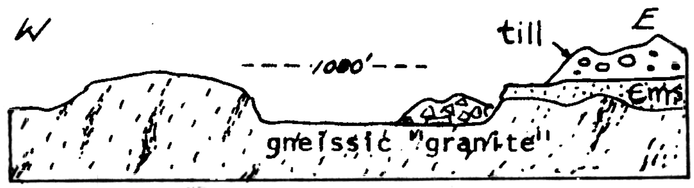


Figure 1 -- Cross-section of pit showing unconformity between Precambrian gneissic "granite" and Late Cambrian Mt. Simon Sandstone (Cms). These are overlain by Pleistocene till.

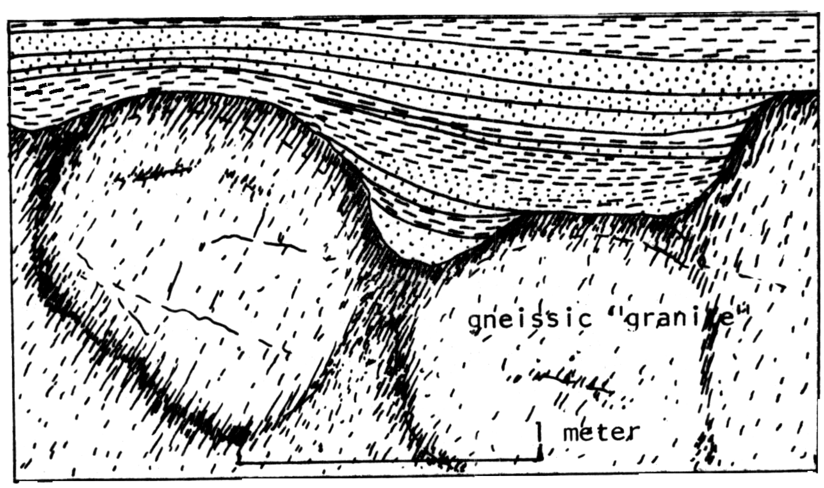
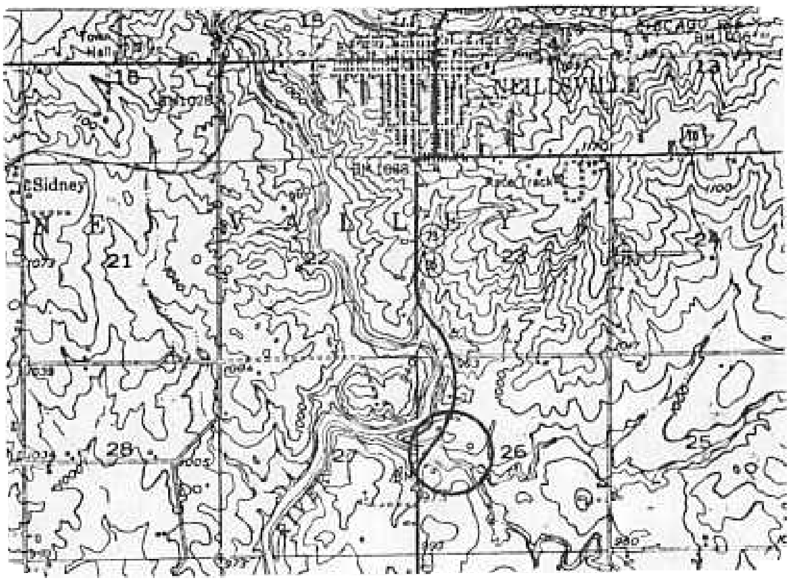


Figure 2 -- Gneissic "granite" was spheroidally weath- and then overlain by Mt. Simon Sandstone as shown above (Sketch made July 18, 1974.)

TITLE: Cunningham Creek Augen Gneiss and Mylonite Gneiss

LOCATION: NW1/4, SW1/4, Sec. 26, T 24 N, R 2 W, Neillsville 15' quadrangle



AUTHOR: P. E. Myers, UW - Eau Claire

DATE: January, 1978

SUMMARY OF FEATURES:

Folded, micaceous mylonite schist and augen gneiss are the main rock types in a major shear zone extending N80°E and S30°W from here. The shear zone is at least 2 kilometers wide. Cataclastic foliation in the schist has been strongly folded about axes which dip steeply westward. Axial planes of these folds strike northeast and are nearly vertical: they indicate right-lateral deformation of cataclastic lamination.

Augen gneiss, exposed in roadcuts along Highway 95 just north of Cunningham Creek, is conposed of very coarse, pink K-feldspar crystal fragments (porphyroclasts) in a flow-laminated matrix of schistose crush debris composed of feldspar, quartz, and biotite (figure 1). The K-feldspar augen (eyes) show Carlsbad twinning and effects of ablational rounding and fragmentation with mylonite injection along cleavages and fractures. The rock probably flowed as an inhomogeneous, granular mass. The precataclastic parent rock was probably a coarsely porphyritic quartz monzonite or granite.

Phacoidal (lensoidal) mylonite schist is well-exposed along Cunningham Creek east of Highway 95. In addition to variable quantities of essential feldspar, quartz, muscovite, and biotite, the schist contains significant quantities of pyrite, which locally is weathered to limonite. Felsic layers are more resistant to weathering and erosion, while micaceous layers are readily eroded away to form depressions. Primary cataclastic schistosity was strongly compressed into chevron-type folds which generally plunge 70° southwest to vertical. Locally chaotic fold orientations suggest torsion and detachment of schist blocks. During tectonic reactivation of the shear zone, primary cataclastic foliation and layering were thrown into a system of steeply plunging folds showing right-lateral displacement.

Gneissic granite(?) well-exposed along the north side of Black River 2.4 km southwest of here (SE 1/4, NE 1/4 Sec. 33) contains large xenoliths of shear folded gneiss and mylonite. The gneissic granite(?) intruded a shear zone. Foliation in the granite(?) may have been developed during or after intrusion. This granite(?)

is mesoscopically identical to the "Neillsville granite" and probably represents the eastern contact zone of a large granitic mass. The Cunningham Creek shear zone, extended west-southwest along strike, connects with a major contact between the "Neillsville granite" on the north and and diorites on the south. The eastern edge of the diorite body is strongly sheared along the Black River shear zone.

Thus, field relations indicate that older porphyritic granite, diorite, and rocks of unknown parentage were cataclastically deformed along a shear zone extending up the Black River and bending northeastward near the mouth of Cunningham Creek. After subsequent intrusion of the "Neillsville granite(?)" the Cunningham Creek portion of the shear zone was reactivated by right-lateral shearing stress: this later movement may have juxtaposed the "Neillsville granite(?)" and the diorites to the south.

It will be noticed that the valley of the Black River is remarkably devoid of glacial deposits. What are some possible explanations for this?

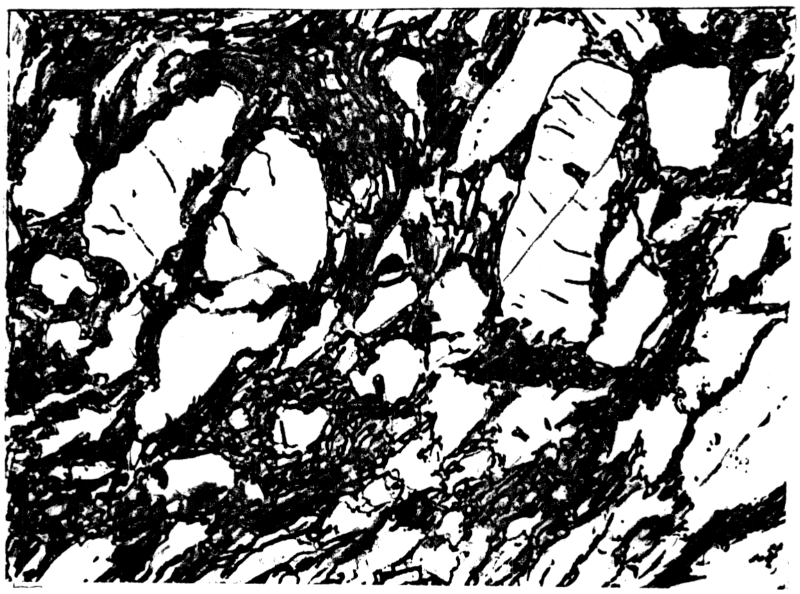
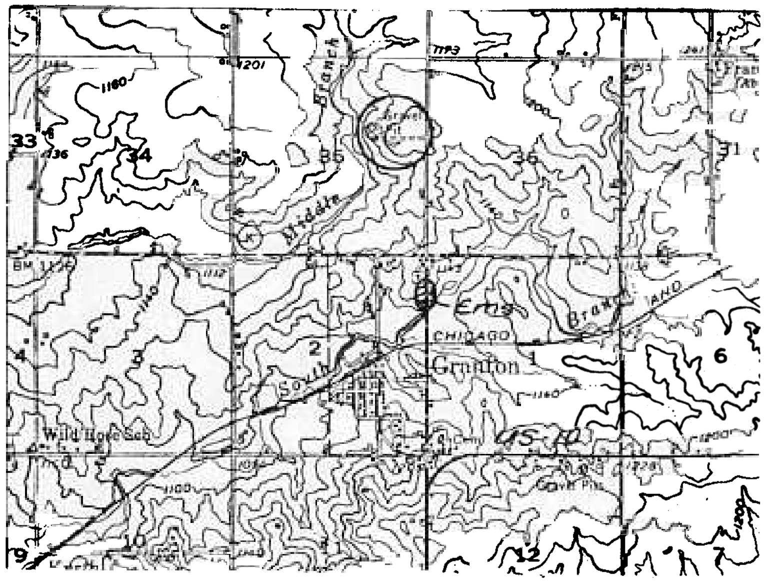


Figure 1 -- Flow-oriented K-feldspar porphyroclasts in mylonitic augen gneiss. White areas are feldspar. Matrix is composed of foliated crush debris. Note segmentation of feldspar porphyroclasts and intrusion of mylonite along fractures in the fragments. Actual size.

TITLE: Basal Conglomerate at Naedler Quarry, Granton

LOCATION: SW 1/4, NE 1/4, Sec. 35, T 25 N, R 1 W, Granton 15' Quadrangle



AUTHOR: P. E. Myers, UW- Eau Claire

DATE: January, 1978

SUMMARY OF FEATURES:

A "rotten granite" quarry in gneissic biotite adamellite (?) on the Marvin Naedler property was reopened in 1974 after several years of inactivity. Be sure to obtain permission from the property owners before entering the quarry.

Cataclastically foliated biotite adamellite (?) composed of plagioclase (?), K-feldspar, quartz, and biotite contains lenticular masses of pegmatite and quartz (Figure 1) which are subparallel to foliation. The foliation trends N85°E, 70-75°N. Slickensides on quartz veins plunge N80°E and 12-13°, a factor suggesting strike-slip motion during shearing and lenticulation of the pegmatite and quartz veins. The pegmatite locally contains large clots of very coarse biotite, part of which is chloritized. Was the foliation in the adamellite (?) developed before or after intrusion of the pegmatite and quartz veins?

The Precambrian gneissic rocks described above are overlain unconformably by Late Cambrian basal conglomerate or breccia composed predominantly of poorly sorted, subangular quartz clasts between 4 and 65 centimeters in maximum dimension. The clasts are embedded in a quartz sand matrix which is cemented with white clay. The clasts show rounding only on edges and corners: they are clearly of very local derivation - probably the quartz veins in the adamellite (?) What happened to the feldspar and biotite? Is the basal conglomerate a beach deposit? A stream deposit? What features might permit resolution of this question? This quartzose basal conglomerate characterizes the Precambrian-Cambrian unconformity throughout this region, although it is rarely this coarse in texture.

Geological and hydrological conditions are strongly reflected in the patterns of agricultural land-use. Wet, uncultivated bottomlands are on clay-rich, weathered Precambrian granitic rocks. Rain, which falls at higher elevations, readily percolates down through the Cambrian sandstones to the impermeable Precambrian surface, and flows along it into the nearest depression.

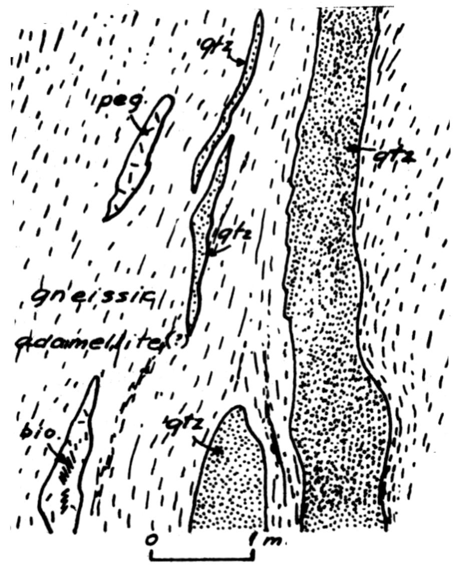
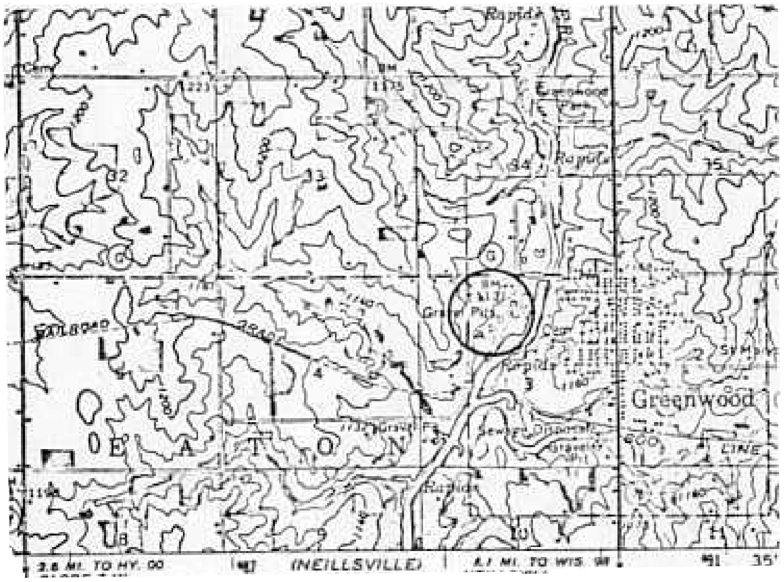


Figure 1 -- Quartz veins and lenses with lenticulated pegmatite veins in foliated biotite adamellite(?)

The elevation of the Precambrian-Cambrian unconformity at this location is about 1180 feet. Cross-bedded Mt. Simon Sandstone crops out along the west side of a road crossing South Branch of O'Neill Creek 1.4 kilometers south-southeast of here (See topographic map on preceding page). The sandstone is exposed down to an elevation of about 1100 feet at the second location. Thus, there is a drop of at least 80 feet between these two locations. It is suggested that an east-northeast-trending ridge or fault scarp between here and Granton was slowly buried by northward encroachment of Late Cambrian seas, and that the sandstones at Granton are older than the basal conglomerate here.

TITLE: Structures in Tonal te Flaser Gneiss at Greenwood

LOCATION: NE 1/4, NW 1/4, Sec 3, T 26 N, R 2 W, Owen 15' quadrangle

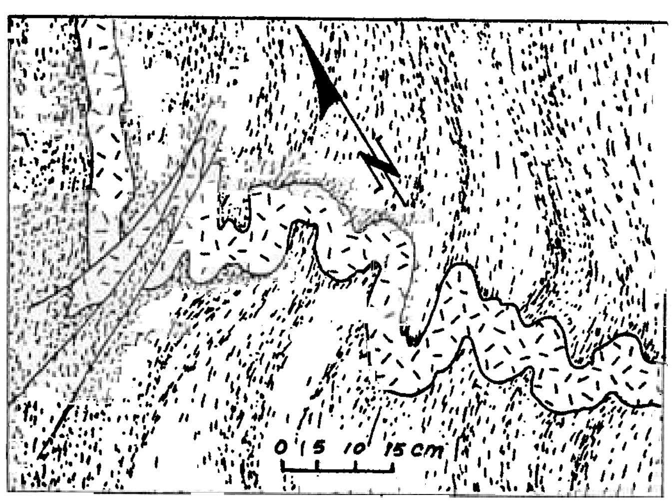


AUTHOR: P. E. Myers, UW - Eau Claire

DATE: January, 1978

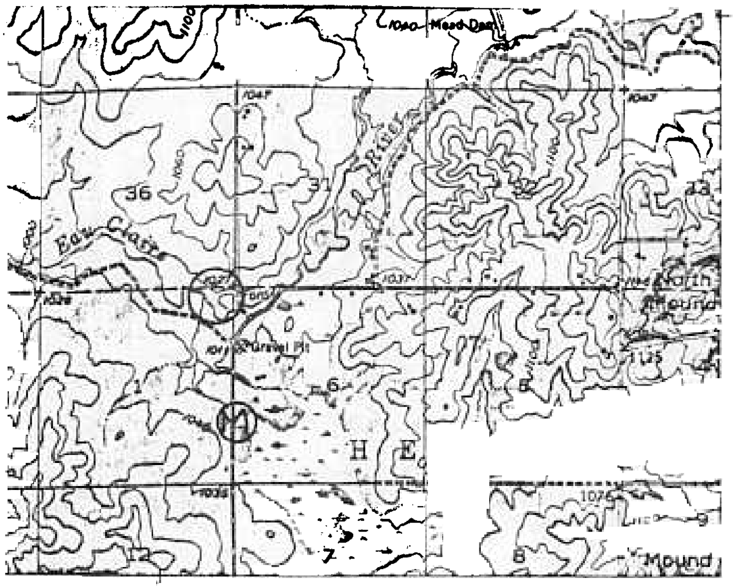
SUMMARY OF FEATURES:

Granitic gneisses are well-exposed along Rock Creek east-northeast of Greenwood (SW 1/4, Sec. 31, T 27 N, R 1 W). These rocks are characterized by conspicuous chevron folds which plunge west at 35°-40°. This deformation is probably contemporaneous with the buckling of cataclastic foliation and layering at Cunningham Creek near Neillsville.



TITLE: Structures in Mica Schist and Quartzite of the Younger(?) Metasedimentary Series

LOCATION: CTH M- south Fork, Eau Claire River: NE /4 Sec. , T.26N R.4W



AUTHOR: Paul E. Myers--UW-Eau Claire

DATE: May 26, 1977

SUMMARY OF FEATURES

Excellent quarry exposure of gently folded muscovite quartzite and kink-banded muscovite-quartz-chlorite(?) schist. An anticlinal axis is exposed on the floor of the quarry (see map, Fig. 1). Some excellent examples of kinkbanding can be seen near the hinge of this fold, which plunges ENE at about 30-40°. The contact between mylonitized granite(?) along Eau Claire River 3 kms west of here, and this rock has not yet been seen in the field.

The quartzite is massive, thick-bedded with occasional quartz clasts up to 0.5 cm. Relict cross-bedding is evidenced by gently intersecting cleavages. Bedding dips gently (35-45°) into the north face of the quarry, where the quartzite is best exposed.

The muscovite-quartz-chlorite(?) schist is pale greenish gray and thinly lenticulated. Foliation is crinkled by cross-folding in the anticline hinge. The schist is much less competent than the quartzite, so it shows the effects of axial flowage in the fold. See Figure 2.

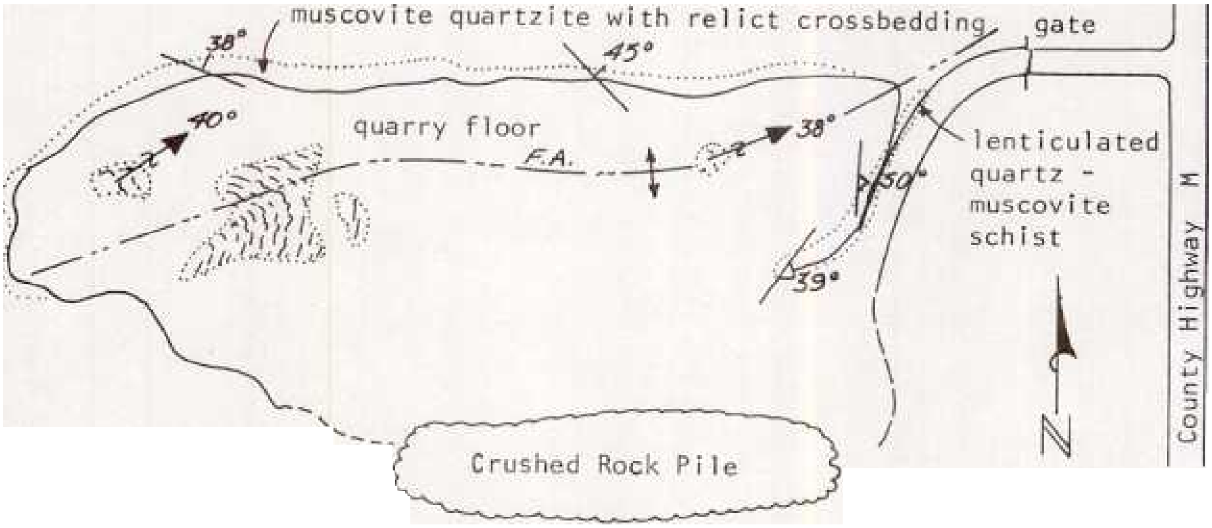


Figure -- Geologic map of quarry showing structural trends

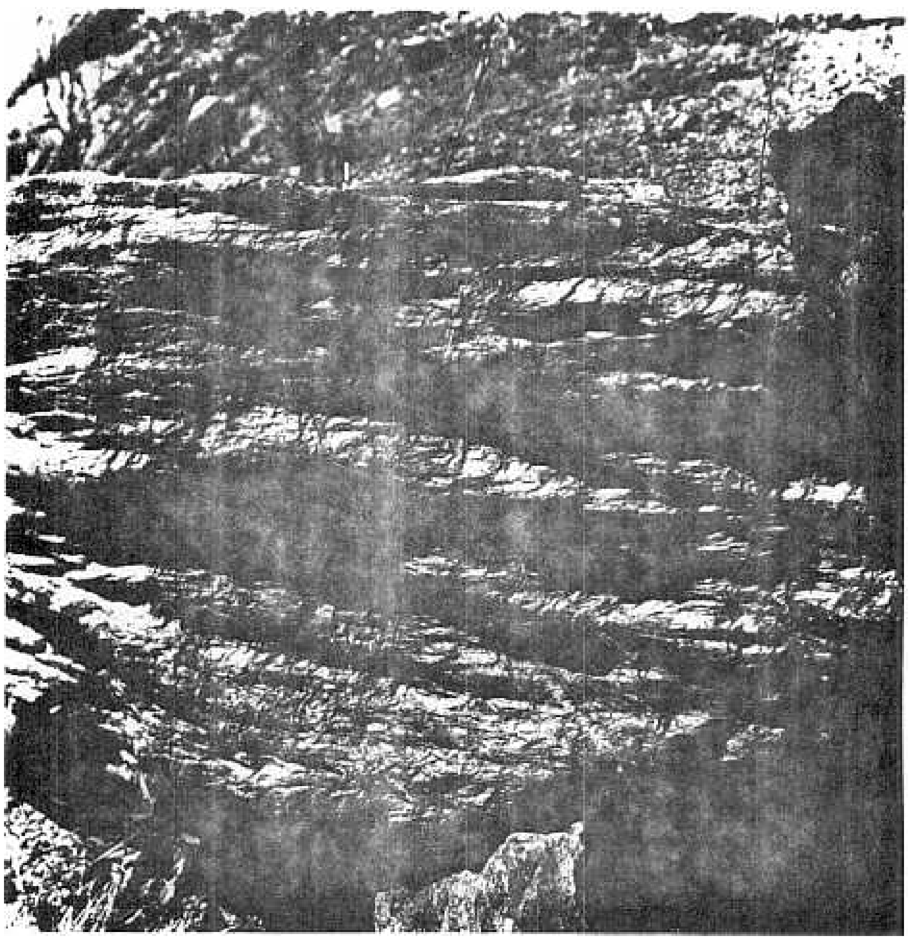
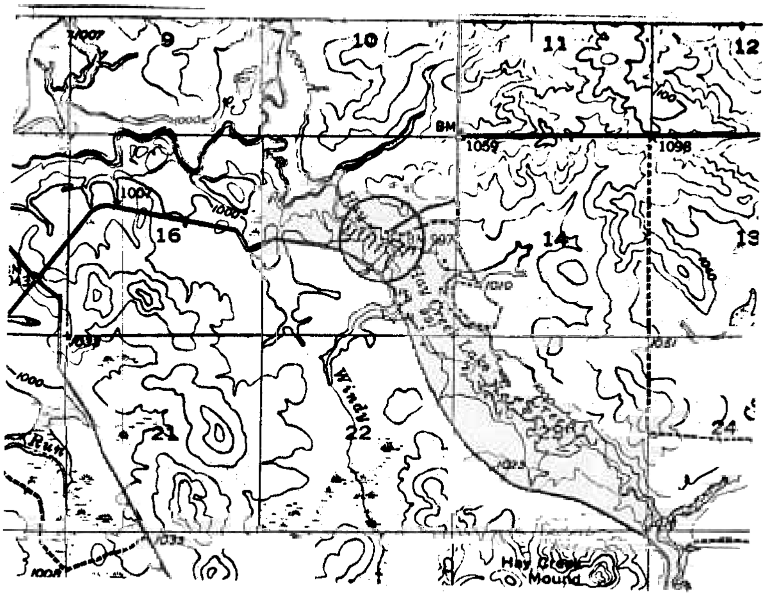


Figure 2 -- Kinkbands in quartz-mica schist near anticlinal axis in quarry floor. Rock fragment not in place. Photo by Gene LaBerge, University of Wisconsin - Oshkosh.

TITLE Felsic Mylonite Under Mt. Simon Sandstone

LOCATION: Hay Creek Dam: SE /4, NW /4 Sec. 15, T 26 N, R 4 W, Fairchild 15' Quadrangle



AUTHOR P E. Myers, U.W - Eau Claire

DATE: May, 1977

SUMMARY OF FEATURES:

Felsic, micaceous mylonite (sheared granite?) with indistinct cataclastic foliation crops out beneath a ledge of conglomeratic Mt. Simon Sandstone on the north side of a plunge pool in Hay Creek about 0.5 kilometers below Hay Creek Dam (Figure 1). Thin compositional layering and foliation trend N87°E, 85°N. Complimentary joints trend N18°W, 73°E and N77°E, 8°S.

The plunge pool has developed by selective erosion of sandstones which filled a depression in the unconformity. This depression shows a local relief of over five meters. The unconformity is sharp and clean with a remarkably thin weathered veneer on the mylonite beneath. The felsic composition of the mylonite probably accounts for its topographic prominance. There is little compositional similarity between the mylonite, which is composed of feldspar, quartz and muscovite, and the overlying sandstone, which is predominantly quartz, a fact which tends to substantiate the effectiveness of "winnowing" or the selective removal of fine-grained weathering products - clays.

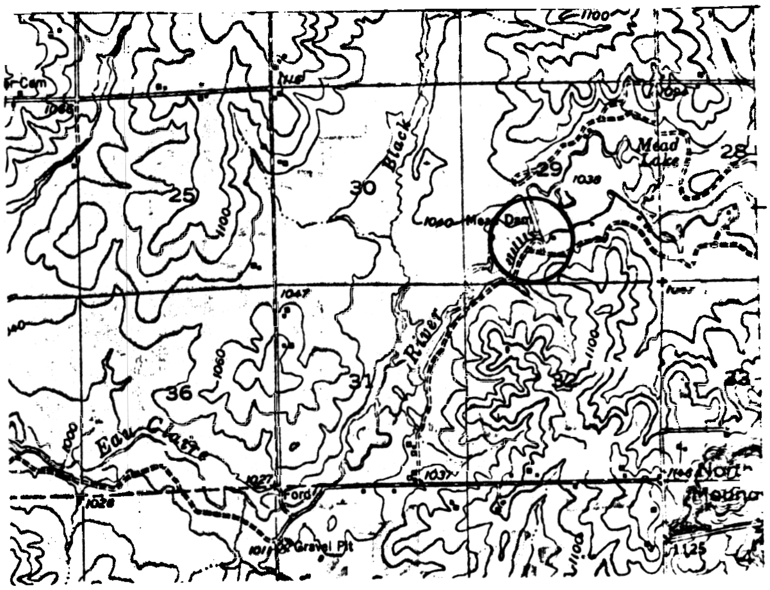
A similar biotite-rich "granite" flaser gneiss exposed along a stream 2 km north of here may represent a less completely comminuted or mylonitized phase of the same parent rock.

Samples of the mylonite were taken in 1973 by W.R. Van Schmus for isotopic dating.

Figure 1 -- Flat-lying, cross-bedded Mt. Simon Sandstone overlying felsic mylonite with vertical foliation. View northeast. Photo by Gene LaBerge, UW - Oshkosh, 1977.

TITLE: Felsic Phyllonite, Granite Pegmatite, and Metaconglomerate

LOCATION: Mead Dam, SE /4 Sec. 29, T.27N, R.3W



AUTHOR: Paul E Myers, UW-Eau Claire

DATE: May 26, 1977

SUMMARY OF FEATURES:

White, fine-grained, muscovite-bearing phyllonite probably derived cataclastically from a felsic volcanic or intrusive rock is exposed on the south side of the spillway and for several hundred meters downstream. Cataclastic foliation (N70°E, 85°N) is produced by lenticulation of quartz and K-feldspar. Muscovite is distributed along cataclastic foliation, which is folded about axes plunging N70°E at 77°.

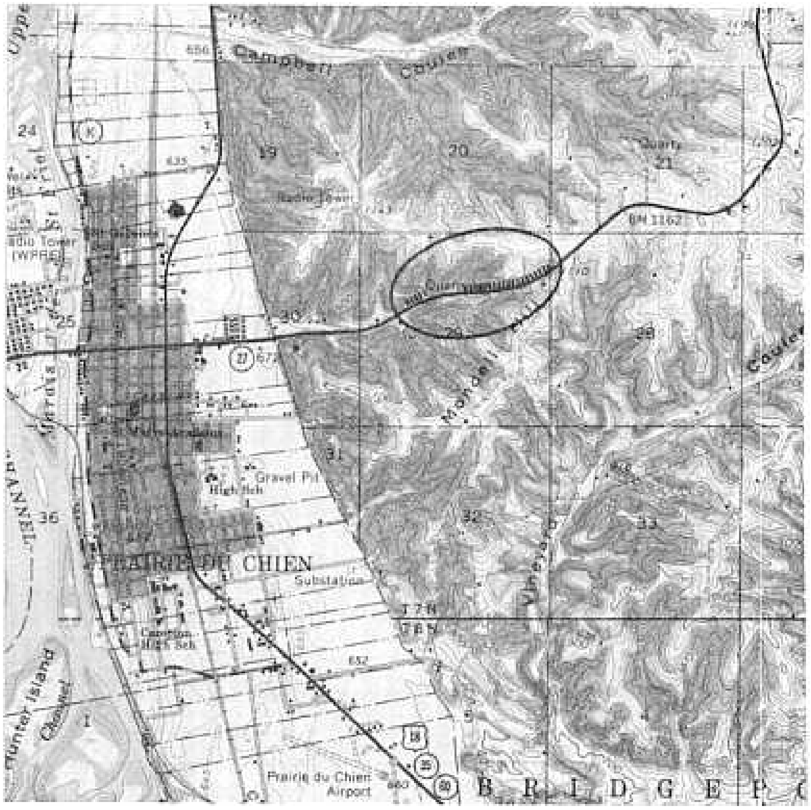
Large boulders in center-stream below the dam are coarse, sheared granite pegmatite. Large blocks of this same rock were used as rip rap along the south spillway of the dam. Distribution of these boulders indicates that the pegmatite is a sill-like instrusion roughly parallel to the cataclastic foliation in the phyllonite.

Probably the most interesting point at this locality is the occurrence in the rip rap used for dam spillway construction, of 1-2 meter, angular boulders of very fresh stretched-pebble metaconglomerate. The pebbles are largely quartz. Their shape is subangular to subrounded, and their size is between 0.5-5.5 cm. Occasional mafic (volcanic?) clasts also occur in the metaconglomerate. The strongly foliated matrix around the clasts is micacous, and appears to consist mainly of muscovite, although biotite may also be present.

Although this rock has not been seen yet in outcrop in this area, the large size and freshness of the boulders, and the occurrence nearby of other siliceous clastic metasediments suggest a local derivation of the boulders.

Title: Prairie du Chien

Location: Exposure in roadcut and quarry at north side of Wisconsin Highway 27 in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 29, T.7N., R.6W., Crawford County (Prairie du Chien 15-minute topographic quadrangle, 1967).



Author: M. E. Ostrom (modified from L. M. Cline, 1970)

Description: Unconformity at base of St. Peter Sandstone and sections of Shakopee and Platteville Formations are exposed. A well-developed U-shaped channel of St. Peter Sandstone cuts out several feet of Shakopee Dolomite and sandstone in a cutbank on the north side of the road. Just east of the channel the sheet phase of the St. Peter rests disconformably on several feet of dolomite in the upper part of the Shakopee. Below the dolomite member, but also in the Shakopee Formation, are several thick beds of sandstone. As these horizontal beds of Shakopee are traced westward toward the St. Peter channel, the upper dolomite disappears and the sandstone in the Shakopee curves downward toward the channel. The dips in the Shakopee are believed to be secondary, being due, in part, to pre-St. Peter solution of carbonate in the Shakopee with a corresponding reduction in volume and collapse toward the channel. Insoluble argillaceous residues of the Shakopee carbonate beds may be seen just east of the channel. The same relationship may be seen just west of the channel where sandstones in the Shakopee dip eastward toward the channel; the latter dips have been accentuated by some small-scale post-St. Peter faulting. There is strong possibility that pre-St. Peter solution of Shakopee carbonate below road level is partly responsible for some of the dips. The possibility should not be overlooked that ground water, moving freely along the permeable channel phase of the St. Peter, may have accomplished additional solution of the Shakopee at a much later geologic date; this is suggested by the small scale faulting along the west wall of the St. Peter channel.

The New Richmond Sandstone occurs at a lower stratigraphic position in a quarry about 200 yards west and on the north side of the road. In this quarry well-bedded sandstones and dolomites of the New Richmond may be seen about midway in the west face where they rest on the more massive, cavernous and biostromal dolomites of the Oneota. Note here the thin green shaly bed which marks the top of the New Richmond.

Upslope from the St. Peter channel and just out of sight around the bend in the road, the Platteville Formation is nicely exposed in a cutbank on the north side of the highway. Thick-bedded, blue-gray, buff-weathering dolomites of the Pecatonic Member of the Platteville constitute the lower few feet of the cut. The overlying argillaceous, nodular calcitic limestones belong to the McGregor Member. The McGregor offers very good fossil collecting in contrast to the relatively barren Pecatonica Dolomite.

A description of the section follows

ORDOVICIAN
Champlainian series
Chazyan stage

St. Peter Sandstone (26.3 feet)

240.5' - 265.5'	25.0'	Sandstone, white, massive, well-sorted, grains rounded and frosted, bedding not apparent, thickness varies for the sandstone fills a channel which is 20-25 feet deep into the underlying dolomite.
239.2' - 240.5'	1.3'	Sandstone, mostly, of varying character, poorly sorted, includes red residual clays at the base

Canadian series

Lookmantown stage

Prairie du Chien Formation

Shakopee Dolomite Member (62.5 feet)

238.7' - 239.2'	0.5'	Sandstone, white, friable, medium-grained, medium-sorted, grains rounded.
238.2' - 238.7'	0.5'	Dolomite, fine-grained, buff to gray
237.7' - 238.2'	0.5'	Dolomite, fine-grained, buff, vuggy.
234.7' - 237.7'	3.0'	Dolomite, fine-grained, buff, with green shale partings.

231.7' - 234.7'	3.0'	Dolomite, red to gray, medium-grained, massive vuggy.
229.7' - 231.7'	2.0'	Dolomite, fine to coarse-grained, brown to gray
226.7' - 229.7'	3.0'	Sandstone, grains rounded and frosted, each grain coated with layers of brown dolomite.
221.7' - 226.7'	5.0'	Sandstone, brown to white, thin to thick bedded cross-bedded, poorly-sorted.
218.7' - 221.7'	3.0'	Dolomite, very sandy, brown to gray, medium-grained.
217.7' - 218.7'	1.0'	Dolomite, reddish gray, medium-grained, thin-bedded.
212.7' - 217.7'	5.0'	Covered interval, approximately.
187.7' - 212.7'	25.0'	Dolomite, poorly exposed, mostly thin-bedded, reddish gray, medium-grained, sandy in part, approximately.
182.7' - 187.7'	5.0'	Dolomite, brown to gray, medium-grained, bedding irregular, large Cryptozoans.
179.7' - 182.7'	3.0'	Dolomite, thin-bedded, fine-grained, buff.
178.7' - 179.7'	1.0'	Dolomite, brown, finely-crystalline, large Cryptozoans, very irregular inthickness, much secondary calcite.
176.7' - 178.7'	2.0'	Dolomite, brown, medium-grained, bedding irregular, Cryptozoans.

Prairie du Chien Formation

New Richmond Sandstone Member (18.5 feet)

172.7' - 176.7'	4.0'	Conglomerate, sandy, dolomitic with green shale partings, some cherty colites in nodules, rounded flat pebbles of buff fine-grained dolomite.
170.7' - 172.7'	2.0'	Dolomite, brown, medium-grained, 'wavy" bedded
170.4' - 170.7'	0.3'	Shale, green soft
169.9' - 170.4'	0.5'	Sandstone, white, friable, poorly-sorted, large grains rounded and frosted.
165.4' - 169.9'	4.5'	Dolomite, very sandy, brown, brecciated, some beds of soft green shale.
163.6' - 165.4'	1.8'	Sandstone, white, friable with green shale partings and zones of dense, dark brown dolomite.

162.6' - 163.6'	1.0'	Dolomite, sandy, buff and fine-grained
160.1' - 162.6'	2.5'	Dolomite, buff and fine-grained, thin-bedded.
159.6' - 160.1'	0.5'	Sandstone, white, friable, with thin dolomite beds throughout, a green shale bed near the top.
158.1' - 159.6'	1.5'	Sandstone, white, some friable, some well cemented, medium-sorted, grains rounded and frosted.
158.0' - 158.1'	0.1'	Shale, persistent, green, soft.

Prairie du Chien Formation

Oneota Dolomite Member (158.0 feet)

115.0' - 158.0'	43.0'	Dolomite, massive, cherty, vuggy, bedding irregular medium-grained, some thin beds toward the base, approximately.
50.0' - 115.0'	65.0'	Dolomite, poorly exposed, brown to gray, medium-grained, approximately.
0.0' 50.0'	50.0'	Dolomite, brown to gray, mostly massive and coarsely crystalline, some thin-bedded and fine-grained, approximately.

BASE OF EXPOSURE

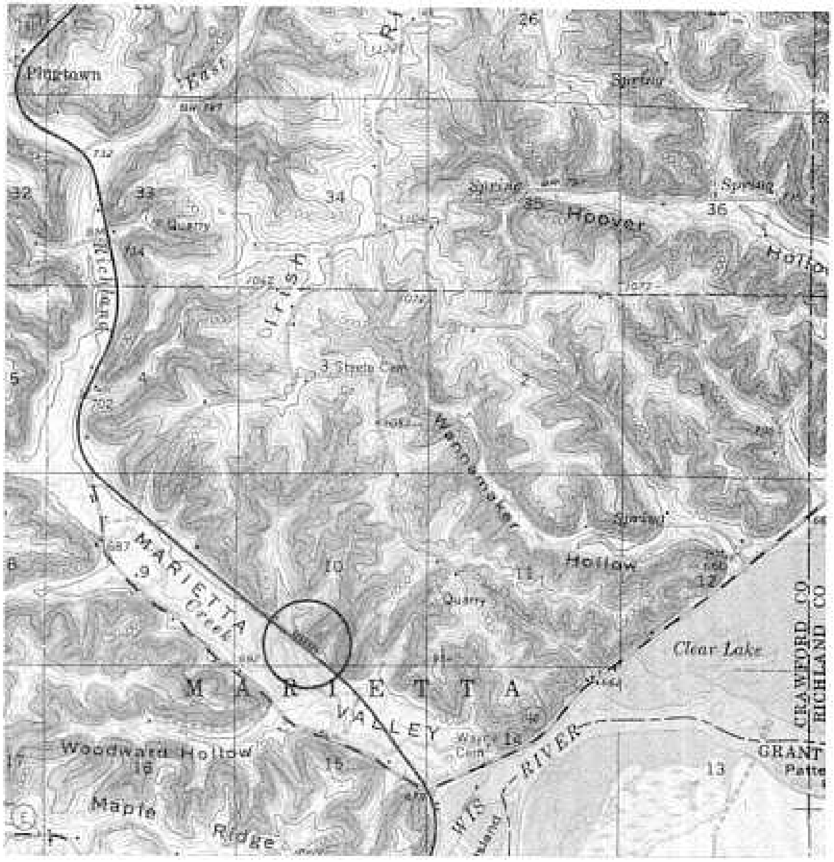
Significance: This is an excellent exposure at which to examine the pre-St Peter unconformity.

What is your interpretation of the contact relationship between the St. Peter Sandstone and older rocks? What is the evidence? Explain the shale in the base of the St. Peter. What is the relative age of the unconformity? of the base of the St. Peter?

References: Shea, 1949; Cline, 1959; Ostrom, 1970

Title: Marietta Valley

Location: Exposures in roadcuts at east side of U. S. Highway 61 about 1.3 miles north of junction with State Highway 60 in the SE$\frac{1}{4}$, NW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 10, T.8N., R.3W., Crawford County (Boaz 15-minute topographic quadrangle, 1966).



Author: M. E. Ostrom (modified from McGannon, 1960)

Description: Exposure of Jordan Sandstone, St. Lawrence Formation (Lodi Member and Black Earth Member), and Lone Rock Formation.

Description follows:

CAMBRIAN SYSTEM

Jordan Formation (+30.4 feet)

74.3' - 75.1'	0.8'	Dolomitic, clayey, gray to buff, thin-bedded, hard, conchoidal fracture.
73.9' - 74.3'	0.4'	Conglomerate, flat-pebbles; matrix brown, hard, coarsely crystalline, silty and sandy dolomite. Pebbles are sandstone, white, fine-grained, soft, glauconitic, dish-shaped, and up to 2 inches.

- 73.9'	1.3'	Dolomite, reddish brown, sandy, very hard, silty; forms ledge.
72.2' - 72.6'	0.4'	Conglomerate, flat-pebbles, matrix buff to brown, hard, dolomitic siltstone. Pebbles are sandstone, white to greenish, medium-to-coarse-grained, generally soft, small and dish-like, and locally edgewise.
72.2'	27.5'	Sandstone, buff to white, very fine-gravel, silty, generally friable and siltstone, sandy, with abundant burrows filled with brown clay. Some thin irregularly spaced, brown to green, dolomitic shale or shaly dolomite interbeds and laminae. Burrows most abundant in upper 10 feet. Appears massive on outcrop.

St. Lawrence Formation

Lodi Member (21.0 feet)

44.5' - 44.7'	0.2'	Siltstone, dolomitic, irregularly mottled buff and dolomite, green, and clayey.
36.5' - 44.5'	8.0'	Siltstone, white, sandy, regular to irregular interbeds, and generally friable and shale, dolomitic, green to brown and dolomite, clayey. Shale common in thin wavy laminae. Siltstone predominates Some burrows. Massive outcrop.
36.0' - 36.5'	0.5'	Dolomite, clayey, gray to green-gray, hard, and fissle.
- 36.0'	1.7'	Siltstone, dolomitic, buff white, thin beds alternating regularly with dolomite, clayey, green-gray.

Black Earth Member (9.3 feet)

34.3'	0.4'	Dolomite, clayey, gray to green-gray, hard, and friable.
- 33.9'	0.4'	Dolomite, dark brown-gray, coarsely-crystalline, glauconotic, and hard. Very uneven bed.
- 33.5'	0.7'	Dolomite, clayey, green, thin-bedded, hard, with conchoidal fracture.
32.8'	3.9'	Dolomite, clayey, green-gray, hard, alternating with layers of siltstone, white to buff. Dolomite predominates.
26.1' - 28.9'	2.8'	Dolomite, clayey, mottled green and siltstone, dolomitic and silty. Ledge on outcrop. Crown 3" soft and friable siltstone.

25.0' - 26.1'	1.1'	Shale, dolomitic, green, fissle, weak.

Lone Rock Formation

Reno Member (25.0 feet)

0.0' - 25.0'	25.0'	Burrowed-stone, dolomitic, tan to light brown, thin-to-medium-bedded, very hard, forms ledge. Some glauconite below contact but very sparse or absent in most of unit. Burrow fillings light tan dolomite; matrix light brown dolomite. A few interbeds with mottled and burrowed light green, clayey dolomite and buff silty dolomite.

BASE OF EXPOSURE

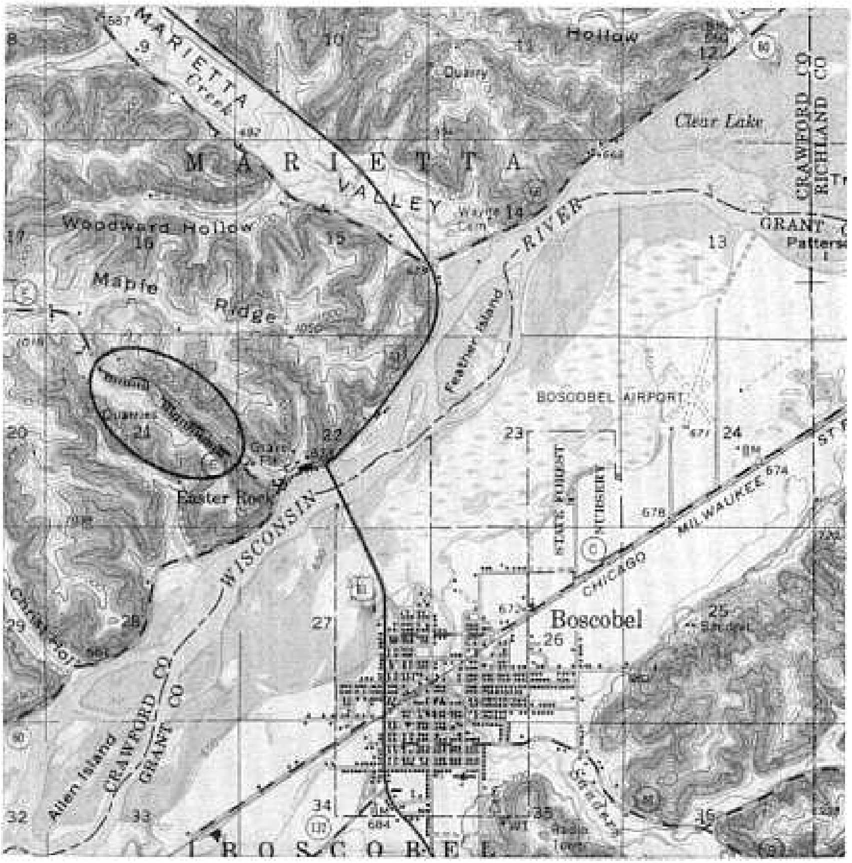
Significance: This section should be compared to those seen at the Arcadia, Coon Valley, and Reads Creek stops.

How are the contact relationships of the Lone Rock/St. Lawrence and St. Lawrence/Jordan different from those seen at previous stops? How are they the same? What has caused the difference? Why is there glauconite in the Lone Rock and not in the Lodi? Is the lithology of the St. Lawrence Formation significantly different from that seen at previous stops? What is significant?

References: McGannon, 1960

Title: Easter Rock

Location: Large quarry and roadcut along the west side of County Trunk Highway "E" in the SW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 21, T.8N., R.3W., Crawford County (Boscobel 15-minute topographic quadrangle, 1933).



Author: M. E. Ostrom (modified from Ostrom and Cline, 1970)

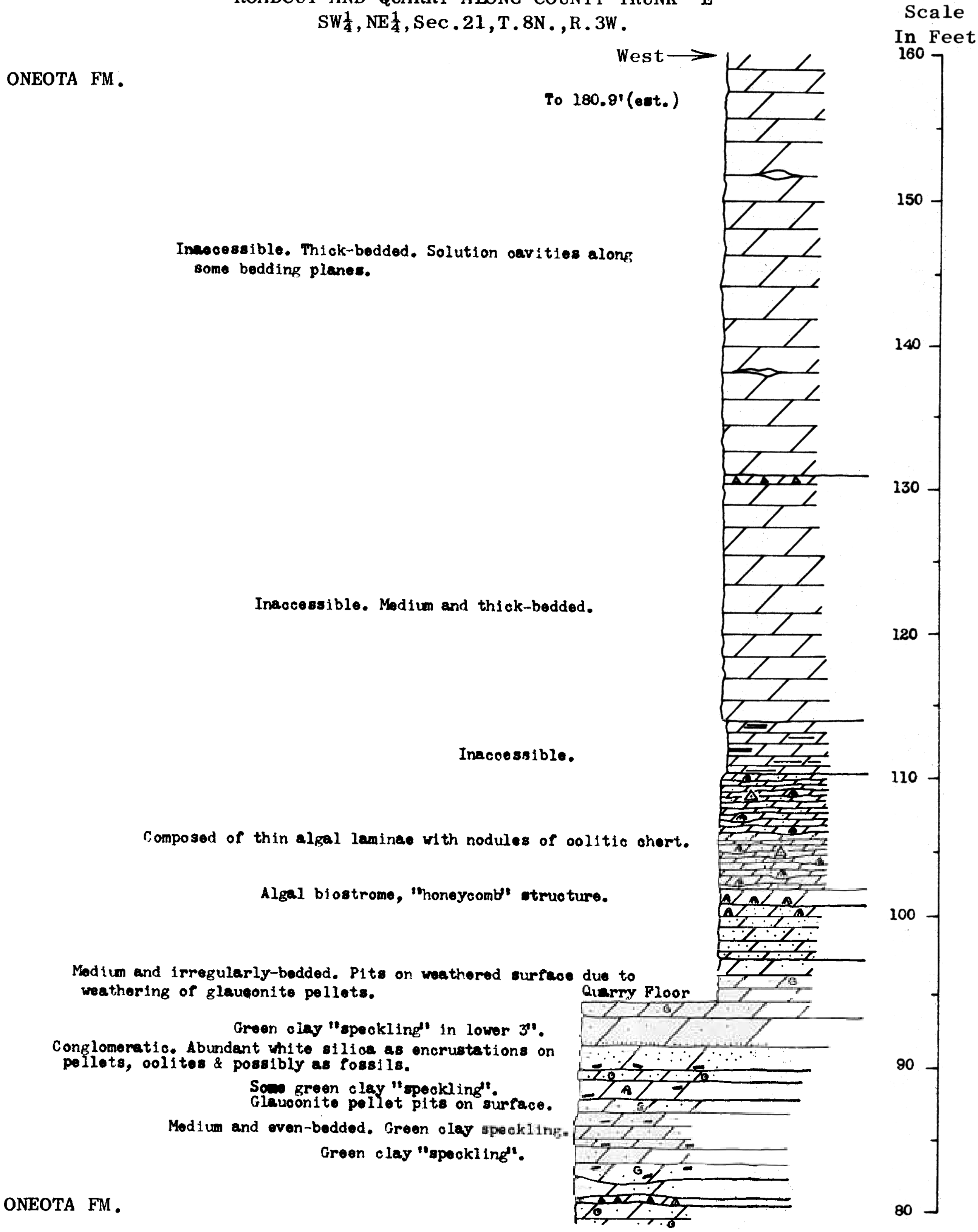
Description: The main objective of this stop, and the description of the section in the bluff at the north end of the Wisconsin River bridge, is to examine the contacts between the Norwalk, Van Oser, and Oneota in detail, especially to study the Jordan Sandstone and the "transition beds" in the base of the Stockton Hill Member of the Oneota Formation. There are several distinctive lithologic horizons in the Stockton Hill namely an oolitic chert bed and a dolomite bed speckled with green shale, which persist eastward and northeastward as far as the Green Bay area in northeastern Wisconsin as was shown by Starke (1949). In tracing the zones eastward from Boscobel, Starke (op. cit.; see diagram) has shown gradual overlap of these zones by younger Oneota strata until about 40 feet of basal Oneota is overlapped along the axis of the Wisconsin Arch (refer to STOP 19).

The contact of the Jordan and Oneota Formations and the lithology of the lower part of the Oneota (Sunset Point) are especially well shown in the road cut along Highway "E". Description of Easter Rock on north at junction of State Highway 60 with U. S. Highway 61 at north end of Boscobel bridge over Wisconsin River. It

Easter Rock

ROADCUT AND QUARRY ALONG COUNTY TRUNK "E"

SW¼, NE¼, Sec. 21, T. 8N., R. 3W.



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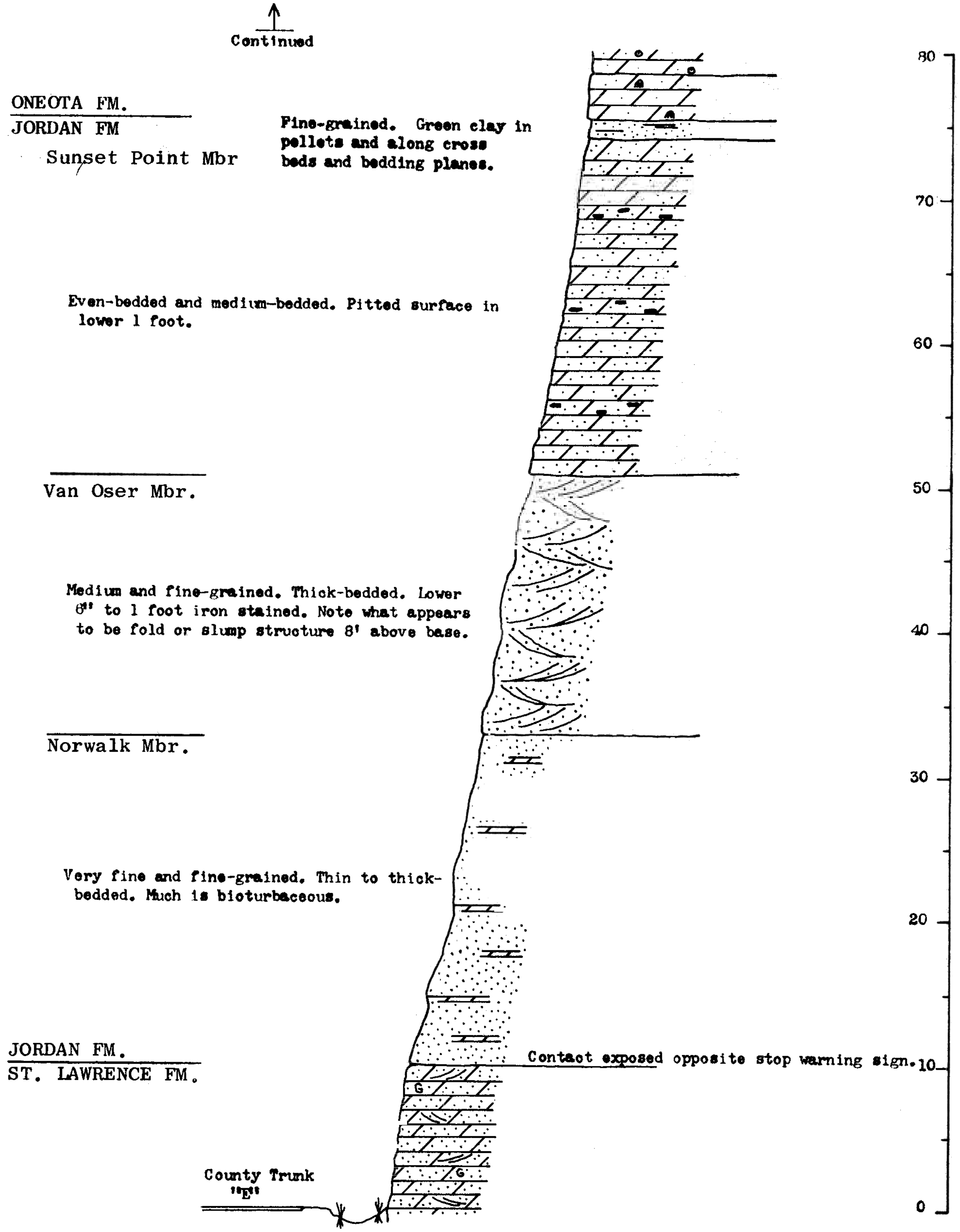
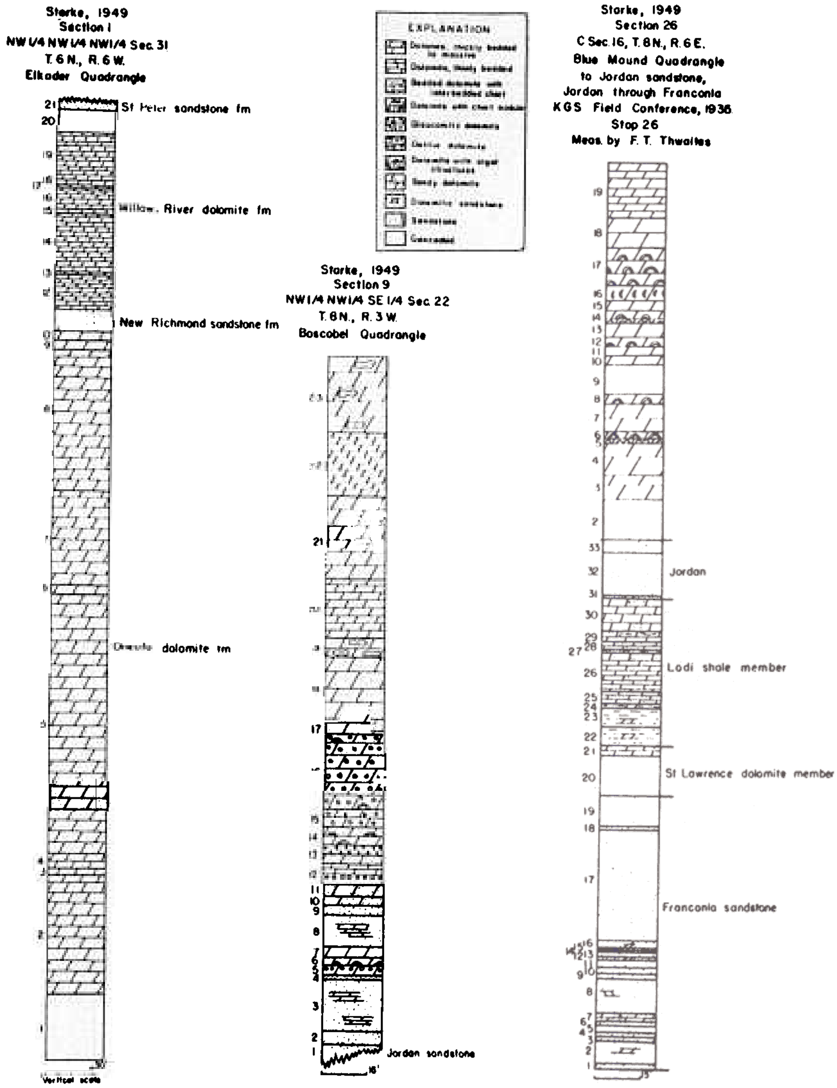


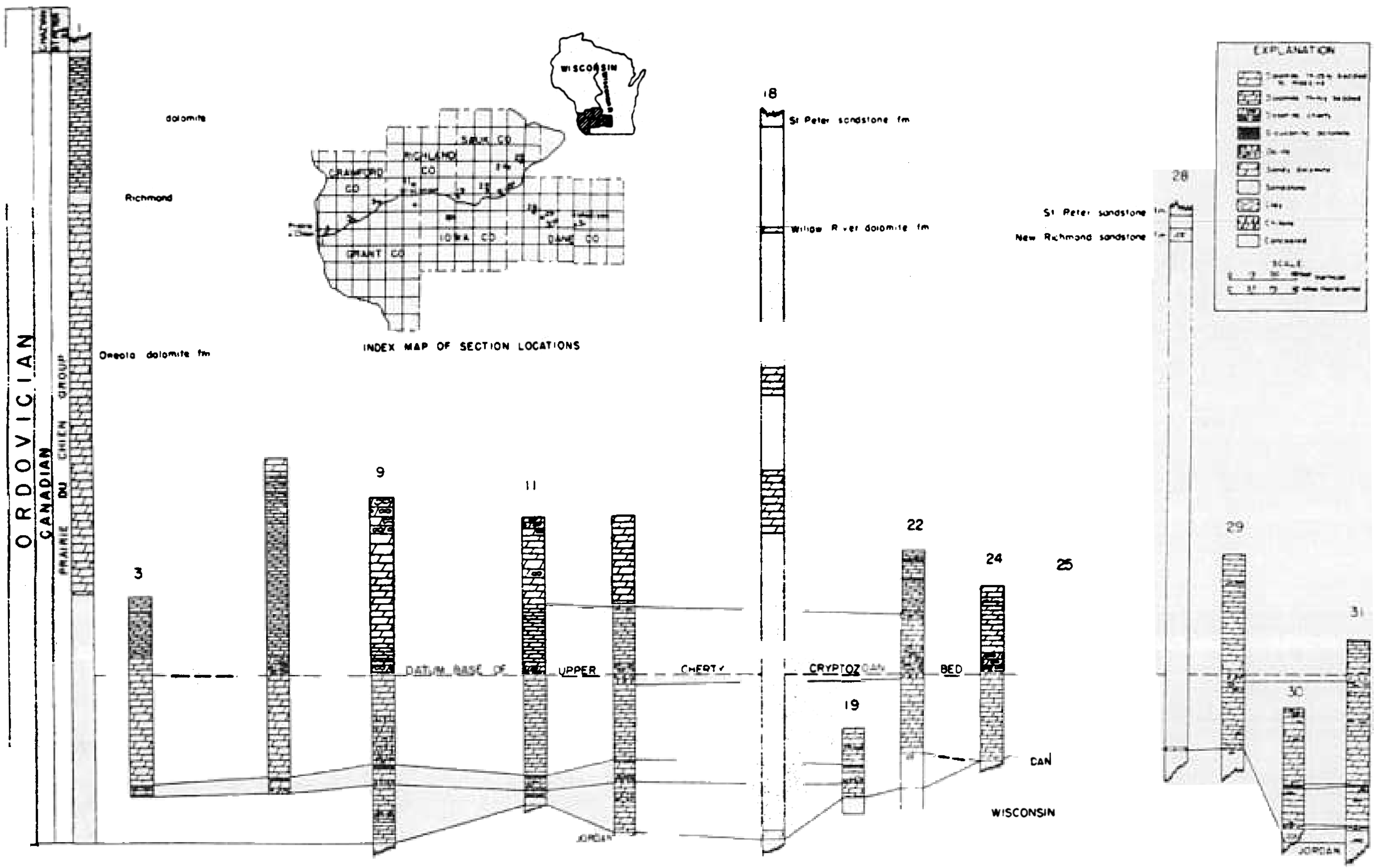
Continued
ONEOTA FM.
JORDAN FM
Sunset Point Mbr
Fine-grained. Green clay in pellets and along cross beds and bedding planes.
Even-bedded and medium-bedded. Pitted surface in lower 1 foot.
Van Oser Mbr.
Medium and fine-grained. Thick-bedded. Lower 6" to 1 foot iron stained. Note what appears to be fold or slump structure 8' above base.
Norwalk Mbr.
Very fine and fine-grained. Thin to thick-bedded. Much is bioturbaceous.
JORDAN FM.
ST. LAWRENCE FM.
Contact exposed opposite stop warning sign.
County Trunk "E"
G
G
80
70
60
50
40
30
20
10
0



Wyalusing

Boscobel

Mazomanie



by
George Starke
University of Wisconsin, 1949

was here that Starke (1949) described the oolitic chert bed and "green-speckled" bed. His description of Easter Rick follows:

ORDOVICIAN SYSTEM
Prairie du Chien Group

Oneota Formation

67.2'	8.0'	Dolomite; gray, thick-bedded; contains some large chert nodules.
52.4' - 59.2'	6.8'	Dolomite; light gray, extremely fine-grained
43.4' - 52.4'	9.0'	Dolomite; buff, fine-grained, in thick beds
37.7' - 43.4'	5.7'	Dolomite; gray, some buff stringers, in 6-inch beds.
35.3' - 37.7'	2.4'	Dolomite; contains cryptozoan structures; cherty; persistent bed.
27.8' - 35.3'	7.5'	Dolomite; gray, fine-grained, thick-bedded.
Not measured		Dolomite; gray, some fossil fragments (Starke does not give thickness)
27.8'	8.0'	Dolomite; gray to buff, fine-grained, oolitic throughout, some small biocherms.
17.8' - 19.8'	2.0'	Dolomite; oolitic, arenaceous, with white cherty areas
16.0' - 17.8'	1.8'	Dolomite; fine-grained, undulating beds, biochermal.
14.0' - 16.0'	2.0'	Dolomite; arenaceous, upper part green and glauconitic.
11.7' - 14.0'	2.3'	Dolomite; buff, oolitic at base, upper surface pillow-like.
10.4' - 11.7'	1.3'	Dolomite; orange, includes some lenses of white quartz sandstone.
9.6' - 10.4'	0.8'	Dolomite; buff, arenaceous
9.6'	1.0'	Sandstone; white.
8.6'	3.4'	Dolomite; fine-grained, very arenaceous, some oolite.
5.2'	1.1'	Dolomite; gray to buff, fine-grained, some scattered orange pebbles.
4.1'	0.7'	Dolomite; buff, fine-grained, biochermal.
3.4'	1.0'	Dolomite; gray, hard, fine-grained, becoming arenaceous and oolitic in upper three inches.
2.4'	0.5'	Sandstone; white, medium-grained

1.9'	0.4'	Sandstone; buff, dolomitic, grains frosted; some cross-bedding.
1.5'	1.5'	Sandstone; gray, with pockets of green clay.

Trempealeau Group

Jordan Formation

Not measured	Sandstone; thick-bedded, buff with lenses of white cross-bedded. No thickness given but, as you can see, it makes a nice cliff.

BASE OF EXPOSURE

It appears that deposition of the Jordan Sandstone gradually gave way to the dolomite deposition of the Oneota. There are ripple marks and mud cracks in beds 2, 3, and 4, which one might take as evidence of shoaling conditions but it is perhaps just as reasonable to assume gradually deepening waters from Jordan into Oneota time, thus making it possible for fine-grained sediments to settle out, preserving the ripples and making it possible for shrinkage cracks to be developed and preserved. Minor amounts of quartz sand continued to accumulate in the Oneota carbonate-forming zone, at least up to the 110' level of the described section.

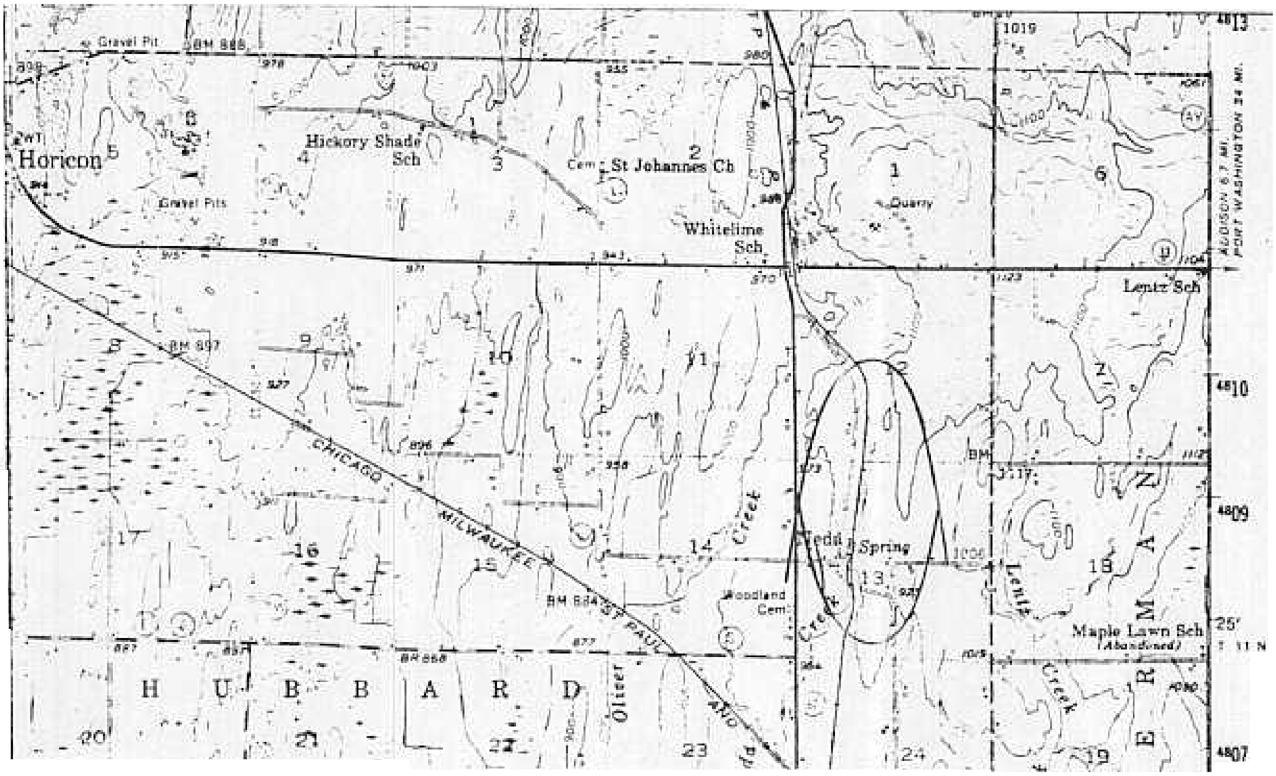
Significance: This exposure illustrates the thin beds of oolitic chert and of "green-speckled" beds which can be traced to the Green Bay area of eastern Wisconsin. It also affords a chance to examine various unit contrast relationships, the transition beds of the Sunset Point Member, and sedimentary structures.

Examine each unit. What environment of deposition do you assign to each? What is your supporting evidence? Assuming that individual thin beds can be traced from this area all the way to Green Bay, what sort of environmental conditions might have been the cause?

References: Ostrom, 1976; Starke, 1949

Title: Neda Iron Deposit

Location: Just east of Neda, Wisconsin. E½, NW¼, Sec. 1, T.11N., R.16E. (Horicon 15-Minute Quadrangle) Dodge Co.

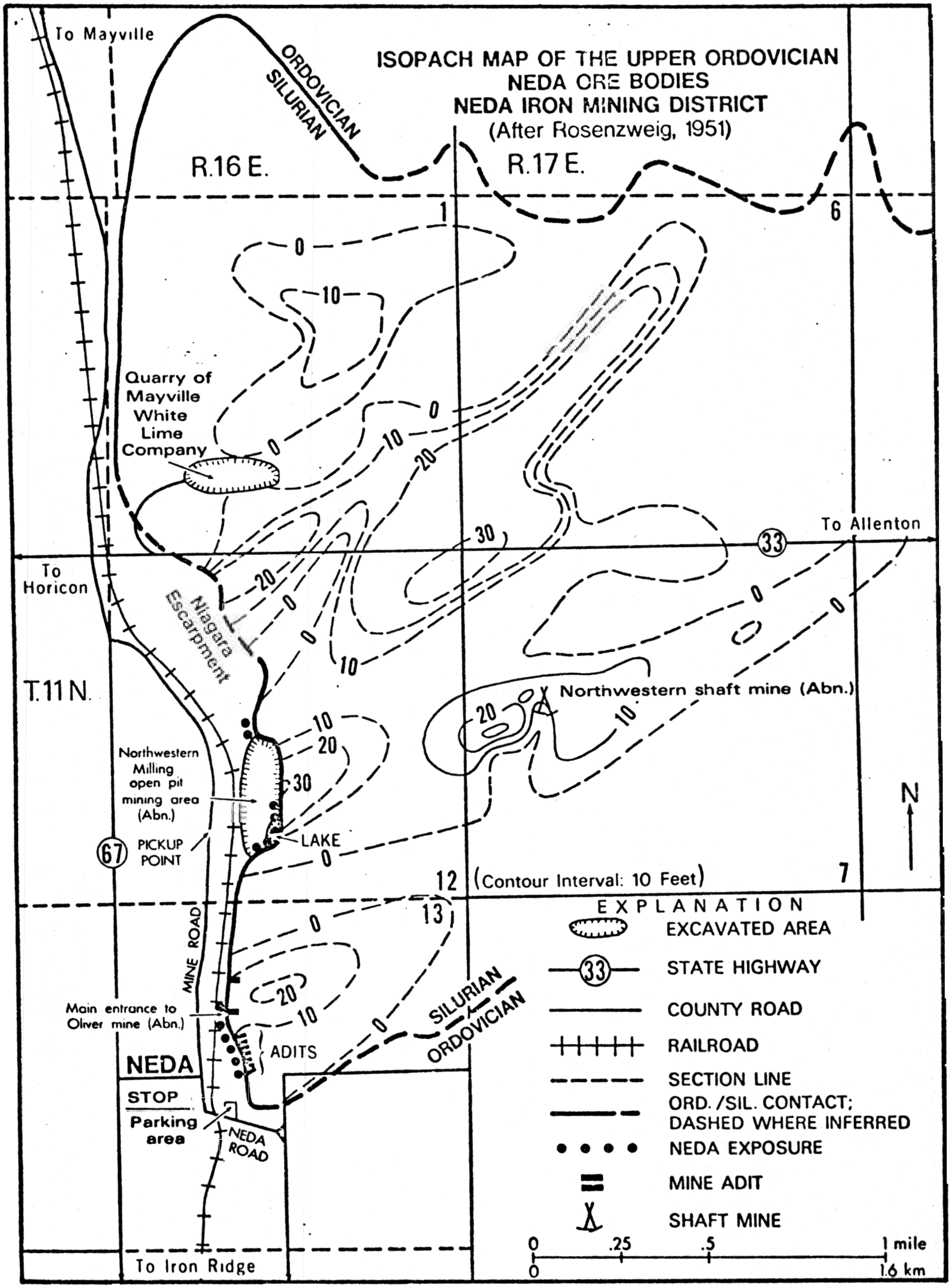


Author: Gene L. LaBerge (modified from Cunningham, Witt, and Palmer, 1976; Paull, 1977)

Description: The Neda Formation is an iron-rich sedimentary rock underlain by the Upper Ordovician Maquoketa Shale and overlain by the Lower Silurian Mayville Dolomite. It is a patchy deposit, present at only 8 known localities in eastern Wisconsin, and in a few places in Illinois, Iowa, Kansas and Missouri (Paull, 1977). The thickest known development of the Neda underlies Manitowoc, Wisconsin. At Neda the thickest orebody was 37 feet (Rosenzweig, 1951). The Neda consists of three "members": a lower shaly unit, a soft-ore unit, and an upper hard-ore unit.

The Maquoketa Shale, which underlies the Neda, is exposed in the road ditches on the hill just east of Neda. The Maquoketa is a greenish gray to bluish shale with dolomitic layers. It is quite fossiliferous here with abundant brachiopods, bryozoans and some corals and gastropods. The top of the Maquoketa exposed in the ditches along the road east of Neda is 20-30 feet higher than the base of the Mayville Dolomite exposed several hundred yards to the north, suggesting considerable relief on the top of the Maquoketa Shale.

The lower shaly unit consists of 2-3 feet of chocolate-colored shale with shiny Maquoketa shale pebbles covered by a film of iron oxides (Rosenzweig,



From Paull, 1976.

1951). Scattered iron-rich ooliths occur along bedding planes of the shale at the base of the unit (indeed, their presence defines the base) and become abundant upward until they constitute the bulk of the layers (Rosenzweig, 1951). Thus, the Maquoketa appears to grade upward into the Neda.

The soft-ore unit is a friable, reddish brown, thin to medium bedded, cross-bedded oolitic goethite-hematite, with some shaly interbeds. The ooliths have an average size of about 1 mm and are somewhat flattened. The long dimension of most ooliths is parallel to the bedding, but some are randomly oriented. Although most Recent oolites are composed of calcium carbonate, these oolites are composed mainly of goethite, which forms concentric layers around a nucleus. Rosenzweig (1951) recognizes four types of nuclei: 1) fossil fragments, 2) fragments of reworked ore, 3) mineral or rock fragments, and 4) cruciform specular hematite. All the nuclei are now hematite or goethite.

The hard ore unit is a dense compact layer of massive, dark red to purple hematite, generally less than a foot thick. Ooliths are present, but do not constitute a large part of the ore, and some thin interbeds and clasts of shale are present. Small pebbles of hematite are common, and appear to be an intraformational conglomerate. The hard ore appears to have formed by weathering and reworking of the soft (oolitic) ore.

Unconformably overlying the hard ore is the Middle Silurian Mayville Dolomite, a gray, medium to thick bedded cherty dolomite that forms a resistant cover on the softer Maquoketa shale and Neda formation in this area. A quarry in the Mayville Dolomite operated by the Mayville White Lime Company is located 2 miles north of Neda. The geological map of the Neda area shows the relationship of the Neda formation to the overlying Mayville Dolomite; the Neda is preserved only where it was protected by the Mayville.

Significance: The Neda iron deposit was mined almost continuously from 1849-1928, and provided an important resource for this part of Wisconsin. Some of the ore was smelted in Mayville, and was the basis for a modest local steel industry. Although much ore remains in the deposit, the relatively high phosphorous content, patch distribution, and "soft" nature of the ore as well as the necessity of utilizing underground mining methods make this deposit non-profitable to mine in the foreseeable future.

The origin of the Neda has been debated for nearly 100 years, and the geological setting in which the ore formed is still not agreed upon. Paull (1977) presented an excellent summary of the ideas on the origin of the Neda, and included his interpretation of the depositional environment. A number of factors must be considered in explaining the deposit: 1) the relief on the top of the Maquoketa suggests an erosion surface; 2) the elongate lens-like shape of the orebodies may indicate its development in channels, or perhaps in shoals (mounds) on the sea floor; 3) the increase upward in the abundance of ooliths in the lower member suggests that the Neda is gradational from the Maquoketa; 4) oolites generally form in shallow agitated waters; 5) all Recent oolites are calcareous; 6) because the iron is chemically precipitated, it is virtually impossible to indicate its source, except that it must have come from the overlying sea water; 7) the hard-ore layer on top of the Neda has the appearance of a "reworked" ore, or perhaps a weathered zone formed by exposure of the ore; 8) the Mayville Dolomite uncomforably overlies the deposit with much of the Lower Silurian (Alexandrian) missing, indicating a significant hiatus; 9) the lack of detrital sedimentary rocks above the unconformity suggests the lack of any nearby landmass of significant size.

Paull (1977) concludes that the Neda originated as a calcareous oolite similar to the present day Bahama Banks that developed on the Maquoketa. He suggests that the carbonate ooliths were replaced by iron oxides in a weathering environment during a regression of the Late Ordovician sea, and prior to the transgression in Lower Silurian time. He cites fossils replaced by iron oxides and the fact that modern day oolites are calcareous to indicate a secondary origin for the deposit. Do replaced fossils prove a secondary origin for the entire deposit, or are they replaced by iron oxides because they are in an iron deposit?

An alternative explanation might be that the deposit developed in a shallow marine environment during an upwarp of the Maquoketa Shale. The ooliths may originally have been chamosite (an iron-aluminum layer silicate) as is the case in a number of other Phanerozoic sedimentary iron deposits (e.g. Devonian deposits in Libya (Khaled Hangari, personal comm., 1977), the Silurian Wabana deposits of Newfoundland (Hayes, 1915, 1929), Ordovician in France (Cayeux, 1922; Chauvel, 1962). The ooliths may, in part, be formed by reworking of the Maquoketa Shale in the shallow-water environment. Iron was introduced, perhaps by bacterial action extracting iron from the overlying waters and accumulating primary ferruginous ooliths. Chamosite ooliths are commonly flattened and occur in a matrix of siderite. This iron-rich deposit may then be oxidized to hematite/goethite with a further uplift of the Maquoketa (or lowering of sea level, or may be oxidized at some later date. The iron is subject to change whenever oxidizing conditions develop. The ultimate <u>source</u> of the iron may be almost impossible to locate and is not necessarily germaine to the <u>deposition</u> of the deposit.

The presence of a massive carbonate (the Mayville Dolomite) immediately above an erosion surface seems to preclude the presence of a large landmass. It seems more likely that the Neda developed in a shallow water, but off-shore environment. Later transgression (or deepening) of the sea over the area initiated the deposition of carbonate on the eroded Maquoketa-Neda surface

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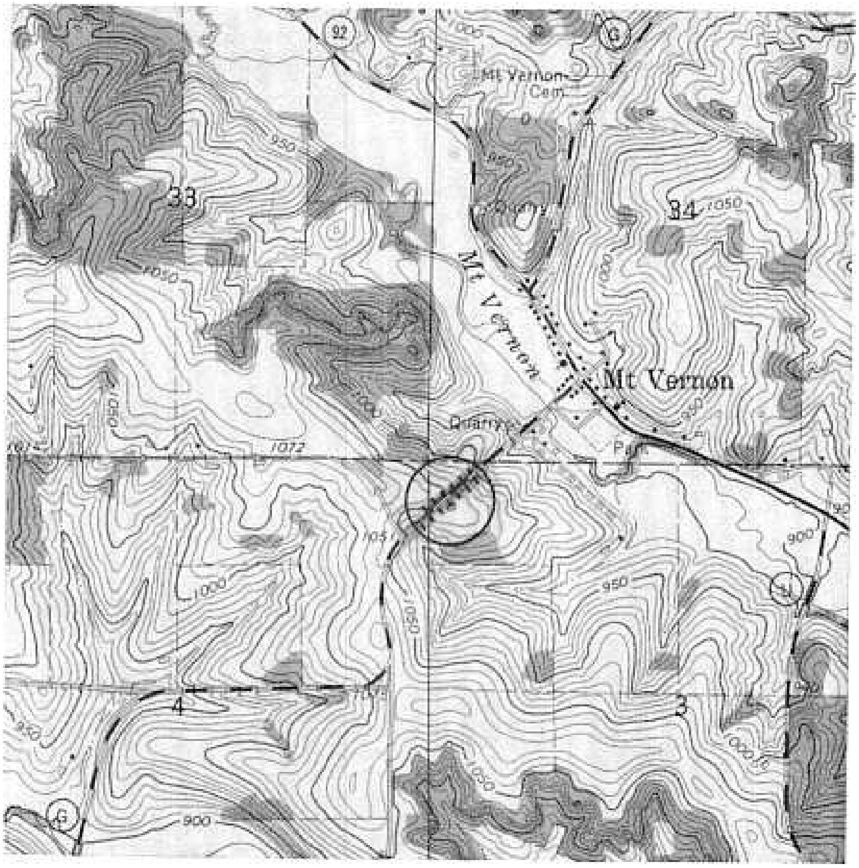
Title: Mt. Vernon

Location: Exposure in roadcut at both sides of County Highway "G" 0.2 miles west of village of Mt. Vernon in the NW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 3, T.5N., R.7E., Dane County (Mt. Vernon 7.5-minute topographic quadrangle, 1962).



Author: M. E. Ostrom (modified from Ostrom 1965)

Description: Generalized diagrams of exposures on each side of the highway and a plan view, are shown on the next page. Close examination will reveal many faults of minor displacement now shown on the diagram. Can you find more?

1. Bedding: Oneota is massive- or thick-bedded; Shakopee is thin- or medium-bedded.

2. Texture: Oneota is commonly medium-crystalline and coarser textured whereas the Shakopee is finely-crystalline.

3. Impurities: Oneota has less sand and clay than the Shakopee, especially in its upper part.

4. Sedimentary structures: bedding planes in the Shakopee are commonly marked with worm trails and shrinkage cracks.

5. Fossils: With rare exception the only fossils noted in the Oneota are cryptozoa, whereas gastropods, algae, and locally brachipods may be common in the Shakopee. Fossils are rare at this exposure.

Although it cannot be seen clearly at this exposure the contact of the New Richmond Sandstone Member of the Shakopee Formation with the underlying Oneota Dolomite Formation is one of marked truncation. This truncation can be seen in the outcrop area of the Prairue du Chien Group between Bagley, Grant County, Wisconsin, and Hager City, Pierce County, Wisconsin. (Davis, 1965). Ulrich (1924) considered this truncation sufficient to establish the existence of the Canadian System. Thus, the list of systems present in the Upper Mississippi Valley area according to Ulrich would include the Cambrian (Mt. Simon through Van Oser), Ozarkian (Sunset Point through Oneota), Canadian (the Shakopee), and Ordovician (St. Peter through Maquoketa).

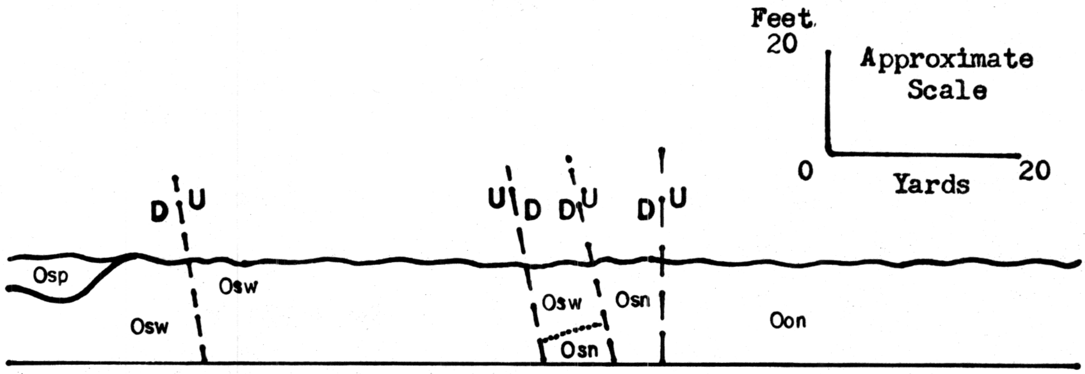
In Wisconsin the New Richmond Sandstone rarely approaches the "purity" of the Tonti Member of the St. Peter Formation or the Van Oser Member of the Jordan Formation and when it does it is very thin. However, in southeastern Minnesota the New Richmond Sandstone attains outcrop thicknesses of nearly 50 feet and consists of over 95 percent quartz sand. It commonly has a thin bed of green shale or argillaceous and silty sandstone on its top which is considered to be the approximate historical analogue of the Glenwood Shale or the Franconia "greensands".

If the assumption is correct that the Tonti and Van Oser members which are moderately well-sorted massive quartz sandstones, were deposited in a beach-nearshore environment, then it can also be assumed that where the New Richmond has a similar character it was deposited in a similar environment. It also follows that because at this outcrop there is no "clean" quartz sandstone in the New Richmond that the beach-nearshore environment did not extend into this area.

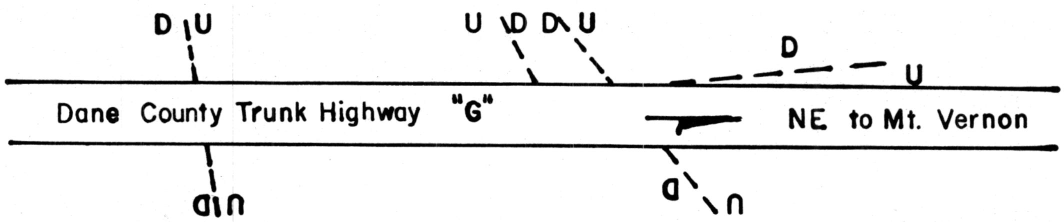
Significance: This exposure presents an excellent opportunity for comparing the Oneota and Shakopee Formations, for examining the content of the New Richmond and William River members of the Shakopee Formation, for examining the pre-St. Peter erosion surface, and for seeing faulting on the edges of the "stable" Wisconsin dome.

What differences can you find between the Oneota and Shakopee Formations? What is the environmental significance? How are they related to the New Richmond Formation? What was the environment of deposition? What is the relationship of the Oneota Formation to the St. Peter Formation? What is the historical significance of this contact? What is the orientation of the faults? How would you trace them across the landscape?

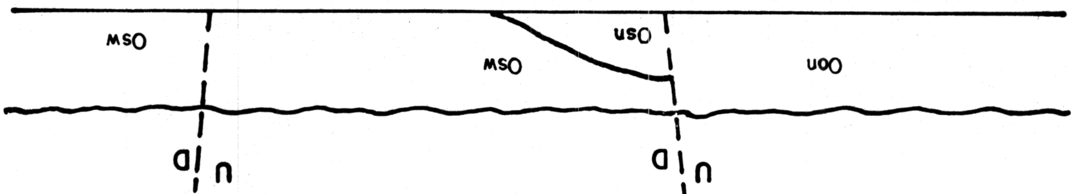
References: Ulrich, 1924; Davis, 1965; Ostrom, 1965.



A. Outcrop in northwest roadcut.



B. Plan view.

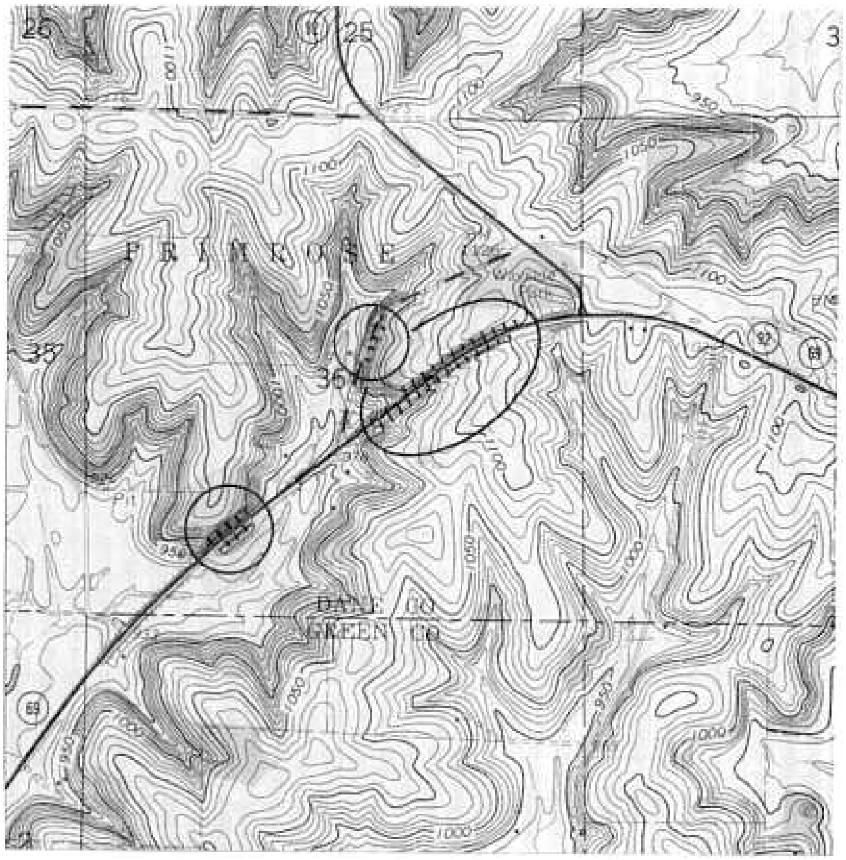


C. Outcrop in southeast roadcut (turn upside down to read).

Diagrammatic sketch of roadcuts on Dane County Trunk Highway "G" west of Mt. Vernon at Stop #12. Oon, Oneota Formation; Osn, New Richmond Member of Shakopee Formation; Osw, Willow River Member of Shakopee Formation; Osp, St. Peter Formation.

Title: New Glarus North

Location: Road cut on State Highway 69, 3.5 miles north of New Glarus and 4.5 miles west of Belleville in the SW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 36, T.5N., R.8E., [redacted] Dane County (Belleville 7.5-minute topographic quadrangle, 1962).



Author: M. E. Ostrom (modified from Ostrom, 1965 and 1970)

Description: This exposure shows the effect of the Wisconsin arch on the Glenwood Member and is an excellent place at which to observe the Platteville Formation. Note especially the character of the Spechts Ferry Member as compared to exposures at Potosi Hill and Hoadley Hill.

The Glenwood Member has been traced from near Beetown in southwestern Wisconsin to New Glarus. It has an apparent truncation at the top from west to east. Throughout the area it is overlain by a sandy dolomite bed which is from 6" to 22" thick and which contains phosphate pellets in its base (The Chana Member of the Illinois Geological Survey) and which marks the base of the Pecatonica Member. This contact is even and there is no sign of reworking such as a conglomerate. The angular relationship is believed to be depositional in origin and the contact to represent a subaqueous diastem or cessation of deposition.

The contact of the Glenwood Member with the Pecatonica Member is easily recognized because of the basal phosphatic and sandy dolomite bed in the

Pecatonica whereas that at the base of the Glenwood is very difficult to determine especially in the subsurface. Above the Glenwood Member individual thin stratigraphic units can be traced over broad areas (Templeton & Willman, 1963) whereas below it the units are limited in extent. Furthermore, the contact marks the change from rocks composed predominantly of non-calcareous clastic material to rocks composed of carbonate.

For this reason the Wisconsin Geological and Natural History Survey is considering removing the Glenwood Member from the Platteville Formation and assigning it instead to the St. Peter Formation. This would separate the predominantly non-calcareous clastic rocks from the carbonate rocks, it would provide for an easily recognizable and mapable contact on the outcrop as well as in the subsurface, and it would be a practical division for economic mapping purposes.

An additional proposal under consideration by the Survey is the grouping of all the rocks now referred to as the Galena-Platteville, or as rocks of Mohawkian age, etc., under a single name. Although the name Ottawa Megagroup has been proposed (Swann & Willman, 1963) for these rocks this name has certain unacceptable qualities. First, the name as originally applied referred to those rocks above the St. Peter, Simpson, Glenwood, or Aylmer clastics and below the Maquoketa Shale Formation. However, it has since been used to include the Glenwood Member (Templeton and Willman, 1963). Second, the name Ottawa in the upper Mississippi Valley area connotes silica sandstone mined at Ottawa, Illinois (the St. Peter Sandstone of Ordovician age), and at Ottawa, Minnesota (the Jordan Sandstone of Cambrian age). Third, its designation as a megagroup rather than as a super group or group does not conform to recommendations of the Code on Stratigraphic Nomenclature so is unlikely to meet with broad acceptance. And fourth, the name Ottawa was taken from Ottawa, Canada, which is far removed from the Upper Mississippi Valley area wherein all other names applied to subdivisions of these rocks have their derivation and is, therefore, of scant reference use to geologists working in the area.

The name under consideration is Sinnipee Group taken from Sinnipee Cemetery which is located at the top of the bluff north of the mouth of Sinnipee Creek in Grant County, Wisconsin. In this bluff nearly all of the rocks from the top of the Glenwood Member into the Stewartville Member of the Galena Formation are exposed. The missing part of the Stewartville Member, the overlying Dubuque Member, and the contact of the Dubuque Member with the overlying Maquoketa Formation are exposed less than 6 miles away near Dubuque, Iowa.

ORDOVICIAN SYSTEM
Sinnipee Group (tentative name)

Decorah Formation

Ion Member (+15 feet)

0'	15'	+15'	Dolomite, light gray mottled and streaked very light yellowish brown, medium-crystalline, medium- to thin-bedded, with green shale in partings and disseminated throughout rock. Abundant fossils, many large, especially on bedding planes. Porous zone of brachiopod molds 12" above base.

Guttenberg Member (8.7 feet)

15' - 23.7'	8.7'	Dolomite, gray mottled and streaked light yellowish brown, fine- and medium-crystalline, dense, thin- and regularly-bedded, with brown shale and argillaceous dolomite partings. Very fossiliferous; not especially the large brachiopods. Upper few feet becomes thick-bedded with persistent ½" green shale parting at top: upper few feet have rougher texture than lower part.

Spechts Ferry Member (1.0 feet)

23.7' - 24.4'	0.7'	Dolomite, light yellowish brown and gray, medium-crystalline, appears massive but is thin-bedded. Upper 3" gray mottled light yellowish brown with abundant phosphate pellets and fragments.
24.4' - 24.6'	0.2' ± 0.1'	Dolomite, light yellowish brown, fine- and medium-grained, thin- and irregularly-bedded, argillaceous.

Platteville Formation

Quimby's Mill Member (15.2 feet)

24.6'- 39.3'	14.7'	Dolomite, light gray, very finely-crystalline, dense, medium- and thick-bedded, regularly-bedded moderately fossiliferous (well exposed contact in NW but 15 yards NE of warning sign at S. side of road). Few chert nodules.
39.3' - 39.8'	0.5'	Dolomite, light yellowish brown, fine- and medium-crystalline, dense, thin- and irregularly-bedded, trace of green clay.

McGregor Member (46.0 feet)

39.8' - 51.3'	11.5'	Dolomite, light gray, fine- and medium- crystalline, dense, medium-bedded, laterally persistent beds, fossiliferous, upper few feet appear to be burrowed. Locally quite vuggy.
51.3' - 85.8'	34.5'	Dolomite, very light yellowish gray, fine- and medium-crystalline, dense, very irregular and thin beds which appear nodular due to nonpersistence of beds. Locally reddish brown, thin and irregularly-bedded dolomite in basal 6" to 1'. Fossils locally abundant, especially well-preserved on bedding planes.

Pecatonica Member (20.0 feet)

85.8' -105'	19.2'	Dolomite, very light yellowish brown mottled yellowish brown, medium- and fine-crystalline, medium- and thick-bedded, weathers to thin beds, dense with

		few fossil molds. Weathered surface appears to be shaly.
105.0'-105.7'	0.7'± 0.5'	Dolomite, light yellowish gray mottled very light yellowish brown, fine- and medium-crystalline, massive-appearing but weathers to thin and irregular beds. Sandy in base with rare phosphate pellets. Few fossils. Uneven base may be due to solution.

St. Peter Formation

Glenwood Member (1.7 feet)

105.7'-106.4'	0.7'+ 0.2'	Argillaceous bed: basal 3" is sandstone, poorly-sorted, grains from coarse to fine size, very argillaceous; overlain by 3" to 9" of reddish brown clay; overlain by less than 3" of very light yellowish brown dolomitic clay and argillaceous dolomite. Upper contact shows marked relief which appears to be due to chemical alteration and solution of the overlying dolomite.
106.4'-107.4'	1.0'± 0.2'	Sandstone, reddish brown, coarse- and medium-grained, massive-bedded, locally cross-bedded, poorly-sorted, locally cemented with iron oxide. Contains abundant pebbles and cobbles that appear to have been derived from the underlying Tonti Member (ripclasts). Base slightly uneven.

Tonti Member (+80.0 feet)

107.4'-184.4'	+80.0'	Sandstone, very light yellowish brown to white, medium- and fine-grained, massive-bedded, cross-bedded, well-sorted, grains rounded and subrounded.

BASE OF EXPOSURE AT ROAD LEVEL

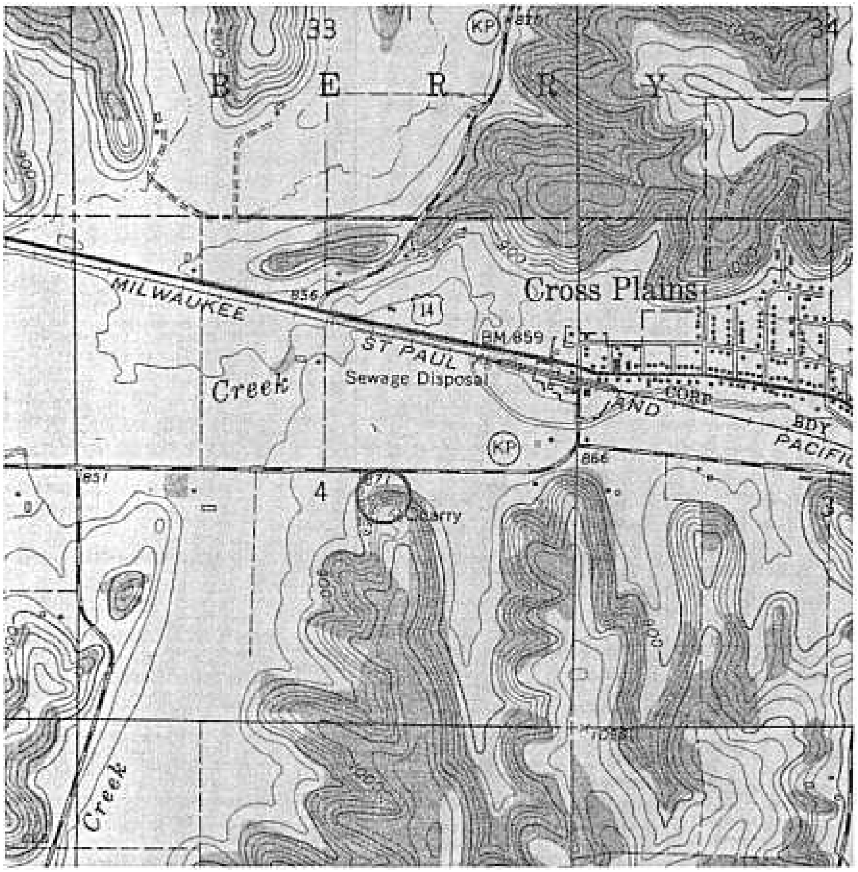
Significance: This exposure shows the effect of the Wisconsin arch on the Glenwood Member and is an excellent place at which to observe the Platteville Formation. Note especially the character of the Glenwood and overlying Platteville, the Quimbys Mill, Spechts Ferry, and Guttenberg.

What was the sources of the St. Peter Sandstone? From which direction? How does the Glenwood exposed here differ from that seen at Bridgeport, Lancaster, Dickeyville, and Hoadley Hill? Has the Quimbys Mill changed? If so, how? The Spechts Ferry? The Guttenberg? What is the significance of the changes, if any? Note the variety of fossils, their condition and orientation? What significance do they have? Note bedding characteristics? What is the significance in terms of depositional history?

References: Templeton and Willman, 1963; Swann and Willman, 1963; Ostrom, 1965 & 1970.

Title: Cross Plains West

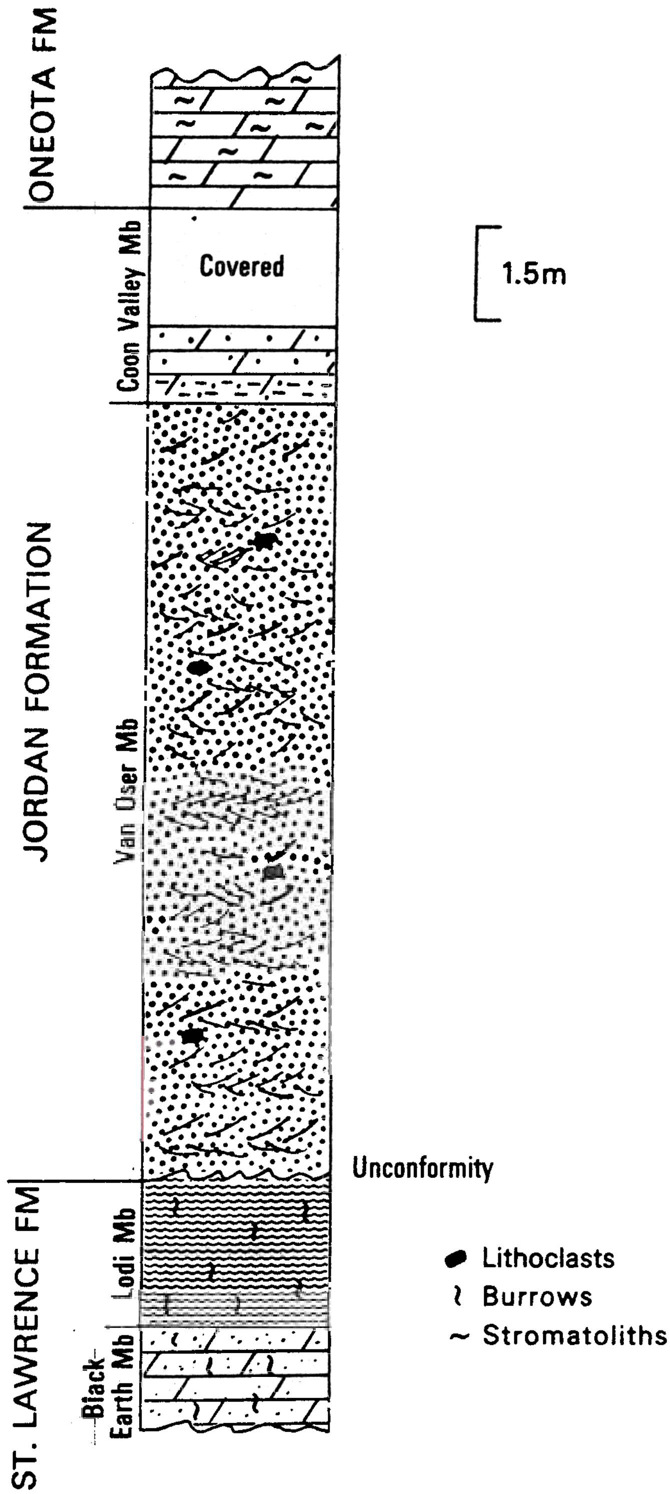
Location: Quarry south of County Highway KP, .7 km southwest of Cross Plains, Wisconsin in the NW¼, NW¼, SE¼, Sec. 4, T.7N., R.7E., Dane County (Cross Plains 7.5 minute topographic quadrangle, 1962).



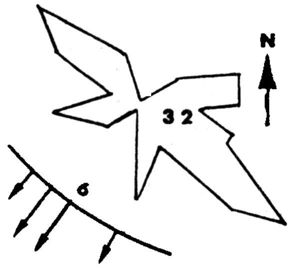
Author: I. E. Odom

Description: This exposure is significant because the disconformable contact between the Jordan (Van Oser Member) and the St. Lawrence Formations is well exposed. The Lodi Siltstone and underlying Black Earth Dolostone are both reddish, a local coloration developed along the axis of the Wisconsin Arch. At this location, the Black Earth is very silty, and both it and the Lodi are intensely bioturbated. At the type section of the Black Earth Member located 4.5 km west on U.S. 14, there is a thick sequence of dolostone containing algal structures. Algal structures are common in the Black Earth Dolostone only in the vicinity of the Wisconsin Arch and around the Baraboo Syncline.

CROSS PLAINS (WEST), WIS.



U.S. 14 near
Festge Park



R.H. Dott, Jr.

Paleocurrent directional data for the Van Oser Member.

Neither the Coon Valley Member nor its contact with the overlying Oneota Formation are well exposed. Baraboo Quartzite lithoclasts are moderately abundant in the Van Oser Sandstone. The upper part of the Van Oser Sandstone is cemented by calcite (popcorn concretions).

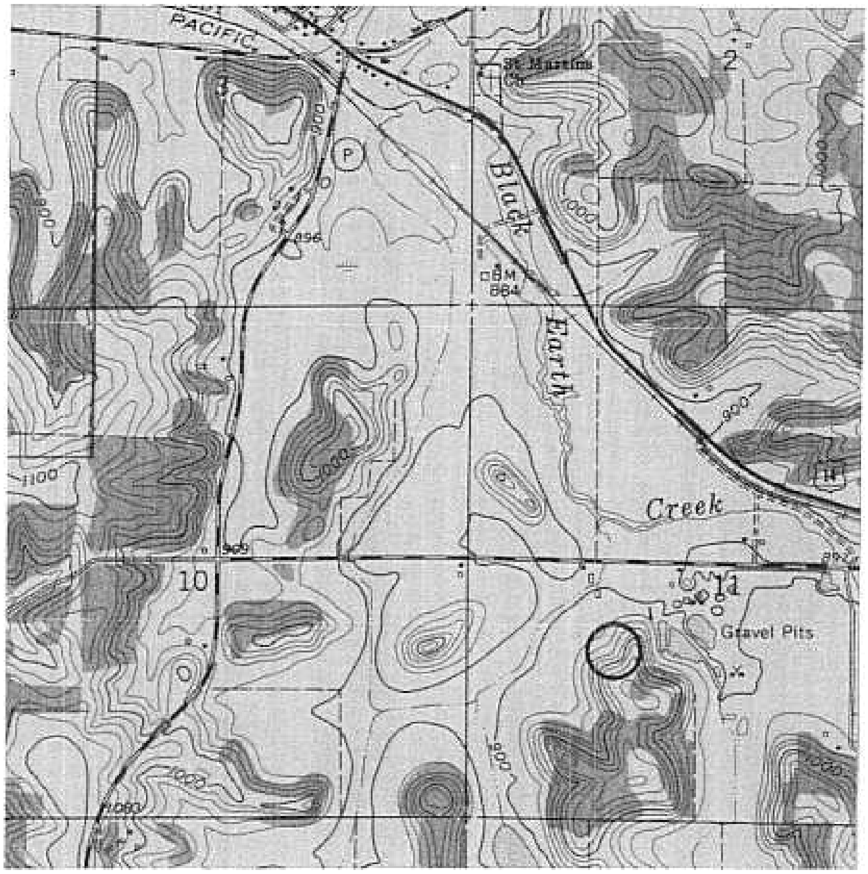
Interpretations: What is the age of the oxidation of iron in the St. Lawrence? Is it due to pre-Van Oser subaerial weathering? Is there evidence in the Van Oser that suggests the oxidation might be recent in age? See description accompanying Outcrop 7 for further discussion of the sedimentology of the St. Lawrence Formation. For additional information on the regional lithology of the St. Lawrence Formation see Ph.D. thesis by McGannon (1960) and Nelson (1956).

Note: Permission must be obtained to enter this quarry. The present owner lives in the first house on the north side of Highway KP toward Cross Plains

Outcrop 5

Title: Cross Plains East

Location: Capitol Stone Quarry, 2 km east of Cross Plains, Wisconsin in the SW$\frac{1}{4}$, NW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 11, T. 7N., R. 7E., Dane County. (Cross Plains 7.5 minute topographic quadrangle, 1962).

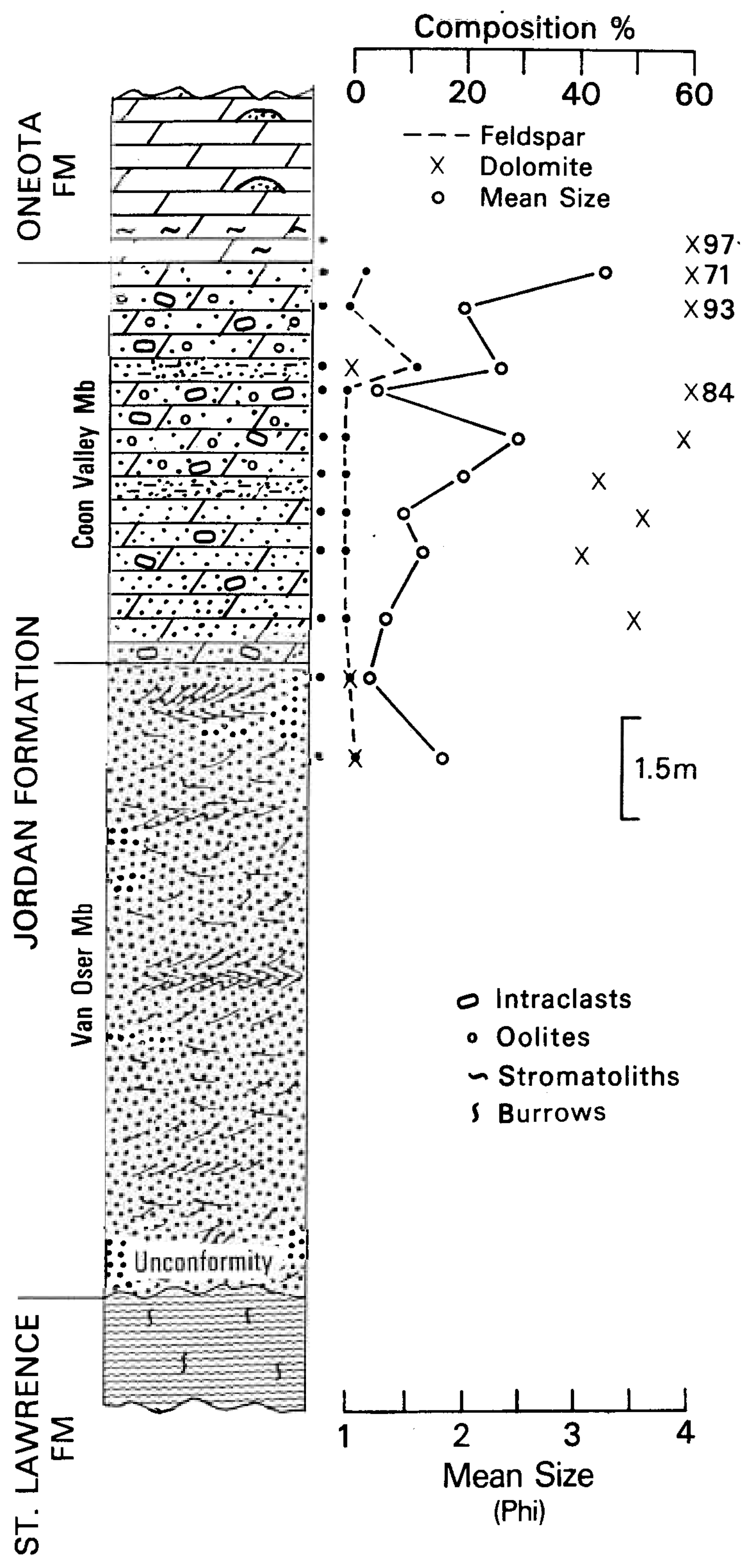


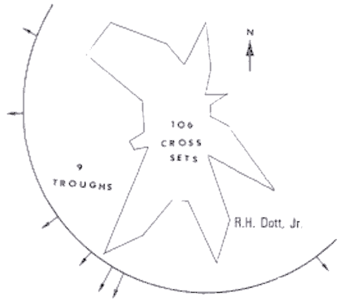
Author: I. E. Odom

Description: The Oneota, Jordan, St. Lawrence and the top of the Lone Rock Formations are exposed in the quarry and in the hillside below (The Lone Rock is not included in the above section because it may have been recently covered by fill for a new quarry road). The Norwalk Member of the Jordan is absent and the Van Oser Member rests unconformably on the St. Lawrence. This same stratigraphic relation can also be seen on U. S. Highway 14 north of the quarry. The Van Oser Member is transitional with the Coon Valley Member, which is in turn transitional into the Oneota Dolostone.

This exposure and others nearby (Outcrops 6 and 7) provide unequivical proof that a local unconformity (disconformity) exits on the axis of the Wisconsin Arch between the Jordan (Van Oser) and St. Lawrence Formations. The unconformity migrates up section toward the west, and at Soldiers Grove, Wisconsin, it is present between the Van Oser and Norwalk Members.

CROSS PLAINS, WIS.





Paleocurrent directional data for the Van Oser Member.

Parts of the Van Oser Member are highly cross-stratified. Current directional data (shown above) by R. H. Dott, Jr. show a dominantly southwest transport. Grains of Baraboo Quartzite have been found near the top of the Van Oser and in the base of the overlying Coon Valley Members, which demonstrates sand transport from the direction of the Baraboo Islands (Figs. 22 and 31).

The Coon Valley Member is represented by dolomitic sandstones and sandy, "oolitic" dolostones which contain abundant intraclasts. The upper contact of the Coon Valley is placed at the top of the sandy dolostones and below the prominent algal dolostone bed that occurs at the base of the Oneota. Although the Oneota is not sandy, two thin sandstone lenses occur a few feet above the contact. This is the only locality where sandstone has been found interbedded with nonsandy Oneota. See Figure 33 for further data on the petrology of the Coon Valley Member and the Oneota Dolostone at this quarry.

Along the axis of the Wisconsin Arch, the thickness of the Coon Valley is locally more variable than elsewhere in the Upper Mississippi Valley (Figs. 16 and 17). Although it is slightly more than 4 meters at this location, in several nearby outcrops the Coon Valley is approximately 1 1/2 meters in thickness, and in one outcrop near Sauk City, Wisconsin, it is represented by just .3 meters of shaly sandstone.

Interpretations - The Jordan-St. Lawrence stratigraphic relationships indicate that following deposition of the Norwalk Member (several feet of the Norwalk is present in nearby outcrops) regional uplift occurred, especially in the area of the Wisconsin Arch. This uplift resulted in a short interval of subaerial erosion which locally entirely removed the Norwalk and variable amounts of the St. Lawrence Formation. The Van Oser Sandstone was deposited in this area over an irregular surface and is considered to be part of the Cross Plains Bar complex, which in Cambrian time is believed to have extended westward from the north end of the Baraboo Islands (Fig. 22). The lithoclasts of Baraboo Quartzite attest to the direction of sediment transport.

No Sunset Point Sandstone is known in this area. The western most outcrop of what is interpreted to be the Sunset Point Sandstone occurs at Middleton, 11 km east; thus it is inferred that the margin of the Sunset Point lagoon during deposition of part of the Van Oser in the Cross Plains area was located near Middleton. The lithic nature of the Coon Valley Member at this location records a transition from a littoral to a carbonate shelf environment. Adams (this guidebook) concludes that the Oneota Formation and perhaps the upper part of the Coon Valley Member in this area were deposited in a supratidal environment.

OUTCROP 1

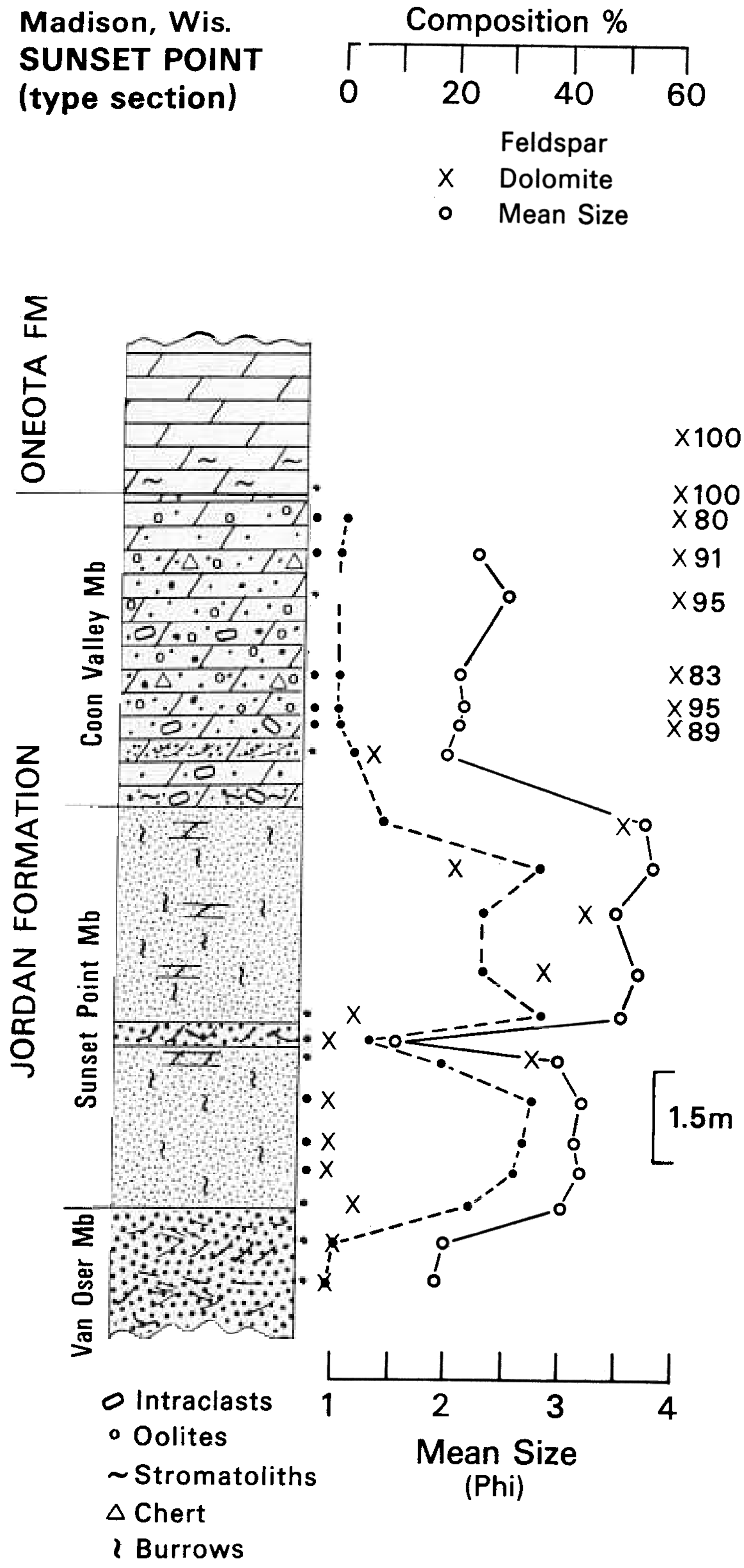
Title: Madison-Hoyt Park

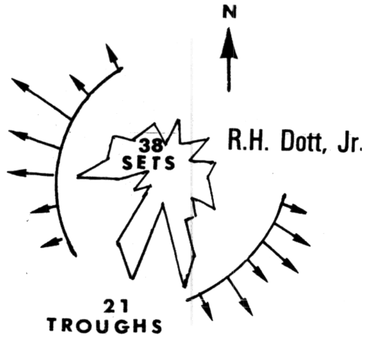
Location: Near Intersection of Bluff Street and Du Rose Terrace, Madison, Wisconsin in the SE¼,SE¼, NE¼, Sec. 20, T.7N., R.9E., Dane County (Madison West 7.5 minute topographic quadrangle, 1974).

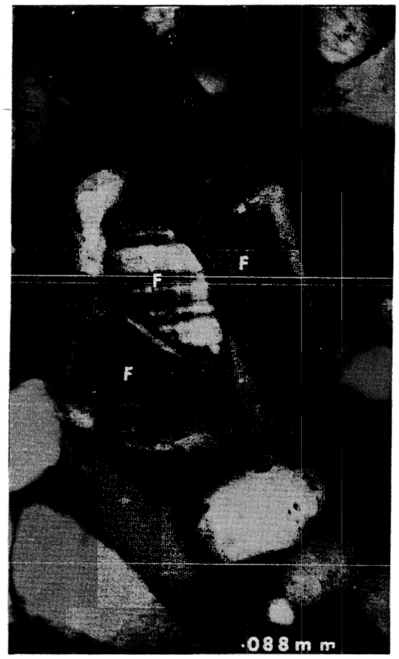
Author: I. E. Odom

Description: The section above is a composite of exposures along Bluff Street and in an abandoned quarry just (above) south of the Bluff Street outcrop in Hoyt Park (do not tresspass on private property and please do not mutilate the outcrops). This is the type section of the Sunset Point Sandstone Member of the Jordan Formation as currently defined (formerly the Madison Sandstone). The upper part of the Sunset Point was first described by Irvin in 1875, however, the lower 3 meters and the underlying Van Oser Sandstone apparently were not exposed prior to about 1960.

The petrologic and textural data for the Sunset Point Member show that it is a highly feldspathic, very fine-grained sandstone. The upper part is thinly bedded and dolomitic and was previously quarried for building stone (used in several building on the UWM Campus). The lithology of the lower unit of the


Madison, Wis.
SUNSET POINT
(type section)
Composition %
0
20
40
60
Feldspar
X Dolomite
o Mean Size
ONEOTA FM
JORDAN FORMATION
Coon Valley Mb
Sunset Point Mb
Van Oser Mb
X100
X100
X80
X91
X95
X83
X95
X89
1.5m
Intraclasts
Oolites
Stromatoliths
Chert
Burrows
1
2
3
4
Mean Size
(Phi)





(Above) Current directional data, Sunset Point Member.

(Right) Authigenic and detrital feldspar (F) in lower unit of Sunset Point Sandstone.

Sunset Point differs from the upper unit only in that it is less dolomitic, more massive, and contains scattered medium size grains. The thin bed of cross-stratified, medium-grained, quartzose sandstone that separates the upper and lower units of the Sunset Point Sandstone varies in thickness over the full outcrop from a few centimeters up to .3 meters. Ostrom (1964) reported a thin quartz granule "conglomerate" in the base of the upper Sunset Point unit. The contact of the Sunset Point Sandstone with the overlying Coon Valley Member was thought by Ulrich (1924) to be a major uncomformity separating the Cambrian from his Ozarkian System.

Note the pinkish color of several of the massive beds of the Sunset Point Sandstone. This color is a reflection of their high K-feldspar content. Both units of the Sunset Point Sandstone are bioturbated and contain burrows and other trace fossils. The walls of buildings on the UWM Campus constructed of this stone are an excellent place to study the trace fossils. Fossils collected from the Sunset Point Member by G. O. Raasch are identified as Cambrian in age and include Tellurina and Saukia. Skolithos burrows are common in the lower unit, whereas a Cruizana assemblage dominates the upper unit.

At the base of the Sunset Point Sandstone is a fine- to medium-grained, quartzose sandstone assigned to the Van Oser Member. A much greater thickness of the Van Oser was at one time exposed at the intersection of Bluff Street and Du Rose Terrace.

The upper beds of the Sunset Point Sandstone and the Coon Valley Member are exposed in the abandoned quarry. The Coon Valley Member consists of 5 meters of dolomitic, conglomeratic sandstones and sandy, oolitic dolostones (see paper by Adams, this guidebook), the base of which contains a prominent bed of very sandy, conglomeratic, algal dolostone. The Coon Valley Member is in turn overlain by nonsandy algal and oolitic dolostones, the lower portion of which locally weathers with a honeycomb appearance, that are assigned to the Oneota Formation. Many more meters of the Oneota are exposed elsewhere in Hoyt Park.

To fully comprehend the stratigraphic sequences in subsequent outcrops to be examined, it is necessary to thoroughly study the lithic characteristics of the Sunset Point and Coon Valley Members of the Jordan and the basal beds of the Oneota Formation at these outcrops. The lithic nature of the Van Oser Sandstone can better be observed at Outcrop 2. Also, more accessible exposures of the Oneota are present at Outcrops 5 and 6.

Interpretations: The Sunset Point Sandstone is believed to be a local lithic unit that is time-stratigraphically equivalent to part of the Van Oser Member rather than being younger than the Van Oser as was previously thought (Odom and Ostrom, this guidebook). The Sunset Point can be traced northward in a narrow belt to near Dane, Wisconsin, a distance of about 15 miles. It can be shown to grade laterally toward the west into fine- to medium-grained, quartzose sandstones of the Van Oser Member, and it also disappears laterally in all other directions. Also, at Outcrop 4 the Sunset Point Member is overlain by the Van Oser Member.

Based on its lithic properties, sedimentary structures, and stratigraphic and geographic patterns of occurrence, the Sunset Point Sandstone is interpreted to represent a lagoonal environment. It is envisioned that this local lagoon was situated between the Cross Plains and East Madison Bar complexes and leeward of the Baraboo Islands (Fig. 22). The medium-grained sandstone that separates the upper and lower units of the Sunset Point Member is believed to be a washover fan from a nearby Van Oser bar caused by one or more storms. A part of the East Madison Bar complex was located as close as 5 km to the southeast. Note the bimodal distribution of current direction indicators.

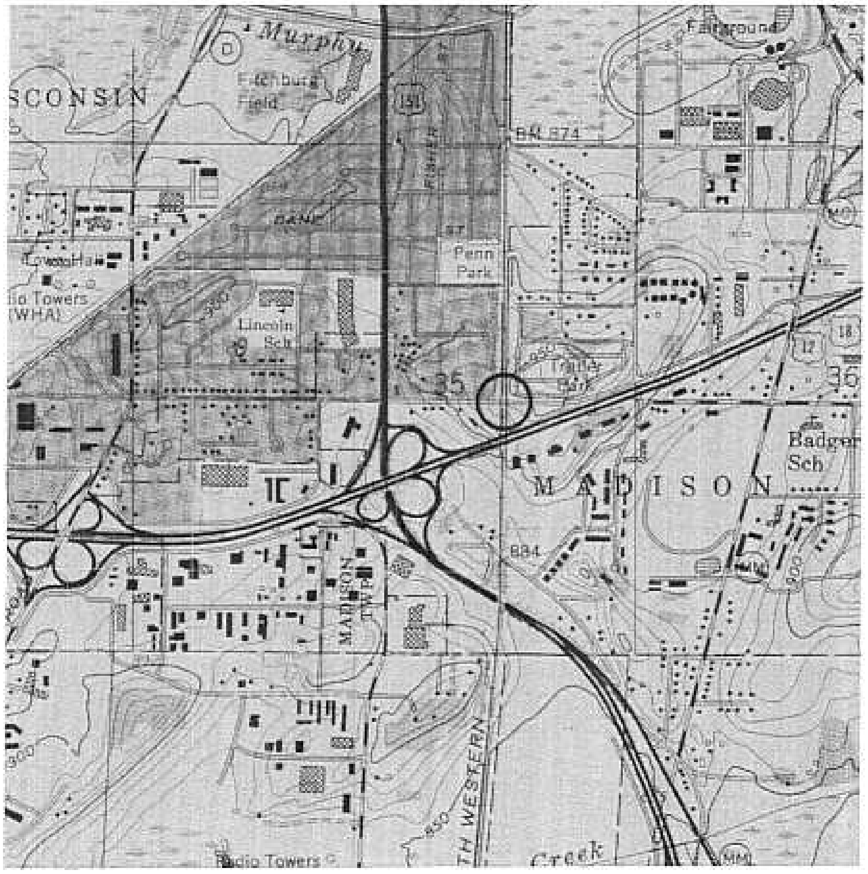
Although the Sunset Point Sandstone is overlain here and at the Shorewood Quarry, one mile north, by the Coon Valley Member, at Outcrop 4 it is overlain by the Van Oser Member. These stratigraphic relations and the fact that the Sunset Point disappears laterally in all directions are the primary evidences for the interpretation that the Sunset Point is a local facies and time-stratigraphically equivalent to the Van Oser Member.

The lithic characteristics of the lower portion of the Coon Valley Member suggest deposition primarily in littoral and shallow carbonate shelf (subtidal) environments with strong wave and current activities. Adams (this guidebook) concludes that the upper part of the Coon Valley Member was deposited in an intertidal environment that slowly changed to a supratidal, hypersaline environment (Oneota Formation). It is possible that the upper Coon Valley represents coalescing sandy oolite shoals resulting from the interplay between storm-generated and tidal currents around small algal mounds, however, I am suspect that some (perhaps most) of the oolites may be vadose in origin.

Outcrop 2

Title: Madison - Penn Park

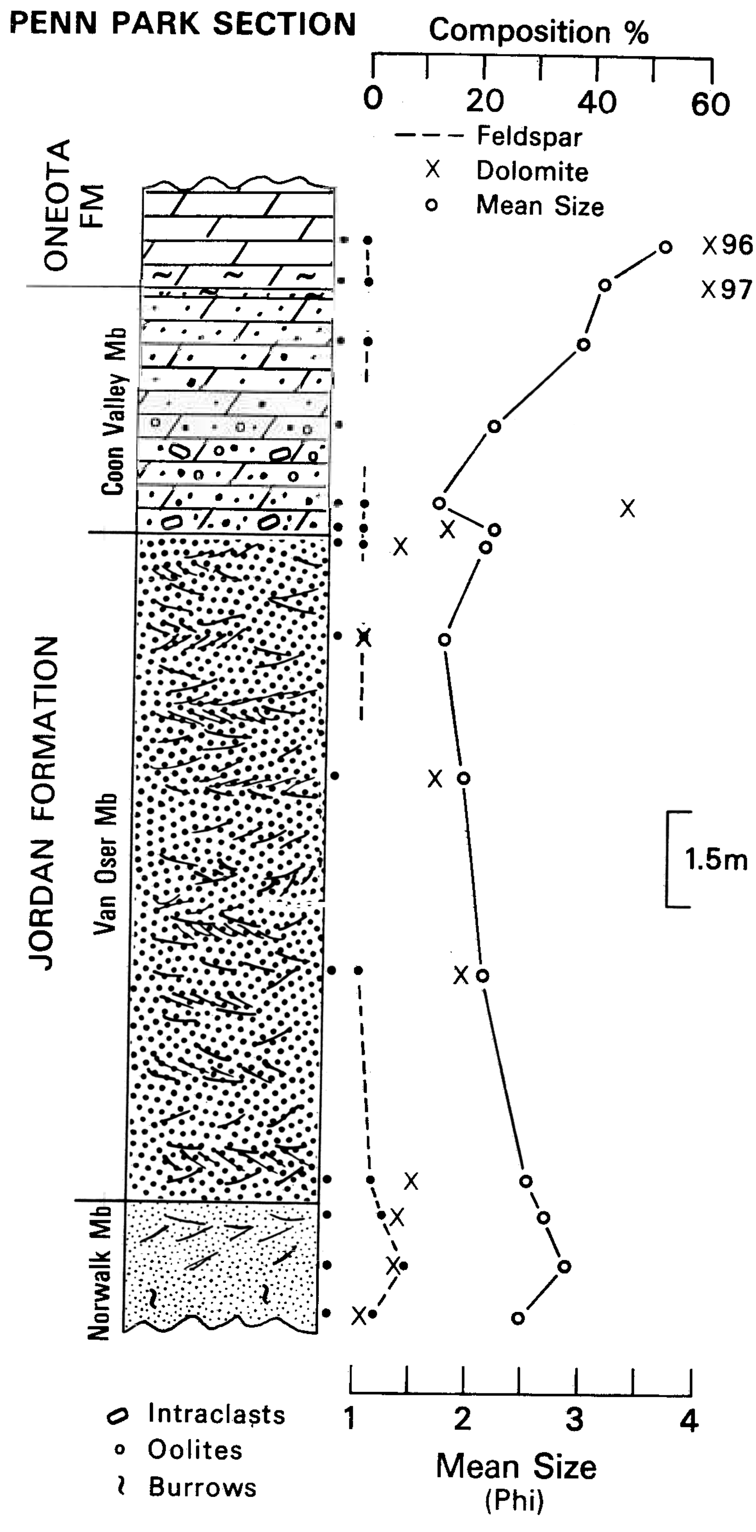
Location: Chicago and Northwestern Riilroad Cut at Badger Road east and south of Penn Park in the SE corner, SW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 35, T. 7N., R. 9E., Dane County. (Madison West 7.5-minute topographic quadrangle, 1974).

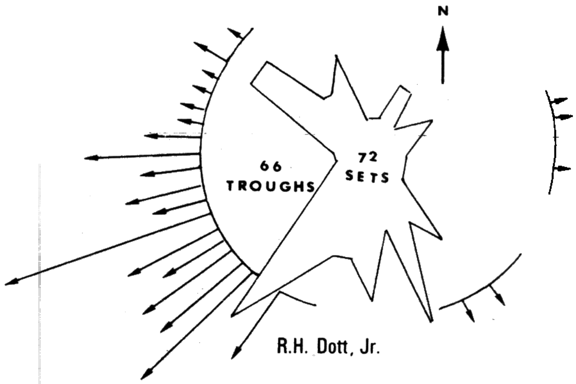


Author: I. E. Odom

Description: This outcrop of the Jordan Formation is very significant because no sandstones characteristic of the Sunset Point Member are present, yet the outcrop is just 5.5 km (3.4 miles) southeast of the Sunset Point type section. The lower two meters of fine-grained, slightly feldspathic sandstone is assigned to the Norwalk Member because its texture and mineralogy are typical of beds that are frequently transitional between the Norwalk and Van Oser Members (Outcrop 3). According to Twenhofel, Raasch, and Thwaites (1935), the Lodi Siltstone was once exposed in this cut.

Note that the stratigraphic interval where the Sunset Point Sandstone might be expected to occur is entirely fine to medium-grained, highly cross-stratified sandstone (Van Oser) which coarsens upward. Although it contains dispersed


PENN PARK SECTION
Composition %
0
20
40
60
Feldspar
Dolomite
Mean Size
ONEOTA FM
JORDAN FORMATION
Coon Valley Mb
Van Oser Mb
Norwalk Mb
X96
X97
1.5m
Intraclasts
Oolites
Burrows
1
2
3
4
Mean Size
(Phi)



Paleocurrent directional data for the Van Oser Member.

dolomite crystals, the overall mineralogy, texture and structure of this sandstone unit (10.5 m) are very similar to the Van Oser Member exposed elsewhere in the Madison area.

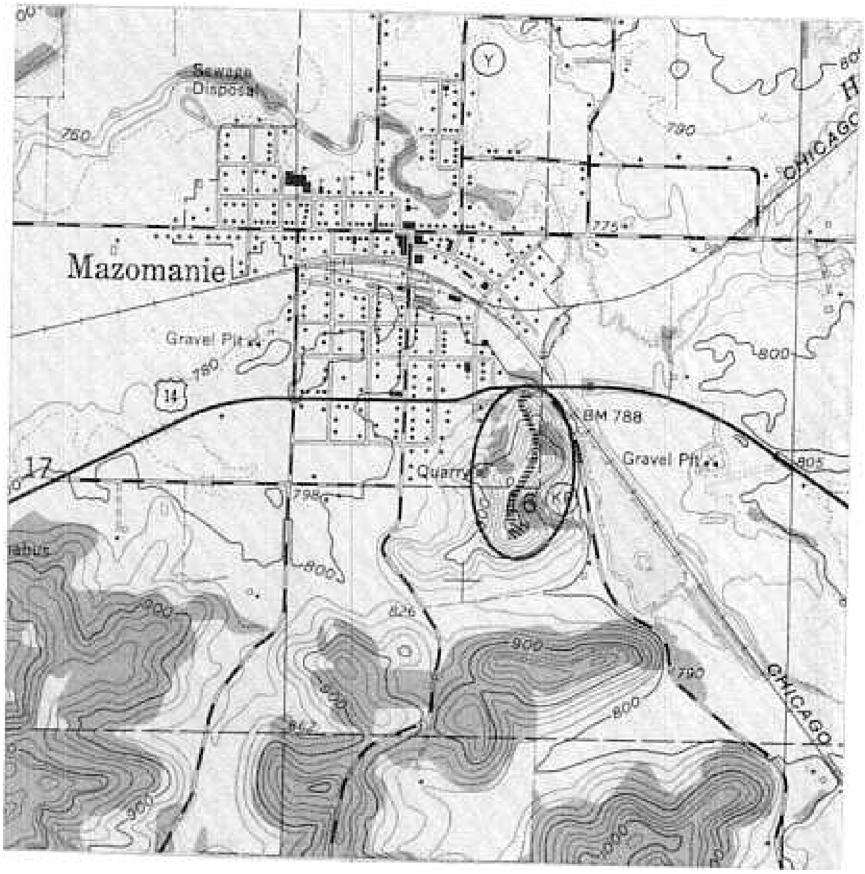
The Van Oser Member is here overlain by "oolitic", sandy dolostones and dolomitic sandstones (Coon Valley Member) very similar to those overlying the Sunset Point at its type section, and the lower beds of the Oneota Dolostone supersede the Coon Valley. More accessible outcrops of the upper part of the Coon Valley Member and of the lower beds (algae) of Oneota Dolomite are present along Badger Road south of the bridge.

Interpretations: The Van Oser Sandstone at this locality is interpreted to be part of the East Madison Bar complex (Fig. 26), and the local lagoon in which the Sunset Point Sandstone was simultaneously being deposited was located to the northeast. The dominant current directions were to the south and west (Dott, 1977) in agreement with the proposed model that the Sunset Point lagoon was surrounded by Van Oser bars which egressed from the ends of the Baraboo Islands (Fig. 22).

The lithic characteristics of The Coon Valley Member again suggest that it was deposited in a dominantly subtidal carbonate shelf lithotope influenced by strong wave and current activities. The Oneota Dolostone contains the same types of algal structures as at Outcrop 1, which Adams (this guidebook) interprets to be indicative of a supratidal environment.

Title: Mazomanie Bluff

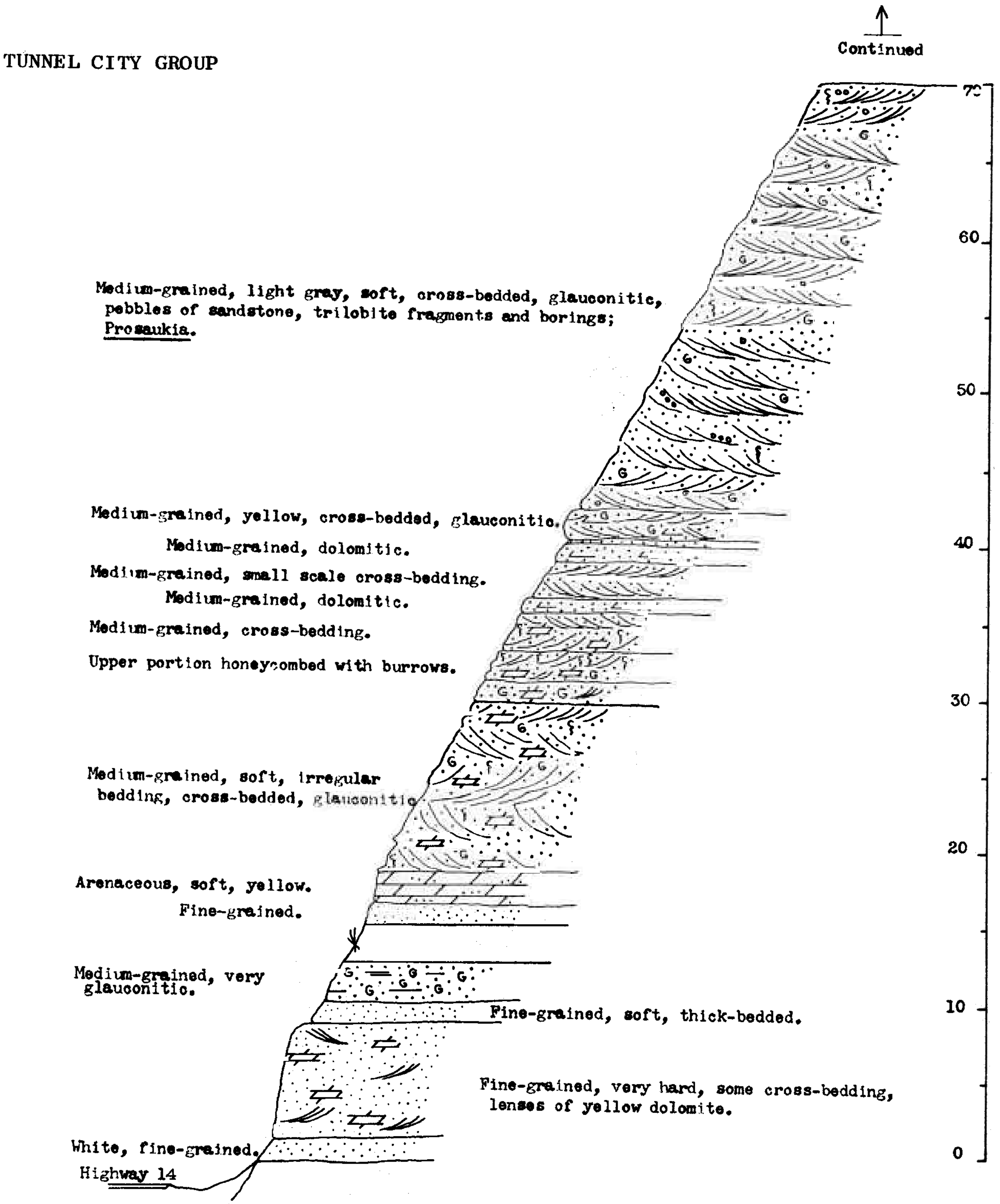
Location: Bluff at southwest end of bridge over Black Earth Creek in the SE¼, NW¼, Sec. 16, T.8N., R.6E., Dane County (Mazomanie 7.5-minute topographic quadrangle, 1962).



Author: M. E. Ostrom (modified from Starke, 1949, Cline, 1959 & 1960, and Ostrom and Cline, 1970).

Description: The Wisconsin Arch has been seen to exercise an influence on the lithology and thickness of various formations and members as can be seen by comparisons of outcrops located in this area and westward to the Mississippi River. The Wisconsin Arch evidently was positive throughout much of the Upper Cambrian and Lower and Middle Ordovician time as is shown by the thinning of many of the units over the arch (Starke, 1949; Ahlen, 1952; Emrich 1962; Ostrom, 1966, 1969; Melby, 1967). The Jordan Sandstone, for example, thins to 18 feet over the arch. The marked change in lithology and sharp contact between the St. Lawrence Formation and Jordan Sandstone at the Black Earth quarry could be interpreted as indicating pre-Jordan erosion as was suggested by Ostrom (1964). The Oneota rests with apparent unconformity on the Jordan on the basis of the fact that the "transition beds" of the basal Oneota are absent as was shown by Starke (1949) who ascribed the relationship to pre-Oneota erosion of the Jordan sands. However, the absence of these beds can also be accounted for by assuming that as the sea transgressed so did the lithic boundary separating

MAZOMANIE BLUFF SECTION
SE¼, NW¼, Sec. 16, T. 8N., R. 6E.



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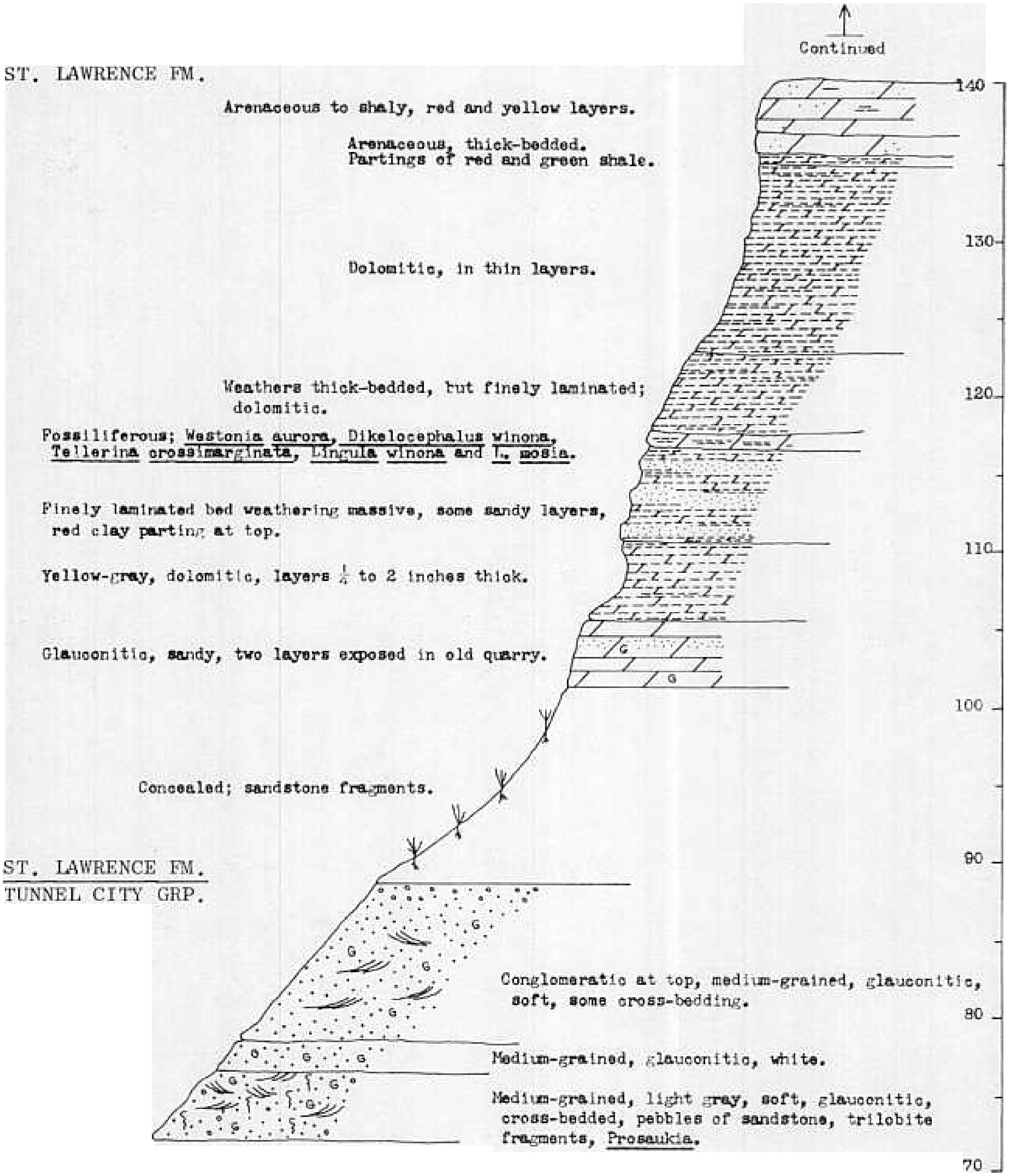
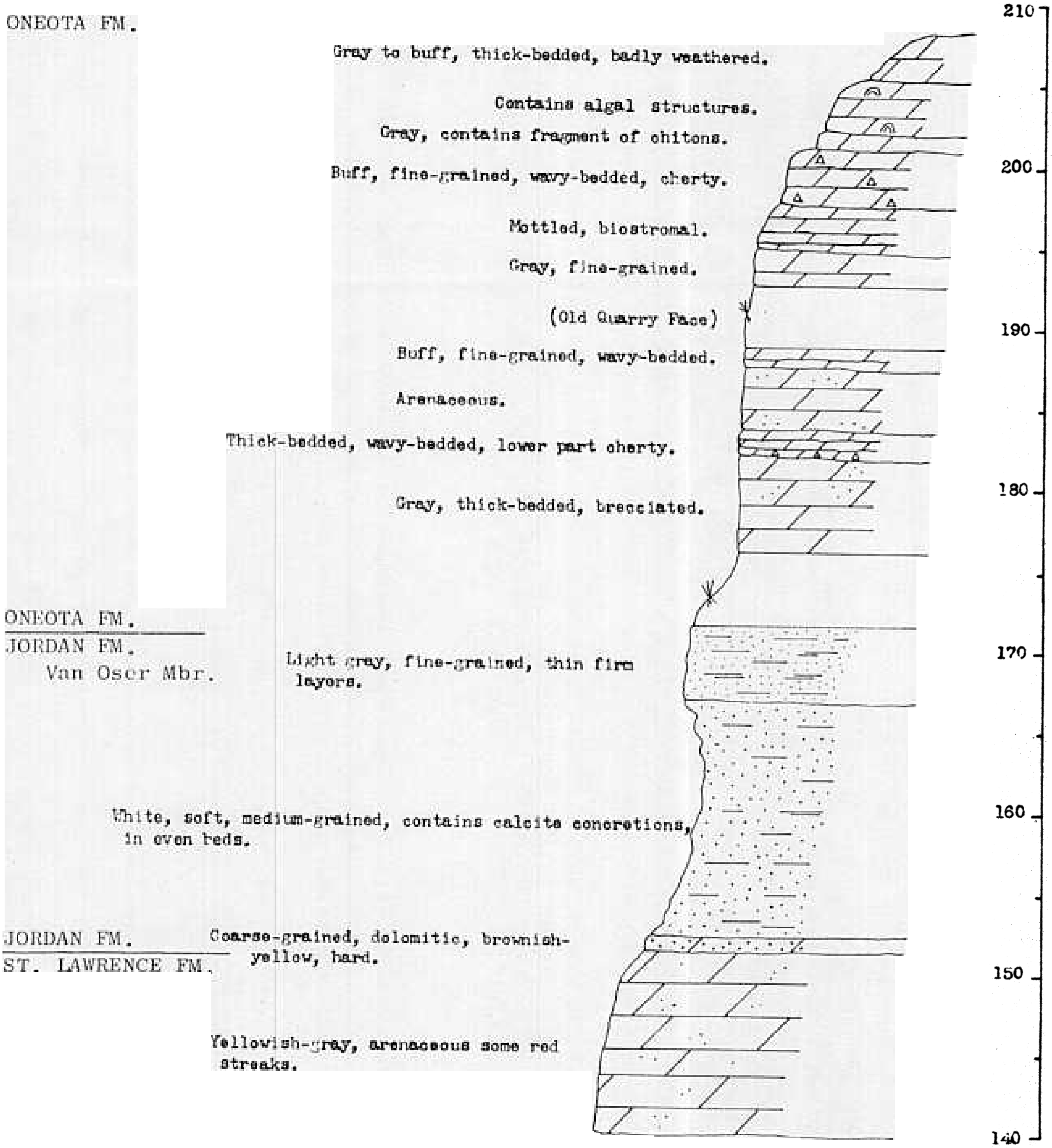


Continued
ST. LAWRENCE FM.
Arenaceous to shaly, red and yellow layers.
Arenaceous, thick-bedded.
Partings of red and green shale.
Dolomitic, in thin layers.
Weathers thick-bedded, but finely laminated; dolomitic.
Fossiliferous; Westonia aurora, Dikelocephalus winona, Tellerina crossimarginata, Lingula winona and L. mosia.
Finely laminated bed weathering massive, some sandy layers, red clay parting at top.
Yellow-gray, dolomitic, layers ¼ to 2 inches thick.
Glauconitic, sandy, two layers exposed in old quarry.
Concealed; sandstone fragments.
ST. LAWRENCE FM.
TUNNEL CITY GRP.
Conglomeratic at top, medium-grained, glauconitic, soft, some cross-bedding.
Medium-grained, glauconitic, white.
Medium-grained, light gray, soft, glauconitic, cross-bedded, pebbles of sandstone, trilobite fragments, Prosaukia.
140
130
120
110
100
90
80
70

CONTINUED



ONEOTA FM.
Gray to buff, thick-bedded, badly weathered.
Contains algal structures.
Gray, contains fragment of chitons.
Buff, fine-grained, wavy-bedded, cherty.
Mottled, biostromal.
Gray, fine-grained.
(Old Quarry Face)
Buff, fine-grained, wavy-bedded.
Arenaceous.
Thick-bedded, wavy-bedded, lower part cherty.
Gray, thick-bedded, brecciated.
ONEOTA FM.
JORDAN FM.
Van Oser Mbr.
Light gray, fine-grained, thin firm layers.
White, soft, medium-grained, contains calcite concretions, in even beds.
JORDAN FM.
ST. LAWRENCE FM.
Coarse-grained, dolomitic, brownish-yellow, hard.
Yellowish-gray, arenaceous some red streaks.
210
200
190
180
170
160
150
140

the "transition beds" from the underlying "sand beds". Thus, the lithic boundary would cross time boundaries. By this method individual beds among the "transition beds" would represent approximately time intervals and successively younger beds would reach further landward to form an overlapping pattern (Ostrom, 1964a).

Twenhofel, et al. (1935) assigned the upper 25 feet of the Tunnel City Sandstone at this exposure (Franconian) to the Reno Member. Ninety-three feet of the underlying section were referred to the Mazomanie and Birkmose members without attempt at differentiation. It is noteworthy that zone 24 (refer to Appendix), which is in the Lodi Siltstone 120 feet above the base of the outcrop, has yielded the world-famous Dikelocephalus fauna described by Ulrich and Resser (1916), although the genus is not restricted to the Lodi. Fossils are rare.

Black Earth Creek valley immediately above Mazomanie contains many feet of outwash sand and dolomitic gravel graded to the high sand terrace in the Wisconsin River valley.

Significance: The main purpose of this stop is to observe the effect of the Wisconsin arch on the Tunnel City Formation, St. Lawrence Dolomite, Lodi Siltstone and Jordan-Oneota contact.

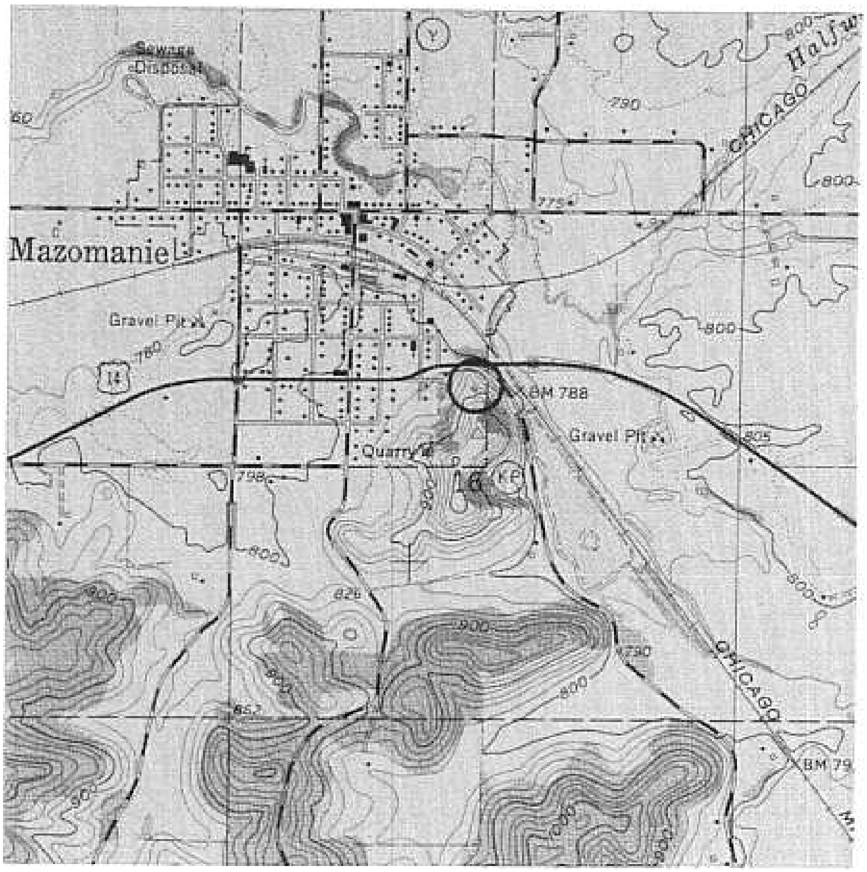
How is the Tunnel City Formation here different from exposures in western Wisconsin? What is the significance in terms of history and environment of deposition? How does the St. Lawrence Formation exposed here compare with that exposed at the Arcadia stop? Significance? How does the Jordan Formation at this stop differ from that seen at previous stops? Significance? What is the historical and environmental significance of the contact of the Jordan with the Oneota? What fossil evidence can you find? What does it signify?

References: Ulrich & Resser, 1916; Twenhofel et al., 1935; Ahlen, 1952; Starke, 1949; Cline, 1959 and 1960; Emrich, 1962; Ostrom, 1964, 1966, 1969, and 1970; Melby, 1967.

OUTCROP 7

Title: Mazomanie (School House) Bluff

Location: South of U.S. Highway 14 at east edge of Mazomanie, Wisconsin in the NE¼, SE¼, NW¼, Sec. 16, T.8N., R.6E., Dane County (Mazomanie 7.5 minute topographic quadrangle, 1962).

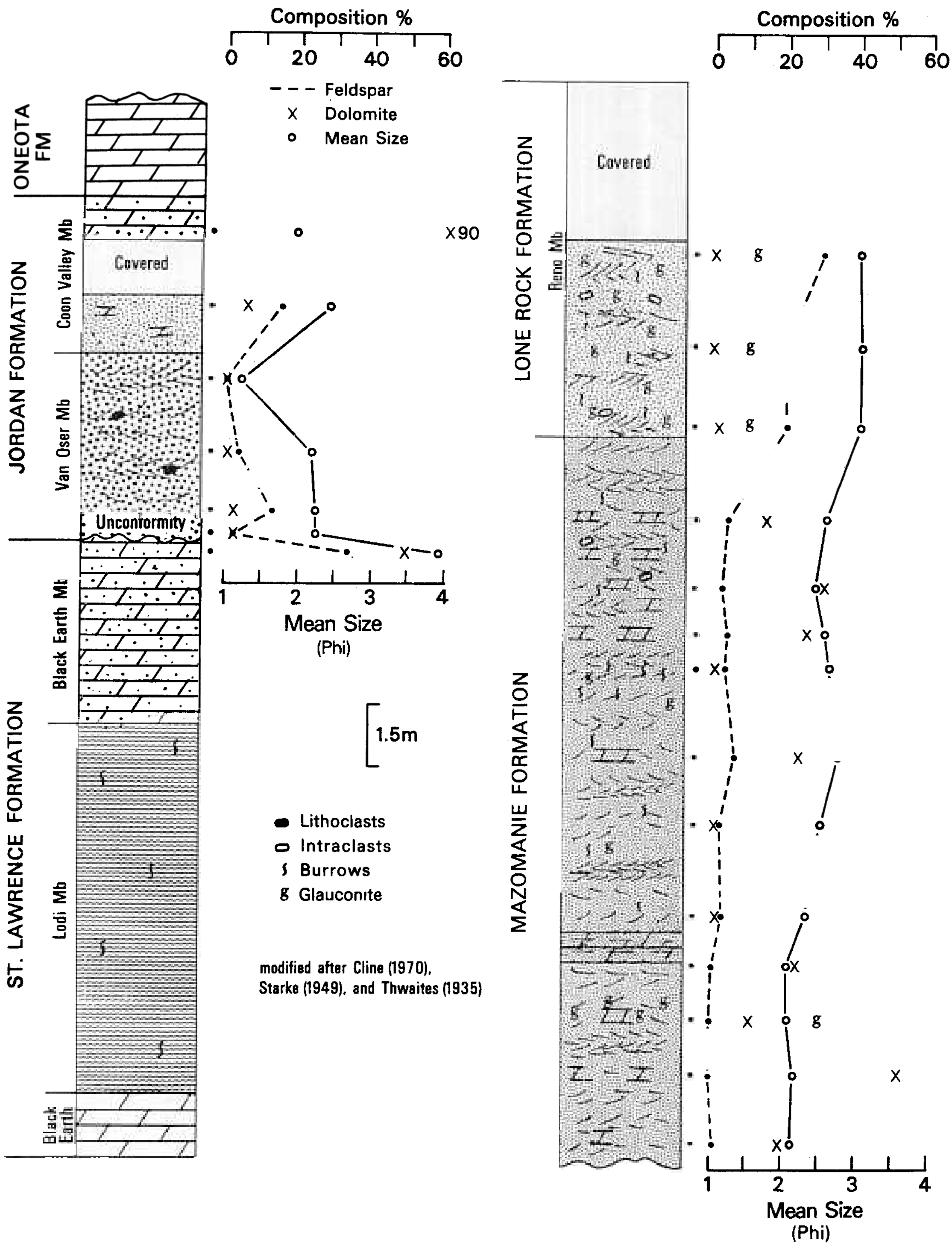


Author: I. E. Odom

Description: School House Bluff is considered to be the type section of the Mazomanie Formation, and it is a magnificent exposure for the total stratigraphic section is the most complete in central Wisconsin. Most of the Oneota, the Jordan, the St. Lawrence and large parts of the Lone Rock and Mazomanie Formations are well exposed. The main purpose for examination of this section is to observe the effects of the Wisconsin Arch on the local sedimentation of the Jordan, St. Lawrence, and Mazomanie Formations.

The Wisconsin Arch was definitely a positive area during the deposition of the Mazomanie, Jordan, and perhaps to a lesser extent the St. Lawrence Formations. The Norwalk Member of the Jordan is entirely absent (eroded). The Van Oser Member thins to 5.5 meters, the minimum thickness observed in Wisconsin, and it is disconformable with the Black Earth Dolomite. The Coon

MAZOMANIE, WIS.



Valley Member of the Jordan is also thin. Transportation of sand from the direction of the Baraboo Islands is shown by lithoclasts of Baraboo Quartzite in the Van Oser Member, some of which are up to one centimeter in diameter. The famous Dikelocephalus fauna has been collected at this locality from the middle of the Lodi Member.

Based on mineralogical and textural analyses, the upper 4.5 meters of the Tunnel City Group is assigned to the Reno Member of the Lone Rock Formation and the lower 15 meters to the Mazomanie Formation. These analyses show that the Reno Member is a glauconitic, feldspathic, very fine-grained sandstone, whereas the Mazomanie at this location is essentially a fine-grained quartzose sandstone, although it contains thin zones in which glauconite is moderately abundant. Both the Mazomanie and the Reno Member are locally intensely burrowed (Skolithos assemblage), dolomitic at certain horizons, and contain intraclasts. Trough and some planar-shaped cross stratification are present, especially in the Mazomanie.

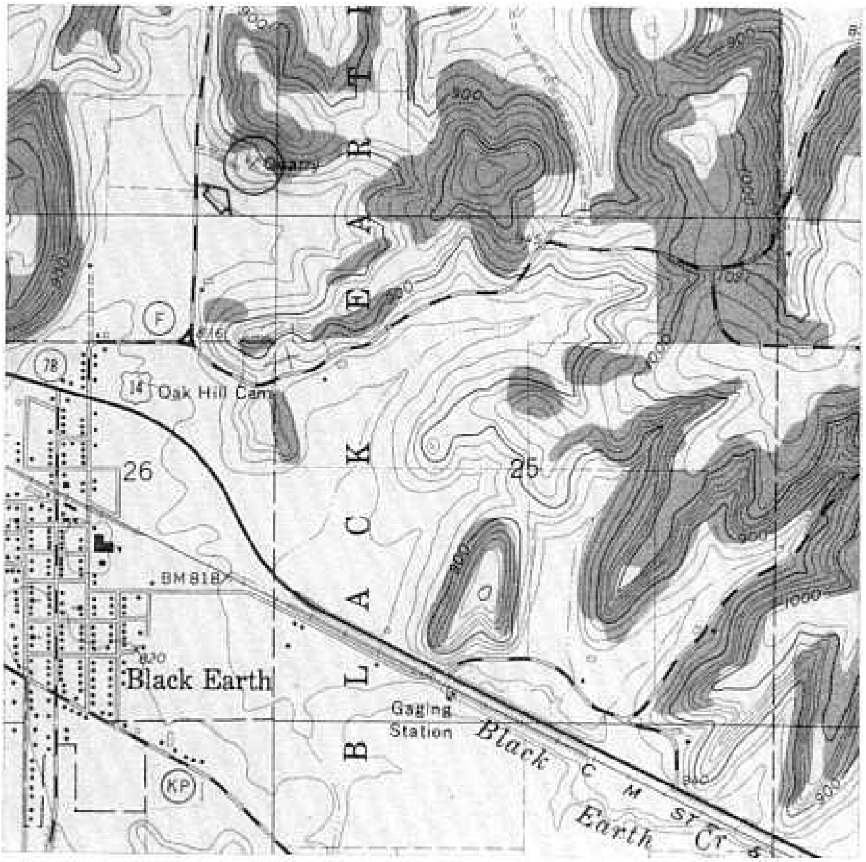
Interpretations: This outcrop further documents that the Wisconsin Arch influenced local sedimentation in Late Cambrian and Early Ordovician time, and that uplift and local erosion occurred prior to deposition of the Van Oser Sandstone. It is interpreted that the absence of the Norwalk Member is due to erosion rather than to nondeposition because several feet of the Norwalk lithology can be identified in nearby outcrops where it was not completely eroded. The local thickening of the St. Lawrence might also indicate that the Wisconsin Arch was a factor in its deposition. The abundance of algal mounds in the St. Lawrence only along the crest of the arch (McGannon, 1960) possibly indicates a type of "reef" development with the algal mats serving to trap and hold sediment. The "reef" dolostones were more resistant to erosion, as they are at the present time, because they formed hills of low relief on the pre-Van Oser erosional surface. Variations in the elevation of the base and increase in the thickness of the Van Oser Member nearby suggest that it was possibly being deposited in surrounding areas before its deposition at this locality; however, no specific beach deposits or lithoclasts of the St. Lawrence have been identified in the Van Oser Sandstone.

The presence of bioturbation, thin bedding and lamination in the Lodi Siltstone, algal structures in the Black Earth Dolostone, some mottling, and possibly dessication cracks (?) have prompted speculations that the St. Lawrence Formation was deposited in intertidal and perhaps supratidal environments. Although such sedimentary structures might form in tidal environments, as well as in other environments, the regional stratigraphy and sedimentology of the St. Lawrence and overlying and underlying lithic units make a tidal interpretation for the entire St. Lawrence highly dubious. More diagnostic indicators of tidal environments such as fining upward sequences, seaward-coarsening, tidal channels, and true flaser bedding, which would be necessary to show water movement, are absent in the St. Lawrence. The thin, scattered conglomerate beds that occur locally in the St. Lawrence, previously suggested to reflect tidal processes, could easily have been formed by hurricane-force storms (see paper by Dott, this guidebook). A shallow subtidal environment seems more probable for most of the St. Lawrence, but the algal mounds along the arch possibly formed in a tidal environment.

The probable nature of the regional and local depositional environments of the Mazomanie Formation and Reno Member of the Lone Rock Formation is discussed by Odom (this guidebook). The quartzose sandstones that compose the Mazomanie at this location are interpreted to have accumulated on a littoral shoal paralleling the Wisconsin Arch (Fig. 35). The quartzose Mazomanie accumulated simultaneously with the feldspathic Mazomanie and with the glauconitic Reno Member in off-shore areas to the west, south and east (Figs. 35 and 36). The Reno facies migrated over the arch with the transgression that occurred in late Franconian time (Fig. 35).

Title: Black Earth

Location: Exposures in Valley-Hites Quarry in the SE¼, SE¼, Sec. 23, T.8N., R.3W., Dane County (Black Earth 7.5-minute topographic quadrangle, 1962).

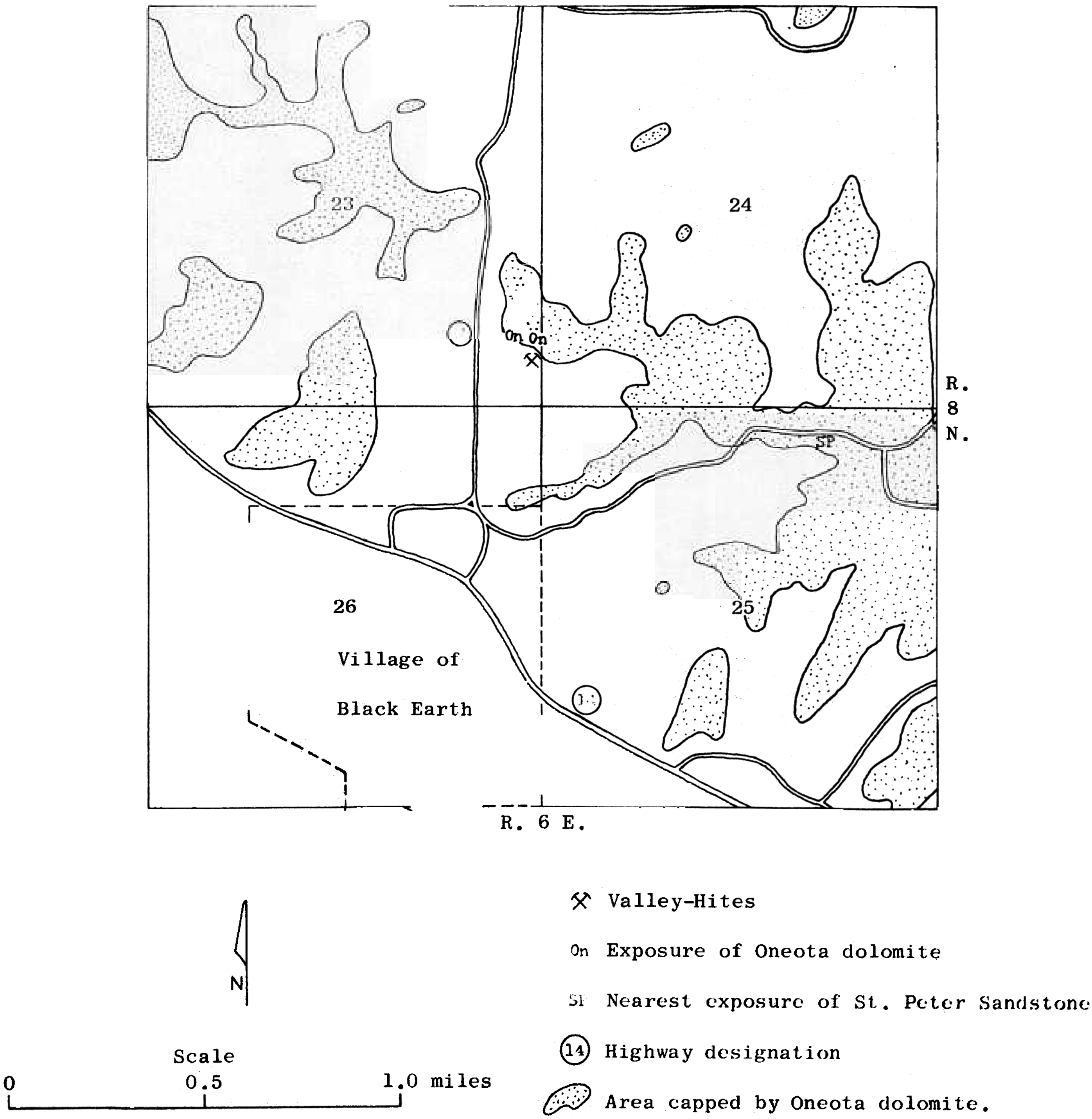


Author: M. E. Ostrom (modified from Ostrom, 1970)

Description: The Valley-Hites Quarry section shows an unconformable relationship of the St. Lawrence and Jordan formations. From the evidence at this exposure it is apparent that 12 to 14 feet of the Lodi Siltstone Member of the St. Lawrence Formation was removed by erosion prior to deposition of the Jordan Sandstone. The contact is uneven and clasts of Lodi are incorporated in the lower 3 feet of the Jordan.

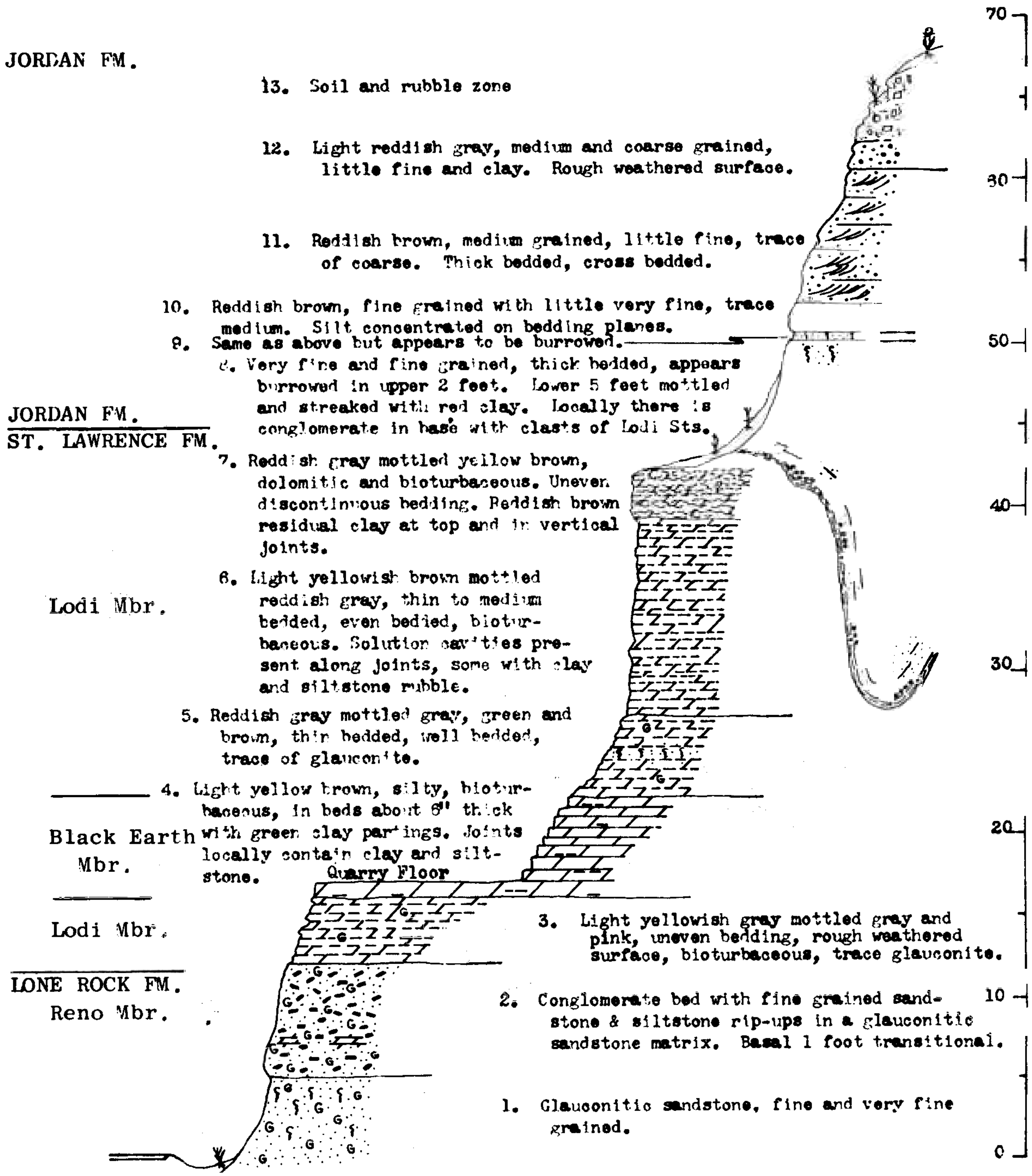
This relationship supports the theory of post-St. Lawrence and pre-Jordan regression and erosion followed by transgression and deposition which led to formation of the Jordan Sandstone (Ostrom, 1964). The angular unconformable relationship is illustrated at the west end of the quarry by 6 feet of Lodi Saltstone above the Black Earth Dolomite and below the Jordan Sandstone whereas about 100 feet to the southeast near the center of the quarry face there is about 20 feet of Lodi.

The possibility that the sandstone here might be the St. Peter Formation was considered but was dismissed for a combination of reasons, foremost which is that rock fragments in the lower few feet of the sandstones are similar to



Map of Black Earth area showing location of Valley-Hites Quarry and distribution of ridges capped by Oneota dolomite.

SE$\frac{1}{4}$, SE$\frac{1}{4}$, sec.23,T.8N.,R.3W.
$\frac{1}{2}$ Mile North of Black Earth



rocks older than the Jordan Sandstone and bear no resemblance to younger rocks. Other confirming evidences are: 1) There is a distinct textural change in the sandstone from a burrowed fine and very fine grained sand in the base to a medium and coarse cross-bedded sand in the top which coincides with the difference between the Norwalk and Van Oser members of the Jordan, respectively; 2) there is no known St. Peter Sandstone within a one mile radius of the quarry and all of the local hills, which essentially surround the quarry except for a gap about ½ mile wide located ½ mile to the southwest and two small gaps to the northwest (refer to map), are capped by Oneota dolomite; 3) there is Oneota float in the soil zone at the top of the sandstone in the quarry; and 4) about 150 feet up-hill from the quarry there is Oneota dolomite in a small excavation which suggests that the Oneota dolomite occurs above the sandstone; 5) the erosion surface at the top of the St. Lawrence is inclined northward into the hill and thus beneath the Oneota dolomite cap; and similarly, 6) cross beds in the sandstone are inclined mainly north and northwest beneath the dolomite cap indicating transport of sand in that direction which is interpreted to indicate that the sandstone persists beneath the Oneota. Thus it is inferred the sandstone is indeed Jordan rather than St. Peter.

The lighologic section at other exposures in the area is similar to that of the Valley-Hites Quarry except they lack the obvious angular relationship between the St. Lawrnce and Jordan. At these exposures the contact of the two formations ranges from abrupt lithologic change (examples: bluff at the east side of the village of Mazomanie about 3.5 miles west of the Valley-Hites Quarry and a roadcut located about 615 miles east of the quarry and 1.9 miles east of the village of Cross Plains at the north side of U. S. Highway 14 in the SW¼, NE¼, Sec. 11, T.7N., R.7E.) to one of apparent transition (example: road cut at the west side of County Highway "F" about 0.4 miles north of the quarry entrance). Sharp lithologic change at this contact can also be seen in a roadcut on Highway 93 south of Arcadia and about 120 miles to the northwest of Black Earth at the Viroqua/Reedstown stop.

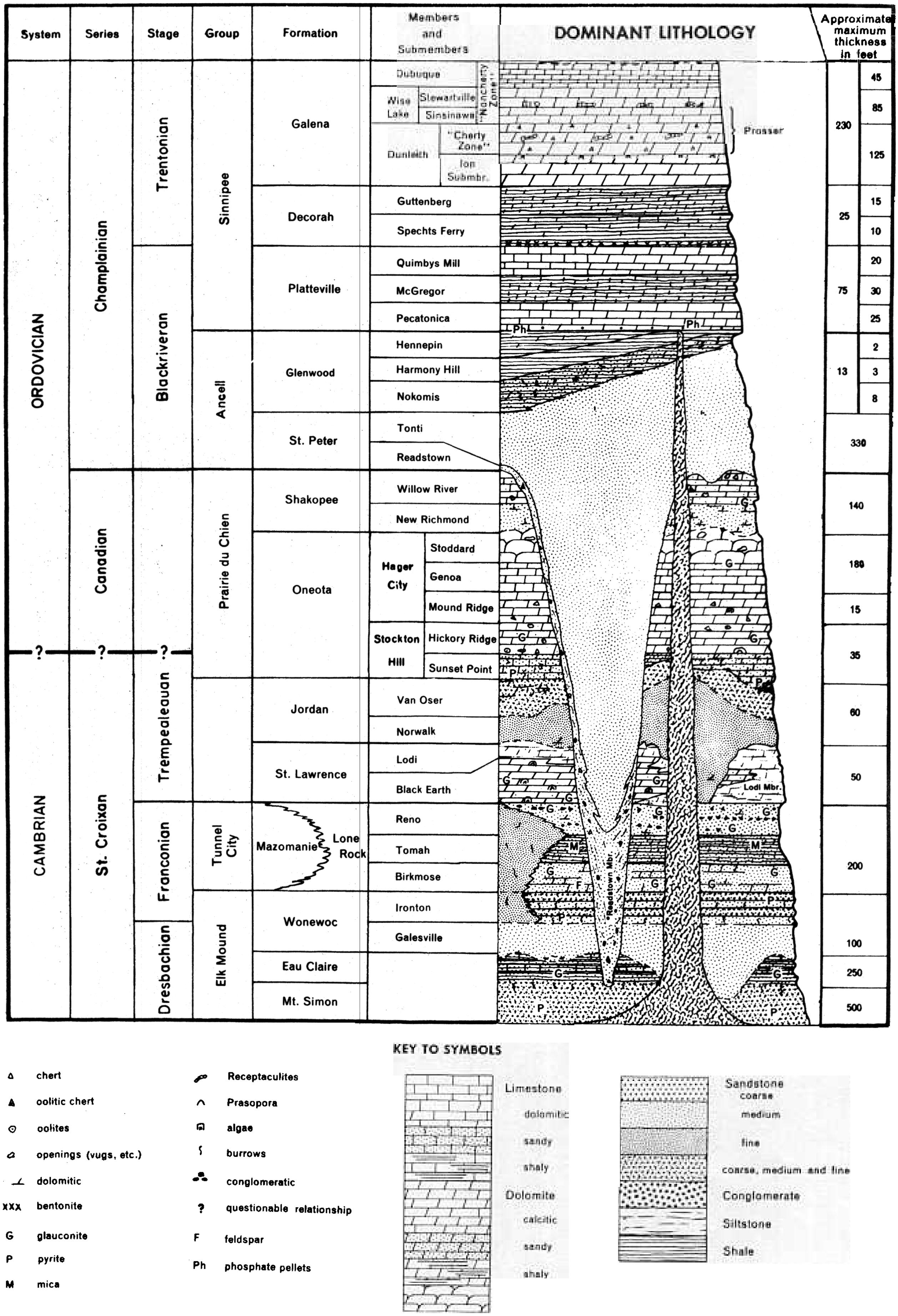
Additional evidence to support the presence of this unconformity on a regional scale is provided by the record of subsurface well cuttings. A cross section constructed from studies of cuttings from wells located on an approximately north-south line through Winnebago County in east-central Wisconsin shows this relationship clearly (Ostrom, 1964 and 1970, p. 29, Fig. 17). In addition, many wells in southeastern Wisconsin have no Jordan Sandstone and the underlying St. Lawrence Formation and the Tunnel City Group are markedly thinned which suggests their removal by erosion prior to deposition of younger rocks. Examples of well logs which show these relationships are attached (Dg-59, all units present; Dg-135, no Jordan but abundant red shale; Ww-539, no Jordan and thin St. Lawrence; Ra-359, no Jordan or St. Lawrence).

An interesting feature of the Valley-Hites Quarry is the evidence for solution and clay formation along joints and fractures in the St. Lawrence Formation. It appears the red clay in the base of the Jordan Sandstone was derived from the St. Lawrence which is interpreted to signify pre-Jordan development of the solution features and of the clay. Driller's reports of caves and the presence of thick sections of red shale, siltstone, and sandstone in the St. Lawrence Formation in southeastern Wisconsin tend to support this theory. The red color of the Jordan Sandstone is noted at many but not all of its exposures in the Black Earth area.

Significance: This exposure shows the relationship the St. Lawrence Formation to the Jordan Formation and provides evidence of the historical significance of this relationship.

What is the relationship of the St. Lawrence Formation to the Jordan Formation? What is the evidence? What happened prior to deposition of the Jordan? How was the Jordan deposited?

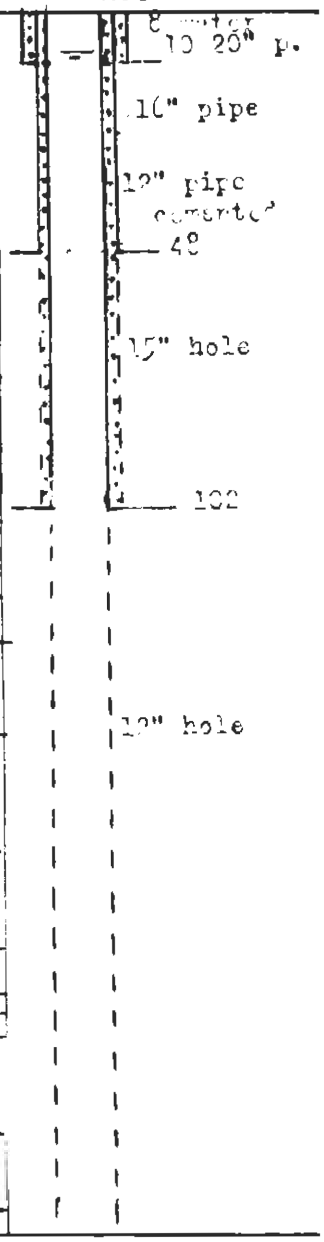
References: Ostrom, 1964 and 1970.


System
Series
Stage
Group
Formation
Members and Submembers
DOMINANT LITHOLOGY
Approximate maximum thickness in feet
ORDOVICIAN
CAMBRIAN
Champlainian
Canadian
St. Croixan
Trentonian
Blackriveran
Trempealeauan
Franconian
Dresbachian
Sinnipee
Ancell
Prairie du Chien
Tunnel City
Elk Mound
Galena
Decorah
Platteville
Glenwood
St. Peter
Shakopee
Oneota
Jordan
St. Lawrence
Mazomanie
Lone Rock
Wonewoc
Eau Claire
Mt. Simon
Dubuque
Wise Lake
Stewartville
Sinsinawa
"Noncherty Zone"
Dunleith
"Cherty Zone"
Ion Submbr.
Prosser
Guttenberg
Spechts Ferry
Quimbys Mill
McGregor
Pecatonica
Hennepin
Harmony Hill
Nokomis
Tonti
Readstown
Willow River
New Richmond
Hager City
Stoddard
Genoa
Mound Ridge
Stockton Hill
Hickory Ridge
Sunset Point
Van Oser
Norwalk
Lodi
Black Earth
Reno
Tomah
Birkmose
Ironton
Galesville
Readstown Mbr.
Lodi Mbr.
230
45
85
125
25
15
10
75
20
30
25
13
2
3
8
330
140
180
15
35
60
50
200
100
250
500
KEY TO SYMBOLS
chert
oolitic chert
oolites
openings (vugs, etc.)
dolomitic
bentonite
glauconite
pyrite
mica
Receptaculites
Prasopora
algae
burrows
conglomeratic
questionable relationship
feldspar
phosphate pellets
Limestone
dolomitic
sandy
shaly
Dolomite
calcitic
sandy
shaly
Sandstone
coarse
medium
fine
coarse, medium and fine
Conglomerate
Siltstone
Shale

COLUMBUS MILK PRODUCERS CO-OP WELL NO. 3, ASTICO, DODGE CO., WIS.
Sec. 15, T. 10 N., R. 13 E.
Layne-Galloway Well Corporation, Contractors, 1956
Samples examined by F. T. Thwaites, Nos. 189099-189148

Alt 820'

Formation	Thickness	Depth	Ft.	Description
DR	15	0-5	5	Till, brown-gray, weathered
		5-10	5	Till, sandy, brown-gray, dolomitic
		10-15	5	Till, light gray, dolomitic
PRAIRIE DU C		15-50	35	Dolomite, light gray; no sample 30-35
		50-55	5	Sandstone, fine to coarse, pink-gray
		55-60	5	Sandstone, fine to coarse, light gray, dol.
		60-65	5	Dolomite, sandy, very light gray
TREMPEALEAU		65-75	10	Sandstone, coarse to fine, pink, lt. grey
		75-90	15	Sandstone, very fine, light gray, very dolomitic
		90-95	5	Sandstone, medium to coarse, lt. gy, very dol.
		95-120	25	Sandstone, very fine, light gray, dolomitic
		120-130	10	Siltstone, light gray, dolomitic
	85	130-150	20	Siltstone, light pink, dolomitic
FRANCONIA		150-175	25	Siltstone, sandy, pink, glauconitic
		175-195	20	Sandstone, very fine, pink-grey, dolomitic
		195-205	10	Sandstone, fine to medium, light gre y, dol.
		205-210	5	Sandstone, very fine, light gray, very dol.
		210-215	5	Sandstone, medium to coarse, light gray, dol.
		215-235	20	Sandstone, medium to coarse, very light gray
		235-250	15	Sandstone, fine to medium, very light gray
	105	250-255	5	Sandstone, medium to coarse, very light gray



Formations: Drift; Prairie du Chien (Lower Magnesian); Trempealeau; Franconia
Sand in water probably from below 215
Tested at 300 g.p.m. specific capacity = 16.7 g.p.m./ft.

Well name City of Whitewater, Wis. Well #7
Sample Nos. 259741 to 259920

Formation	Depth	Thick.	Lith.	Description
ST PETER	180-195	15		Ss,yl gry,M&C,rnd,P srtg,tr fn; slt tr pyr-cem & lim-cem
	195-200	5		Ss,pl yl gry,M&fn,rnd,P srtg,VP lim-pyr&dol-cem,ltl Vfn,trC;tr cvd dol
	200-210	10		Ss, pl gry yl,M & fn, rnd,P srtg,VP lim-pyr&dol-cem,ltl Vfn,trC;
	210-220	10		Ss,yl gry,M&fn,rnd P srtg,VP lim-,pyr&dol-cem,trC;tr lim-cem&cvd dol
	220-225	5		Ss,Vpl yl or,M&C,rnd,P srtg,VP lim-cem,tr fn; tr Fe-cem
	225-235	10		Ss,Vpl yl or,M&C,rnd,P srtg,VP lim-cem,tr fn & Vfn; tr Fe-cem
	235-250	15		Ss,lt yl gry,M&fn,rnd,P srtg,VP lim-cem,tr C & Vfn; tr Fe-cem
	250-260	10		Ss,lt yl gry,M&C,rnd, P srtg, VP lim-cem,tr fn; tr lim-cem
	260-265	5		Ss,lt yl gry,M&fn,rnd,P srtg, VP lim-cem,tr C; tr lim-cem
	265-270	5		Ss, yl gry, M & C, rnd, P srtg, P lim-cem,tr fn; ltl lim-cem
	270-275	5		Ss, yl gry, M & C, rnd, P srtg, P lim-cem,ltl W-cem Ss;mch loose dol
	275-280	5		Ss,yl gry,M&C,rnd,P srtg,P lim-cem,ltl W-cem Ss;mch loose dol,tr pyr
	280-290	10		Dol,yl gry mot wh,Vfn,slgt por;tr qtz xls on dol,wh glaucic Ss,qtz snd
	290-295	5	G	Dol,lt ol gry mot wh,Vfn,tr por;tr glauc,qtz xls,Fe stn, & cht
	295-300	5		Dol, lt ol gry mot wh,Vfn,slgt por; tr glauc,qtz xls, Fe stn & cht
	300-305	5	G	Dol, ol gry, fn, dns; tr M; ltl glauc, tr Fe stn
	305-310	5	G	Ss, gn gry,fn,Sang,F srtg,P dol-cem,ltl M;ltl glauc, tr Fe stn,cht
	310-315	5	G	Ss,gn gry,fn,Sang,F srtg,P dol-cem,ltl M;ltl glauc,tr Fe stn,cht
	315-325	10	G	Dol, gn gry,fn,mch fn snd; ltl glauc, tr Fe stn & Fe-cem
	325-330	5	G	Ss,gn gry,fn,Sang,F srtg,P dol-cem,mchVfn,tr M;ltl glauc,dol,tr Fe stn
	330-335	5	G	Dol,gn gry,fn,Sang,F srtg,P dol-cem,mch fn snd;ltl glauc, trM snd
	335-340	5	G	Ss,gn gry,fn,Sang,F srtg,P dol-cem,trM;mch dol,ltl glauc,trlim-cem
	340-350	10	G	Ss,yl gry&gry or pnk,M&fn,Srnd,P srtg,P dol-cem,trVfn;mch dolic cem
	350-355	5		Ss,yl gry,M&fn,Srnd,P srtg,P dol-cem,trVfn&VC;mch dolic cem,trFe stn
	355-360	5	G	Ss,yl gry,fn,Sang,F srtg,P dol-cem,trM,trVfn;mch dol-cem,tr lim-cem
	360-370	10	G	Ss,lt ol gry,fn,Sang,G srtg,P dol-cem,trVfn;mch dol cem,tr lim-cem
	370-375	5	G	Ss,lt ol gry,fn,Sang,F srtg,P dol-cem,trM;mch dol cem,tr lim-cem,
VILLE	375-385	10		Ss,Vpl or,M&fn,rnd,P srtg,P dol-cem,ltlC;ltl dol cem, tr Fe stn
	385-405			Ss,Vpl or,M&fn,rnd,P srtg,P dol-cem, ltl C; ltl dol cem, tr Fe stn, tr pl yl or dol
	405-415			Ss,Vpl gry or&pl yl or,M&fn,rnd,P srtg,P dol-cem, ltl C;ltl dol cem, tr Fe stn,
	415-430	15		Ss,Vpl or,M&fn,rnd,P srtg,tr C; tr pl or dol, lim-cem & Fe stn
	430-435	5		Ss,Vpl or,fn,Srnd,P srtg,ltlM&C;tr pl or dol,lim-cem & Fe stn
	435-440	5		Ss,Vpl gry or&pl yl or,fn&M,Srnd,trVpl or dol, lim-cem & Fe stn
	440-445	5		Ss,Vpl gry or&pl yl or,fn,Srnd,P srtg,trVpl or dol,lim-cem&Fe stn
	445-450	5		Ss,Vpl gry or&pl yl or,M&fn,rnd&Srnd,trVfn;trVpl or dol,lim-cem&Fe
	450-455	5		Ss,Vpl gry or&pl yl or,fn,rnd&Srnd,ltlM;trVpl or dol,lim-cem&Fe stn
	455-460	5		Ss,Vpl gry or&pl yl,or,M&fn,rnd&Srnd,P srtg,trVpl or dol,lim-cem
	460-465	5		Ss, pl yl,fn,rnd&Srnd,P srtg,ltl M;Vpl or dol, lim-cem & Fe stn
	465-480	15		Ss,Vpl gry or&pl yl or,fn,ltlM;Vpl or dol,lim-cem&Fe stn,dol-cem ltl Vpl or
50'	480-485	5		Ss,Vpl gry or&pl yl or,fn,VP dol-cem,ltlM;ltl pl or dol-cem,tr st
EAU CLAIRE	485-490	5	G	Ss,Vpl rd,fn&Vfn,trM;mch rd stn,ltl pl rd&pl yl or glaucic dol,glauc
	490-495	5		Sh,pl rd,Pdol-cem,mch gn&dk rd sh;mch pl rd glauc;dol qtz st,tr fn snd
	495-500	5	G	Ss,pl rd,fn&Vfn,Sang,P dol-cem,mch pl rd dol,ltl gn sh,tr glauc
	500-505	5		Sh,pl rd,P dol-cem,mch Vfn&fn snd;ltl st&pl rd dol, tr gn sh
	505-515	10	G	Sh,pl rd,P dol-cem,mchVfn&fn snd;ltl st&pl rd dol, tr gn sh,ltl glauc oily appearance
	515-520	5	G	Dol,rd,fn&Vfn,dns;mch fn&Vfn snd,& pl rd sh,ltl glauc & st
	520-525	5	G	Dol,rd mot pl gn&pl yl gry,fn&Vfn,dns;ltl fn&Vfn snd&gry rd sh,
	525-530	5	G	Dol,pnk yl gn gry mot,Vfn,dns; tr glauc
	530-535	5	G	Dol, lt ol gry,Vfn,dns; mot gry dol,tr pyr,glauc,pl gn sh&Fe stn
	535-540	5	G	Dol,dk gn gry&gry gn,Vfn,ltl glauc&pyr,tr Vglaucic sh & gry sh
	540-545	5	G	Dol,dk gn gry,Vfn,trFe stn,pyr,gry & gn sh & glauc
	545-550	5		Sh,,lt ol gry,dolic,ltl pnk glaucic dol
	550-560	10		Ss,pnk yl gn gry mot,fn,rnd,P srtg,slgt dolic,gry glaucic dol,ltl mch m;mch pnk gn & sh

Log No. 95-Ra-359
Sample Nos. All Retained

Well name: Ives Grove Golf Links

Formation	Depths	Graphic Section	Rock Type	Color	Grain Size Mode	Grain Size Range	Miscellaneous Characteristics
SINNIPEE GROUP	820-825		Dolomite	Gray brown	Fn	Fn/M	Mottled. Little red speckling, pyrite.
	825-830		"	"	"	"	Mottled. Trace pyrite, red speckling.
	830-835		"	"	"	"	Same
	835-840		"	"	"	"	"
	840-845		"	"	"	"	"
	845-850		"	"	"	"	"
	850-855		"	"	M	"	Much Fn-C quartz sand. Trace pyrite.
	855-860		"	"	"	"	Much floating quartz and quartz sand. Trace pyrite.
	860-865		"	"	"	"	Same
	865-870		"	"	"	"	"
	870-875		No sample.				Driller reports Galena-Platteville.
	875-880		Dolomite	Green gray	Fn	--	Much sand. Little shale. Trace pyrite, ripclasts.
	880-885		"	"	"	--	Same
	885-890		"	"	"	--	"
	890-895		"	"	"	--	"
335'	895-900		"	"	"	--	Little sand, shale. Trace pyrite.
ST. P.	900-905		Sandstone	Pink gray	C	Fn/C	Little sandy dolomite, dolomite-silica cement.
	905-910		"	"	M	"	Same
	910-915		"	"	M & C	Fn/VC	Same plus trace pyrite.
	915-920		"	"	C	"	Same.
	920-925		"	"	"	"	Same plus trace white chert.
30'	925-930		"	"	"	"	Same
PRAIRIE DU CHIEN	930-935		Dolomite	"	M	--	Much oolitic chert, quartz sand. Trace green shale.
	935-940		"	"	"	--	Same
	940-945		"	"	"	Fn/M	"
	945-950		"	"	"	"	Same plus trace pyrite.
	950-955		"	"	"	"	Same plus trace glauconite.
	955-960		"	"	"	"	Trace quartz sand, chert, green shale.
	960-965		"	"	"	"	Same plus trace glauconite.
	965-970		"	"	"	"	Same but no glauconite.
	970-975		"	"	"	"	Trace quartz sand, green shale.
	975-980		"	"	"	"	Same
	980-985		"	"	Fn	"	Trace green shale.
	985-990		"	"	"	"	Same
	990-995		"	"	"	"	"
	995-1000		"	"	"	"	Same plus trace drusy quartz.
	1000-1005		"	"	"	"	Little drusy quartz. Trace green shale, pyrite.
	1005-1010		"	"	"	"	Same
	1010-1015		"	"	"	"	"
	1015-1020		"	"	"	"	Little green shale. Trace pyrite, quartz, sand.
	1020-1025		"	"	"	"	Same plus trace glauconite.
	1025-1030		"	"	"	"	Same but trace green shale.
	1030-1035		"	"	"	"	Much green glauconitic shale. Tr pyr, glauc, drsy qtz, [illegible]
	1035-1040		"	Pnk gry&gn	"	"	Little green shale. Trace drusy quartz, pyrite, sand.
115'	1040-1045		"	Pnk gray	"	"	Little glauconite. Trace pyrite, floating quartz.
TUNNEL CITY	1045-1050		"	Pnk gry&gn	"	"	Much floating qtz, green shale. Ltl glauc. Tr pyrite.
	1050-1055		Sandstone	"	M	Vfn/C	Much dol cement. Ltl shale, red speckling. Tr glauc, pyr.
	1055-1060		"	Red brown	"	"	Much dolomite cement. Trace shale, glauconite.
	1060-1065		"	"	"	"	Much dolomite cement, glauconitic shale.
	1065-1070		"	"	Fn	Vfn/M	Much dolomite cement, gn mottled rd sh. Tr glauconite.
	1070-1075		"	"	M	Vfn/C	Same but little glauconite.
35'	1075-1080		"	"	"	"	Same
WONEWOC SANDSTONE	1080-1085		"	Pnk gry&gn	M & C	Fn/VC	Little green shale. Tr lim, dol cement, glauconite.
	1085-1090		"	"	"	"	Same
	1090-1095		"	"	M	"	"
	1095-1100		"	Pnk gray	C	Fn/C	Trace green shale, dolomite-pyrite cement.
	1100-1105		"	"	M	"	Little limonite. Trace green shale, dol, pyrite cement.
	1105-1110		"	"	"	Vfn/M	Little limonite. Tr dolomite--pyrite cement, white chert.
	1110-1115		"	"	Fn&M	"	Same
	1115-1120		"	"	"	"	"
	1120-1125		"	"	Fn	"	Trace limonite, dolomite-pyrite cement, white chert.
	1125-1130		"	"	"	"	"
	1130-1135		"	"	"	"	"
	1135-1140		"	"	"	"	"
65'	1140-1145		"	"	"	"	"
E.C.	1145-1150		"	Gry or pnk	Fn	Vfn/fn	Little red shale. Trace green shale, limonite.

UNIVERSITY OF WISCONSIN GEOLOGICAL & NATURAL HISTORY SURVEY
1815 University Avenue, Madison, Wisconsin 53706

Log No. Dg-135

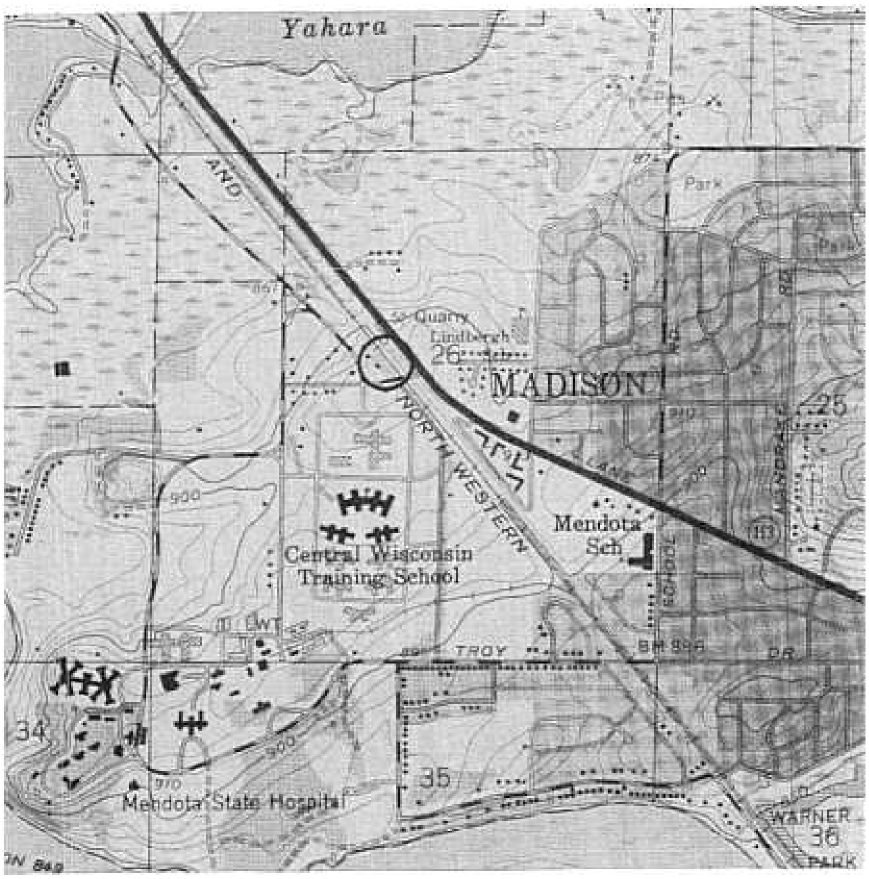
Well name City of Juneau, Wis. Well #3*
Sample Nos. 267079 to 267205

P		190-200	10	Dol, lt ol gry mot gry gry-gn&wh, dns, tr pnk&gry rd, ltl M, tr descem pyr
V		200-205	5	Dol, lt ol gry, dns, ltl fn; tr descem pyr bn shly dol&pyr veins
I		205-210	5	Dol, lt ol gry mot pl yl bn yl gry&gry, dns, ltl Vfn&M; tr xln&descem pyr
		210-215	5	Dol, Vlt ol gry mot gry&lt bn, dns, Vsndy; mch M/VC rnd/Sang snd&tr pyr ce
L	65	215-220	5	Dol, lt ol gry mot gry&pl bn, dns, trM/VC; tr xln&descem pyr&rd bn specks
S		220-225	5	Ss, Vlt ol gry, F srtg, VP pyr-&dol-cem, ltl fn; tr pyr&dol-cem tr dol
T		225-230	5	Ss, Vlt ol gry, P srtg, tr pyrp&dol cem, mch fn, ltl Ctr VC&Vfn; tr dol
		230-235	5	Ss, Vpl or, P srtg, tr dol-, lim-&pyr cem, mch fn&C, tr Vfn; tr dol&gn sh
		235-240	5	Ss, Vpl or, P srtg, tr F pyr-cem, mch fn&C, tr VC; tr gn sh
P		240-245	5	Ss, Vpl or, F srtg, mch C, ltl fn&VC; tr gn sh, pyr&Fe stn
E		245-250	5	Ss, Vpl or, F srtg, mch M, ltl VC; tr gn sh, pyr, Fe stn&dol-cem
T		250-255	5	Ss, Vpl or, P srtg, mch fn&C, tr Vfn&VC; ltl pl gn&pl yl bn sh
		255-260	5	Sh, pl rd mot Vpl gn, F srtg, mica; tr Vfn/C snd&wh cht
E		260-265	5	Sh, pl rd, F srtg, ltl pl gn; tr Vfn/C snd, mch cht
R		265-270	5	Sh, pl rd, F srtg, ltl pl gn; tr Vfn/C snd, ltl cht
	55	270-275	5	Sh, pl gn, G srtg, tr pl rd; ltl Vfn snd&cht, tr st, yl gry dol&glauc&qtz
		275-280	5	Dol, yl gry, slgt dns; mch fn/C snd, ltl or&wh cht; tr glauc, gn&rd&gry sh
p		280-285	5	Dol, lt ol gry, dns, ltl sndy; ltl Vfn/C snd, cht, gn rd&bn sh, tr pyr
		285-290	5	Dol, Vpl yl bn, dns, ltl sndy; tr Vfn/M snd, cht&pyr, ltl gn sh
d		290-295	5	Dol, Vpl yl bn mot or pnk&wh, dns, ltl M; tr rd&gn sh, cht, glauc&Vfn snd
		295-300	5	Dol, Vpl yl bn, fn, dns, tr M; tr gn&rd sh
u		300-305	5	Dol, Vpl yl bn mot wh, dns, tr Vfn&C, mch sndy(fn); ltl fn/C snd, tr pyr
		305-310	5	Dol, Vpl yl bn mot wh, dns, tr C, tr sndy; tr Vfn/VC snd&pyr, ltl pl bn ools
C		310-315	5	Dol, Vpl or mot pl yl bn, dns, ltl Vfn&C, ltl sndy; tr pyr, ools, wh cht,
		315-320	5	Dol, Vpl or mot pl yl bn, dns, tr Vfn&C, ltl sndy; tr pyr, oolic cht,
	55	320-330	10	Dol, pl yl bn mor wh, fn, dns, tr M&Vfn, mch sndy; mch ools, oolic cht, tr qtz&qtz grans mch fn/Csnd, ltl VC tr gn sh&pyr
		330-335	5	Sh, pl rd bn, F srtg, slgt dolic, ltl hd mica, ltl pl gn; ltl st, tr Vfn/VC
S		335-340	5	Sh, pl rd bn, P srtg, slgt dolic tr pl gn&dk rd, mica; ltl fn snd&st, tr M/VC
T.		340-345	5	Sh, pl rd bn, P srtg, ltl gn&dk rd, mica; ltl pl gn dol, tr Vfn/C snd,
L		345-355	10	Dol, pl rd mot pl gn&pl or, fn&Vfn, dns, sty, sndy(Vfn); ltl pl gn&gry rd,
A		355-360	5	Ss, gry or pnk, P srtg, F dol-cem, mch C&fn, ltl VC&Vfn; ltl Vfn qtz,
		360-370	10	Ss, gry ;or pnk, M, Sang, P srtg, F dol-cem, mch C&fn, ltl VC&Vfn; tr Vfn qtz gvl, mch sndy dol, ltl glaucic dol, mch gn sh, tr rd
W	45	370-375	5	Ss, gry or pnk, P srtg, mch F pl or dol-cem, mch C&fn, ltl VC, tr Vfn;
T.		375-380	5	Ss, gry or pnk, M&fn, Srnd, F srtg, F dol-cem, ltlC, tr Vfn; tr sndy dol
C I T Y		380-405	25	Ss, gry or pnk, M&fn, Sang, F srtg, ltl P dol-cem, ltl Vfn, tr C; tr gn sh
	45	405-420	15	Ss, gry or pnk, F srtg, ltl P dol-cem, mch M, ltl Vfn, tr C; ltl-mch st
W	I r	420-435	15	Ss, gry or pnk, P srtg, VP dol-cem, mch C, ltl fn&VC; few grans, ltl glaucic Vpl rd dol, tr st
	G	435-440	5	Ss, wh, P srtg, mch C&fn, tr VC; tr lim, dol, gn sh&st
O	a	440-445	5	Ss, wh, fn&Vfn, Sang, F srtg, ltl M&C; tr lim
		445-450	5	Ss, wh, M&fn, Sang, F srtg, ltl Vfn&C; tr lim
N	l	450-455	5	Ss, wh, P srtg, mch Vfn&C, tr VC; tr grans, lim&st
	e	455-460	5	Ss, wh, M, Srnd, P srtg, tr or pnk&wh dol-cem, ltl fn, tr VC; tr st
E	s	460-465	5	Ss, wh, M&C, rdn, P srtg, tr pl pnk&wh dol-cem, tr fn; tr gn&rd sh&st
W	v	465-475	10	Ss, gry or pnk, M&C, Srnd, F srtg, tr pl or pnk&pl rd dol-cem, tr fn;
O	i	475-485	10	Ss, gry or pnk, M&C, Srnd, P srtg, tr pl or pnk&pl rd dol-cem, tr fn&Vfn; tr st
	l	485-490	5	Ss, Vpl or, M&C, Srnd, P srtg, mch fn&C, tr VC; tr lim&st
C	l	490-495	5	Ss, Vpl or, M&C, Srnd, P srtg, ltl fn, tr VC; tr st&or pnk dol
	e	495-500	5	Ss, Vpl or, M&C, Srnd, P srtg, tr dol-cem, tr fn, Vfn&VC; tr st, dol, &gn sh
		500-510	10	Ss, Vpl or, M&C, rnd, F srtg, tr fn; tr st, bn&gry sh, dol&ig snd
		510-515	5	Ss, gry or pnk, F srtg, tr P pnk dol-cem, tr fn&Vfn; tr st, tr dk gry sh
		515-520	5	Ss, gry or pnk, F srtg, ltl pnk yl or F dol-cem, tr fn&Vfn; tr st [illegible]
		520-540	20	Ss, gry or pnk, M&C, rnd, F srtg, ltl pnk yl or F dol-cem, tr fn&Vfn; tr st, tr dk gry sh, tr ig snd
		540-545	5	Ss, gry or pnk, F srtg, tr pl rd VP dol-cem, mch fn, ltl C, tr Vfn; tr gn sh
		545-555	10	Ss, gry or pnk, M&C, rnd, F srtg, ltl pl rd&tr bn dol-cem, tr fn&VC; tr gn sh&ig snd
		555-560	5	Ss, or pnk, P srtg, ltl F pl rd dol-cem, tr fn, Vfn&VC; tr st&grans,

OUTCROP 4

Title: Madison-Mendota Station

Location: Chicago and Northwestern Railroad Cut at Mendota Station in the SE¼, SE¼, NW¼, Sec. 26, T.8N., R.9E., Dane County (Waunakee 7.5 minute topographic quadrangle, 1974).

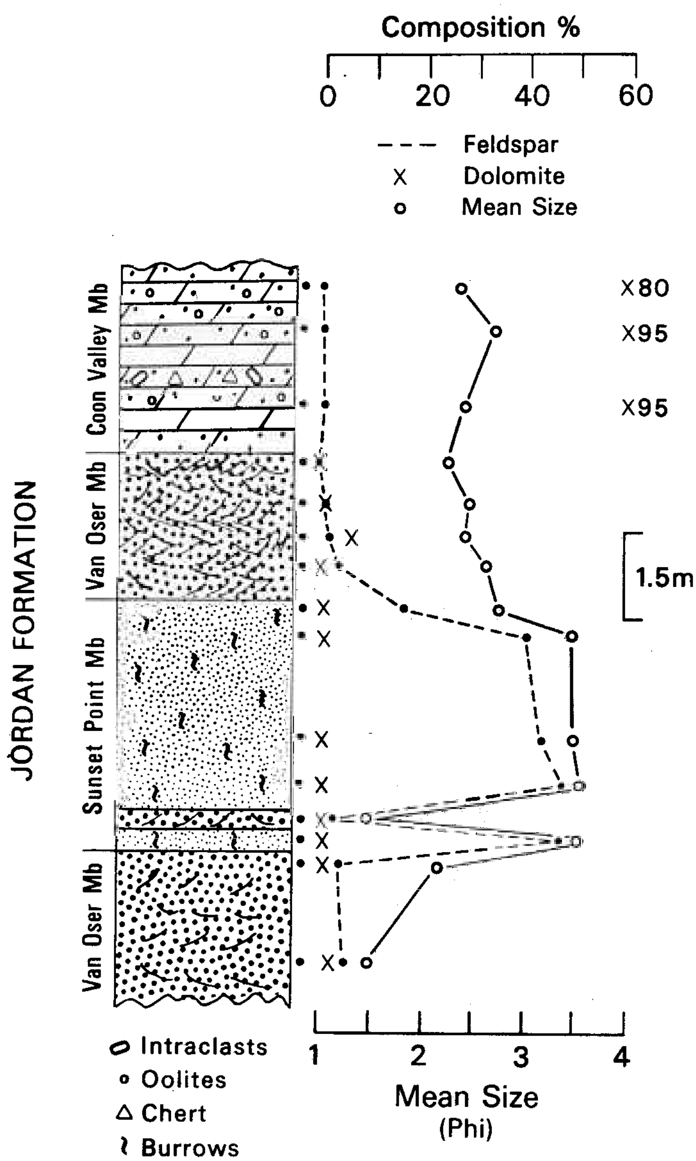


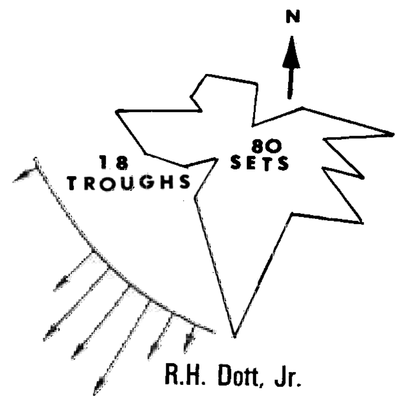
Author: I. E. Odom

Description: The Mendota Station section is highly important relative to the stratigraphic position of the Sunset Point Member, and to the physical nature of sedimentation during the time that the Jordan Formation was deposited in central Wisconsin. This section has figured prominantly in past controversy regarding the stratigraphy and sedimentology of the St. Lawrence and Jordan Formations since E. O. Ulrich first described it in 1911, yet the lithic succession prior to 1976 was poorly understood. Past literature records this section as containing only the Van Oser Sandstone (at the base), the Sunset Point Sandstone and the Oneota Dolomite.

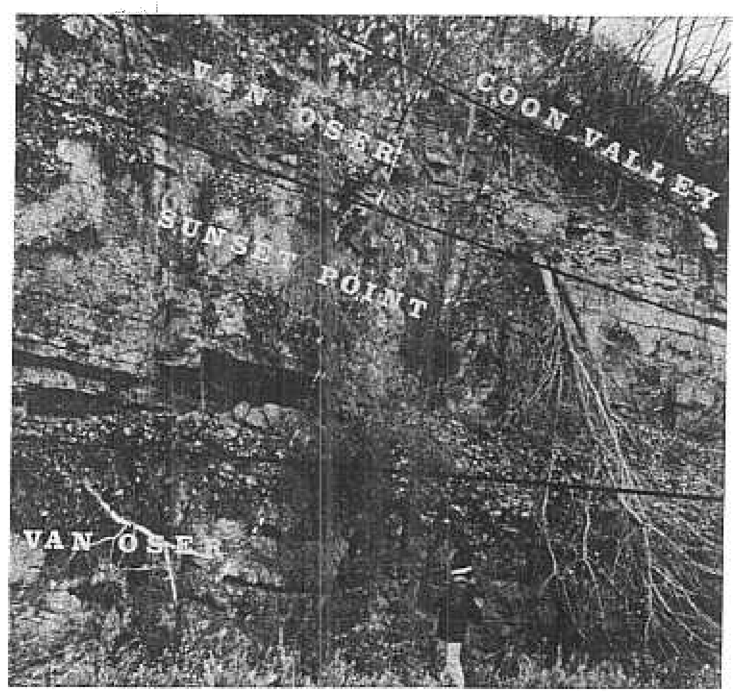
Recent studies of the lithology and sedimentary structures of this section, especially the texture and mineralogy, show that the very fine-grained, feldspathic

MENDOTA STATION SECTION





Orientation of cross sets and plunge direction of trough axes in upper unit of the Van Oser Sandstone.



Stratigraphic relations in the Mendota Station Railroad cut.

Sunset Point Sandstone is both overlain and underlain by fine- to medium-grained, quartzose Van Oser Sandstone. The upper unit of the Van Oser Sandstone is in turn overlain by sandy dolostones and dolomitic sandstones (Coon Valley Member). The Sunset Point Sandstone is somewhat thinner, more massive and less dolomitic than at its type section. Between the lower Van Oser Sandstone and the Sunset Point Sandstone is a mixed zone of very fine-grained, feldspathic sandstone and medium-grained, quartzose sandstone. The contact of this zone with the underlying Van Oser Member rises in the section from the south toward the north end of the cut, but this is not considered to indicate an unconformable relationship. The Sunset Point Sandstone is gradational into the upper unit of the Van Oser Sandstone.

While the lower unit of the Van Oser Sandstone is only moderately cross stratified, the upper unit is highly cross stratified, especially on the east side of the cut. Dott shows a southwest current direction for the upper Van Oser unit based on the plunge of trough axes, while cross sets show more divergent current directions.

The Coon Valley Member crops out sporatically in the brushy area at the top of the outcrop and directly overlies the Van Oser. The sandy, "oolitic" dolostones and dolomitic sandstones contain reddish, conglomeratic, chert bands identical to those in the Coon Valley Member at the Sunset Point type section. The basal conglomeratic algal bed present at the base of the Coon Valley at the Sunset Point type section has not been observed in this outcrop.

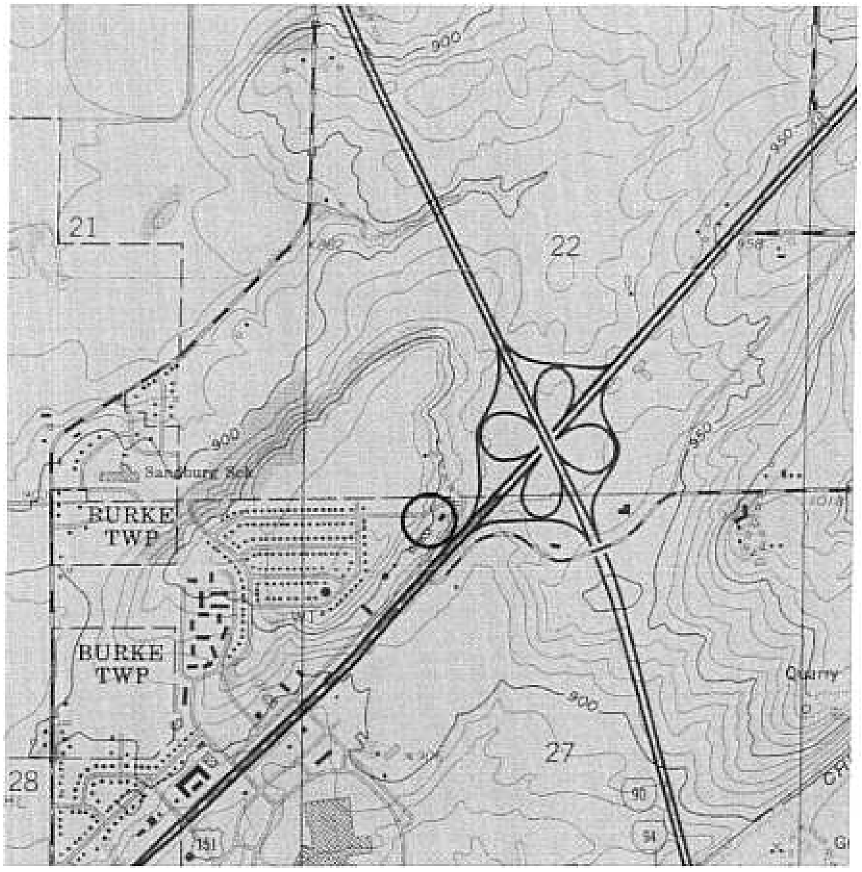
Interpretations: The stratigraphic relations in this exposure and the fact that the Sunset Point Sandstone is not traceable beyond a local area in and north of Madison are the primary evidence for the interpretation that the Sunset Point Sandstone is a local lithic facies of the Van Oser Sandstone. This interpretation is further supported by the regional occurrence and the physical sedimentology of the Van Oser Sandstone.

Based on the fact that the Sunset Point Sandstone is absent only a few miles east of this outcrop, it is concluded that this area was near the eastern side (south side in Cambrian time) of the lagoon in which the Sunset Point Sandstone was deposited (Fig. 22). The lower unit of the Van Oser Sandstone represents a littoral environment existing prior to the development of the Sunset Point lagoon. The upper unit of the Van Oser Sandstone records a shift of the East Madison Bar complex (Fig. 22) into the margin of the Sunset Point lagoon. At this location, the sandy, "oolitic" dolomites of the Coon Valley Member were deposited on the Van Oser Sandstone rather than on the Sunset Point Sandstone. This stratigraphic relation does not imply that deposition of the Coon Valley Member necessarily began earlier at the Sunset Point type section.

Outcrop 3

Title: Madison - Howard Johnson East

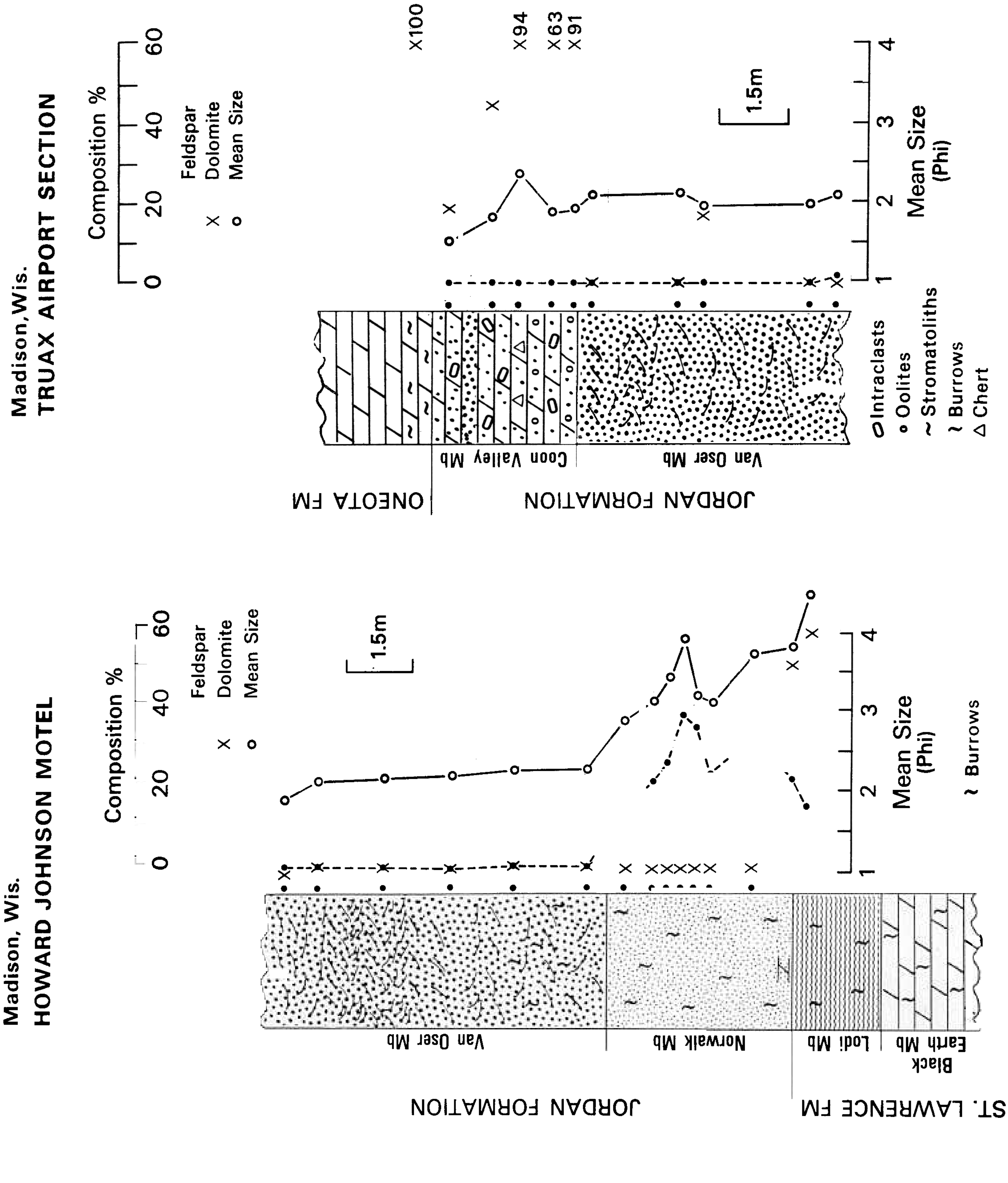
Location: Rear of Howard Johnson Motel near U.S. 151 and I-90 Interchange in the NE$\frac{1}{4}$, NW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 27, T. 8N., R.10E., Dane County. (DeForest 7.5 topographic quadrangle, 1974).



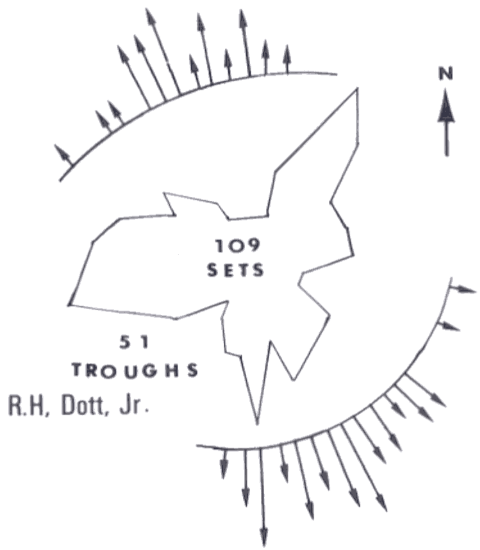
Author: E. Odom

Description: This section was measured in 1976 and is a composite of exposures at the rear of and in the driveway to the Howard Johnson Motel and at the rear of Barnaby's Restaurant. Unfortunately, the Lodi Siltstone and Norwalk Sandstone Members, once exposed behind Barnaby's, have been covered to prevent mass wasting and damage to property at the top of the cut. The upper few feet of the Norwalk Member, however, are still exposed behind the Road Star Motel a few hundred meters to the southwest. To further illustrate the bedrock succession in this area of Madison, a section is included of an exposure on Messerschmidt Road northeast of Truax Air Field (4 km - 2.5 miles to the northwest).

The bedrock exposed in the northeastern part of Madison includes the St. Lawrence, the Jordan, and the lower part of the Oneota Formations. The Norwalk,



Madison, Wis.
HOWARD JOHNSON MOTEL
Composition %
0
20
40
60
Feldspar
Dolomite
Mean Size
1.5m
Mean Size
(Phi)
1
2
3
4
Burrows
Van Oser Mb
Norwalk Mb
Lodi Mb
Black Earth Mb
JORDAN FORMATION
ST. LAWRENCE FM
Madison, Wis.
TRUAX AIRPORT SECTION
Composition %
0
20
40
60
Feldspar
Dolomite
Mean Size
X100
X94
X63
X91
1.5m
Mean Size
(Phi)
1
2
3
4
Intraclasts
Oolites
Stromatoliths
Burrows
Chert
Coon Valley Mb
Van Oser Mb
ONEOTA FM
JORDAN FORMATION



(Left) Current directional data based on the plunge of trough axes and dip of cross sets in the Van Oser Sandstone, Howard Johnson Motel.

(Right) Cross stratification in the Van Oser Sandstone, Howard Johnson Motel.

Van Oser and Coon Valley Members of the Jordan are represented, with the Van Oser being by far the thickest. These members and the adjacent formations are stratigraphically transitional. It is important to note that the Sunset Point Sandstone is again not present in this area.

An additional point of interest at this locality is the local highly cross-stratified nature of the Van Oser Member. Note that current directional data for this outcrop (shown on page 109 and in Fig. 28), both the plunge of trough axes and the dip of cross sets compiled by R. H. Dott, Jr., show two modes nearly 180^{o} apart. Directional data for the Truax Section, however, show a generally southwest transport (Fig. 28).

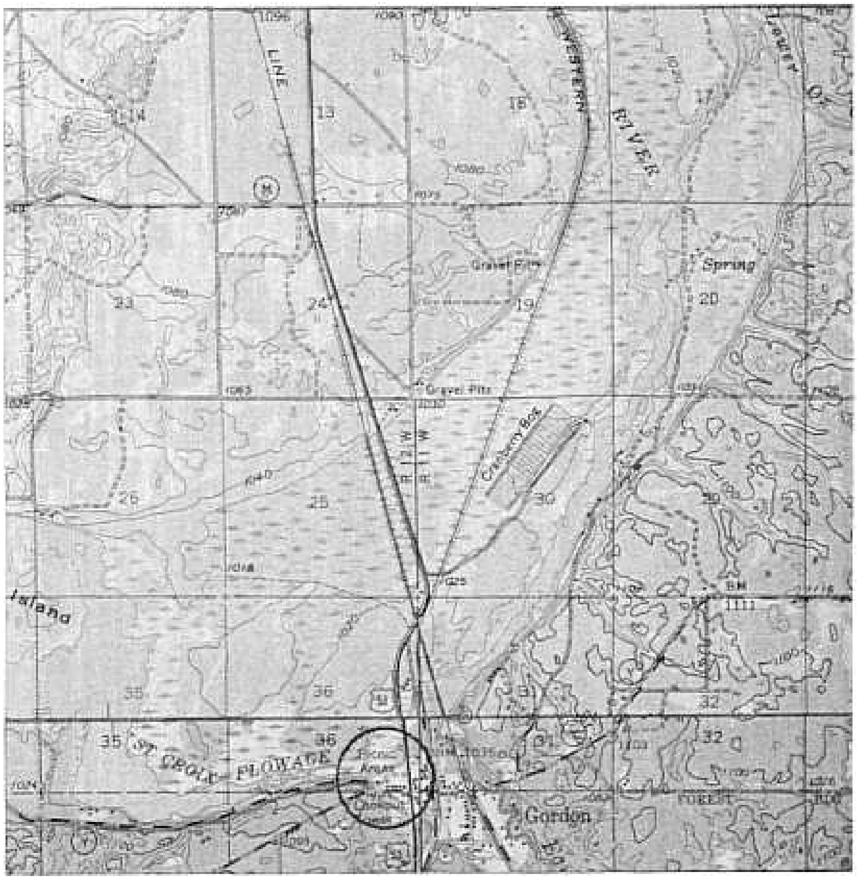
Interpretations - Based on the regional lithic nature and occurrence of the St. Lawrence Formation, it is considered to have been deposited in an inner neritic environment immediately shoreward of a carbonate platform. Local conglomeratic beds and algal mounds (note present here) suggests very shallow water. The algal structures and conglomerates have been previously interpreted to indicate intertidal or supratidal conditions (see Outcrop 7). The Black Earth Dolostone is transitional with the feldspathic Lodi Siltstone, which is in turn transitional into the very fine-grained, highly feldspathic Norwalk Sandstone of the Jordan Formation. The very fine grain size and bioturbated nature of the Norwalk Sandstone are interpreted to be indicative of a lagoonal environment (Odom and Ostrom, this guidebook). The textural and structural properties of the Van Oser Sandstone indicate a hydrologic regime characteristic of a littoral environment referred to herein as the East Madison Bar complex. The ebb and flow of tidal currents within this bar complex is a possible explanation for the bimodal nature of the current direction indicators in the Van Oser Sandstone of this area (Fig. 28). The lithic and structural characteristics and thickness of the Coon Valley Member in this area are similar to the Coon Valley at Outcrops 1 and 2.

Remarks on Geologic Structure of the Madison Area. Disrupted bedding toward the west end of the Howard Johnson Motel cut suggests that a small fault may be present. During my studies of the bedrock of the Madison area, I identified three significant faults, and I am suspect that many others exist. Structurally, the Howard Johnson exposure is situated on a horst bounded by northeast-southwest trending faults. The northwest bounding fault passes beneath Truax Air Field, whereas the southeast bounding fault passes through the village of Burke. These faults have vertical displacements of at least 20 to 25 meters (60-80 feet) The stratigraphic relations in the East Madison area were initially confusing but became crystal clear when the presence of these faults was recognized.

The third clearly recognizable fault is located near Cross Plains, and it is discussed in the description of Outcrop 5. Open file reports and recently acquired well data in the files of the Wisconsin Geological and Natural History Survey indicate that other faults, some perhaps with displacements greater than 30 meters, occur in the area.

Title: St. Croix River Overlook

Location: SE, Sec. 36, T. 44 N., R. 12 W., Minong and Solon Springs Quadrangles. Park in Wayside at edge of river valley just north of Gordon.



Author: David M. Mickelson

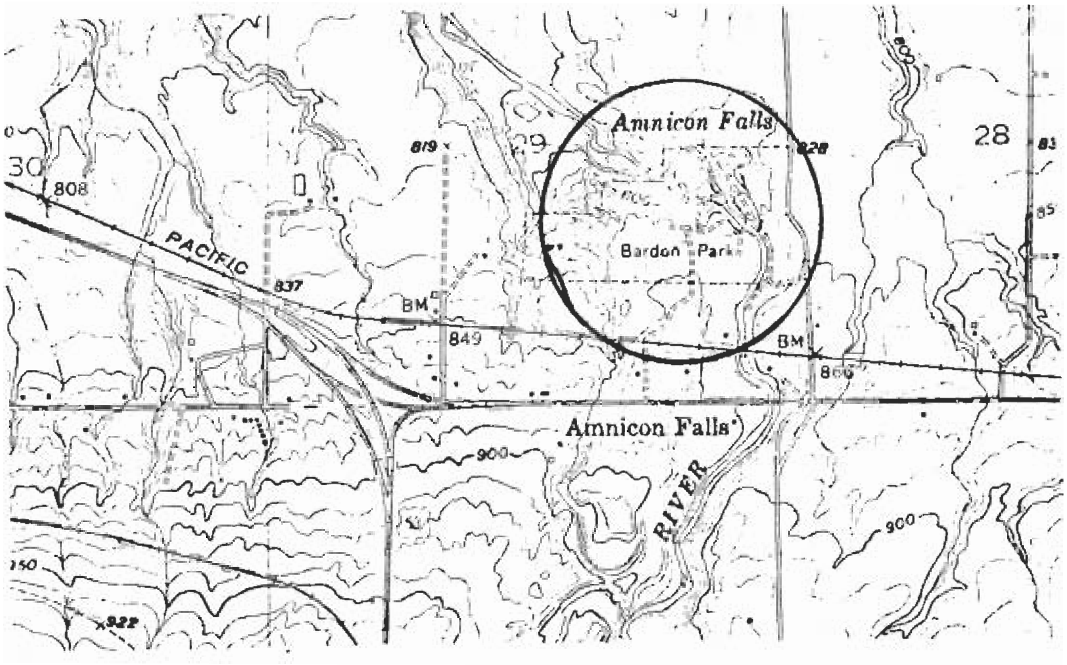
Description: The view to the north and east is of the obviously underfit St. Croix River. Note how wide the valley is in comparison to the size of the stream it contains. Now look directly across the river. Note one clear terrace level and another which is somewhat subdued in the distance.

Significance: The reason the river valley is so wide here is that much larger volumes of water flowed through the St. Croix in times past. The history of the St. Croix, especially in southern portion is very complex and it has carried water from the Mississippi drainage as well as Lake Superior numerous times during Late Wisconsin time (Black, 1974; Wright and Ruhe, 1965). In this area we see the results of drainage from the Lake Superior basin during ice retreat. The dates of this drainage are not clear but when glacier ice blocked the present eastern outlet and lower areas between here and there, water from the basin drained down the St. Croix.

References: Sardeson, 1936

Title: Douglas Fault, Keweenawan Basalts, Bayfield Sandstone

Location: Amnicon Falls State Park, NE¼, SE¼, Sec. 29, T.48N., R.12W.
(South Range 7½ Minute Quadrangle)



Author: Gene L. LaBerge

Description: Amnicon Falls is formed by the Amnicon River flowing off the south-dipping, resistant Keweenawan basalts onto the soft, flat-lying Bayfield Sandstones. The contact between the basalts and the sandstone is the Douglas Fault, readily visible on the east side of the river, immediately below the Falls. Fault breccia and gouge are present along the south-dipping Douglas thrust fault.

The Keweenawan basalts were erupted from about 1200-1000 million years ago, and intruded by gabbros (visible here in the river valley south of the rainroad bridge at the south edge of the park (Mengel, 1970)). The age of the Bayfield Sandstone is uncertain; some workers believe they were deposited in Keweenawan time, 800-1000 million years ago, while others believe they may be lower and/or Middle Cambrian in age (about 500 million years old).

The Douglas Fault is a major thrust fault along which the basalts have been thrust northward over the Bayfield Sandstones, with vertical movement in the neighborhood of 10,000 feet (Craddock, 1972). It has been traced for nearly 100 miles across Wisconsin and Minnesota. The age of the fault is not precisely known. It is clearly post-Bayfield Sandstone in age, but since we don't know the age of the Bayfield, the age of the faulting is unknown.

Significance: The major structural feature in the Lake Superior Region is the Lake Superior Syncline, with Keweenawan basalts overlain by sandstones. In the central part of the syncline a large block of volcanics has been uplifted. This block is bounded on the north by the Douglas Fault and on the south by the Lake Owens and Keweenaw Faults, and is referred to as the "central horst." The boundary faults are thrust faults, the Douglas Fault dipping southward and the Lake Owens and Keweenaw Faults dipping northward, indicating compressional movements.

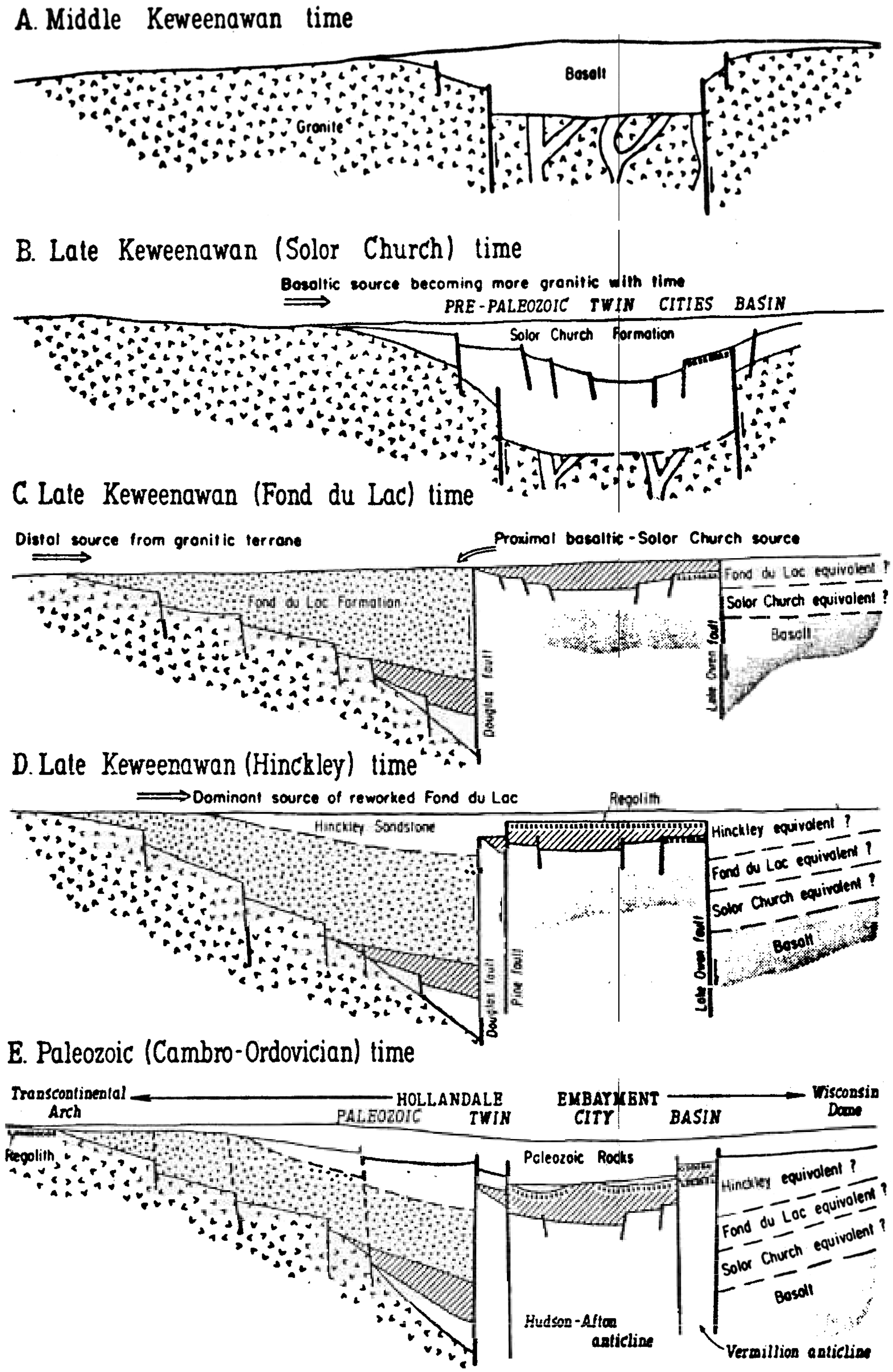
Faulting occurred after deposition of the Bayfield Sandstones, but movements after late Cambrian seas covered the area are negligible. The Minnesota Geological Survey (Morey, 1972, and Craddock, 1972) believes that the major faults are part of the general Keweenawan structure, and therefore of Precambrian age. Thus, if the Douglas Fault is Keweenawan in age, the Bayfield Sandstone must also be Precambrian. On the other hand, if the Bayfield Sandstone is Lower or Middle Cambrian, the Douglas Fault must also be Cambrian in age.

References:

Craddock, C., 1972, Late Precambrian: Regional Geologic Setting: in Geology of Minnesota: A Centennial Volume edited by Sims and Morey, Minn. Geol. Survey, pp. 281-291.

Mengel, J. T. Jr., 1970, Geology of the Western Lake Superior Region; Geology Dept., UW-Superior.

Morey, G. B., 1972, Petrology of Keweenawan Sandstones in the subsurface of Southeastern Minnesota: in Geology of Minnesota: A Centennial Volume edited by Sims and Morey, Minn. Geol. Survey, pp. 436-449.

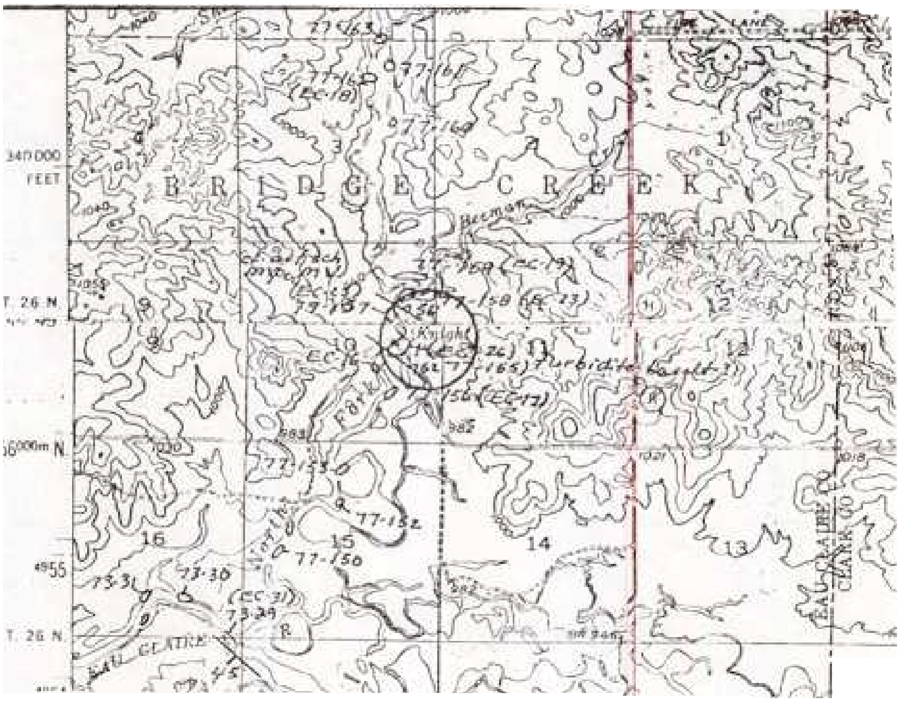


Schematic east-west cross-sections showing the inferred evolution of the St. Croix horst from Middle Keweenawan (?) to approximately Middle Ordovician time. A, Middle Keweenawan time; B, Solor Church time; C, Fond du Lac time; D, Hinckley time; and E, Early Paleozoic time.

From Morey, 1972.

Pillowed(?) Metabasalts and Graywackes ?) and Granitic Intrusions

LOCATION: Knight Pool, Channey Road, SE 1/4, NE /4, Sec. 10, T 26 N, R 5 W
Fairchild and Stanley 15' quadrangles EC County



AUTHOR: P.E. Myers, U.W.-Eau Claire

DATE: January, 1978

SUMMARY OF FEATURES:

A large outcrop along the North Fork of Eau Claire River about 120 meters upstream from Channey Road exposes banded, gneissic amphibolite with relict volcanic structures, including highly deformed pillow structures(?) which are preserved as epidote clots. Cataclastic lamination in the amphibolite is N68°W, 73°N. Coarse metagraywackes are intercalated with the metabasalts. Lineation plunges 0-15°E in the plane of cataclastic foliation. Figure 1 shows one of the more likely pillow structures.

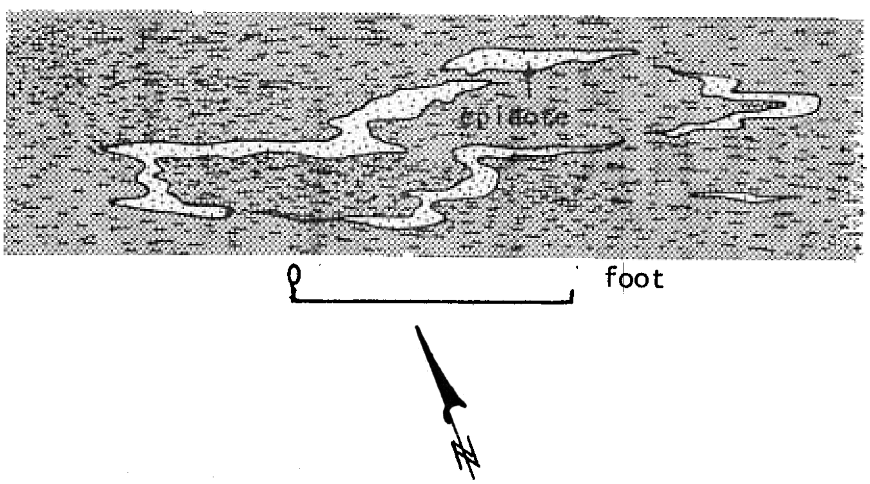


Figure 1 -- Relict, shear-folded pillow structure(?) n hornblende schist, metabasalt.

Granitic (probably leucocratic tonalite and trondhjemite) bands are structurally interlayered with the amphibolite. Several ages of granitic intrusion and shearing are indicated by their mutually cross-cutting relations. The granitic intrusions, mainly as thin veinlets, although concordant in many places, appear to have produced metasomatic alteration in adjacent amphibolite. Some granitic dikes and veinlets display cataclastic foliation: one of these cuts a non-sheared medium-grained granitic veinlet (Figure 2) Explain this - if you can...

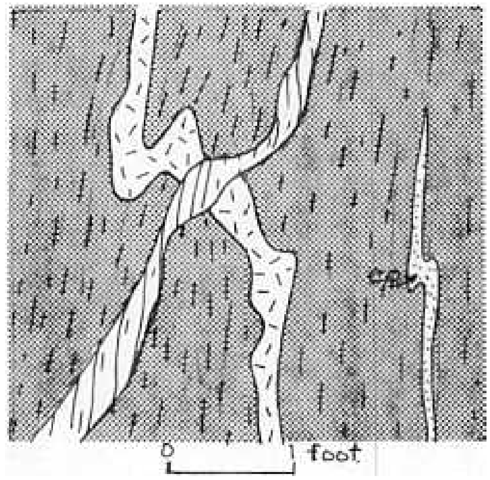


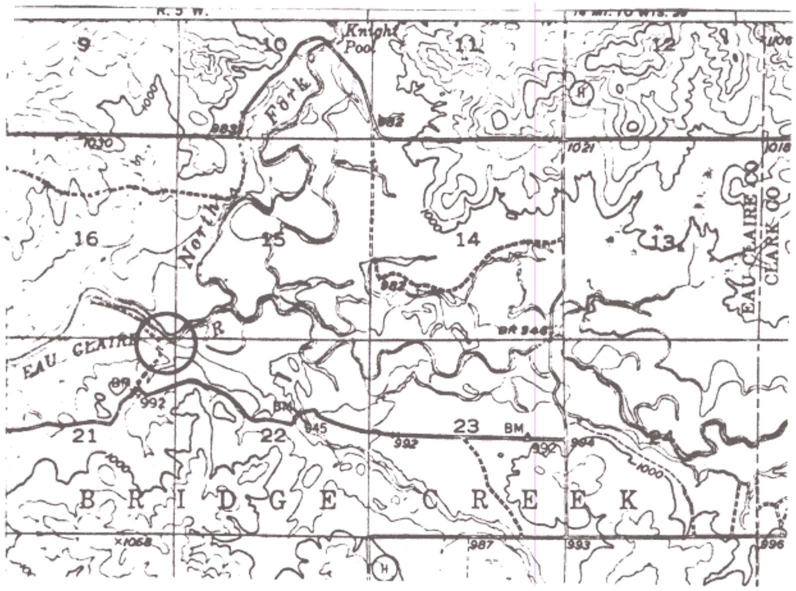
Figure 2 -- Cataclastic leuco-tonalite(?) veinlet cutting non-foliated aplite in hornblende schist.

SIGNIFICANCE:

Basalts and graywackes are uncommon in the Chippewa amphibolite complex to the west. They probably represent submarine flows and sediments associated with island arc volcanism. These rocks, because of their lower grade of metamorphism and sedimentary affiliations probably belong to the younger sedimentary sequence which rests unconformably upon the Chippewa amphibolite complex and should correlate with bedded tuffaceous sediments near the confluence of North and South Fork of Eau Claire River about 3 kilometers southwest of here. It is emphasized that much more detailed field and laboratory work is needed to confirm this hypothesis, if indeed such confirmation is possible at all.

TITLE: Younger(?) metasediments--Late Middle Precambrian?

LOCATION: Confluence of North and South Forks, Eau Claire River
NE 1/4, NE 1/4, Sec. 21, T.26N, R.5W



AUTHOR: Paul E. Myers, UW-Eau Claire

DATE: May 26, 1977

SUMMARY OF FEATURES:

Thin-bedded, conglomeratic, tuffaceous siltstone and sandstone form a stream-cut ledge along the south side of Eau Claire River near the remains of an old cabin. Bedding is N60°W, 45-60°SW. The conglomerate (locations A and B) consists of subrounded to subangular quartz and subordinate feldspar clasts 1/4 mm in diameter. These rocks are poorly sorted and well-stratified texturally. The matrix of the conglomerate is micaceous and siliceous; it may also contain a cement of hematite, part of which is leached in weathering to form ferruginous coatings on the quartz and impregnations of the feldspar clasts.

The metaconglomerate is apparently underlain by phillitic metatuff(?). Absence of deformation and metamorphism in these rocks suggests a younger age than the amphibolitic rocks which are well-exposed only short distances up and downstream. The two rock sequences may be represented by a folded unconformity.

Hornblende gneiss 1 km downstream grades within several feet into hornblende schist showing relict plagioclase clasts much like those in the metatuff at location C here, but much more highly metamorphosed. Samples of the amphibolite and metatuff were taken (1973) by W. R. Van Schmus for radiometric analysis.

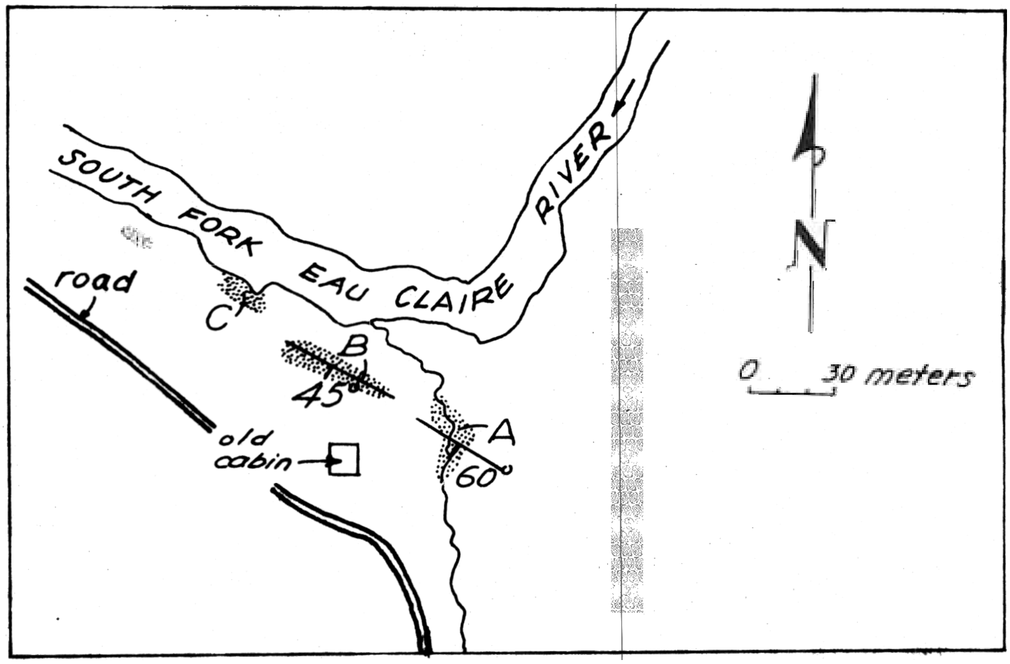
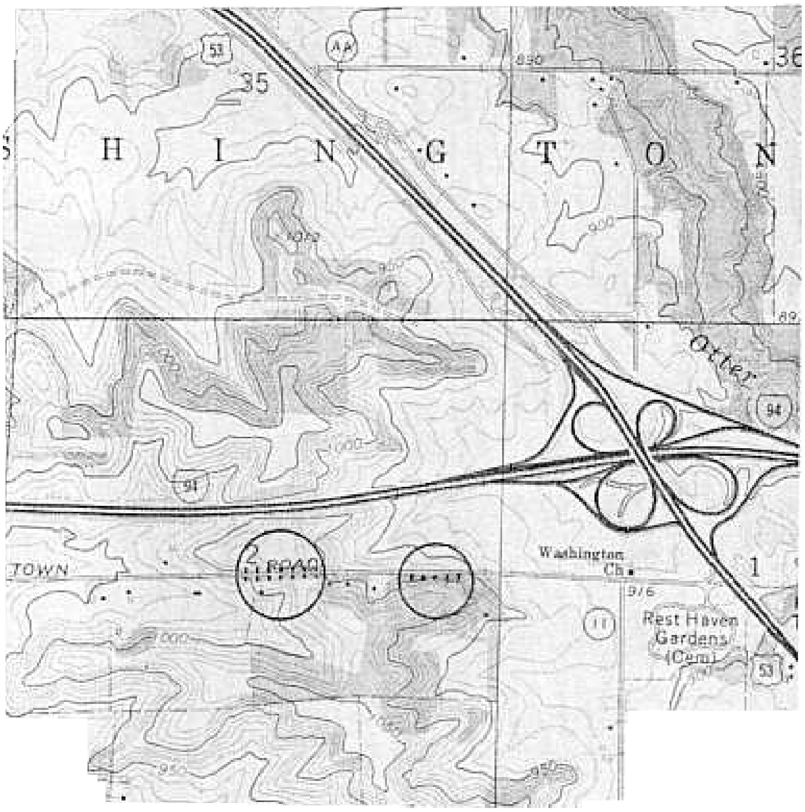


Figure   Outcrop geologic map

Title: Rest Haven Gardens Town Road

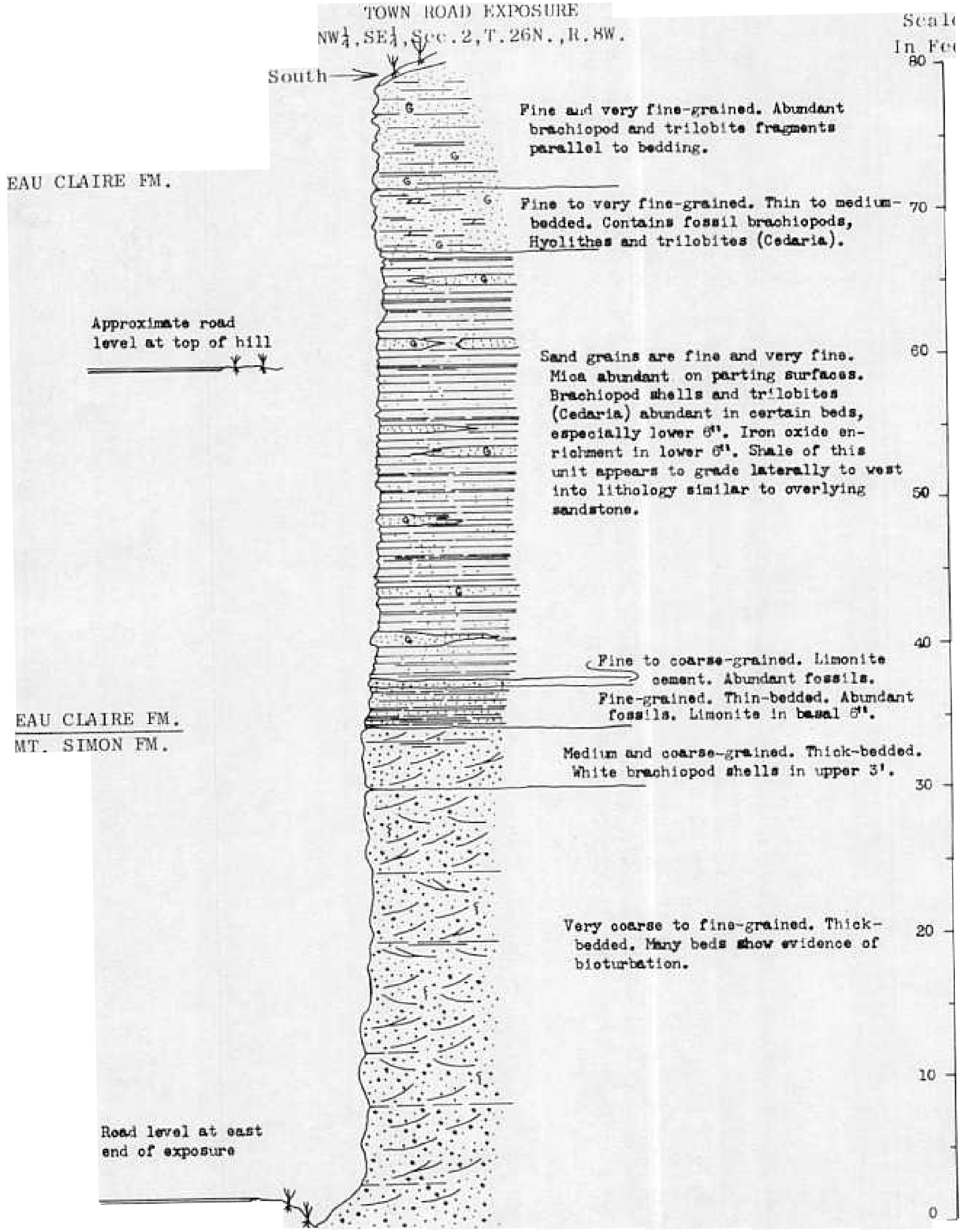
Location: Roadcuts on east-west asphalt roads 0.8 miles west of junction of U. S. Highway 53 with County Highway "II" south of City of Eau Claire on the north line of the NW$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 2, T.26N., R.9W., Eau Claire County (Eau Claire East 7.5-minute topographic quadrangle, 1972).



Author: M. E. Ostrom (modified from Ostrom, 1970)

Description: At this exposure the contact relations of the Mt. Simon and Eau Claire formations are clearly shown. The Mt. Simon consists primarily of medium and coarse-grained sandstone with some fine-grained sandstone. The upper approximately 20 feet of the formation consists of transitional beds composed of particles ranging in size from silt to granules. Certain of these beds are thoroughly burrowed. The upper few feet of the transition beds commonly contain brachiopods.

The Eau Claire Formation is distinquished from the Mt. Simon by its generally finer grain size and thin-bedding, and by the presence of glauconite, trilobites, and abundant shale. Commonly the contact is marked by iron oxide enrichment in a zone about one foot thick.



TOWN ROAD EXPOSURE
NW¼, SE¼, Sec. 2, T. 26N., R. 8W.
Scale
In Fe
South
EAU CLAIRE FM.
Fine and very fine-grained. Abundant brachiopod and trilobite fragments parallel to bedding.
Fine to very fine-grained. Thin to medium-bedded. Contains fossil brachiopods, Hyolithes and trilobites (Cedaria).
Approximate road level at top of hill
Sand grains are fine and very fine. Mica abundant on parting surfaces. Brachiopod shells and trilobites (Cedaria) abundant in certain beds, especially lower 6". Iron oxide enrichment in lower 6". Shale of this unit appears to grade laterally to west into lithology similar to overlying sandstone.
Fine to coarse-grained. Limonite cement. Abundant fossils.
Fine-grained. Thin-bedded. Abundant fossils. Limonite in basal 6".
EAU CLAIRE FM.
MT. SIMON FM.
Medium and coarse-grained. Thick-bedded. White brachiopod shells in upper 3'.
Very coarse to fine-grained. Thick-bedded. Many beds show evidence of bioturbation.
Road level at east end of exposure
80
70
60
50
40
30
20
10
0

In a recent study of the Eau Claire Formation in western Wisconsin sponsored by the Wisconsin Geological Survey and used by Bradford Morrison (1968) for a Master's Degree at the University of Wisconsin it was determined that the Eau Claire could conveniently be subdivided into 5 laterally persistent lithologic units which are:

E. Upper Thick-Bedded Unit. Sandstone, fine and very fine-grained, thick to medium-bedding, glauconitic; Upper unit at STOP 4; missing at STOP 7. About 20' thick.

D. Upper Thin-Bedded Unit. Sandstone, fine and very fine-grained, thin distinct bedding, very glauconitic. Described as "usually missing from sections." Lower Unit at STOP 4 and upper unit at STOP 7. About 15' thick.

C. Lower Thick-Bedded Unit. Sandstone, fine and very fine-grained, thick-bedded, locally very glauconitic. A few very clay-rich irregularly-bedded units separating the more characteristic thick-bedded units. Thick-bedded unit at entry at STOP 7. About 25' thick.

B. Lower Thin-Bedded Unit. Sandstone, fine and very fine-grained, mixed thin and thick beds, thin beds regular and distinct, glauconitic, high clay content, mica common. Abundant fossils and trail markings. Unit at top of exposure at STOP 3 and at path level and below springs at grotto at STOP 7. About 20' thick.

A. Shaly beds. Shaly sandstone and shale, very fine and fine-grained and, very thin-bedded, individual beds often indistinct and seldom over 3" thick. Abundant fossils and trail markings. Lower unit at STOP 3. About 15' thick.

Whereas the transition beds in the top of the Mt. Simon are believed to have formed in a nearshore environment located near to but seaward of the beach the Eau Claire Formation, by way of contrast, is believed to have formed in an offshore area of lower energy located seaward of the nearshore environment. This interpretation, is suggested by uniform but thin and laterally persistent beds, presence of glauconite, presence of marine animals in a variety of forms and abundant trail markings, and small scale cross-bedding. Bedding character is interpreted to indicate brief episodes of higher energy and the increase in carbonate content indicates conditions of light and water depth were conducive to formation of carbonate.

The history suggested by these rocks is one of deepening waters probably caused by subsidence of the land surface and northward transgression by the sea over the land (Ostrom, 1964a). Thus beach deposits (thick-bedded Mt. Simon) are mantled by nearshore deposits (transitional Mt. Simon) which are in turn mantled by offshore deposits (Eau Claire). A recurrence at higher levels of any of the lithologies noted would indicate regression. That this happened can be seen at the Galesville stop where the Mt. Simon lithology is repeated in the Galesville Sandstone Formation.

The type section of the Eau Claire is located in the east side of Mt. Washington in the City of Eau Claire but is no longer accessible to groups. The following description of the type section is slightly modified from W. H. Twenhofel (1935):

Section at Stop 34 Mt. Washington, Wisconsin

Section at Mt. Washington, 4 miles from Eau Claire, Wisconsin, in the NE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 25, T.27N., R.LOW, Eau Claire County (Chippewa Falls 15-minute topographic quadrangle, 1936).

CAMBRIAN

St. Croixan series
Elk Mound Group (205.3 ft.)
Eau Claire Formation (60.0 ft.)

Top of rock, about 2 feet soil and drift above

192.3'-205.3' 23.0' 8. Upper quarry face, southwest corner shows only exposure. Sandstone, medium-grained, massive, glauconitic, yellow, in lenticular beds. Basal beds about 2 feet. About 15 feet above the base a non-laminated soft layer of yellow and brown greatly burrowed silty sandstone with poor brachipod shells, oboloid shells abundant in some beds, a bed 8 feet from base is literally jammed with trilobites. Hyolithes primordialis (Hall), "Crepicephalus" danace (Walcott), "Crepicephalus" unca (Walcott), Dresbachia amata (Walcott) Lonchocephalus chippewaensis (Owen), "Agnostus" sp., Anomocarella volux (Walcott), "Pagodia" thea (Walcott), Coosia connata (Walcott), Crepicephalus sp. nov., Dicellomus politus (Hall), new species of Obolus, Lingulella, Lingulepis.

145.3'-182.3' 37.0' 7. Lower quarry face. Sandstone, fine grained, yellow to light brown, irregularly bedded, lenticular beds from $\frac{1}{2}$ inch to 8 inches. Partings of pale blue-green silt with mud cracks; oboloid and linguloid brachiopods, layer 10 feet from base shows excellent heads and tails of Cedaria woosteri. Extends to top of cliff or level of upper quarry floor=top of Cedaria zone. Cedaria woosteri (Whitfield), Menomonia calymonoides (Whitfield), Hyolithes primordialis (Hall), Obolus namouna (Walcott), Obolus rhea (Walcott), Lingulepis sp. nov., Lingulepis cf. ancuminata (Conrad).

Mt. Simon Formation (138.0 ft.)

138.0'-145.3' 7.3' 6. Sandstone, medium to coarse-grained, in alternating thick and thin beds, yellow to gray or brown, Obolus namouna (Walcott) (base of lower quarry).

123.0'-138.0' 15.0' 5. Sandstone, medium to coarse-grained, massive bedded, beds to 2 feet, yellow to brown, laminated, sparing oboloids=basal Cedaria zone.

Mt. Simon member (123 ft. exposed)

-123.0'	53.0'	4.	CONCEALED to base of cliff on northeast side of Mount Washington with a few ledges of coarse to medium-grained sandstone in upper 10 feet. Note: 124 feet from terrace level below to flat of quarry floor.
60.0' -70.0'	10.0'	3.	CONCEALED on terrace with road.
33.0' -60.0'	27.0'	2.	Sandstone, coarse-grained, unfossiliferous, white to yellow, cross-laminated; granules and pebbles of quartz, sorting poor, units 2 inches to 12 inches, foresets short and steep, dip east or northeast, cliff.
-33.0'	33.0'	1.	CONCEALED to corner of school grounds with small ledges of medium-grained sandstone in upper 10 feet.

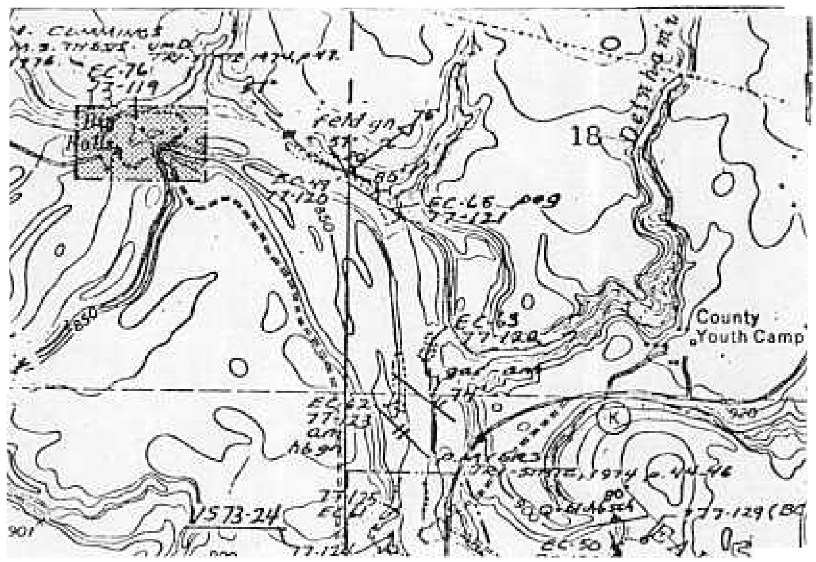
Significance: This exposure illustrates the contact relationships and the major mineralogical and lithological differences between the Mt. Simon and Eau Claire Formations. In addition, the Eau Claire Formation is the oldest major fossil-bearing Formation in the Paleozoic of Wisconsin.

What is the significance of the contact relationships between the two formations? What environments do the formations represent and what is the evidence? Could a reverse relationship of the two formation lithologies occur, namely Mt. Simon type lithology above Eau Claire-type lithology? What kinds of fossils occur in the Mt. Simon? the Eau Claire? What is their significance in terms of environmental interpretation?

References: Thwaites, 1935; Twenhofel, Raasch, & Thwaites, 1935; Ostrom, 1964 and 1970; Morrison, 1968.

TITLE: Geology of the Big Falls Area

LOCATION: Eau Claire River, NW /4, SE 1/4, SEc. 13, T.27N., R.8W, Eau Claire County



AUTHORS: M.L. Cummings, UW-Madison, and P.E. Myers, UW-Eau Claire

DATE: September, 1974

SUMMARY OF FEATURES:

Precambrian gneiss and schists at Big Falls County Park are composed of alternating hornblende-rich and plagioclase-rich bands. Structural and petrographic studies indicate three deformational events accompanied by extensive recrystallization and followed by three episodes of faulting. Composition suggests a gabbroic protolith differentiated to anorthositic gabbros and gabbros. The complex is older than 1840 m.y. and possibly Archean in age.

DESCRIPTION:

Precambrian amphibolite gneisses and schists crop out along and in the Eau Claire River at Big Falls County Park in northcentral Eau Claire County (Sec. 13, T.27N., R.8W.). The Precambrian rocks are overlain with angular unconformity by cross-bedded, conglomeratic-to medium-grained Upper Cambrian Mt. Simon Formation. Slumped blocks of Mt. Simon sandstone along the west river bank (Fig. 1), have slid along the green clay layer between Precambrian and overlying Cambrian rocks. Glacial outwash caps the sandstone and overs most of the river valley.

Four Precambrian gneiss and schist units were mapped (Fig. 1): (1) banded amphibolite gneiss (b.a.g.), (2) amphibolite schists (a.s.), (3) transition gneisses (t.g.) between the amphibolite schists, and (4) feldspathic gneiss (f.g.)

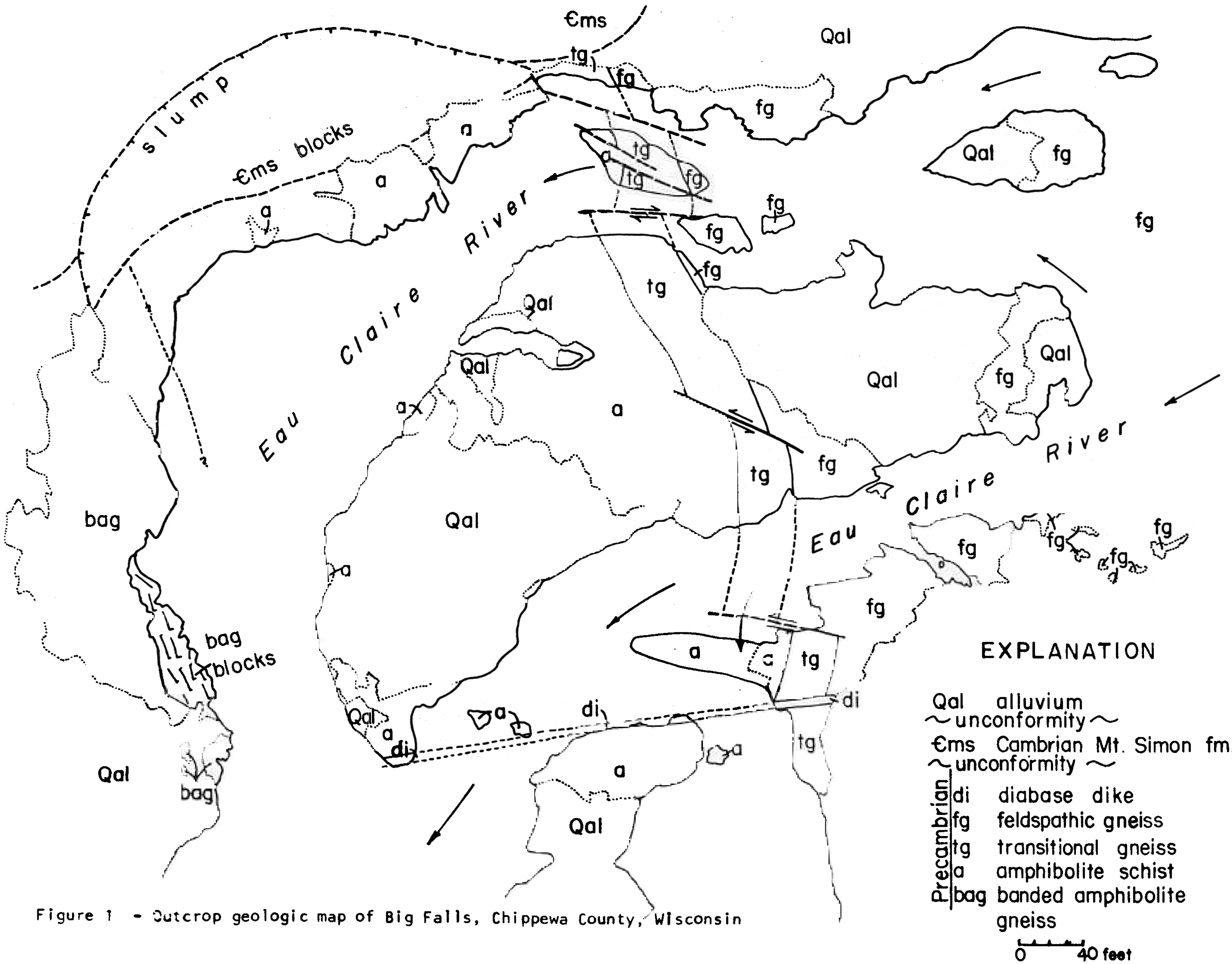


Figure 1 - Outcrop geologic map of Big Falls, Chippewa County, Wisconsin

The banded amphibolite gneiss is characterized by alternating hornblende-rich and plagioclase-rich bands. Hornblende-rich bands are from 0.6 cm to nearly 20 cm wide, but more commonly in the range of 0.12 to 2.5 cm wide. The plagioclase-rich bands are generally 0.6 cm to 31 cm side. Garnet porphyroblasts to 13 cm in diameter are present in parts of the outcrop.

The amphibolite schist is a unit with compositional variation most apparent as changes in the percentage of hornblende. Garnet porphyroblasts up to 2.5 cm in diameter define one compositional band while garnet porphyroblasts up to 0.6 cm in diameter associated with cummingtonite form another persistent compositional band. Thinly banded hornblende-plagioclase rocks are the most typical.

The transition geniss east of the amphibolite schist is characterized by lenticular segregation of hornblende and plagioclase. The segregations are usually 2.5 cm to 3.8 cm long and 0.6 cm to 1.3 cm wide. Thin hornblende and plagioclase bands are also present. A second transition gneiss is composed of thin hornblende and plagioclase bands and common development of silver-gray chlorite.

Compositional banding in the feldspathic gneiss is poorly defined. The percentage of plagioclase is usually greater than 80% of the rock, and compositional banding results from a slight increase in abundance of hornblende.

Most work was concentrated on the banded amphibolite gneiss and the amphibolite schist because of definable structures and less intense faulting.

EVIDENCE FOR DEFORMATIONAL EVENTS

Structural elements in the rocks suggest three deformational events, followed by faulting and joingint. Evidence for each event will be presented and correlated with the textural evidence.

Evidence for the earliest deformation, although sparse, includes: (1) intergrowths of hornblende in large, shattered garnet porphyroblasts wrapped by compoistional banding and (2) lack of structural continuity between rootless intrafolial folds and external foliation.

The second deformation is responsible for the gross structures in the rocks. During the second deformation foliations were wrapped around earlier-formed garnet porphyroblasts and intrafolial folds were transposed. Fold forms and boudinage suggest a high degree of plasticity and flowage. In the banded amphibolite gneiss, the mechanism of deformation suggested by the folds is slip along certain major hornblende-rich bands with folding of the rocks between the major slip planes. The west side of the folds is typically moved south, suggesting a left-handed couple across the folds. Compositional banding is wrapped around axes plunging north 40° to 57°. Folds have nearly vertical axial planes.

Deformation in the amphibolite schist followed the same pattern with movement along discrete planes and folding of the intervening rock. Fold axes plunge south between 20° and 38°, and axial planes are vertical to steeply dipping. Some fold forms show axial plane development of shear planes resulting in shearing out of axial surfaces. Microscopic investigation indicates that faulting occurred late in the deformation, but prior to final recrystallization. The nearly vertical faults have strikes between N10°W and N25°W and show apparent left-lateral displacement. The faults are best observed in the banded amphibolite gneiss, but are obscure in the amphiobolite schist.

The third deformation was neither intense nor penetrative. Narrow shear bands, granulated textures along a 5 to 8 km shear zone, and rotated blocks are the major observable features. Additional petrographic evidence for the third deformation is described later.

Structures produced by three major deformations are overprinted by two different types of faulting. The oldest fault set is responsible for the development of lens-shaped bodies of rock bounded by shear planes Deformation appears confined to the edges of the lenses and to the shear planes with little internal effect. Type and amount of movement is not knonw. Lens forms are vaiable in size, and the banded amphibolite gneiss shows a development of smaller lenses along zones of interference between larger lenses.

The lens structures are cut by two fault sets. The first trends N85°E and is apparently right-lateral with displacements as much as 6 m. The second fault set is N70°W and is left-lateral with displacements up to 4.5 m.

EVIDENCE FOR RECRYSTALLIZATIONS

Evidence for three main deformational episodes is supported by petrographic studies and phase relations. Three separate recrystallizations of the rocks are proposed. The following section summarizes textural evidence for each recrystallization, correlates the features of recrystallization with their reasonable counterparts resulting from deformation, and presents chemical data.

The first recrystallization may have been synchronous with the first deformational event. Evidence for it is sparse. Garnet is the only mineral from this event. In the banded amphibolite gneiss, the farnets are intergrown with coarse hornblende formed during the third recrystallization. This hornblende is of different compoistion than other hornblende in the rocks (see Table 10-2), and has similarites to the enclosed garnet, i.e., low TiO_2 content. Coarse hornblende forms sheaths around the garnets. Textural evidence and compositional differences suggest reaction of the garnets with their surroundings after formation. The reaction may reflect retrograde reaction before the second recrystallization or during the second prograde recrystallization. Similar evidence of garnet reaction is present in the amphibolite schist. Chemical analyses of the garnet porphyroblasts (Table 1) were performed by microprobe. No attempt was made to map compositional zoning within the crystals. Garnets in the amphibolite schist are higher in the almandine end member (70%) than those from the banded amphibolite gneiss (58%) which are higher in grossular (24% vs. 11%).

Ratios of 100 Mg/(Mg+Fe) also indicate the greater proportion of ron in the amphibolite garnets (13% vs. 20%).

The second recrystallization produced a medium-grained texture that appears relict in thin section. Minerals which crystallized during the second event are hornblende, plagioclase, and probably cummingtonite, plus accessory minerals. Recrystallization occurred late or after the second deformation, as orientations are weak or absent in plagioclase and hornblende.

The third recrystallization only partially destroyed earlier textures. The most thorough recrystallization seems to have been in the amphibolite schist, where much of the rock is texturally equilibrated. HOrnblende, plagioclase, epidote, cummingtonite, and sphene recrystallized in the third event. Plagioclase, produced during the second recrystallization, was trained and commonly granulated during the third recrystallization. During destruction of coarse plagioclase grains, the first observable feature is strained twin lamallae followed by development of patchy compositional zoning with compositions varying from An_{59} to An_{49} in a single crystal. The coarse crystal is segregated into 1 mm grains that are untwinned and do not show compositional zoning. Plagioclase in the amphibolite schist is commonly recrystallized, and exhibits reverse compoistional zoning with cores of approximately An_{25} and rims of An_{44}. The contact between core and rim is sharply defined. The observed zoning may result from destruction of a calcium-rich phase, i.e., epidote, during metamorphism with the released calcium taken up by the plagioclase.

PHASE GEOCHEMISTRY

Amphiboles in the banded amphibolite gneiss are hornblendes, while in the amphibolite schist, hornblende and cummingtonite coexist. Three hornblende grains were analyzed from the banded amphibolite gneiss (Table 2). Sample WP-7 is from a hornblende-rich band and represents a product of the third recrystallization. Sample WP-7 P2-1 is from the same thin section as WP-7 P1-1, but it is from a plagioclase-rich band that developed during the second recrystallization. Number 7-29-72 is also a third recrystallization project and is intergrown with the garnet porphyroblasts. Hornblende WP-7 P1-1 and WP-7 P2-1 are similarly saturated with respect to cummingtonite molecule. Sphene is an important accessory mineral, especially in hornblende-rich bands. Development of sphene is probably the result of the expulsion of TiO_2 from the hornblende lattic during the third recrystallization. As titanium content in hornblended is controlled by temperature (Leake, 1972), this implies that the third recrystallization took place at lower temperature than the second, when titanium was still in the hornblende lattice.

The amphibole plases in the amphibolite schist are hornblende and cummingtonite. Hornblende W-29 ITable 3) is a "typical" hornblende of the amphibolite schist and is the result of the third recrystallization. Hornblende W-24, which contains fine opaque inclusions concentrically in and around the core and along fractures, is considered relict from the second recrystallization. Hornblende W-21, cummingtonite W-21, and garnet W-21 are from the same sample. The two amphiboles are considered to have recrystallized during the third recrystallization. The cummingtonite molecule is common in all hornblendes from the amphibolite schist. Hornblende W-24 and W-29 are similar in composition, but W-24 contains an opaque phase which microprobe analysis indicates contains at least 11 weight percent titanium. These opaque inclusions formed during the third recrystallization by the expulsion of titanium from hornblende formed during the second recrystallization.

Hornblende W-21 is subcalcic with cummingtonite molecule present at the expense of calcium and alumina. Ionic formulas for hornblende and cummingtonite indicate more Mg than Fe per formula unit (Table 3). This results in high magnesium content. Cummingtonite-bearing bands are low in calcium. The increasing demand of plagioclase and hornblende for calcium and alumina with rising temperature results in preferential development of cummingtonite and subcalcic hornblende.

Whole rock chemical analyses were made of two samples of banded amphibolite gneiss selected to represent extremes in abundance of hornblende (Table 4). The results indicate low silica with high alumina and calcium. The high alumina and calcium reflect high modal percentage of plagioclase. Oxidation ratios for 2 Fe_2O_3 + FeO) in W1-C and W2-C are 0.371 and 0.362 respectively. These values are abnormally high compared with values of 0.20 or less for most garnet-bearing rocks. Oxidation of the rocks strongly affects the crystallization of garnet. The ratio suggests that the third recrystallization was accompanied by higher oxygen fugacity than the previous two. Epidote, formed during the third recrystallization, contains 0.83 ions of Fe^{3+} of a possible 1.0 ions per formula unit and indicates a relaxation during the third recrystallization. The ratio of K_2O/Na_2O is extremely low (0.103, W1C and 0.135, W2C). Low values of $K_2O/Na_2)^2$ are characteristic of old rocks, especially Archaen rocks, where $K_2O/Na_2{}^2$ is generally less than 1% (Engel, et.al., 1974). The values of $K_2O/Na_2{}^2$ at Big Falls suggests an Archaen age.

In summary, the gneisses and schists at Big Falls County Park have been deformed and recrystallized during three metamorphic and deformational events with late faulting and alteration. Whole rock chemical analysis of the banded amphibolite are compatible with a protolith of an anorthositic gabbro while individual phases analyzed in the amphibolite schist are not incompatible with a magnesian mafic rock such as a norite. The Big Falls gneisses and schists are a possible part of a differentiated gabbroic intrusive that was emplaced before 1900 m.y. and may be Archaen in age.

REFERENCES:

Leake, B.E., 1972, Garnetiferous striped amphibolites from Connemara, Western Ireland, Mineralogical Magazine, vol. 38, no. 298, pp. 649-665.

Engel, A.E.J., Itson S.P., Engel C.G., Stichney, D.M., 1974, Crystal evolution and global tectonics: a retrogenic view, GSA Bulletin, vol. 85, no. 6, pp. 843-858.

TABLE 10-1 - GARNET PORPHYROBLASTS FROM THE BANDED AMPHIBOLITE GNEISS AND THE AMPHIBOLITE SCHIST

Oxide	7-29-72 Weight %	W-21 Weight %
SiO_2	38.02	37.62
Al_2O_3	20.34	19.46
TiO_2	0.12	
FeO^*	25.69	29.11
	3.56	2.65
Mn	1.66	2.80
CaO	8.40	3.59
	97.79	95.23

Number of ions in structural formula * +

	7-29-72		W-21	
Si	6.11		6.26	
Al	3.81	$\Sigma Y^{+3} = 3.82$	3.78	$\Sigma Y^{+3} = 3.78$
Ti	0.01			
Fe^{+2}	3.45	$\Sigma X^{+2} = 5.98$	4.05	$\Sigma X^{+2} = 5.75$
Mg	0.85		0.66	
	0.23		0.40	
Ca	1.45		0.64	

* All iron as FeO

\+ Structural formula $X_6 Y_4 Si_6 O_{24}$

Molecular % in terms of garnet end members

	7-29-72	W-21
Alm.	57.7	70.4
Spess.	3.8	6.9
Pyr.	14.2	11.5
Cross.	24.2	11.1

TABLE 10-2 - HORNBLENDE FROM THE BANDED AMPHIBOLITE GNEISS

Oxide	WP-7 P2-1 Weight %	WP-7 P1-1 Weight %	7-29-72 Weight %
SiO_2	43.43	41.97	42.59
Al_2O_3	14.07	13.65	18.76
TiO_2	1.18	1.12	0.27
MgO	7.59	7.99	6.87
MnO	0.35	0.42	0.48
FeO*	18.64	17.79	15.44
CaO	11.18	11.21	10.92
Na_2O	0.58	0.43	0.59
K_2O	0.34	0.34	1.13
	97.36	94.92	96.46

Number of ions for structural formula *+ based on 23 oxygen

	WP-7 P2-1		WP-7 P1-1		7-29-72	
Si	6.51	8.00	6.46	8.00	6.31	8.00
Al	2.46 (1.49 / 0.97)		2.45 (1.54 / 0.91)		3.24 (1.69 / 1.55)	
Ti	0.13	5.19	0.13	5.21	0.03	5.07
Mg	1.70		1.83		1.52	
Mn	0.05		0.06		0.06	
Fe^{+2}	2.34		2.28		1.91	
Ca	1.80	.97	1.85	1.98	1.73	.90
Na	0.17		0.13		0.17	
K	0.06	0.06	0.07	0.07	0.21	0.21

* Total iron as FeO

\+ Structural formula $A_{0-1}\ X_2\ Y_5\ Z_8\ O_{22}\ (OH,F)_2$

TABLE 10-3 - AMPHIBOLES FROM THE AMPHIBOLITE SCHIST

		W-24	Hbe. W-21	Cumm. W-21
Oxide	Weight %	Weight %	Weight %	Weight %
SiO_2	40.32	41.78	46.85	53.79
Al_2O_3	14.02	13.12	8.04	1.06
TiO_2	0.75	0.90	0.40	0.02
FeO*	15.83	16.93	21.29	23.24
MgO	10.90	10.91	14.68	16.96
MnO	0.29	0.48	0.36	0.52
CaO	10.37	10.76	5.20	0.08
Na_2O	0.67	0.62	0.77	
K_2O	0.34	0.22		-
	93.49		97.59	96.11

Number of ions per structural formula + unit based on 23 oxygen

Si	6.26	8.00	6.35	8.00	6.96	8.00	7.96	8.00
Al	2.56 < 1.74 / 0.82		2.35 < 1.65 / 0.70		1.41 < 1.04 / 0.37		0.18 < 0.04 / 0.14	
Ti	0.09		0.11		0.09			
Fe^{+2}	2.05	5.52	2.16	5.53	2.65	6.41	2.94	6.93
Mg	2.52		2.48		3.25		3.79	
Mn	0.04		0.06		0.05		0.06	
Ca	1.72	1.92	1.76	1.94	0.83	1.05	0.08	0.08
Na	0.20		0.18		0.22			
K	0.07	0.07	0.04	0.04				

* Total iron as FeO

\+ Structural formula $A_{0-1} X_2 Y_5 Z_8 O_{22} (OH,F)_2$

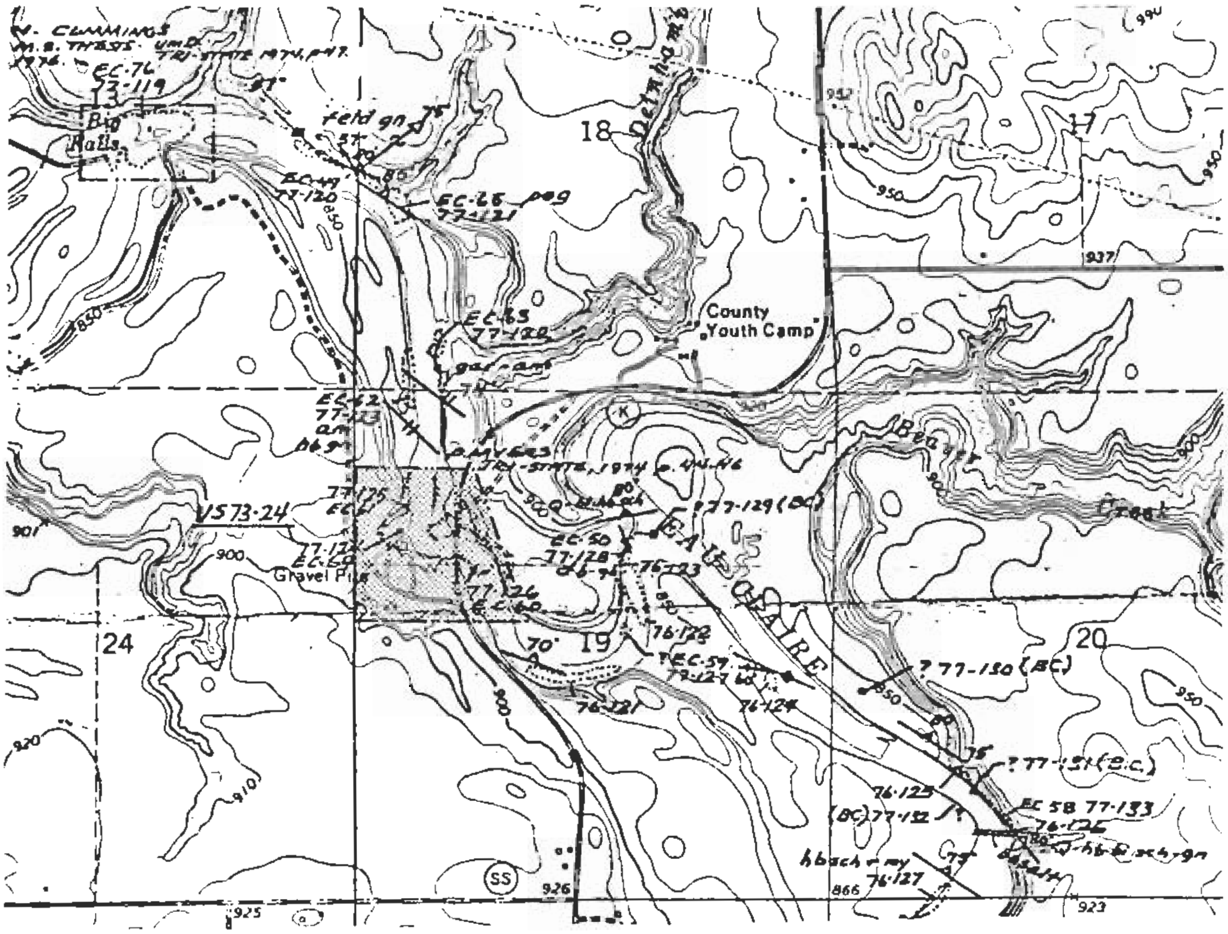
TABLE 10-4 - WHOLE ROCK CHEMICAL COMPOSITIONS FROM THE BANDED AMPHIBOLITE GNEISS

	W1-C	W2-C
Oxide	Weight %	Weight %
SiO_2	49.35	47.75
Al_2O_3	23.72	25.63
Fe_2O_3	1.23	1.28
FeO	4.17	4.53
MgO	3.05	1.55
MnO	0.08	0.08
CaO	12.89	14.61
K_2O	0.32	0.31
Na_2O	3.09	2.29
TiO_2	0.28	0.33
P_2O_5	0.11	0.11
CO_2	0.22	0.26
H_2O	1.32	0.95
	99.83	99.68

Analyst: K. Ramlal, University of Manitoba, Winnipeg, Manitoba.

TITLE: Little Falls Breccia

LOCATION: Hwy K at Eau Claire River, SW 1/4, NW 1/4 Sec. 19, T.27 N., R.8 W.
Fall Creek 7.5' Quadrangle



AUTHOR: P. E. Myers, UW-Eau Claire

DATE: December, 1977

SUMMARY OF FEATURES:

A flow-laminated, mafic intrusion breccia comprising xenoliths of banded amphibolite, hornblendite, porphyritic basalt(?), and porphyroblastic, foliated biotite granite in a groundmass of flow-lineated hornblende gabbro and/or tonalite (1840 ± 50 m.y.) is cut by muscovite granite pegmatite and diabase dikes and overlain unconformably by Late Cambrian Mt. Simon Sandstone. A green, clay paleosol(?) of residual origin separates the sandstone from underlying amphibolite on a surface of 5 meters relief. This surface dips west-southwest at about the same angle as the gradient of Eau Claire River. Numerous springs feed the river from a sandstone aquifer just above the clay paleosol(?).

DESCRIPTION:

THE BRECCIA

Flow-oriented xenoliths in the breccia are predominantly massive and banded amphibolite (Figure 2-C and D). Some are angular, and some are rounded. Their long dimensions lie in a nearly vertical plane which strikes north-northwest. (See Figure 1.) Since xenolith angularity is roughly proportional to hornblende content, it is thought that the mobile phase in the rock is represented by the feldspathic fraction. In addition to amphibolite xenoliths, the breccia also contains clasts of amphibolitized pyroxenite(?) and porphyritic basalt or lamprophyre as well as a large fragment of foliated, porphyroblastic biotite granite whose composition, texture, and contact relations will be discussed separately below.

Several stages in the intrusion sequence are represented by portions of the outcrop shown in the Geologic Map, Figure I. The earliest intrusion phase (Figure 2-A) is represented by thin, breccia dikes which spread laterally into pre-existing lamination in the amphibolite. With increasing fluid phase the stoped xenoliths become detached, rotated, and displaced. At an intermediate stage, the breccia contains 30 to 60 percent xenoliths in a flow-laminated, gabbroic matrix (Figure 2-C). Further from the intrusive contact, the gabbro (Location J in Figure 1) contains only occasional xenoliths which show gradational boundaries. Gabbro from Location J was deemed sufficiently uncontaminated to warrant U/Pb-zircon dating by W.R. Van Schmus (oral communication). An age of 1840 $\pm$ 50 m.y. was obtained.

Although the amphibolites at Little Falls closely resemble those at Big Falls, the breccia is unique to Little Falls. The breccia was not seen in a traverse upstream where nearly continuous exposure of tonalite and biotite amphibolite displays the lithologic heterogeneity of these rocks.

A large fragment of foliated, porphyroblastic biotite granite is exposed at Locality E. The fragment was mapped in detail (Figure 3). The granite contains 1-3 cm porphyroblasts of K-feldspar in a foliated granoblastic matrix of microcline, quartz, and brown biotite. Sodic plagioclase is accessory. Lenticular form of the K-feldspar porphyroblasts indicates recrystallization before and/or during cataclasis. The gradational contact between the fragment and enclosing breccia is marked by an inward substitution of K-feldspar for plagioclase and biotite for hornblende and by an increase in abundance of quartz. The gradational contact along at least the west side of the fragment indicates that it is a xenolith and not a fault slice, although its shape and position were probably modified by post-intrusive shearing. What are the age and origin of the foliation in the granite? Was the granite intruded into amphibolite? If so, when? Under what temperature-pressure conditions (depth) did these events take place? Evidence?

PEGMATITE DIKES

Biotite-muscovite granite pegmatite with K-feldspar crystals up to 30 cm in maximum dimension cut at nearly right angles across flow lamination in enclosing breccia. Orientation of the dikes suggests that they were intruded during stress release and/or thermal contraction of the intrusion breccia. Quartz veins and lenses of similar orientation and origin are exposed at the east end of the outcrop here at Little Falls. The best pegmatite exposure is a Location F, where the one to three-meter dike contains very large, bent and marginally crushed K-feldspars. Although not visibly offset by shear zones at Little Falls, the internal deformation in the dike indicates it was intruded prior to major shearing.in the Middle Precambrian.

SHEAR ZONES

Interlensing, west-northwest-trending shear zones involving modest right-lateral displacement and conspicuous drag folding (Locations D and G, Figure 2-E and F) have segmented and transposed primary flow lamination in the intrusion breccia. Where small shear zones converge, the breccia is converted to a zoned, laminated dike-like body with walls of hornblende schist and a core of quartz-epidote mylonite up to 1.5 meters wide. If this small scale transposition of primary lamination is expanded to map scale, one can readily see how primary layering may be

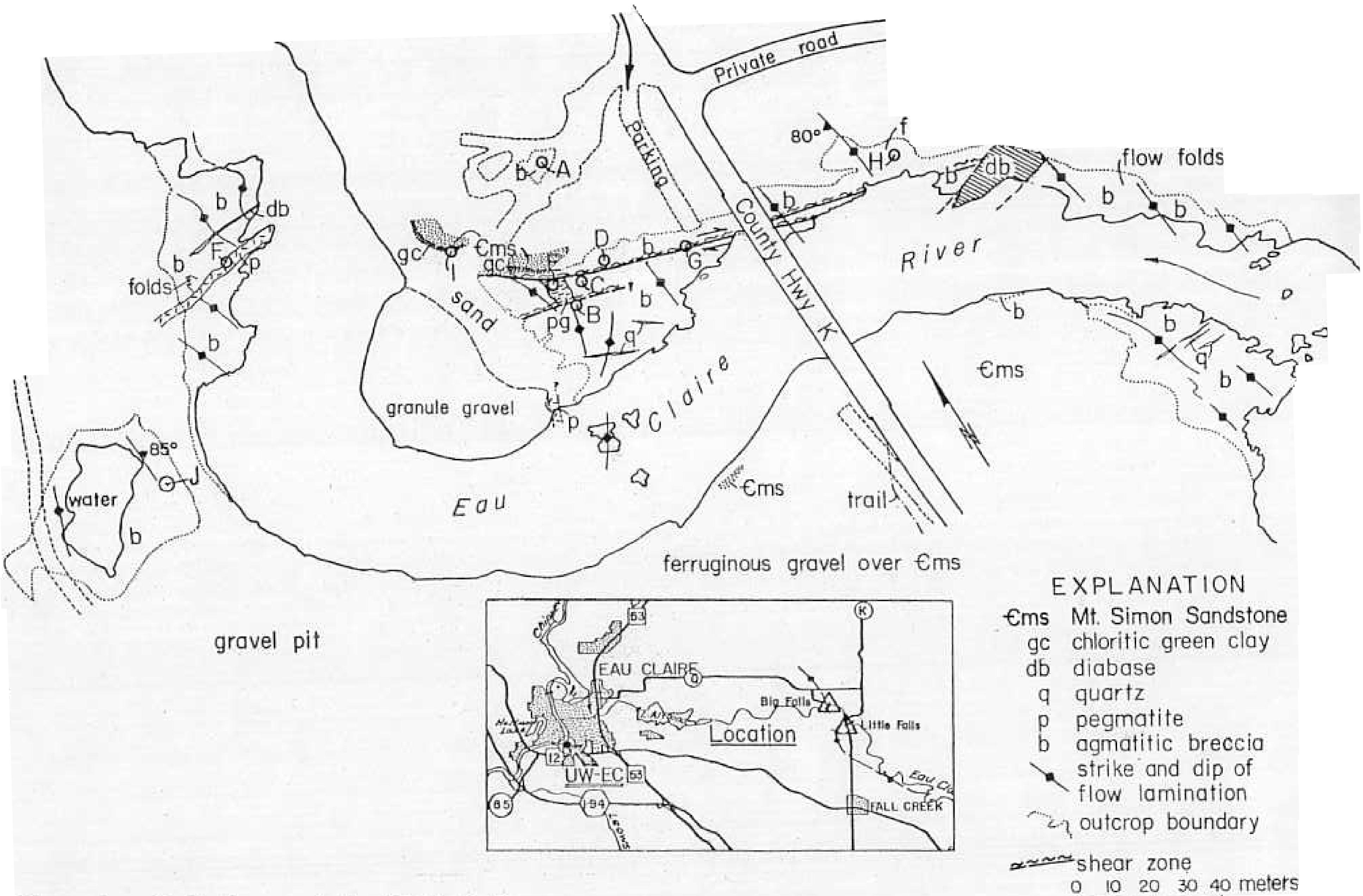


Figure 1 -- Geologic map of the Little Falls area

totally obliterated and replaced by a secondary lamination parallel to shear dislocation in the rock. Many of the interlensing structures of the Precambrian terrane of central Wisconsin may represent large-scale tectonic transposition by shearing.

The shearing seen at Locations D and G probably offsets pegmatites but not the diabase dikes. Its age is therefore probably Late Middle Precambrian (Penokean?)

A much earlier deformation produced the banding in the amphibolites before intrusion of the gabbro 1840 ± 50 m.y. ago.

DIABASE DIKES

East-northeast-trending, Late Precambrian (Keweenawan?) basalt-diabase dikes cut the breccia near locations F and H. Their chilled margins indicate shallow intrusion after considerable erosion.

THE PRECAMBRIAN-CAMBRIAN UNCONFORMITY

A surface of deep weathering and erosion with about 20 meters of relief dips gently west-southwest beneath Late Cambrian Mt. Simon Sandstone throughout the region. The Eau Claire River flows approximately down the dip of this major unconformity. Chemical weathering of underlying amphibolitic rocks engendered a highly impermeable green, illitic clay. Some of this weathering may have occurred after deposition of the sandstone by reaction of circulating groundwater with ferromagnesian minerals in the amphibolites. Groundwater circulating downward through the Mt. Simon Sandstone flows laterally along the clay layer until it comes out at the surface as a spring. Since the Precambrian-Cambrian unconformity is generally just above or below the level of the Eau Claire River, the river's major discharge is major from groundwater systems. Its discharge varies only slightly even during prolonged periods of drought

Figure 2 -- Structures in tonalite intrusion breccia at Little Falls

A. Breccia "dike" in amphibolite at location A (Fig. 1) Note rotation of amphibolite xenoliths when they become detached. Thin veinlets of tonalite penetrate layering in amphibolite. Is the light-colored, feldspathic fraction of anatectic origin? Scale is 6 inches long.

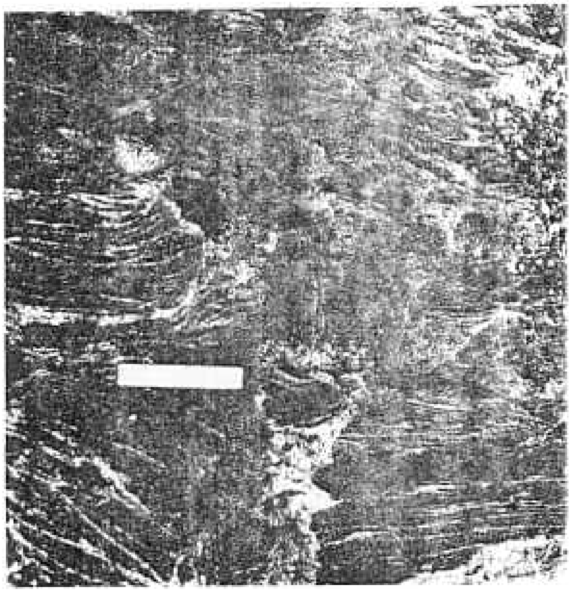
B. Anastomosing feldspathic stringers in amphibolite. Local contortion of cmphibolite and stringers suggests synkinematic anatexis and/or tonalite intrusion. Location H

C. Detail of massive and laminated amphibolite xenoliths in tonalite intrusion breccia at location D (Fig. 1)

D. Detail of mafic amphibolite xenoliths in hornblende tonalite matrix at location D (Fig. 1)

E. Fault zone cutting flow lamination in intrusion breccia at location C (Fig. 1) Right-lateral movement on this fault is indicated by drag of lamination into concordance with the fault. Quartz and epidote are concentrated along the zone of mylonite in the fault zone

F. Detail of shear displacement (right-lateral) of amphibolite xenolith at location C. (This structure is also visible in right side of photo E)



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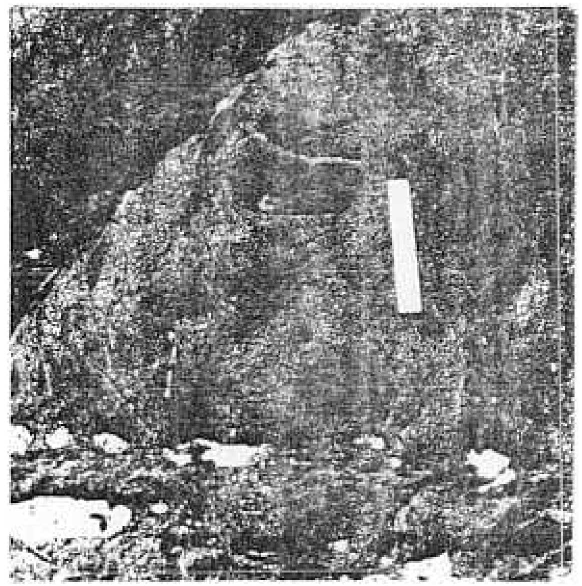
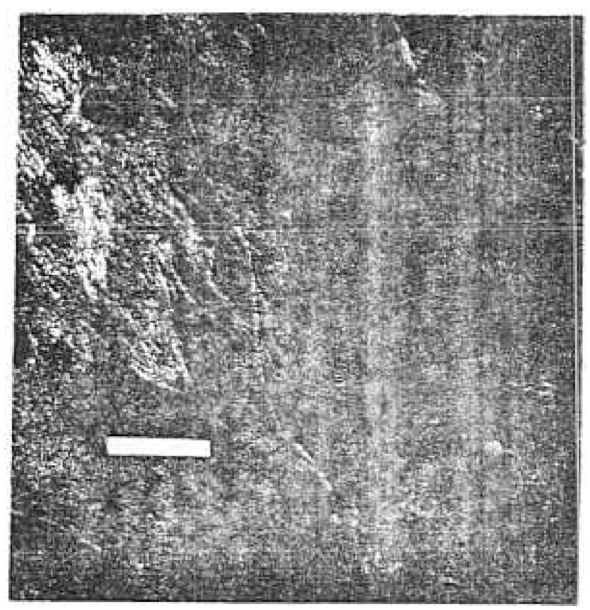




E.

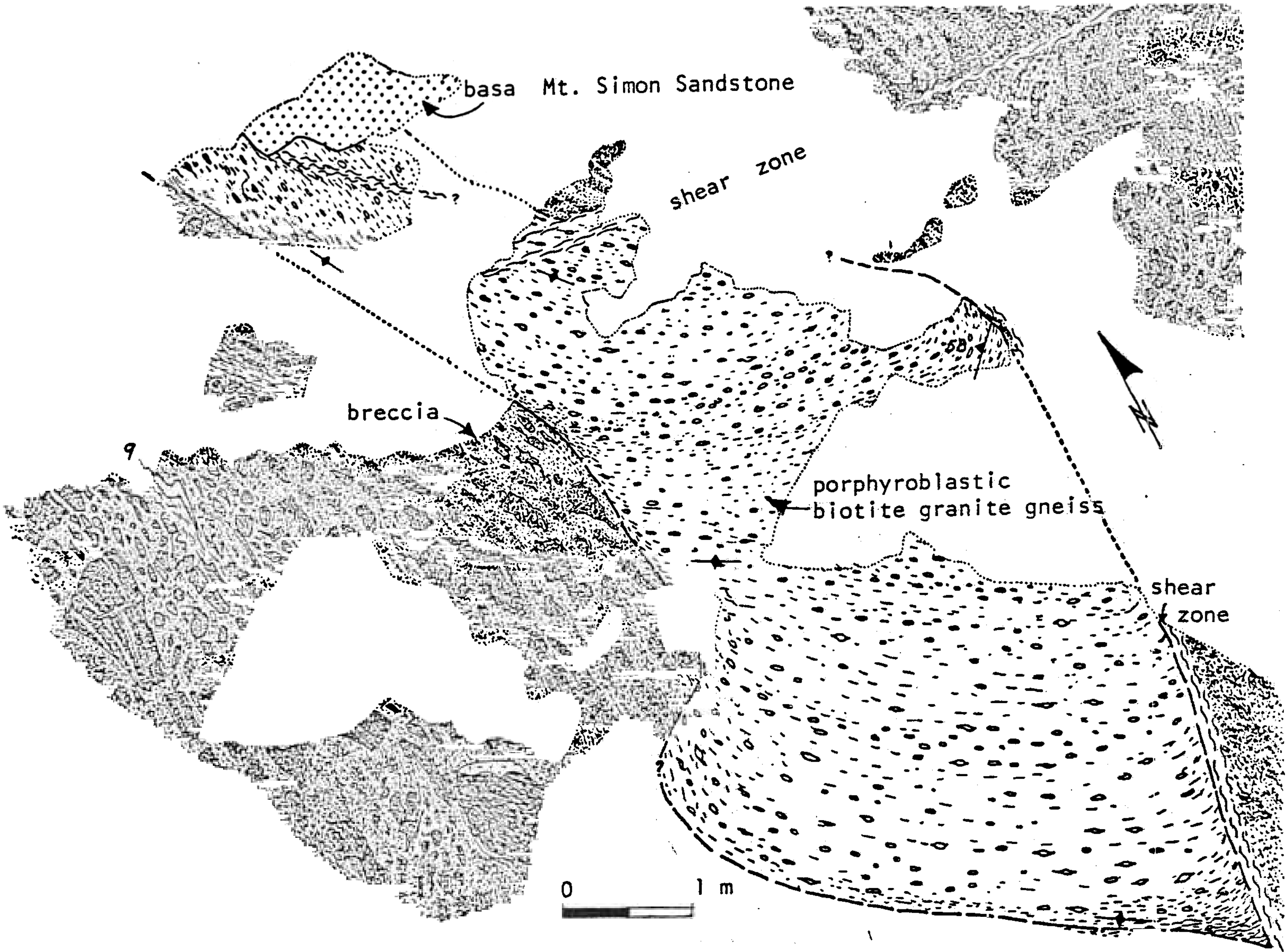
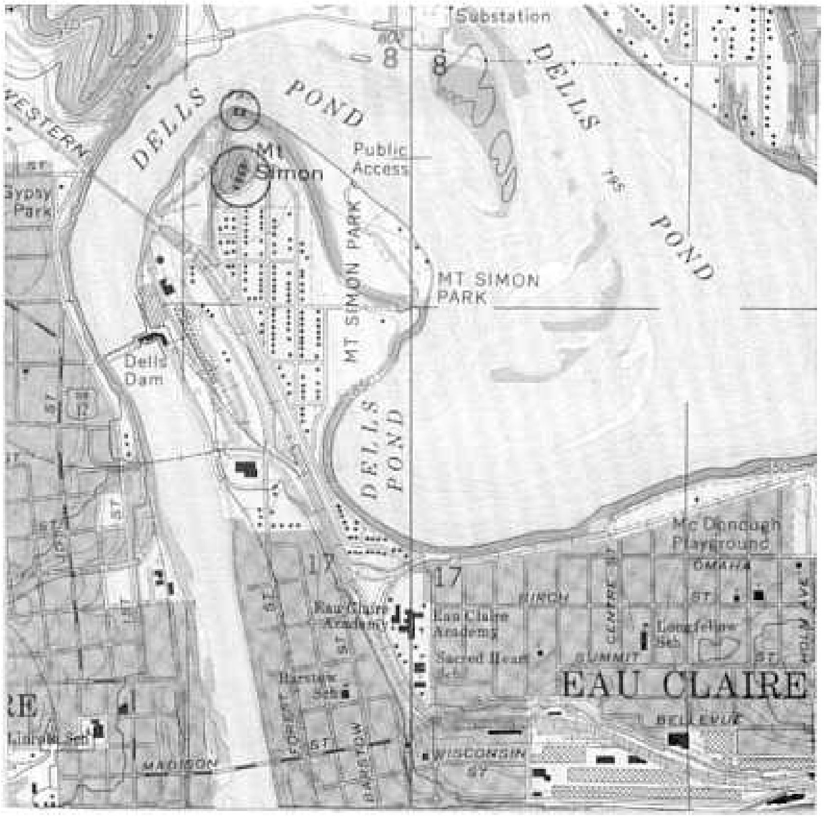


Figure 3 -- Deformed xenolith of porphyroblastic biotite granite gneiss in hornblende tonalite intrusion breccia (Location E on Fig. 2) Drag folded foliation along granite gneiss xenolith suggests frictional contact between the xenolith and flowing intrusion breccia. Note alignment of amphibolite xenoliths in the flow-laminated tonalite.

Title: Mt. Simon

Location: Type section of Mt. Simon Sandstone Formation. Exposure in bluff of Chippewa River and in hill called Mt. Simon in City of Eau Claire in the SW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 8, T.27N., R.9W., Eau Claire County (Elk Mound 7.5-minute topographic quadrangle, 1972). Section includes all rock exposed from top of hill called Mt. Simon northwest to base of river bluff.

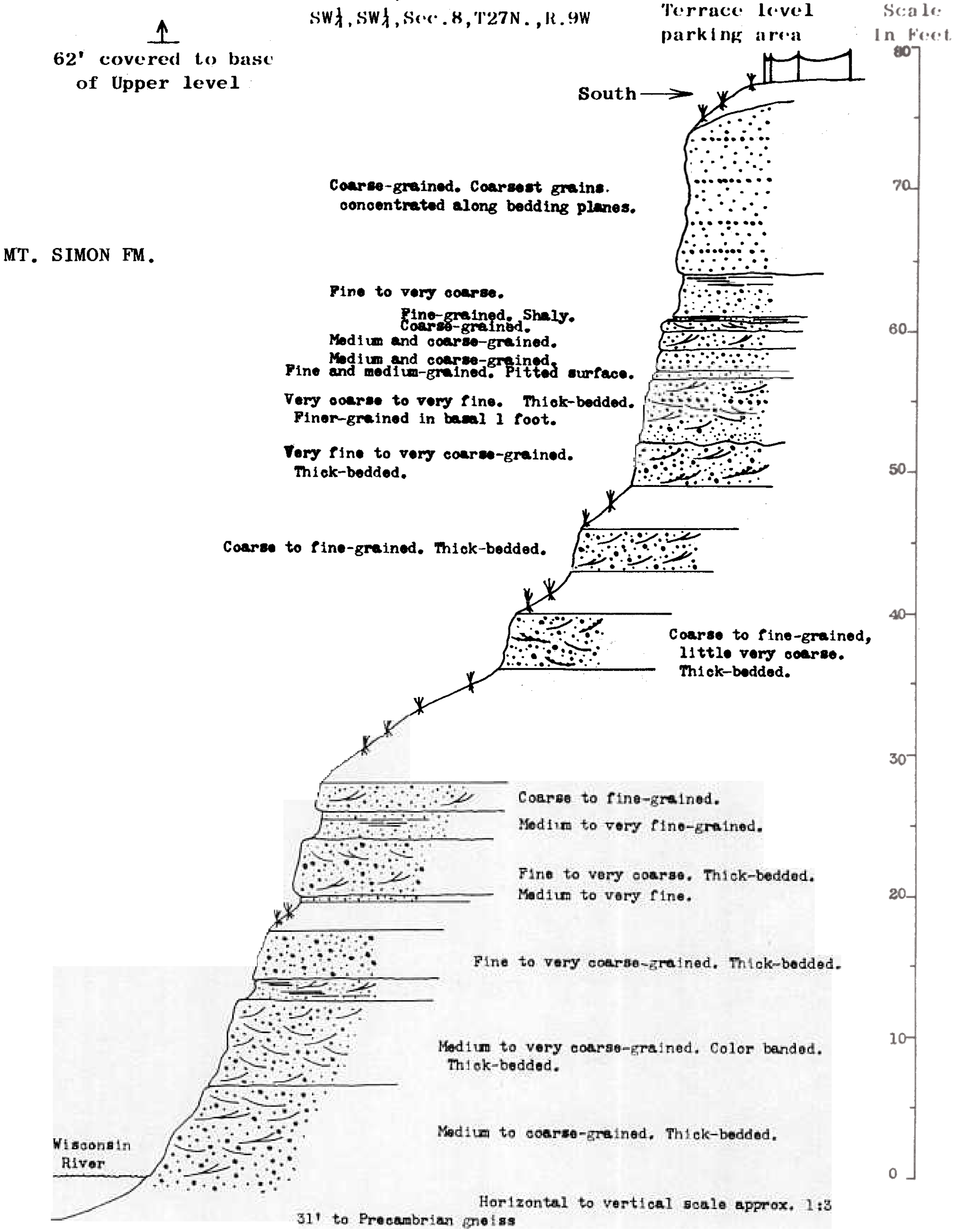


Author: M. E. Ostrom (modified from Ostrom, 1970)

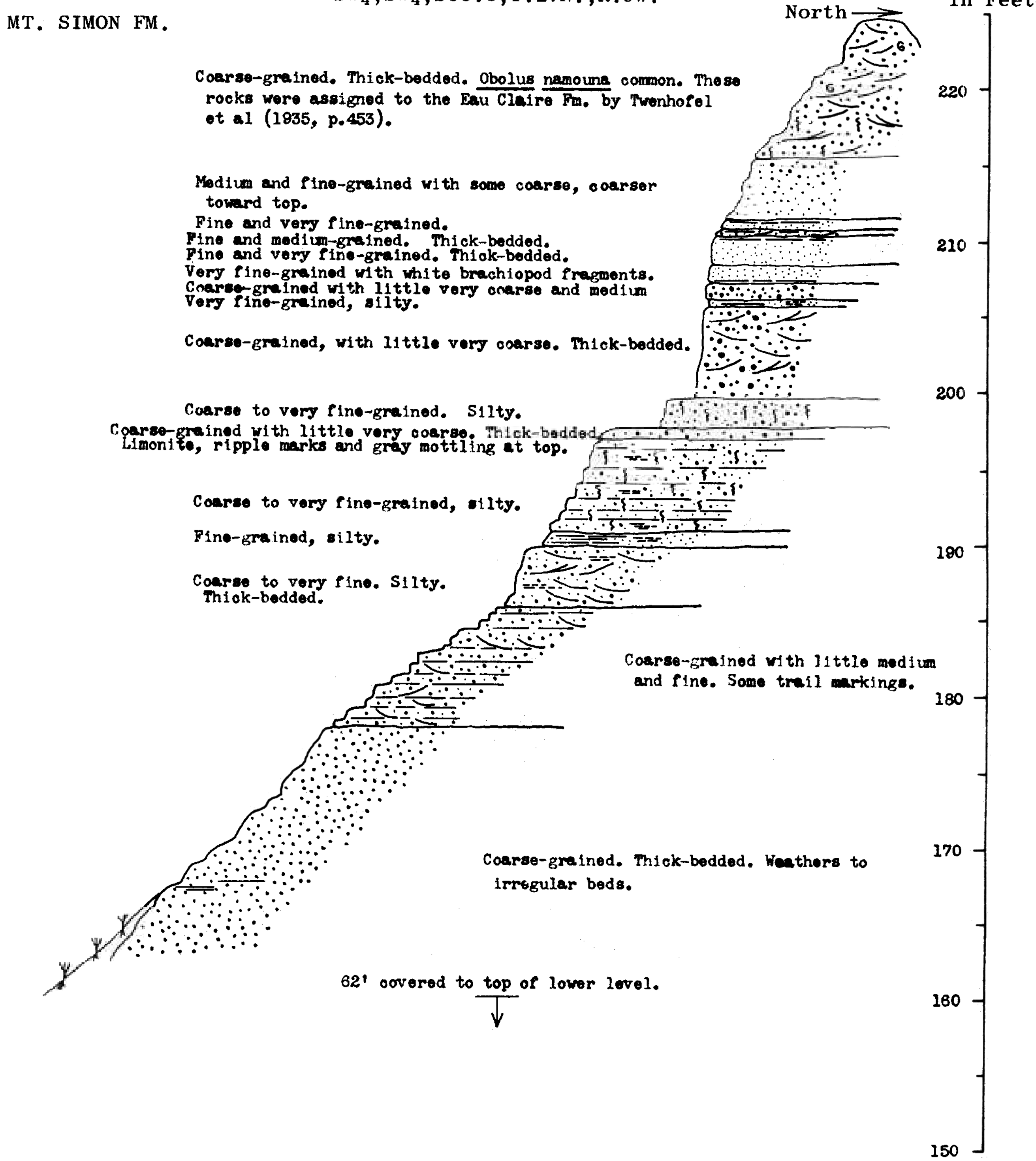
Description: The Mt. Simon Sandstone at this, its type exposure, grades upward from well-sorted, thick-bedded, coarse-grained, sandstone in the lower part to finer-grained, thinner-bedded, transitional beds at the top. Although the formation contains brachiopod shells in its upper few feet it is assigned to the Mt. Simon rather than the Eau Claire on the basis of lithologic similarity. The Mt. Simon is assigned a Dresbachian age because it is transitional with the overlying Eau Claire Formation which has a Dresbachian fauna (the tribolites Crepicephalus and Cedaria).

Previous mineralogical analyses of the Mt. Simon at this site indicate a range in feldspar content of from 2.06% to 5.0% (Stauffer & Thiel, 1941; Crowley & Thiel, 1940; Potter & Pryor, 1961). However, a study by Asthana (1968) sponsored by the Wisconsin Geological Survey shows that the range in feldspar content of samples collected at regular 5-foot intervals from this exposure is from 1.4%

MT. SIMON OUTCROP
Lower Level
SW¼,SW¼,Sec.8,T27N.,R.9W



MT. SIMON OUTCROP
Upper Level
SW$\frac{1}{4}$,SW$\frac{1}{4}$,Sec.8,T.27N.,R.9W.



Horizontal to vertical scale approx. 1:3

to 40.0% with an average of 17.5%. Combined plagioclase-microcline percentages range from 0.64% to 12.7%.

Predominant heavy minerals in the Mt. Simon Sandstone are ilmenite, leucoxene, zircon, tourmaline, and garnet (Tyler, 1936).

The overlying Eau Claire Formation where samples near its base at Mt. Washington (type section of the Eau Claire Formation) has a minimum feldspar content of 42% and a combined plagioclase/microcline content of 12%.

The only other mineralogical information available on the Eau Claire Formation is an analysis by Potter & Pryor (1961) which indicates 12.5% feldspar in outcrops near Merrillan in northwestern Jackson County. Other analyses from scattered outcrops of the Eau Claire show variable amounts of tourmaline and zircon, ilmenite, magnetite, and garnet, but all are present.

Of particular interest at this exposure are the transitional beds which are also well-exposed at the Rest Haven Gardens Town Road exposure south of the Eau Claire city limits. These have been recognized at many outcrops in this vicinity but have not been traced to other areas due to lack of outcrops revealing this part of the section.

The transition beds are believed to have formed in a nearshore marine environment located seaward of the beach. The transition beds are characterized by wide range in grain size from clay to very coarse sand and granules, well-defined bedding, different lithology from bed to bed, uniform lithology of individual beds, and by vertical burrows which are confined to certain beds.

Significance: The lithologic character of the Mt. Simon Formation and its stratigraphic boundaries are illustrated by this stop. Note compositional and textural characteristics, especially those from the lower 170 feet of exposure to the upper 50 feet.

What differences do you observe in terms of mineralogy, texture, sedimentary structures, and evidence of life? What is the significance of these differences? Have you seen sandstones with these characteristics at previous stops?

References: Tyler, 1936; Crowley & Thiel, 1940; Stauffer & Thiel, 1941; Potter & Pryor, 1961; Ostrom, 1966 & 1970; Asthana, 1968.

The Mount Simon Formation at Eau Claire, Wisconsin

M. E. Ostrom, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin 53705

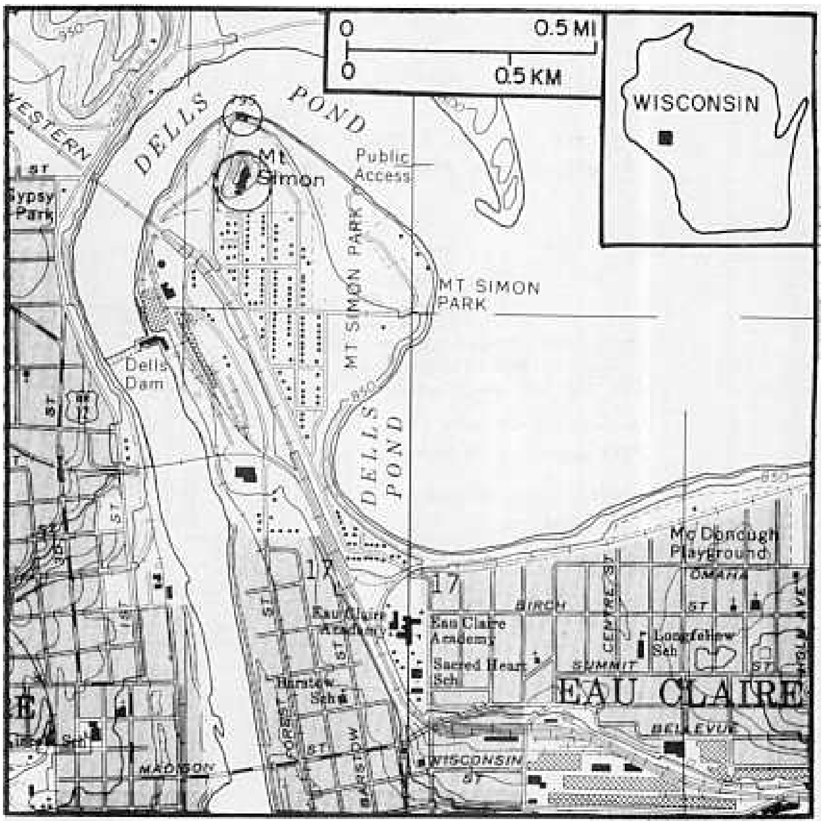


Figure 1. Map showing location of exposures discussed in text.

LOCATION

Exposure in bluff of Chippewa River and in hill called Mount Simon in City of Eau Claire (Fig. 1), in the SW¼SW¼Sec.8,T.27N.,R.9W., Eau Claire County (Elk Mound 7½-minute Quadrangle). Section includes all rock exposed from top of hill called Mount Simon northwest to base of river bluff.

SIGNIFICANCE

This is the type section of the Mount Simon Formation. The lithologic character of the Mount Simon Formation and its stratigraphic boundaries are illustrated in Figure 2.

DESCRIPTION

The Mount Simon Formation here grades upward from well-sorted, thick-bedded, coarse-grained sandstone in the lower part to finer grained, thinner bedded, transitional beds at the top. Although the section contains brachiopod shells in the upper few feet, these beds are assigned to the Mount Simon rather than the Eau Claire Formation on the basis of lithologic similarity. The Mount Simon is assigned a Dresbachian age because it is transitional with the overlying Eau Claire Formation, which has a Dresbachian fauna (the trilobites *Cedaria* and *Crepicephalus*).

Previous mineralogical analyses of the Mount Simon at this site indicate a range in feldspar content of from 2.06 to 5.0 percent (Stauffer and Thiel, 1941; Crowley and Thiel, 1940; Potter and Pryor, 1961). However, a study by Asthana (1969) shows that the range in feldspar content of samples collected at regular 5-ft (1.5 m) intervals from the exposure is from 1.4 to 40.0 percent with an average of 17.5 percent. Combined plagioclase-microcline percentages range from 0.64 to 12.7 percent.

Predominant heavy minerals in the Mount Simon Sandstone are ilmenite, leucoxene, zircon, tourmaline, and garnet (Tyler, 1936).

The overlying Eau Claire Formation, where sampled near its base at Mount Washington (type section of the Eau Claire Formation), has a minimum feldspar content of 42 percent and a combined plagioclase/microcline content of 12 percent.

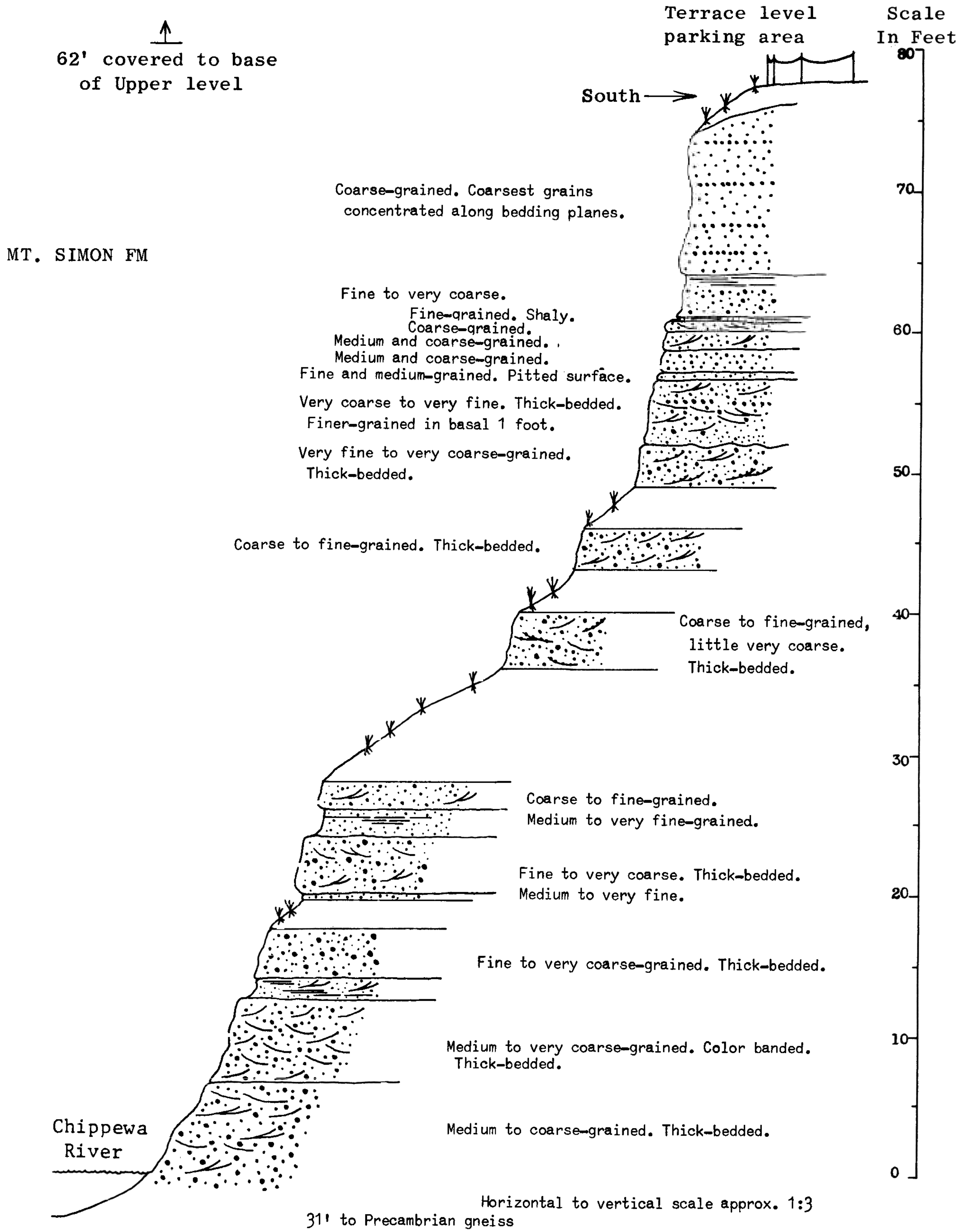
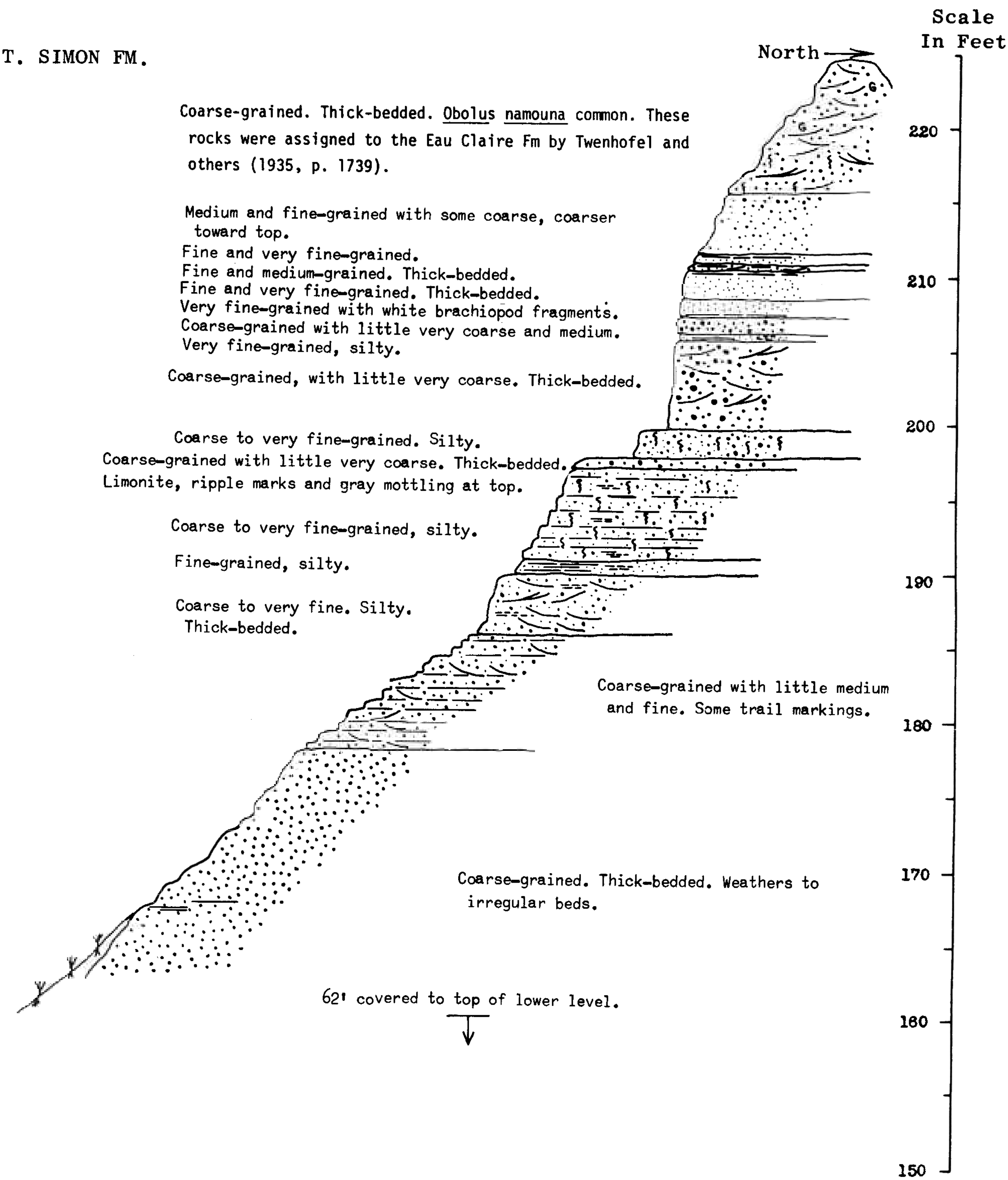


Figure 2. Stratigraphy of Mount Simon Formation in its type section.

MT. SIMON FM.



Horizontal to vertical scale approx. 1:3

The only other mineralogical information available on the Eau Claire Formation is an analysis by Potter and Pryor (1961) that indicates 12.5 percent feldspar in outcrops near Merrillan in northwestern Jackson County. Other analyses from scattered outcrops of the Eau Claire show variable amounts of tourmaline, zircon, ilmenite, magnetite, and garnet.

Of particular interest at this exposure are the transitional beds, which are also well exposed at the Rest Haven Gardens Town Road exposure south of the Eau Claire city limits (Ostrom, 1966, 1970). These beds have been recognized at many outcrops in this vicinity, but have not been traced to other areas due to lack of outcrops of this part of the section.

The transition beds are believed to have formed in a near-shore marine environment located seaward of the beach. The transition beds are characterized by a wide range in grain size from clay to very coarse sand and granules, well-defined bedding, different lithology from bed to bed, uniform lithology of individual beds, and by vertical burrows that are confined to certain beds.

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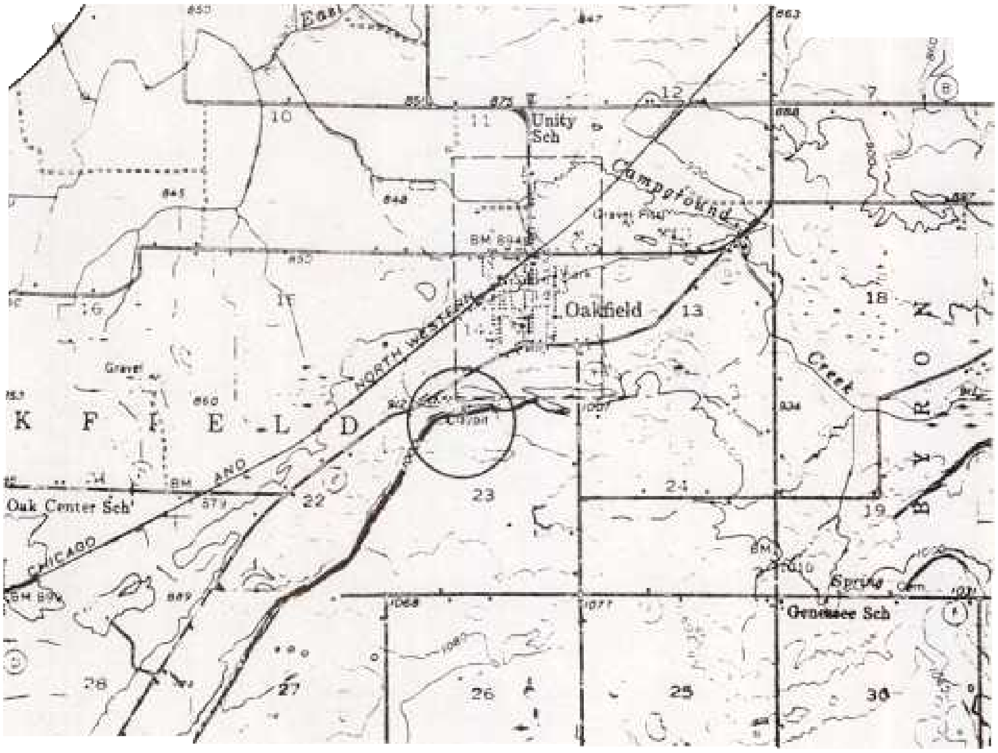
Tyler, S. A., 1936, Heavy minerals of the St. Peter Sandstone in Wisconsin: Journal of Sedimentary Petrology, v. 6, p. 77–79.

Title: The Maquoketa Shale

Location: Oakfield Brick Plant, Oakfield, Wis.
Sec. 23, T.14N., R.16E. (Fond du Lac Co.
Get permission from



Author: Gene L LaBerge (modified from Gutoski, 1976, and Gavin, 1976)

Description: The Maquoketa Shale was named from exposures along the Little Maquoketa River about 12 miles west of Dubuque, Iowa, by White (1870). In the type area it is a blue or gray dolomitic, silty, fissile shale with some gray-buff, medium grained, argillaceous dolomite layers and lenses. It ranges in thickness from 108 to 240 feet. The Maquoketa was subdivided into three members by Templeton and Willman (1963). They are, in ascending order, the Scales (shale), the Fort Atkinson (dolomitic), and the Brainerd (shale) members. The Scales is approximately 100 feet thick, the Fort Atkinson about 40 feet, and the Brainert about 100 feet thick. The Maquoketa is very fossiliferous locally with Late Ordovician brachiopods, bryozoa, graptolites, trilobites, and conodonts.

This quarry exposes 22 feet of the Fort Atkinson member and 35 feet of the Scales member. The Scales member forms the main exposure and is typical of the formation. It is a soft, fissile, thin bedded, dark gray shale, weathering light gray to tan. The Scales is very pure here, containing dominantly clay minerals, hence the feasibility of a brick plant. Fossils are not generally abundant, but the upper few feet of the

Scales contains well preserved brachiopods and bryozoans. The gradational contact between the Scales and the overlying Fort Atkinson is exposed in the excavated ledge at the northeast end of the pit.

The Fort Atkinson member consists of tan-colored, thinly beeded, medium- to coarse-grained argillaceous dolomite layers interbedded with gray shaley layers. Numerous lenses and pods of clay are contained in the dolomite which appear to be "rip-ups" of shale incorporated in the dolomite, possibly formed when storm waves stirred up the bottom. Fossils are abundant in the dolomite, but are poorly preserved.

The Maquoketa Shale is used for the manufacture of bricks by the Oakfield Brick and Tile Company. The shale is blasted from the walls, crushed to a fine size, and screened. The fine powder is then mixed with water in a "pug mill" and extruded through a rectangular opening the size of bricks. It is cut by a wire into "slabs" the thickness of bricks and placed on pallets. The raw bricks are dried in the drier tunnels for about 72 hours at 400°C to drive all excess water off the bricks. They are then fired in the bee hive kilns at 1800°F (for building brick) or 2200°C (for facing brick). The firing converts the hydrous clay minerals to anhydrous oxides. The relatively high lime content of the Maquoketa (±15% CaO) results in buff-colored bricks.

The prominent ridge south of the quarry is the late Early Silurian Mayville Dolomite of the Niagara Escarpment. The Maquoketa exposed here was protected from erosion by the capping of resistant dolomite.

Significance: The Maquoketa Shale is the result of two phenomena: 1) major tectonic activity in the northern Appalachian geosyncline, and 2) major transgression of the epeiric seas over the continent. Throughout the Late Cambrian and Ordovician, the seas advanced and withdrew from Wisconsin at least five times (as we will see later). Evidence from sediment distribution patterns suggests that Wisconsin was a land area during much of the time. However, during Late Ordovician time, the seas had transgressed over almost the entire continent. It was during this maximum transgression that the Maquoketa Shale was deposited.

The Late Ordovician was also the time of the first major deformation of the eugeosynclinal portion of the Appalachian geosyncline, called the Taconian Orogeny. The deformation elevated parts of New England above sea level and exposed the sediments to erosion. Streams flowing westward off the Taconic Mountains carried great volumes of sediments into the shallow seas covering the interior of North America. This produced a large delta and alluvial plain of sediments to the west known as the Queenston Delta. Although the sand and silt were deposited mainly in New York and Pennsylvania, the finer muds were carried as far west as Iowa. Thus, the Maquoketa Shale is at the western end of a large delta extending westward from New York.

The Maquoketa Shale has been very important in shaping the topography of eastern Wisconsin. It is easily eroded, but is underlain and overlain by resistant dolomites. The removal of the Maquoketa by pre-glacial streams and Pleistocene glaciers has produced a broad lowland extending from Green Bay through Lake Winnebago and Horicon Marsh down the Rock River Valley to Illinois. The lowland is nearly 20 miles wide and is underlain by the Galena Dolomite of the Sinnippee Group. On the east the lowland is bounded by the prominent Niagaran Cuesta formed by the Silurian dolomites.

South of the brick plant, a road leads to an abandoned dolomite quarry that affords an excellent view of the lowland. The terminal moraine of the Valders(?) ice lies just north of Oakfield.

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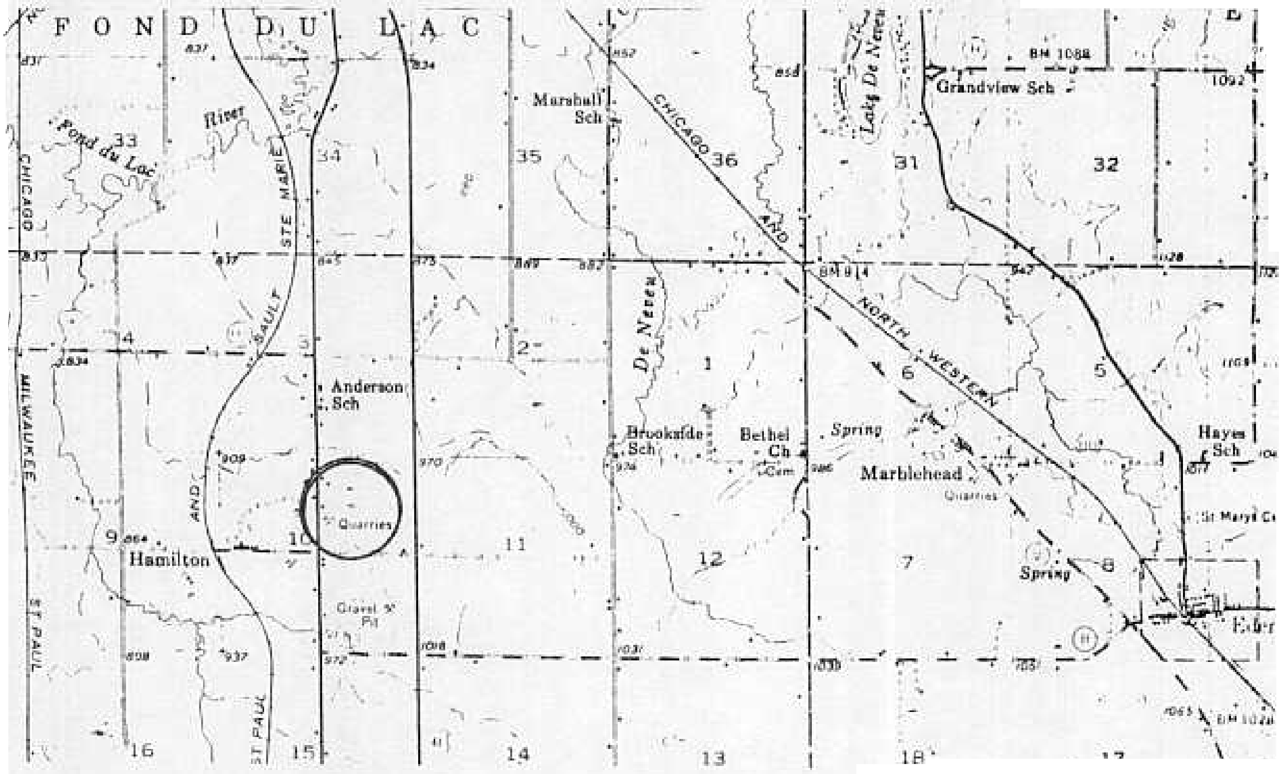
Title: Silurian dolomites of eastern Wisconsin

Location: Panetti Stone Quarry, NE¼, Sec. 10, T.14N., R.17E.
Get permission from John Panetti, Fond du Lac Stone Co
Fond du Lac, WI, (Phone: 414-922-4790).



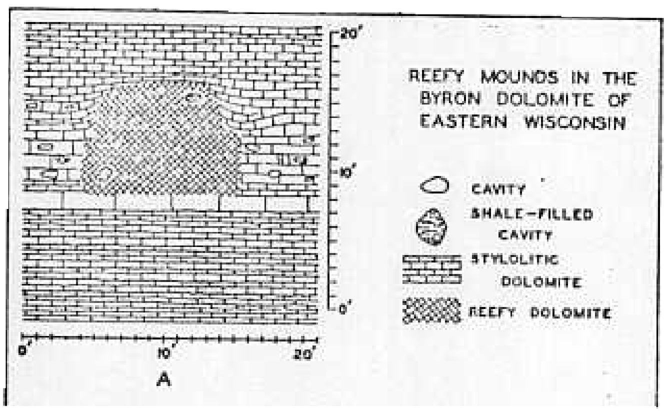
Author: Gene L. LaBerge (modified from Froemke, 1976)

Description: This quarry is in the lower part of the Middle Silurian dolomite. The Silurian in eastern Wisconsin consists almost entirely of dolomite which has been divided into six formations -- the Mayville, Byron, Hendricks, Manistique, Racine, and Waubakee Dolomites in ascending order (Ostrom, 1967). The formations exposed at this quarry are the Mayville Dolomite of late Alexandrian age and Byron Dolomite of Niagaran age. The Mayville is a thick bedded, cherty, fossiliferous, pink dolomite containing numerous domal structures generally believed to be "reef mounds" (bioherms). The bedding draped over the mounds produces the irregularities in the quarry floor. The Byron is a thinly bedded, semi-lithographic, buff to gray dolomite with scattered small bioherms (Shrock, 1939).

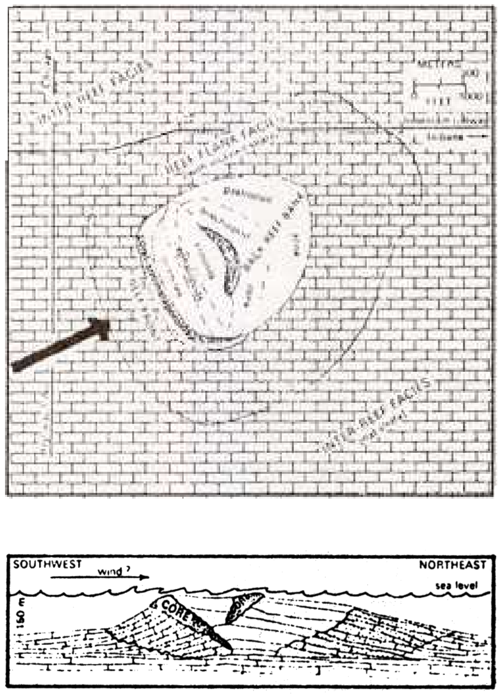
Blatt, Middleton and Murray (1972, pp. 410-411) define a bioherm as a mound of carbonate mud with larger skeletal fragments "floating" in the carbonate mud. Shrock (1939) described the Silurian bioherms in eastern Wisconsin as cuboidal, domal, or ridge-like masses of porous and cavernous crudely bedded, barren to highly fossiliferous dolomites that grade laterally and vertically into well-bedded dense to saccaroidal, relatively unfossiliferous dolomite. The bioherms range in size from mounds 10 feet high and 30 feet in diameter to ridge-like masses a quarter of a mile long. Those visible in this quarry are mainly small mounds of massive, clay-rich, unfossiliferous dolomite. One is visible on the south wall of the quarry; another on the west quarry wall. The bioherms are best developed in the upper part of the Mayville and lower Byron formations. Shrock (1939) concludes that they began forming in late Mayville time and continued growing into early Byron time.

The bioherms are different from typical Silurian reefs in that they lack the various reef facies. They may also form differently, or in a different environment than true reefs. In typical reefs (such as exposed in the Thorton quarry SE of Chicago (Ingels, 1963) and Quarry Park at Racine (Paull & Paull, 1977, pp. 170-171)), the various reef facies are revealed clearly by both lithology and fossil communities. Stromatoporoids and corals built the main wave-resistant core, while crinoids, mollusks and brachiopods dominated the back-reef and flanking deposits. During maximum development, the reefs assumed an atoll-like pattern (Ingels, 1963) restricting circulation in the Michigan Basin which resulted in accumulation of layers of salt as much as 100 feet thick. The Silurian contains the first coral reefs in the geologic record. In contrast, the diminutive bioherms exhibit little evidence of wave resistance, and also lack the facies characteristic of reefs. Furthermore, conclusive evidence of a rigid framework does not exist in most of the Silurian bioherms. Soderman and Carozzi (1963) suggested that the bioherms developed as a product of a constructing algae living in a relatively quiet, non-subsiding environment.

The diagrams illustrate the differences.



Diagrammatic cross-section of typical bioherm. (From Shrock, 1939.)



Diagrammatic map and cross-section of a typical Niagaran reef. Note difference between reef and bioherm. (From Ingels, 1963)

Question: If the bioherms are not reefs, what causes the massive mound-like structure?

At the Marblehead Quarry about 3 miles east of here, a highly fossiliferous horizon (a biostrome) approximately 20 feet thick extends laterally for hundreds of yards at the top of the Mayville. The most abundant fossils are internal molds of the pentameroid brachiopod *Virgiana decussata* (Whiteaves), along with algal stromatolites, simple corals and *Favosites* (Froemke, 1976). The biostrome is one of many at this horizon throughout the Great Lakes region (Ehlers & Kesling, 1947). They appear to have been shoals of brachiopod shells in relatively shallow parts of the basin variably bonded together by algal and coral growth. The genetic relationship between the biostromes and bioherms and coral reefs is not clear.

Along the west wall of the quarry are two structures in the Mayville Dolomite. The northernmost of these is triangular in the section exposed with the beds dipping inward to form a small syncline. The lowermost beds are brecciated and the fold narrows upward, terminating abruptly at the apex with flat-lying beds overlying the structure. The bedding within the structure is more apparent and appears to be thinner than in the adjacent dolomite. This feature is an excellent example of the "pitch and flat" structure we will examine in connection with the lead-zinc deposits in southwestern Wisconsin. Sketch the structure and compare it with one we will see near Platteville.

Several hundred feet south of the synclinal "pitch and flat" structure is a small tight fold in the thin-bedded dolomite. The fold plunges westward, and a small fault occurs near the axis of the anticlinal portion of the fold. Like the syncline described above, the fold dies out upward. What is the origin of these structures? Are they penecontemporaneous slump of carbonate mud off topographic ridges (bioherms?)? Are the later features produced by collapse of a cave in the underlying dolomite? The fact that the thin beds within the structures seem to be pulled apart vertically suggests that collapse of an underlying cave may be a more plausible explanation.

The dolomite in the quarries here has a variety of uses. The thin-bedded dolomite is broken along the bedding planes and then cut into blocks for building stone. The massive dolomite is not suitable for building stone, but is crushed and used for road or concrete aggregate. Some is also crushed to a fine powder and heated to convert it into lime and used for agricultural purposes. Lime is used as a soil conditioner to reduce soil acidity and to improve the texture of the soil.

Significance: The Silurian dolomites form a resistant unit up to six hundred feet thick that extends throughout eastern Wisconsin and continues eastward around the northern end of Lakes Michigan and Huron to Niagara Falls between Lakes Erie & Ontario. The dolomite overlies several hundred feet of Maquoketa Shale which is easily eroded. The western edge of the east-dipping dolomite forms an excellent example of a cuesta, with the ridge of dolomite bounded on the west by a broad lowland.

The Silurian dolomites here rest unconformably on the Maquoketa Shale, or Neda Formation of Late Ordovician age. The Mayville Dolomite is late Early Silurian (Alexandrian) age. Thus, most of the Early Silurian is missing in eastern Wisconsin (unless the Neda Formation is Early Silurian). The deposition of rather pure dolomite directly on shales on a regional erosion surface poses a problem. Why were no clastic sediments deposited in the Silurian seas in this area? Was the erosion of the underlying sediments done on a land surface? If so, why was the soft Maquoketa Shale still preserved? And why was dolomite deposited instead of clastic sediments when the sea again advanced over the area in Middle Silurian time? Was the erosion at the top of the Maquoketa accomplished in a submarine environment by an off-shore buckle roughly analogous to the Bahama Banks? If this was the case, a deepening of the sea to allow the accumulation of lime mud may account for the Mayville Dolomite resting unconformably on the Maquoketa.

Another interesting problem related to the Silurian (and other) carbonate rocks of Wisconsin is the origin of dolomites. Since dolomite does not precipitate in any appreciable quantity from sea water, the rocks must have been converted to dolomite from limestones. When were these rocks dolomitized? During, or shortly after, deposition? During diagenesis? During weathering? Silurian carbonates are not uniformly dolomitized, so age alone does not produce dolomite. Were these rocks initially limestones with an abnormally high magnesium content, making them more easily dolomitized?

Answers to these questions are not readily forthcoming, yet they are important to consider in explaining the nature and origin of these rocks.

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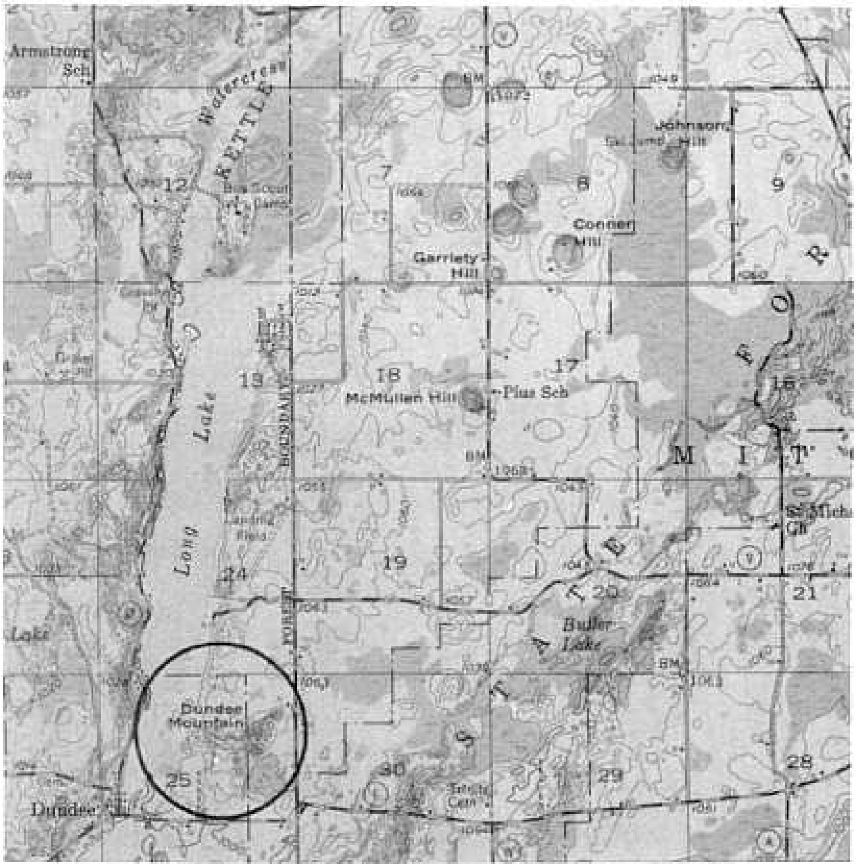
Title: Dundee Mountain

Location: NE 1/4, Sec. 25, T. 14 N., R. 19 E., Kewauskum 15' Quadrangle, Fond du Lac Dounty Park along road.



Author: David M. Mickelson

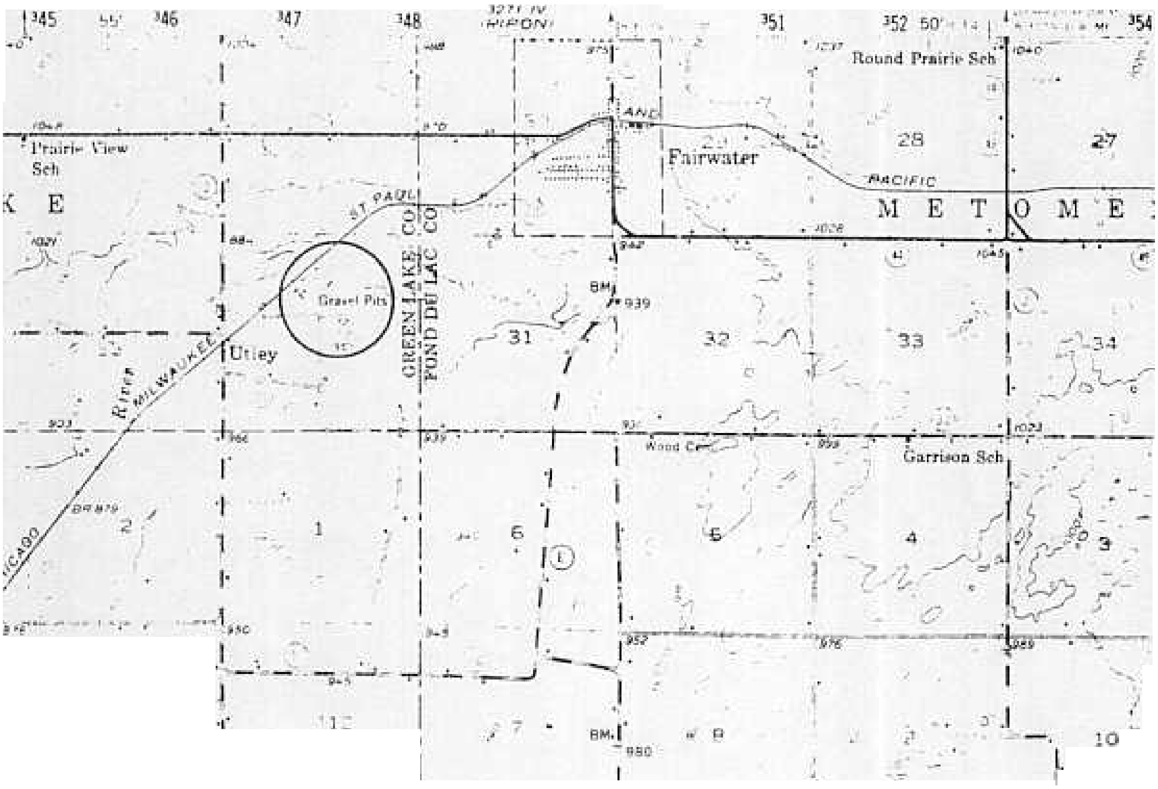
Description: Like Garriety Hill and others in the vicinity, Dundee Mountain is a kame. It is not symmetrical, however, but elongate in the east-west direction. The elongation simply reflects the shape, controlled by crevasses, of the depression in the ice surface into which materials were deposited. The irregular shape of the kame is much more typical of kames in general than the symmetrical, conical hills in the vicinity (see Garriety Hill).

Significance: This is another excellent example of a moulin kame. Picture in your mind the way it formed. Note that the parking lot which was here has been closed. This is because off-road vehicles were ripping up vegetation and greatly increasing erosion on the northwest face of the kame.

References: Alden, 1918; Black, 1971, 1974

Title: The Utley Rhyolite

Location: NW¼, SW¼, NE¼, Sec. 36, T.14N., R.13E. (Fox Lake 15 Min. Quad.) Green Lake County. Get permission from Lester Schwartz, Art Dept., Ripon College, Ripon, Wisconsin. Phone: 748-8106.

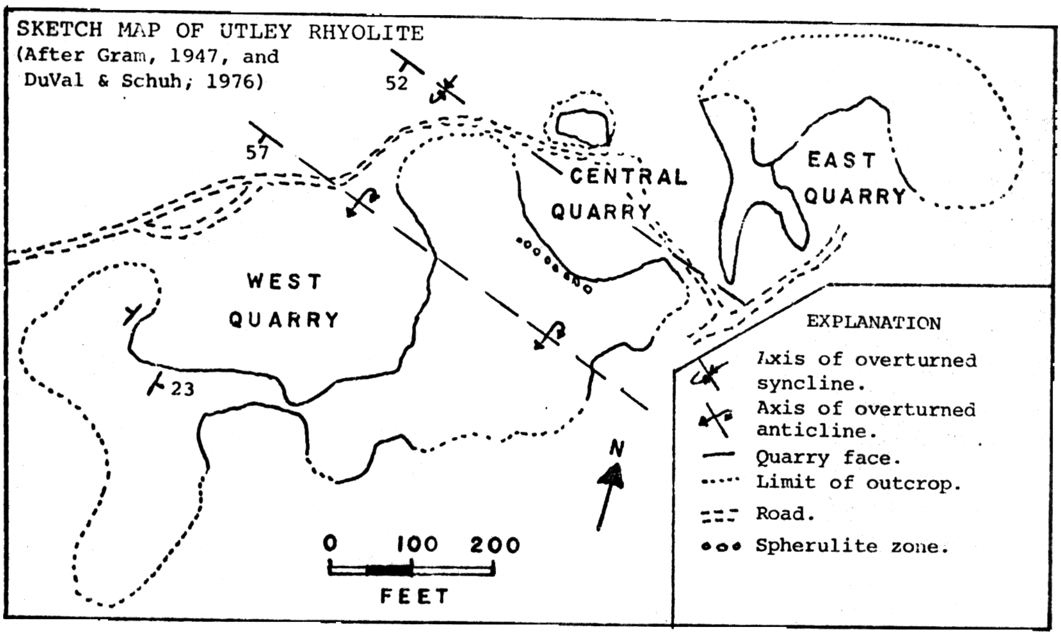


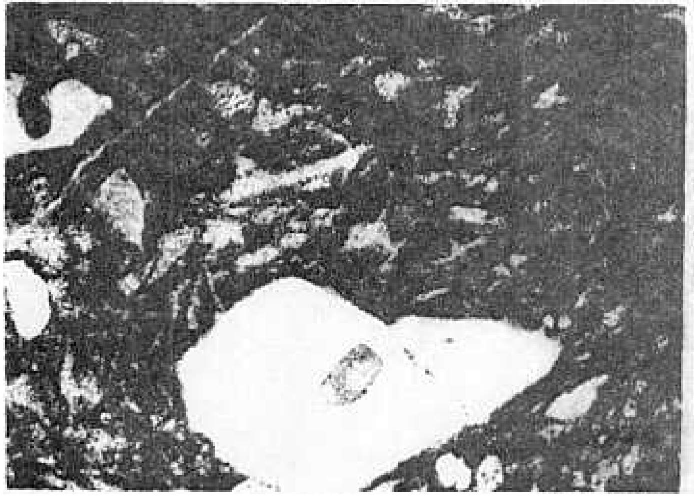
Author: Gene L. LaBerge

Description: The Utley Rhyolite is one of ten isolated knobs of Precambrian igneous rocks (mainly rhyolites) that protrude through the Paleozoic cover in southeastern Wisconsin. The inliers extend from Berlin southwestward to the Baraboo area. The rhyolites stood as prominent hills on the Precambrian surface, and were rocky islands in the lower Paleozoic seas for nearly a hundred million years. The Utley rhyolite was largely (or entirely) buried by the Prairie du Chien Dolomite, but was partially exhumed during the erosion during a regression of the Middle Ordovician sea shortly thereafter. The advance of the sea over this unconformity resulted in the deposition of St. Peter sandstone in a channel cut into the Prairie du Chien. The large sand quarry just east of the rhyolite is in this channel filling of St. Peter sandstone. The rhyolite was buried again by the St. Peter and Platteville Dolomites and is being exhumed again by erosion.

The dark color of the Utley Rhyolite is typical of most Precambrian rhyolites in Wisconsin. Quartz and feldspar phenocrysts are abundant and present in about equal amounts. The matrix is an aphanitic mixture of quartz and feldspar. Weidman (1898) interpreted this rock as a meta-rhyolite, Gram (1952) interpreted it as a tuff and Asquith (1964) interpreted it as a welded tuff. Smith (1974, 1975, in press) has shown that the various rhyolites in southern Wisconsin formed from ash-flow deposits and chemically are genetically related. Fragmental texture is visible on the weathered surface at a number of places in the quarry. A distinctive zone of "spherulites" on the top of the west wall of the central quarry (see map) trends northwesterly. Gram (1947) concluded that the structure in the quarry consists of a northwesterly trending anticline and syncline. However, the structure has not been worked out in detail, and may be more complex. The rhyolites here illustrate well the problems of mapping structures in Precambrian volcanic rocks. Can you recognize any distinctive zones or features that show the structure?

Microscopically, the rhyolites here show remarkably well preserved shard structures (see photos), some of which are deformed (flattened), others are not. The deformed shards indicate that these are welded tuffs. Many of the quartz phenocrysts are embayed, indicating that the crystals were beginning to melt as a result of changing conditions in the magma (mainly a loss of volatiles) during and after extrusion. The abundance of shards and broken phenocrysts attests to the violent eruption that formed the deposit.





Undeformed shard fragments (white) with quartz phenocryst in rhyolite tuff from Utley. x25.

Flattened shards and broken phenocrysts in welded tuff from Utley. x25.

Significance: The rocks at Utley and other localities in south central Wisconsin are welded tuffs that formed as a result of extremely violent eruptions common to rhyolitic volcanoes. The resulting ash-flow deposits are widespread deposits. The following summary is summarized, in part, from the U.S. Geological Survey Atlas of Volcanic Phenomena (1971). A mass of granitic magma forms near the base of the crust, perhaps 30 miles deep in the earth. The magma contains up to 10% volatiles, mainly water vapor dissolved in the magma. The magma is lighter than the surrounding rocks and rises slowly through the crust. As it approaches the earth's surface, the area above the rising magma is domed, and circular to elliptical fractures are formed. The central area subsides somewhat on the ring of fractures. Some of the magma escapes to the surface along the ring of fractures, building a series of small andesitic and rhyolitic cones.

The rising magma eventually reaches a level in the crust where the pressure of the dissolved gases exceeds that of the overlying rocks. The result is a violent expansion of the gas, frothing and fragmenting the magma, and driving it upward to the surface where it bursts forth along the circular fractures as a seething mixture of gas-charged dust, ash and pumice. This exceptionally fluid gas-solid mixture expands with hurricane force, streams down valleys and around hills, spreads out over low areas, and comes to rest as a great sheet of steaming ash-flow tuff. Repeated eruptions, adding sheet upon sheet of tuff, build an ash-flow field hundreds to thousands of feet thick that covers several thousand square miles.

As the upper part of the magma chamber is drained by the eruptions, the crust in the central part of the area collapses to create a huge circular depression called a caldera. Following the collapse some ash is ejected along the ring fractures to form ash cones. The final phase is the eruption of viscous rhyolite, largely depleted of gas, as a series of domes or spires.

The violence of the eruption is so great and the volcanic materials are so hot that many of the glassy volcanic fragments are still soft when the ash-flow sheet comes to rest. The fragments are commonly flattened and may partially melt ("weld") together to form very hard rocks called welded tuffs. Commonly, the bottom of an ash-flow unit is not welded because of the rapid cooling against the underlying land surface. And the top tends to be non-welded due to rapid loss of heat to the atmosphere. The central part of ash-flow units, however, may be so densely welded that they become a solid glassy obsidian.

The magma that cooled and crystallized below the surface formed bodies of granite, such as those now exposed at Redgranite and Montello. Smith (in press) shows that the rhyolites are nearly identical in chemical composition, indicating that they are part of the same magma. Van Schmus (1976) shows that both the granites and rhyolites originated about 1765 million years ago, perhaps during the waning stages of the Penokean Orogeny that affected most of northern Wisconsin. Van Schmus (1976) further shows that the rocks were subjected to a "thermal event" at 1650 m.y. ago that "reset" the Rb/Sr age of the rocks. Smith (in press) concludes that the sheets of ash flow rhyolite (and the Baraboo Quartzite) were folded during the 1650 m.y. event.

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Asquith, G. B., 1964, Origin of Precambrian Wisconsin Rhyolites: Jour. Geology, Vol. 72, pp. 835-847.

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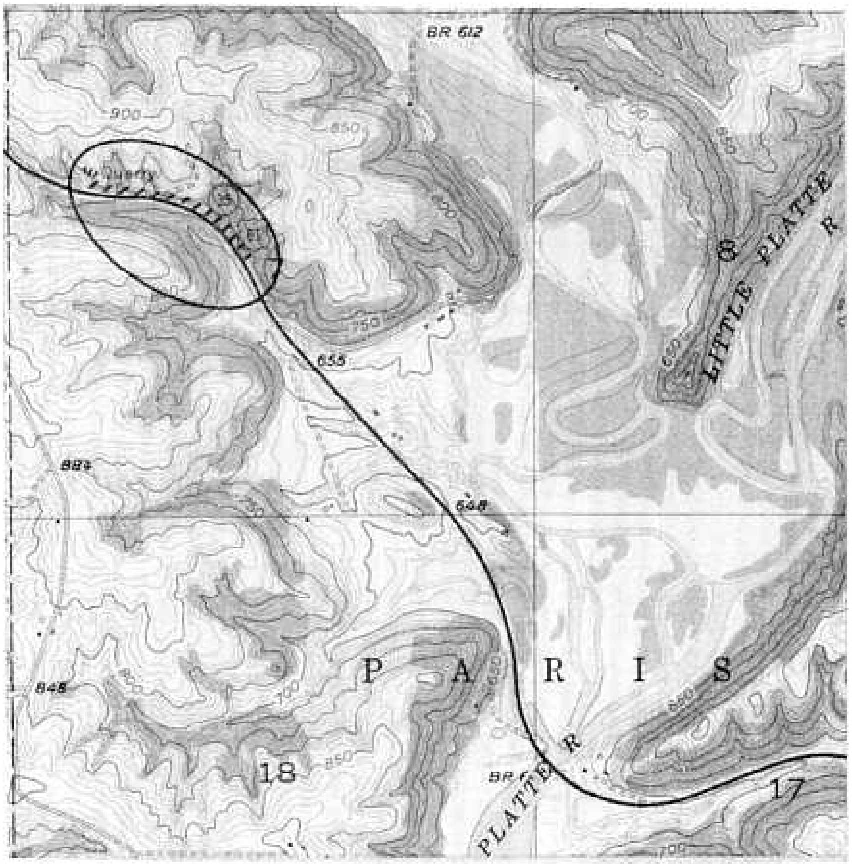
Smith, E. I., (in press), Precambrian Rhyolites and Granites in South Central Wisconsin: Field Relations and Geochemistry: Geol. Society of America Bulletin.

Van Schmus, W. R., Thurman, E. M., and Peterman, Z. E., 1975, Geology and Rb/Sr Chronology of Middle Precambrian Rocks in Eastern and Central Wisconsin: Geol. Soc. America Bull. Vol. 86, pp. 1255-1265.

Weidman, S., 1904, The Baraboo Iron-bearing District of Wisconsin: Wis. Geol. Nat. Hist. Survey Bull. 13, 190 p.

Title: Potosi Hill

Location: Roadcut at east side of U. S. Highway 61 in the SW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 7, T.2N., R.2W., Grant County. (Potosi 7.5-minute topographic quadrangle, 1972).



Author: M. E. Ostrom (modified from Cline et al, 1956, Kruse, 1970).

Description: The lower part of the section exposed here can be examined in closer detail at the Hoadley Hill Stop. The major emphasis here is focused on the upper part which includes the Spechts Ferry, Guttenberg, and Ion Members of the Decorah Shale Formation and the lower part of the Galena Dolomite Formation. The Quimbys Mill Member consists of purplish gray-brown, sublithographic, thick-bedded, conchoidally fractured limestone with uneven upper surface and shale at its base. It is called the "Glass Rock" locally because when broken, and when broken pieces are shaken together, it sounds like broken glass.

The Quimbys Mill is overlain by the Spechts Ferry Member which consists of fossiliferous, gray-brown limestone with green shale interbeds. At this exposure two thin beds of "metabentonite" occur near its base. Metabentonite is believed to be the product of alteration of volcanic ash dust. The metabentonites are orange to light reddish brown and about 2 inches thick.

The Spechts Ferry is overlain by the Guttenberg Limestone Member which consists of hard, finely crystalline, thin-bedded, fossiliferous, light brown, limestone with brown carbonaceous shale interbeds. The presence of these interbeds has led to the member being referred to as the "Oil Rock" in the southwest Wisconsin zinc-lead mineral district.

The Ion Dolomite Member overlies the Guttenberg. It is a gray to blue dolomite, medium-crystalline, and medium-to thick-bedded with green shale interbeds. It is locally called the "Blue".

The Galena Dolomite Formation overlies the Ion. It is a light buff to drab, cherty, thick-bedded, vuggy dolomite with medium to coarse sugary grains. The basal contact is gradational. A zone of *Prasopora insularis* Ulrich marks the top of the Ion Member in some areas. It is absent here.

Good fossil hunting in the Spechts Ferry and Guttenberg Members.

Near the north end of the roadcut there is a quarry in which can be seen an example of "pitch-and-flat" structure which is the main site of zinc and lead mineralization in the district. Here there is no mineralization.

Description of outcrop follows:

ORDOVICIAN SYSTEM

Galena Dolomite Formation
Cherty Unit

45.8' - 65.8'	20.0'	Dolomite, yellowish-buff, medium-to coarse-grained, vuggy, abundant white chert in upper 10'.

Decorah Formation (43.8 feet)

Ion Dolomite Member (19.5 feet)
(Gray unit)

38.3' - 45.8'	7.0'	Dolomite, buff, thick-to massive-bedded, vuggy, green shale partings throughout, sparry calcite present.
33.8' - 38.3'	5.0'	Covered interval.
32.8' - 33.8'	1.5'	Dolomite, buff, medium-grained, medium-bedded, with green shale partings.

(Blue unit)

27.2' - 32.3'	5.1'	Dolomite, purplish gray, medium-grained, slightly fossiliferous. Green shale present as partings, and as a 0.5' bed 0.8' below the top of the interval, calcite present.
26.3' - 27.2'	0.9'	Shale, green. 0.3 green dolomitic shale in middle of interval.

Guttenberg Limestone Member (15.3' feet)

- 26.3'	4.6'	Limestone, purplish brown, fine-grained to sublithographic, fossiliferous, upper 1' fine-to medium-grained, brown shale present as partings, calcite and limonite after iron sulfide present in small amounts.
21.6' - 21.7'	0.1'	Metabentonite, brownish orange, crumbly, sticky when wet.
12.0' - 21.6'	9.6'	Limestone, purplish brown, sublithographic, thin-wavey-bedded, fossiliferous, brown carbonaceous shale present as thin beds and partings, calcite and limonite present.
11.0' - 12.0'	1.0'	Limestone, brown-gray, fine-grained, thick-bedded

Spechts Ferry Shale Member (9.0 feet)

10.2' - 11.0'	0.8'	Shale, orange-gray, calcareous, and limestone, tan-gray, fine-grained, limestone 0.4' to 0.7' from base of unit.
10.2'	0.6'	Limestone, gray, fine-grained, thin-bedded.
9.6'	3.2'	Shale, gray, green, brown, fissle, some beds fossiliferous, limestone present as thin lenses near middle of the interval.
6.4'	0.8'	Limestone, tan, with iron oxide mottlings, fine-grained, thin-bedded.
3.9' - 5.6'	1.7'	Shale, gray-green-brown. Fissle, with thin lenses of gray fine-grained limestone.
3.2' - 3.9'	0.7'	Limestone, dark to light gray, thin-bedded, fossiliferous.
- 3.2'	0.5'	Shale, brown-green-orange-gray, brown carbonaceous shale parting at top, metabentonite near middle.
2.7'	0.5'	Limestone, purplish-brown, fine-grained, thin-bedded, very fossiliferous, fucoids at base.
2.2'	0.2'	Metabentonite, orange, sticky when wet, with brown shale partings.

Platteville Formation

Quimbys Mill Member (1.2 feet)

- 2.0'	1.2'	Limestone, purplish gray-brown, sublithographic, thick-bedded, conchoidal fracture, irregular upper surface, shale at base.

McGregor Limestone Member (0.8 feet)

0.' - 0.8'	0.8'	Limestone, purplish gray-brown, fine-to medium-grained, thick-bedded.

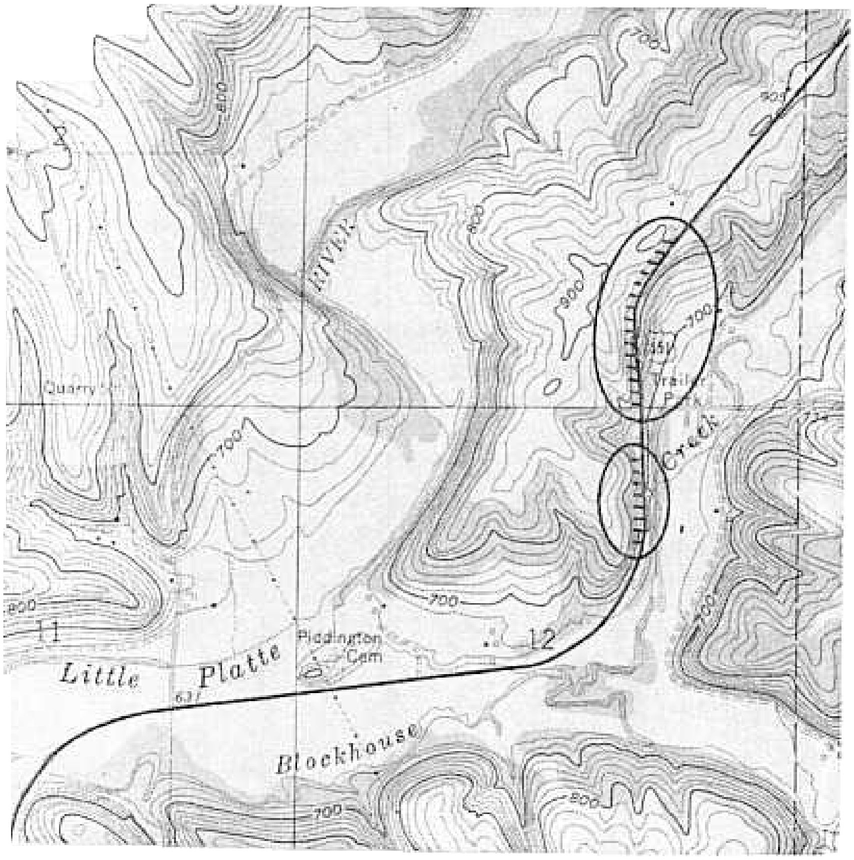
Significance: The Spechts Ferry and Metabentonite beds are not present everywhere. In addition, in the district mineralization it quite often occurs where the Spechts Ferry is thickest.

How could one account for the local absence of the Spechts Ferry Member? The metabentonite beds? How could one account for the thickening of the Spechts Ferry Shale coincident with mineralization? for the location and mineralization of "pitch-and-flat" structures?

References: Cline et al., 1956; Templeton and Willman, 1963; Kruse, 1970.

Title: Hoadley Hill

Location: Exposure in roadcut at north side of U. S. Highway 151 about 6.5 miles southwest of Platteville in the NW¼, NW¼, Sec. 12, T.2N., R.2W., Grant County (Dickeyville 7.5-minute topographic quadrangle, 1972).



Author: M. E. Ostrom (modified from Agnew et. al., 1956)

Description: This is the reference section for the Platteville Formation. The strata exposed here are the upper part of the St. Peter Sandstone, the Glenwood Formation, a complete section of the Platteville Formation, and the lower part of the Decorah Formation. Description from Agnew et. al., (1956) is:

ORDOVICIAN SYSTEM

Decorah Formation

Spechts Ferry Shale Member (+1.0 feet)

62.9' - 63.4'	0.5'+	Shale, bluish-green.
62.7' - 62.9'	0.2'	Bentonite, white; weathers orange brown.
62.5' - 62.7'	0.2'	Shale, yellowish-green above to bluish-green below.

62.4' - 62.5'	0.1'	Shale, brown and olive, soft.

Platteville Formation (54.3 feet

Quimbys Mill Member (0.3 - 0.5 feet)

62.0' - 62.4'	0.4'±	Limestone, dark purple, fine-crystalline, dense, conchoidal fracture; very wavy upper surface; thin dark-brown to black, fossiliferous platy shale parting at base.

McGregor Limestone Member (30.9 feet)

61.1' - 62.0'	0.9'	Limestone, light-gray, very fine crystalline, very dense, conchoidal fracture like "glass rock" above, fairly massive, very fossiliferous; wavy upper surface.
60.4' - 61.1'	0.7'	Limestone as next above but less dense, medium-bedded above to thin- bedded below, fossiliferous wavy upper surface.
58.8' - 60.4'	1.6'	Dolomite, light olive drab, fine crystalline, "sugary", argillaceous, very thin-bedded; molular.
55.8' - 58.8'	3.0'	Dolomite as above but thick-bedded; calcite near middle.
55.2' - 55.8'	2.6'	Limestone, thin-bedded yet stands massively as one unit; light greenish gray brown; weathers brown, with a few argillaceous streaks; sparingly fossiliferous, but with fossils and fucoids on top surface.
51.8' - 55.2	3.4'	Limestone, thin-bedded as above but the beds are distinct; modular beds and shaly partings; argillaceous is upper 0.3 feet, which is very fossiliferous
48.2' - 51.8'	3.6'	Limestone, light buffish gray, in medium to thick beds; in places gradational into above unit.
44.3' - 48.2	3.9'	Limestone, light greenish to bluish gray, in massive beds but composed of thin beds which are not separated; ample shaly material in wavy bands; fairly fossiliferous, argillaceous; a peculiar mottled light gray and darker gray 0.1-foot zone, 1 foot below top.
40.3' - 44.3'	4.0'	Limestone, light gray, very fine crystalline, very dense, sublithographic, in extremely thin and modular beds with thin calcareous shaly partings which become thinner below; the shale beds are light grayish blue,mottled, very fossiliferous; weathers slightly recessed.

40.3'	3.6'	Limestone, as above, but beds are not quite as thin; fossiliferous; poor gastropod zone 1.7 feet above base; shaly zone at base.
36.7'	3.6'	Limestone, dolomite, light-gray, fine crystalline, very slightly argillaceous, very fossiliferous, medium-bedded; indistinct argillaceous partings, not wavy; calcite and limonite, especially in basal 0.6 feet.

Pecatonica Dolomite Member (21.5 feet)

28.3' - 33.1'	4.8'	Dolomite, light grayish brown, very coarse crystalline and vuggy, upper 2 feet a mixture of lithology and a somewhat argillaceous fine crystalline "sugary" laminated dolomite; a 1-foot bed of very vuggy dolomite from 1.8 to 2.8 feet above base; shaly in lower part; stylolitic partings 1 foot above base.
21.4' - 28.3'	6.9'	Dolomite, medium gray, laminated, somewhat argillaceous, fine-crystalline "sugary", fossiliferous, especially in lower 0.9 feet; medium- to thick-bedded; shaly at top; weathers brownish in lower 2.5 feet.
- 21.4'	3.6'	Dolomite, medium gray, laminated, argillaceous; very fossiliferous partings.
17.8'	1.4'	Dolomite, light grayish brown, very coarse crystalline and vuggy; thin brownish gritty dolomitic and platy shaly parting at top.
13.6' - 16.4'	2.8'	Dolomite, medium gray, laminated, somewhat argillaceous, fine crystalline.
13.6'	2.0'	Dolomite, medium gray, laminated, argillaceous, silty and sandy with fine to coarse quartz grains similar to those of the St. Peter Sandstone, phosphate nodules abundant (especially in two zones, one at base, the other 1 foot above base).

Glenwood Formation (1.5 feet)

- 11.6'	0.4'	Shale, sandy with rounded quartz grains, khaki to drab, soft; phosphate nodules.
11.0' - 11.2'	0.2'	Shale, sandy, olive to grayish brown; mottled yellowish brown, friable.
10.4 - 11.0'	0.6'	Shale, sandy, medium- to dark-gray, olive, blocky, very hard.

	10.4'	0.3'	Shale, medium-gray, blocky, hard, sandy; streak of carbonaceous material at top.

St. Peter Sandstone Formation (+10.2 feet)

10.0' -	10.1'	0.1'	Sandstone, red and white; rounded; frosted, coarse to medium-grained.
	10.0'	0.2'	Sandstone, gray, pinkish, very friable.
	9.8'	0.1'	Sandstone, brown, iron-stained, hard
	9.7'	1.3'	Sandstone, yellow to gray, very friable, with irregular lower surface.
8.3'	8.4'	0.1'	Sandstone, light-gray, very friable.
8.1'	8.3'	0.2'	Sandstone, yellow to dark-brown, laminated, hard.
7.0'	8.1'	1.1'	Sandstone, gray and yellow; hard irregular lower surface.
	7.0'	7.0'+	Sandstone as above, but medium- to fine-grained; spoils.

BASE OF EXPOSURE

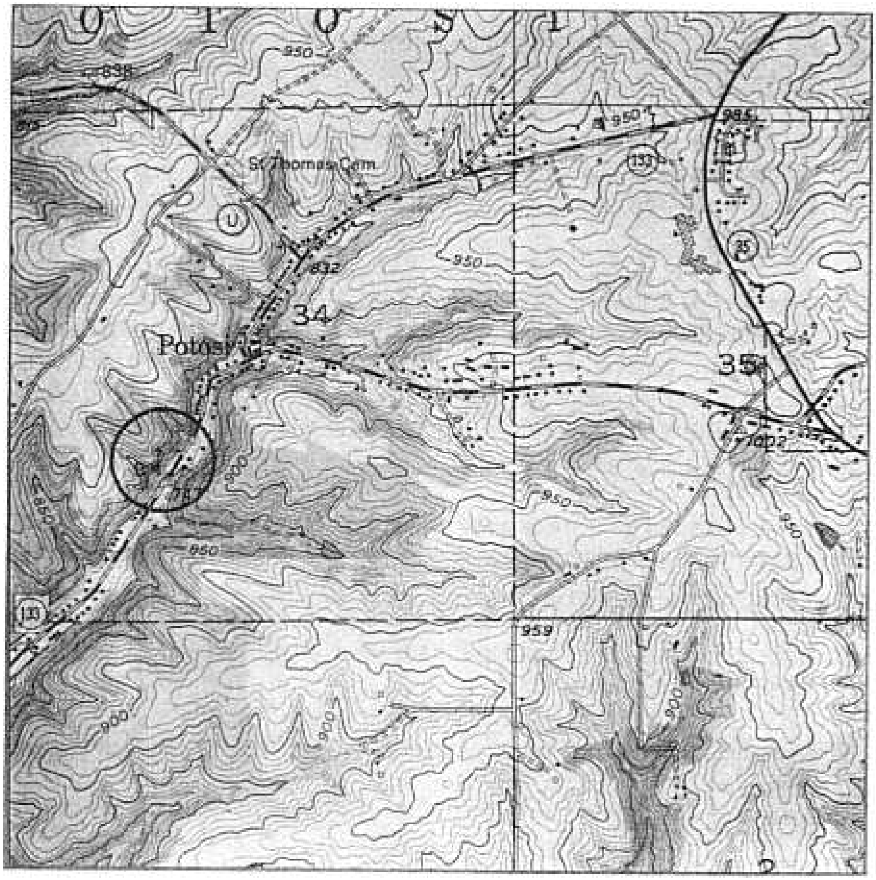
Significance: This is the reference section for the Platteville Formation. The contact relationships and lithologies of the St. Peter, Glenwood, Platteville, and Decorah Formations can be examined.

Note the lithology, mineralogy, and structure of the St. Peter Formation. What direction did it come from? Does it contain evidence of life? How do you account for its mineral homegeniety? What was the environment of deposition? Does it change toward the top? What is the significance of no change? of change? What is the relationship of the St. Peter to the Glenwood? Note the various beds of the Glenwood. What is their significance? If they could be traced for long distances of several hundred miles, what would be the significance? What is the nature and significance of the Glenwood/Platteville contact? Note the variable Platteville lithology, i.e. phosphate nodule beds, fossil beds, sandy beds, etc. What is their significance? What would be the significance if they could be traced several hundred miles?

References: Dapples, 1955; Agnew et. al., 1956; Templeton and Willman, 1963; Ostrom, 1964 and 1970.

Title: St. John Mine (Snake Cave)

Location: Opening is in valley wall on the north side of State Highway 133 about 0.2 miles south of intersection of County Highway "O" and State Highway 133 in Potosi in the SW¼, NW¼, SW¼, Sec. 34, T. 3 N., R. 2 E., Grant County (Potosi 7.5-minute topographic quadrangle, 1972).



Author: M. G. Mudrey, Jr., (Modified from St. John Mine brochure, L.C. Ihm, owner, and Whitlow and West, 1966).

Description: This mine is a natural cave that was extensively exploited for lead prior to 1870. By 1843, it had yielded 250,000 pounds of lead. The Potosi sub-district produced 21,300 tons of 80 percent lead from 1862 to 1876. Galena occurs in gash veins and openings along minor joints. The vein strikes N. 65° W., and is noted for its length and continuity.

Host rock is Ordovician Galena Dolomite, with Maquoketa Shale on the ridge to the west.

The floor of the cave is in the Dunleith Member (cherty lower unit) of the Galena Dolomite. In most outcrops, it is a pale-yellowish-brown to light-olive-gray and grayish-orange fine- to medium-grained vuggy fossiliferous dolomite containing abundant chert as nodules or as nearly continuous layers. Chert in the Dunleith Member is nodular and distributed parallel to the bedding. Near mineralized zones chert is selectively mineralized and contains microscopic grains of disseminated iron sulfide that color it bluish gray and locally very dark gray.

The top of the cherty unit is marked by two discontinuous layers of chert odulesn separated from the main cherty section by 6-9 feet of non-cherty dolomite.

The roof of the cave is in the Wise Lake Member (non-cherty upper unit) of the Galena Dolomite. The strata of the non-cherty unit are pale-yellowish-brown to yellowish- and grayish-orange fine-grained porous fossiliferous dolomite.

The minerals of the zinc and lead deposits in the Potosi quadrangle are mostly simple sulfides, carbonates, and sulfates. The primary sulfide minerals are sphalerite, galena, pyrite, marcasite, chalcopyrite, and digenite. Galena is fairly stable and persists above the water table; the others are commonly altered. These include smithsonite, cerussite, limonite, melanterite, malachite, azurite, and erythrite.

History: St. John Mine, originally a natural cave, was first named LaSalle Cave, after Robert Cavelier Sieur de La Salle, an early French explorer in North America, who traveled with his company on an expedition through the upper Mississippi River Valley in 1679 and again in 1687 after King Louis XIV names him Viceroy of North America. LaSalle is the man who claimed and named Louisiana Province for the French king.

St. John Mine was worked by the Indians many years before white pioneers arrived in the 1827 "lead rush". Drifts of the old mine follow the natural crevices filled with stalactites.

The foxes who used it for dens are said to have uncovered the rich lead deposits near the entrance by digging and running in and out the natural cave crevice. The Indians mined galena for barter but it was left to the white men to extensively develop these diggings.

The first white man known to have worked St. John Mine and who gave it the name it still bears was Willis St. John, who made a small fortune from this mine between 1828 and 1870.

In the Upper Mississippi Valley, lead seems to have been discovered about 1692 by Nicholas Perrott. This metal was also noted in 1700 by LeSueur, who took lead out of a place which we believe from the description must have been Snake Hollow, now Potosi, Wisconsin. In 1766 John Carver brought to St. Louis a 500 pound hunk of lead he had received from barter with the Indians who mined a cave on the eastern Mississippi bank somewhere between the mouth of the Grant and Platte Rivers. This 500 pound piece of lead may have been taken from St. John Mine, which points to the importance St. John Mine played in bringing settlers to the lead region.

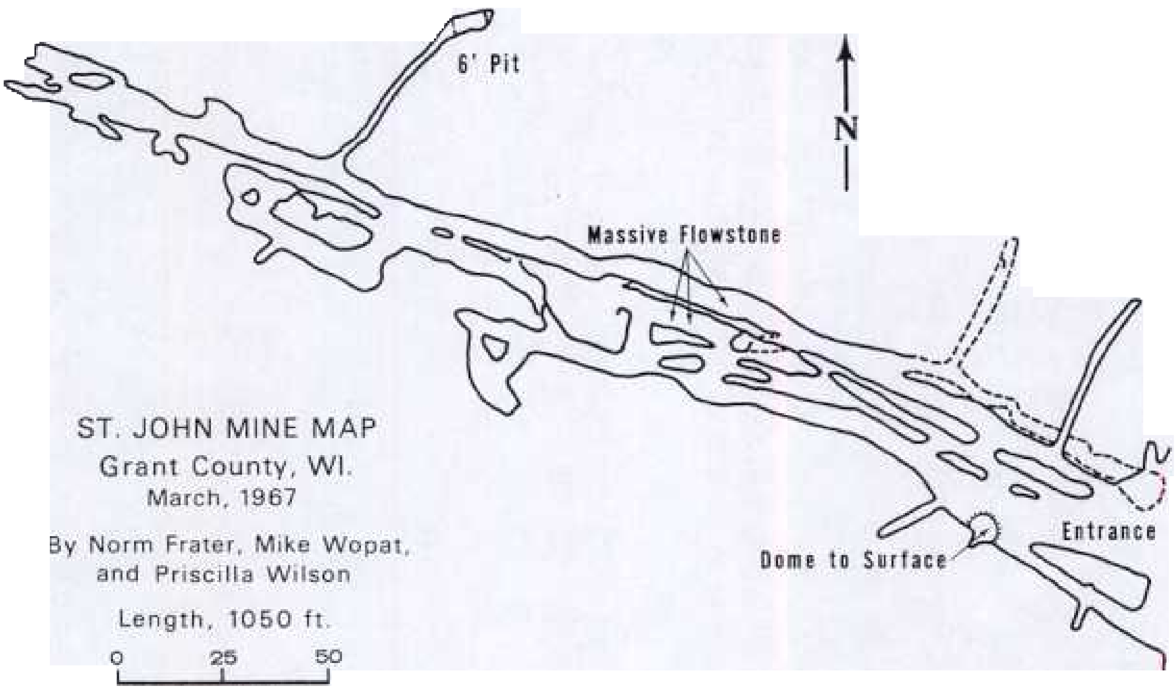
and "lead rush of 1827", the convening of the first Wisconsin Territorial Legislature in 1836, Potosi and its suburbs (La Fayette, Van Buren, Dutch Hollow British Hollow, Buena Vista, and Rockville) flourished. Potosi in 1838 was hoping to become the capital of Wisconsin; first state capitol was Belmont, but Madison won out. The Mexican War of 1847; the Gold Rush of '49 and the cholera epidemic in 1854 depleted its citizens for a few years; but by 1859 when the Civil War broke out, production of lead, and with it the growth of the village of Potosi, was on an upswing.

Well over two-thirds of all lead for the North was supplied during the Civil War by the Galena, Benton, New Diggings, Shullsburg, Mineral Point and Potosi mines. The remainder was furnished by mining towns called Platteville Hardscrabble, Yuba, and Meeker's Grove, all in the southwestern Wisconsin zinc-lead region.

References: Whitlow, J. W., and West, W. S., 1966, Geology of the Potosi quadrangle, Grant County, Wisconsin, and Dubuque County, Iowa: U.S. Geol. Survey Bull. 1123-I, p. 533-571.

Heyl, A. V., Jr., Agnew, A. F., Lyons, E. J., and Behre, C. H., Jr., 1959, The Geology of the Upper Mississippi Valley Zinc-Lead District: U.S. Geol. Survey Prof. Paper 309, 310 p.

Ihm, L. C., undated, St. John Mine Brochure, Potosi, Wisconsin.



Title: Pigeon Creek

Location: Exposures in roadcuts and streams cuts along County Highway "N" in the SE¼, NE¼, Sec. 19, T.4N., R.3W., Grant County (Hurricane 7.5-minute topographic quadrangle, 1962).

Author: M. E. Ostrom

Description: Description begins at top with lower massive bed of dolomite and extends downward to the St. Peter Formation.

ORDOVICIAN SYSTEM

Platteville Formation

Pecatonica Member (1.8 feet)

21.5' - 23.3'	1.8'	Dolomite, buff, dense in upper part, slightly porous in lower 10": Phosphatic nodules abundant in lower 10".

Glenwood Formation

Hennipen Member (1.8 feet)

21.4' - 21.5'	0.1'	Shale, weathers green, otherwise very dark brown and blocky. Slakes easily.

19.7' - 21.4'	1.7'	Shale, grayish brown, dolomitic, thinly laminated, blocky fracture (yeast-like). Estimated 50% carbonate.

Harmony Hill Member (2.2')

19.5' - 19.7'	0.2'	Shale, iron-rich; phosphatic grains and orange and black specks.
17.5' - 19.5'	2.0'	Shale, bright greenish gray in upper 10" changing to light gray in middle and to yellowish gray at base. Laminated and at top, and unlaminated in base part. Yellow clay slakes easily; green clay slakes.

Nokomis Member (2.5 feet)

17.0' - 17.5'	0.5'	Sandstone, limonite-centered, hard, forms ledge of irregular thickness; burrowed.
15.5' - 17.0'	1.5'	Sandstone, hard, limonite- and dolomite-silty. bed. Burrowed.
15.0' - 15.5'	0.5	Sandstone, coarse-grained to conglomerative, white to very light gray, slightly irregular base with staining below.

St. Peter Formation

0.0' - 15.0'	15'+	Sandstone, very light gray, medium and coarse-grained, well-sorted, thick-bedded.

BASE OF EXPOSURE

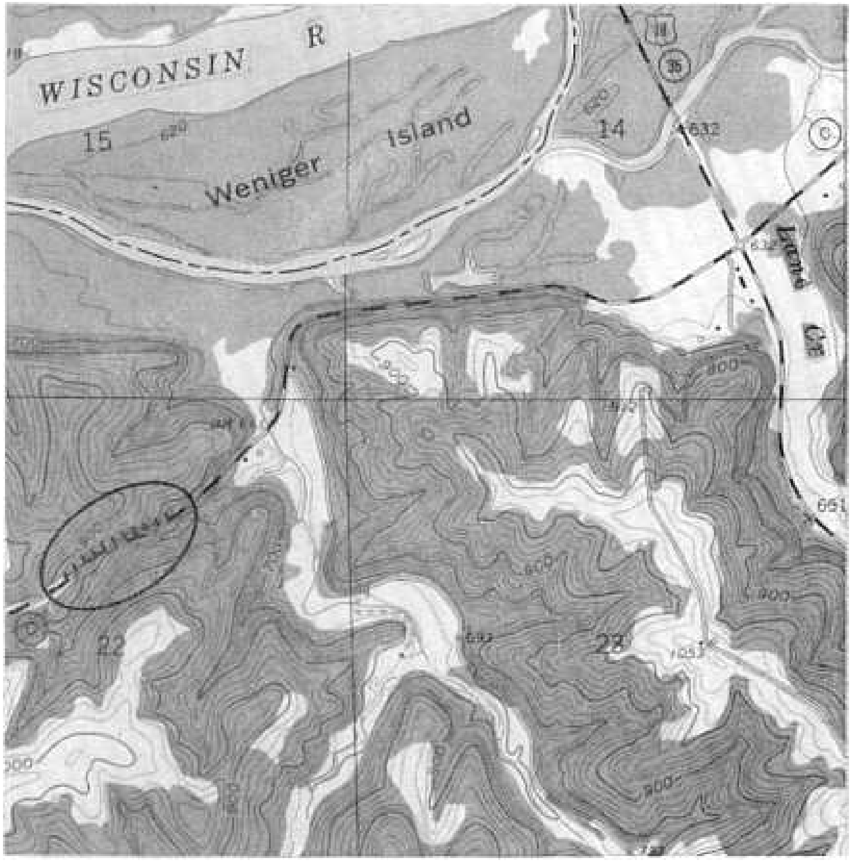
Significance: Exposure of section similar to that seen at Bridgeport West stop.

Note the individual units. Are they distinct and persistent? Recall exposures seen at Viroqua/Readstown and Bridgeport West stops. How do they compare with this exposure? Have you seen the phosphatic pebbles before? What do they signify?

References: Ostrom 1969.

Title: Bridgeport West

Location: Exposures in roadcut at north side of County Highway "C" in the SE¼, NW¼, NE¼, Sec. 22, T.6N., R.6W., Grant County (Bagley 7.5-minute topographic quadrangle, 1962).



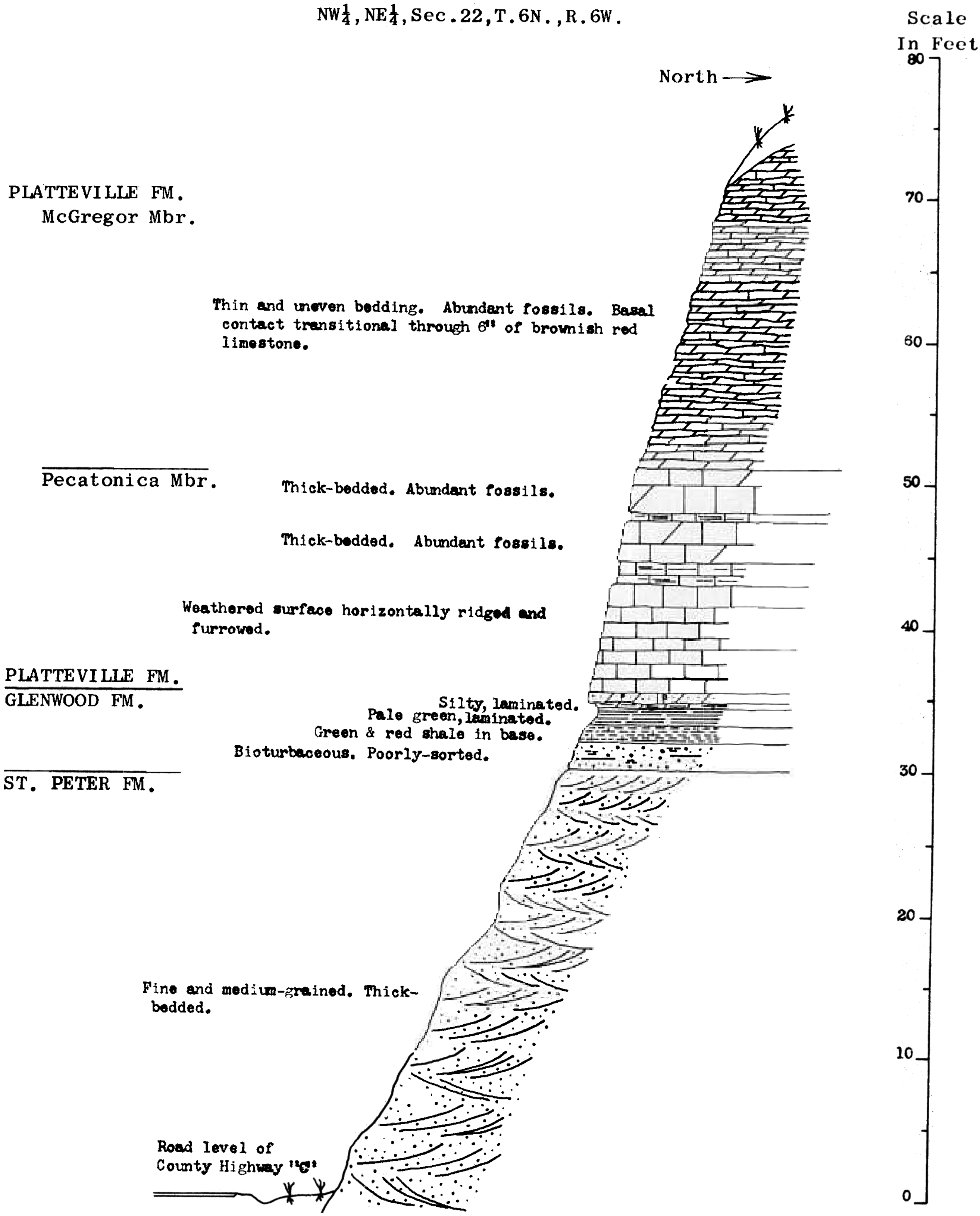
Author: M. E. Ostrom (modified from Ostrom, 1970)

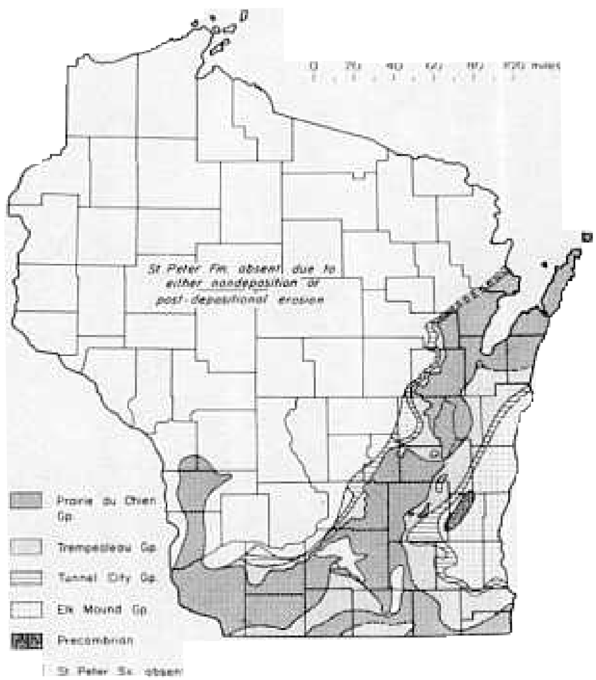
Description: At this site all four lithotopes of the uppermost cycle, which has the St. Peter Sandstone in its base, are exposed as are the contact relationships of St. Peter, Glenwood and Platteville Formations.

At the Prairie du Chien Stop the erosion surface at the base of the St. Peter was especially well shown. Dapples (1955) demonstrated that this erosion surface could be traced over a broad area extending from western Tennessee to Wisconsin. A map by Ostrom shows the geology of the pre-St. Peter surface in Wisconsin and indicates that the St. Peter rests on successively older rocks as one proceeds from western Wisconsin to the vicinity of Milwaukee. It is postulated that there was pre-St. Peter uplift in the vicinity of Milwaukee and that the uplifted surface was subsequently eroded. Although data are sparse there is very good agreement between thick sections of St. Peter which are interpreted to coincide with Pre-St. Peter surface which were likely exposed by erosion. The data suggest stream drainage to the southwest away from the Milwaukee area.

Bridgeport West

ROADCUT ON COUNTY TRUNK "C"
NW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 22, T.6N., R.6W.





Paleogeology of the pre-St. Peter erosion surface in southern and eastern Wisconsin.

The thick-bedded quartzarenite is represented by the St. Peter Sandstone and the reworked poorly-sorted quartzarenite by the lower 2 feet of the Glenwood Formation. The reworked quartzarenite is transitional through about 1.4 feet of siltstone and shale into the shale lithotope and this is in sharp contact with the base of the overlying carbonate lithotope which is the Platteville Formation.

The Glenwood Formation in Wisconsin thins to the east toward the Wisconsin Arch from a maximum thickness of about 13 feet in the vicinity of Beetown to less than a foot near New Glarus. A study by Ostrom (1969) showed that as one proceeds eastward the upper or shale unit thins to disappearance and the underlying poorly-sorted reworked quartzarenite is in direct contact with the overlying carbonate lithotope. Traced further to the east, in the vicinity of New Glarus south of Madison, the reworked quartzarenite thins to less than 1 foot.

The contact of the Glenwood Formation with the Platteville Formation is one of apparent unconformity. This relationship is attributed to lateral variations in environmental conditions at the time of formation rather than to post-Glenwood erosion because there is no evidence except the apparent regional truncation described above that would indicate the Glenwood was eroded.

This limit of the New Richmond Sandstone is along a line trending southwestward from about Danville, in east-central Illinois, toward Cape Girardeau, Missouri (Workman and Bell, 1949).

The New Richmond developed in the littoral zone during the succeeding cycle. It is succeeded by poorly known or defined deposits of the nondepositional and depositional shelf zones similar to those of the preceding Jordan cycle, and is overlain by deposits of the carbonate zone, the Shakopee Dolomite, developed further seaward. In more seaward areas to the south the Shakopee Dolomite is continuous with the Oneota Dolomite of the preceding Jordan cycle and consists almost entirely of carbonate. Northward, as for example, near Utica in north-central Illinois, the Shakopee overlies the New Richmond and has a variable lithology which consists of dolomite containing layers of quartzarenite, shale, and discontinuous thin beds of oolitic chert. The dolomite beds range up to 10 feet in thickness, are seldom more than 3 feet thick, and are commonly very fine-grained, and their upper surfaces may be ripple marked and mudcracked. The sandstone beds may be cross-bedded and commonly contain pebbles and cobbles derived from the underlying dolomite bed in their lower part. Beds of shale reach a known maximum thickness of 6 inches. The variable lithologic character of the Shakopee in this area is interpreted to indicate frequent environmental changes and "....fluctuation of conditions of sedimentation characteristic of shallow water deposition" (Cady, 1919). It is postulated that the Shakopee Formation accumulated in a very shallow environment situated shoreward from an area of algal headlands. This zone is considered to have been a broad, flat, and shallow lagoon or shoaling area subjected to the influence of the land on one side and the algal headlands and reefs on the other, while at the same time being influenced by other factors affecting the carbonate deposition.

The Shakopee Dolomite and older strata were eroded in northerly areas in Wisconsin during pre-St. Peter regression to an indefinite northeast-trending strandline through western Kentucky (Dapples, 1955). The geology of the eroded surface is shown in the accompanying diagram (Ostrom, 1964). The surface is one of prominent relief.

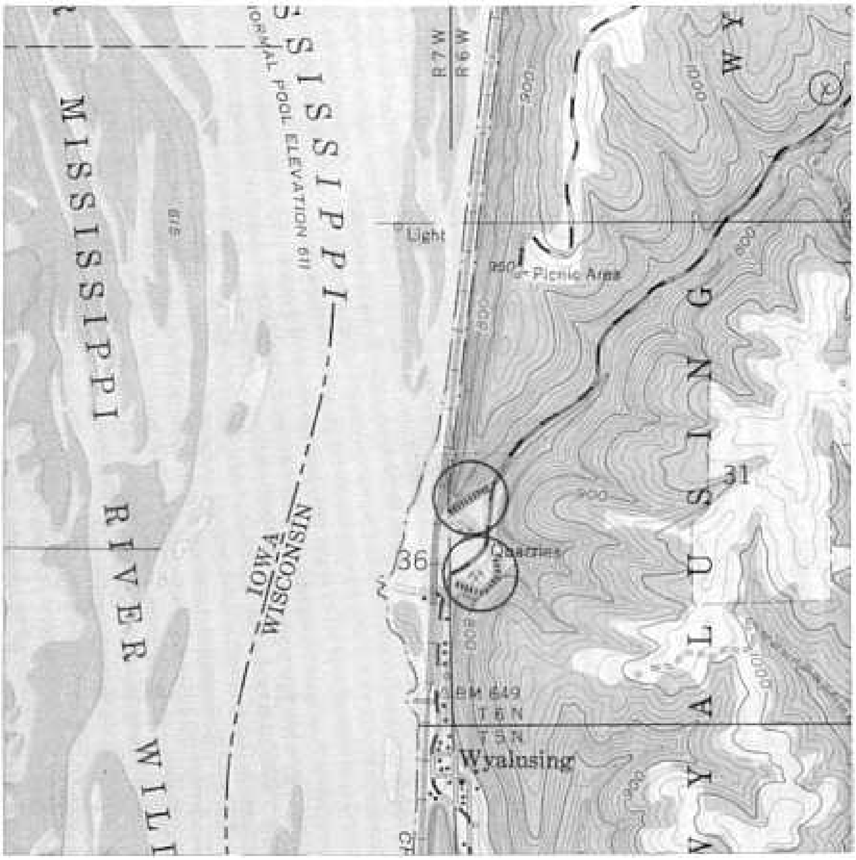
Significance: This is an opportunity to examine all four lithotapes of the St. Peter cycle and their contact relationships.

How do the lithotapes exposed here compare to those seen at the Viroque/Readstown stop? What are the differences between this cycle and the Galesville cycle seen at the Bruce School, Galesville, Duerch Peak, and Mt. Zion stops? What is the environmental and historical significance of these differences?

References: Dapples, 1955; Ostrom, 1964 and 1970.

Title: Wyalusing

Location: Chicago, Burlington, and Quincy Railroad quarry on County Highway "X" at north edge of the community of Wyalusing in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 31, T.6N. R.6W., Grant County (Clayton 7.5-minute topographic quadrangle, 1962).



Author: M. E. Ostrom (modified from Starke, 1949, Shea, Cline 1959 and 1960, and Ostrom and Cline 1970).

Description: This quarry, exposing approximately 185 feet Prairie du Chien strata, is probably the most nearly complete exposure of the Prairie du Chien in the state of Wisconsin. George Starke (1949) described the rocks exposed in this quarry and estimated that the floor of the quarry lies some 30 feet above the base of the Oneota Formation.

The Willow River Formation at this site was studied in detail by Carozzi and Davis (1964).

Angular unconformity of beds at the Oneota/New Richmond contact is clearly shown on the high southeast quarry face. Here eastward dipping beds of Oneota Dolomite are overlain by flat-lying beds of the New Richmond Member.

There is an excellent exposure of the Oneota and Shakopee Formations in a quarry at the north village limits of Bagley. It can be reached by following

CHICAGO, BURLINGTON AND QUINCY RAILROAD QUARRY
NW$\frac{1}{4}$,SW$\frac{1}{4}$,Sec.31,T.6N.,R.6W.

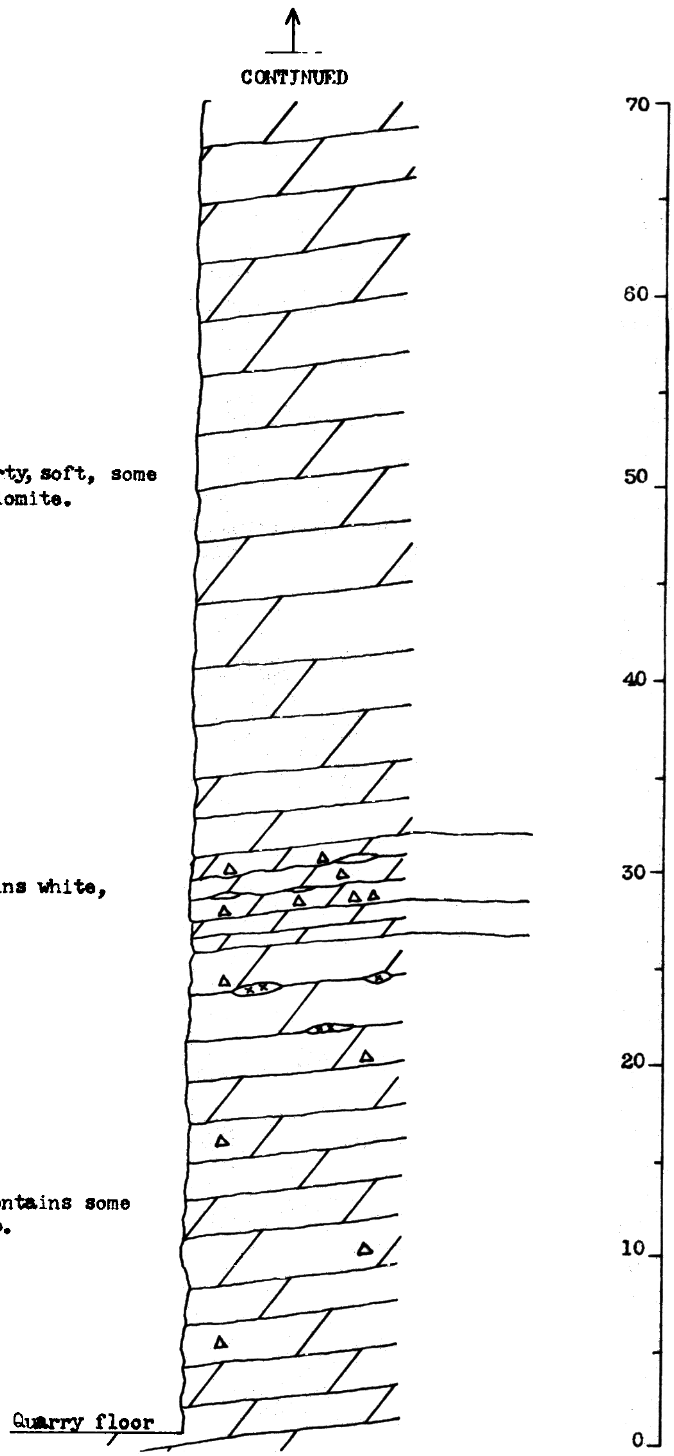
ONEOTA FM.

Gray, very thick-bedded, non-cherty, soft, some areas fine-grained gray buff dolomite.

Very fine-grained, undulating bed, contains white, gray and black chert; cavernous.

Gray to buff, coarse-grained, in 4" beds.

Gray to buff to orange, thick-bedded; contains some white chert; some clay pockets near top.



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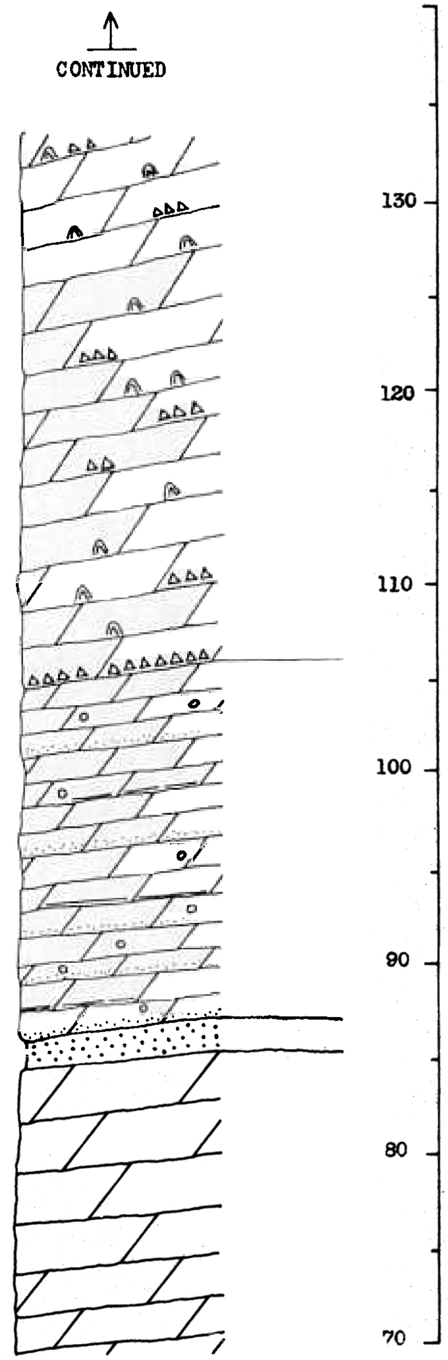


Algal structures profuse; stringers of chert throughout; basal foot is weathered chert.

Conglomeratic with dark gray pebbles; well-bedded with some green shale partings and some clean white quartzose beds.

White, medium-grain; some green specks.

Gray, very thick-bedded, non-cherty, soft, some areas fine-grained gray buff dolomite.

CONTINUED

White, stained brown, medium-grained, well-sorted and rounded grains.

ST. PETER FM.

SHAKOPEE FM.
Willow River Mbr.

Gnarled appearance, thick 1' beds with some stringers of sandstone.

Brecciated.

6 inch beds separated by gray shale.

Thinly-bedded, green shale partings; floating grains of quartz sand.

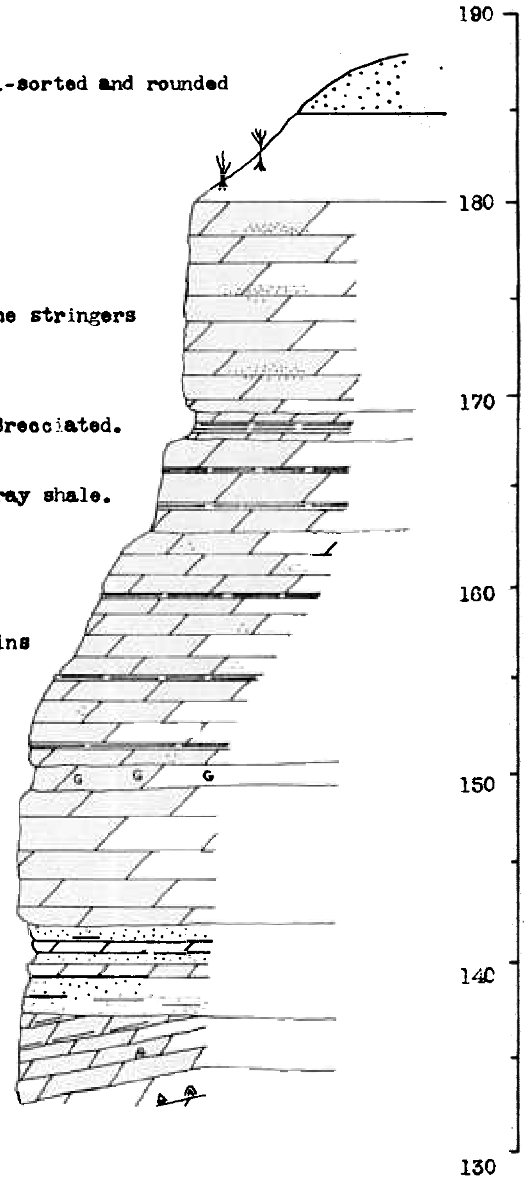
Green, glauconitic.

Fine-grained; weathers to irregular surface.

New Richmond Mbr.

ONEOTA FM.

Weathers to irregular surface; some algal structures.



County Highway "X" south for a distance of 3.5 miles from the Wyalusing Quarry Stop. The Bagley quarry is an especially good location to examine fossil algae.

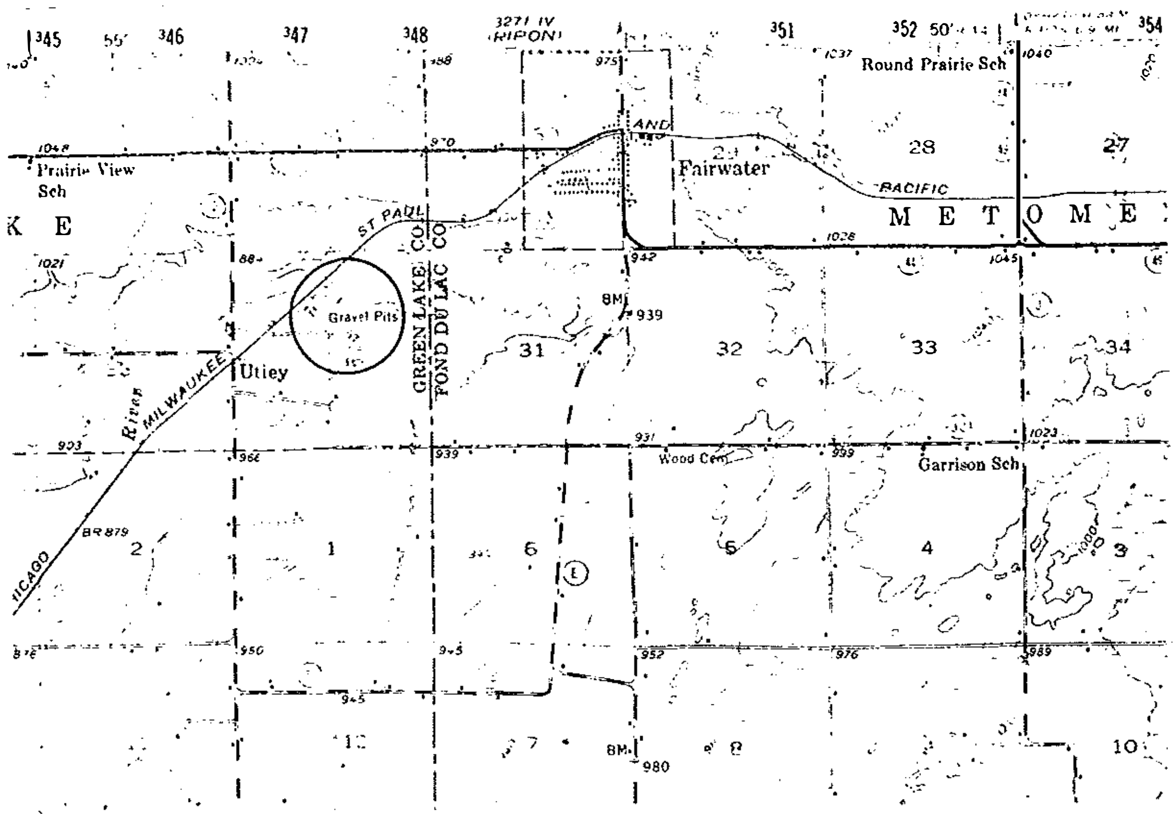
Significance: Exposure clearly illustrates the contact relationship of the Shakopee and Oneota Formations.

What is the relationship? What is your interpretation? Have you seen a similar relationship at previous stops? Closely examine the dolomite. Can you find fossils and what are they? Note the oolites. What do they signify? Note the beds of stromatolitions. What do they signify? What was the environment of deposition of the Oneota Formation?

References: Starke, 1949; Shea, 1960; Cline 1959 and 1960; Ostrom and Cline, 1970; Carozzi and Davie, 1964.

Title: The Utley Rhyolite

Location: NW¼, SW¼, NE¼, Sec. 36, T.14N., R.13E. (Fox Lake 15 Min. Quad.) Green Lake County. Get permission from Lester Schwartz, Art Dept., Ripon College, Ripon, Wisconsin. Phone: 748-8106.

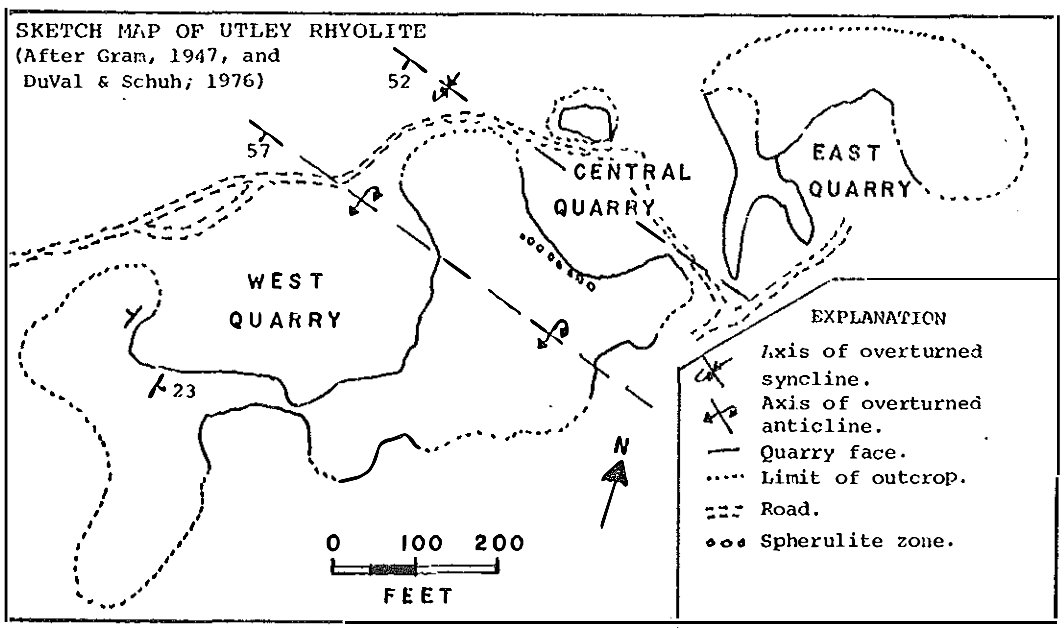


Author: Gene L. LaBerge

Description: The Utley Rhyolite is one of ten isolated knobs of Precambrian igneous rocks (mainly rhyolites) that protrude through the Paleozoic cover in southeastern Wisconsin. The inliers extend from Berlin southwestward to the Baraboo area. The rhyolites stood as prominent hills on the Precambrian surface, and were rocky islands in the lower Paleozoic seas for nearly a hundred million years. The Utley rhyolite was largely (or entirely) buried by the Prairie du Chien Dolomite, but was partially exhumed during the erosion during a regression of the Middle Ordovician sea shortly thereafter. The advance of the sea over this unconformity resulted in the deposition of St. Peter sandstone in a channel cut into the Prairie du Chien. The large sand quarry just east of the rhyolite is in this channel filling of St. Peter sandstone. The rhyolite was buried again by the St. Peter and Platteville Dolomites and is being exhumed again by erosion.

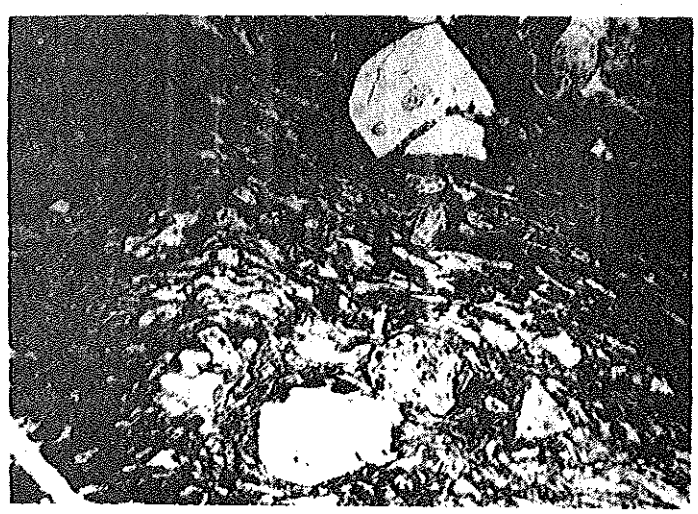
The dark color of the Utley Rhyolite is typical of most Precambrian rhyolites in Wisconsin. Quartz and feldspar phenocrysts are abundant and present in about equal amounts. The matrix is an aphanitic mixture of quartz and feldspar. Weidman (1898) interpreted this rock as a meta-rhyolite, Gram (1952) interpreted it as a tuff and Asquith (1964) interpreted it as a welded tuff. Smith (1974, 1975, in press) has shown that the various rhyolites in southern Wisconsin formed from ash-flow deposits and chemically are genetically related. Fragmental texture is visible on the weathered surface at a number of places in the quarry. A distinctive zone of "spherulites" on the top of the west wall of the central quarry (see map) trends northwesterly. Gram (1947) concluded that the structure in the quarry consists of a northwesterly trending anticline and syncline. However, the structure has not been worked out in detail, and may be more complex. The rhyolites here illustrate well the problems of mapping structures in Precambrian volcanic rocks. Can you recognize any distinctive zones or features that show the structure?

Microscopically, the rhyolites here show remarkably well preserved shard structures (see photos), some of which are deformed (flattened), others are not. The deformed shards indicate that these are welded tuffs. Many of the quartz phenocrysts are embayed, indicating that the crystals were beginning to melt as a result of changing conditions in the magma (mainly a loss of volatiles) during and after extrusion. The abundance of shards and broken phenocrysts attests to the violent eruption that formed the deposit.



Undeformed shard fragments (white) with quartz phenocryst in rhyolite tuff from Utley. x25.

Flattened shards and broken phenocrysts in welded tuff from Utley. x25.



Significance: The rocks at Utley and other localities in south central Wisconsin are welded tuffs that formed as a result of extremely violent eruptions common to rhyolitic volcanoes. The resulting ash-flow deposits are widespread deposits. The following summary is summarized, in part, from the U.S. Geological Survey Atlas of Volcanic Phenomena (1971). A mass of granitic magma forms near the base of the crust, perhaps 30 miles deep in the earth. The magma contains up to 10% volatiles, mainly water vapor dissolved in the magma. The magma is lighter than the surrounding rocks and rises slowly through the crust. As it approaches the earth's surface, the area above the rising magma is domed, and circular to elliptical fractures are formed. The central area subsides somewhat on the ring of fractures. Some of the magma escapes to the surface along the ring of fractures, building a series of small andesitic and rhyolitic cones.

The rising magma eventually reaches a level in the crust where the pressure of the dissolved gases exceeds that of the overlying rocks. The result is a violent expansion of the gas, frothing and fragmenting the magma, and driving it upward to the surface where it bursts forth along the circular fractures as a seething mixture of gas-charged dust, ash and pumice. This exceptionally fluid gas-solid mixture expands with hurricane force, streams down valleys and around hills, spreads out over low areas, and comes to rest as a great sheet of steaming ash-flow tuff. Repeated eruptions, adding sheet upon sheet of tuff, build an ash-flow field hundreds to thousands of feet thick that covers several thousand square miles.

As the upper part of the magma chamber is drained by the eruptions, the crust in the central part of the area collapses to create a huge circular depression called a caldera. Following the collapse some ash is ejected along the ring fractures to form ash cones. The final phase is the eruption of viscous rhyolite, largely depleted of gas, as a series of domes or spires.

The violence of the eruption is so great and the volcanic materials are so hot that many of the glassy volcanic fragments are still soft when the ash-flow sheet comes to rest. The fragments are commonly flattened and may partially melt ("weld") together to form very hard rocks called welded tuffs. Commonly, the bottom of an ash-flow unit is not welded because of the rapid cooling against the underlying land surface. And the top tends to be non-welded due to rapid loss of heat to the atmosphere. The central part of ash-flow units, however, may be so densely welded that they become a solid glassy obsidian.

The magma that cooled and crystallized below the surface formed bodies of granite, such as those now exposed at Redgranite and Montello. Smith (in press) shows that the rhyolites are nearly identical in chemical composition, indicating that they are part of the same magma. Van Schmus (1976) shows that both the granites and rhyolites originated about 1765 million years ago, perhaps during the waning stages of the Penokean Orogeny that affected most of northern Wisconsin. Van Schmus (1976) further shows that the rocks were subjected to a "thermal event" at 1650 m.y. ago that "reset" the Rb/Sr age of the rocks. Smith (in press) concludes that the sheets of ash flow rhyolite (and the Baraboo Quartzite) were folded during the 1650 m.y. event.

<u>References</u>

Asquith, G. B., 1964, Origin of Precambrian Wisconsin Rhyolites: Jour. Geology, Vol. 72, pp. 835-847.

Gram, V. E., 1947, Tectonic Features of the Utley Meta-rhyolite: Jour. Geology, Vol. 55, pp. 427-438.

Smith, E. I., (in press), Precambrian Rhyolites and Granites in South Central Wisconsin: Field Relations and Geochemistry: Geol. Society of America Bulletin.

Van Schmus, W. R., Thurman, E. M., and Peterman, Z. E., 1975, Geology and Rb/Sr Chronology of Middle Precambrian Rocks in Eastern and Central Wisconsin: Geol. Soc. America Bull. Vol. 86, pp. 1255-1265.

Weidman, S., 1904, The Baraboo Iron-bearing District of Wisconsin: Wis. Geol. Nat. Hist. Survey Bull. 13, 190 p.

Middle Ordovician rocks at Potosi Hill, Wisconsin

M. E. Ostrom, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin 53705

LOCATION

Roadcut at east side of U.S. 61 and Wisconsin 35 about 1 mi (1.6 km) northwest of bridge over Platte River and 4 mi (6.4 km) northwest of Dickeyville in the SE¼,NW¼,Sec.7, T.2N.,R.2W., Grant County, Wisconsin in the Potosi 7½-minute Quadrangle (Fig. 1).

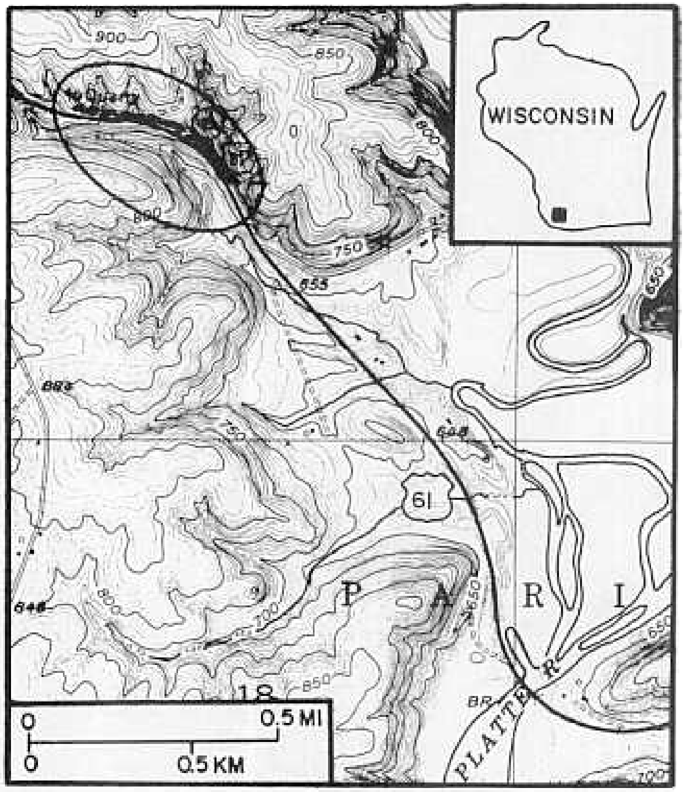


Figure 1. Location of exposure of Middle Ordovician strata in roadcut at Potosi Hill, Wisconsin.

SIGNIFICANCE

This is an excellent and easily accessible exposure of the upper few feet of the St. Peter Sandstone and the Glenwood Formation, Platteville Formation, Decorah Formation, and lower part of the Galena Formation (Fig. 2) (Ostrom, 1978). The Platteville, Decorah, and Galena Formations are the principal hosts of zinc and lead mineralization in the southwest Wisconsin zinc-lead mineralized district.

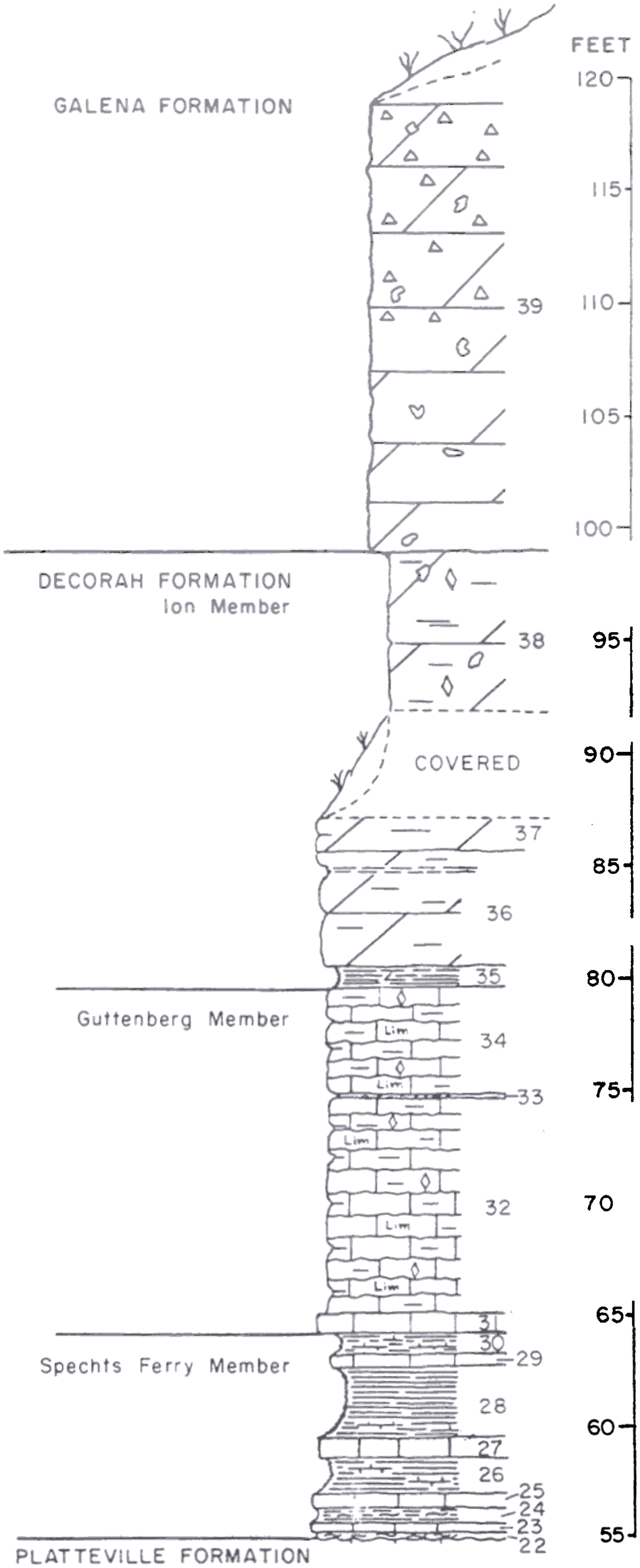
The St. Peter Sandstone was named by Owen (1847) for exposures along the St. Peter River (now the Minnesota River) near St. Paul, Minnesota. The St. Peter consists of very light yellowish gray to white, fine to coarse, subrounded to rounded quartz sand grains. It is typically very friable. It is cross-bedded, thick bedded to thin bedded, and locally massive. In the district it is from 0 to more than 300 ft (0 to 90 m) in thickness and averages about 40 ft (12 m). Variations in thickness are attributed to deposition on an erosion surface. The only fossils noted in the St. Peter are *Skolithos* (vertical straight burrows) and *Corophoides* (U-shaped burrows).

The St. Peter Sandstone is conformably overlain by the Glenwood Formation. The Glenwood was named by Calvin (1906, p. 75) from exposures in Glenwood Township (T.98N.,R.7W.) near Waukon, Iowa. Three members are recognized in the Glenwood Formation in southwest Wisconsin (Templeton and Willman, 1963; Ostrom, 1969). In the base of the Glenwood is the Nokomis Member, which consists principally of sandstone and is transitional with the St. Peter. It is distinguished from the St. Peter Sandstone by a more yellowish and greenish coloration and by a notable change in bedding character from cross-bedded, even-bedded, and uniform-textured sandstone to reworked, burrowed, and poorly sorted sandstone with more or less green clay. It is both silty and argillaceous. The Nokomis ranges from 8 ft (2.4 m) thick near Beetown (16 mi; 26 km northwest of Potosi Hill) to less than 1 ft (0.3 m) thick in the vicinity of New Glarus (about 65 mi; 105 km to the east).

The Nokomis Member is conformably overlain by the Harmony Hill Member, which consists of pale green to greenish gray shale with scattered rounded clear quartz sand grains. It decreases from 3.5 ft (1 m) thick in the western part of the district to zero in the east. The Harmony Hill is conformably overlain by the Hennepin Member. The Hennepin consists of brownish and locally calcareous shale with scattered phosphatic nodules and clear rounded quartz sand grains. It thins from 5 ft (1.5 m) thick in the western part of the district to zero in the east.

The Glenwood Formation is conformably overlain by the Platteville Formation, which is subdivided in ascending order into the Pecatonica, McGregor, and Quimbys Mill members. The Pecatonica Dolomite Member was named by Hershey (1894, p. 175) from exposures in the Pecatonica River valley in southwestern Wisconsin near the Illinois border. The Pecatonica is predominantly medium-grained, granular, thick- to thin-bedded dolomite. The lowermost bed, the Chana Member of Templeton and Willman (1963), contains phosphatic pellets and rounded clear quartz sand grains. The Pecatonica ranges from 20 to 25 ft (6 to 7.6 m) in thickness in the district.

The McGregor Limestone Member was named by Kay (1935, p. 286) from an exposure near McGregor, Iowa. It is from 25 to 30 ft (8 to 9 m) thick and consists of irregularly bedded, thin- to medium-bedded, light gray to buff argillaceous dolomite



Ordovician System
Champlainian Series
Sinnipee Group

Galena Dolomite Formation
Cherty Unit

39. Dolomite, yellowish-buff, medium- to coarse-grained, vuggy, abundant white chert in upper 10 ft (3 m).

Decorah Formation
Ion Dolomite Member
(Gray Unit)

38. Dolomite, buff, medium- to coarse-grained, thick- to massive-bedded, vuggy, green shale partings throughout, sparry calcite present. Covered interval.
37. Dolomite, buff, medium-grained, medium-bedded, with green shale partings.

(Blue Unit)

36. Dolomite, purplish-gray, medium-grained, slightly fossiliferous. Green shale present as partings, and as a 0.5 ft (15 cm) bed 0.8 ft (25 cm) below the top of the interval.
35. Shale, green. 0.3 ft (9 cm) green dolomitic shale in middle of interval.

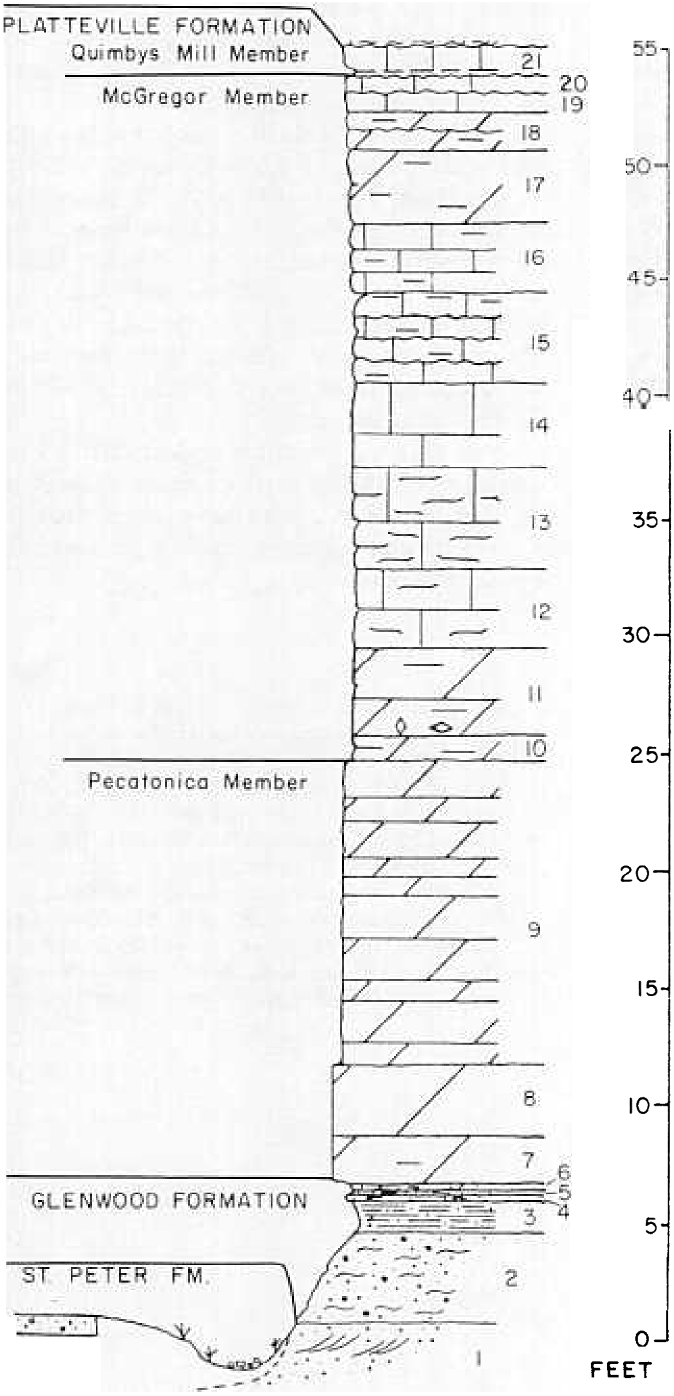
Guttenberg Limestone Member

34. Limestone, purplish-brown, fine-grained to sub-lithographic, fossiliferous, upper 1 ft (30 cm) fine- to medium-grained, brown shale present as partings, calcite and limonite after iron sulfide present in small amounts.
33. Metabentonite, brownish orange, crumbly, sticky when wet.
32. Limestone, purplish-brown, sublithographic, thin wavey bedding, fossiliferous, brown carbonaceous shale present as thin beds and partings, calcite and limonite present. Thin metabentonite bed at base.
31. Limestone brown-gray, fine-grained, thick-bedded.

Spechts Ferry Shale Member

30. Shale, orange-gray, calcareous, and limestone, tan-gray, fine-grained; limestone 0.4 to 0.7 ft (12 to 20 cm) above base.
29. Limestone, gray, fine-grained, thin-bedded.
28. Shale, gray, green, brown, fissle, some beds fossiliferous, limestone present as thin lenses near middle of the interval.
27. Limestone, tan, with iron oxide mottling, fine-grained, thin-bedded.
26. Shale, gray-green-brown. Fissle, with thin lenses of gray fine-grained limestone.
25. Limestone, dark to light gray, thin-bedded fossiliferous.
24. Shale, brown-green-orange-gray, brown carbonaceous shale parting at top, metabentonite near middle.
23. Limestone, purplish-brown, fine-grained, thin-bedded, very fossiliferous, fucoids at base.
22. Metabentonite, orange, sticky when wet, with brown shale partings.

Figure 2 (this and facing page). Section exposed in roadcut at Potosi Hill, Wisconsin.



Platteville Formation
Quimbys Mill Member

21. Limestone, purplish-ray-brown, sublithographic, thick-bedded, conchoidal fracture, irregular upper surface, shale at base. Metabentonite in top of shale.

McGregor Limestone Member

20. Limestone, purplish-gray-brown, fine to medium crystalline, thick-bedded; wavy upper surface.
19. Limestone, light gray, very fine crystalline, thin-bedded, fossiliferous; wavy upper surface.
18. Dolomite, yellowish-brown, fine crystalline, sugary texture, argillaceous, thin-bedded; discontinuous beds/nodular appearance.
17. Dolomite, light olive-brown, fine crystalline, sugary texture, argillaceous, thick bedded.
16. Limestone, light brown to greenish-brown, medium to fine crystalline, with some argillaceous partings; some fossil shells and fucoids on bedding planes.
15. Limestone, light brown to light greenish-brown, fine to medium crystalline, thin-bedded and uneven beds with nodular appearance, shale partings. Argillaceous in upper 0.6 ft (18 cm) with abundant fossils.
14. Limestone, light brownish-gray, medium to fine crystalline in medium to thick beds.
13. Limestone, light greenish-gray, fine and medium crystalline, thick-bedded with abundant discontinuous wavy shale partings. Shale partings are greenish-gray, mottled and very fossiliferous.
12. Limestone, same as above but fewer shale partings.
11. Dolomite, light gray, fine crystalline, slightly argillaceous, very fossiliferous, in medium beds, discontinuous faint shale partings. Some clear calcite and dolomite in lower 0.5 ft (15 cm).
10. Dolomite, light gray to light brownish-gray, fine crystalline with thin shale partings up to 1 in (2 cm) thick between beds. Shale is bluish-green and brown. Fossiliferous.

Pecatonica Member

9. Dolomite, brownish-gray, fine to medium crystalline, sugary texture, thin- to medium-bedded, even-bedded, beds 0.1 to 18 in (2 mm to 45 cm) thick. Weathered surface shows distinct but discontinuous thinner beds.
8. Dolomite, brownish-gray, fine crystalline, in single bed, upper 0.5 in (1 cm) stained brown. Scattered dark brown fossil molds and traces. Weathered surface shows wavy horizontal bedding features.
7. Dolomite, brownish-gray, fine crystalline, faint horizontal shale traces, dark brown phosphatic pebbles up to 2 mm, abundant dark brown fossil hash.

Glenwood Formation
Hennepin Member

6. Dolomite, very silty, yellowish-brown, very fine crystalline, abundant phosphatic pellets up to 2 mm, scattered round medium quartz sand grains.
5. Sandstone, brown, very fine- and fine-grained with little medium-grained, abundant grayish-green shale.
4. Sandstone, dark brown, fine- and medium-grained, argillaceous, poorly sorted, iron-oxide cemeted, abundant phosphate pellets up to 2 mm.

Harmony Hill Member

3. Shale, brown and bluish-green in upper 2 in (5 cm) grading downward to bluish-green with some reddish-brown; little rounded medium grained quartz sand.
2. Sandstone, mottled light yellowish-green, light greenish-yellow, and reddish-brown, medium- and fine-grained with some very fine and very coarse grains, poorly sorted, abundant pale green clay in matrix, reworked/bioturbated texture.

St. Peter Formation
Tonti Member

1. Sandstone, light yellowish-gray, very fine- to medium-grained, some light brown stains cross bedded.

Base of exposure in drainage ditch.

and limestone. The overlying Quimbys Mill Member was named by Agnew and Heyl (1946, p. 1585) from a quarry exposure about 5 mi (8 km) west of Shullsburg, Wisconsin. Its thickness varies in the district from less than 1 ft to more than 18 ft (0.3 to 5.5 m) thick and consists of purplish gray-brown, sublithographic, thick-bedded, conchoidally fractured limestone with an uneven upper surface and with shale at its base.

The Platteville Formation is overlain disconformably by the Spechts Ferry Shale Member of the Decorah Formation named from exposures in the city of Decorah, Iowa (Calvin, 1906, p. 61). It thins eastward from 8 ft thick to less than 1 ft (2.4 to 0.3 m). The Spechts Ferry Member consists of fossiliferous, gray-brown limestone with green shale interbeds. At this exposure two thin beds of "metabentonite" occur near its base. The metabentonites are orange to light reddish brown and about 2 in (5 cm) thick. Phosphatic nodules occur locally in the upper 1 ft (0.3 m).

The Spechts Ferry Member is conformably overlain and transitional with the Guttenberg Limestone Member, which consists of hard, fine crystalline, thin-bedded, fossiliferous, light brown limestone with brown petroliferous shale partings and interbeds. The presence of these interbeds has led to the member being referred to as the "Oil Rock." In the district the Guttenberg Member thins eastward from more than 14 ft to less than 7 ft (4 to 2 m).

The Spechts Ferry is conformably overlain by the Ion Member, which is a gray to blue dolomite, medium-crystalline, and medium to thick bedded with green shale interbeds. The amount of shale decreases to the east. The Ion maintains a thickness of about 20 ft (6 m) across the district.

The Decorah Formation is conformable with and transitional with the overlying Galena Dolomite Formation. The Galena was named (Owen, 1840, p. 19, 24) from exposures in the vicinity of the city of Galena in northwest Illinois. It is a light buff to drab, cherty, thick-bedded, vuggy dolomite with medium to coarse sugary grains. A zone of *Prasopora insularis* Ulrich marks the top of the Ion Member in some areas, but is absent here. In most of the district the Galena is dolomitized and the sparse fossils are poorly preserved. It is from 220 to 230 ft (67 to 70 m) thick throughout the district.

Near the north end of the roadcut, there is a quarry, now occupied by a junkyard, in which, on the southeast wall, can be seen an example of "pitch-and-flat" structure, which is the principal site of zinc and lead mineralization in the district. Here there is no mineralization.

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Middle Ordovician Platteville Formation, Hoadley Hill, Wisconsin

M. E. Ostrom, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin 53705

LOCATION

Exposure in roadcut at north side of U.S. 151 about 6.5 mi (10.8 km) southwest of Platteville in the W½,NE¼,Sec.12, and the W½,SE¼,Sec.1,T.2N.,R.2W., Grant County, Wisconsin on the Dickeyville 7½-minute Quadrangle (Fig. 1).

SIGNIFICANCE

This is the reference section for the Platteville Formation in the southwest Wisconsin zinc-lead district (Agnew and others, 1956; Ostrom, 1978). The strata exposed here are the upper part of the St. Peter Sandstone, the Glenwood Formation, a complete section of the Platteville Formation, and the lower part of the Decorah Formation (Fig. 2).

The Hoadley Hill exposure shows the interrelationship and lithologic characteristics of the St. Peter, Glenwood, and Platteville Formations in the classic southwest Wisconsin zinc-lead district. The St. Peter Sandstone was named by Owen (1847, p. 170) for exposures in bluffs of the St. Peter River valley (now Minnesota River), near St. Paul, Minnesota. It consists of clear, fine to coarse rounded to subangular quartz grains and is generally poorly cemented. It is white to very light gray and very light buff, thin to thick bedded, locally massive and cross-bedded, and is variable in thickness in the district ranging from 0 to more than 350 ft (0 to 100 m) thick and averaging about 50 ft (15 m) thick. Thickness variations are attributed to deposition of the sand on a deeply dissected erosion surface.

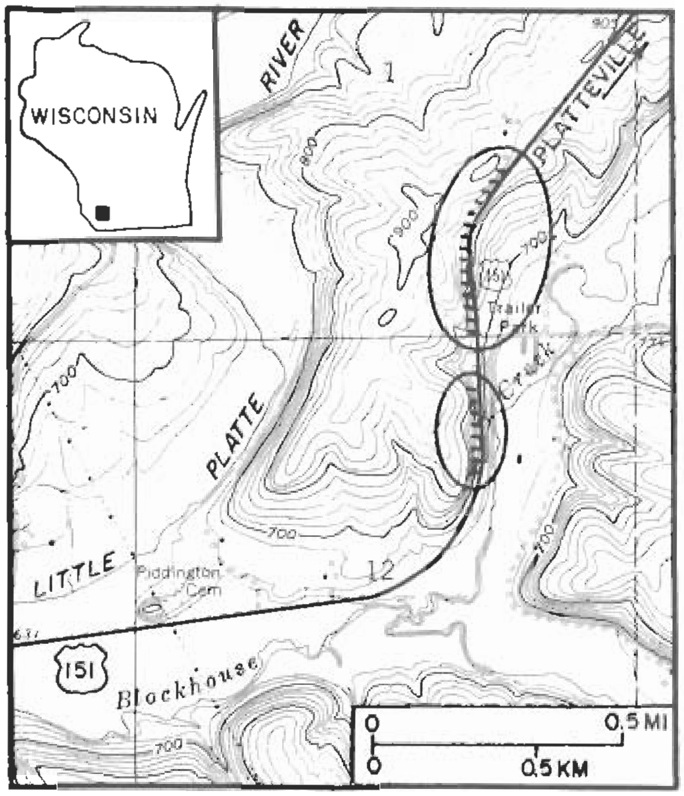


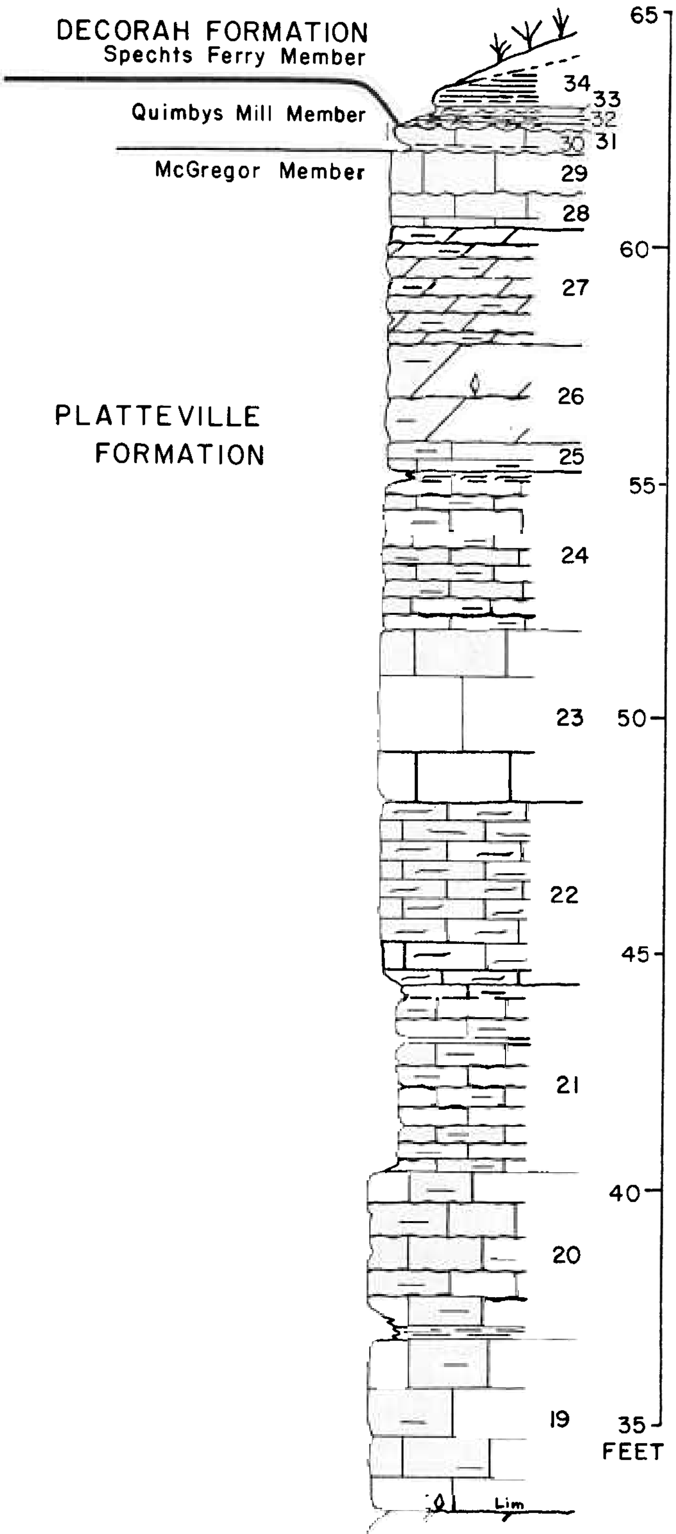
Figure 1. Location of exposure of Middle Ordovician Platteville Formation in roadcut at Hoadley Hill, Wisconsin.

The Glenwood Formation conformably overlies the St. Peter Formation. It was named by Calvin (1906, p. 75) from exposures in Glenwood Township (T.98N.,R.7W.) a short distance northwest of Waukon, Iowa. The classification used here is that of the Illinois Geological Survey (Templeton and Willman, 1963) as modified by Ostrom (1969). Three members are recognized in the Glenwood Formation in southwest Wisconsin. In ascending order these are the Nokomis, Harmony Hill, and Hennepin. The Nokomis Member consists principally of sandstone and is transitional with the underlying St. Peter Sandstone. It is distinguished from the St. Peter Sandstone by light yellowish and greenish coloration and by a notable change in bedding character from cross-bedded, even-bedded and even-textured sandstone to reworked, burrowed, and poorly sorted sandstone with more or less green clay. It is both silty and argillaceous. In the district the Nokomis ranges from 8 ft thick (2.5 m) near Beetown, about 25 mi (40 km) west-northwest of Hoadley Hill, to less than 1 ft (0.3 m) thick in the vicinity of New Glarus, located about 55 mi (88 km) to the east. The Nokomis Member is conformable with the overlying Harmony Hill Member.

The Harmony Hill Member is a pale green to greenish gray shale with scattered rounded clear quartz sand grains. It is up to 3.5 ft (1 m) thick in the western part of the district and is absent in the east. The Harmony Hill Member is conformable with the overlying Hennepin Member, which consists of brownish and locally calcareous shale with scattered phosphatic nodules and clear rounded quartz sand grains. It is 5 ft (1.5 m) thick in the western part of the district and thins to disappearance in the east.

The Platteville Formation overlies and is conformable with the Glenwood Formation. It is one of the mineralized formations in the southwest Wisconsin zinc-lead mining district and was named by Bain (1905, p. 19) for exposures in the vicinity of Platteville, Wisconsin. It is known throughout the district, and within the Driftless Area, from exposures at the surface and in mines and from drill cuttings. In the district the Platteville Formation ranges in thickness from about 55 ft (17 m) in the west to near 75 ft (23 m) in the east, near Shullsburg.

The Platteville Formation consists of three members, which in ascending order are the Pecatonica, McGregor, and Quimbys Mill. The Pecatonica Dolomite Member was named by Hershey



Ordovician System
Champlainian Series
Sinnipee Group

34. Shale, bluish-green.

33. Bentonite, white; weathers orange brown.

32. Shale, yellowish-green above to bluish-green below.

31. Shale, brown and olive, soft.

30. Limestone, dark purple, fine-crystalline, dense, conchoidal fracture; very wavy upper surface; thin, dark-brown to black, fossiliferous platy shale parting at base.

29. Limestone, light-gray, very fine crystalline, very dense, conchoidal fracture like "glass rock" above, fairly massive, very fossiliferous; wavy upper surface.

28. Limestone as next above but less dense, medium-bedded above to thin-bedded below, fossiliferous; wavy upper surface.

27. Dolomite, light olive drab, fine crystalline, "sugary," argillaceous, very thin-bedded; nodular.

26. Dolomite as above but thick-bedded; calcite near middle.

25. Limestone, thin-bedded yet stands massively as one unit; light greenish gray brown; weathers brown, with a few argillaceous streaks; sparingly fossiliferous, but with fossils and fucoids on top surface.

24. Limestone, thin-bedded as above but the beds are distinct; nodular beds and shaly partings; upper 0.3 ft (10 cm) is argillaceous and very fossiliferous.

23. Limestone, light buffish gray, in medium to thick beds; in places gradational into above unit.

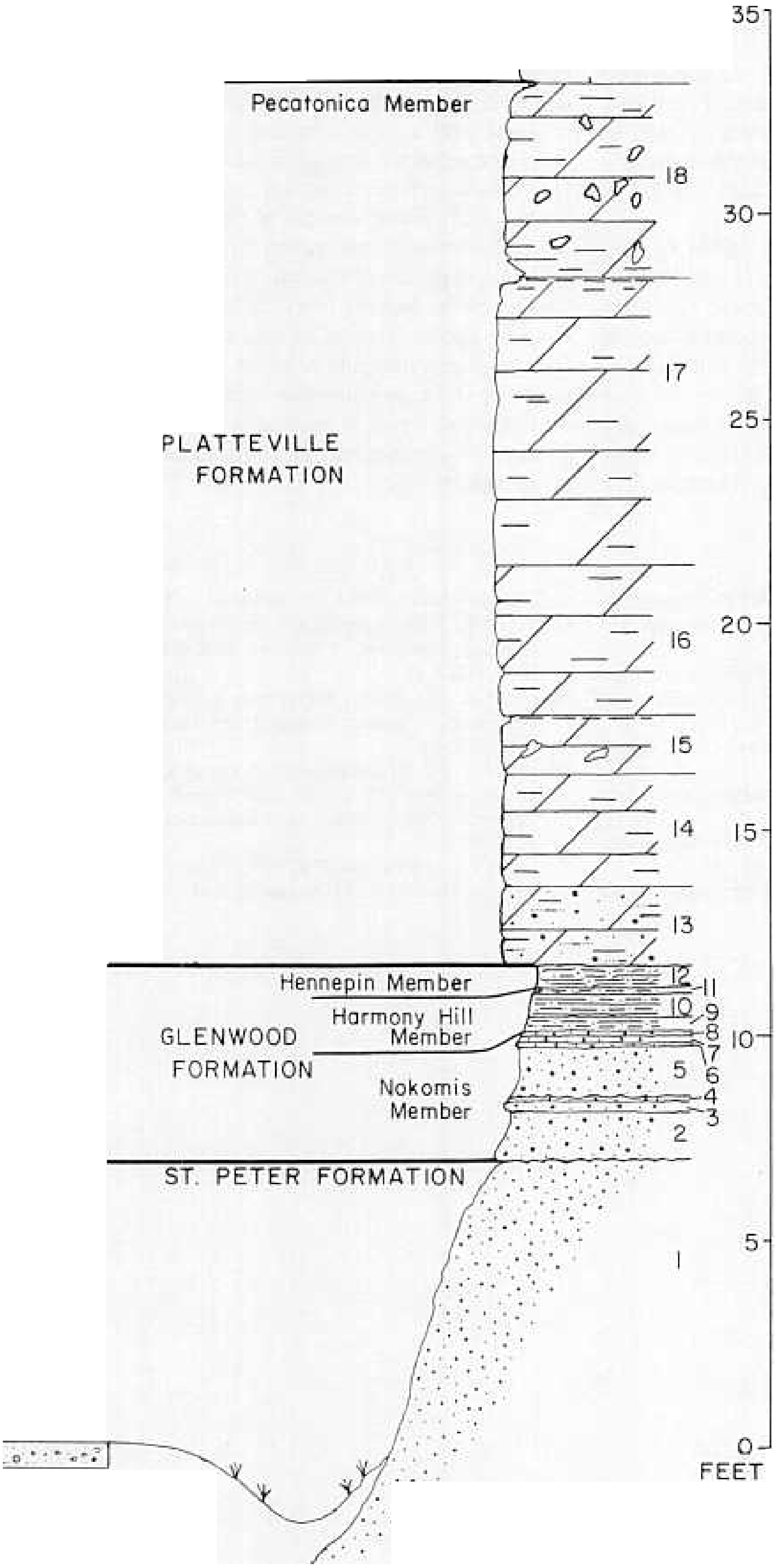
22. Limestone, light greenish to bluish gray, composed of thin beds but appears massive; abundant shaly material in wavy bands; fairly fossiliferous, argillaceous; a peculiar mottled light gray and darker gray 0.1-foot (3 cm) zone, 1 ft (30 cm) below top.

21. Limestone, light gray, very fine crystalline, very dense sublithographic, in extremely thin and nodular beds with thin calcarous shaly partings which become thinner below; the shale beds are light grayish blue, mottled, very fossiliferous; weathers slightly recessed.

20. Limestone, as above, but beds are not quite as thin; fossiliferous; poor gastropod zone 1.7 (50 cm) above base; shaly zone at base.

19. Limestone, dolomite, light-gray, fine crystalline, very slightly argillaceous, very fossiliferous, medium-bedded; indistinct argillaceous partings, not wavy; calcite and limonite, especially in basal 0.6 ft (18 cm).

Figure 2 (this and facing page). Section exposed in roadcut at Hoadley Hill, Wisconsin.



18. Dolomite, light grayish brown, very coarse crystalline and vuggy, upper 2 ft (60 cm) a mixture of lithology and a somewhat argillaceous fine crystalline "sugary" laminated dolomite; a 1-ft (30 cm) bed of very vuggy dolomite from 1.8 to 2.8 ft (55 to 85 cm) above base; shaly in lower part; stylolitic partings 1 ft (30 cm) above base.

17. Dolomite, medium gray, laminated, somewhat argillaceous, fine-crystalline "sugary," fossiliferous, especially in lower 0.9 ft (27 cm); medium- to thick-bedded; shaly at top; weathers brownish in lower 25 ft (75 cm).

16. Dolomite, medium gray, laminated, argillaceous; very fossiliferous partings.

15. Dolomite, light grayish brown, very coarse crystalline and vuggy; thin brownish gritty dolomitic and platy shaly parting at top.

14. Dolomite, medium gray, laminated, argillaceous, fine crystalline.

13. Dolomite, medium gray, laminated, argillaceous, silty and sandy with fine to coarse quartz grains similar to those of the St. Peter Sandstone, phosphate nodules abundant (especially in two zones, one at base, the other 1 ft (30 cm) above base .

12. Shale, sandy with rounded quartz grains, khaki to drab, soft; phosphate nodules.

11. Shale, sandy, olive to grayish brown; mottled yellowish brown, friable.

10. Shale, sandy, medium- to dark-gray, olive, blocky, very hard.

9. Shale, medium-gray, blocky, hard, sandy; streak of carbonaceous material at top.

8. Sandstone, red and white; rounded; frosted, coarse to medium-grained.

7. Sandstone, gray pinkish, very friable.

6. Sandstone, brown, iron-stained, hard.

5. Sandstone, yellow to gray, fine to coarse grained, very friable, reworked and burrowed, with irregular lower surface.

4. Sandstone, light-gray, very friable.

3. Sandstone, yellow to dark-brown, laminated, hard.

2. Sandstone, gray and yellow, fine to coarse grained, reworked and burrowed; hard irregular lower surface.

1. Sandstone as above, but medium- to fine-grained.

Base of exposure in roadside ditch

(1894, p. 175) from exposures in the Pecatonica River valley in southwestern Wisconsin near the Illinois border. It consists predominantly of medium-grained, granular, thick- to thin-bedded dolomite. The lowermost bed, the Chana Member (Templeton and Willman, 1963) contains phosphatic pellets as well as rounded quartz sand grains similar to those in the underlying Glenwood Formation. The Pecatonica is from 20 to 25 ft (6 to 8 m) thick in the district.

The McGregor Limestone Member was named by Kay (1935, p. 286) from an exposure in a ravine 1 mi (1.6 km) west of McGregor, Iowa. The McGregor Member consists of uneven bedded, thin- to medium-bedded, light gray to buff argillaceous dolomite and limestone and is from 25 to 30 ft (8 to 9 m) thick. The McGregor Member contains commercial deposits of zinc-lead ore. The Quimbys Mill Member was named by Agnew and Heyl (1946, p. 1585) from an exposure in a quarry at Quimbys Mill located 5 mi (8 km) west of Shullsburg, Wisconsin. The member ranges from less than 1 ft (0.3 m) in thickness to more than 18 ft (5.5 m). It consists of light brown, thin- to medium-bedded, crystalline sublithographic limestone and finely granular dolomite. This member is locally called the "glass rock" because it breaks with a conchoidal fracture. The Quimbys Mill also contains commercial deposits of zinc-lead ore.

The Platteville Formation is overlain discomformably by the Spechts Ferry Shale Member of the Decorah Formation. The Decorah Formation was named by Calvin (1906, p. 61) from exposures in the city of Decorah, Iowa. The Decorah Formation consists of the Spechts Ferry, Guttenberg, and Ion members. Only the Spechts Ferry is exposed at this outcrop. The Spechts Ferry consists principally of bluish green to brown shale with nodules and discontinuous thin beds of limestone. A thin metabentonite bed, which is believed to be an alteration product of volcanic dust, occurs near its base and can be correlated on a broad regional scale.

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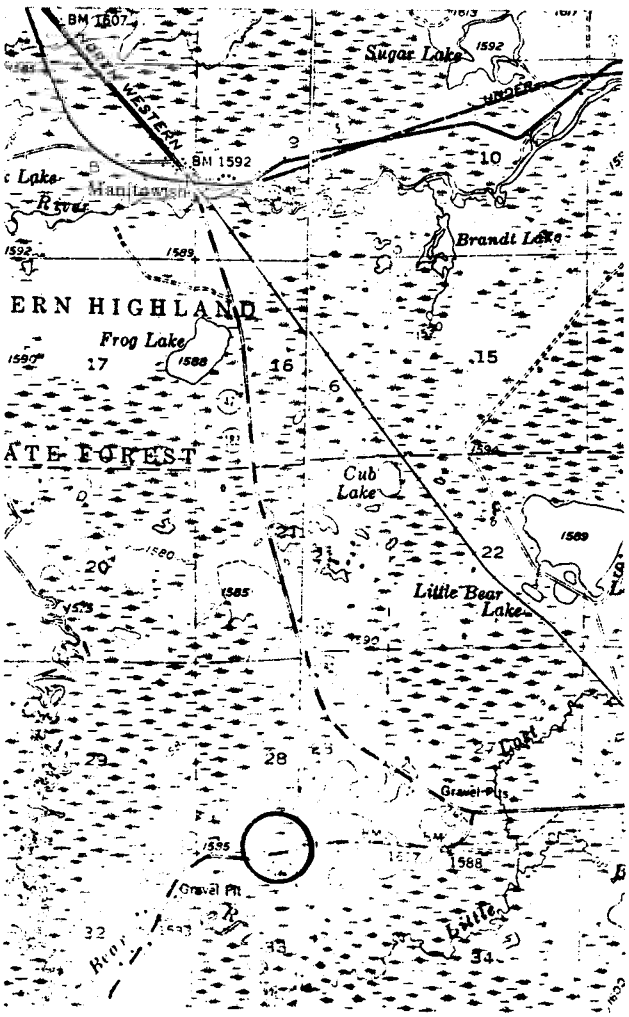
Title: Powell Kyanite

Location: SE¼, SW¼, Sec. 28, T.42N., R.4E.
(Mercer 15 Minute Quadrangle) on Hwy. 182

Author: Gene L. LaBerge



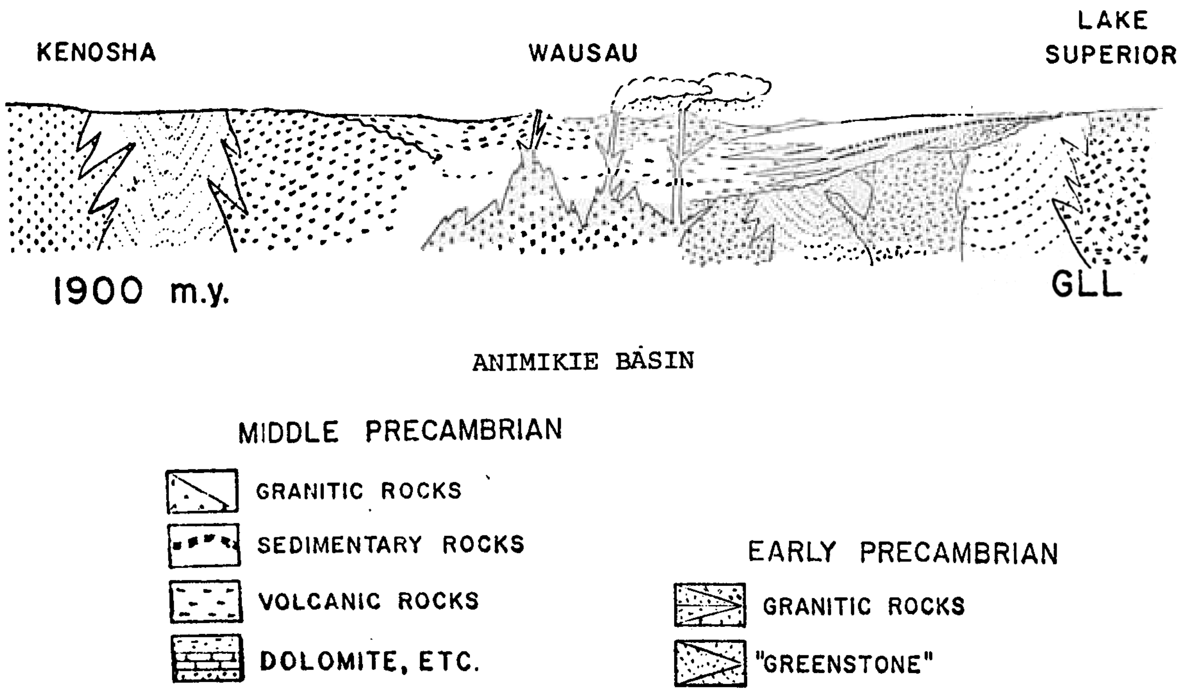
Description: The exposures here are a coarse-grained quartz-plagioclase-biotite-kyanite-muscovite-garnet-staurolite schist or gneiss. Grain size of most minerals is .5-1 cm, but kyanite blades up to 5 cm are present. Clusters of possible sillimanite needles are present in some of the coarser material.

Numerous rod-like (boudinaged?) quartz pods and scattered quartz-feldspar or pegmatites are present. The rocks have been intensely deformed with complex small-scale folds visible on several of the outcrops. Determine the orientation of the fold axes.

Although this is an isolated exposure of Precambrian rocks, it has been traced to the north-east by exploratory diamond drilling in the early 20th Century (see report by Allen and Barrett, 1915). James (1955) includes this area in his "Watersmeet Node," an elongate area of high-grade regional metamorphism. The metamorphic intensity decreases outward in all directions from this central high (Dutton & Bradley, 1970). The exploratory drilling that established this as part of a belt of metamorphic rocks was done along a linear magnetic anomaly caused by a metamorphosed magnetite-rich iron-formation. Metamorphism here reached at least the kyanite, and perhaps the sillimanite grade. Question: What causes the oval-shaped area of high grade metamorphism in this part of Wisconsin?

Significance: These rocks are generally believed to be highly metamorphosed equivalents of the Tyler Slate we examined near Hurley. Their association with magnetic iron-formation is an important aspect leading to the correlation If this interpretation is valid, then these rocks must have been deformed and metamorphosed during the Penokean Orogeny, about 1800-1850 million years ago. Recall that the slates and iron formation at Hurley were largely unmetamorphosed and undeformed during the Penokean Orogeny, and that Early Precambrian greenstones and granite occur between here and Hurley. Thus, there is no simple transition from the relatively unmetamorphosed and metamorphosed rocks to the north and those exposed here.

West along this zone at Butternut the iron-formation and graywackes are interbedded with volcanic rocks. Approximately 30 miles south of here the Middle Precambrian rocks are dominantly volcanics. Thus, the Animikie Basin becomes progressively volcanic in character southward as shown in the diagram.



(From LaBerge, in preparation)

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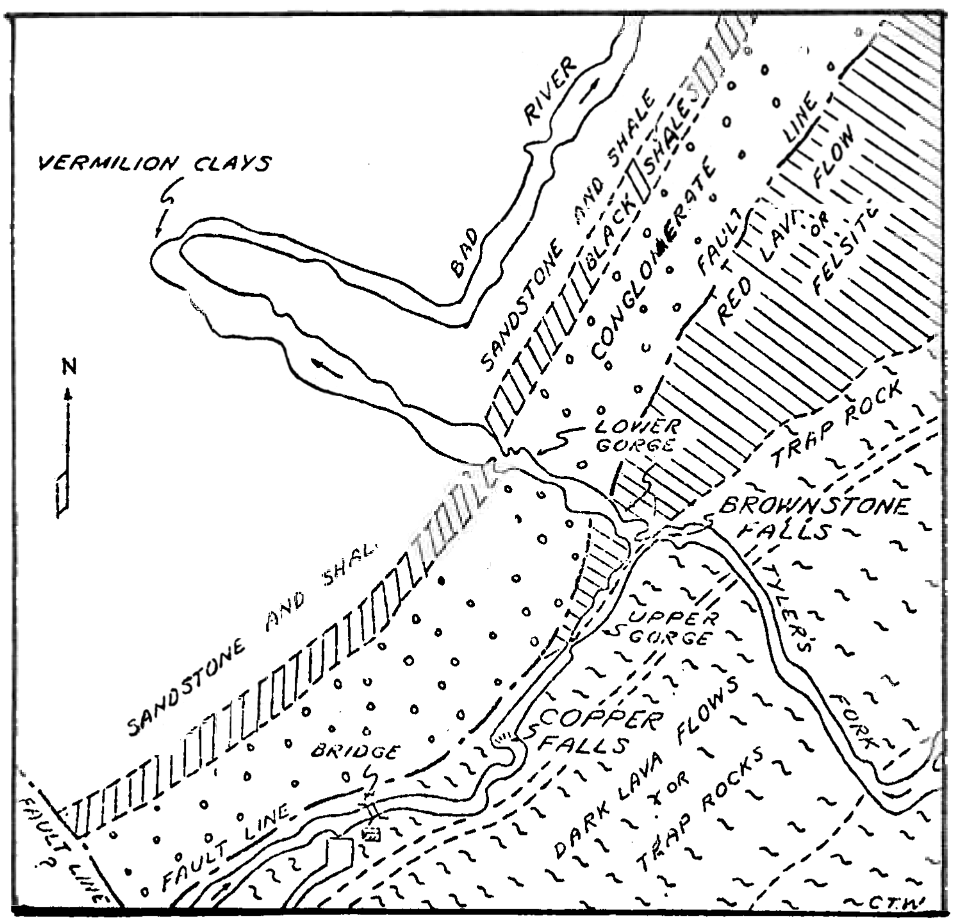
Title Keweenawan Basalts, Copper Harbor Conglomerate

Location: Copper Falls State Park. SE¼, Sec. 17, T.45N., R.2E.
Mellen 1:48,000 Planimetric Quadrangle.

Author: Gene L. LaBerge

Description: Copper Falls is formed where the Bad River, flowing northward to Lake Superior cuts through the resistant ridge of Keweenawan lava flows. The ridge, formed by erosion of the tilted edge of the basalts, is continuous for more than 150 miles northeast to the end of the Keweenaw Peninsula. Within the Park, the Bad River flows roughly parallel to the strike of the basalts, then turns approximately 90° and crosses the lavas at Copper Falls. Downstream about ¼ mile from Copper Falls, the Tylers Fork River joins the Bad River at Brownstone Falls, which occurs at the contact between basalts to the south and felsite (rhyolite) flow to the north.

The Copper Harbor Conglomerate is exposed in the lower gorge at "Devils Gate" about 600 feet downstream from Brownstone Falls, and immediately northwest of the conglomerate is the black Nonesuch Shale that contains the important sedimentary White Pine Copper deposit about 70 miles northeast of here. And northwest of the Nonesuch Shale is the Freda Sandstone. Thus, a fairly complete Keweenawan section is exposed in the Park.



SKETCH MAP OF COPPER FALLS STATE PARK Showing the General Boundaries of the Rock Formations

G. T. OWEN

(Modified after Aldrich)

Scale - 1" = 1/10 mile

Note: The rock formations are largely concealed by the glacial drift except at the falls and in the stream gorges Boundaries concealed by the drift are projected boundaries

Downstream from the exposures of Freda Sandstone the valley walls are composed of red lake clays formed in Glacial Lake Ashland, a precursor of Lake Superior that stood approximately 521 feet above the present level of Lake Superior. The high hill across the river from the pavillion is a moraine (terminal?) from an earlier advance of the ice.

Significance: The rock sequence exposed here illustrates the change in Keweenawan time from a dominantly volcanic regime to one of sedimentary character. The volcanic rocks are dominantly basalts, but rhyolites are present at a number of levels in the 40,000 foot thick pile. Interestingly, there are few andesites.

The lava flows are believed to have been flowing southward in this general area as indicated by the bent "pipe amygdules" formed by gas bubbles rising through the cooling lava as it flowed. Thus, during the volcanic stage the area now occupied by Lake Superior was higher than the surrounding area.

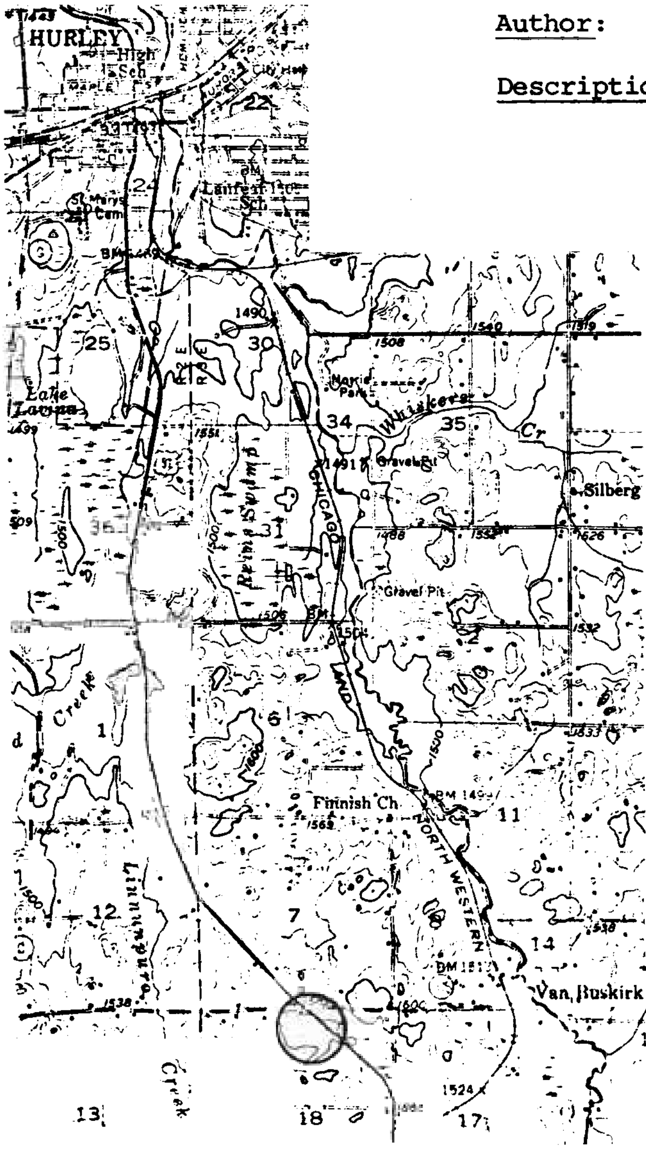
Cross bedding in the Outer Conglomerate and Freda Sandstone shows that these sediments were deposited by northward moving currents, indicating that a basin had developed in the present site of Lake Superior. Thus, while subsidence may have begun during the volcanic episode, volcanic activity kept the "basin" filled. When volcanism ceased, subsidence of the tremendous pile of basaltic rocks continued forming a basin. Sediments deposited by streams and in the quiet waters kept the basin more or less filled during later Keweenawan time, and perhaps on into early Cambrian time.

References:

Owen, G. T., 1938, The Geology of Copper Falls State Park, Wisconsin Conservation Dept., 6 p.

Title: Early Precambrian Granite

Location: U.S. Hwy. 51 about 5 miles south of Hurley (just south of County Hwy. C). NE¼, NE¼, Sec. 18, T.45N., R.2E. (Ironwood, Wis.-Mich. 15 Minute Quadrangle)



Author: Gene L. LaBerge

Description: This exposure is typical of granitic rocks intrusive into the Early Precambrian greenstones in the northern part of the Lake Superior region. Both the granites and greenstones were extensively eroded prior to deposition of the Middle Precambrian sedimentary sequence that includes the iron-formation. The contact between Early Precambrian granites and the sediments is exposed at several places along the Gogebic Range, for example at the Anvil Mine just east of Bessemer, Michigan (Schmidt and Hubbard, 1972).

The rock is a somewhat gneissic biotite quartz monzonite. There is some cataclasis (crushing) of the quartz and feldspar, presumably associated with the deformation that produced the gneissosity in the rock. Schmidt (1972) discusses some of the complex field relations within this very inhomogeneous granitic mass.

Significance: The relatively unmetamorphosed Early Precambrian granites and greenstones are part of an extensive terrane that formed about 2600-2700 million years ago (Morey & Sims, 1976). Rocks of this type and age are common for several hundred miles north of here (north of the Keweenawan rocks of the Lake Superior Basin), but are scarce or absent to the south. Rocks of probable Early Precambrian age to the south are mainly gneisses, amphibolites, and migmatites of much higher metamorphic grade, such as those we will see in the Eau Claire-Chippewa Falls area. Radiometric ages reveal that these rocks formed more than 300 million years ago, and thus constitute an older terrane (the "gneiss terrane" of Morey and Sims, 1976). The boundary between these two terranes is not exposed, but is believed to be about 10 miles south of here (see map by Sims, 1976).

Thus, there are two basically different types of Early Precambrian crustal rocks in Wisconsin, and this exposure lies near the southern boundary of the relatively unmetamorphosed greenstone-granite terrane. Question: In what type of tectonic environment was the greenstone-granite terrane developed? Is the difference in metamorphism and deformation result solely from a difference in age, that is, does it represent the last batch of greenstone-granite sequences, or is the difference more fundamental?

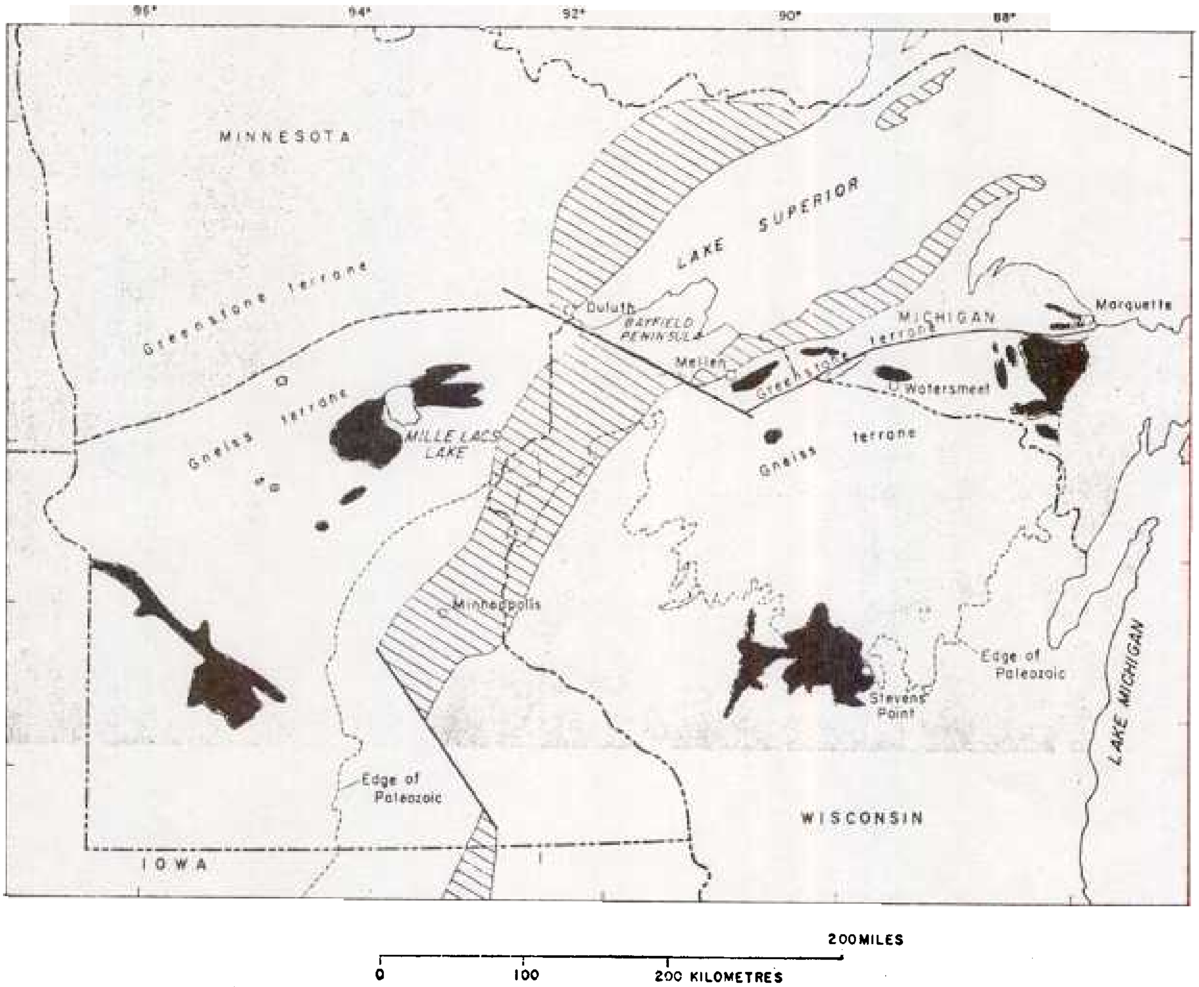


FIG. 5. Map of Lake Superior region showing distribution of Precambrian W greenstone and gneiss terranes. Modified from Morey and Sims (1976, fig. 8). Except for midcontinent gravity high (line rule), younger rocks of Precambrian X and Y ages are omitted. Heavy solid lines, possible Keweenawan transform faults, reactivated from older continental fault systems (modified from Chase and Gilmer, 1973); dense random pattern, exposure of Precambrian W gneiss; black, exposure of Precambrian W greenstone (Michigan and Wisconsin only); dark stipple, minimum inferred extent of gneiss terrane at surface and in subsurface; light stipple, minimum inferred extent of greenstone terrane at surface and in subsurface. Bayfield Peninsula is underlain by Precambrian Y or Z sedimentary rocks.

(From Sims, 1976.)

<u>References:</u>

Morey, G. B. and Sims, P. K., 1976, "Boundary Between Two Precambrian W Terranes in Minnesota and Its Geologic Significance," Geol. Soc America Bull., Vol. 87, pp. 141-152.

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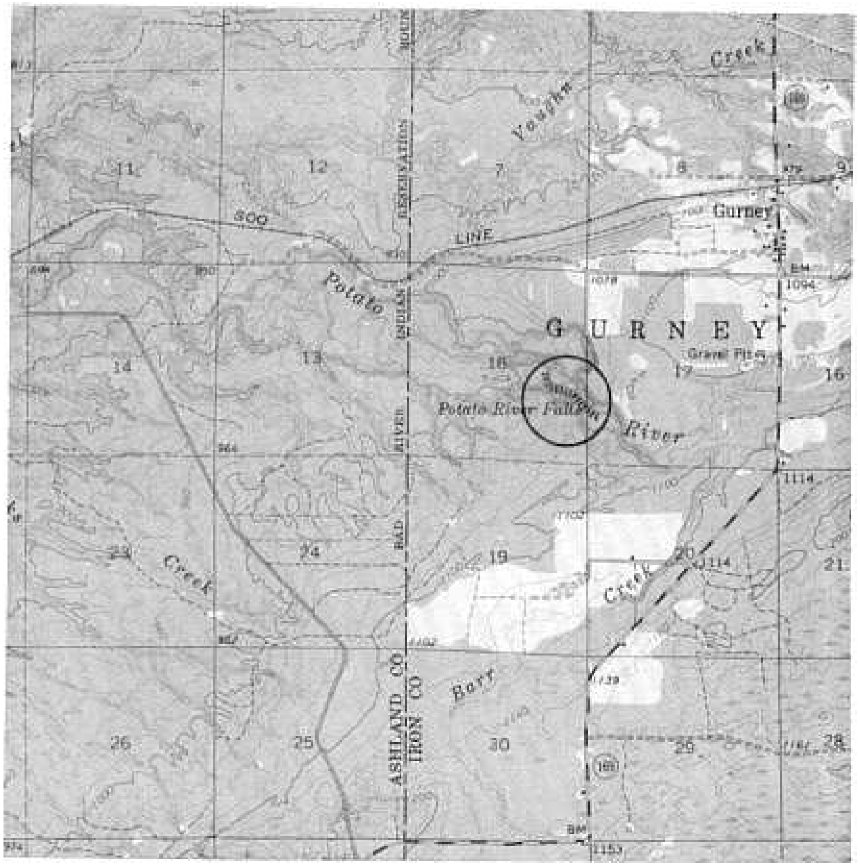
Title: Potato River

Location: Exposures in banks of Potato River at County Park 1.5 miles southwest of Gurney on secondary road and in the NE$\frac{1}{4}$, NE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 18, T.46N., R.1W., Iron County (Mellen 15-minute topographic quadrangle, 1967).



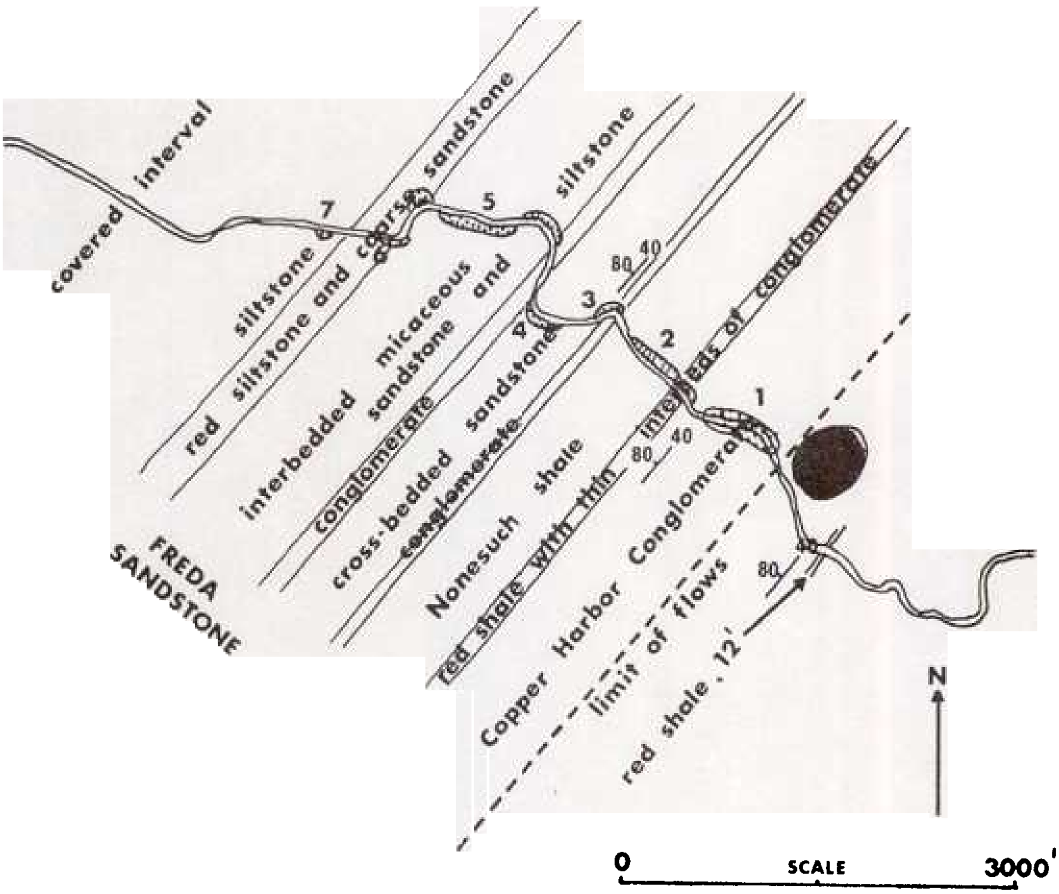
Author: M. E. Ostrom (modified from Myers, 1931)

Description: Thick section of Copper Harbor Conglomerate, Nonesuch Shale, and Freda Sandstone is exposed in the bed and banks of the Potato River in the County Park. The description from Myers (1971, pp. 222 & 223) is given on the attached illustrations.

Significance: Exposure affords opportunity to examine the three formations which comprise the Oronto Group of the Upper Keweenawan Series, i.e. the Copper Harbor Conglomerate, Nonesuch Shale, and Freda Sandstone and their lithologies, mineralogies, contact relationships, sedimentary structures, and other features.

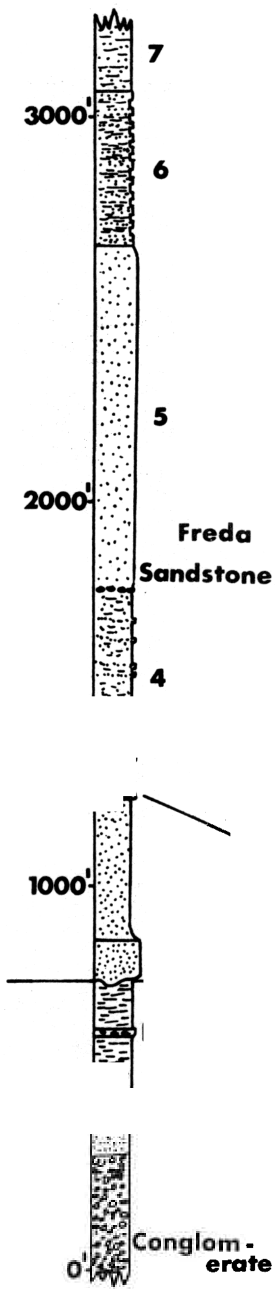
Recall the White River and South Fish Creek stops. From a regional and structural perspective, what do you interpret happened to these strata? Considering the mineralogy and lithologic composition of the formation, what was their origin? Was it the same? What direction was the source of the sediments? Was it the same for each formation? What was the environment of deposition for each formation? How were they related spacially?

References: Myers, 1971



Index map showing the location of exposures of Oronto Group rocks, Potato River, E½, Sec.18, T.46N, R.1W, Wisconsin. Outcrop numbers correspond to numbers on stratigraphic column.

STRATIGRAPHIC COLUMN OF EXPOSURES ON THE POTATO RIVER, E 1/2, SEC. 18, T. 46 N, R. 1 W, WISCONSIN



Covered Interval. Thickness of covered interval estimated to be over 4000 feet.

Grayish red and grayish red purple siltstone with minor soft thin sandstone. Poorly exposed.

Interbedded grayish red fine- to medium-grained sandstone and siltstone. Beds typically 10' in thickness, but 50' zone of sandstone present at base. This sand is coarse, grayish red purple. Near top of this zone is 8' grayish brown siltstone. Cut-and fill; birdseye leaching.
Tectonic Attitude: Strike N40 E, Dip 80 NW

Very uniform, resistant sandstone; medium to coarse grained; grayish red purple and very micaceous. Cut and fill (1) present; occasional cross-bedding, current ripple marks. Isolated pebbles up to 1" in diameter (quartz). Increasingly conglomeratic toward base. Minor siltstone beds (1') scattered throughout section.

Soft grayish red purple micaceous siltstone with occasional layers of hard grayish red sandstone. One thin layer of conglomerate near top. Sandstone is medium grained; abundant clay shale pebbles randomly distributed. Birdseye leaching and leaching along bedding planes and joints.

Soft, grayish red purple sandstone; micaceous. Underlain by conglomerate with pebbles up to 6" Calcite cement prominent in hand specimen and under microscope.

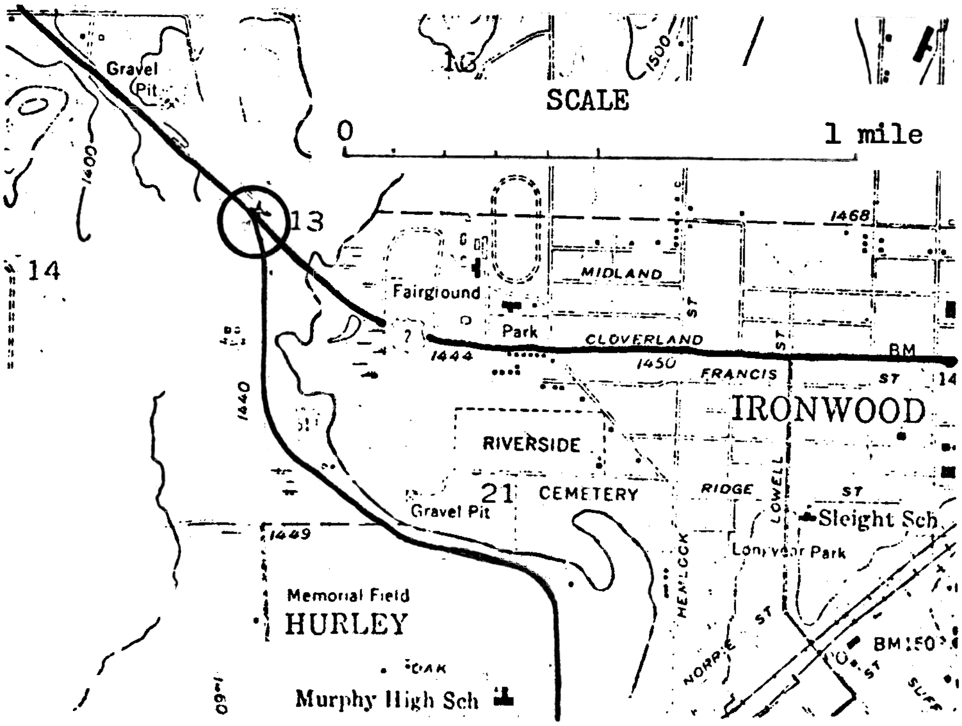
Zone of interbedded sandstone and siltstone (minor). Siltstone units 3-6" thick; leaching and minor copper staming. Basal 20' consists of hard grayish red sandstone and siltstone. Some evidence of cut and fill; contact with Nonesuch may be minor diastem

Interbedded fine-grained sandstone, siltstone and silty shale. Sedimentary structures identified included parting lineation and cut-and-fill. In general, section is composed of thin-bedded (2-5"), well sorted, and highly indurated silty shale.

Conglomerate; clasts up to 8"; estimate 75-80% vol. R. F.; quartz + quartzite 20-25%. Some epidotized volcanic R. F.s. Pebbles rounded, rare percussion marks; faint suggestion of cross-bedding.

Title: Tyler Formation

Location: SE¼, SE¼, NE¼, Sec. 14, T.46N., R.2E.
Hurley, Wis., on U.S. Highway 2 beneath overpass at junction with U.S. Highway 51.



Author: Gene L. LaBerge

Description: This exposure is characteristic of most of the Tyler Formation (Aldrich, 1929). The unit is generally referred to as the Tyler "Slate" although slates makes up less than one-third of the formation; graywacke sandstone makes up a majority (Alwyn, 1976). The formation is over 7,000 feet thick here, and increases to about 12,000 feet at Mellen (Alwyn, 1976). To the east it has been completely removed by erosion prior to deposition of Keweenawan rocks (Schmidt & Hubbard, 1972). The rocks here are only slightly metamorphosed. Graded beds and other primary sedimentary structures indicate that the beds are not overturned (Schmidt & Hubbard, 1972).

Note that the rocks dip steeply to the northwest, and that the cleavage dips less steeply than the bedding. This cannot be axial plane cleavage developed at the time the rocks were tilted to their present position because if that were the case the cleavage should dip more steeply than the bedding as shown in Figure 1A. Since axial plane cleavage (or fracture cleavage) dips more steeply than the bedding, it must have formed during an earlier deformation when the rocks were dipping to the south.

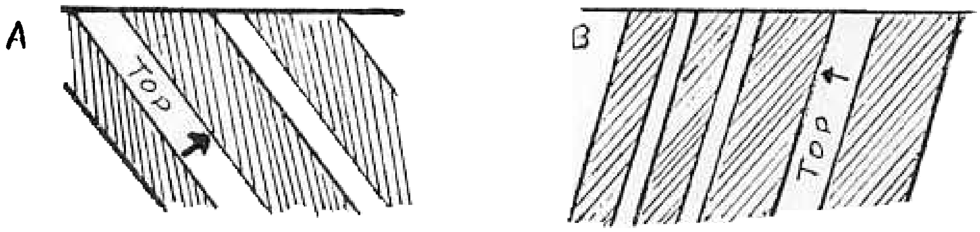


Figure 1. A represents normal relationship where the cleavage dips more steeply than bedding. B represents situation at this outcrop. Note that if A is rotated counterclockwise about 100^{o} both bedding and cleavage are parallel with B.

Significance: The Tyler Formation is part of a very thick, extensive unit known variously as the Michigamme Formation in Michigan and the Virginia and Thomson Formations in Minnesota. These formations are all remarkably similar, in appearance and all overlie the Middle Precambrian iron-formations of the Animikie Basin. They are derived in part from the erosion of older Precambrian granitic rocks (Alwyn, 1976), and in part from erosion of contemporaneous volcanic islands. The rocks were deformed and metamorphosed slightly during the Penokean Orogeny about 1800 million years ago.

The relationship of the cleavage to the bedding suggests that there is an anticline to the north of here -- in the Lake Superior Syncline. Thus, these rocks appear to have been rotated as a block nearly 90^{o} after the cleavage had developed. North of here the Keweenawan rocks dip more steeply than the Tyler formation (Schmidt & Hubbard, 1972), and the lavas flowed downhill from the north. This indicates that a block of rocks some 80 miles long and perhaps 10 miles wide was rotated as a unit during Keweenawan time (Hendrix, 1960), perhaps the result of a rift opening in the present site of Lake Superior.

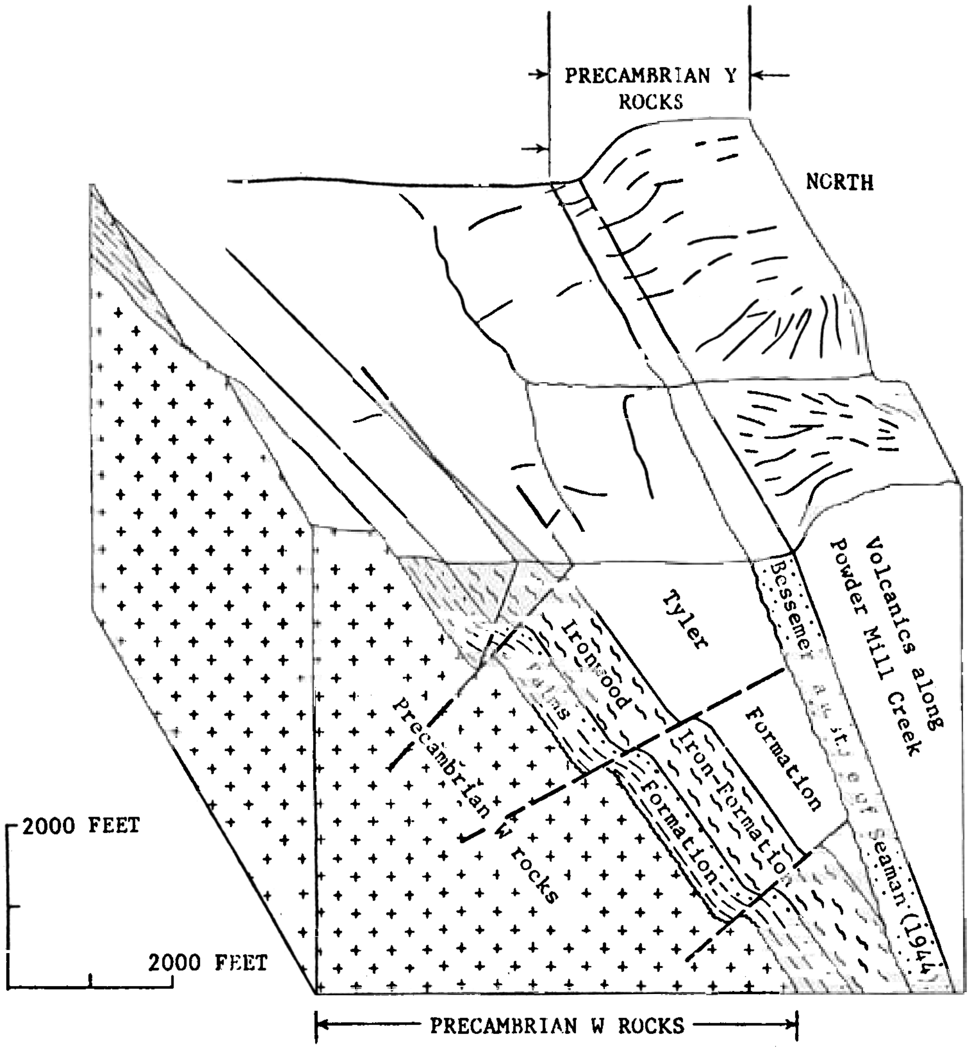
References:

Aldrich, H. R., 1929, The Geology of the Gogebic Iron Range of Wisconsin, Wis. Geol. Nat. Hist. Survey Bull. 71, 279 p.

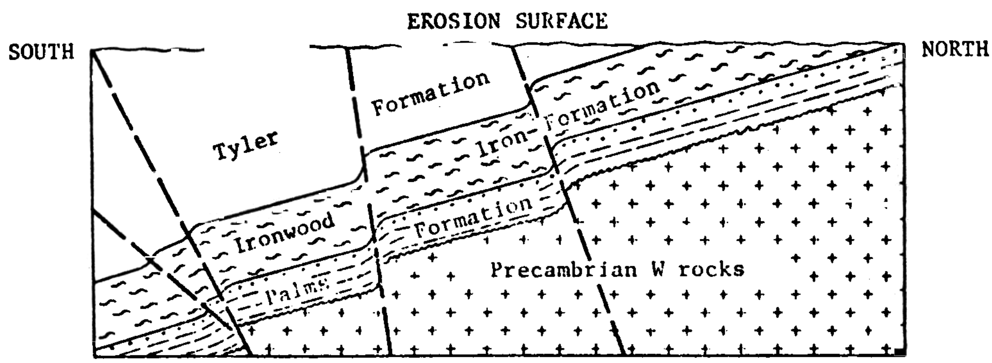
Alwyn, B. W., 1976, "Sedimentation of the Middle Precambrian Tyler Formation of North Central Wisconsin and Northwestern Michigan," Unpublished M.S. Thesis, Univ. of Minn.-Duluth, 175 p.

Hendrix, T. E., 1960, "Structural History of the Eastern Gogebic Range Unpublished Ph.D. Thesis, Univ. of Wisconsin.

Schmidt, R. G. and Hubbard, H. A., 1972, "Penokean Orogeny in the Central and Western Gogebic Region, Michigan and Wisconsin," Field Trip A, 18th Annual Institute on Lake Superior Geology, Houghton, Mich.



Generalized diagram of the relationship of Precambrian rocks in the central Gogebic district

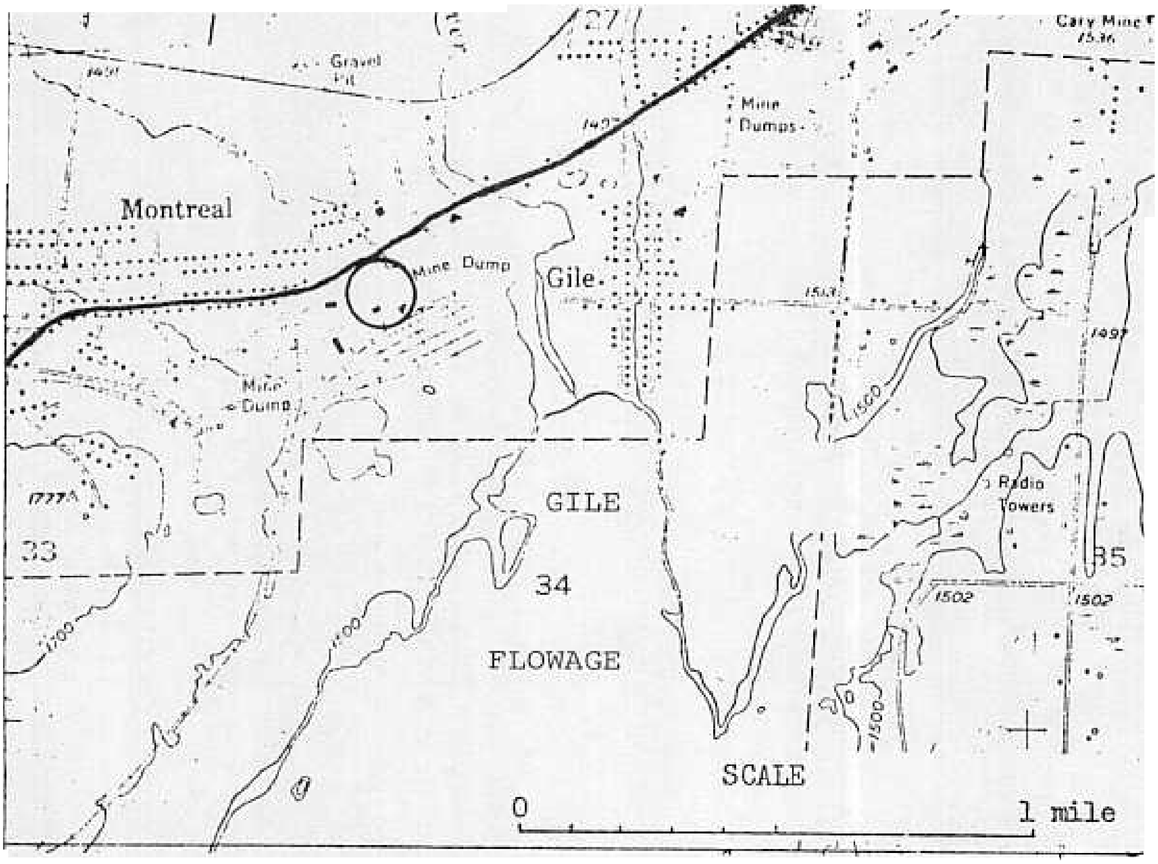


Hypothetical post-Penokean pre-Keweenawan cross-section on same surface as front of block diagram above

From Schmidt & Hubbard, 1972.

Title: Natural Iron Ore

Location: NE¼, NE¼, Sec. 33, T.46N., R.2E., Montreal Mine
(Ironwood, Wis.-Mich. 7½ Minute Quad.)



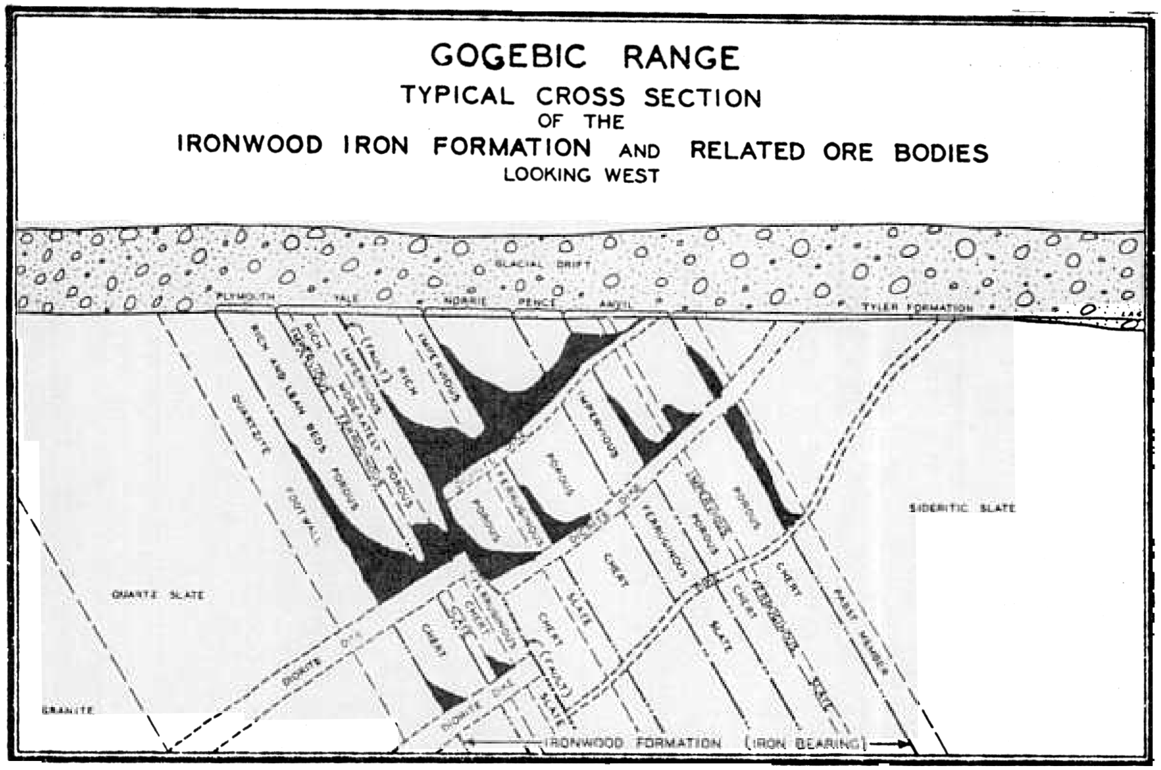
Author: Gene L LaBerge

Description: The waste piles here are typical of the natural "soft" iron orebodies throughout the Lake Superior region. The ore consists mainly of fine earthy mixtures of hematite, goethite, and "limonite," with nodular masses of botryoidal goethite. The waste pile is composed of highly oxidized iron formation containing too much silica to be used for iron ore.

Natural iron ore is formed from iron-formation by dissolving the silica from the rock and leaving the iron behind to accumulate. This involves dissolving and transporting almost 50% by volume of the rock! In northern Minnesota this leaching was accomplished by surface weathering. Here on the Gogebic Range and on the Marquette Range the leaching was done by rising hydrothermal solutions since many orebodies have no connection with the surface (Bailey & Tyler, 1960). As shown in the accompanying diagram, diabase dikes and impervious slate layers within the iron formation were important in channeling the flow of water that produced the natural iron ores.

Significance: Iron ore was first discovered in the Lake Superior region at Negaunee, Michigan, in 1844, and mining operations commenced shortly thereafter. Ore was discovered on the Gogebic range at Bessemer, Michigan, in 1873, and over 300 million tons of ore was mined before operations ceased in 1966 (Schmidt & Hubbard, 1972). Vast quantites of iron is still available from the iron formations if we can upgrade them by removing the silica (taconite operation).

Several intriguing questions arise concerning the natural ores. Where did the hundreds of millions of tons of silica dissolved from the orebodies go? Was it carried in solution to the sea? How long did it take to form the orebodies? When did the orebodies form? During the Precambrian? Paleozoic? Mesozoic? Tertiary? All four? There are reports of cobbles of iron ore in Keweenawan rocks north of here, so at least some ore is pre-Keweenawan.



From Schwartz (Ed.), 1956, G.S.A. Guidebook, Field Trip 1 "Precambrian of Northeastern Minnesota."

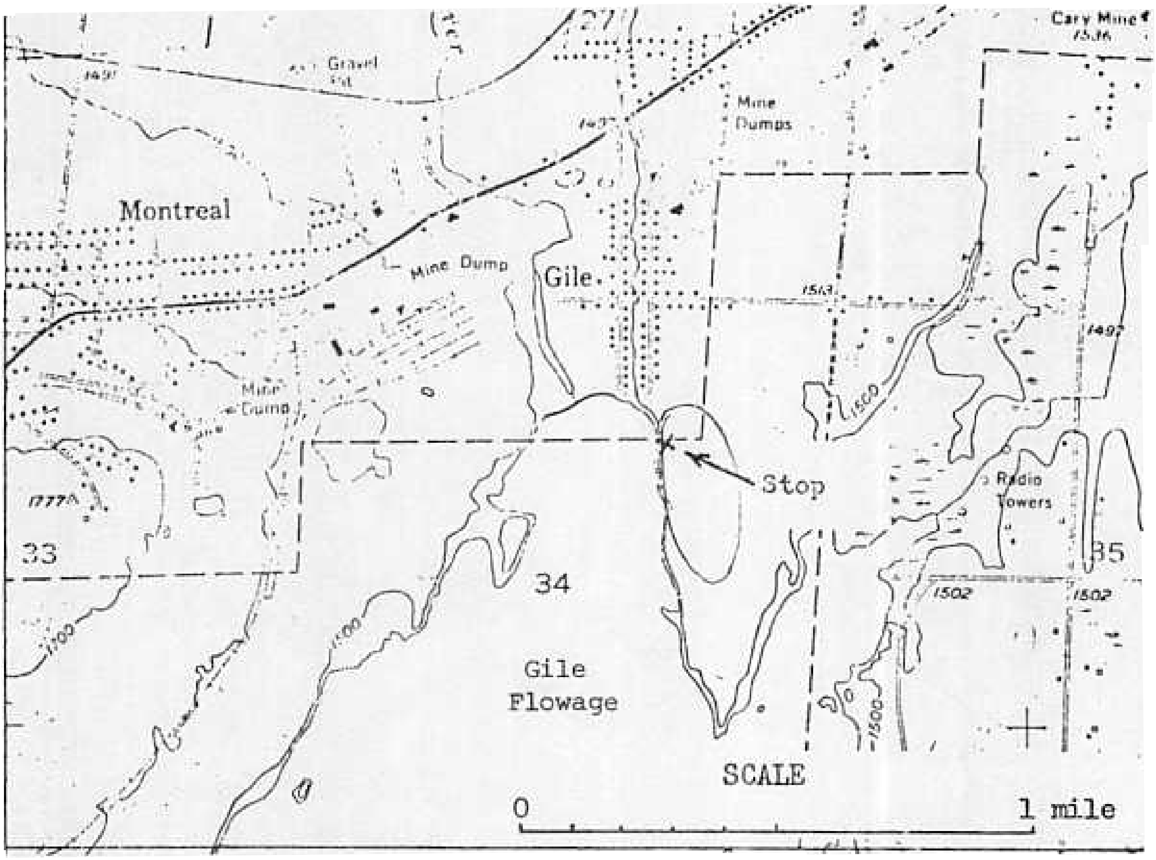
References:

Bailey, S. W. and Tyler, S. A., 1960, Clay Minerals Associated with the Lake Superior Iron Ores, Econ. Geol., Vol. 55, pp. 150-175.

Schmidt, R. G. and Hubbard, H. A., 1972, "Penokean Orogeny in the Central and Western Gogebic Region, Michigan and Wisconsin," Field Trip A, 18th Annual Institute on Lake Superior Geology, Houghton, Mich.

Title: Early Precambrian Greenstone

Location: South edge of Gile, Wis., SW¼, NE¼, Sec. 34, T.46N., R.2E. (Ironwood, Wis.-Mich. 15 Minute Quad.) (Gile Flowage)



Author: Gene L. LaBerge

Description: A large area of outcrop is present on the hill along the east side of Gile Flowage. The main rock type is a metabasalt (or greenstone) along with several small intrusives. At the north end of the exposure the greenstone is a coarse tuff with spectacularly elongated fragments. Further south along the hill pillow lavas with unusually large pillows are exposed.

The marked elongation of the volcanic fragments has been produced tectonically, for they must have initially been roughly equidimensional. The style of deformation in the greenstones here is markedly different than that in the overlying sedimentary rocks, and therefore must represent an earlier deformation. This difference in style of deformation, along with abrupt changes in lithology, have long been recognized as indicating a significant age difference between the greenstones and granites and the sedimentary rocks (Irving and Van Hise, 1892). Question: What type of deformation produces the rod-like elongation exhibited in the volcanics here?

Significance: The greenstones here are similar to the metavolcanics that underlie much of the Gogebic Range. They consist mainly of pillowed and massive, steeply dipping basaltic rocks that have been metamorphosed only to the greenschist facies. Despite the intense deformation, the rocks retain well-preserved primary textures and structures. The granitic rocks that intrude the volcanic sequence are about 2700 m.y. old (Sims, 1976), and thus the volcanics must be older than that. The igneous and tectonic events represented by the greenstones and associated granites are perhaps the last rock-forming event in the Early Precambrian. After the formation of these rocks, the area was subjected to erosion for several hundred million years before the sea again advanced over the area and the Middle Precambrian sediments, including iron-formation, were deposited.

The common occurrence of pillow structures and water-laid tuffs in the greenstones (and associated graywackes) indicates that the rocks were formed in a submarine environment. However, the tectonic setting where greenstone "belts" were formed has been greatly debated (e.g. Annhaeueser, and others, 1969; Goodwin, 1968; Hutchinson, 1973) The generally low grade of metamorphism in the greenstones, except adjacent to intrusions, argues against the greenstones and granites being roots of former mountain ranges. Also, the presence of greenstone belts of approximately the same age (2700 m.y.) covering large parts of the Canadian Shield (Morey and Sims, 1976) presents problems in explaining the tectonic setting in which the rocks formed.

The 2700 m.y. old greenstone-granite terrane extends only 10-20 miles south of the Gogebic Range in Wisconsin. South of that, Early Precambrian rocks are gneisses and amphibolites and are commonly more than 3,000 m.y. old (Sims, 1976). The origin of these different rock types and their relationship to one another is one of the major unresolved problems of the Lake Superior region.

References:

Anhaeueser, C. R., Mason, R., Viljoen, M. J., and Viljoen, R. P., 1969, Reappraisal of Some Aspects of Precambrian Shield Geology; Geol. Society of America Bull., Vol. 80, pp. 2175-2200.

Goodwin, A. M., 1968, Evolution of the Canadian Shield; Presidential Address; Geol. Assoc. of Canada, Vol. 19, pp. 1-14.

Hutchinson, R. W., 1973, Volcanogenic Sulfide Deposits and Their Metallogenic Significance; Econ. Geol., Vol. 68, pp. 1223-1246.

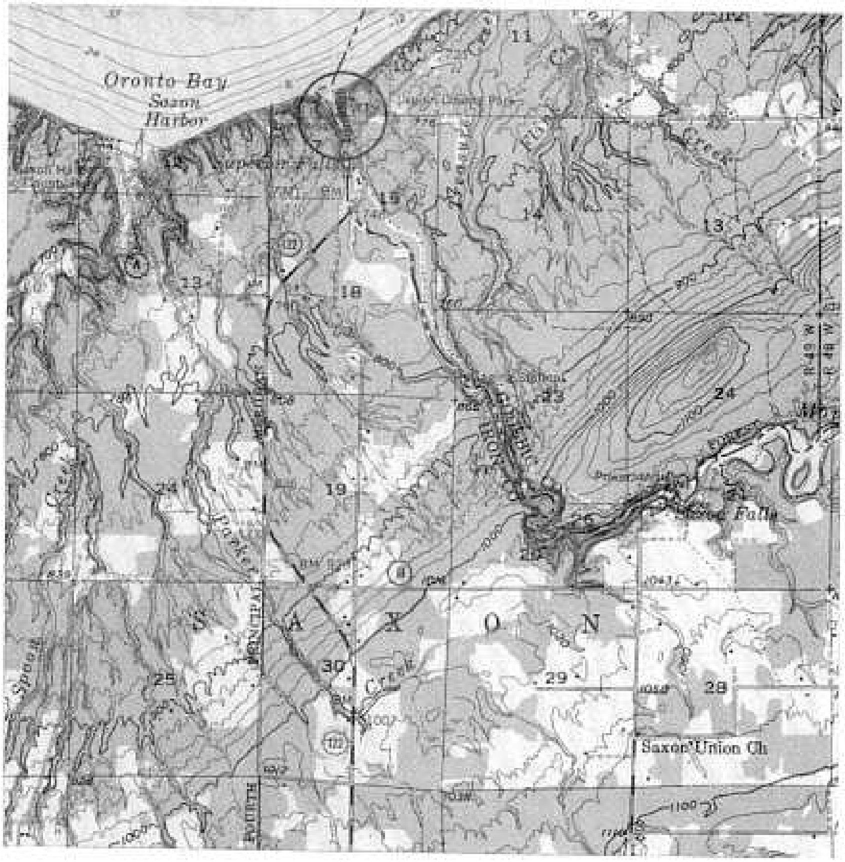
Irving, R. D. and Van Hise, C. R., 1892, The Penokee Iron-Bearing Series of Michigan and Wisconsin; U.S. Geol. Survey Monograph 19, 534 p.

Morey, G. B. and Sims, P. K., 1976, Boundary Between Two Precambrian W Terranes in Minnesota and Its Geologic Significance; Geol. Soc. America Bull., Vol. 87, pp. 141-152.

Sims, P. K., 1976, Precambrian Tectonics and Mineral Deposits, Lake Superior Region; Econ. Geol., Vol. 71, pp. 1092-1127.

Title: Montreal River

Location: In Montreal River Gorge from mouth in $SE\frac{1}{4}$, $SW\frac{1}{4}$, Sec. 7, T.47N., R.1E Iron County (Little Girls Point 15-minute topographic quadrangle, 1956). Can be reached by road and foot path from Michigan side of river and northeast of power dam.



Author: M. E. Ostrom, modified from R. D. Irving (1880, p. 191-192) and Hite (1968, p. 111).

Description: Gorge cut in Keweenawan sediments and volcanics by Montreal River. Exposures from river mouth upstream to Superior Falls are in the Upper Keweenawan Freda Formation. Further upstream, as at the Saxon Power Station, Middle Keweenawan volcanics and interbedded sediments are exposed. A summary section of rocks exposed in the Montreal River gorge is as follows:

PRECAMBRIAN

Upper Keweenawan (13,550.0 ft.)

Freda Sandstone Formation (12,000 ft. ±)

Sandstone, red and brownish red, fine-grained, abundant feldspar, shaly. 12,000.0 ft.

Nonesuch Shale Formation (350 ft.)

Shale and fine-grained sandstone; black to brown, abundant feldspar, calcareous, micaceous; layers of black shale, thinly laminated, up to 50 feet thick. 350.0 ft.

Outer Conglomerate Formation (1200 ft.)

Conglomerate, boulders 4 to 15 inches in diameter of basalt, rhyolite, gabbro, quartzite, vein quartz, slate, iron formation, granite, and others. Little sandy matrix; much calcite. 1200.0 ft.

Middle Keweenawan (1,209.0 ft.)

Alternating layers of volcanic flows (diabase), red shaly and feldspathic sandstone, and thinly laminated red shale. 1,209.0 ft.

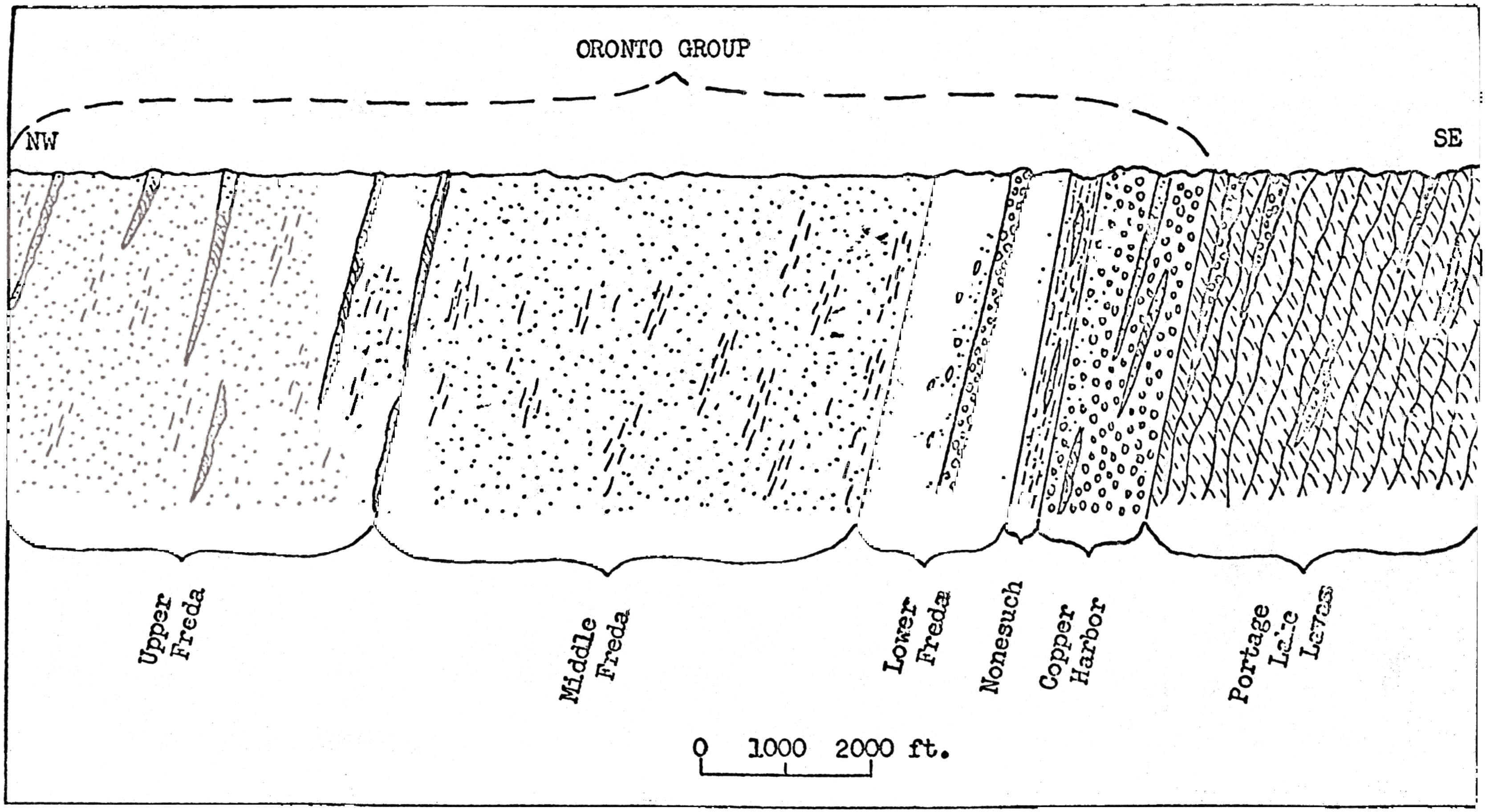
A detailed description of the Freda Sandstone section from Superior Falls downstream to the Superior Power Station (modified from Hite, 1968, p. 111):

PRECAMBRIAN

Upper Keweenawan

Freda Sandstone Formation (100.0 ft.)

9.0'	9.0'	8.	Siltstone, red, micaceous and laminated, interbedded with white to green feldspathic sandstone, fine-grained, thin-bedded.
-29.0'	20.0'	7.	Sandstone, red, fine-grained, abundant feldspar, bedding poorly developed, shale pebbles common in upper part.
29.0' -33.0'	4.0'	6.	Sandstone, red, very fine- and fine-grained, laminated, cross-bedded.
-51.0'	18.0'	5.	Shale and fine siltstone, brick red, abundant feldspar micaceous, laminated, interbedded coarse-grained cross-bedded sandstone 6 ft. below top of unit.
51.0' -77.0'	26.0	4.	Sandstone, red, very fine- to fine-grained, abundant feldspar, laminated, with micro cross-bedding which becomes more abundant upward in section; distorted bedding in middle portion of section.
77.0' -87.0	10.0'	3.	Siltstone, red, micaceous with abundant feldspar, laminated with shales and cross-bedded siltstones.



Idealized section of the Oronto Group along the Montreal River, Wisconsin
Mouth of river is at left of diagram.

87.0' -95.0'	8.0'	2.	Siltstone, red, micaceous with abundant feldspar, irregular laminations with micro cross-bedding and ripple marks in upper part; interbedded with red fine-grained sandstone.
95.0' -100.0'	5.0'	1.	Sandstone, red, fine-grained, abundant feldspar, laminated, rib and furrow structures.

Significance: Principals of geologic history and of geomorphic processes are illustrated by this exposure. The geologic section as shown in the idealized cross-section (Hite, 1968, p. 26) indicate both a major change in materials deposited in the area and a significant structural deformation. The lithologic and structural relationship of these rocks to both older and younger rocks is significant to reconstructing the regional historical geology. For example, how are they related to younger and essentially flat-lying rocks exposed to the west and north of this area and which contain less feldspar and less shale? Why are these rocks assigned to the Precambrian? What was the source of materials which formed these rocks?

Geomorphic processes of distribution and construction relating to both stream and wave action are in evidence. Explain the steep bluffs of the Lake Superior shoreline, the "bar" of boulders which blocks the mouth of the Montreal River, the deep gorge from Superior Falls to the lake shore, and the reason for the location of Superior Falls. Have these features been formed by recent events relating to man's activities? For example, are the steep bluffs along the lake shore a product of natural events? Are they man-caused? A combination of the two?

References: Irving, 1880; Thwaites, 1912; Hite, 1968

Title: Blue Mounds

Location: Major mounds north of U. S. Highway 151 and centered in the NW$\frac{1}{4}$ of Section 1, T. N., R. E., Iowa County and the SW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 6, T. N., R. E., Dane County (Blue Mounds 7.5-minute topographic quadrangle, 1962).

Author: M. E. Ostrom (modified from Black, 1970)

Description: (modified from R. F. Black, 1970): A log of the well in Blue Mounds State Park and at the top of West Blue Mounds indicates the rocks which occur beneath the ground surface (see attachment). West Blue Mound (1716 feet) and East Blue Mound (about 1490 feet above sea level) rise 300 to 500 feet above the general level of the surrounding upland cut in the Galena-Decorah-Platteville dolomites of Ordovician age (see diagram). West Blue Mound is capped with 85 feet of dolomite and chert of Niagaran (Silurian) age; all dolomite in the upper 75 feet is completely silicified (Thwaites, 1960, p. 26). Between the 1630-foot and 1380-foot contours the mound is ringed by gentle slopes on the Maquoketa Shale (upper Ordovician). The flat surface of East Blue Mound is developed in the Maquoketa Shale; only 80 feet remain according to one drill hole (Cline, 1965, Pl.4). Relatively few fragments, up to four feet across, of the younger silicified Niagaran unit are scattered over the top and flanks.

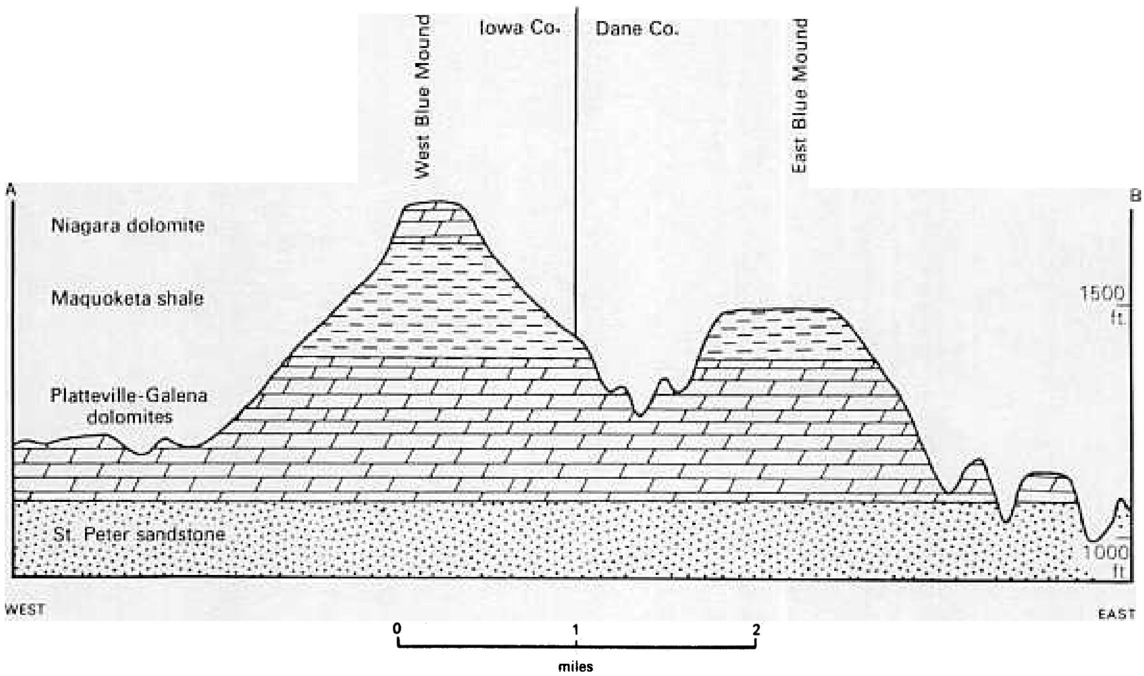
West Blue Mound is an outlier of the Niagaran escarpment that lies about 50 miles to the southwest in Illinois and Iowa and about 70 miles eastward in eastern Wisconsin. Other smaller and lower outliers in southwestern Wisconsin, closer to the escarpment, can be seen from the top of Blue Mound. None occurs in southeastern Wisconsin where Martin (1932, p. 65-66) thought glaciation had destroyed them.

Outliers if flat-lying strata or gently-dipping cuestas are common in many parts of the world. As isolated hills capped with resistant rocks readily correlated with those of the nearby units, they have been considered the result of normal but long-term erosion processes. However, remote outliers owe their existence to peculiarities in the development of the drainage network which in turn result commonly from unusual structures, properties of the rock, and position with respect to drainage divides. In this regard West Blue Mound seems entirely fit with its resistant cap and its position in a major drainage divide. However, East Blue Mound does not seem fit. It lies adjacent to West Blue Mound on the same drainage divide, but is capped with fissile shale with thin beds of dolomite at the very surface. Loess only 1 foot to 4 feet thick covers the shale. Soil profiles examined only in the field, suggest it is not older than Late Wisconsinan. The slopes established on the Maquoketa shale are similar for both mounds, yet East Blue Mound has a much larger and flatter top than West Blue Mound.

Southwestern Wisconsin, the Western Upland of Martin (1932, p. 41-80), long has been known as the Driftless Area (Chamberlin and Salisbury, 1885). There, seemingly subaerial erosion has been modifying the landscape continuously since Mesozoic times. Unfortunately, little agreement exists among investigators as to the ages of the present-day landforms or their significance in the evolutionary history of the region.

Evidence of glaciation comes from abundant but thinly and widely scattered Precambrian rocks and Paleozoic chert and sandstone that rest on younger formations under loess. A large drift deposit near Muscoda has been opened for aggregate since MacClintock (1922) identified it. It is in the center of the Driftless Area and is interpreted as evidence of a former front of ice that came from the northwest. Ice-contact deposits grade eastward into coarse deltaic deposits and into rhythmically bedded, clayey silt and sand. Those deposits were covered in part by fluvial sediments from the east up to levels of about 60 feet above the present Wisconsin River. They seem unquestionably to be early Pleistocene in age. Kame-like deposits with constituents of local materials topographically above source areas, anomalous clay minerals and rubbles and other features best explained by glaciation are relatively common north of the Wisconsin River (Akers, 1961 and 1964). Many of those deposits lie under loess apparently younger than 30,000 radiocarbon years old.

Around Blue Mounds the paucity or absence of coarse chert and silicified rubble in the streams and on the flatter divides is puzzling if the region has been undergoing long-continued down wasting only by processes now affecting the landscape (see Part A this guide). Both the Niagaran and Galena Dolomites are exceedingly rich in siliceous material. Abundant blocks of chert and of silicified dolomite of various sizes up to 25 feet across lie on the shale slopes of West Blue Mound, but fewer and smaller blocks flank East Blue Mound. Deployment of the blocks into fields as much as one mile downslope from the Niagaran cap is considered the result of former peri-glacial mass movements radially outward over the shale slopes of 3-7 degrees (Smith, 1949) (Fig. 5).



Cross section through Blue Mounds, from east to west

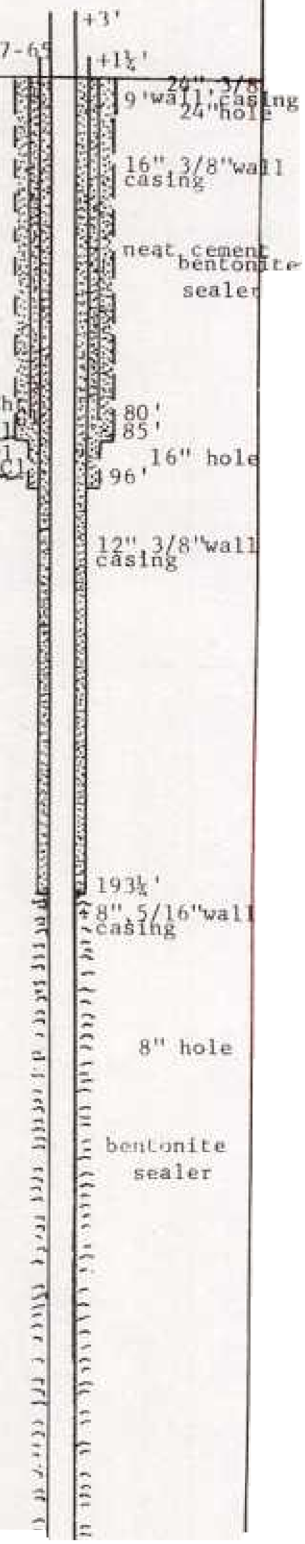
Significance: The origin of the Blue Mounds is not known for certain. The presence of thick sections of Maquoketa Shale and Silurian dolomite are historically important.

What is the historical significance of the presence of Maquoketa Shale and Silurian Dolomite in the Mounds? What is the significance of their absence in the surrounding area? Explain. Noting that West Mound is capped by dolomite and East Mound by shale, how do you interpret their history of formation? You are in the "Driftless" area. What difference can you note in the topography to the east and west of the mound area? What evidence would you look for to indicate that the area was glaciated? That it was not glaciated? How was the Silurian dolomite removed? If by solution, what is the evidence? Where would you look for evidence? If by mechanical processes, what is the evidence? Where would you look for evidence? How do you explain the presence of the Cave of the Mounds at Blue Mounds Cave?

References: Chamberlain & Salisbury, 1885; MacClintock, 1922; Martin, 1932; Smith, 1949; Akers, 1961 & 1964; Cline, 1965; Black, 1970.

Wisconsin Conservation Dept., Blue Mounds State Park, Upper Area, Well "A",
NW ¼, Sec. 1, T 6N, R 5E
Ed Niffinegger, Jr. - 6-14-65
Sample Nos. 256270-256494A - Examined by Janet Olmstead, 9-17-65

Formation	Depth (ft)	Thickness	Description
SURFACE	0-4	4	Gvl,Mxd,VFn,VyAng,P,Snd,Cl
	4-8	4	Gvl,YlOrMxd,Vfn,VyAng,P,QtztFe;Snd,Cl,St,Aggate
	8-12	4	Snd,GryOrMxd,VC,VyAng,P,Qtzt-Gvl,&SameAsAbove
	12-16	4	Snd,Same&DkYlOr,VC,Ang,P,QtztGvl,St,Cl,OxFe
	16-24	8	Snd,SameAsAbove,McheOrSt,LtlYlGryQtz,TrM,Fn,LtlFnGvl Cl,TrAggate
	24-28	4	Snd,SameAsAbove,M,C,VC,MchFn,Cht,Aggate,WhQtzt
	28-36	8	Snd,PlYLGryOr,CVC,Ang,P,MchVFn,FnGvl,MchFnSnd,LtlSt,MchFn
	36-40	4	Snd,Same,M,C,Ang,P,St,Qtzt,Cht,Jasper,SndAggs,
	40-44	4	Snd,Same,C,VC,VAng,P,St;FnVFn,TrM,MchVFnGvl
	44-52	8	Gvl,DkYlOrSt,Fn,M,Ang,P,M,Fn,Snd,Qtzt,Cht,Cl
	52-56	4	Snd,GryOrSt,C,Ang,P,Gvl,Qtzt,Cht,MchSt,Gvl
	56-60	4	Snd,Sty,DkYlOr,M,C,Ang,P,Qtzt,Cht,MchCht,Jasper
	60-64	4	St,DkYlOrSt,M,C,Ang,P,LtlLim;MchFn,VFnAngQtz
	64-76	12	Cl,MdOrBn,Si:P,LtlLim,Cht;-C-VFn,TrRndSnd
	76-80	4	Dol?,DkYlOrMxd,Vfn,Fn,Ang,P,(Dolic)MchFn&MDol&Cht
	80-84	4	Cl,Same,Dolc:G,PorCht,Lim,DolGvl,Sn,Snd,Gvl,Cl
	84-88	4	Snd,Shly,OlGryMxd,C,VC,Sang,VP,PyrXls,Dol,Cht,Cl
96'	88-92	4	Cl,LtYlBn,Dolc:VP,Cht,Sh,LtlSnd,CongSndGvl
	92-96	4	Cl,Same,GryRdShPebs,LtlCht,TrPyr,Fn,M,Snd,Cl
MAQUOKETA	96-112	16	Sh,LtGnBlGry,Dolc:P
	112-124	12	Sh,LtOlGn,Dolc:P,Mch VFn DolXls
	124-128	4	Sh,LtOlGn,Dolc:P,Mch Mxd Dol
	128-132	4	Sh,LtOlGn,Dolc:P,Mch VFn Dol Xls
	132-140	8	Sh, Lt Gn Gry,Dolc:P,Mch VFn Dol Xls
	140-148	8	Sh, Lt Gn Gry,Dolc:P,Mch VFn Dol Xls
	148-152	4	Sh, Lt Yl Bn, Dolc:P,Mch VFn Dol Xls
	152-160	8	Dol,LtYlBn,M,Fn,Dolc:P,Por, Tr Sh, Pyr
	160-168	8	Dol,Lt Yl Bn Mot Lt Gry, por,TrSh, Pyr
	168-176	8	Sh, LtGnGry,MFn,Dolc:P, Mch Dol Xls
	176-236	60	Sh,LtGnGry,M,Fn,Dolc:P,Ltl Dol Xls
	236-240	4	Sh,LtYlGryBn,Dolc:P, Ltl Dol Xls
	240-244	4	Sh,Lt Yl Gry Bn, Dolc:P, Mch Dol Xls
	244-248	4	Dol, Mxd, M,Fn, Dns, Ltl Sh
	248-260	12	Dol, Mxd, M, Fn, Dns, Mch Sh
	260-264	4	Dol, Md Yl Bn, M, Fn, Dns, Mxd,MchSh,Pyr
	264-268	4	Sh, Mxd, Dolc:P, Mch Dol Xls
	268-272	4	Sh, Dk Bn Mxd, Dolc:P, Mch Dol Xls
	272-288	16	Sh, Dk Bn Mxd, Dolc:P
220'	288-316	28	Sh, Dk Bn
GALP	316-324	8	Dol, Lt Yl Gry Bn, M, Fn, Dns, Tr Sh
	324-328	4	Dol, Lt Yl Gry Bn, M, Fn,Dns,TrSh,Calc Xls
	328-344	16	Dol, Lt Yl Gry Bn, M, Fn,Dns, Tr Pyr



Wis. Conservation Dept., Blue Mounds State Park, Upper Area, Well "A",
Sample Nos. 256270-256494A

Formation	Depth	Thickness	Description	Remarks
GALENA PLATTEVILLE	344-352	8	Dol,LtOr,M,Fn,Dns,TrC,TrPyr	
	352-360	8	Dol,LtOr,M,Fn,Dns,TrC,TrSh	
	360-364	4	Dol,LtOr,M,Fn,Dns,TrC,Slt	
	364-372	8	Dol,LtRdOr,M,Fn,Dns	
	372-436	64	Dol,LtYlBn,M,Fn,Dns	8" hole
	436-448	12	Dol,LtYlBn,M,Fn,Dns,TrC	
	448-456	8	Dol,LtYlBn,M,Fn,Dns	
	456-488	32	Dol,LtYlBn,M,Fn,Dns, TrC	
	488-504	16	Dol,LtYlBn,M,Fn,Dns,TrC,TrCh	
	504-508	4	Dol,LtYlBn,M,Fn,Dns,TrC	
	508-512	4	Dol,LtYlBn,M,Fn,Dns,TrC,TrPyr	
	512-524	12	Dol,LtYlBn,M,Fn,Dns,TrC	
	524-528	4	Dol,LtYlBnMxd,M,C,Dns,TrFn	
	528-536	8	Dol,LtYlBnMotLtGry, M,Fn,Dns,TrC,TrPyr,Sh	
	536-540	4	Dol,LtYlGryBn,M,Fn,Dns,ReC,TrPyr,Sh	
	540-552	12	Dol,MdGryBn,M,Fn,Dns,MchSh,TrPyr	
	552-560	8	Dol,LtYlGryBn,M,Fn,Dns,LtlSh,Pyr	
	560-564	4	Dol,LtYlRdBn,M,Fn,Dns,TrSh	
	564-576	12	Dol,LtYlRdBn,M,Fn,Dns,TrSh,Pyr	
	576-580	4	DolLtYlRdBn,M,Fn,Dns,LtlSh,Pyr	
	580-592	12	Dol,LtYlGryBn,M,Fn,Dns,LtlSh,Pyr	
	592-596	4	Dol,MdGryBn,M,Fn,Dns,MchSh,Pyr	
	596-604	8	Dol,MdYlBn,M,Fn,Dns,LtlPyr,Sh	
	604-616	12	Dol,MdYlBn,M,Fn,Dns,TrPyr,Sh	
	616-620	4	Dol,MdYlBn,M,Fn,Dns,LtlPyr,Sh	
608'	620-624	4	Dol,LtYlGryBn,M,Fn,Dns,TrPor,TrPyr,Sh,Ss	
ST PETER	624-628	4	Ss,LtGryBn,M,C,Rnd,P,TrVC,TrPyr,"caved" Dol	
	628-632	4	Ss,LtGryBn,M,C,Rnd,P,TrFn,TrPyr	
	632-640	8	Ss,LtGryBn,M,Fn,Srnd,P,TrVFn,TrPyr	642'
	640-652	12	Ss,LtOrBn,M,Fn,Srnd,TrVFn,TrPyr,Stnd Lim	
	652-656	4	Ss,LtOrBn,M,Fn,Srnd,TrC,TrPyr,Stnd Lim	
	656-664	8	Ss,LtYlBn,M,Fn,Srnd,TrC,TrPyr	
	664-668	4	Ss,LtYlBn,M,C,Srnd,P,TrFn,TrPyr	
	668-676	8	Ss,MdYlBn,M,Fn,Srnd,P,TrC,VFn	
	676-684	8	Ss,LtOrBn,M,Fn,Srnd,P,TrC,VFn	680' water lvl
	684-688	4	Ss,LtOrBn,M,Fn,Srnd,P,TrC,LtlSh,Dol	
68	688-692	4	Ss,LtOrBn,M,Fn,Srnd,P,TrC,Mch Dol, Sh	
PduC	692-696	4	Ss,Dol,LtYlBn,M,Fn,Dns,TrSh	

Wis. Conservation Dept., Blue Mounds State Park, Upper Area, Well "A"
Sample Nos. 256270-256494A

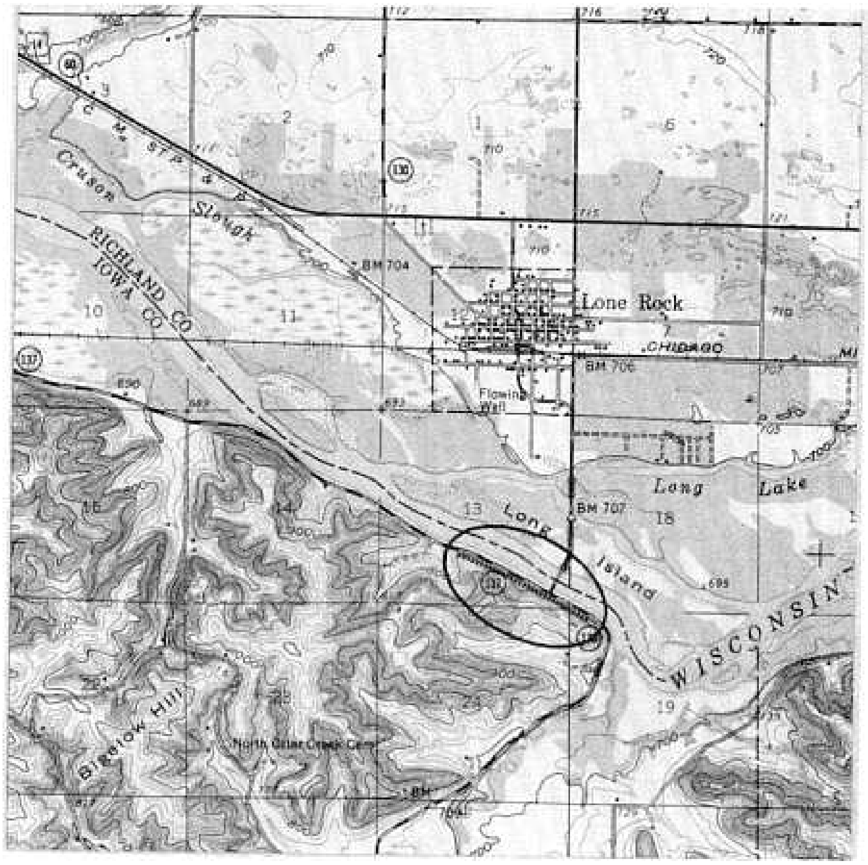
Formation		Depth	Thickness	Description	Construction
PRAIRIE du CHIEN		696-712	16	Dol, LtYlBn, M, Fn, Dns, TrSh, Cht	
		712-724	12	Dol, VyLtYlBn, M, Fn, Dns, TrPor, MchSs, TrSh	
		724-728	4	Dol, VyLtYlBn, M, Fn, Dns, TrPor, MchSs, TrSh, TrPyr	
		728-732	4	Dol, VyLtYlBn, M, Fn, Dns, TrPor, LtlSs, Sh	8" hole
		732-736	4	Dol, VyLtYlBn, M, Fn, Dns, LtlSrndPyr, TrSs	
		736-740	4	Dol, VyLtYlBn, M, Fn, Dns, TrC, TrSh	
		740-744	4	Dol, VyLtYlBn, M, Fn, Dns, TrC, TrSh, Pyr, Cht	
		744-748	4	Dol, VyLtYlBn, M, Fn, Por, TrSh, Pyr	
		748-752	4	Dol, VyLtYlBn, M, Fn, Por, LtlSs, Sh	
		752-776	24	Dol, LtYlBn, M, Fn, Dns, LtlCht, TrSh	
		776-788	12	Dol, LtYlGryBn, M, Fn, Dns, TrCht, TrSh	
		788-792	4	Dol, LtYlGryBn, M, Fn, Dns, TrSh	
		792-804	12	Dol, LtYlBn, M, Fn, Dns, TrSh, Cht	
		804-812	8	Dol, LtYlBn, M, Fn, Dns, LtlSh	
		812-820	8	Dol, LtYlBn, M, Fn, Dns, TrSh	
		820-840	20	Dol, LtYlBn, M, Fn, Dns	
		840-844	4	Dol, LtYlBn, M, Fn, Dns, TrPor	
		844-848	4	Dol, LtYlBn, M, Fn, Dns, TrPor, TrCht	
	164'	848-856	8	Dol, LtYlBn, M, Fn, Dns, TrSs	
TREMP		856-872	16	Ss, VyLtRd, M, Fn, Srnd, P, Si:P, TrC, TrOols, Dol, (Cvd)	
		872-880	8	Ss, VyLtRd, M, Fn, Srnd, P, Si:P, TrC, LtlDol	
		880-888	8	Ss, VyLtRd, M, Fn, Srnd, P, Dolc:E, LtlSh, Dol	
		888-904	16	Dol, LtGryBn, M, Fn, Dns, TrSh, Ss, Pyr	903

Formations: Surface, Maquoketa, Galena-Platteville St Peter
Prairie du Chien, Trempeleau.

Well tested for 24 hours at 130 gpm with 7 feet of drawdown
Specific capacity = 18 ± gpm per foot of drawdown.
Driller reports total depth of only 903'.
Driller reports grout to depth of 642'.

Title: Lone Rock South

Location: Exposure in roadcut at south end of Highway 130 bridge over Wisconsin River in south bluff of Wisconsin River in the SE¼, SE¼, Sec. 13, T.8N., R.2E., Iowa County (Spring Green 15-minute topographic quadrangle, 1960).



Author: M. E. Ostrom

Description: Exposure of Wonewoc and Tunnel City Formations. Here the Ironton Member of the Wonewoc is absent, the Birkmose Member of the Lone Rock is thinned, the interbedding of the Mazomanie and Reno Members is shown, and abundant sedimentary structures can be examined.

A description is:

CAMBRIAN SYSTEM
Tunnel City Group

Lone Rock Formation

Reno Member (+60.0')

85.0' - 145.0'	60.0'	Sandstone, light yellow brown, fine-grained, thin to medium bedded, cross-bedded, and dolomitic with a moderate amount of glauconite.

		Mazomanie Member (10.0')
70.5' - 85.0'	10.0'	Sandstone, light gray, fine-grained, medium-bedded, cross-bedded, with some burrows.
		Reno Member (4.5')
70.5' - 75.0'	4.5'	Sandstone, light yellow brown, fine-grained, thin-bedded, abundant cross-bedding, very glauconitic, with some thin beds of intraformational conglomerate. Some beds burrowed. Conglomerate at base.
		Mazomanie Member (6.0')
64.5' - 70.5'	6.0'	Sandstone, light brown mottled brown, fine-grained, very silty, dolomitic, with few thin clean sand layers. Has reworked appearance.
		Reno Member (7.0')
57.5' - 64.5'	7.0'	Sandstone, light yellow brown, fine and very fine-grained, cross-bedded, dolomitic and very glauconitic. Few thin beds of conglomerate and 1" beds of slightly sandy and glauconitic, dolomitic siltstone interbedded with green shale and sand and glauconite.
		Mazomanie Member (5.0')
52.5' - 57.5'	5.0'	Sandstone, light yellow gray, fine-grained, thin and medium bedded, cross-bedded.
		Reno Member (23.0')
29.5' - 52.5'	23.0'	Sandstone, light yellow green, fine and very fine-grained, thin and medium bedded, cross-bedded, glauconitic, dolomitic. Many thin beds of intraformational conglomerate and 1-foot conglomerates bed at base.
		Tomah Member (7.0')
22.5' - 29.5'	7.0'	Sandstone, very light yellow brown, very fine-grained, shaly and dolomitic with mica flakes on bedding planes, slightly glauconitic, thin and irregular bedding, blocky fracture. More shaly and micaceous toward base.
		Birkamose Member (2.5')
2.15' - 22.5'	1.0'	Sandstone, brown and light yellowish brown, fine and very fine-grained, dolomitic, very glauconitic, with abundant sandstone pebbles.

20.0' - 21.5'	1.5'	Dolomite, reddish brown, fine crystalline, very sandy, glauconitic, with abundant sandstone pebbles in lower 1.0'. Slightly uneven base.

Elk Mound Group

Wonewoc Formation

Galesville Member (+20.0')

0.0' - 20.0'	+20.0'	Sandstone, very light yellowish gray, fine and medium-grained, thick-bedded, cross-bedded. Some beds have thin discontinuous green shale partings that follow cross beds.

BASE OF EXPOSURE

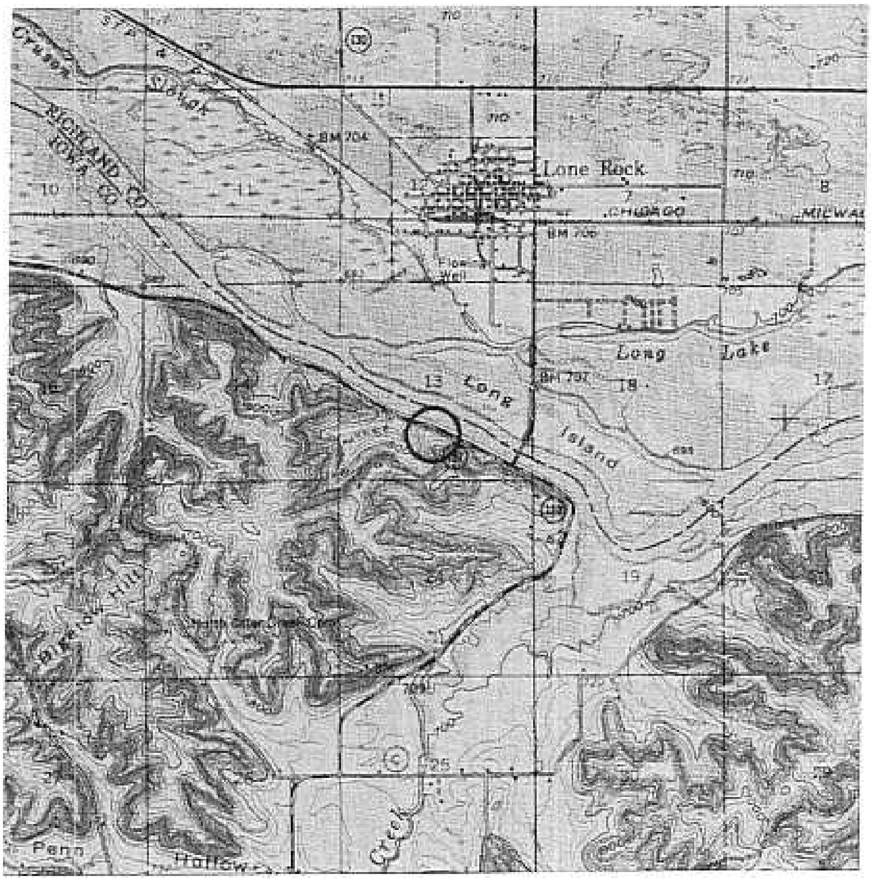
Significance: At this exposure the major items of interest are the relationship of the Galesville to Lone Rock, absence of the Ironton, interbedding of the Mazomanie and Reno members, and presence of abundant intraformational conglomerates. What is the contact relationship of the Wonewoc Formation with the Lone Rock Formation? What happened to the Ironton Member? How does this relate to other members such as the and Sunset Point? What is the significance of the Birkmose Member and especially its conglomerative character? Examine the sedimentary structures in the Lone Rock Member. What do they signify? What is the significance of cross-bedding? Ripple marks? Do they differ from the Mazomanie to the Reno to the Galesville? How do you explain the intrafractional conglomerates? Why is glauconite concentrated in some beds and not others? What fossil evidence can you find? What is your interpretation of the environment and depositional history of the Wonewoc/Tunnel City?

References: Ostrom, 1964, 1967, and 1970.

OUTCROP 9

Title: Lone Rock

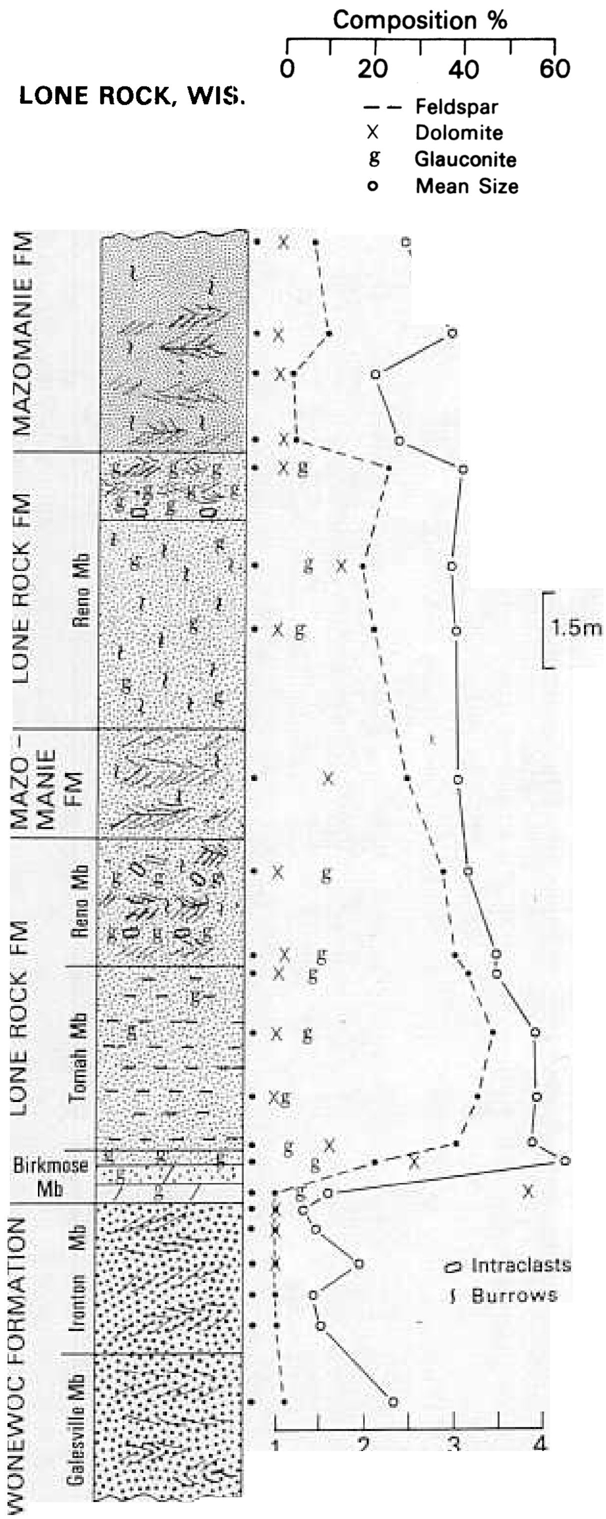
Location: Road Cut on Wisconsin Highway 133, south side of Wisconsin River, 3.2Km south of Lone Rock, Wisconsin in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 13, T.8N., R.2E., Iowa County (Spring Green 15-minute topographic quadrangle, 1960).



Author: I. E. Odom

Description: This outcrop is an excellent representation of the lithic and sedimentologic characteristics and of the stratigraphic relations of the Lone Rock, Mazomanie, and Wonewoc Formations adjacent to the Wisconsin Arch. Ostrom (1966) chose this outcrop for the type section of the Lone Rock Formation (part of the Tunnel City Group), and except for the Birkmose Member it is a good example of the lithic characteristics of the formation.

The lower 6 meters of the road cut and the bluff down to river level are composed of medium to fine-grained, quartzose, well and moderately well-sorted Galesville and possibly the Ironton Sandstones of the Wonewoc Formation. Generally, the Ironton Sandstone is slightly coarser than the Galesville, and it often contains thin beds that are poorly sorted. These lithic characteristics are not too evident at this outcrop, thus the Ironton may actually be


LONE ROCK, WIS.
Composition %
0
20
40
60
Feldspar
Dolomite
Glauconite
Mean Size
MAZOMANIE FM
LONE ROCK FM
Reno Mb
MAZO-
MANIE
FM
LONE ROCK FM
Reno Mb
Tomah Mb
Birkmose
Mb
WONEWOC FORMATION
Ironton Mb
Galesville Mb
1.5m
Intraclasts
Burrows
1
2
3
4

absent (Ostrom, 1966).

The Birkmose Member of the Lone Rock Formation is thin and contains appreciable reddish dolostone and flat pebble conglomerate throughout this area of Wisconsin. Toward the west, it thickens and more dolomitic and glauconitic sandstones are present (Fig. 35). The very fine-grained sandstones with shale interbeds that succeed the glauconitic sandstone at the top of the Birkmose are assigned to the Tomah Member. This lithology is typical of the Tomah over thousands of square miles in western Wisconsin and eastern Minnesota. As shown in Figure 35, the Tomah thickens west of the Mississippi River, and in southern Minnesota and north central Iowa it composes the entire Lone Rock Formation above the Birkmose Member.

The Tomah Sandstones almost always contain more than 35% K-feldspar, unless they are very dolomitic, and some coarse siltstone beds locally contain 70% feldspar. This high feldspar content is related to the Tomah's exceedingly fine grain size, good sorting, and very leptokurtic kurtosis. The Tomah contains Cruziana and possibly Zoophycos trace fossil assemblages. (Note to petrology instructors -- A suite of thin sections from this outcrop is ideal for use in sedimentary petrology classes to show the strong relationship of feldspar content to grain size that is typical of all Cambrian sandstones in the Upper Mississippi Valley as well as the nature of feldspar overgrowths, the effects of environments on mineralogical sorting, and the principle that mineralogical maturity is not always related to the mineralogy of the source rocks).

The Tomah Member is usually transitional through approximately 1 meter with the overlying Reno Member. The Reno Sandstone is slightly coarser than the Tomah, usually cross-stratified, and very glauconitic. It too contains appreciable feldspar. The enrichment of glauconite in thin bands is related to reworking by currents; the glauconite bands are analogous to heavy mineral concentrations. Note that intraclasts frequently occur near the base as well as within the highly glauconitic beds, and that scour marks occur in the top of the underlying beds. The Reno Member as well as the Mazomanie Formation contains trough and some wedge and tabular-shaped cross sets. Numerous other bed forms and biogenic marks, especially burrows and trails, (Skolithos and Cruziana assemblages) are also present.

The upper part of the Lone Rock section shows the repetition of the glauconitic Reno Member with the sparingly glauconitic Mazomanie Formation. The lower portion of the upper Reno tongue is composed of the rock type that Berg (1954) and others called "wormstone" (see p. 92 for description). Note that the lower tongue of the Mazomanie Formation is very fine-grained and feldspathic, whereas the upper tongue contains both quartzose and feldspathic sandstones. Quartzose Mazomanie Sandstone does not extend westward far beyond this outcrop, however, feldspathic Mazomanie Sandstone is present westward to beyond Richland Center, Wisconsin. The regional facies relations of the Lone Rock and Mazomanie Formations are shown in Figures 35 and 36 and are discussed in the paper by Odom (this guidebook).

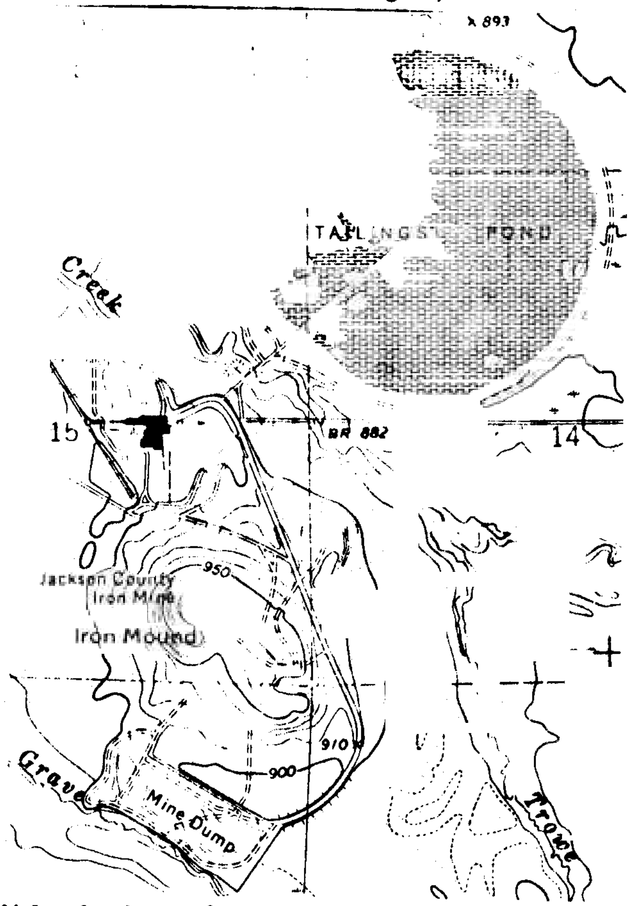
Interpretations: Quite different interpretations of the depositional environments of the formations (Tunnel City Group) present here are presented by Odom (this guidebook) and by Byers (this guidebook). Readers are referred to these papers, however, I advise against the suggestion made by Byers that before you ponder the depositional environments you don special "eyeglasses" for the purpose of making "glauconite" invisible (see Fig. 36).

It is suggested that the origin of the massive, argillaceous "wormstone" beds in the Reno Member (beds of this nature are more numerous and thicker farther west) is related in part to bioturbation and in part to soft sediment deformation (see paper by Odom, this guidebook). This opinion is based largely on the presence of ramdomly oriented clasts that are always present. What other sedimentological processes might form this type of structure? The possibility that the "wormstones" represent tidal channel deposits has been considered, but this origin appears to be ruled out because individual beds often can be traced for many miles.

During investigations of the mineralogical and chemical nature of glauconite in the Cambrian of this area, considerable effort was made to identify the environment where the pellets initially formed. The author has hypothesized (Odom, 1976) that the pellets initially formed in the "wormstones" beds and were subsequently widely distributed in the cross-stratified sandstones by currents that reworked the "wormstones". This major evidences supporting this view are the frequent heavy concentrations of glauconite in sandstones immediately above the wormstones and the presence of scour and cut-and-fill structures in the top of the "wormstone" beds.

TITLE: Geology of the Jackson County Iron Mine

LOCATION: SE 1/4, Sec. 15, T 21 N, R 3 W, Hatfield SW Quadrangle, Jackson County, Wisconsin



AUTHOR: David G. Jones, UW-Madison

DATE: December, 1977

SUMMARY OF FEATURES:

A 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, magnetite, and grunerite. Surrounding the iron formation is a 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.

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

The Precambrian terrane is unconformably overlain by an Upper Cambrian conglomerate and sandstone.

INTRODUCTION:

The Jackson County Iron Mine located in Jackson County, Wisconsin, is an open pit taconite operation producing about 750,000 tons of pellets per year. The ore body is a lens-shaped body 915 meters in maximum length within the mine and 150 meters in maximum width. The ore mineral is magnetite, and the grade of the iron formation usually varies between

20-50%, the average being 35% 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 NW-SE and dips 70-75 degrees SW 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 NE of the iron formation (see Fig. 1) 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 meters. The mineral assemblage, however, is constant.

Hangingwall Schist: The weathered rock which is located along the SW side and sweeps around the NW end of the iron formation is called the hangingwall schist (see Fig. 1). 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 NW and varies between 6 meters and 50 meters. Weathering is apparently controlled by some type of fracture pattern that locally increases 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 band range from a few millimeters to nearly a meter 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-Ca-rich hornblende
5. quartz-grunerite-Ca-rich hornblende-magnetite
6. quartz-magnetite-garnet-ferroactinolite-calcite-K-feldspar
7. quartz-garnet-biotite-Ca-rich hornblende

Garnets commonly appear in the iron formation as isolated porphyroblasts 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 millimeters 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 porphyroblasts 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 meters to 3 or 4 meters. They are usually in sharp contact with the iron formation. Again the mineralogy is extremely variable. The assemblages present include:

1. biotite-Ca-rich hornblende-epidote-K-feldspar
2. talc-grunerite-biotite-chlorite
3. grunerite-Ca-rich hornblende-magnetite
4. biotite-Ca-rich hornblende-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 ploygonized 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. Further examination reveals tight small-scale isoclinal folding of 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 NE wall of the pit, however, minor isoclinal folds can be found in place. Fold axes plunge 70-75 degrees in a southwesterly direction and parallel the lineations as 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 meter in thickness occur in the iron formation. Boudins represent both isolated fold hinges and thickened, separated portions of fold limbs.

A series of two, possibly three, broad, open fold patterns has been imprinted onto the isoclinal folds. The broad, open folds can only be seen within the iron formation in the NE wall of the mine.

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 NW but pinches and swells for about a mile to the SE of the present pit.

The local outcrop pattern of the iron formation (see Fig. 1) indicates a distinct thickening and thinning. Presumably, this represents large-scale boudinage with nearly vertical axes and is a result of the same forces that produced the samll-scale penetrative deformation.

Talc Schist: A zone of talc schist is located within the iron formation in the eastern portion of the mine (see Fig. 1). The long axis of the talc zone is about 200 meters long and is parallel to the structural grain of the iron formation. At its widest portion the talc schist approaches 50 meters. 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 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 SW 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-Ca-rich hornblende-biotite-magnetite-apatite
4. talc-garnet-andalusite-cummingtonite

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

Other Rock Units: In the NE wall, on the upper bench, at the NW 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 a highly sheared rock with large augen (1 cm.) of K-feldspar embedded in a predominantly quartz-K-feldspar matrix. The recrystallized texture and concordant position indicate its formatin prior to regional metamorphism and deformation.

Five diabase dikes ranging in size from 2 meters to approximately 20 meters 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 the intrusions.

UNCONFORMITY:

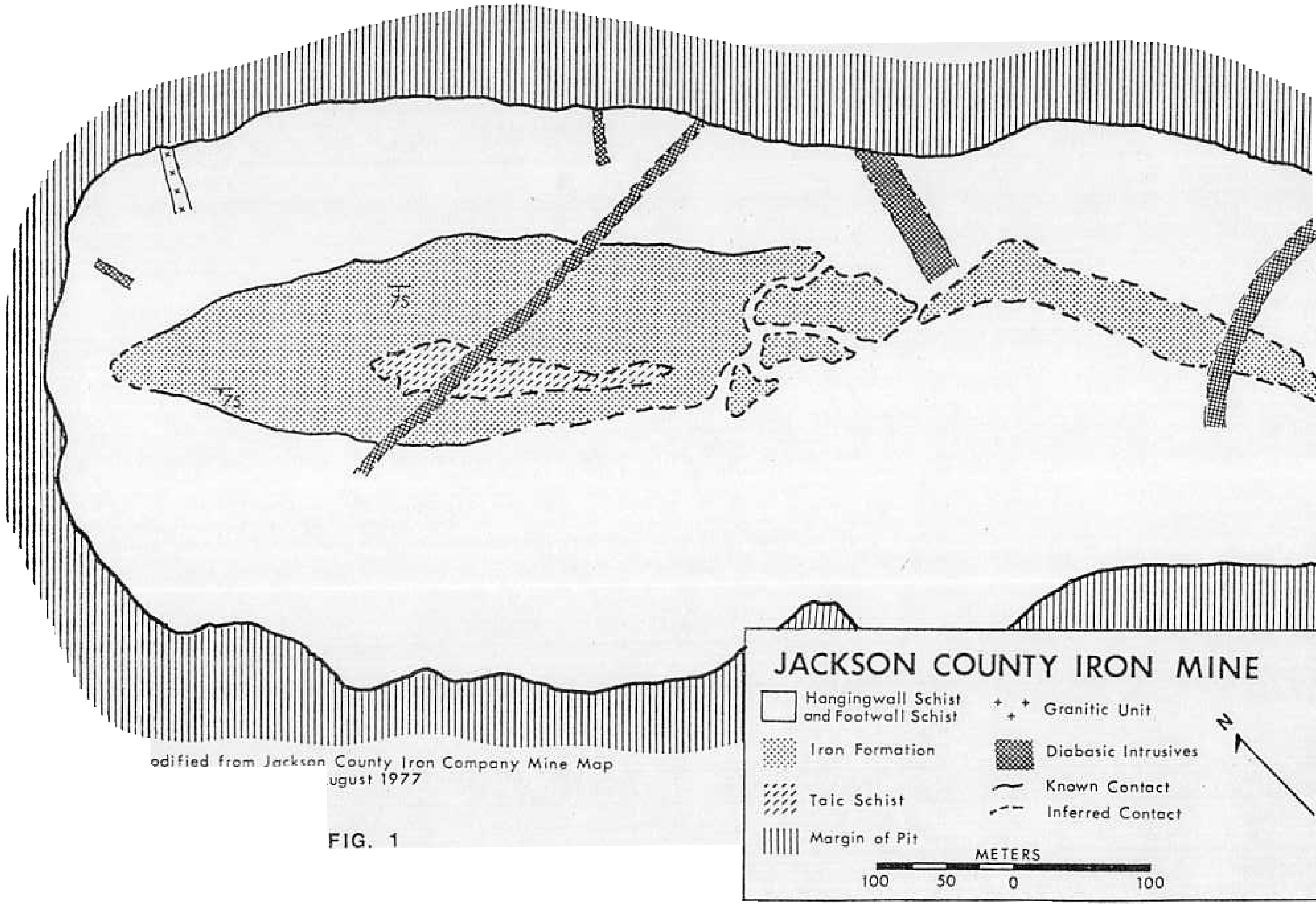
Overlying the Precambrian rocks are Upper Cambrian sandstones. The contact is unconformable, and immediately above the undulating surface is a conglomerate containing clasts of angular to subangular hematitic iron formation and a matrix of well sorted and well rounded, coarse-grained, quartz sand. The hematitic clasts range up to nearly 2 meters in diameter. The conglomerate grades rapidly upward into poorly indurated Upper Cambrian sandstone which thickens locally to the SE 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 structure. The iron formation appears to have been isoclinally folded aobut a near vertical axis. Small-scale features within the iron formation supporting this hypothesis include isolated and rotated fold hinges, mineral lineations, and the predominance of paraliel, 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.

Fig. 1 illustrates that the major part of the ore body is a partially detached hinge of an isoclinal fold. One line of evidence supporting the occurrence of the hinge is that the pattern of the magnetic survey does not extend the ore body to the NW beyond what is exposed in the mine. The SW limb of the fold has been attenuated just beyond the zone of talc schist. The NE limb, however, seems to continue disjointedly to the SE in what appears to be a slightly offset segment of the iron formation with a more northerly trend.



odified from Jackson County Iron Company Mine Map
ugust 1977

FIG. 1

Archean gneiss at Lake Arbutus Dam, Jackson County, Wisconsin

R. S. Maass and B. A. Brown, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin 53705

LOCATION

SE¼,Sec.3,T.22N.,R.3W., Hatfield 7½-minute Topographic Quadrangle. Outcrop along the Black River below the eastern half of Arbutus Dam (Fig. 1). Approach is on a 0.2-mi-long (0.3 km) gravel road that intersects Clay School Road 0.1 mi (0.2 km) west of the Green Bay and Western Railroad tracks. Additional outcrop occurs for 0.6 mi (1 km) downstream from dam.

SIGNIFICANCE

The main outcrop area immediately below the dam is one of the largest, if not the largest, outcrop of Archean rocks in Wisconsin (Brown and others, 1983). 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 about 2,815 Ma and deformed at least twice, with the latest deformation and metamorphism occurring during the Penokean orogeny, about 1,850 Ma. Postdeformational cross-cutting mafic dikes are also present at this locality.

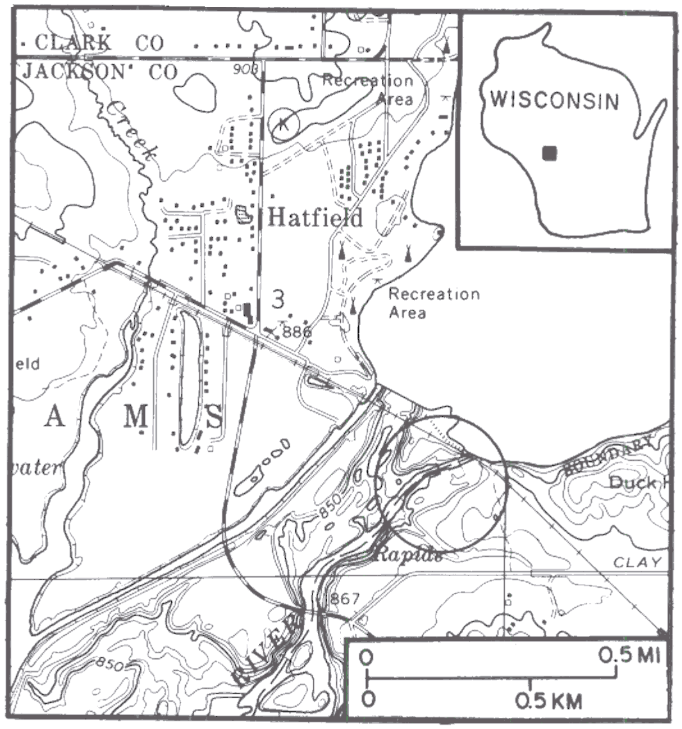


Figure 1. Map showing location of site at Arbutus Dam (circle).

DESCRIPTION

The principal unit exposed (Fig. 2) 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, approaching several meters of massive gneiss. Folding and foliation are best displayed in the more thinly 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 0.4-mi-long (0.6 km) 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. 3). 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 that would indicate a later simple folding pattern of the F_1 axes do not exist, and the interference patterns are therefore believed

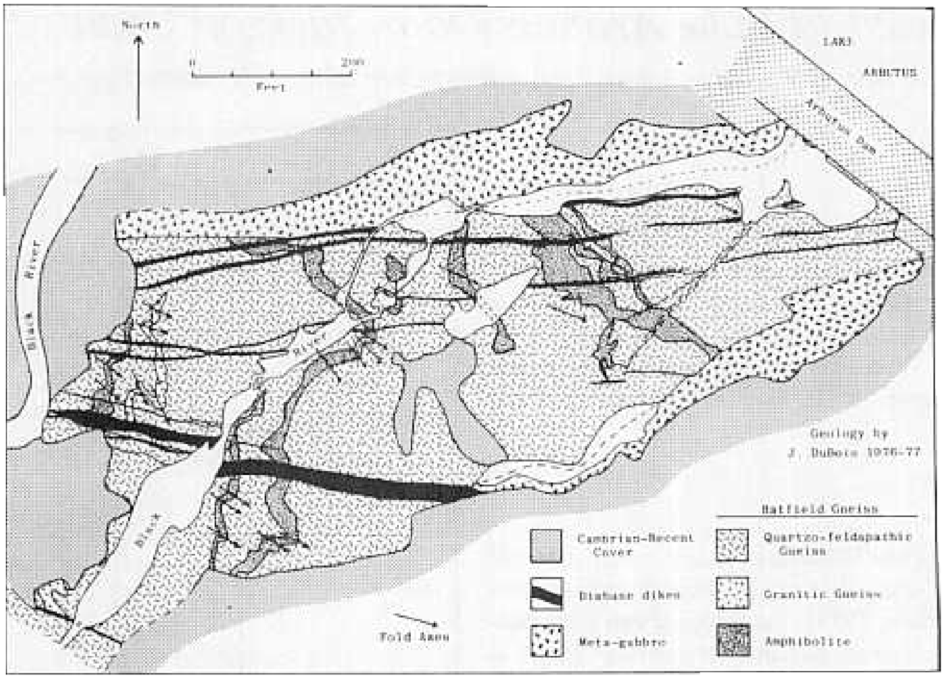


Figure 2. Geologic map of Archean bedrock exposed south of Arbutus Dam.

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 three 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 0.6 mi (1 km) downstream from the dam. The zircon crystals are brown, euhedral 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 (2,815 ± 20 Ma) 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 this stop and further downstream do not plot coherently on an isochron diagram, indicating partial resetting during subsequent metamorphism.

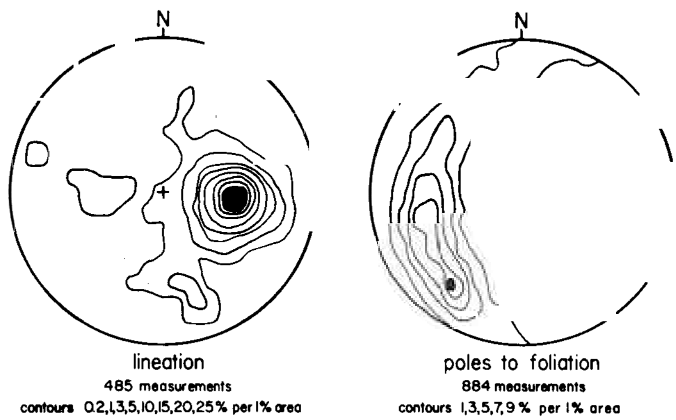


Figure 3. (Maass and Van Schmus, 1980, Fig. 11). Lower hemisphere stereographic projections of structures in the Hatfield Gneiss. (left) Lineations defined by fold axes, crenulations, and mineral elongations. The mean orientation of the lineations is S.84°E. with a plunge of 51°ESE. (right) Plot of poles 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.

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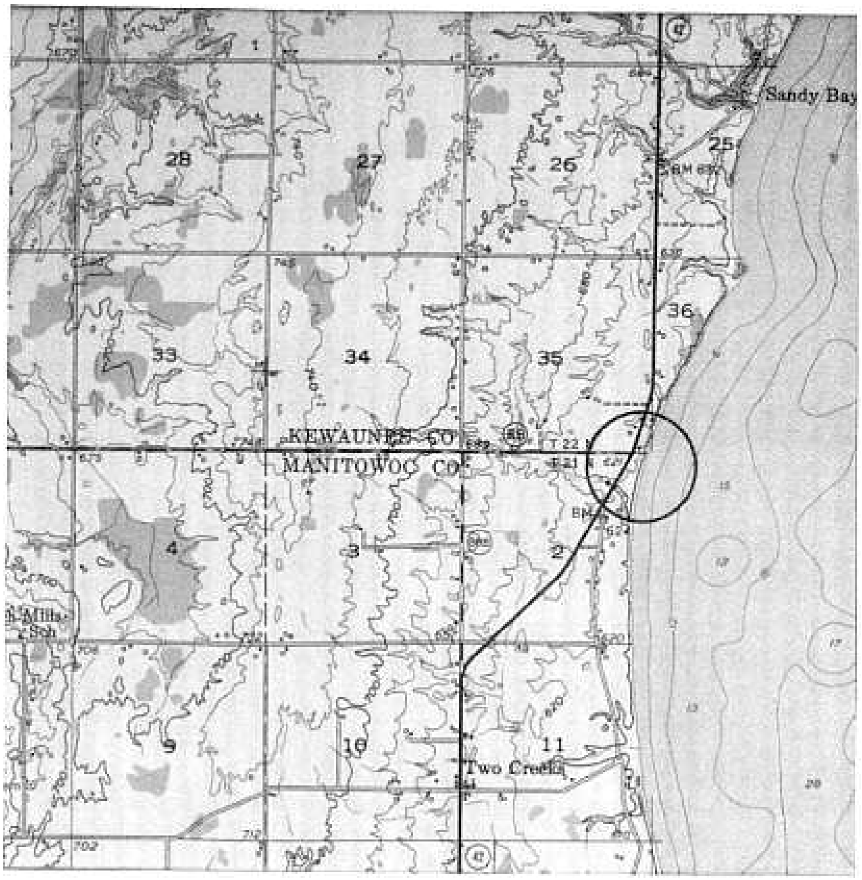
DuBois, V. F., and Van Schmus, W. R., 1978, Petrology and geochronology of Archean gneiss in the Lake Arbutus area, west-central Wisconsin [abs.]: Proceedings of the 24th Institute on Lake Superior Geology, Milwaukee, p. 11.

Maass, R. S., and Van Schmus, W. R., 1980, Precambrian tectonic history of the Black River valley: 26th Institute on Lake Superior Geology, Guidebook 2, 43 p.

Title: Two Creeks Forest Bed

Location: SE Corner, Sec. 35, T. 22 N., R. 24 E., Kewaunee 15' Quadrangle, Manitowoc County Line. Park at entrance of field to east of Hwy. 42 at intersection with C.T.H. BB. Walk across field to edge of lake.



Author: David M. Mickelson

Description: The following units are present here (from lowest to highest, thus oldest to youngest) but you may have to walk the shore to the south to see all of the units. The oldest recorded event here is ice advance and deposition of a compact pink to grey till. This is present just above beach level and may be covered with slumped debris. Ice retreated and lake sediments (sand and some interbedded silts and clays) were deposited directly over the till. Water level then dropped, evidently after ice had retreated north of the straits of Mackinac, and a spruce forest grew on the land surface. You can find logs (mainly spruce although Tamarack and Birch have been found), and forest litter containing twigs, cones, needles and air breathing and gill-breathing snails. Similar modern day environments exist in northern Wisconsin, Michigan, Minnesota, and parts of Canada.

Lake levels then rose again, killing the trees and depositing more sand and interbedded silts and clays. The ice which blocked the Lake Michigan outlet, causing the water to rise, then advanced over the area depositing the upper red, clayey till. This till is equivalent to the Two Rivers Till (see description of type locality).

This is a good example of a rapidly eroding shoreline. During high water of the early 1970's the bluff retreated more than 20 feet. All of the sand and finer materials are eroded away by waves and carried by longshore drift to areas of deposition like Point Beach (see description). Only coarser materials are present on the beach during most of the year.

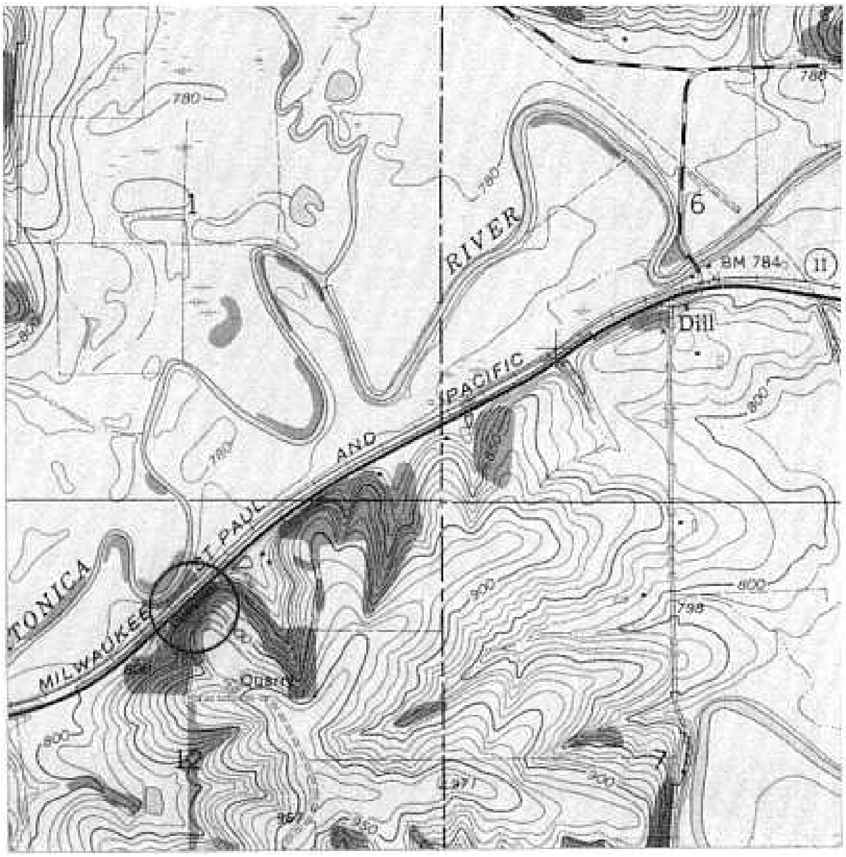
Significance: The existence of buried forest material in this area has been recognized since the 1800's. This locality is an important one because the radiocarbon dated logs (11,800 years before present, Broecker and Farrand, 1963) provide an absolute date on late-glacial sequences in the Lake Michigan Basin.

One other C^{14} date is recorded on a bryophyte (moss) bed in the northern part of the southern peninsula of Michigan. Evenson (*et al*., 1976) review the literature and the controversy about the significance of this site. It is now believed (Evenson, *et al*., 1976) that the Twocreekan interval is one of many retreat phases separated by minor advances. A time-distance diagram is shown below.

References: Alden, 1918; Black, 1971, 1974 and many given therein; Thwaites, and Bertrand, 1957.

Title: Dill

Location: Exposure in roadcut at south side of State Highway 11 approximately 1.5 miles east of South Wayne and 0.6 miles west of the Green/LaFayette County line in the SE¼, NE¼, NW¼, Sec. 12, T.1N., R.5E., LaFayette County (Browntown 7.5 minute topographic quadrangle, 1962).



Author: M. E. Ostrom

Description: At this exposure the Prairie du Chien Dolomite and the Platteville Formation are separated by a thin bed of St. Peter Formation.

The Prairie du Chien Dolomite is gray, fine and medium grained, and has thin and medium undulating beds. It is from 3 to 4 feet thick. The upper surface is in apparent angular uncomformity with the St. Peter Formation.

The St. Peter Formation is light yellowish gray to pale yellowish green, medium and fine grained with some coarse, and ranges from 6 inches to 12 inches in thickness. Traced eastward to Browntown the St. Peter thickens to over 60 feet. At Browntown is a large quarry which produced foundry sand from the St. Peter. The contact of the St. Peter with the overlying Platteville Formation rises to the east.

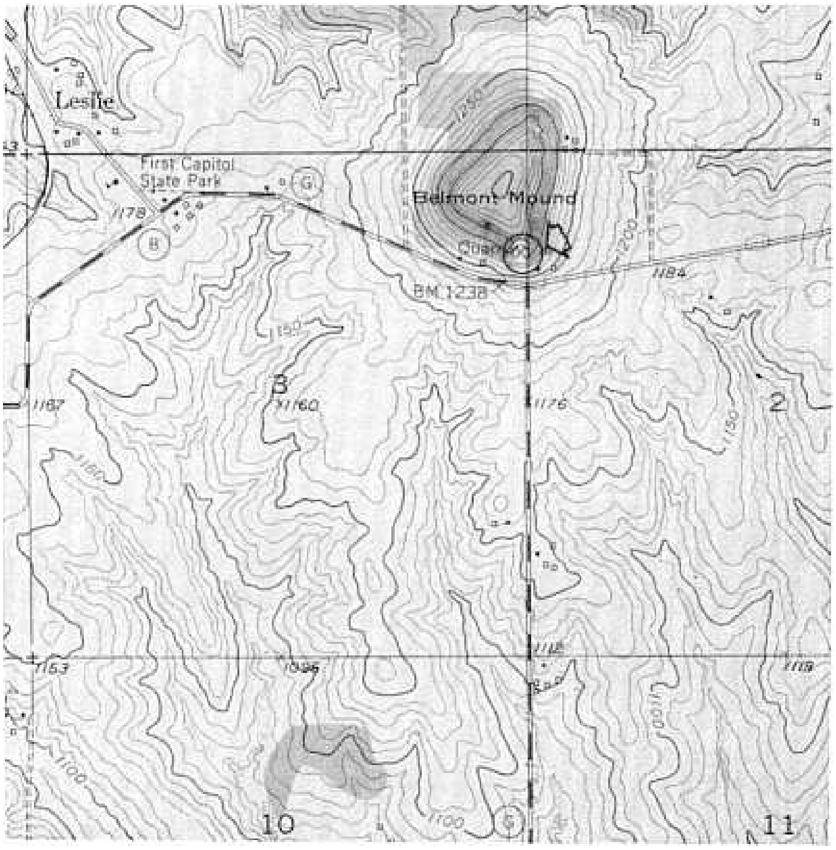
The Platteville Formation at this exposure is 7 feet thick and consists of the Pecatonica Member. The Pecatonica is dolomite, fine and medium grained, dense, medium- and thick-bedded, and fossiliferous. The lower 12 inches to 16 inches contains sand grains and scattered phosphate pellets.

Significance: Here the St. Peter Sandstone is thinned to 6 inches. The outcrop illustrates the thickness variability of the St. Peter and the lithologic differences between the Prairie du Chien Group and the Platteville Formation. It also provides the opportunity to discuss the historical significance of the variable relationships of these three stratigraphic units as observed at this and previous exposures and to interpret regional relationships.

References: Ostrom, 1964 and 1970

Title: Belmont Mound

Location: Abandoned quarry in south end of Belmont Mound located north of the City of Belmont on County Trunk Highway "G" in the SE$\frac{1}{4}$, NE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 3, T.3N., R.1E., Lafayette County (Mifflin 7.5-minute topographic quadrangle, 1952).



Author: M. E. Ostrom (modified from Agnew et. al., 1956)

Description: In southwest Wisconsin Silurian rocks are found only in the "mounds" and at the southern edge of the mining district. According to Agnew et. al. (1956), "The Silurian rocks in the district are mainly yellowish-buff, medium- to coarse-grained, "sugary" dolomite, in part vuggy.... The basal 20 feet of strata is argillaceous dolomite." In the district this is overlain in succession by about 65 feet of cherty dolomite, 20 feet of non-cherty strata, and 90 feet of cherty dolomite with Pentamerus, a large brachiopod, at its top. At this location both galena and sphalerite crystals have been observed in the dolomite.

The Silurian is underlain by Upper Ordovician Maquoketa Shale which is in this area everywhere covered. The contact between the two is believed to be unconformable. The basal argillaceous silty zone of the Silurian appears to thicken and thin inversely with the thickness of the underlying Maquoketa.

Silurian rocks will also be observed at the Blue Mounds Stop. At that location an interesting effect of rock alteration has caused the complete sequence of Silurian dolomite to be silicified. This is attributed to leaching and weathering of a dolomite that contained siliceous fossil shells.

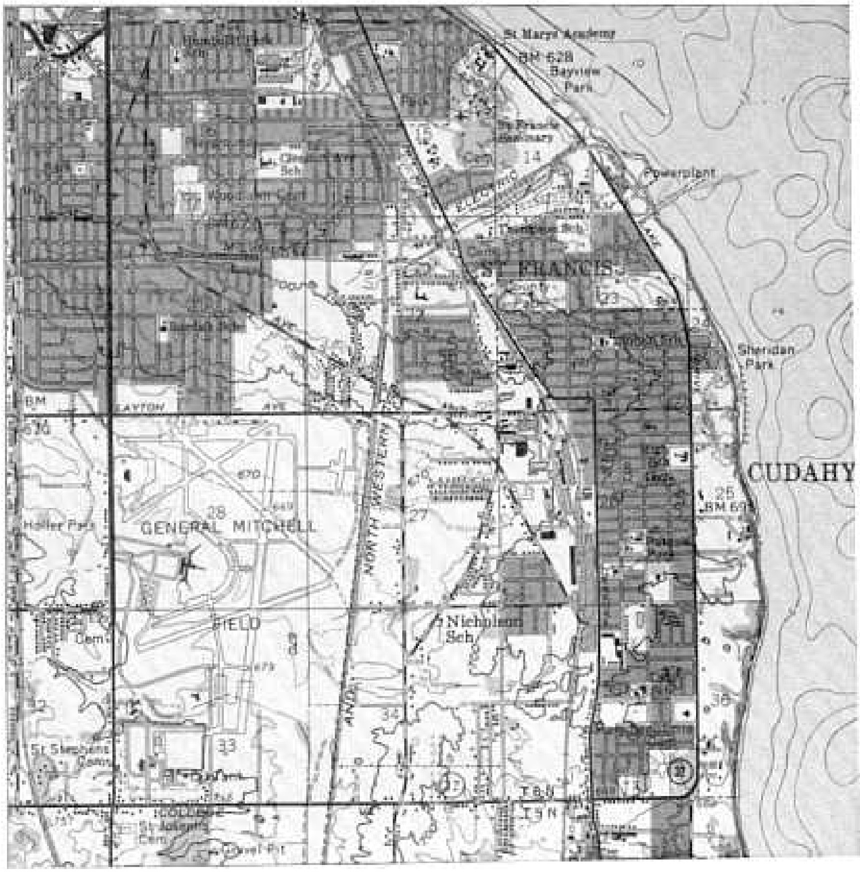
Significance: Mounds of Silurian are peculiar to this district. In addition, this is one of the few locations in southwest Wisconsin where the Silurian dolomite can be observed.

What is the significance of the Silurian mounds? Why is the Maquoketa Shale concealed in this area? What is the implication of finding sphalerite and galena in the Silurian dolomites? Do you believe it possible for there to be an erosional unconformity between the Maquoketa Shale and Silurian Dolomite? Explain your conclusion.

References: Agnew et. al., 1956.

Title: St. Francis Power Plant Site

Location: NE 1/4, NE 1/4, Sec. 23, T. 6 N., R. 22 E., Milwaukee South 15' Quadrangle, Milwaukee County. Enter either through the north end of Sheridan Park or cut across the field owned by the Power Company. The best exposure is about 100 yards south of the Power Company fence. Permission is probably not necessary unless drilling or similar activity is planned.



Author: David M. Mickelson

Description: This bluff has a fairly high erosion rate and when lake levels are high, water is against the base of the bluff throughout. The power plant to the north acts as a groin and slows longshore drift (sediment movement) from the north (Mickelson, et al., 1977). The plant is protected by rip-rap (dolomite blocks) which absorb wave energy and slow erosion. Because the blocks break up in time this type of protection needs continuing maintenance. To the south, in Sheridan Park the effect of groins can be observed.

The bluff face exhibits several tills and stratigraphic relationships and it is worth spending several hours examining the deposits carefully and trying to work out geologic history (Mickelson, et al., 1977, Appendix 3). Note particularly:

1. The lower most unit is a sandy, bouldery till much like the mid-Woodfordian tills elsewhere in southern Wisconsin. Near the top of this unit, a somewhat more silty till with large boulders is present. Was this from the same glaciation?

2. A concentration of boulders overlies these units and represents a period of wave erosion. This means that for a period of time after ice retreat, lake levels were much as they are today. Lake level then rose and deposited sand and mixed silts and clays.

3. Above this another till is present representing another ice advance into the area. Can you find an erosional lag on this till?

4. A channel, probably eroded during a low stage of the lake cuts the sequence and is filled with sand and gravel. Note how this channel now concentrates groundwater flow and enhances bluff erosion.

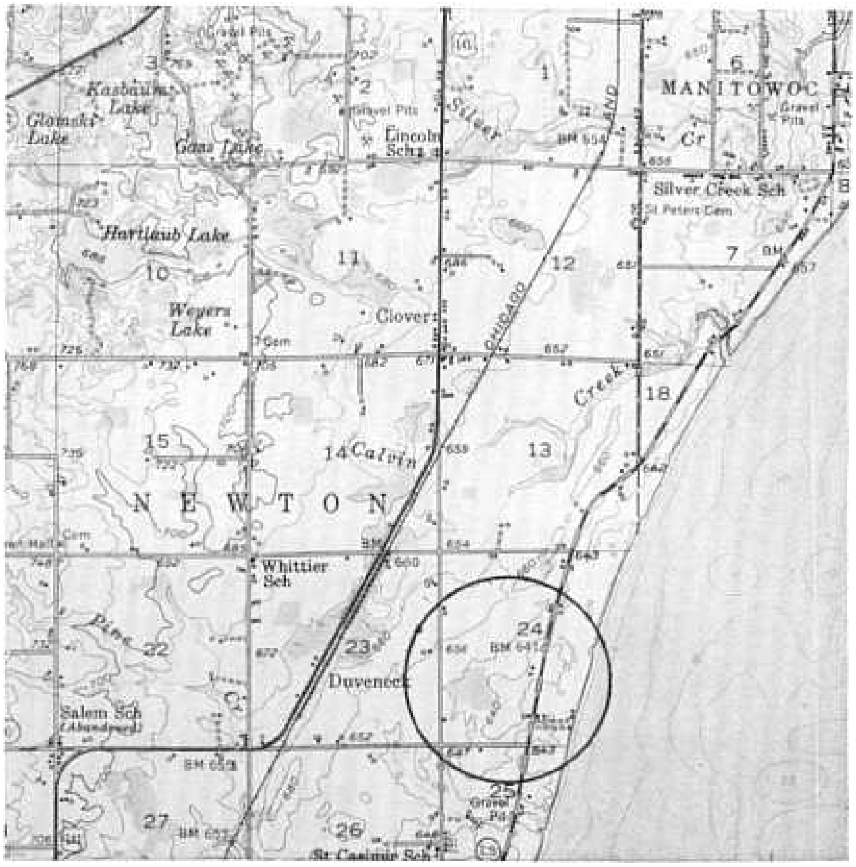
5. These sediments grade up to silts and silty clays near the top of the bluff. In places, a thin till is present over and interbedded in these lake sediments. This means that high lake levels existed before and after the last ice advance.

6. Now climb back up to the bluff top. Note that the surface rises to the south and that this rise swings to the northwest across the road. This feature is a high shoreline (Alden, 1918, Glenwood Stage) developed just after deglaciation. As you walk southward along the bluff top, note that the uppermost lake sediments get coarser and thinner as you approach the former beach. At the crest of the rise, till is present at the bluff top.

Significance: This is the best exposure of multiple tills along the southern Wisconsin shore of Lake Michigan. It will be the subject of a M.S. thesis at Milwaukee (R. Klauk, pers. comm.).

Title: Beach of Glenwood Stage of Lake Michigan

Location: SW 1/4, Sec. 24, T. 18 N., R. 23 E., (along C.T.H. L5), Manitowoc Quadrangle, Manitowoc County. This is a view stop and it is not necessary to enter private land. Stop along road and note low ridge to west of road in southern part of section, then crossing road in central part of section.



Author: David M. Mickelson

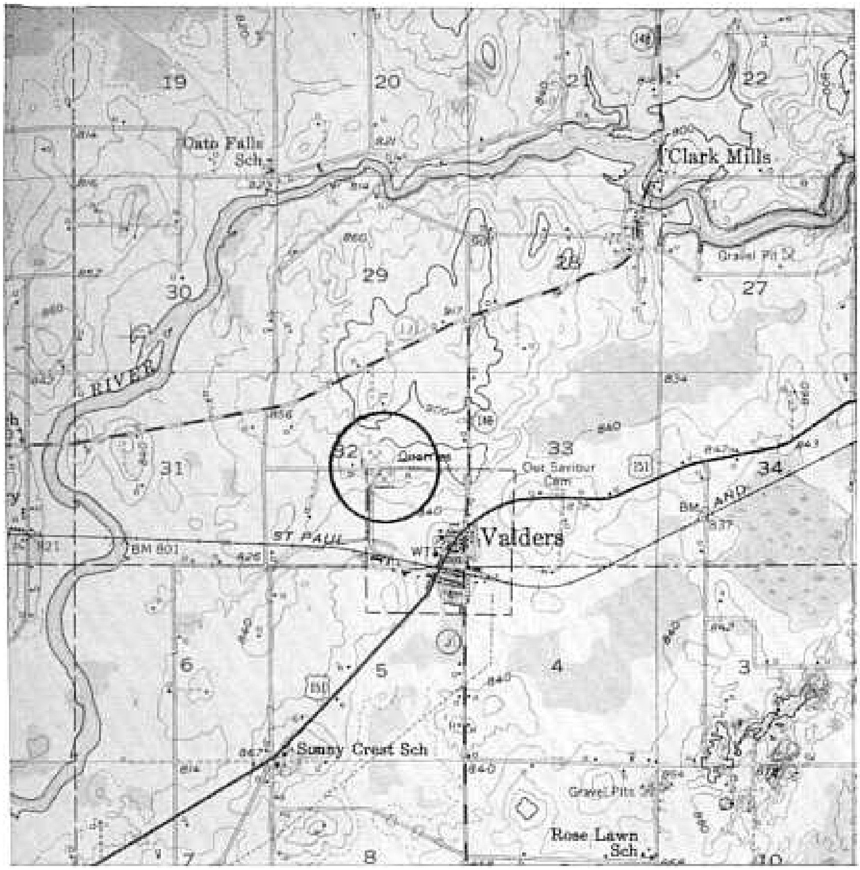
Description: During Woodfordian time, whenever glacial ice blocked the straits of Mackinac, the level of Lake Michigan rose above present levels. The lake formed is referred to as Glacial Lake Chicago and various stages, or lake levels, existed at different times. The outlet of Glacial Lake Chicago was through the present location of Chicago (Hough, 1958) and down the Illinois River to the Mississippi.

The beach you can see was formed during one of the Glenwood Stages when water left beaches now between 640' and 660' Hough (1958). These are the highest beaches present along the lake and they can be seen here and there south of this location around southern Lake Michigan and north of here to the city of Manitowoc (see St. Francis Power Plant Site).

Significance: The existence of the shoreline is important because it provides relative dates on the tills of the region (Evenson, 1973). South of Manitowoc, the shorelines cut and therefore post-date the upper-most tills. North of Manitowoc the Glenwood shorelines do not exist because glaciation more recent than the latest Glenwood Stage has destroyed them (see Type locality of the Two Rivers Till). What distribution of deposits might you expect in the shallow subsurface here? How could you prove this is a beach?

Title: Valders Quarry

Location: SW 1/4, NW 1/4 Sec. 32, T. 19 N., R. 23 E., Reedsville 15' Quadrangle, Manitowoc County. The approach should be from dirt road west off Hwy. 148 less than 1/2 mile N. of Hwy. 151 at crest of hill. Drive to edge of area that has been stripped and walk to north. Edge of quarry is very unstable! Groups should obtain permission from Valders Lime and Stone Co., just south of quarry.



Author: David M. Mickelson

Description: Excellent striations on the Silurian dolomite are preserved. The striations were cut by rocks included in the base of the glacier which smoothed and scratched the bedrock surface. Along the north edge of the quarry in a location difficult to get to is a buff, sandy till of mid-Woodfordian age. Beneath this till is one set of striations with a trend nearly north-south. In other parts of the quarry, red, clayey till is atop the dolomite and two sets (north-south and east-west) of striations are present.

Significance: Clearly, because only the north-south set underlies the oldest till and both sets of striations underlie the younger, the striations indicate first ice advance from the north, then ice advance from the east. The red till is called the "Valders till" (Thwaites, 1943). It was assumed by Thwaites and others that this till was equivalent in age to that above the Two Creeks Forest Bed (see description). Evenson (1973; et al., 1976), Mickelson and Evenson (1975), have argued against this idea because of geomorphic arguments and depth of leaching. Acomb (1978) supports Evenson with clay mineral studies which show that this till lies stratigraphically beneath the Forest Bed.

References: Alden, 1918; Black, 1971; Thwaites, 1943; Thwaites and Bertrand, 1957.

Title: Algonquin-Nipissing Lake Plain

Location: NE 1/4, Sec. 16, T. 19 N., R. 24 E., Manitowoc 15' Quadrangle, Manitowoc County. Park in rest area off Hwy. 42 and walk down path to Lake bluff. Rip-rap may cover this section in the future.

Author: David M. Mickelson

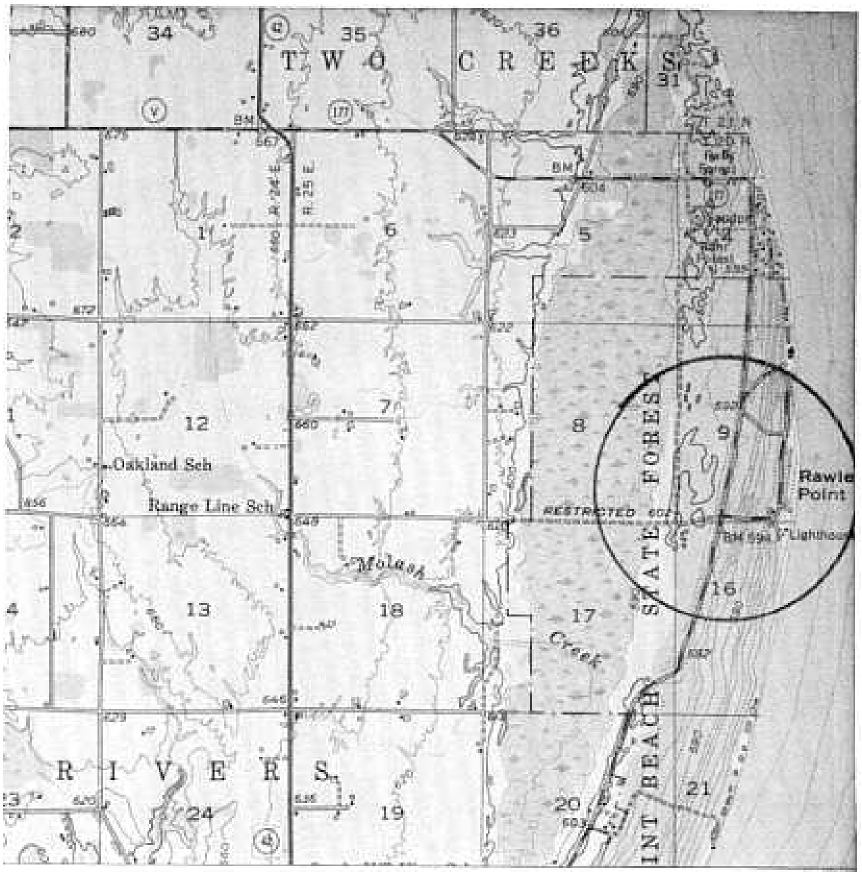
Description: The bluff is low here because lake levels were at this level (605') twice since glacial time. This area has been eroded by waves so much of the stratigraphic section is truncated. At the base of the bluff a sandy, bouldery till is present. This is overlain by at least one, and possibly two red tills. Note how the tills are truncated by the overlying lake sand in the northern parts of the cut exposure truncate the till units creating an unconformity. It is clear that erosion preceded disposition of the sands. Most of the shore along this terrace is protected by revetments of rip-rap.

Significance: We are in the Two Rivers Lowland, just south of the Two Rivers Moraine. According to Evenson (1973; Mickelson and Evenson, 1975; Evenson, et al., 1976) this lowland was not crossed by post-Twocreekan ice. Tills here and to the south have been examined by Acomb (1978) and the compositions of the clay fractions differ from that of the Two Rivers till. Note the various attempts at erosion control along this stretch of shoreline.

References: Thwaites and Bertrand, 1957.

Title: Point Beach State Forest

Location: T. 20 N., R. 25 E., Manitowoc 15' Quadrangle, Manitowoc County. Enter park from Two Rivers (south end) or on Hwy. 172 from Hwy. 42 north of Two Rivers. Park just inside main entrance gate and walk to beach.



Author: David M. Mickelson

Description: This is one of the few areas where natural accretion or deposition along the shoreline is taking place in Wisconsin. You probably noted the ridges and swales parallel to the shoreline which you crossed coming into the park. All of them are old beaches (primarily fore dunes) deposited along shorelines during the last 8,000, or so, years. Note that you crossed somewhat stabilized dunes in walking to the beach. These are composed of sand blown off the beach face by onshore winds. The dunes appear to be stable but it is a fragile environment and slight changes in vegetation caused by fire, climate change or man's activities could produce an active dune field.

On the beach itself, note that the materials are sand. The sand is derived from erosion of bluffs and entering streams to the north and to a lesser extent from the south. The sand is transported by currents moving along shore pushed by the prevailing winds and by the movement of sand grains along shore by waves hitting the beach at an angle. The distribution of currents in the lake causes sand to accumulate here instead of being carried further along shore. If there are waves when you visit you can observe this longshore drift.

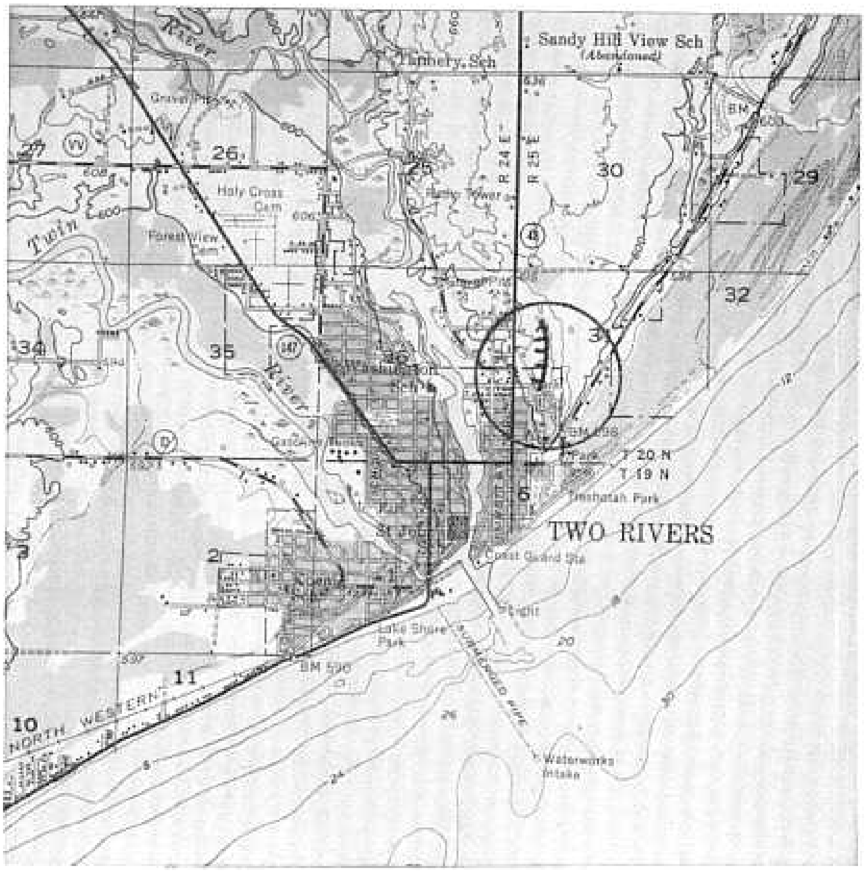
Examine the sand in the beach by looking at a cut face. Note that layering or stratification in the sand has been produced by wave action. The stratification here is produced by alternating lighter (color and weight) layers of grains of primarily quartz and calcium carbonate (limestone) grains and layers of heavier and darker grains of magnetite and hematite (iron oxide), garnets, illmenite and others.

<u>Significance</u>: Contrast this area with those seen in most places along the coast where the shore is being eroded. Outline the variables that might determine whether erosion or deposition takes place.

<u>References</u>: DuBois, 1973

Title: Type locality of the Two Rivers Till

Location: NW 1/4, Sec. 31, T. 20 N., R. 24 E., Manitowoc 15' Quadrangle, Manitowoc County. Enter along north side of Chevrolet dealer on Hwy. 42 north of Two Rivers. Pit is difficult to drive into and if anyone is home in trailer, obtain permission there.



Author: David M. Mickelson

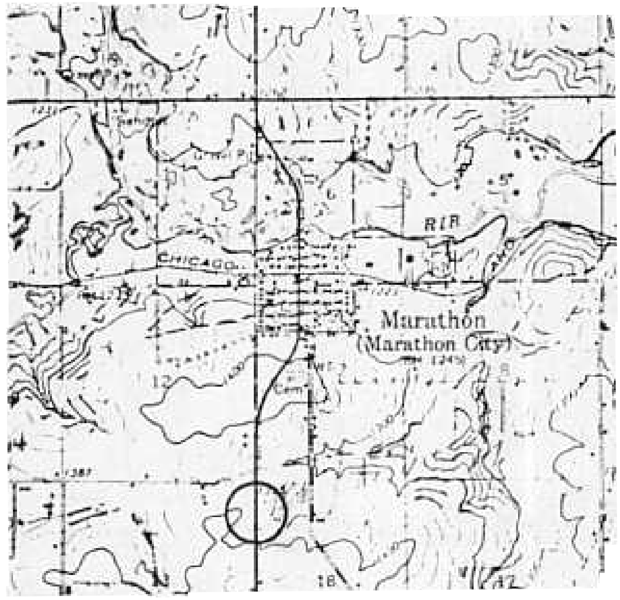
Description: The pit face shows red till over sand. About 50 feet of sand is present beneath the pit floor and below this is another red till. We are at the edge of the Two Rivers Moraine and the red till here, unlike those to the south, is not cut by the Glenwood shoreline. The till in the exposure shows differences from top to bottom. In the lower part silt and sand is interbedded with the till and the till becomes more uniform upward These could mark two different glacial events but it seems more likely that as ice advanced down the basin in water, icebergs and the advancing ice margin dropped debris into water. Later, as the ice grounded because of lake level drop or ice thickening, more typical till was deposited.

Significance: Previous to 1973, it was believed by most workers that the most recent of the red till along Lake Michigan covered the Two Creeks Forest Bed (see description) and extended to Milwaukee. In 1973 Evenson noted that the Glenwood shoreline did not cut the red till north of Manitowoc (Two Rivers till) and that the last dated Glenwood stage was older than the Two Creeks Forest Bed. Thus he concluded that the red tills south of Manitowoc were older than the Two Creeks Forest Bed and thus older than the Two Rivers till. Mickelson and Evenson (1975) presented evidence from depth of carbonate leaching studies that the Two Rivers Till is much less leached than tills to the south of the Two Rivers Lowland. Acomb (1978) presents clay mineral evidence that agrees with this interpretation. Black (1977), however, has disagreed with Evenson's interpretation.

References: Thwaites and Bertrand, 1957

TITLE: Cataclastic Degradation of Intrusion Breccia near Marathon

LOCATION: SW 1/4, NW 1/4, Sec. 18, T 28 N, R 6 E, Marathon 15' quadrangle



AUTHOR: Paul E. Myers, UW - Eau Claire

DATE: February, 1978

SUMMARY OF FEATURES:

Strongly chloritized quartz syenite(?) or adamellite(?) aplite containing large, rounded tonalite xenoliths shows progressive development of cataclastic schistosity and xenolith flattening southward across the roadcut. The tonalite xenoliths are medium gray, whereas the aplite is pink. With increasing cataclasis, the tonalite becomes pale yellow-green owing to the presence of chlorite and epidote. The xenoliths are reduced to less than one-tenth their original thickness in the steeply dipping, northeast-trending shear zones. Xenolith elongation is consistently 15 to 20° more northerly in strike than schistosity, and have a southeasterly dip of 60 to 70°. If xenoliths were elongated parallel to the original (prekinematic) intrusive contact, the shear zone cut the N20°E(?) contact along a more easterly trend. Although interlensing, chlorite-rich surfaces appear to be "slip planes", very little slippage can be seen where these surfaces cross xenolith boundaries.

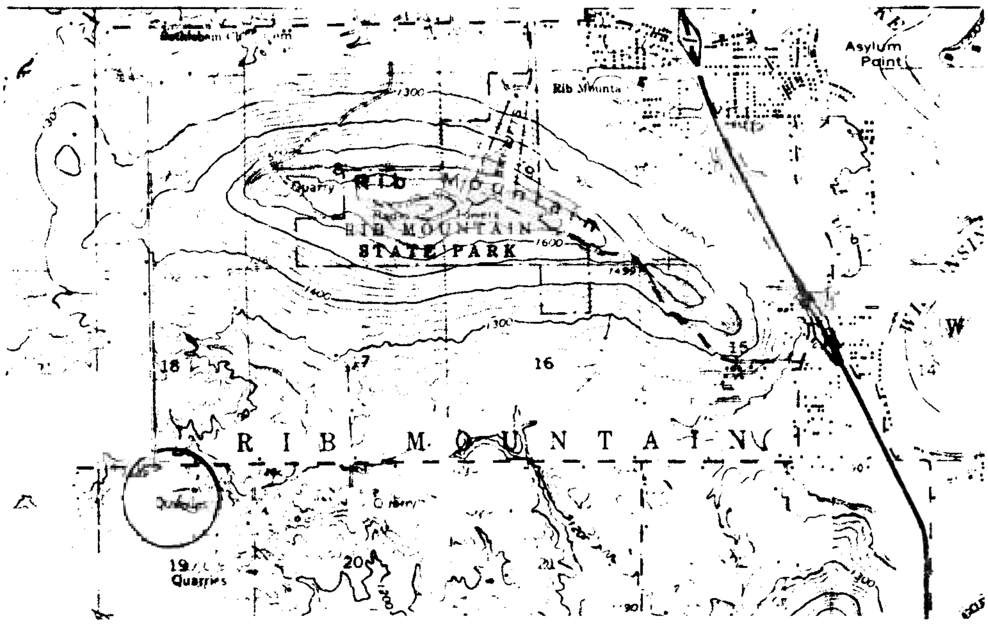
Pegmatite-filled gash fractures trending N55°E, 30°($\pm$ 10°) SE have 1-3 cm masses of chlorite and actinolite. Quartz also fills gash fractures in relatively unsheared aplite.

The tonalite xenoliths are composed of radial aggregates of plagioclase with 15-20% quartz. Primary mafic minerals are thoroughly altered to epidote and green chlorite. Plagioclase is strongly sericitized. The radial aggregation of primary plagioclase in the tonalites suggests cumulate texture.

The chief purpose of examining this outcrop is to demonstrate the affect of primary composition on the color and fabric of cataclastic rocks. Primary features are totally obliterated, and transposed into the plane of cataclastic schistosity.

TITLE: "Rotten Granite"

LOCATION: NE 1/4, NW 1/4, Sec. 19, T28N., R7E., Wausau 15' Quadrangle



AUTHOR: Paul E. Myers, UW-Eau Claire

DATE: February, 1978

SUMMARY OF FEATURES:

This outcrop of Ninemile granite (1500 ± 50 m.y.) exemplifies the "rotten" granites which are used for road construction throughout Marathon county. Their friability is at least partly a result of extensive chemical weathering. The time and exact nature of the weathering are not known. Other factors, such as original shapes of grains, effects of shearing, and tectonic "unloading" may have had a contributory influence. Because of their importance as a local resource, their occurrence and mode of formation assume special significance.

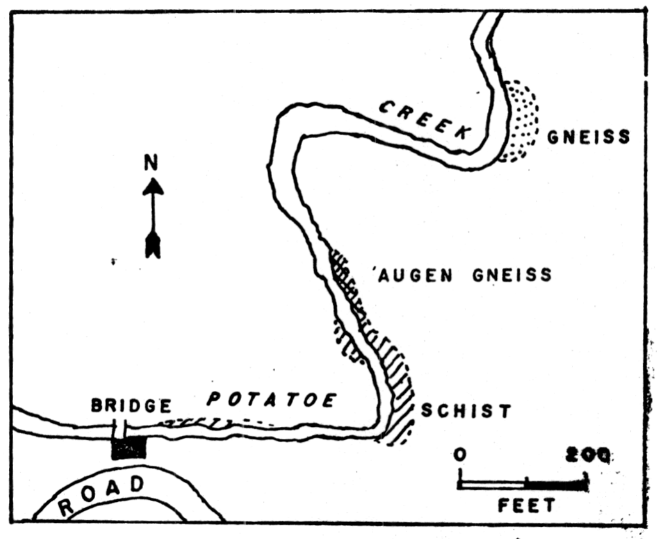
Examine the "fresh" and weathered granite under a hand lens. What are the shapes of the grains? Compare grain shape in fresh granite with that in weathered granite fragments. Do the grains have interlocking boundaries? To what extent has grain shape been modified by weathering? The Ninemile granite north of here forms large areas of low outcrop which stand topographically higher than areas underlain by other rock types such as greenstone, quartz diorite, schist and syenite. In the quarry, resistant knobs of relatively fresh, non-friable granite are enveloped by exfolia of fragmental granite. The deep red color of "rotten" granites also must signify a unique set of weathering conditions, such that ferric ion has been leached from biotite and deposited in and around kaolinized K-feldspars.

These rocks closely resemble "saprolites" of the Piedmont province of eastern United States, where granitic rocks showing faithful preservation of textures are so water-saturated and decomposed that they can be shoveled from an "outcrop". Deep circulation of groundwater and leaching of silica are common processes today in sub-tropical regions of lateritic weathering. Circulating groundwaters would preferentially leach sharp projections, corners, and edges of quartz grains and reduce intergranular adhesion. Dott and Batten (Evolution of the Earth, 2nd ed., 1976, p. 213) indicate that Wisconsin was at tropical latitude during the Cambrian period, when this region suffered prolonged exposure. Several questions persist, however. For instance, there appears to be a subtle spatial association between location of "rotten" granite quarries and shear zones. Did shearing locally weaken the granites? How? To what degree has modern groundwater circulation been responsible for the formation of these "rotten" granites? Were these areas realtively untouched by Pleistocene glacial scour?

Thesis anyone? It's a beauty!

Title: Sheared Gneisses, Athens County Park

Location: NE¼, NW¼, SW¼, Sec. 6, T.29N., R.4E.
(Athens 15 Minute Quad.) Marathon Co.



Author: Gene L. LaBerge

Description: Several major fault zones cross Marathon County. This is a continuation of the same zone we visited at the previous stop but here the older gneisses have been caught up in the shearing.

At the south end of the exposure (refer to sketch map), the rock is very schistose, consisting of quartz, plagioclase, hornblende, biotite, epidote, chlorite and minor magnetite. The hornblende is moderately to well foliated and lineated. The rock was interpreted by Weidman (1907) as a meta graywacke, and part of the Hamburg Slates that occur northeast of here. The mineralogy and texture of the rock suggests that it may be a meta graywacke.

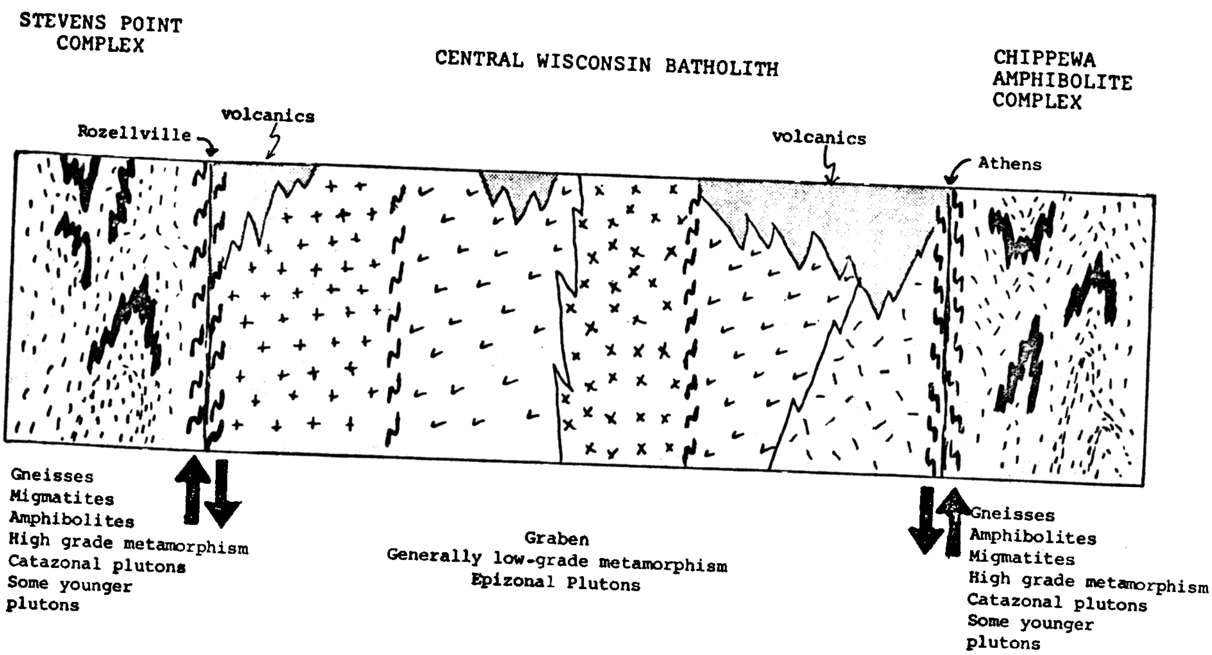
North (downstream) from the schist are several outcrops of biotite-rich, well-foliated augen gneiss. The biotite encloses lens-shaped pods of quartz and feldspar. This rock appears to be a highly sheared intrusion, or perhaps a sheared gneiss. The larger grains are somewhat cataclastic, but the finer matrix has been thoroughly recrystallized.

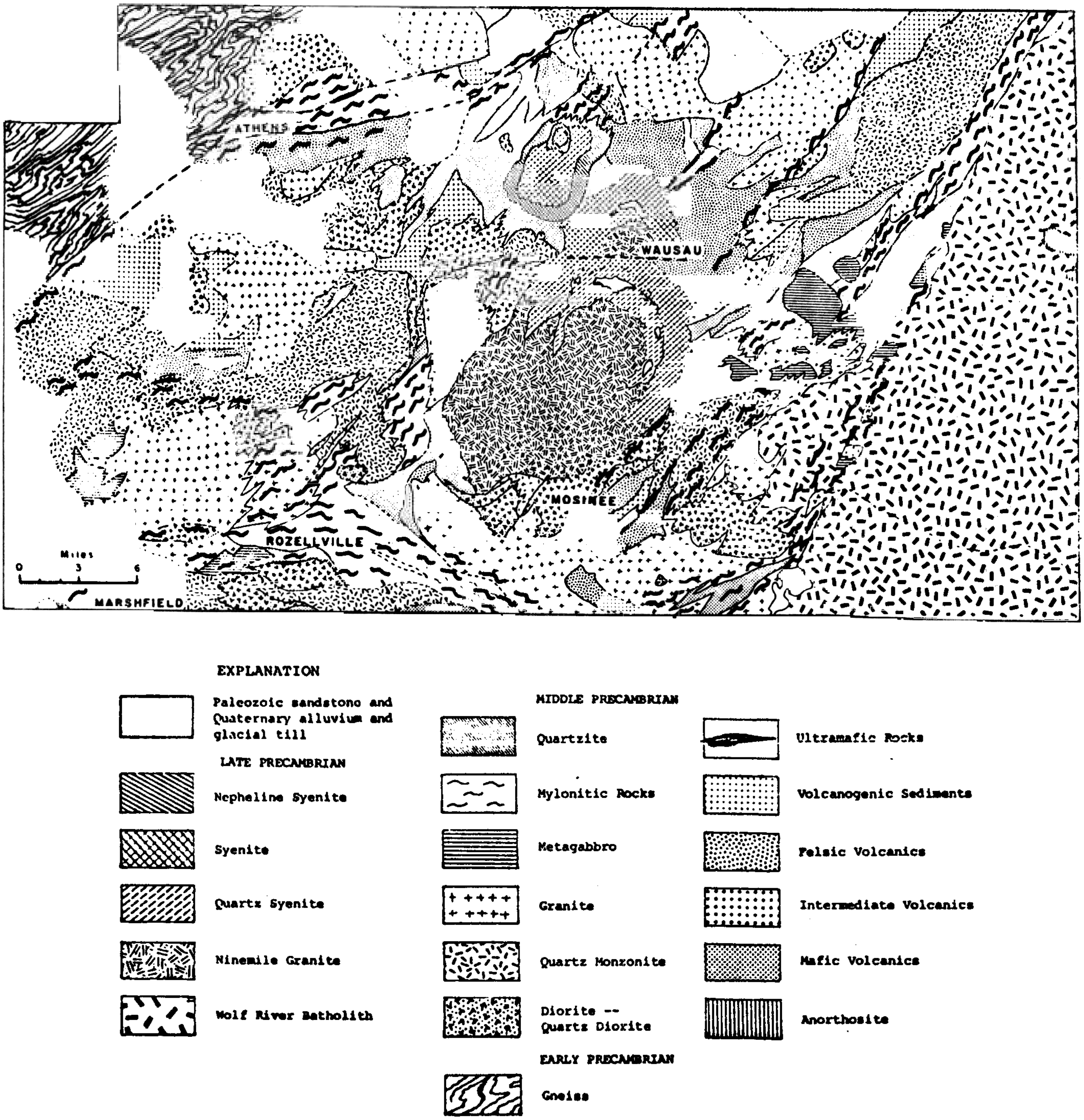
Exposures of fine-grained pink granitic gneiss with several large quartz veins are present about 200 feet northeast of the park boundary, and gneisses and mylonites are exposed in the valley of Black Creek near the bridge on Hwy. 97 at the north edge of Athens.

Significance: A major structural boundary passes through Athens trending about N60°E. South of the lineament are volcanic rocks and granites that have been only slightly metamorphosed. North of the lineament the rocks are high grade gneisses, amphibolites and migmatites (LaBerge, 1977). Along the lineament are mylonites, phyllonites and other intensely sheared rocks along with a number of ultramafic bodies, such as we saw at the last stop. The width of the shear zone ranges up to nearly 2 miles, so that large volumes of rock have been sheared. In places (such as the last stop) the shearing affected mainly the low-grade volcanic and sedimentary rocks. The gneisses as well as sediments have been involved in the shearing here. A similar shear zone along the south side of Marathon County (see County map) brings gneisses into contact with low grade volcanics and intrusions. The gneisses are common to the south.

The presence of low-grade metamorphic rocks bounded on the north and south by gneisses and separated by broad shear zones containing ultramafic bodies indicates large scale block faulting. The low-grade volcanics and granites appear to occupy a graben-like structure with horsts of gneisses uplifted to both the north and south. The diagram illustrates these relationships across this part of Marathon County.

These large scale faults appear to have been active over several hundred million years of time, and represent the major structural features in central Wisconsin.





References:

LaBerge, G. L., 1977, Major Structural Features in Central Wisconsin and Their Implications on the Animikie Basin; 23rd Annual Inst. on Lake Superior Geology, Thunder Bay.

Weidman, S., 1907, The Geology of North Central Wisconsin; Wis. Geol. Nat Hist. Survey Bull. 16, 697 p.

TITLE: Ultramafics at Contact of Gneiss Terrane

LOCATION: NW 1/4, SW 1/4, Sec.30, T29N., R5E., Hamburg 15' Quadrangle

AUTHOR: Paul E. Myers, UW-Eau Claire

DATE: February, 1978

SUMMARY OF FEATURES:

A small, ENE-trending, lenticular body of massive metaperidotite(?) separates hornblende-biotite-tonalite-gneiss to the north from phyllites of sedimentary parentage to the south. The ultramafic rock was apparently carried up along a major fault which raised more highly metamorphosed tonalite gneisses on the north.

DISCUSSION:

Muscovite phyllite with foliation and subparallel relict bedding N74°E, 75°N and subordinate cleavage N35°E, 74°NW is probably derived from an arkosic sandstone. Relict quartz and feldspar clasts and bedding are best seen on horizontal surfaces toward their fault contact with the ultramafic rock. The phyllites contain streaked lensoids of K-feldspar and diamond-shaped hematite replacements. A conspicuous lineation formed by the intersection of foliation and cleavage plunges N36°W at 68-74°.

Biotite-hornblende tonalite pencil gneisses along Rib River north of here have lineations plunging N50-65°W at 55-65°. Foliation, where present, dips steeply NNW.

The coarse-grained ultramafic rock is composed of relict pyroxene which appears to have been altered to chlorite. The restricted occurrence of ultramafic bodies between high grade gneisses and low grade metasedimentary-metavolcanic terranes suggests that they lie along major high-angle faults and were emplaced during or after faulting. Their lack of foliation suggests the latter although rock masses can be carried up along faults without much internal deformation.

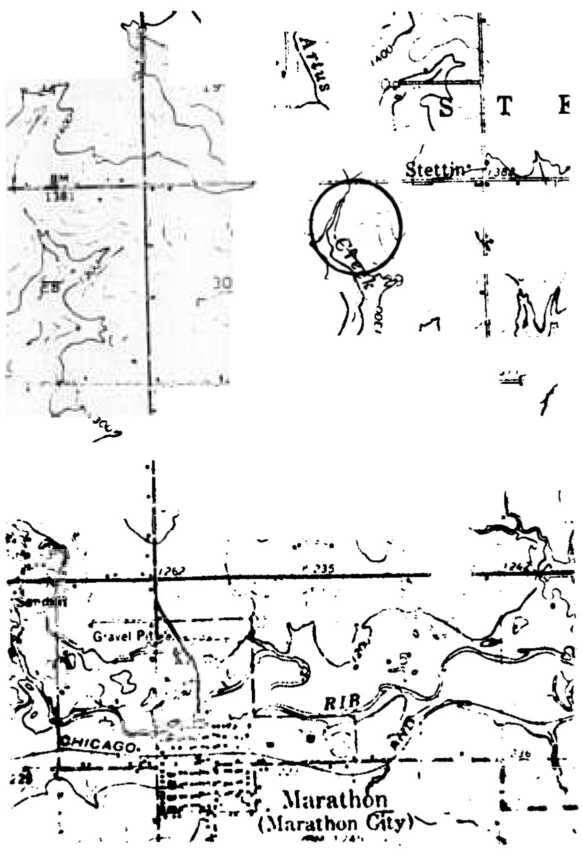
Although the ultramafic body is about 300 meters wide here, it was not observed in outcrop along Rib River just east of here. Shape and extent of the body are unknown. A prominent magnetic anomaly south of the gneiss-phyllite contact is enlongated parallel to the contact. Hematite in the phyllite may have been altered to magnetite during intrusion of the ultramafic so that the magnetic anomaly actually marks a contact metamorphic aureole.

As usual, the rock relationships here elict more questions than answers.

Title: Artus Creek Greenstone

Location: In pasture along the east side of Artus Creek.
NE¼, NW¼, NW¼, Sec. 29, T.29N., R.6E.
(Marathon 15 Minute Quadrangle, Marathon County)
(Get permission from Harold Theis (pronounced "Tice")
R. R. 2, Marathon, Wis., Phone: 715-845-2667.)

Author Gene L. LaBerge



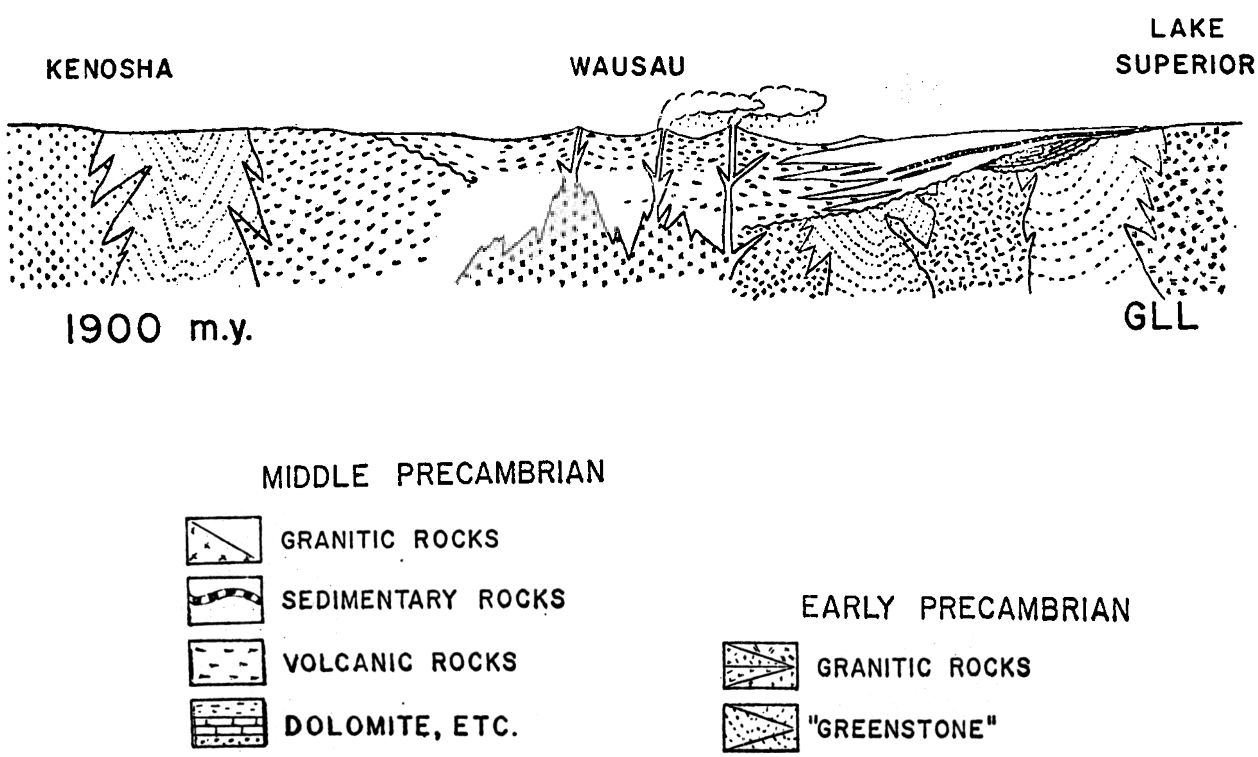
Description: At this stop there are numerous exposures of pillowed basaltic greenstone. Due to the irregular fracture pattern on the surface of the outcrop, the pillows are not very evident. However, they are well exposed on several small south-facing ledges farther from the road.

The pillows range in size from less than one foot to at least three feet in diameter. Pillows are widely used for top determination in mapping volcanic rocks. The accompanying photo, taken at this stop, shows the classical domal top and pointed bottom of the pillow. While the dip of the flows is readily determined from pillows, they do not show the strike. This must be determined by tracing a distinctive lithology (or pillowed unit). Where exposures are as limited as they are in Marathon County, it is extremely difficult to determine the strike of the basalts.

The greenstones here consist of sodic plagioclase, actinolite, epidote, chlorite, and minor carbonate and quartz. Epidote and actinolite are the dominant minerals in some samples. The term "greenstone" derives from the greenish color of the rock which is produced by the abundance of actinolite, epidote and chlorite. At the time of formation the selvages (rinds) around the pillows were probably a hydrated basaltic glass (palagonite); however, they are now dominantly quartz and epidote. The mineralogy of the rock is very different from that of fresh basalts, and is due to the low grade metamorphism the rocks have undergone.

Significance: Pillowed basalts are widely distributed in an east-west trending "belt" across northern Wisconsin. They are abundantly exposed near Pembine in Marinette County, and sporadically exposed to the west of there, including the Monico area in Oneida County. The Bouguer Anomaly Gravity Map of Wisconsin (Ervin & Hammer, 1974) suggests that these rather

Middle precambrian pillow lavas along
Artus Creek. Pencil points at the
top of the pillow.



heavy rocks (a resulting gravity high) extend almost continuously from the Michigan border west beyond Ladysmith in Rusk County. Rhyolites are also present at most localities along this belt, indicating a long belt of volcanic activity. The widespread occurrence of pillows indicates a submarine origin for most of the volcanics.

Radioactive age dating on these rocks indicates that they were formed between 1900 m.y. and about 1825 m.y. ago (Van Schmus, Thurman and Peterman, 1975; Sims, 1976). Thus, they are approximately the same age as the iron-formation and graywacke on the Gogebic Range, and must, therefore, have formed as part of the same basin of deposition -- the Animikie Basin (LaBerge, 1977) (see diagram).

The volcanic rocks in Marathon County have been extensively intruded by granitic rocks and are separated by a large wedge-shaped mass of gneisses and amphibolites that appear to be much older. However, the volcanic rocks here are believed to be part of the Animikie Basin because they are of the same age, and were formed mainly in a subaqueous environment. At the succeeding stops, we will examine the possible relationships between these various rock sequences.

References:

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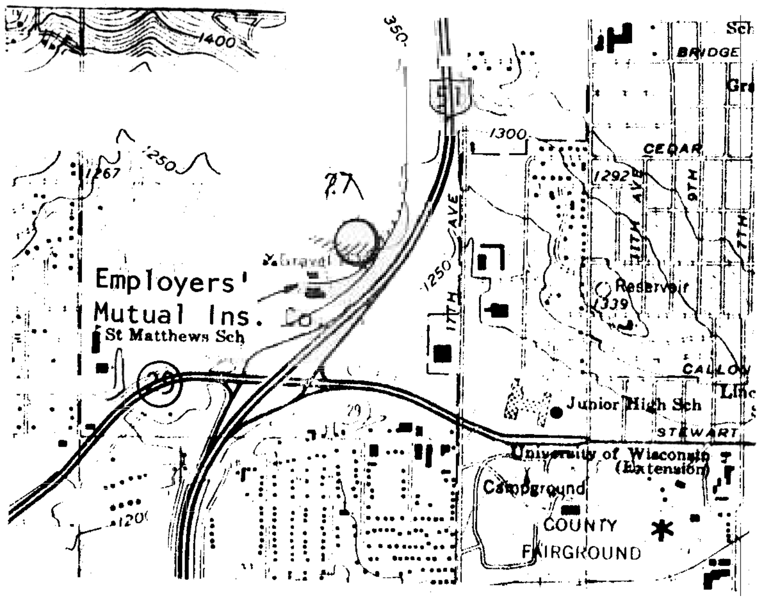
Van Schmus, W. R., Thurman, M. E. and Peterman, Z. E., 1975, Geology and Rb/Sr Chronology of Middle Precambrian Rocks in Eastern and Central Wisconsin: Geol. Soc. America Bull., Vol. 86, pp. 1255-1265.

TITLE: Lensoidal Quartz Syenite, Employers' Mutual Insurance Company

LOCATION: NW 1/4, SE 1/4, Sec. 27, T 29 N, R 7 E, Wausau West 7.5' Quadrangle



AUTHOR: Paul E. Myers, UW - Eau Claire

DATE: January, 1978

SUMMARY OF FEATURES:

Coarse-grained, pink and brownish gray quartz syenite contining up to 60 percent volcanic xenoliths (best seen on horizontal surfaces) is exposed in an old quarry behind the offices of Employers' Mutual Insurance Company. This rock exemplifies contaminated quartz syenite of the "intermediate zone" of the Wausau syenite pluton (Fig. 1.) Associated quartz syenite elsewhere in this zone contains large, metasomatized quartzite and/or mica schist xenoliths, the most spectacular of which is exposed on the summit of Rib Mountain. The Rib River "lineament" separates the two crescentic segments of the Wausau syenite body. The core and southern half of the syenite pluton are displaced by the Ninemile granite (1500 m.y.). Concentric xenolith orientation in both the Wausau and Stettin syenite plutons suggests laminar flow of viscous, water-deficient magma in volcanic pipes.

DESCRIPTION:

The quartz syenite at this location is composed of coarse perthite (80%), quartz (10%), and sodic pyroxene partially replaced by mixtures of dark green amphibole, carbonate, and magnetite (10%). Quartz is interstitial. Large magnetite segregations can be observed along the road on the east side of this outcrop.

The trachyte or rhyolite(?) xenoliths are lensoidal with blunt, broken east ends and rounded (assimilated?) west ends. Their orientation is consistently N 70-75° W, vertical in this area (Fig. 2), and they are seen best on horizontal surfaces. Large quartzite xenoliths occur in the quartz syenite along the ridge crest north of here. The crescentic form of this part of the Wausau syenite body also shows as a conspicuous magnetic anomaly owing to the high concentration of magnetite as sheets and lenses in these rocks. The xenoliths show up on fresh surfaces mainly as slightly finer grained, darker colored

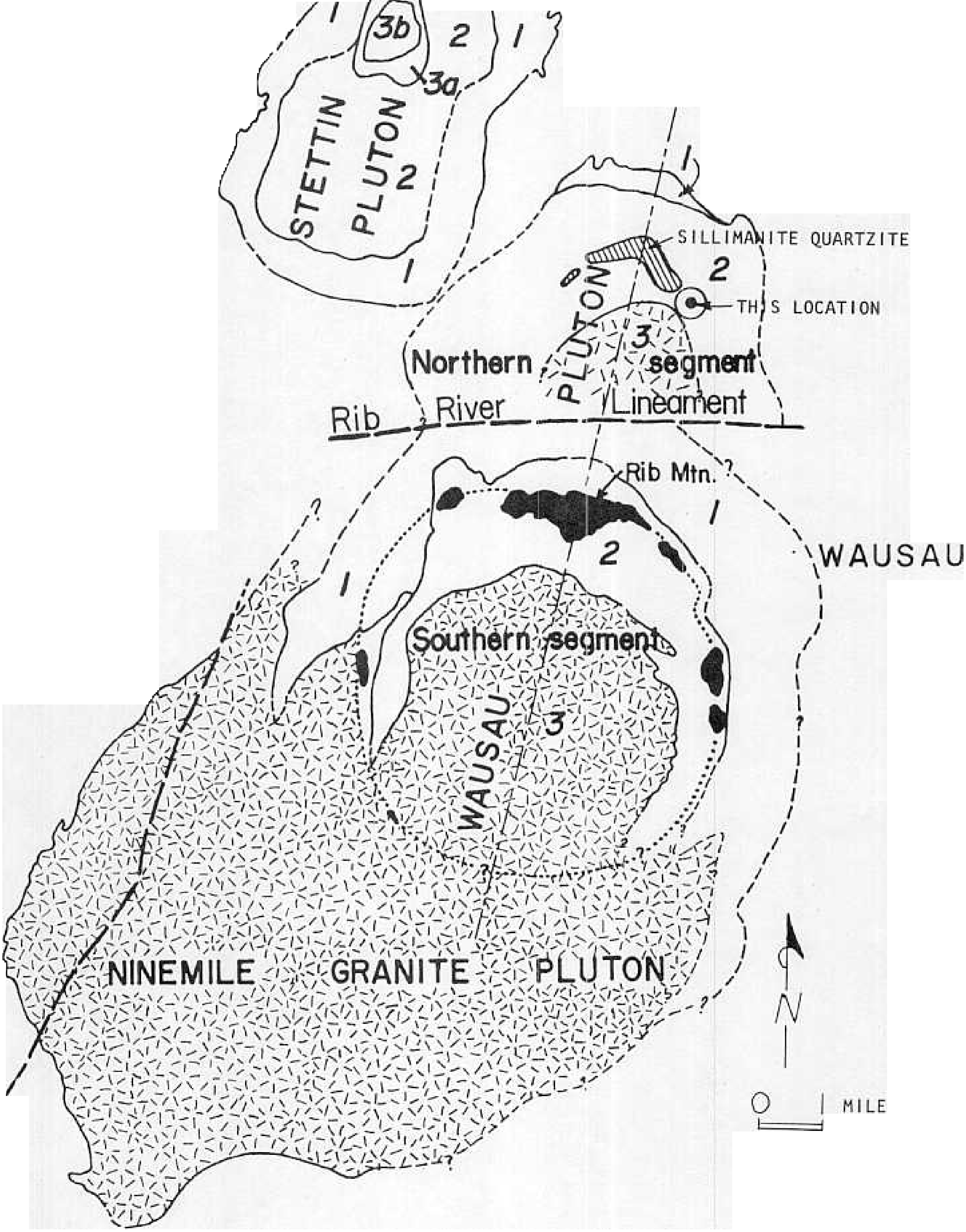


Figure 1 -- Generalized geologic map of the Stettin and Wausau syenite bodies and the Ninemile granite pluton which intrudes the Wausau syenite. Unit 1 is wall zone gneissic syenite, unit 2 is amphibole and pyroxene syenite of intermediate zone, and unit 3 is core zone. Black is quartzite.

masses. In addition to the angular volcanic xenoliths, the quartz syenite here contains mafic schlieren and clots showing irregular shape and orientation as well as gradational boundaries, a factor suggesting more distant derivation and more thorough assimilation of the mafic schlieren and clots in the syenite magma.

Although the concentric structure of the Wausau and Stettin syenite bodies suggests subvolcanic intrusion, numerous questions arise concerning emplacement mechanism. Xenoliths of highly disparate lithology, and metamorphic grade occur side by side in these plutons. Their lenticular shape suggests mechanical segmentation before or during syenite intrusion. Convoluted flow lineation in amphibole syenite (as at the Old Technical Institute in Wausau) indicates viscous flow, probably due to water-deficiency of the magma. At many locations it is very difficult to distinguish the intrusive phase: indeed, one is hard-pressed to find an uncontaminated syenite exhibiting the features of a true intrusive rock. Sillimanite-bearing quartzite occurs as a tabular xenolith in fine-grained hornblende syenite 2.5 km west-northwest of here. The sillimanite suggests considerable upward transport of the xenolith from a high-grade metamorphic basement. The mica schist and metagabbro(?) xenoliths at Mosinee Hill and along the east side of the Wausau syenite body also suggest a deep-seated source. The close-spaced juxtaposition of xenoliths of disparate lithology indicates considerable vertical movement of wallrock fragments. To what degree did collapse modify these intrusive relationships? Does the quartz syenite represent a syenite magma which was contaminated by xenolithic quartzite? To what degree was the syenite able to assimilate xenoliths? Textural relations seen throughout the pluton suggest little assimilation but considerable dilation owing at least in part to explosive eruption.

REFERENCES:

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Geisse, Elaine, The petrography of the syenites, nepheline syenites and related rocks west of Wausau, Wisconsin, M.A. Thesis, Smith College, 1951

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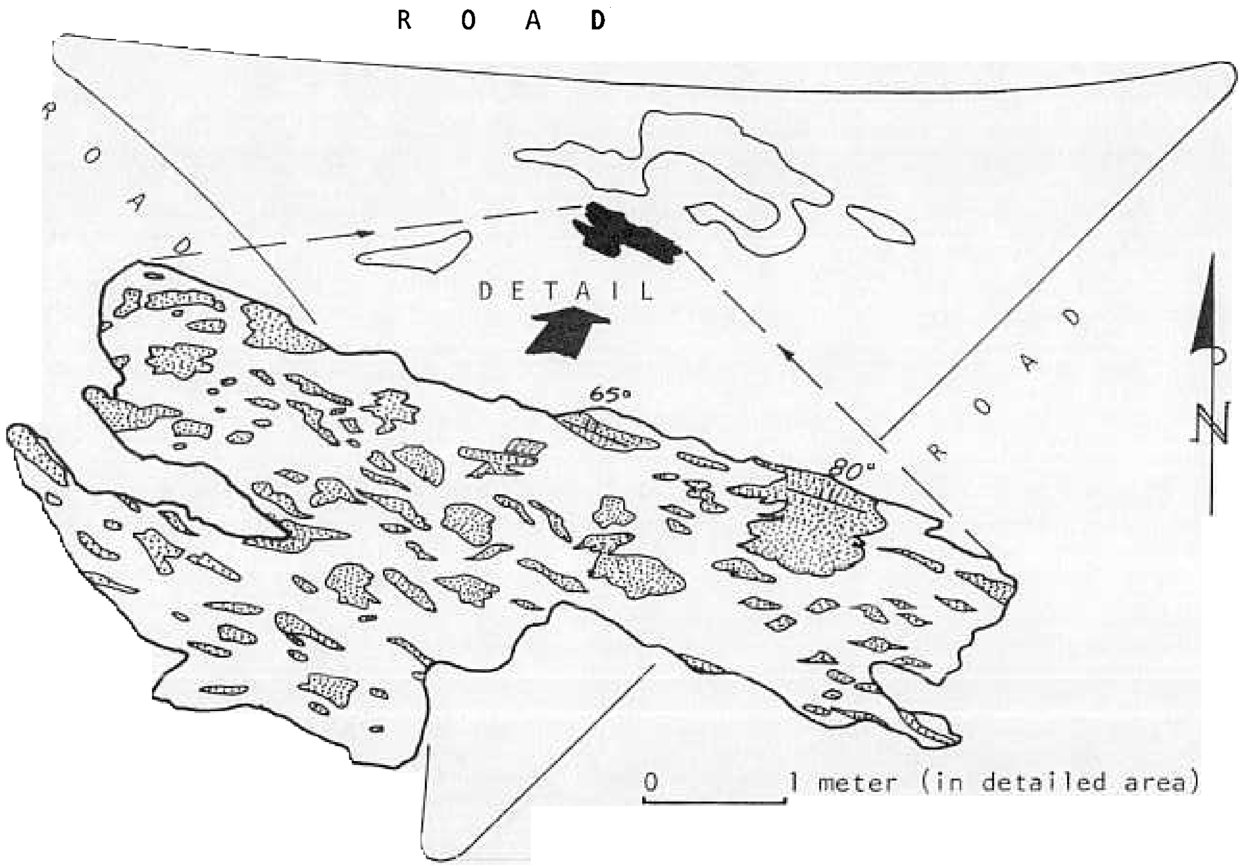
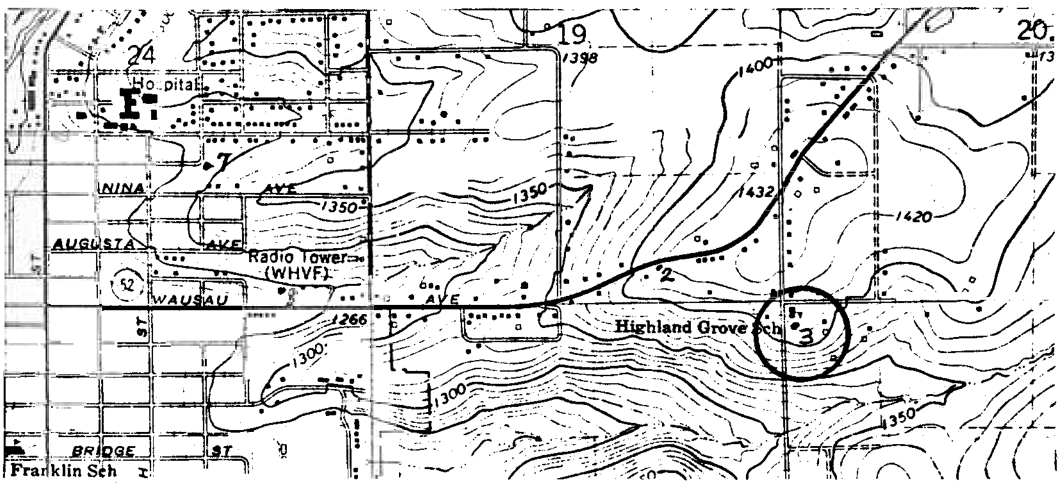


Figure 2 -- Volcanic xenoliths (dotted) in flow-lineated amphibole quartz syenite (white). Outcrops in grassed area between three roads behind Employers' Mutual Insurance Company.

Title: Rhyolites, Highland Grove School

Location: NW¼, NW¼, NW¼, Sec. 29, T.29N., R.8E. (Wausau East 7½ Minute Quad.) Get permission from Robert Zielsdorf, 2105 25th St., Wausau. Phone: 715-842-2592



Author: Gene L. LaBerge

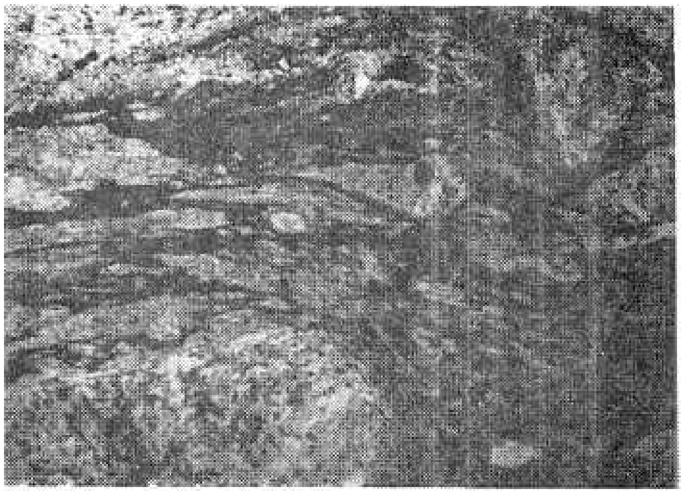
Description: Considerable parts of Marathon County, including that part of Wausau east of the Wisconsin River, are underlain by several types of rhyolitic volcanic rocks. They include lithic and crystal tuffs, welded tuffs, breccias, volcanic mudflows (lahars), flow-banded rhyolites, and volcanic sandstones. At this stop we will see examples of tuffs and welded tuffs, lahars and flow-banded rhyolites.

The outcrops along 25th Street at the brink of the hill are welded crystal tuffs. Flattened shard structures that curve around the phenocrysts can be seen on weathered surfaces.

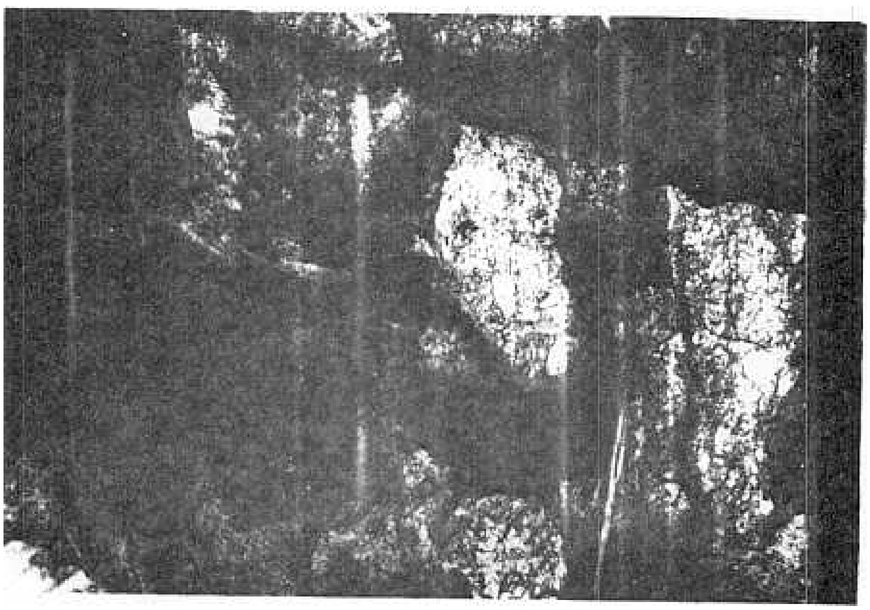
Photograph A shows an example of the texture. A fine, massive, non-porphyritic unit exposed in the woods south of the house appears to be formed of fine ash, and south of the ledge (downslope) is a lapilli tuff. A coarse conglomeratic (laharic) deposit is exposed in the pasture just east of the woods.

Photograph B shows the texture of the lahar.

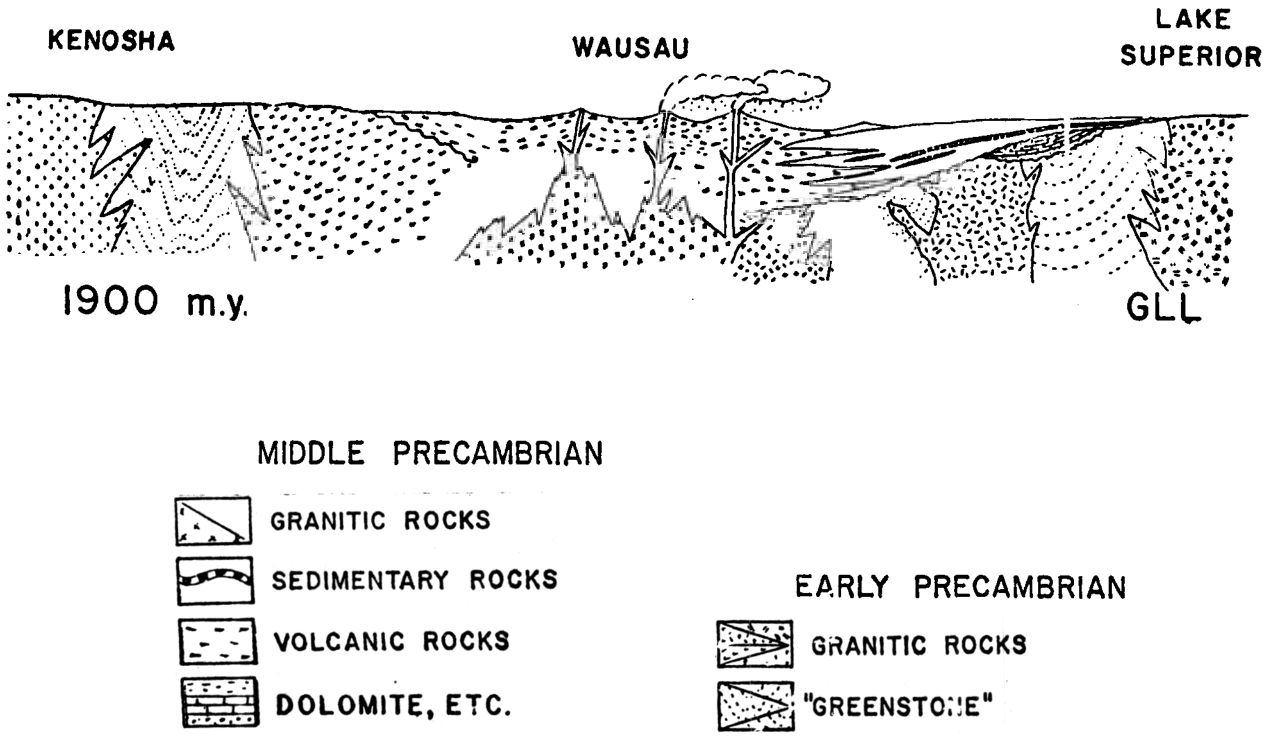
Microscopic examination shows that the rhyolite is a very fine mixture of quartz and feldspar containing larger quartz and oligoclase phenocrysts. The common occurrence of shard structures (Photo A), relict spherulitic and axiolithic structures and perlitic cracks indicate that the rocks were initially glassy, but have devitrified (crystallized) over the 1900 million years since they were erupted (Van Schmus and others, 1975). The presence of minor foliated sericite and carbonate in the rocks indicates that they are slightly metamorphosed, but the preservation of shard structures shows that the grade of metamorphism is very low. The volcanic rocks here appear to dip nearly vertically, although measuring a dip and strike in rocks of this type is difficult.

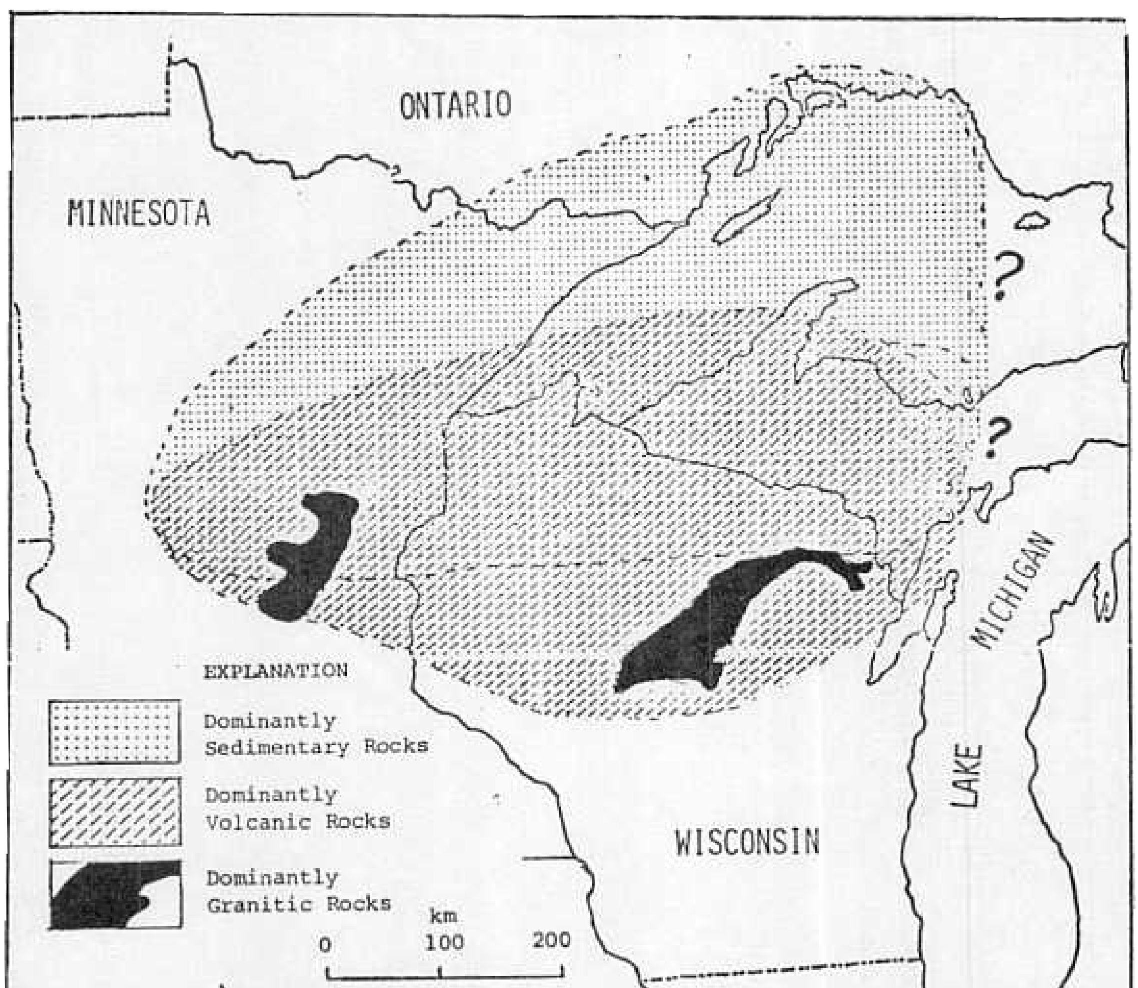


A. Photomicrograph of weldsd tuff showing flattened shards "draped" around lithic fragments. Approximately x100.



B. "Conglomeratic" rhyolite, probably formed by a volcanic mudflow (lahar). Pen shows the scale.


KENOSHA
WAUSAU
LAKE SUPERIOR
1900 m.y.
GLL
MIDDLE PRECAMBRIAN
GRANITIC ROCKS
SEDIMENTARY ROCKS
VOLCANIC ROCKS
DOLOMITE, ETC.
EARLY PRECAMBRIAN
GRANITIC ROCKS
"GREENSTONE"


ONTARIO
MINNESOTA
WISCONSIN
LAKE MICHIGAN
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Dominantly Sedimentary Rocks
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100
200

Significance: The rhyolites of Central Wisconsin were formed at approximately the same time as the Middle Precambrian iron formation and graywackes of the Gogebic Range. Volcanic rocks and granites are of the dominant Middle Precambrian rocks in the north central part of Wisconsin, and appear to form the "igneous portion" of the Animikie Basin (see diagram) (LaBerge, 1977).

The volcanic rocks are largely pillowed basalts and bedded (water lain) tuffs indicating a subaqueous deposition. However, the rhyolites in the Wausau area are mainly subaerial deposits, and may represent a volcanic island in the Animikie Sea. Settings such as this are the site of zinc-copper ore deposits such as those found recently at Ladysmith, Rhinelander, and Crandon. The ore deposits form where zinc and copper-bearing hot springs came out on the sea floor during the volcanic activity. Significantly there are minor occurrences of these sulfide minerals in the Wausau area.

The intrusion of numerous granitic bodies and faulting has segmented the former east-west volcanic terrane in Marathon County. However, a more continuous belt of Middle Precambrian rocks extends from the Michigan border near Iron Mountain westward beyond Ladysmith, and perhaps as far as central Minnesota.

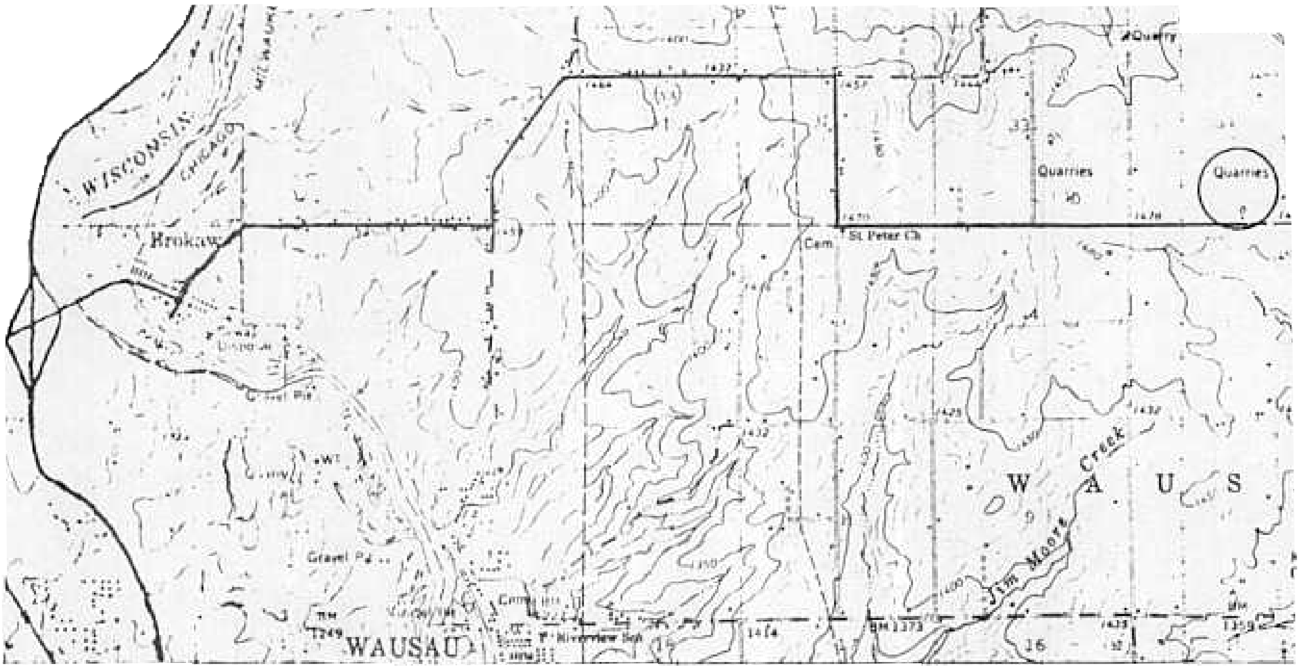
References:

LaBerge, G. L., 1977, Major Structural Features in Central Wisconsin and Their Implications on the Animikie Basin; 23rd Annual Institute on Lake Superior Geology, Thunder Bay.

Van Schmus, W. R., Thurman, M. E., and Peterman, Z. E., 1975, Geology and Rb/Sr Chronology of Middle Precambrian Rocks in Eastern and Central Wisconsin: Geol. Soc. America Bull., Vol. 86, pp. 1255-1265.

Title: Central Wisconsin Batholith

Location: Granite Quarry, SW¼, SW¼, SE¼, Sec. 34, T.30N., R.7E
Marathon County, Merrill 15 Minute Quad.

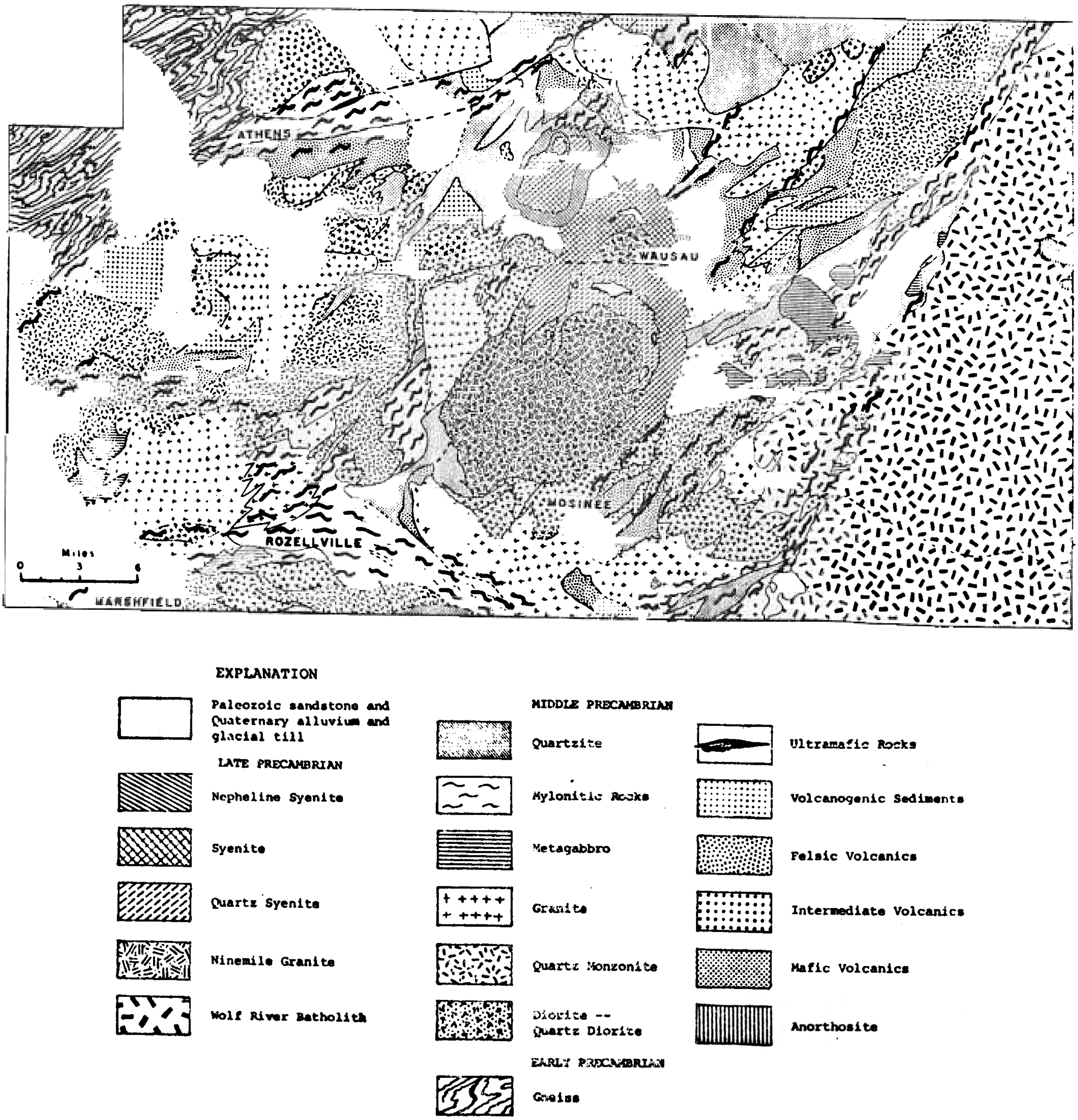


Author: Gene L. LaBerge

Description: The red granite is a homogeneous, non-porphyritic medium grained rock composed mainly of quartz and microcline with lesser amounts of oligoclase and biotite. The red coloration is due to inclusions of fine hematite in the feldspars. The intrusion has two "lobes" -- one east and one west of the Wisconsin River, with a narrow neck connecting the two. The lobe west of the Wisconsin River has a partial rim of quartz monzonite (Myers, 1973), and thus shows compositional zoning. The intrusion occurs approximately along the contact between basaltic on the north and rhyolitic rocks on the south. Basaltic inclusions are relatively common in the granite, and along its northern margin the assimilation of basaltic wallrock has produced an inclusion-rich gray quartz diorite. Contact metamorphism of the basalts and rhyolites is visible near the intrusion.

This rock has been designated the Wisconsin "State Stone" and is quarried in at least four quarries north of Wausau by the Coldsprings (Minn.) Granite Company and Anderson Brothers and Johnson (of Wausau). Quarrying is limited in many areas by the presence of shear zones that cut the granite and render it unusable for quarry stone.

Significance: The granite quarried here is part of the Central Wisconsin Batholith (LaBerge & Myers, 1976). The batholith is comprised of numerous relatively small granitic plutons intruded into a dominantly volcanic sequence about 1850 million years ago. Both the intrusions and the volcanics are part of the Animikie Basin, formed between 2000 and 1800 million years ago (refer to Geological Map of Marathon Co.). The granitic rocks were formed during the Penokean Orogeny that affected most of the Precambrian rocks in Wisconsin south of the Gogebic Range. Broad zones of cataclastic rock have been formed along numerous shear zones that cut both the volcanic and plutonic rocks in Marathon Co. These shear zones are a characteristic feature of the geology of central Wisconsin. The granitic rocks of the batholith extend from the Michigan border westward across much of Wisconsin. Here the plutons intrude Middle Precambrian volcanic rocks, but in the Eau Claire area they intrude Early Precambrian gneisses.



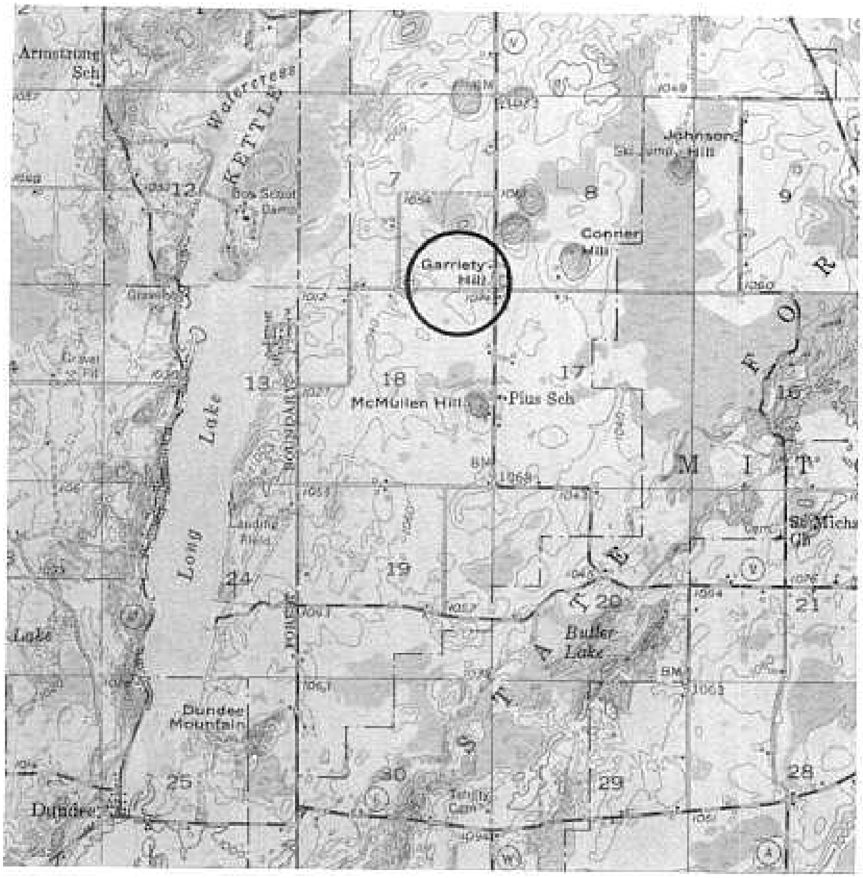
References:

LaBerge, G. L. and Myers, P. E., 1976, The Central Wisconsin Batholith, 22nd Annual Institute on Lake Superior Geology, St. Paul, Minn.

Myers, P. E., in LaBerge, G. L. and Myers, P. E., 1973, Progress Report on Reconnaissance Study of Precambrian Geology of Marathon Co.

Title: Garriety Hill

Location: SW 1/4, Sec. 8, T. 14 N., R. 20 E., Kewaskum 15' Quadrangle, Sheboygan County. Park along E-W. road. Best exposure on south side of kame.



Author: David M. Mickelson

Description: This is one of about a dozen excellent "moulin" kames in the central kettle moraine. Note the slope of the hill and the material in the exposure on the south side. Kames are composed of ice-contact stratified drift and this exposure is typical. The material shows some sorting (separation of different grain sizes) typical of water-laid sediment but much of the layering (bedding) is disturbed and tilted. There are also masses of poorly sorted till intermixed with the sorted debris. Most of the clasts (pebbles to boulders) are quite angular.

Significance: These materials tell us two things:

1. Because of the poor sorting and intermixed till, we know that the material was not carried by moving water very far. The angularity of the particles also suggests this.

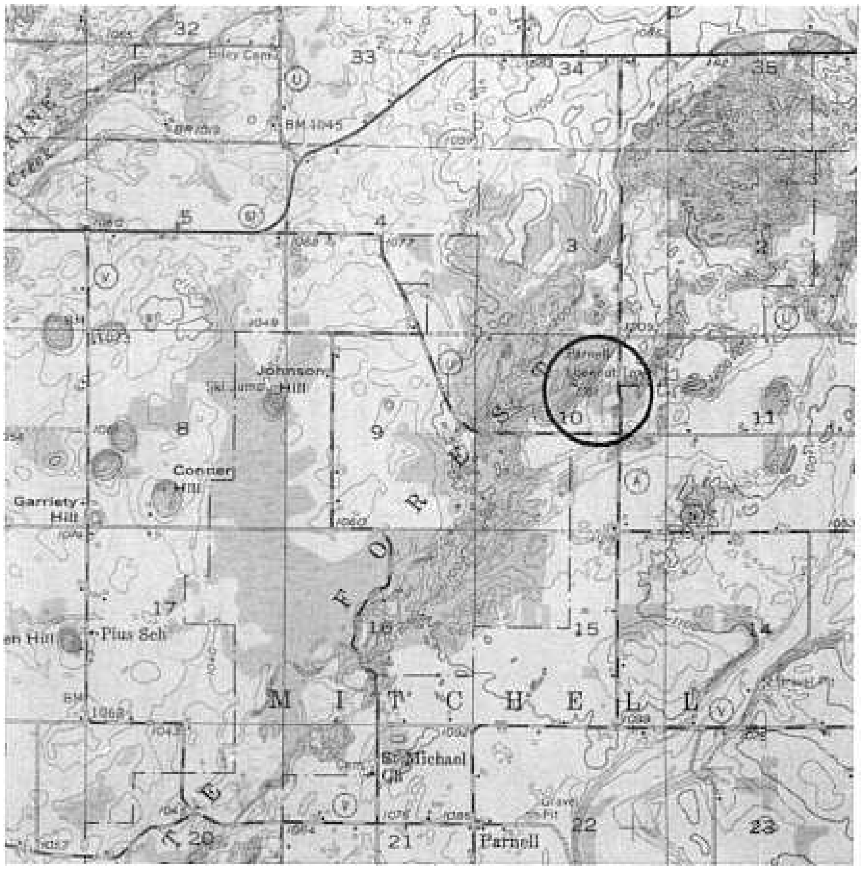
2. The collapsed bedding is indicative of collapse after the sediment was deposited. The material was, therefore, deposited on or against glacial ice which later melted.

Depressions on the ice surface often form when the ice margin begins to retreat. When this occurs at crevasse intersections they form as near vertical shafts (moulins) which extend to the base of the ice. Differential melting then enlarges the depressions and because they are low, deposition of debris melting from the ice ocurs in them. After the surrounding ice has melted, the deposits form these hills called kames.

<u>References</u>: Alden, 1918; Black 1971, 1974

Title: Parnell Lookout Tower

Location: NE 1/4, Sec. 10, T. 14 N., R. 20 E., Kewauskum 15' Quadrangle, Sheboygan County. Park in lot and walk up tower. This lookout tower is open to the public and provides an excellent view of the kettle moraine.



Author: David M. Mickelson

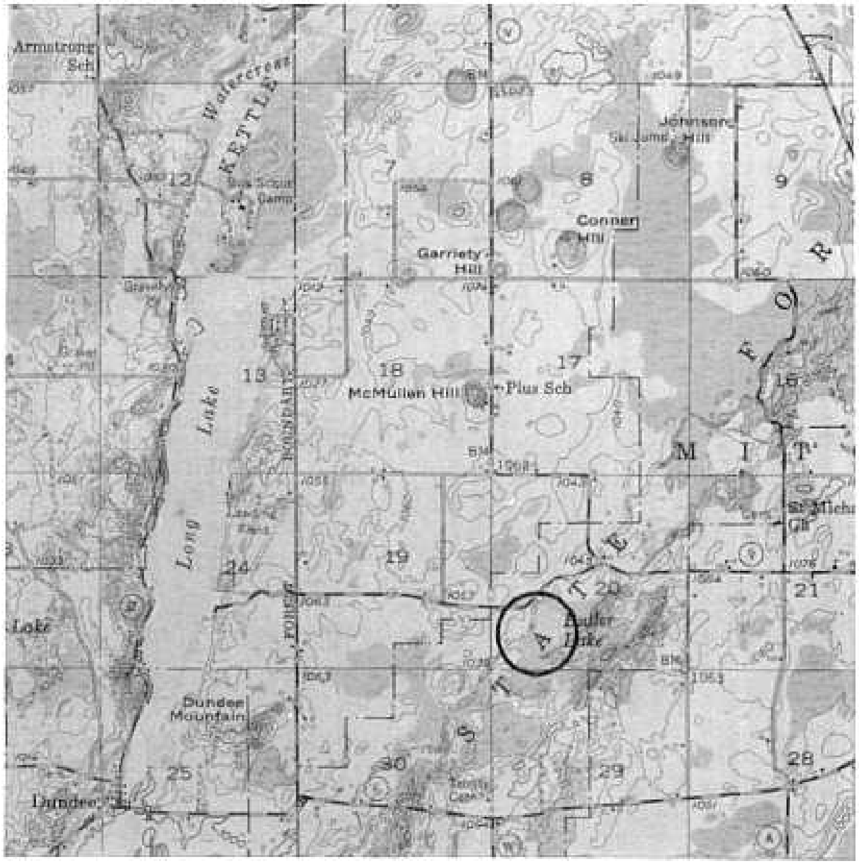
Description: The tower is situated on the rough, hummocky topography of the eastern (Lake Michigan Lobe) edge of the Kettle Moraine. To the east, a drainageway (Mink Creek) formed along the margin of the retreating Lake Michigan Lobe ice, carried meltwater toward the south. This drainageway can be crossed on C.T.H. F just north and south of the town of Parnell. The horizon on the west is the Green Bay Lobe edge of the Kettle Moraine and topography similar to that at the tower exists there. Between the two edges, conical hills (moulin kames) can be seen. These formed in rapidly melting glacier ice as debris from on top of and within the ice accumulated at the base of near vertical shafts in the glacier. The low areas between the kames were subsequently filled with lake sediment and outwash. The composition of these hills can be seen at Garriety Hill. To the southwest of the tower the Parnell esker can be seen (see Greenbush Kettle, Greenbush Ski Run, Mink Creek, Garriety Hill, Parnell Ekser).

Significance: This stop allows a view of the Kettle Moraine from edge to edge so proper perspective on the distribution of deposits and landforms can be gained. The origin of this classic area of glacial deposits has been recognized since 1878 when Chamblin discussed the area.

References: Alden, 1918; Black, 1971, 1974.

Title: Parnell Esker - Butler Lake

Location: SW 1/4, Sec. 20, T. 14 N., R. 20 E., Kewauskum 15' Quadrangle, Sheboygan County. Park in lot.



Author: David M. Mickelson

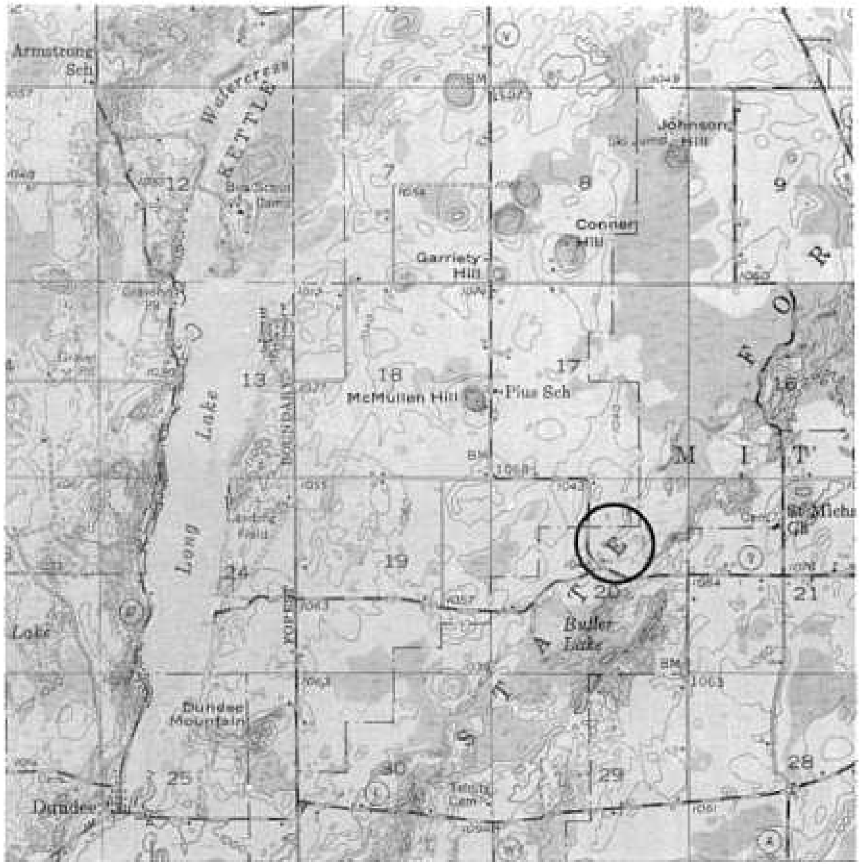
Description: Climb to the crest of the esker ridge and note the shape. As you can see in the gravel pit in the esker just north of here (Parnell Esker-gravel pit), the ridge is made up of stream deposited sand and gravel. The topographic expression also suggests a somewhat winding stream.

Significance: Streams don't deposit sands and gravels in a ridge so we must postulate that these materials were laid down when ice was on both sides of the ridge. In some places evidence indicates that many eskers are deposited in tunnels near the base of the glacier. What type of evidence could be used to document that the esker was deposited in a closed tunnel? Water flowed south through the Parnell esker tunnel. How can current direction be determined in stream deposited material? How might the formation of the esker relate to the formation of the kames to the north? To the kames and kettles in the east and west edges of the Kettle Moraine?

References: Alden 1918; Black, 1971, 1974

Title: Parnell Esker - Gravel Pit

Location: SW 1/4, NE 1/4, Sec. 20, T. 14 N., R. 20 E., Kewauskum 15' Quadrangle, Sheboygan County. Stop along the road and walk in to the old gravel pit.



Author: David M. Mickelson

Description: If you drove in from the north, you may have noticed a long, low ridge across the field to the east. You can now examine the materials in the ridge. Contrast the nature of the deposit with Garriety Hill. Since the gravel pit is no longer used, bedding due to water deposition is difficult to see but it is there. If the exposure were good, you would see that it is collapsed along the edges of the ridge. Unlike Garriety Hill, the materials are well rounded (most of the sharp edges are worn off) suggesting water transport. The deposit is also better sorted and shows less range in grain size. In addition, unlike Garriety Hill, no inclusions of till are present in the exposure. Thus we see evidence of considerable transport by running water in contact with glacier ice.

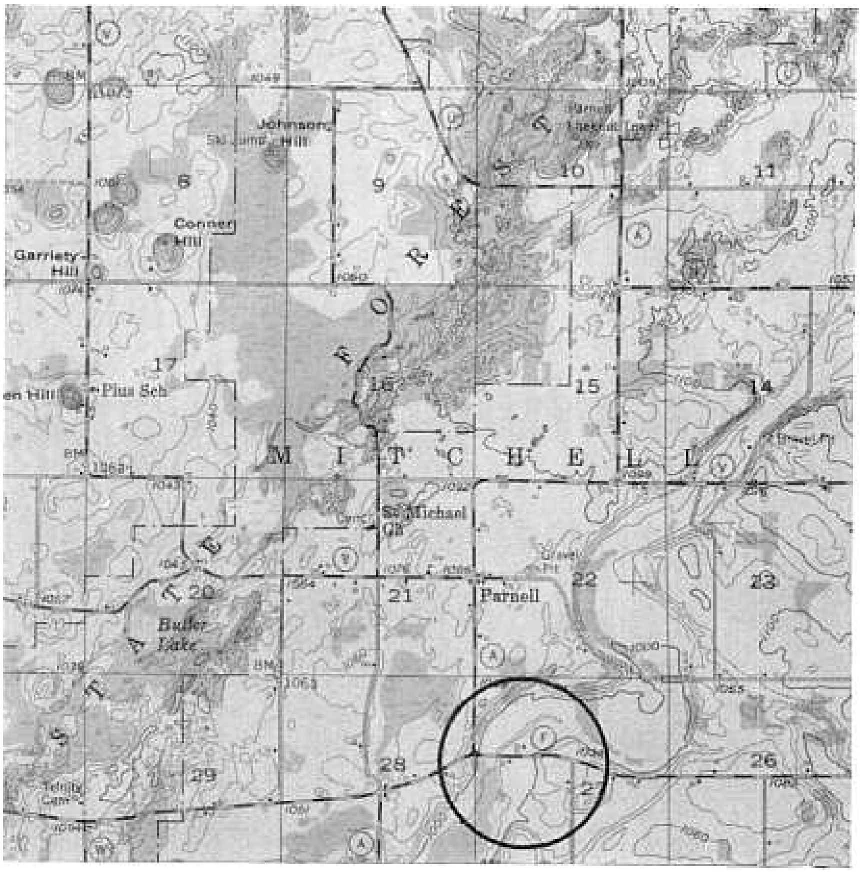
The environment of deposition that can be postulated for an esker like this is a stream flowing in a tunnel beneath or in glacial ice. The Parnell esker can be traced as a discontinuous ridge for several miles and was produced as water flowed toward the southwest through an ice tunnel. Gravels deposited by the stream filled the tunnel and, after the surrounding ice melted, produced this long sinuous ridge. Eskers and kames are considered to be ice-contact stratified drift.

Significance: This and Garriety Hill show a number of clear contrasts even though the deposits are both considred ice-contact stratified drift. Try to list these differences.

References: Alden 1918, Black 1971, 1974

Title: Mink Creek

Location: NW 1/4, Sec. 27, T. 14 N., R. 20 E., Kewauskum 15' Quadrangle, Sheboygan County. Park and view from road.



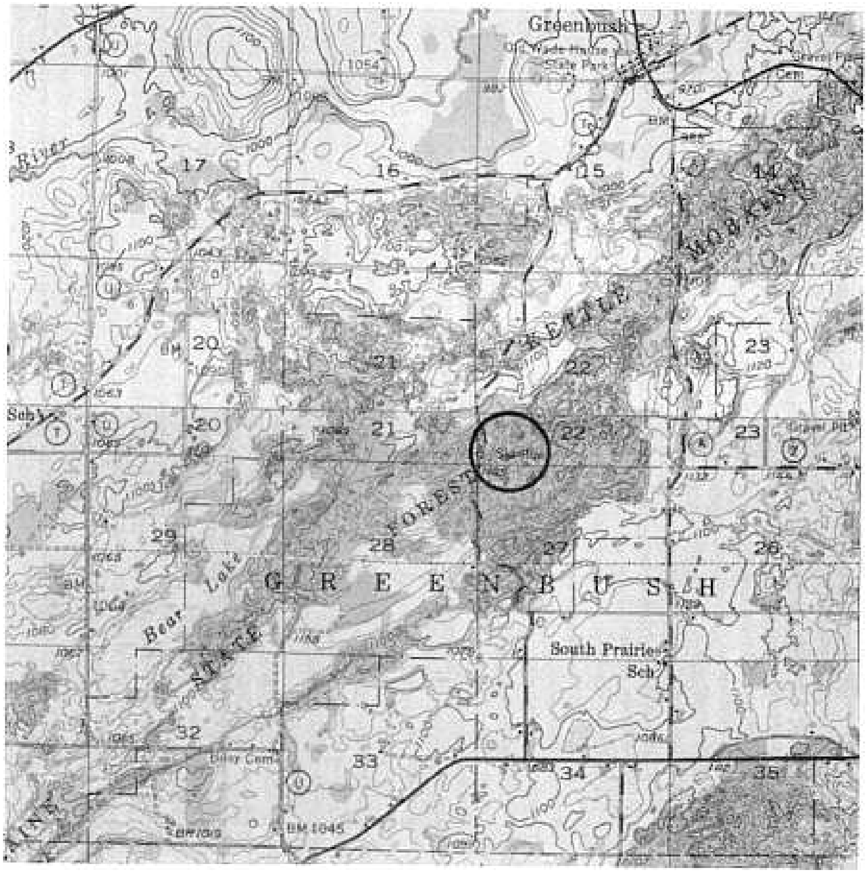
Author: David M. Mickelson

Description and Significance: Stop in the stream valley and note the size of the present-day stream. Could a stream of this size cut a valley this large? This wide valley can be traced northward about 4 miles before it disappears among morainal deposits of the Lake Michigan Lobe. To the south, it flows into the North Branch of the Milwaukee River. Since the wide valley is too large to have been cut by the present stream and since it has no source other than the moraine a short distance to the north, we conclude that it once carried large volumes of meltwater away from the melting ice margin to the northeast. If a pit were dug in the valley floor, sand and gravel would also provide evidence of stream deposition. What kind of stream would have been flowing here at that time?

References: Alden, 1918; Black, 1971, 1974.

Title: Greenbush Ski Run

Location: SW 1/4, Sec. 22, T. 15 N., R. 20 E., Kewaskum 15' Quadrangle, Sheboygan Co. Park in lot at ski area.



Author: David M. Mickelson

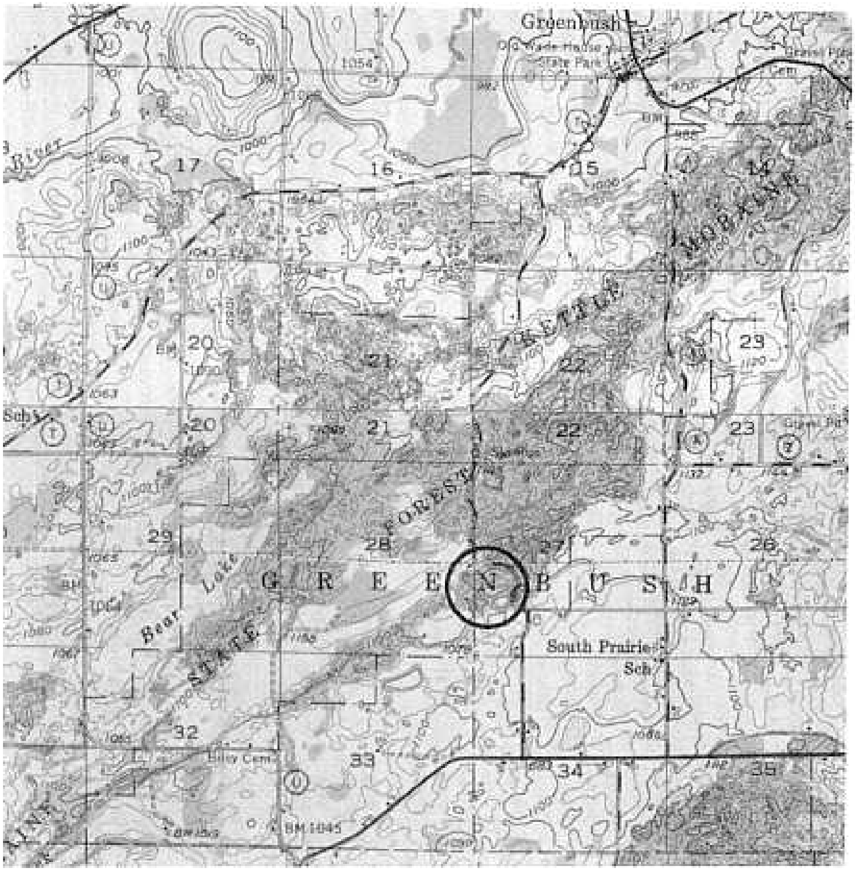
Description: You are now in the western or Green Bay Lobe edge of the kettle moraine. The view to the east exhibits topography typical of both edges of the kettle moraine and it is called "kame and kettle" topography. A mixture of sand and gravel, till, and some lake sediments underlie the surface. This material was deposited as a thick blanket on the ice by streams and melting of dirty ice. As the ice continued to melt, the material slid and flowed into depressions in the ice surface and was subsequently deposited in the irregular set of hills and depressions that you see (see Greenbush Kettle and Parnell Tower).

Significance: Contrast this area with the central Kettle Moraine. Why was so much debris present in the ice here? Why are the landforms so different here than in the central Kettle Moraine?

References: Alden, 1918; Black, 1971, 1974

Title: Greenbush Kettle

Location: SW 1/4, Sec. 27, T. 15 N., R. 20 E., Kewauskum 15' Quadrangle, Sheboygan County. Park near geologic marker.



Author: David M. Mickelson

Description and Significance: Kettle holes are common features in end moraines (glacial debris usually deposited as a hummocky ridge along the ice margin) in Wisconsin. The ice near the base of glaciers is usually laden with debris scraped from the land surface. As the ice thins because of melting debris accumulates on the irregular ice surface. Eventually, only isolated blocks of ice remain and if they are covered with debris, a depression in the land surface is formed after the ice block has melted. The huge number of kettles on both edges of the Kettle Moraine have given the feature its name (see Greenbush Ski Run and Parnell tower).

References: Alden, 1918; Black, 1971, 1974; Thwaites, 1926.

Outcrop 8

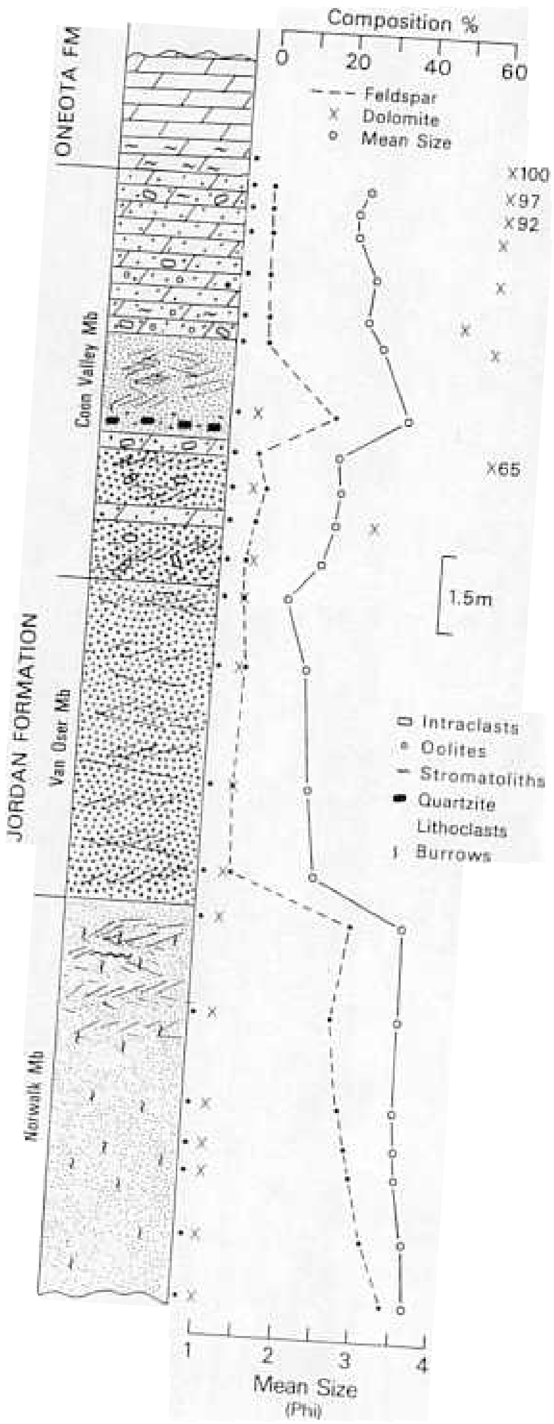
Title: Spring Green

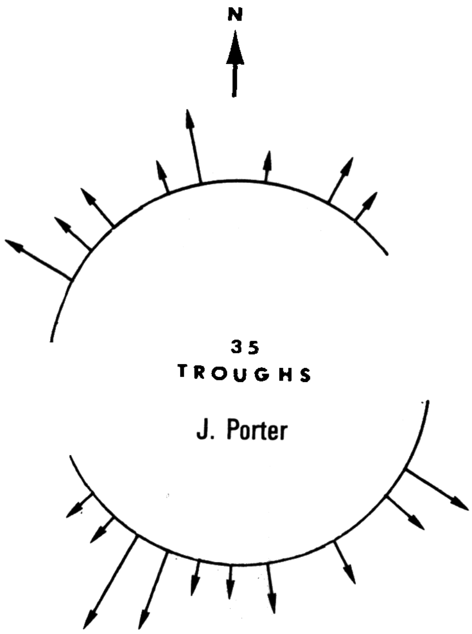
Location: East Side of Wisconsin Highway 23, 4 miles north of Spring Green, Wisconsin in the NW$\frac{1}{4}$, SW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 30, T. 9N., R. 4E., Sauk County. (Spring Green 15-minute topographic quadrangle, 1960).

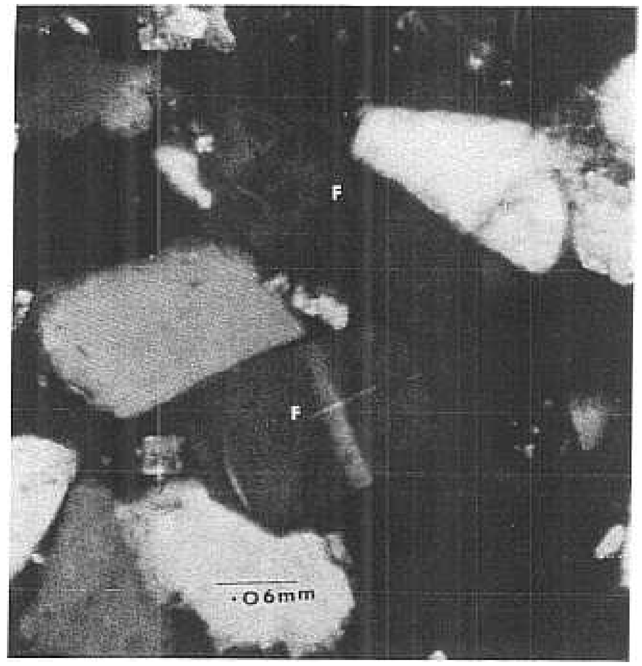
Author: I. E. Odom

Description: This exposure is significant because it illustrates the approximate lithic nature of the Jordan Formation in western Wisconsin, eastern Minnesota, and northeastern Iowa. It also shows the frequent transitional nature of the Jordan and St. LawrenceFormations. Typical of its character elsewhere, here the Norwalk Member is a very feldspathic, very fine-grained sandstone. At this location the Norwalk Member ranges from massive to thinly bedded, and cross stratification is present in the upper 3 to 4 meters, although in other areas it is often entirely massive. Some beds are highly burrowed, which also is a typical characteristic. The plunge of trough axes in the top of the Norwalk Member, determined by Jane Porter (1978) shows two modes approximately 180^{o} apart. No distinct contact between the Norwalk Member and the St. Lawrence Formation is identifiable in the exposure.

SPRING GREEN, WIS.







(Left) Plunge directions of trough axes in the upper portion of the Norwalk Member.

(Right) Detrital feldspar (F) with authigenic overgrowths in the Norwalk Member.

The feldspathic Norwalk Member is in sharp contact with the overlying fine-grained quartzose Van Oser Sandstone, and the Van Oser Sandstone coarsens upward. In many areas a coarsening-upward texture is characteristic of both the Norwalk and Van Oser Members, and the two members are often transitional through an interval of approximately one meter.

The Coon Valley Member,which is 9 meters in thickness, contains approximately 2/3 dolomitic sandstones and 1/3 sandy dolostones, and the upper sandy dolostones are in sharp contact with the overlying nonsandy Oneota Dolostone containing stromatoliths. Note that a thin, sandy dolostone bed containing stromatoliths also occurs near the top of the Coon Valley Member. Stromatoliths are almost always present in the basal beds of the Oneota Dolostone, and it has previously been suggested that stromatoliths might be used to mark the base of the Oneota. Thin, sandy beds containing algal structures are very common in the Coon Valley Member elsewhere in western Wisconsin, thus it would be tenuous to use algal beds for marking the contact between the Jordan and Oneota Formations. On the contrary, if sandy content is used the contact can be easily picked with the aid of a hammer and hand lens.

Note that a prominent zone of Baraboo Quartzite lithoclasts (granules and pebbles) occurs about 3.5 meter above the base of the Coon Valley Member. These attest to the fact that some part of the Baraboo Islands or associated conglomerates were still being eroded during the deposition of this member.

The lower 4.5 meters of dolomitic sandstones in the Coon Valley Member were previously called the Sunset Point Formation or Member. Based on your evaluation of the texture, mineralogy and sedimentary structures, would you consider these dolomitic sandstones to be the lithic equivalent of the type Sunset Point Sandstone at Madison? Although the Coon Valley Member is divisible into two fairly distinct lithic types at this outcrop, this differentiation is quite often not this straight foward, and it is for this reason that the dolomitic sandstones and sandy dolostones which intervene between the Van Oser Sandstone and the non-sandy Oneota Dolomite are combined into a single lithostratigraphic unit. In this context, the Coon Valley Member averages 10.5 meters in thickness and is traceable in outcrop throughout western Wisconsin, eastern Minnesota and northeastern Iowa and also into the subsurface to the south. Note that it is primarily the interval of dolomitic sandstones composing the lower 2/3 of the Coon Valley Member at this outcrop which are not well represented over the Wisconsin Arch.

Interpretations - Odom and Ostrom (this guidebook) and Odom,Wegrzyn and Ostrom (in press) interpret the very fine-grained, feldspathic Norwalk Member to have been deposited in the broad lagoon situated between an off-shore shoal and bar complex to the southwest (Iowa) and a near shore littoral zone to the north (Fig. 21). The current directional data for the Norwalk at this outcrop suggest that tidal processes possibly produced the cross stratification in the upper part. If the bimodal plunge of trough axes is related to the ebb and flood of tides, it would support the model suggested by Odom and Ostrom (this guidebook), which supposes that a significant tidal range was involved in the deposition of the overlying Van Oser Member. The variation of sea level caused by a significant tidal range is also believed to in part account for the widespread distribution of the Van Oser Sandstone.

A sedimentological mechanism is also necessary to explain the distinct stratigraphic differentiation of feldspar in very fine Cambrian sandstones such as the Norwalk. A tenable mechanism for the enrichment of feldspar in very fine sands and its removal from fine and medium sands is that feldspar was selectively reduced in grain size by abrasion in extensive high energy littoral environments, such as the Van Oser Sandstone, then sorted and transported to off-shore and lagoon (Norwalk) environments by currents that were at least partly related to the ebb and flood of tides over the littoral environments.

The sharp contact between the Norwalk and Van Oser Members suggests that they may be disconformable, since these members often are transitional. A minor unconformity is recognizable at this stratigraphic position farther west

The Coon Valley Member appears to represent several types of comparatively high energy environments ranging from littoral to carbonate shelf. Tidal currents may also have been operative during deposition of some lithic types. Mud cracks are sometimes found which strongly suggest local subaerial exposure, thus local intertidal conditions.

Melby (1967) reported Ordovician age conodonts from shaly beds now considered part of the Coon Valley Member. Where then is the Cambro-Ordovician systemic boundary? The best position if based on physical criteria would be at the base of the Van Oser Member.

Geologic features of the Sauk Prairie area

Location. This site is along the east side of Highway 12, about 1.9 km north of the intersection of Highway Z, about 11.6 km north of Sauk City, sec. 23, T10N, R6E (Sauk Prairie, Wisconsin, Quadrangle, 7.5-minute series, topographic, U.S. Geological Survey, 1975) (fig. 1). This site is easily reached from the northbound lane of Highway 12. There is room to park several vehicles in the pullout for the Baraboo Range historical marker. Highway 12 is a divided highway in this area; southbound travelers will need to travel beyond the site to find an appropriate place to enter the northbound lanes.

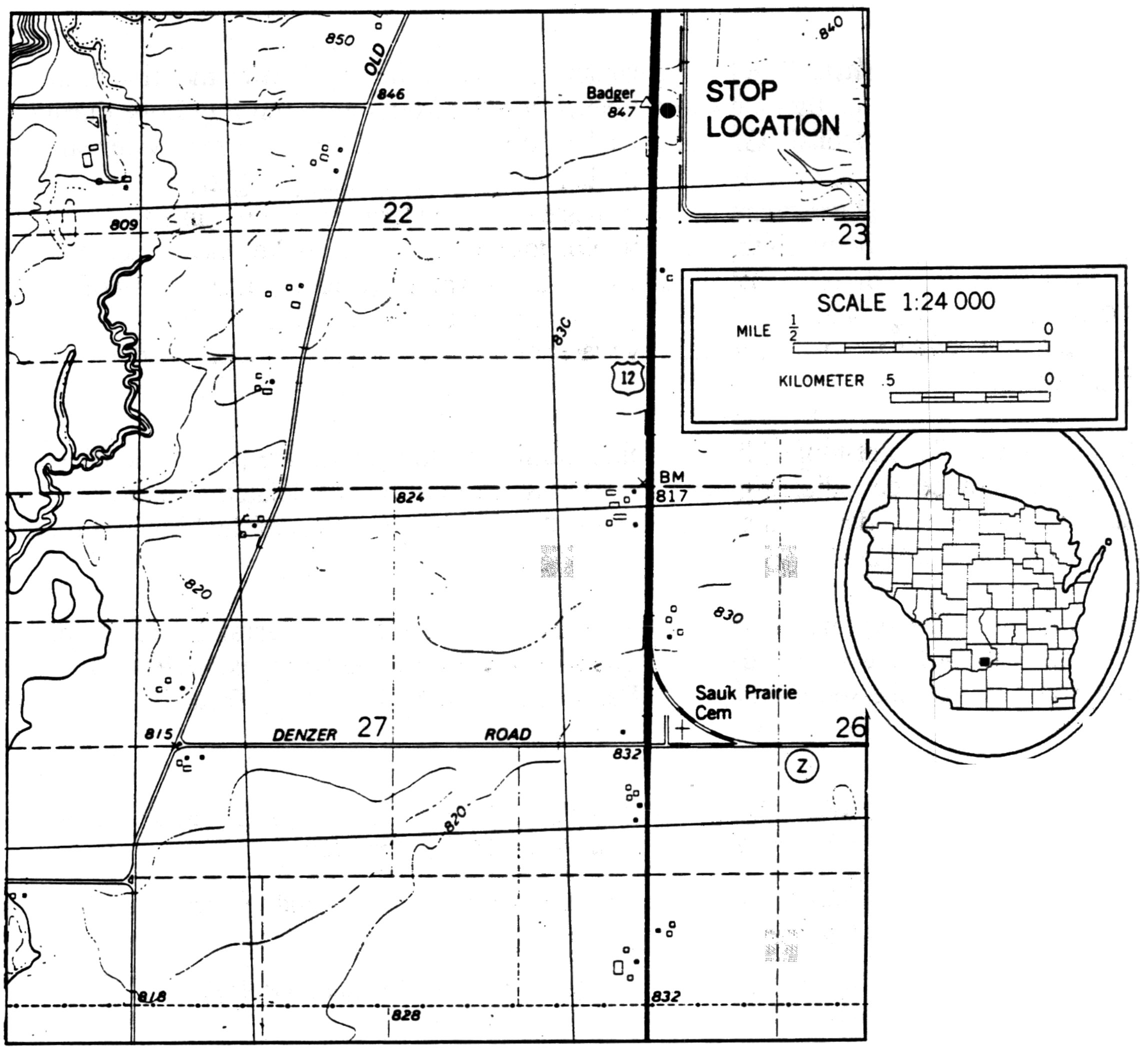


Figure 1. Location of Sauk Prairie area; map shows the flat character of the broad outwash plain on which the stop is located.

Authors. John W. Attig and Lee Clayton, 1990.

Significance. This site provides the opportunity to view the Johnstown moraine, the Johnstown outwash plain and related features, the hills of the Driftless Area (to the west), and the Baraboo Hills (to the north).

The Johnstown moraine. The low ridge about 500 m east of the stop is the Johnstown moraine, named for Johnstown, Wisconsin, east of Janesville. Deposited between about 18,000 and 15,000 years ago, the Johnstown moraine marks the outermost extent of the Green Bay Lobe of the Laurentide Ice Sheet (Attig and others, 1985, Clayton and Moran, 1982). In this area the Johnstown moraine is a hummocky ridge, typically about 300 m wide. To the north-northeast the moraine crosses the crest of the Baraboo Hills. The moraine shows up as a small bump on the skyline. Where the Johnstown moraine crosses the Baraboo Hills it is a narrow ridge, typically no more than 50 m wide. The Johnstown moraine is much broader and has much more relief where it crosses the north and south ends of Devils Lake gorge. The surface of the moraine is typically hummocky and is littered with a variety of rock types, some of which indicate long-distance glacial transport. As you travel north on Highway 12 from this site, you can see the Johnstown moraine behind the U.S. Army Badger Ammunition Plant.

The Johnstown outwash plain. The broad, flat surface west of the Johnstown moraine in this area is the outwash plain deposited by meltwater streams flowing from the Green Bay Lobe during the Johnstown Phase of the Wisconsin Glaciation (Clayton and Attig, 1990). The meltwater-stream sediment in this area is typically 30 m or more thick and is predominantly slightly gravelly sand. As this outwash plain expanded westward and its surface elevation increased, it dammed lakes in the eastward-draining streams between the bedrock hills to the west. These lakes have since drained, but thick lake sediment in these tributaries attests to their former existence. The history of these lakes is discussed by Clayton and Attig (1990). This site is located at the edge of a meltwater-stream channel cut across the outwash plain by water draining from glacial Lake Wisconsin during Elderon time (fig. 1).

The Driftless Area. The flat-topped hills forming the skyline to the west are part of the Driftless Area. There is no evidence indicating that the Driftless Area has been glaciated. The hills are composed of Cambrian sandstone and Ordovician dolomite. The flat tops of the hills in this area are underlain by Oneota dolomite.

The Baraboo Hills. The skyline to the north of the stop is the crest of the Baraboo Hills, which are composed primarily of Proterozoic quartzite. The part of the Baraboo Hills visible from this stop is part of the South Range, the south limb of the Baraboo Syncline (Dalziel and Dott, 1970).

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3817 Mineral Point Road, Madison, Wisconsin 53705

La Rue Quarry

Location. Quarry in quartzite of the Precambrian Baraboo Formation is located southwest of North Freedom in the NW1/4, sec. 22, T11N, R5E, Sauk County (Rock Springs, Wisconsin, Quadrangle, 7.5-minute series, topographic, U.S. Geological Survey, 1975) (fig. 1). This is private property; you *must* gain permission to enter the quarry from Edward Kraemer & Sons, Inc., Plain, Wisconsin.

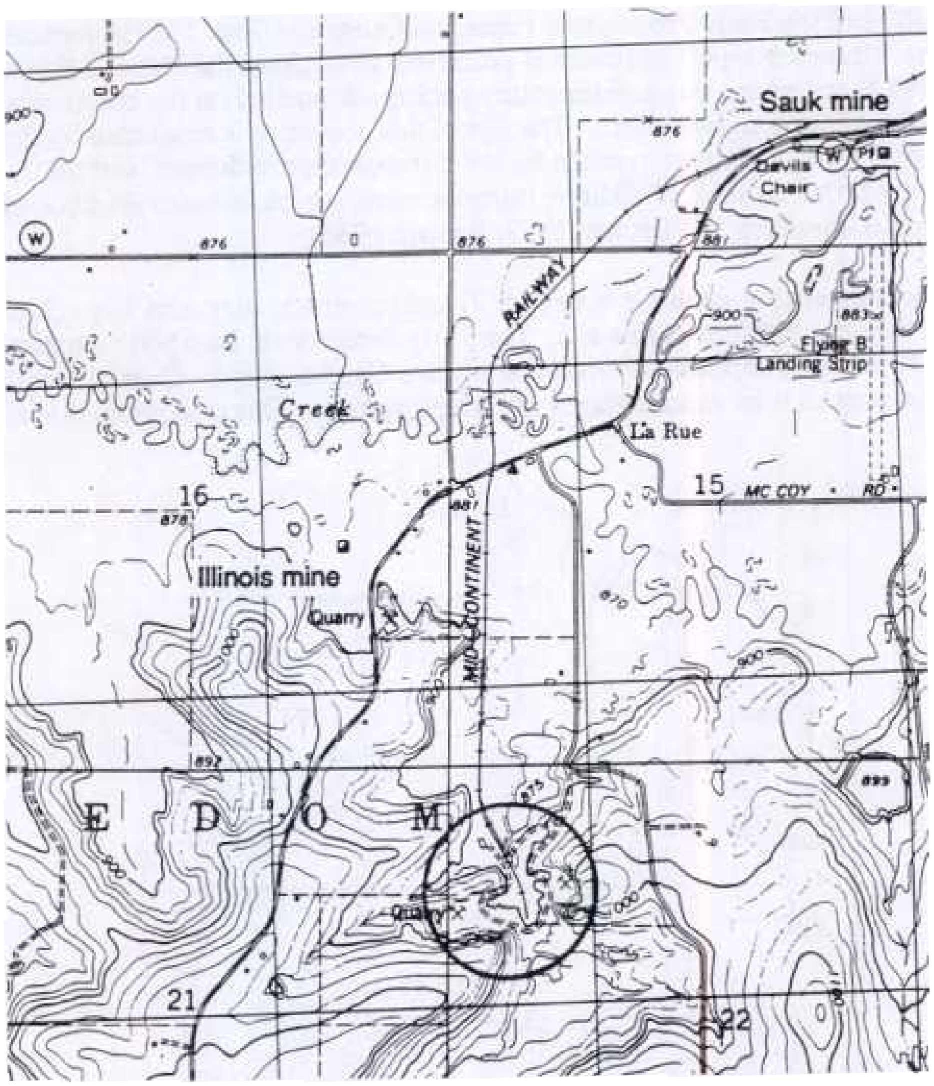

Figure 1. *Location of La Rue Quarry*

Authors B.A. Brown and M.E. Ostrom, 1989 (modified from Ostrom, 1966)

Introduction. The La Rue Quarry is located in the south limb of the Baraboo Syncline and provides an excellent exposure of the upper part of the Baraboo Formation. The Baraboo Formation consists of several hundred metres of metamorphosed quartz sandstone, pebble conglomerate, and minor argillite, interpreted by Dott (1983) to be of predominantly fluvial origin. The quartzite is generally a fining upward sequence, which grades upward from pebbly sandstone into a marine argillite, the Seeley Formation. The upper part of the Baraboo Formation, exposed in this quarry and to the east along Highway 12, contains phyllite beds and marine sedimentary structures such as oscillation ripples. The increasing abundance of phyllitic beds and the appearance of marine sedimentary structures mark the transition from the fluvial environment of the Baraboo Formation into the overlying marine units. North of the quarry, the quartzite is overlain by slate of the Seeley Formation, which is in turn overlain by ferruginous slate and carbonate of the Freedom Formation. The Seeley and Freedom Formations are not exposed, but have been sampled by iron exploration drilling in the area of La Rue and North Freedom and by early mining operations at the Illinois and Sauk Mines (Weidman, 1904).

The Baraboo range is the best exposure in southern Wisconsin of a once-extensive sedimentary sequence representing the "Baraboo interval," a period of anorogenic sedimentary and igneous activity that followed the Early Proterozoic Penokean Orogeny (Dott, 1983; Greenberg and Brown, 1984). The "Baraboo-type" sediment is preserved throughout the Upper Midwest (Greenberg and Brown, 1984) and represents a sedimentary package deposited on the continental crust formed during the Penokean orogenic event. The age of this sequence is bracketed by the age of the 1,760 Ma rhyolite, which is in part overlain by the Baraboo-type sediment, and the 1,500 Ma age of the Wolf River batholith suite of alkaline intrusive rock, which intrudes Baraboo-equivalent quartzite at Waterloo (Greenberg and Brown, 1983; Brown, 1986).

Description. The accompanying geologic map (fig. 2) and schematic diagrams (figs. 3 and 4) clearly illustrate geologic conditions at this site. The Early Proterozoic Baraboo quartzite is unconformably overlain by younger deposits of sandstone of Late Cambrian age. Quartzite within several metres of the contact is in various stages of disaggregation. This disaggregation is caused

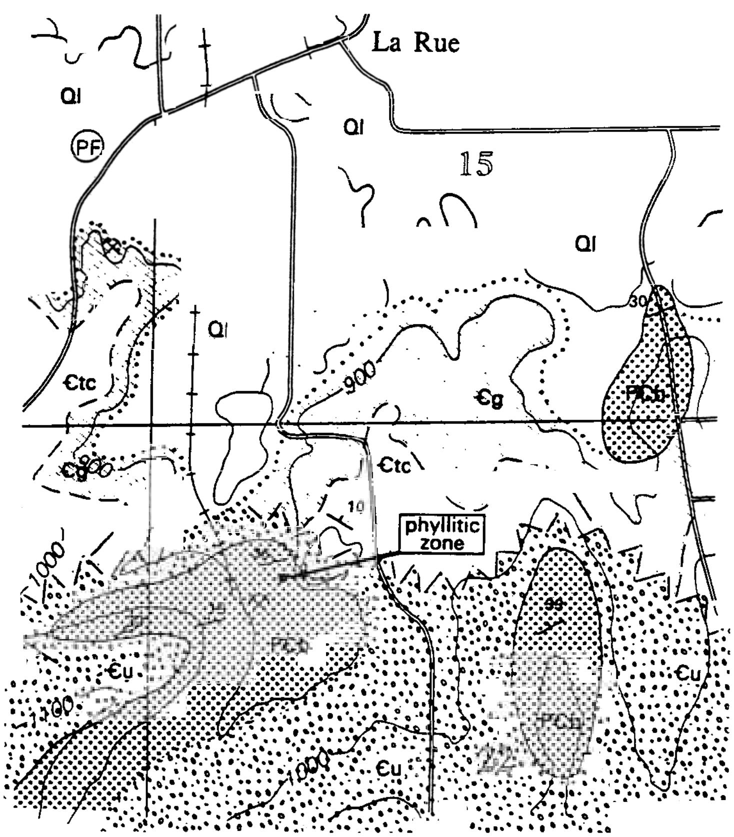

Figure 2. Geologic map of the La Rue Quarry area showing three quartzite hills surrounded by Cambrian strata. Ql = Quaternary sediment; Ctc = Tunnel City Formation; Cg = Galesville Member; Cp = Parfreys Glen Formation; PCb = Baraboo Formation (modified from Usbug, 1968; Dalziel and Dott, fig. 31, 1970).

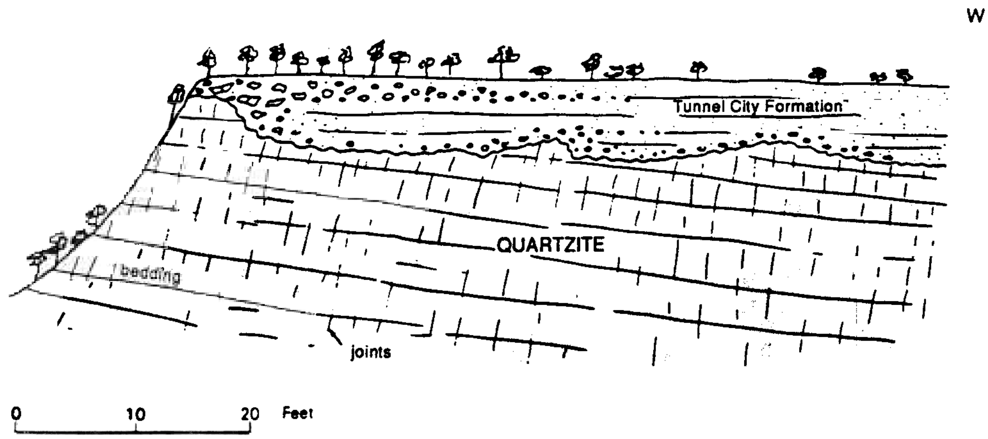

Figure 3. High southwest face of old La Rue Quarry showing conglomerate and sandstone of the Parfreys Glen Formation resting upon quartzite of the Baraboo Formation. Note large, angular quartzite clasts near buried knob at left and conglomerate tongue extending to west (right). Smaller quartzite clasts are all well rounded and clearly were transported (Dalziel and Dott, 1970, fig. 32).

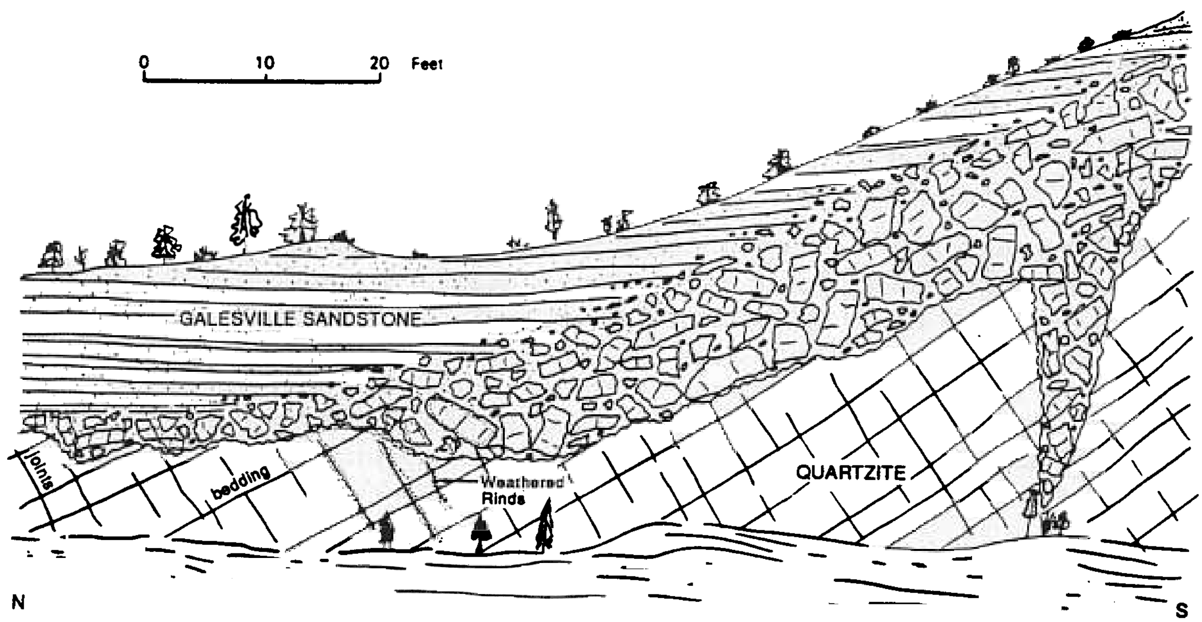

Figure 4. East face of La Rue Quarry showing nonconglomeratic Cambrian sandstone onlapped over angular quartzite blocks that rest upon the unconformity (note deep fissure filled with quartzite blocks at right). Note bleached, weathered rinds on quartzite bedrock and blocks (Dalziel and Dott, 1970, fig. 32).

by a breakdown of the silica cement, which releases rounded to subrounded quartz sand grains. At this location, these sand grains are an important constituent of the overlying Cambrian and Ordovician sandstone. Could disaggregation produce the amount of sand contained in the Cambrian and Ordovician sandstone?

We do not at this time understand how disaggregation occurs; for instance, we do not know why the thoroughly recrystallized quartz cement weathers preferentially, but it is obvious from this exposure that this does occur. A detailed investigation of the quartzite weathering will be necessary before we have a satisfactory answer.

Whether disaggregation of the Baraboo-type sediment could have provided a sufficient volume of sand to form a major part of the Cambrian and Ordovician sandstone will probably never be determined conclusively. Rock of the Baraboo interval, including quartzite or its unmetamorphosed equivalent, formerly extended over much of the Upper Mississippi Valley and western Great Lakes area (Greenberg and Brown, 1984; Dott, 1983; Andersen and Ludvigsen, 1986; Morey, 1984; Southwick and Mossler, 1984). If, on a regional scale, this rock was originally as thick as the preserved Baraboo quartzite (1,200 m or more), it represents a large volume of potential sediment.

It is important to consider how much of the Baraboo interval sedimentary sequence was actually quartzite as seen in the Baraboo area and other preserved remnants. Greenberg (1986) observed that all the Baraboo interval quartzite exposed in Wisconsin, with the exception of the Barron and Flambeau in northwestern Wisconsin, is associated with 1,760 Ma or 1,500 Ma igneous intrusions. It is possible that the quartzite represents sandstone silicified by hydrothermal metamorphic processes. On the other hand, the Barron and the Sioux quartzite of Minnesota and South Dakota show little evidence of deformation and they are not associated with granitic intrusions. Field relationships suggest that they are part of the Baraboo interval sedimentary package. The Baraboo interval lasted nearly 260 million years. A period of nearly 1 billion years passed until deposition of the Cambrian sandstone. This represents an adequate time to deposit and erode several sedimentary sequences.

At La Rue Quarry, pebbles, cobbles, and boulders of quartzite occur with rounded sand grains in a Cambrian basal sandstone, which rests on the quartzite. Quartzite pebbles occur in sandstone at least 12 km east of outcropping quartzite and can be found in the upper part of the Jordan sandstone just north of Spring Green. There seems little reason to doubt that the source of the pebbles and some of the sand was the quartzite. Other evidence, such as heavy mineral suites, suggests that erosion of Baraboo-type quartzite was certainly not the only source of sediment for the Cambrian-Ordovician sandstone of the Upper Mississippi Valley, but it may locally have been an important source of sand grains.

Significance. Quarrying at La Rue has exposed an excellent example of the Precambrian-Paleozoic angular unconformity. The northward dipping Baraboo quartzite is significantly altered in its upper part and is overlain by flat-lying Cambrian sandstone containing altered quartzite boulders and quartz grains derived from the breakdown of the quartzite. This suggests that weathering and disaggregation of the Proterozoic quartzite was a source of sand for younger clastics. The regional extent of Baraboo interval sedimentary rock suggests that quartzite and unmetamorphosed sandstone of this once-extensive sedimentary package may have been a significant source of sand grains that now reside in the Cambrian-Ordovician clastic rocks of the Upper Midwest.

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East Bluff of Devils Lake gorge

Location. Near the junction of the Potholes Trail and the Devils Doorway Trail at the top of the east-west part of East Bluff, in Devils Lake State Park, in the NE1/4 SE1/4 sec. 24, T11N, R6E, and NW1/4 SW1/4 sec. 19, T11N, R7E, Sauk County (Baraboo, Wisconsin, Quadrangle, 7.5-minute series, topographic, U.S. Geological Survey, 1975) (fig. 1). East Bluff can be reached on footpaths from the parking lot on the southeast side of Devils Lake. Follow the path from the north edge of the lot, cross the railroad track, turn left, and follow the Balanced Rock Trail up to the Devils Doorway Trail at the top of the bluff, or cross the track, and turn right and follow the Grottos Trail to the Potholes Trail or CCC Trail up to the Devils Doorway Trail.

Alternatively, park in the lot on the northeast side of Devils Lake and follow the East Bluff Trail to the top of the bluff and south to the Devils Doorway Trail.

Location maps occur at frequent intervals along the trails.

Authors. Lee Clayton and John W. Attig, 1990.

Baraboo Hills. The Baraboo Hills consist of the North Range and the South Range, which join at their ends in the form of an oval. The Baraboo Hills are the surface expression of the Baraboo Syncline. The North Range, 8 km north of here, is less conspicuous than the South Range. The more prominent South Range is 40 km long, from east to west, and is 5 km wide. Devils Lake, in Devils Lake gorge, is near the middle of the South Range (Clayton and Attig, 1990).

Baraboo Formation. The South Range is made up primarily of the Baraboo Formation, which consists of 1.5 km of Early Proterozoic quartzite that dips to the north about 15°. The quartzite consists of cross-bedded and plane-bedded, subrounded to angular, quartzose, very fine to fine sand that has undergone low-grade metamorphism. It is white to dark gray, commonly with a pink, red, or purple tinge. Beds of conglomerate and phyllite are also present in some parts of the formation. Bedding planes with wave ripple marks can be seen in several places along the trails going up the bluff face, indicating a shoreline environment.

Devils Lake gorge. The best views of Devils Lake gorge are from East Bluff and West Bluff. The gorge, which is the only one cutting across the South Range of the Baraboo Hills, is 6 km long and 1 km wide. It is now 150 m deep, but before Pleistocene sediment was deposited in the bottom of the gorge, it was at least 110 m deeper.

The gorge was originally cut through the quartzite of the South Range sometime before the Late Cambrian Epoch (Attig and others, 1990). It was then filled with sediment during the Late Cambrian and the later Paleozoic; remnants of sandstone of the Parfreys Glen Formation can be seen in several parts of the gorge, such as near the southwest shore of Devils Lake. The gorge was later exhumed, perhaps starting during the Mesozoic or Cenozoic. The last surge of erosion occurred when an early version of glacial Lake Wisconsin drained through the gorge (Clayton and Attig, 1989). (Contrary to popular opinion, the preglacial Wisconsin River never flowed this way.) During the Wisconsin Glaciation, and perhaps during earlier ones as well, the gorge was clogged with glacial, fluvial, and lacustrine sediment, which is at least 135 m thick beneath the moraine southeast of Devils Lake. This plug of sediment prevented Lake Wisconsin from again spilling this way, forcing it instead to spill to the northwest, down the Black River (northeast of La Crosse).

Johnstown moraine. Devils Lake occupies a basin created by plugs of material across the gorge north and southeast of the lake. This material is part of a moraine formed during the Johnstown

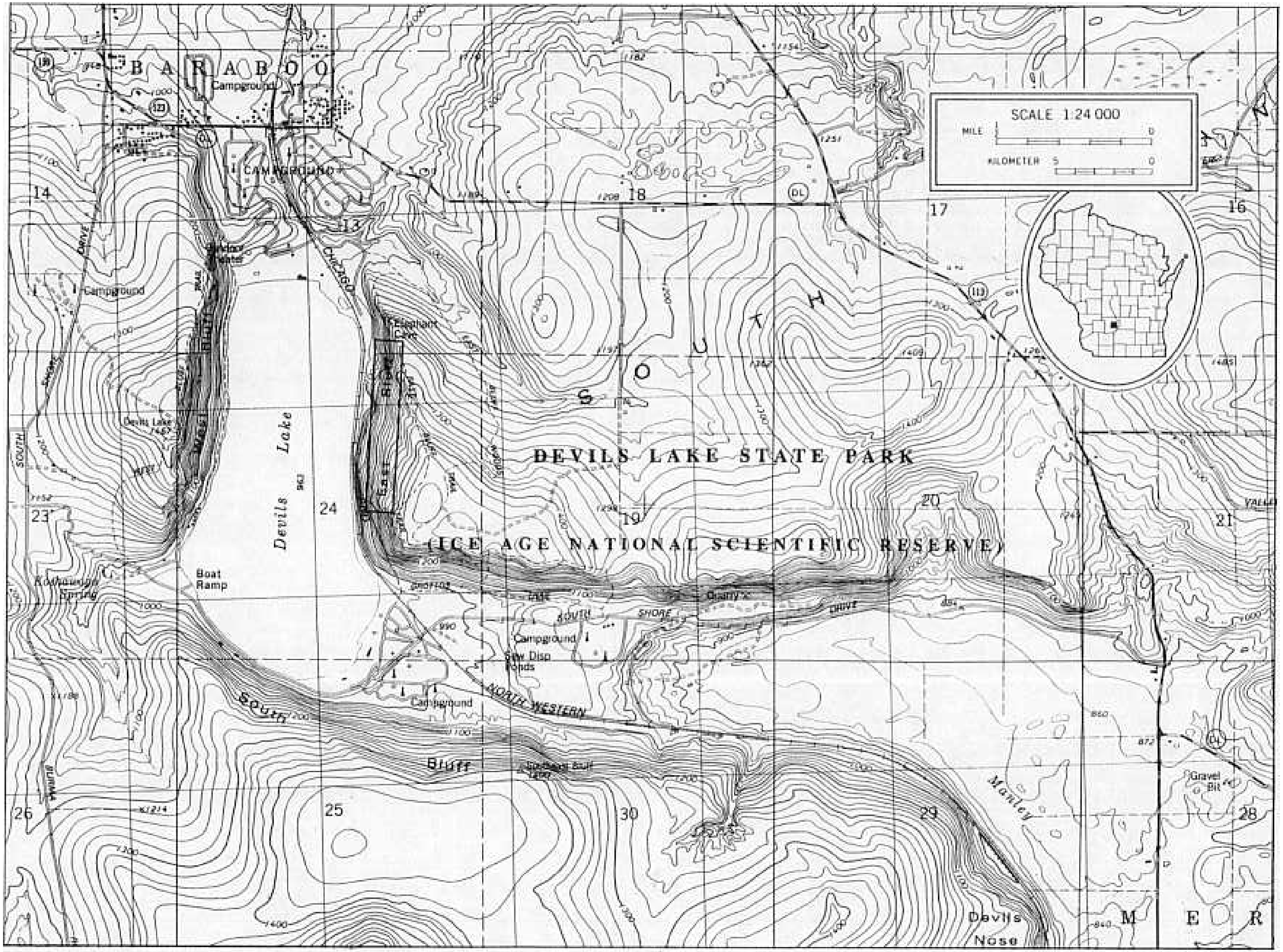

Fig Location of Eas luff of Devils Lake gor

Phase of the Wisconsin Glaciation. The Johnstown moraine can be traced from Johnstown in southeastern Wisconsin, then south and west of Madison, to the Badger Army Ammunition Plant south of the South Range. From there it can be traced up around Devils Nose, down the east end of South Bluff, across the floor of the gorge about 1 km east of the southeast shore of Devils Lake, up the east end of East Bluff to the crest of the South Range 6 km east of the lake, then back to the north end of Devils Lake and northwest to West Baraboo. As viewed from the east part of East Bluff, the moraine to the southeast of the lake is a conspicuous ridge across the gorge. Its west side is 20 m high and its east side is 50 m high. The moraine to the north of the lake is 20 m high and has been breached by a channel now occupied by the railroad. Where the moraine crosses the higher parts of the South Range, it is typically only about 15 m high.

Summit plateaus. The highest summits of the South Range are nearly flat plateaus above an elevation of 425 m (1,400 ft). Summit plateaus occur at the tops of East Bluff, West Bluff, and South Bluff. Devils Doorway Trail is at the south edge of the East Bluff summit plateau. Thwaites (1935, p. 395, 401-402; 1958, p. 140-141, 145-147; 1960, p. 36-38) suggested the plateaus were cut by wave action during the Ordovician Period.

Talus. The talus fans along the walls of Devils Lake gorge are up to 100 m high and are composed of angular boulders of Baraboo quartzite, some more than 3 m across. The boulders were eroded from the cliffs at the top of the gorge during the Wisconsin Glaciation and earlier. The abrupt termination of the talus on South Bluff at the west edge of the Johnstown moraine indicates that the talus formed before the moraine formed or as it formed, not after — probably when permafrost was present and frost action was most active in the cliffs (Smith, 1949, p. 199-203). We know of no evidence that the talus is still accumulating.

Potholes. The quartzite surface on the south side of the summit plateau above South Bluff is pitted with a few dozen potholes (Black, 1964; 1974, fig. 66). Most occur within 100 m west of the junction of Potholes and Devils Doorway Trails, but some occur along the Potholes Trail, a few tens of metres below the plateau. They range from several centimetres to about 1 m in diameter and depth. The potholes were cut by stones in eddies at the bottom of a river. In a few places the quartzite surface between the potholes is polished as a result of sandblasting on the river bed.

Black (1964; 1968; 1974) suggested that the potholes were cut by a glacial meltwater river during Pleistocene time; he also suggested that those along Potholes Trail are plunge pools of a meltwater cascade over the cliff rather than potholes, but we know of no evidence that meltwater ever flowed here. More likely, they formed in the bottom of a river flowing here when the South Range was beginning to be exhumed during the Mesozoic or early Cenozoic, as argued by Thwaites and Twenhofel (1921).

Windrow Formation. The Windrow Formation was named after Windrow Bluff, west of Tomah in west-central Wisconsin (Thwaites and Twenhofel, 1921). It occurs as small isolated bodies of stream gravel on uplands in western and southwestern Wisconsin and adjacent areas. "A pint or so" of what would later be called Windrow gravel was observed in one of the East Bluff potholes by Salisbury (1895, p. 657); K.I. Lange, Devils Lake State Park naturalist, collected a pail of Windrow gravel from one of the potholes along Potholes Trail (verbal communication, 1986), but few other observers appear to have actually seen in-place Windrow Formation here. The "Windrow gravel" commonly reported at East Bluff instead consists of scattered loose pebbles on the quartzite surface or pebbles in Pleistocene hillslope deposits that were in part originally derived from the Windrow Formation. The pebbles consist of polished chert; many are well rounded and some contain Silurian fossils.

Black (1964) suggested that the Windrow gravel at East Bluff was deposited by a Pleistocene meltwater stream, but there is no evidence that meltwater ever flowed across the area. More likely it was deposited by a river that flowed here when the South Range began to be exhumed during the Mesozoic or early Cenozoic, as suggested by Thwaites and Twenhofel (1921).

Andrews (1958) defined an "East Bluff member" of the Windrow Formation, but no type section was designated. However, it seems unlikely that he actually saw any in-place Windrow gravel at East Bluff — more likely he observed the pebbles in Pleistocene deposits that had originally been eroded from the Windrow Formation. For this reason, his "East Bluff member" is considered an invalid stratigraphic name. Andrews correlated his East Bluff member with the Ostrander Member of the Dakota Formation (Early Cretaceous) of southeastern Minnesota, but we know of no evidence that any of the Windrow Formation correlates with the Ostrander.

Quartzite blocks. In the unglaciated part of the South Range, block streams occur on the lower slopes below the summit plateaus. These lobate masses formed when permafrost was present during glaciation (Smith, 1949, p. 203-207). The block streams can be traced up slope to their source, which was commonly a low cliff of quartzite below the edge of a summit plateau. In a few places, angular blocks of quartzite can be seen next to a cliff, caught in the act of being separated from the cliff when the permafrost episode ended.

One much-illustrated quartzite block, upslope from a block field, is next to the service road from Steinke Basin, north of East Bluff. Black (1964, p. 169-171, figs. 1 and 6; 1968, p. 143, fig. 11; 1970, p. 72-73, fig. 15; 1974, p. 106, figs. 65 and 81) thought that it and others like it were glacial erratics. He argued that they are at the crest of the South Range and that no processes other than glaciation could have moved them there. However, this block is at least 10 m below the crest, and all the other large blocks here are also well below the crest, where they probably slid, rolled, or were rafted by solifluction when permafrost was present. Only small quartzite blocks occur on the crest; they lie directly on in-place quartzite or were frost-heaved onto the thin layer of wind-blown silt blanketing the plateau.

Boulders of igneous and metamorphic rock are present on the summit, but they are at the edge of service roads and were removed from the fill used to construct the roads. We have seen no evidence here for glaciation above East Bluff, although the east end of the bluff was clearly glaciated.

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Pleistocene geology of the Steinke Basin area of Devils Lake State Park

Location. Steinke Basin is located in the north-central part of Devils Lake State Park in Sauk County, about 5.6 km south-southeast of Baraboo, Wisconsin, along Highway DL. The west-central part of the Baraboo Quadrangle reproduced as figure 1 has been annotated with the recently approved geographic names Steinke Basin and Johnson Ponds. The area is located in the south half of sec. 18 and the north half of sec. 19, T11N, R7E (Baraboo, Wisconsin, Quadrangle, 7.5-minute series, topographic, U.S. Geological Survey, 1975) (fig. 1). A parking lot south of Highway DL provides access and an area to view the geologic features discussed below The parking lot is a trail head for hiking and cross-country ski trails in the area. A map of hiking trails in Devils Lake State Park is posted at the parking lot.

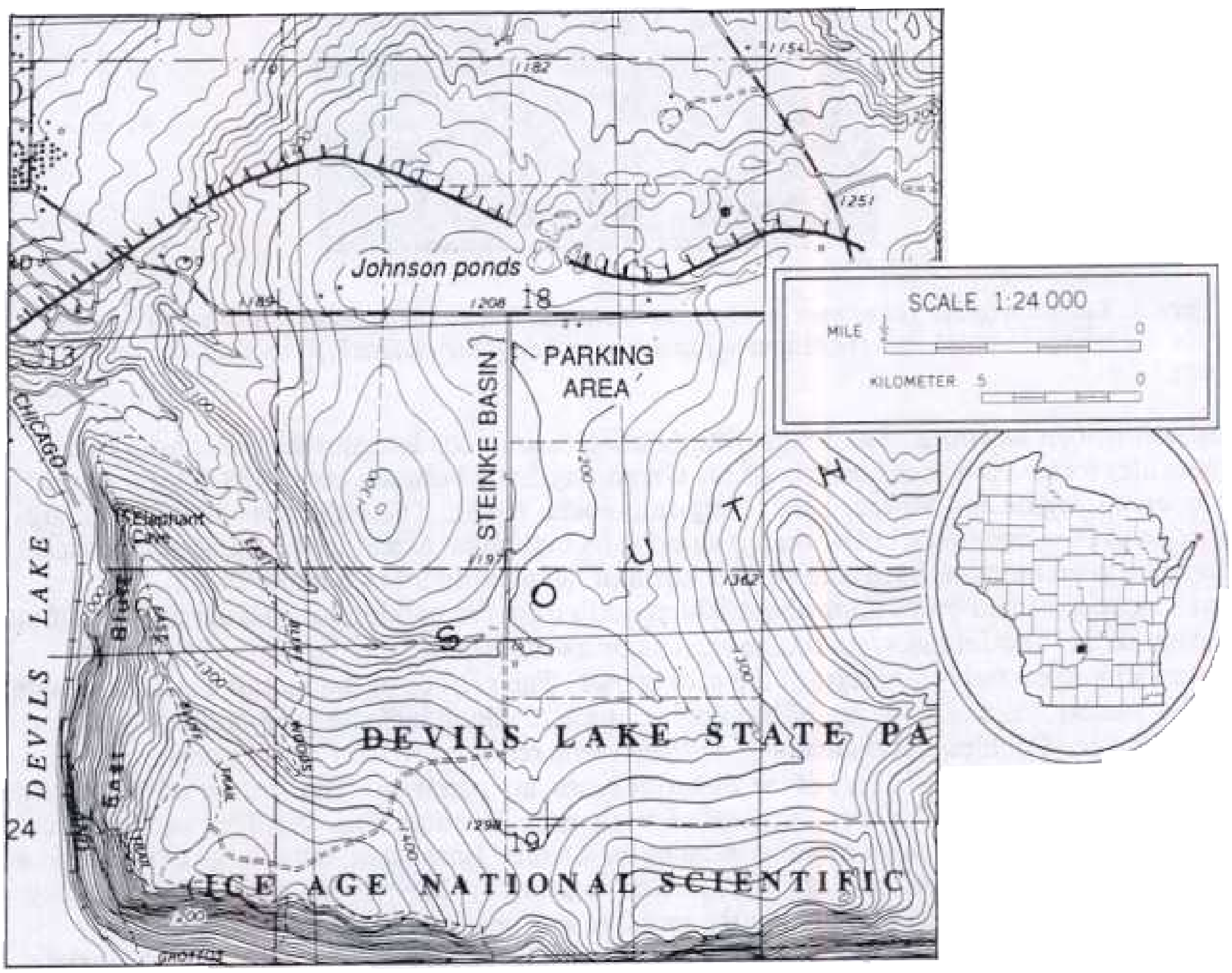

Figure 1. Location of Steinke Basin and the Johnson Ponds. The maximum position of the late Wisconsin ice margin is shown with a hachured line.

Authors. John W. Attig and Lee Clayton, 1990

Significance. The Steinke Basin area provides the opportunity to view the Johnstown moraine (the outermost moraine of the Green Bay Lobe of the Laurentide Ice Sheet), a probable tunnel channel, kettle lakes, an ice-marginal-lake basin, and a sediment fan deposited by a river flowing from beneath the glacier into the lake (Attig and others, 1990; Clayton and Attig, 1990). It is also an excellent location to discuss the interaction of the ice margin with the preglacial topography. The locations of the features discussed here are shown in figure 2.

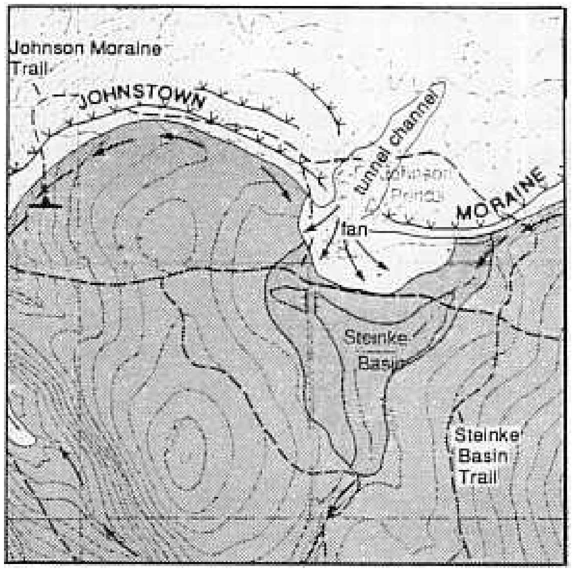

Figure 2. Location of the Johnstown moraine, the Johnson Ponds, the ice-marginal lake in Steinke Basin, the tunnel channel, and the sediment fan at the mouth of the channel (from Attig and others, 1990).

The Johnstown moraine. The Johnstown moraine (named for Johnstown, Wisconsin, east of Janesville) formed along the margin of the Green Bay Lobe between about 18,000 and 15,000 years ago (Clayton and Moran, 1982; Attig and others, 1985). This ridge was deposited along the edge of the Green Bay Lobe when it stood at its maximum extent in the Baraboo Hills area. The Johnstown moraine forms the skyline north of the parking lot in Steinke Basin. The moraine can be explored by walking about 300 m north from the parking lot past the remains of the Johnson farm. The Johnstown moraine trends northwest/southeast to the west of the access trail and has a more easterly trend east of the access trail. The surface of the moraine is littered with cobbles and boulders of a variety of lithologies, some of which indicate long-distance transport by the glacier. Cobbles and boulders of a distinct pale red porphyritic rhyolite, presumably transported from the eastern part of the Superior basin, are common. The surface of the moraine is slightly hummocky in this area; local relief rarely exceeds about 3 m. No deep exposures in the sediment of the Johnstown moraine exist in the Steinke Basin area, but a large exposure in a gravel pit about 4 km to the east has been studied in detail by Clayton and others (1985). They concluded that much of the sediment in the moraine was deposited by meltwater streams — probably streams in tunnels at the base of the glacier. The stream sediment, in turn, is overlain by stratified melt-out till and lodgement till. In addition, it is likely that some debris flowed and fell off the ice front. In the Steinke Basin area, as in other high areas in the Baraboo Hills, the Johnstown moraine is a relatively narrow feature, typically less than 100 m wide. It is typically much broader in adjacent lowland areas.

Tunnel channel and kettle lakes. North of the parking lot is a conspicuous cut through the Johnstown moraine just to the east of the remains of the Johnson farm. The low point in the moraine is a channel eroded into the bed of the glacier and through the moraine by a stream that drained meltwater from the glacier. The floor of the channel slopes upward, to the south, toward the ice margin, indicating that the stream was flowing in a tunnel under the ice. Similar channels were cut beneath the margin of the glacier across much of Wisconsin. Attig and others (1989) interpreted the channels to have formed when meltwater from the thawed bed beneath the glacier burst through a zone along the margin where the glacier was frozen to its bed. A string of small ponds, the Johnson Ponds, marks the bed of the channel. These small kettle lakes probably formed when flow through the tunnel diminished and ice in the roof of the tunnel collapsed. The remaining meltwater drainage through the tunnel filled the area around the ice blocks with sand and gravelly sand. The ice blocks eventually melted, leaving the depressions that now are ponds or small wetlands.

Glacial lake in Steinke Basin. Before the advance of the Green Bay Lobe onto the north side of the Baraboo Hills, Steinke Basin was drained by a stream that flowed to the north. The advancing ice blocked the north-facing valley and dammed a lake in Steinke Basin. The water level in the lake rose until it was high enough to spill out of the south end of the basin and flow westward to the northeast end of Devils Lake. The Johnstown moraine now forms the drainage divide at the north end of the basin. Samples from a drillhole about 300 m south-southeast of the parking lot showed about 10 m of lake sediment overlying quartzite.

Ice-marginal fan. A sediment fan was deposited where the meltwater stream flowed from beneath the glacier into the lake in Steinke Basin. The fan can best be viewed from Highway DL about 200 m west of the entrance to the parking lot in Steinke Basin. From that point the mouth of the tunnel channel can be seen to be the apex of a fan of sediment that was deposited between the margin of the ice and the lake. The surface of the fan slopes to the southwest, south, and southeast, away from the apex. Much of the surface of the fan is now cropland that, when freshly plowed, reveals the nature of the sediment in the fan. At the mouth of the tunnel channel, cobbles are present near the apex of the fan. A short distance from the mouth of the tunnel channel, cobbles are absent and the fan is composed entirely of sand. This change in grain size is the result of decreased gradient downstream from the apex of the fan.

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Parfreys Glen — Cambrian conglomerate and conglomeratic sandstone

Location. Off Highway DL (Parfreys Glen Road), 3.4 km east of Highway 113, SE 1/4 NE 1/4, sec. 22, T11N, R7E, Sauk County (Baraboo, Wisconsin, Quadrangle, 7.5-minute series, topographic, U.S. Geological Survey, 1975) (fig. 1). State Natural Area — NO COLLECTING. State Park sticker required. Contact Park Superintendent, Devils Lake State Park, 55975 Park Road, Baraboo, Wisconsin 53913.

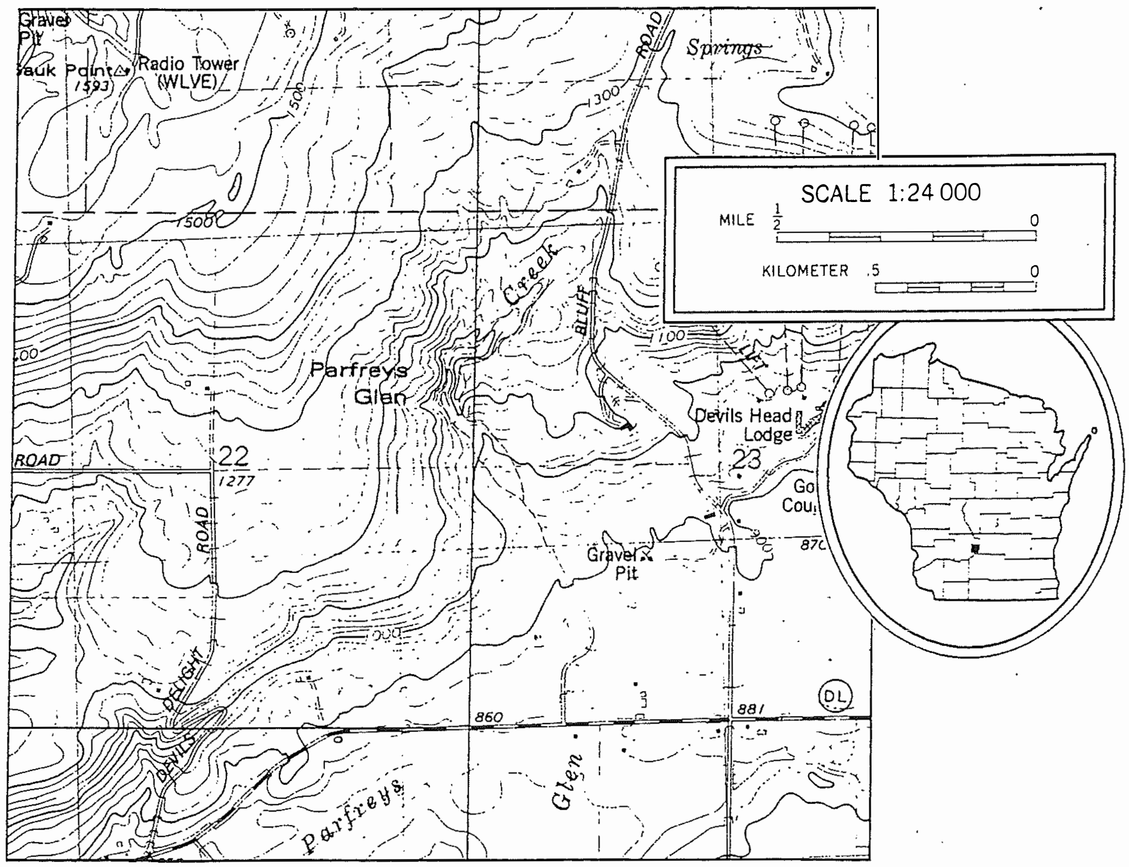

Figure 1. *Location of Parfreys Glen.*

Authors. M.G. Mudrey, Jr., and S.A. Nichols, 1989 (modified from Dott, 1970)

Description. Parfreys Glen is deeply incised into Cambrian conglomerate on the south flank of the Baraboo Hills. It is dedicated to Norman C. Fassett, a former botany professor of the University of Wisconsin-Madison. While chairman of the Scientific Areas Committee (1945-50), Fassett recommended Parfreys Glen as the first Scientific Area (now called State Natural Areas) in Wisconsin. The wall of the gorge exposes conglomerate and conglomeratic sandstone with clasts up to 1 m in diameter. The gorge is generally sheltered from the summer sun and supports a northern flora of white pine, yellow birch, mountain maple, and rare cliff plants (Zimmerman, 1970). A southern, dry-mesic forest of white and black oak, red maple, basswood, ironwood, and shag bark hickory covers the surrounding uplands.

As indicated by its designation as a State Natural Area, this is a special and fragile place. Over the years vegetation in the glen has been disturbed by human activity; as a result, some areas no longer represent an original northern flora (Wynn and Loucks, 1975). Visitors are required to stay on the trail, which follows the creek to the upper end of the gorge. From here, visitors must retrace their steps and return to the parking lot. *Do not climb the gorge walls or take any other route.*

History. "Glen" is a Scottish word for a narrow, rocky ravine. The glen is named after Robert Parfrey (1816-83), an Englishman who in 1865 inherited one of several mills in the area; the foundation of a mill can still be seen south of the first major stream crossing. The earthen and log dam for the millpond was located at the lower end of the gorge, where the trail ascends along the base of the west wall. Water was carried from impoundment to mill via a flume supported on trestles. Parfrey operated his mill until 1876 (Wynn and Loucks, 1975).

Milling in the glen was replaced by hiking and picnicking in the late 1800s. Enough people were visiting to prompt an 1882 rumor that a large hotel was to be built at the glen. Parfreys Glen thus had a long history of public use before the state began acquiring the glen in 1947. The scientific area was designated in 1952, and since then activities have been restricted to the established trail.

Geologic description. Parfreys Glen provides an excellent opportunity to examine Cambrian strata near the Cambrian-Precambrian unconformity. Extensive work in the glen has been done by R.H. Dott, Jr., whose 1970 report is paraphrased here. In this region at least three settings for conglomeratic material have been recognized. 1) At Pine Hollow, east Devils Lake, and La Rue Quarry, the Cambrian-Precambrian unconformity is exposed; Cambrian conglomerate is in direct contact with Precambrian quartzite as buried sea cliffs and stacks. 2) Parfreys Glen and other localities, which consist of conglomerate that is not in direct contact with Precambrian quartzite, represent sites of deposition slightly more seaward from the cliffs (0.25 to 0.5 km). Seismic work in Parfreys Glen suggests the presence of a quartzite knob east of the trail where Dott (written communication, 1989) recognized a knob or top of a cliff. 3) Other localities have only thin, fine-grained conglomerate, scattered pebbly gravel, or both in a quartz-rich sandstone. These were probably deposited seaward about 1 km from the shoreline.

On the basis of elevation, the strata at Parfreys Glen should be the time-equivalent of the Trempealeau Group, but the southward dip of 6° to 10° makes it probable that time-equivalents of the Tunnel City Group also are present.

Orientation of the prominent cross-bedding shows that Cambrian currents flowed toward the southeast. Movement was nearly parallel to the general shoreline, which lay about 1 km to the north. The distribution of conglomerate in discrete, relatively thin layers separated by sandstone records episodic sedimentation. If we assume that the entire sequence exposed here (a maximum of nearly 30 m) represents 10 million years, then the average apparent rate of accumulation was only about 3 m per million years; even a rate twice as fast for a total interval of 5 million years would be geologically slow. The entire sequence represents net accumulation. The clast-supported conglomerate layers suggest that erosion of Precambrian quartzite was also a major process (fig. 2), and that the depositional rate was higher. Regardless of the total time interval represented, "average" rates are clearly misleading. Parfreys Glen records chiefly the results of *episodic* conditions. Probably the average condition involved minor transport of sand, but was interrupted by violent events, such as storms. The latter produced enough wave and current energy to sweep quartzite boulders up to 1,000 kg from the foot of the nearby sea cliffs offshore for at least 0.5 km. The gravel was spread out as thin layers, winnowed to produce lag gravels, and then buried by migrating submarine sand dunes (or sand waves) now reflected by cross-bedding.

Stratigraphic and refraction seismic analysis by McMillan and others (in press) disclosed that the Cambrian sedimentary rock in Parfreys Glen was deposited in a pre-existing valley, which formed a cove in the Cambrian shoreline. The modern glen is off-center to the west in the ancient valley.

Geologic history. Stratigraphic relationships show that by Late Cambrian time the quartzite in the Baraboo Hills had been eroded to nearly its present form. Sandstone presumed to be of Late Cambrian age occurs near the southwest corner of Devils Lake; this indicates that Devils Lake gorge, which lies 4 to 6 km west of Parfreys Glen, had been cut at least to the level of the modern lake by Late Cambrian time. Geophysical investigations and stratigraphic relationships indicate that by Late Cambrian time a valley had also been cut in the Precambrian rock underlying Parfreys Glen. This valley and the remainder of the flanks of the Baraboo Hills were subsequently buried by nearshore sand, gravelly sand, and gravel during the Late Cambrian marine submergence of the area. Much of this marine sediment was lithified to form sandstone and conglomeratic sandstone. By Ordovician time marine sand and mud had buried the Baraboo Hills and filled Devils Lake gorge.

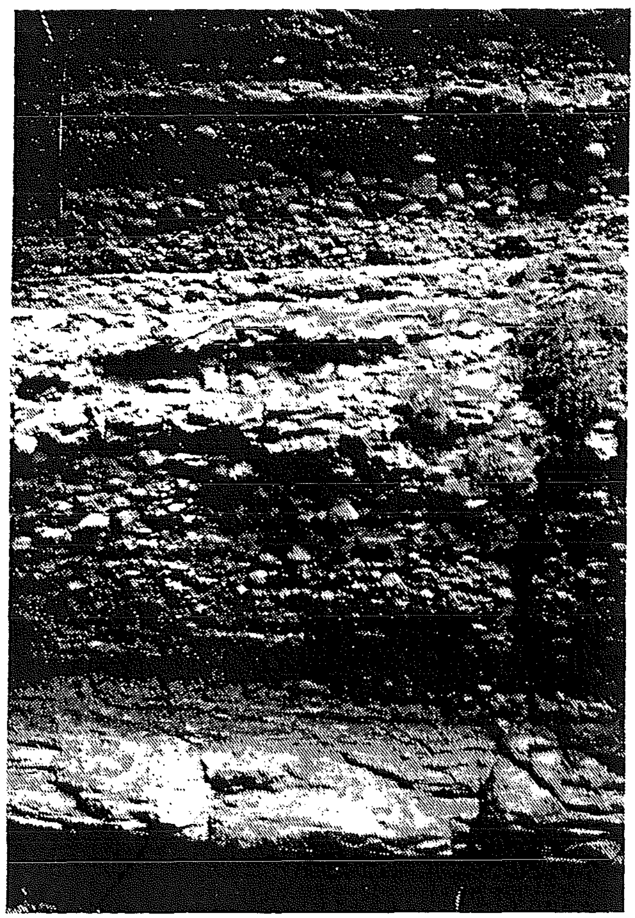

Figure 2. *Typical exposure of Parfreys Glen Formation, showing beds of sandstone interbedded with beds of matrix-supported clasts of Baraboo quartzite. Several indivual beds up to 1 m thick can be seen in this 4-m section.*

It is not known when Paleozoic and possibly younger sediment was eroded from the Baraboo Hills to again expose the Precambrian rock. Siliceous gravel occurring on the East Bluff southeast of Devils Lake has been interpreted to be Cretaceous stream gravel. If this interpretation is correct, the landscape had been lowered at least to the level of the bluff tops in Cretaceous time. The hilltops surrounding the upper part of Parfreys Glen are underlain by quartzite; as the landscape was being lowered, it would be expected that the valley bottoms would migrate away from the high points in the quartzite surface. This may explain the position of Parfreys Glen with its underlying valley in the surface of the Precambrian rock.

The Parfreys Glen area was covered by ice during the last part of the Wisconsin Glaciation. The western edge of the Green Bay Lobe of the Laurentide Ice Sheet advanced several kilometres west of the glen. On the uplands surrounding the glen several metres of till overlie the Precambrian and Cambrian rock in most places. The glen as we see it today may have at least in part been cut by meltwater flowing along the margin of the glacier as it wasted back across the area. However, similar areas, such as Pine Hollow, occur in the unglaciated area and were formed without the help of meltwater. Parfreys Glen lies within a broader valley that would have funneled meltwater from the ice margin through the glen.

Flora. Parfreys Glen contains about 45 tree and shrub species, more than 100 herbs, 14 vascular crytogams (10 ferns, 2 horsetails, and 2 clubmosses), and 34 liverworts and mosses. This biotic diversity is due to the abundance of different microhabitats on the site and to the rich floral diversity of the Baraboo Hills in general. The Baraboo Hills have a diverse flora because the topographic irregularity encompasses a wide range of habitats and because they are at a latitude in the state where the ranges of many northern and southern species overlap (Zimmerman, 1970).

Five species in Parfreys Glen are rare in the state. They exist because of the steep cliffs or because of the damp, cool, shaded glen habitat. The cliff and glen habitats also allow some typically more northerly species such as pipsisswea, wintergreen, partridge-berry, bishops-cap, mountain maple, June-berry, yellow birch, mountain ash, and white pine to exist on the site. The glen flora, including the diversity of mosses on the site, is favored by the combination of deep shade, moisture seepage, and the drainage of cool air into the valley bottoms.

Above the gorge, on the bluff tops, a oak-hickory forest more typical of the region prevails. A number of plants are weeds introduced to the site by European settlement of the area.

Significance. The exposures in Parfreys Glen help us interpret the significance of Cambrian conglomerate and conglomeratic sandstone by providing considerable insight into the Cambrian paleogeography and history of sedimentation. The local source of gravel provided by the Baraboo quartzite highlands makes it possible to see clearly the episodic nature of Paleozoic deposition here. Comparison with the modern oceans, especially in areas of violent tropical storms or of large tsunamis, leads one to wonder if most of the stratigraphic record may not record episodic violent events rather than average tranquil conditions.

Parfreys Glen Formation. The rock described has been designated the type section of the Parfreys Glen Formation (Clayton and Attig, 1990). The Parfreys Glen Formation consists of well cemented sandstone, conglomeratic sandstone, and sandy conglomerate on the flanks of the North and South Ranges of the Baraboo Hills. It is the chronologic equivalent of formations ranging from the Mount Simon through the St. Peter, and perhaps younger ones.

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The Upper Narrows and Van Hise Rock

Location. West side of the Upper Narrows of the Baraboo River, along Highway 136 between the Rock Springs and the bridge over the Baraboo River, E1/2, SE1/4, sec. 29, and the W1/2, SW1/4, sec. 28, T12N, R5E, Sauk County (Rock Springs, Wisconsin, Quadrangle, 7.5-minute series, topographic, U.S. Geological Survey, 1975) (fig. 1). *Caution*: This is a busy highway and a dangerous curve. Watch for traffic. Park at the parking area on the east side of the highway south of Van Hise Rock.

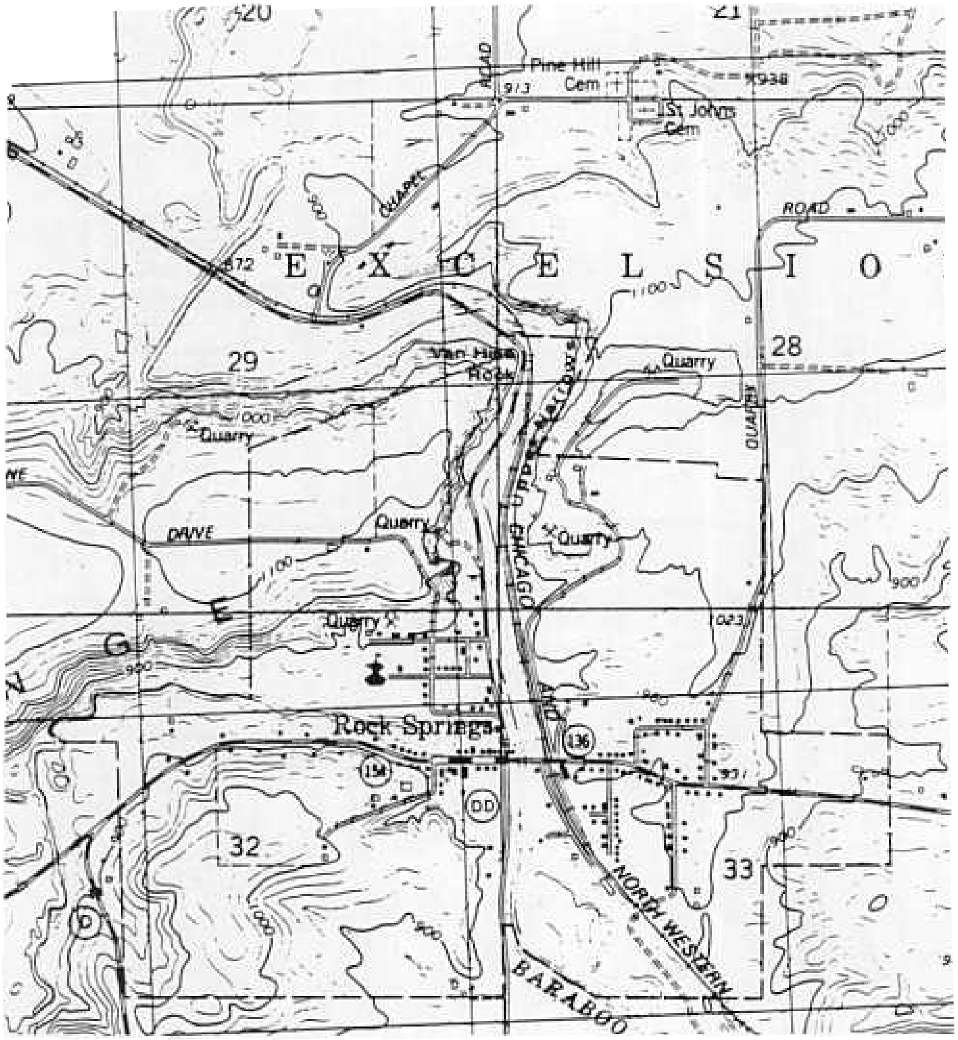

Figure 1. *Location of Van Hise Rock and the Upper Narrows area.*

Authors. B.A. Brown and M.E. Ostrom, 1990 (modified from Dalziel and Dott, 1970).

Introduction. The Upper Narrows, formerly called Ablemans Gorge or Rock Springs Gorge, provides an opportunity to examine significant lithologic characteristics and structural relationships in the Proterozoic quartzite of the Baraboo Formation. The upper bluffs and the ends of the gorge also show the onlapping relationship of the Upper Cambrian formations. Exposures are on both sides of the Baraboo River for 0.8 km from the river bridge at the north end of the gorge to the old sandstone quarry on the south end. The accompanying geologic map (fig. 2) and diagrammatic cross section (fig. 3) taken from Dalziel and Dott (1970) provide a guide to the important geologic features. Van Hise Rock, located south of the bridge and east of the highway, is an excellent example of cleavage refracted from a phyllitic bed into a massive quartzite layer on the north limb of the Baraboo Syncline. This rock has long been used as an example of cleavage refraction; it bears a plaque dedicated to pioneer structural geologist C.R. Van Hise, who first described this phenomenon in the Baraboo Hills.

Description. The Upper Narrows provides a cross section through the vertical north limb of the Baraboo Syncline. The features visible on the west side of the river along Highway 136 are summarized in figure 3.

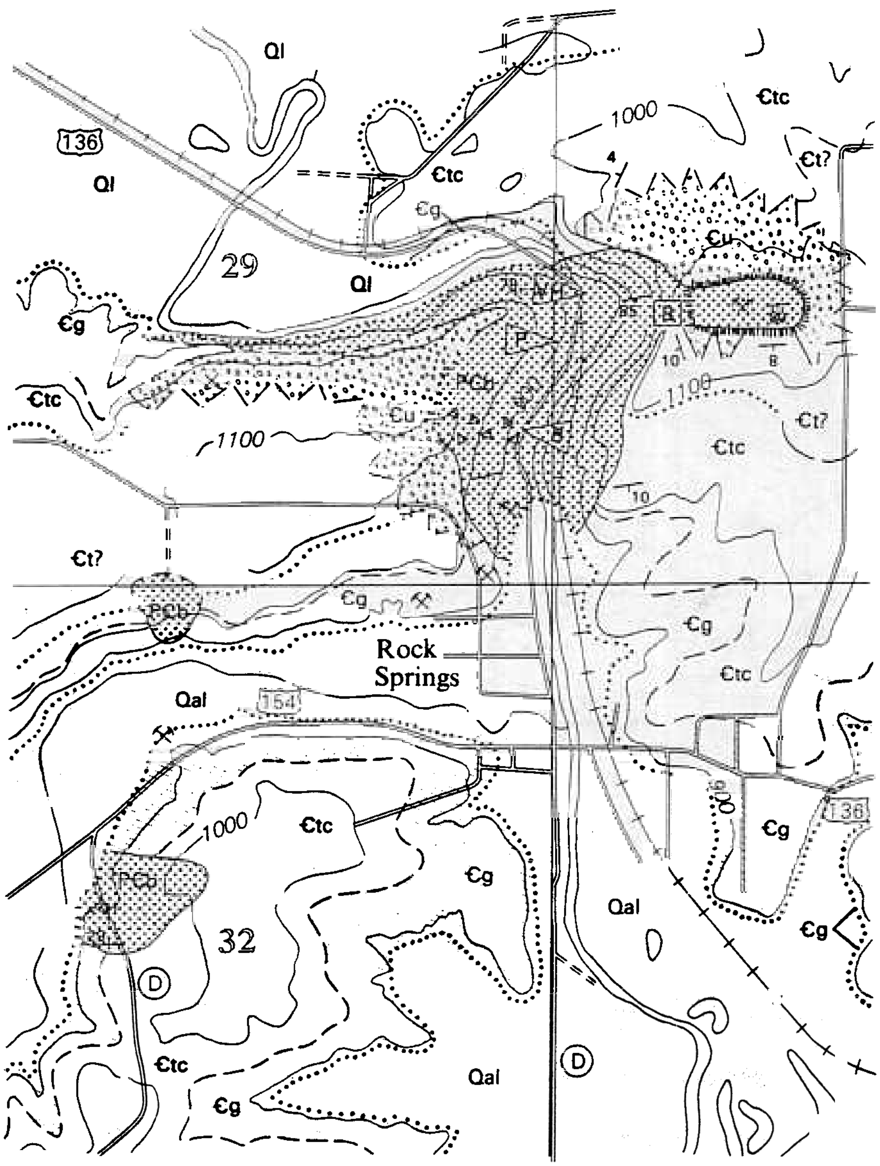

Figure 2. Geologic map of Upper Narrows (Rock Springs) area. On west side of gorge: VH = Van Hise Rock; P = polished quartzite surface; B = breccia zone. Note initial dips and distribution of conglomeratic facies in Cambrian rocks. P€b = Baraboo Quartzite; €g = Galesville Member; €tc = Tunnel City Formation; €t = Trempealeau Group; €p = conglomeratic sandstone of the Parfreys Glen Formation; Qal = river alluvium; Ql = glacial lake beds (modified from Usbug, 1968; Dalziel and Dott, 1970, fig. 21).

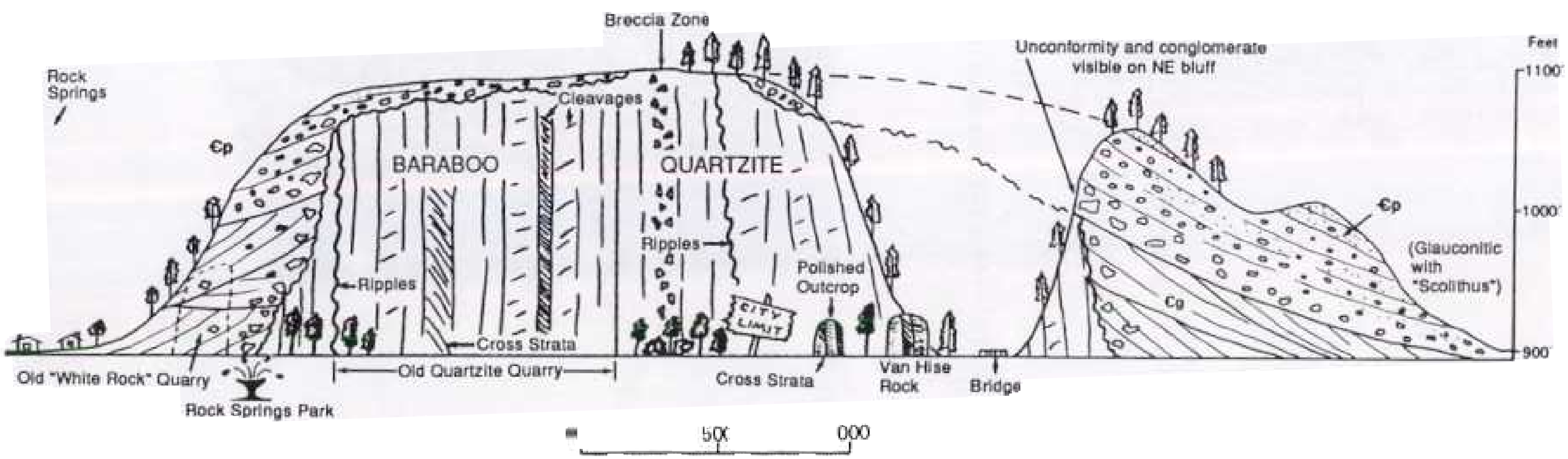

Figure 3. *Diagrammatic cross section of Upper Narrows* ***of*** *the Baraboo River looking west showing key geologic features €p Parfreys Glen Formation (Dalziel and Dott, 970, fig 22*

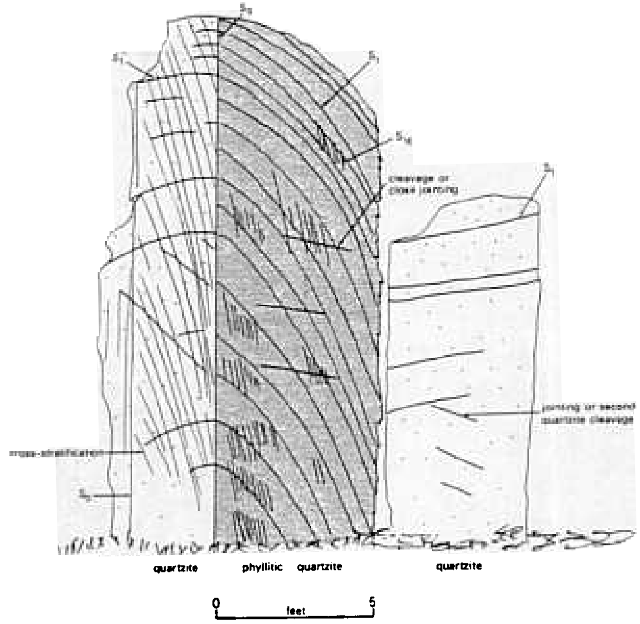

Figure 4. Sketch of structures in Van Hise Rock as seen from the east (Dalziel and Dott, 1970, fig. 23).

Figure 5. Photograph of Van Hise Rock looking northeast from Highway 136. Phyllite bed is dark bed on left. Cliff in background is Baraboo quartzite capped by Cambrian sandstone and conglomerate.

Van Hise Rock consists of two massive beds of Baraboo quartzite separated by a finer-grained bed of phyllite (fig. 4). The phyllite layer, which was originally an argillaceous fine sandstone, is not traceable into the cliff west of the highway. This bed appears to be a lens that pinches out to the west, although similar phyllite beds typical of the middle to upper part of the Baraboo quartzite are visible in the face of the roadcut. Consistent orientation of structures in Van Hise Rock and throughout the gorge area suggests that the rock is in place.

The most striking feature of Van Hise Rock is the refraction of cleavage between the quartzite and phyllite layers. Gently south-dipping cleavage in the quartzite is refracted into phyllite cleavage dipping about 40° to the north (fig. 5). The bedding or cleavage intersection is nearly horizontal and oriented east-west, roughly parallel to the axis of the Baraboo Syncline. A prominent set of joints, often quartz-filled, is developed at high angles to the bedding/cleavage intersection and was interpreted by Dalziel and Dott (1970) to be extensional fractures at right angles to the regional least-compressive stress. Well developed tension gash bands are visible on the north side of Van Hise Rock. Dalziel and Dott (1970) provide a more complete discussion of the structural geology of the Baraboo Syncline.

The roadcut on the west side of Highway 136 opposite Van Hise Rock contains some excellent examples of bedding and cross stratification in the Baraboo quartzite. To the south, at the Rock Springs village limit, a trail leads to the west into an old quartzite quarry. Ripple marks are visible on some bedding surfaces; at the south end, the quartzite becomes a breccia cemented by white vein quartz. These breccias are common in other exposures of the Baraboo interval quartzites. The fragments are angular and appear as if they could be fitted back perfectly. These zones show no evidence of a tectonic origin, no rounding of clasts or cataclasis as would be expected if they originated as fault zones. Greenberg (1986) described similar breccias at Hamilton Mounds and at Waterloo, attributing them to hydrothermal activity.

Farther south, a large quartzite quarry behind Rock Springs Park provides another opportunity to see sedimentary structures such as ripple marks and cross-bedding. At this location the unconformity between the quartzite and the overlying conglomerate of the Parfreys Glen Formation is visible as it was at the north end of the gorge. Rounded clasts of quartzite up to 1 m in diameter are contained in a sandstone matrix.

At the south end of the Upper Narrows, an old quarry produced building stone from sandstone of the Parfreys Glen Formation that is relatively free of the typical coarse quartzite clasts. This sandstone was deposited in the interior of the basin formed by the Baraboo Syncline. Scarce angular blocks of quartzite in the sandstone suggest that this material was deposited in a relatively wave-free area in the lee of the quartzite knob to the north.

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Baraboo Quartzite at Skillett Creek, Wisconsin

B. A. Brown, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin 53705

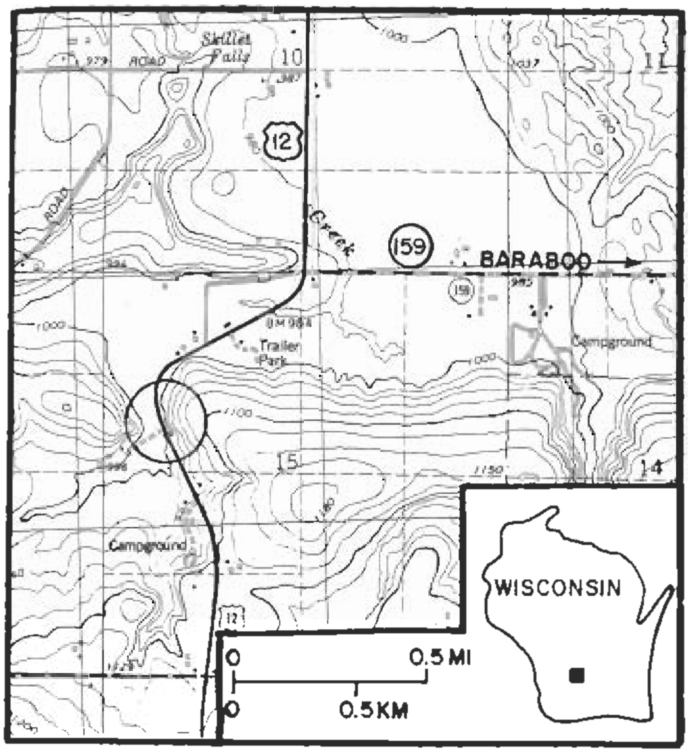

Figure 1. Location map.

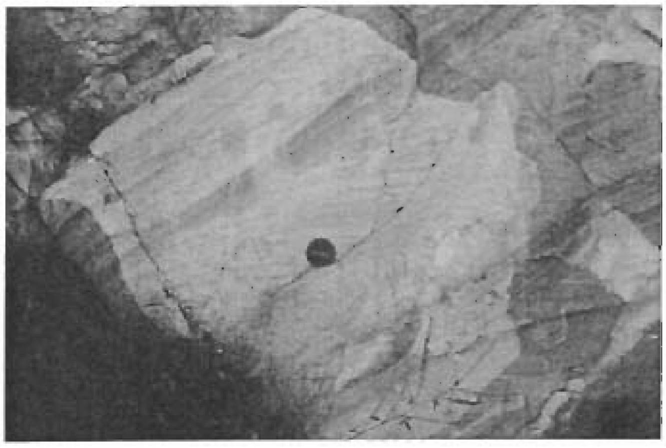

Figure 2. Cross-bedding in Baraboo Quartzite, lower part of exposure near road. Lens cap is 2 in (5 cm) in diameter.

Figure 3. Boudinaged and folded beds of quartzite interlayered with phyllite, upper part of exposure, above massive quartzite. Long dimension is approximately 6.5 ft (2 m).

LOCATION

The exposure is on the east side of U.S. 12, 0.3 mi (0.5 km) south of the junction with Wisconsin 159, SW¼,NW¼,Sec.15,T.-11N.,R.6E., North Freedom 7½-minute Quadrangle (Fig. 1). **Caution:** Traffic on U.S. 12 is heavy, and there is a blind curve just north of the outcrop.

SIGNIFICANCE

This outcrop provides an opportunity to examine both the quartzite and phyllite facies of the Baraboo Quartzite. This is a classic exposure that exhibits important sedimentary and tectonic structures typical of the Baraboo interval rocks of Wisconsin (Greenberg and Brown, 1983, 1984; Brown, 1986).

DESCRIPTION

Pink quartzite, dipping 15° north, is exposed at the southern end of the outcrop. Good examples of sedimentary structures typical of the Baraboo Quartzite, including cross-bedding (Fig. 2) and ripple marks, are present at this exposure. Dalziel and Dott (1970) refer to this exposure as an excellent example of the paleocurrent indicators that suggest a southward sediment transport direction at Baraboo. Locally, cross-bedding in individual sets of laminae shows contortion, particularly oversteepening, which Dalziel and Dott attributed to synsedimentary deformation.

At the north end of the exposure and on top of the cliff, argillaceous beds up to 6.5 ft (2 m) in thickness occur interbedded with thin (1.5 ft or less; 0.5 m) beds of quartzite, (Fig. 3). The thin quartzite beds within the less competent phyllite provide some spectacular examples of boudinage and parasitic folding. The S_1

cleavage, related to the formation of the Baraboo syncline, is nearly parallel to bedding in the phyllite at this location. Later crenulation cleavages and small-scale conjugate kinks cut the S_1 foliation at high angles. Late veins of white quartz cut the thin quartzite beds at a high angle to bedding. In thin section (Fig. 4), crenulation in the phyllite is quite apparent. Mineralogy is quartz, muscovite, and sometimes pyrophyllite, indicating a maximum of upper greenschist facies metamorphism. Recent road construction has uncovered additional exposures about 300 ft (90 m) to the north, around the curve of U.S. 12. This cut exposes the dip slope of the quartzite and contains some excellent tectonic structures, particularly refracted cleavage, in both the quartzite and phyllite.

This is an exemplary teaching outcrop and field trip stop. Please keep hammering and destructive sampling to a minimum.

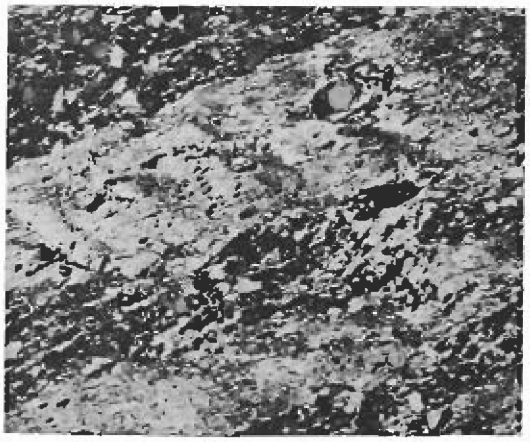

Figure 4. Photomicrograph of crenulated phyllite. Note crenulations at high angle to phyllitic foliation. Field of view is about 8 mm in long dimension.

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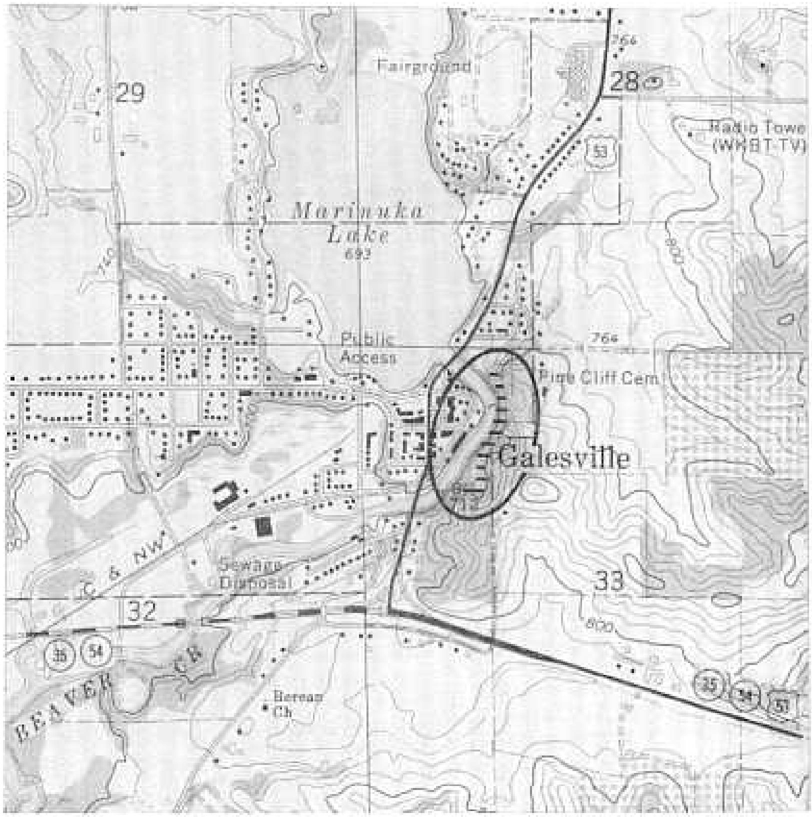
Title: Galesville

Location: Type section of the Galesville Sandstone exposed in bluff of Beaver Creek in City of Galesville in the NE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 33, T.19N., R.8W., Trempealeau County (Galesville 7.5-minute topographic quadrangle, 1973).



Author: M. E. Ostrom (modified from Ostrom, 1966 and 1970)

Description: Outcrop is reached by walking north across highway bridge and thence east along north side of Beaver Creek. Assemble at path gate.

Discussions presented for stops at Rest Haven Gardens Town Road, Strum North, and Whitehall apply equally to this exposure. Of special interest here is the Eau Claire-Galesville contact surface which is sharp along the outcrop face and is markedly uneven. At this exposure erosion of the Eau Claire is obvious on the basis of cut-out and the presence of clasts in the base of the Galesville.

Early descriptions of this outcrop (Trowbridge and Atwater, 1934; Twenhofel et al, 1935) did not recognize the unconformable relationship between the Galesville and Eau Claire. Twenhofel et al (1935) stated that "There does not seem to be any definite evidence of physical change at this boundary." Critical examination here reveals marked physical change and in fact an unconformable relationship produced by pre-Galesville erosion of the Eau Claire. The relationship revealed here, namely that of quartzarenite resting with erosional unconformity on older rocks, is common in the Cambrian and Ordovician strata of Wisconsin and is one factor which led to a cyclic interpretation to explain the history of sedimentation of Upper Cambrian and Lower and Middle Ordovician rocks in the Upper Mississippi

GALESVILLE OUTCROP

NE$\frac{1}{4}$,NW$\frac{1}{4}$,Sec.33,T.19N.,R.8W.

LONE ROCK FM.
Birkmose Mbr.

Fine-grained. Thin-bedded. Some brachiopod shell fragments.

WONEWOC FM.
Ironton Mbr.

Fine and very fine-grained, trace of medium and coarse. Few brachiopod shell fragments.

Medium and coarse-grained, little fine. Few brachiopod shell fragments. Thick-bedded.

Medium and fine-grained, trace of coarse. Medium-bedded.

Fine and very fine-grained, trace medium. Thin-bedded.

Fine and medium-grained, trace coarse. Thick-bedded.

Medium-grained, trace coarse and fine.

Medium-grained, little coarse and fine. Thin to medium-bedded.

Coarse to medium-grained, trace fine. Thick-bedded with some thin beds.

Galesville Mbr.

Fine to medium-grained, little coarse. Thick-bedded with few thin beds.

Fine to very fine-grained, trace medium. Thin-bedded.

Coarse to medium-grained, little fine. Thick-bedded.

Fine to medium-grained, little coarse. Thick-bedded.

Medium-grained, little fine and coarse. Thick-bedded.

Fine to very fine-grained, trace medium. Thick-bedded.

Medium to fine-grained. Thick-bedded.

Medium-grained, little fine and coarse. Thick-bedded.

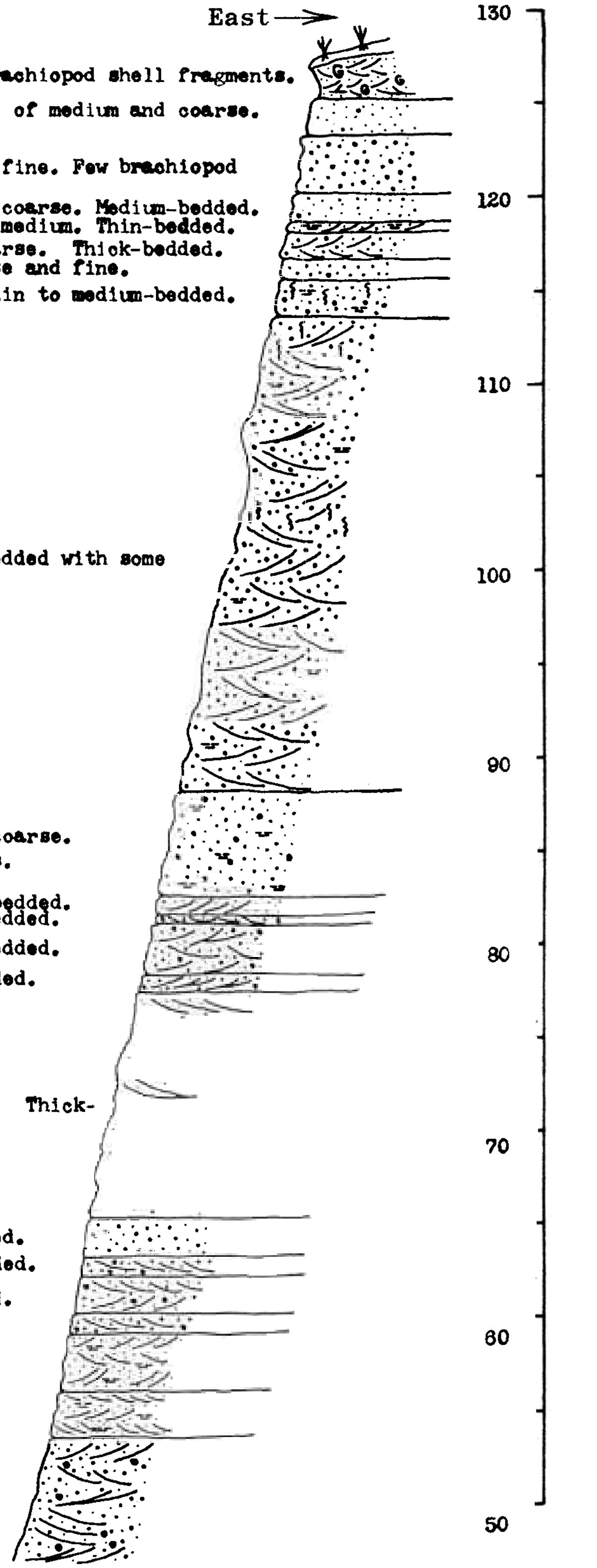
Fine-grained, little medium and coarse. Thick-bedded.

Medium-grained, little fine & coarse. Thick-bedded.

Fine-grained, little very fine. Thick-bedded.

Fine-grained, little very fine. Thick-bedded.

Medium and fine-grained, little very coarse and very fine. Thick-bedded.



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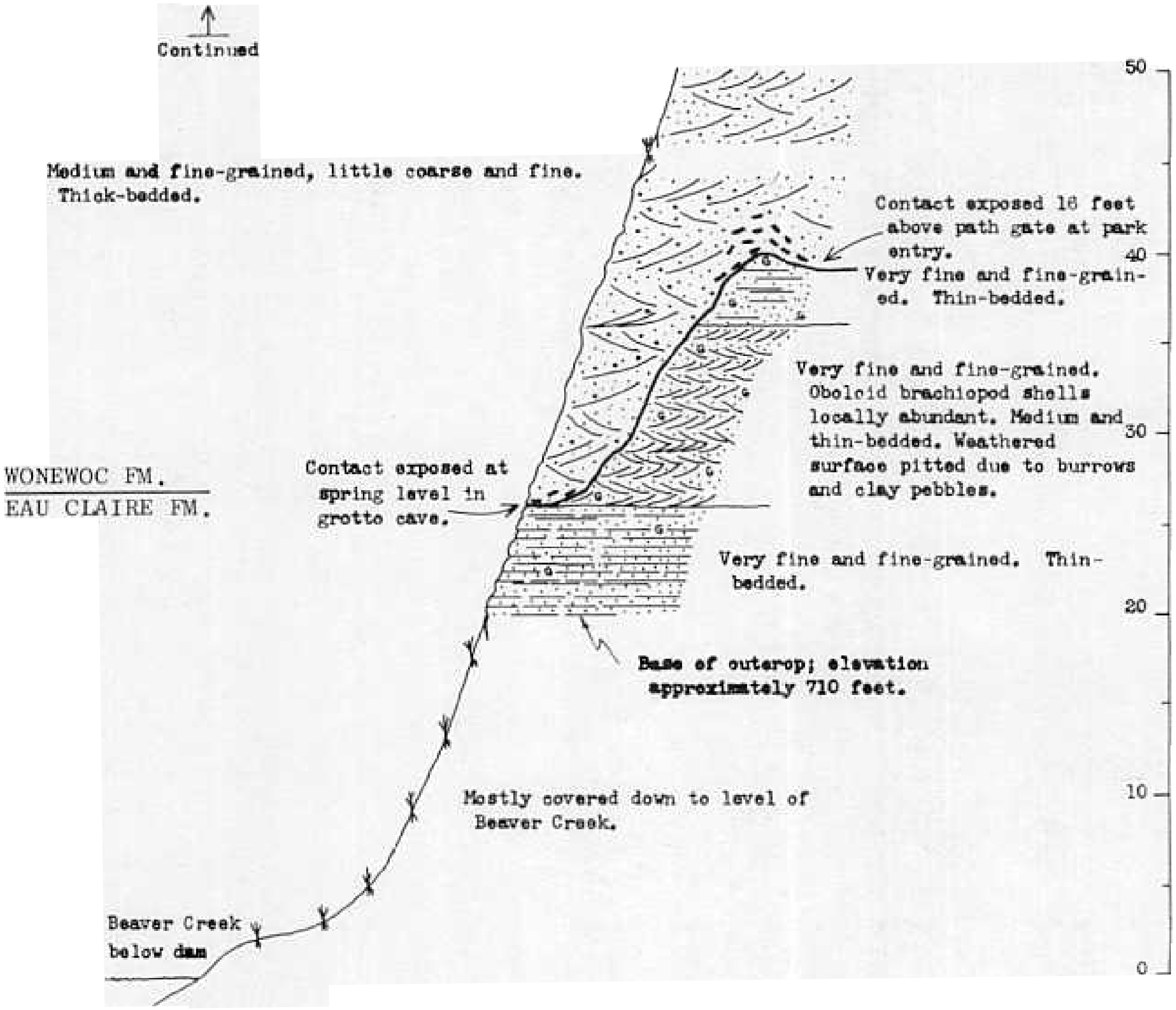


Continued
Medium and fine-grained, little coarse and fine. Thick-bedded.
Contact exposed 16 feet above path gate at park entry.
Very fine and fine-grained. Thin-bedded.
Very fine and fine-grained. Oboloid brachiopod shells locally abundant. Medium and thin-bedded. Weathered surface pitted due to burrows and clay pebbles.
WONEWOC FM.
EAU CLAIRE FM.
Contact exposed at spring level in grotto cave.
Very fine and fine-grained. Thin-bedded.
Base of outcrop; elevation approximately 710 feet.
Mostly covered down to level of Beaver Creek.
Beaver Creek below dam
50
40
30
20
10
0

Valley area (Ostrom, 1964).

Because the contact of the Eau Claire with the Galesville is one of erosional unconformity one must re-examine the position of the Galesville with respect to its assignment to the Dresbachian Stage rather than to the younger Franconian Stage. The Galesville is separated from older rocks by an unconformity, it contains no diagnostic fossils, and it is transitional with the overlying Ironton Member which contains Franconian fossils. Furthermore, the Aphelaspis trilobite zone which closes the Dresbachian and which should occur in the top of the Eau Claire is missing in Wisconsin. Absence of this zone tends to support the contention of post-Eau Claire erosion.

The Birkmose Member in the base of the Lone Rock Formation thins toward the Wisconsin Arch from 15 feet just east of Galesville to less than 6 inches at Ferry Bluff north of Mazomanie (Berg, 1954). The Birkmose is one of several units in the Upper Cambrian and Lower and Middle Ordovician which thin eastward toward the Wisconsin Dome. Some of the others are the Ironton, St. Lawrence, Sunset Point, and Glenwood units.

Log of Village Well #2, located in the NW$\frac{1}{4}$, Sec. 33, T.19N., R.8W., Galesville (description by F. T. Thwaites). Elevation = approximately 720'. Base of outcrop 10' below top of well.

Alluvium

0' - 5'	5.0'	No sample.
5' - 20'	15.0'	Sand, brown yellow, grain size ranges from medium sand down to silt.

Eau Claire Formation

20' - 25'	5.0'	Shale, green gray, silty.
25' - 35'	10.0'	Siltstone, yellow gray.
35' - 45'	10.0'	Siltstone, gray.
45' - 50'	5.0'	Siltstone, yellow gray.
50' - 60'	10.0'	Shale, gray, silty.
60' - 80'	20.0'	Siltstone, yellow gray.
80' - 95'	15.0'	Siltstone, gray.
95' -100'	5.0'	No sample.
100' -130'	30.0'	Shale, gray, silty.
130' -135'	5.0'	Siltstone, light gray.
135' -145'	10.0'	Sandstone, light gray, grain size range from medium sand down to silt.

Mt. Simon Formation

-150'	5.0'	Sandstone, light gray, grain size ranges from coarse sand down to silt.
150' -160'	10.0'	Sandstone, light gray, medium and coarse grained.
-210'	50.0'	Sandstone, light gray, coarse and medium grained.
-215'	5.0'	Sandstone, light gray, grain size ranges from coarse sand down to fine.

	-225'	10.0'	Sandstone, light gray, coarse and medium grained.
	-230'	5.0'	Sandstone, light gray, grain size ranges from medium sand down to silt.
230'	-235'	5.0'	Siltstone, light gray.
235'	-240'	5.0'	Sandstone, light gray, grain size ranges from medium sand down to silt.
	-245'	5.0'	Sandstone, light gray, grain size ranges from coarse sand down to silt.
	-252'	7.0'	Sandstone, light gray, grain size ranges from fine sand down to silt.

BOTTOM OF HOLE

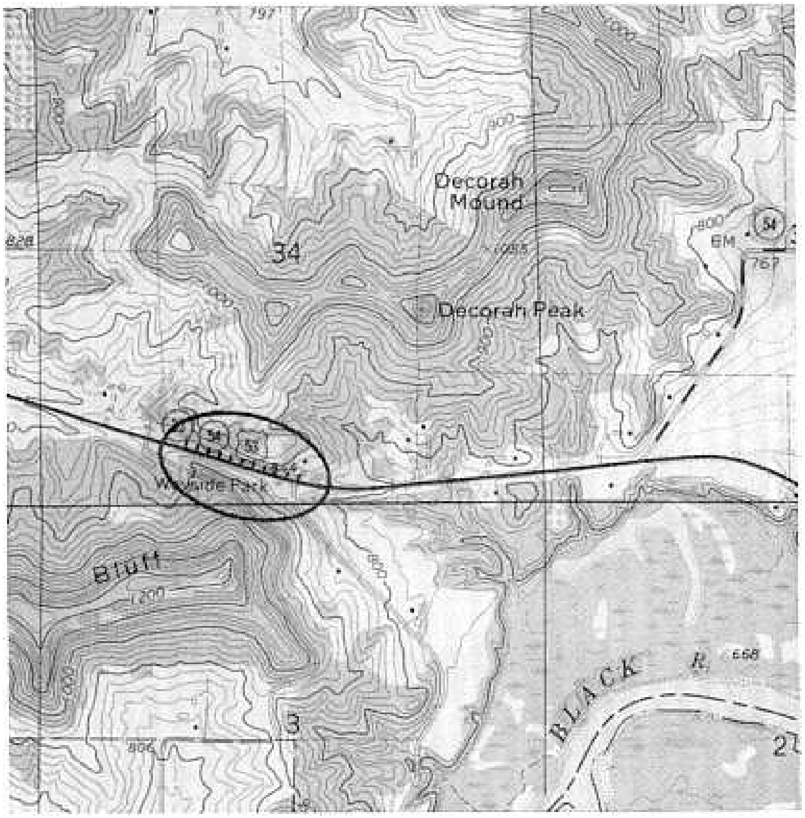
Significance: This outcrop reveals the contact relationship of the Eau Claire Formation with the Wonewoc Formation. The initial description indicated this contact to be transitional.

Examine the textural, mineralogical, bedding, and fossil characteristics of the two formations. Based on your observations, is the contact of the two formations transitional or sharp? What is the evidence? What is the significance of the contact, texture, mineralogy, bedding, and fossil characteristics in terms of geologic history? of depositional environment?

References: Trowbridge and Atwater, 1934; Twenhofel et al., 1935; Berg, 1954 Ostrom, 1964, 1966 and 1970.

Title: Decorah Peak

Location: Exposure of north side of Highway 53 in roadcut 1.2 miles east of City of Galesville at Decorah Peak in the SW$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 34, T.19N., R.8W., Trempealeau County (Galesville 7.5-minute topographic quadrangle, 1973).



Author: M. E. Ostrom (modified from Ostrom, 1970)

Description: Outcrop displays the Wonewoc and Lone Rock Formations to excellent advantage. Refer to the Whitehall stop for detailed discussion. Following is a description of the exposure:

CAMBRIAN SYSTEM
St. Croixan Series - Franconian Stage

		Lone Rock Formation Reno Member (20.0 + feet)
57.2' - 77.2'	20.0+	Sandstone, gray green and brown, fine grained, thin bedded and cross-bedded, glauconitic; some beds of ripclast; much "wormstone" in lower 10 feet.
		Tomah Member (10.0 feet)
47.2' - 57.2'	10.0'	Sandstone, light yellow gray, fine and very fine

			grained, shaly and micaceous, dolomitic, thin bedded, trace of glauconite.
			Birkmose Member
	- 47.2'	8.0'	Sandstone, very fine grained, and siltstone, gray thin bedded and uneven bedding, dolomitic, trace glauconite.
	- 39.2'	5.0'	Dolomite and greensand conglomerate and interbedded greensand.
	34.2'	2.5'	Sandstone, gray green, fine grained with little medium and very fine, massive, cross bedded, very glauconitic
Elk Mound Group Wonewoc Formation			
			Ironton Member
26.7' - 31.7'		3.5'	Sandstone, light yellow gray, fine grained with little very fine and medium, slightly silty, massive bedded with poorly defined cross bedding. Base slightly uneven.
23.2' - 26.7'		3.5'	Sandstone, light yellow gray, coarse and medium grained with little fine, massive bedded and cross bedded; scattered brachiopod fragments.
20.2' - 23.2'		3.0'	Sandstone, light yellow brown, medium and coarse grained, massive bedded, scattered brachipod fragments.
18.7' - 20.2'		1.5'	Sandstone, light yellow gray, fine grained with little medium and trace of very fine, silty, massive bedded. "Wormstone bed".
17.7' - 18.7'		1.0'	Sandstone, light yellow gray, medium and coarse grained, massive bedded and cross bedded.
16.7' - 17.7'		1.0'	Same as #8 but predominantly fine and medium grained.
	16.7'	9.0'	Sandstone, light yellow brown, medium and coarse grained, massive bedded and cross bedded.
	7.7'	5.0'	Sandstone, brown, medium and coarse grained with a little very coarse, slightly silty. "Wormstone bed"
	2.7'	0.7'	Sandstone, light yellow brown, very fine and fine grained with a trace of medium and coarse.
0.0'	2.0'	2.0'	Sandstone, light yellow brown, coarse and medium grained, massive bedded.

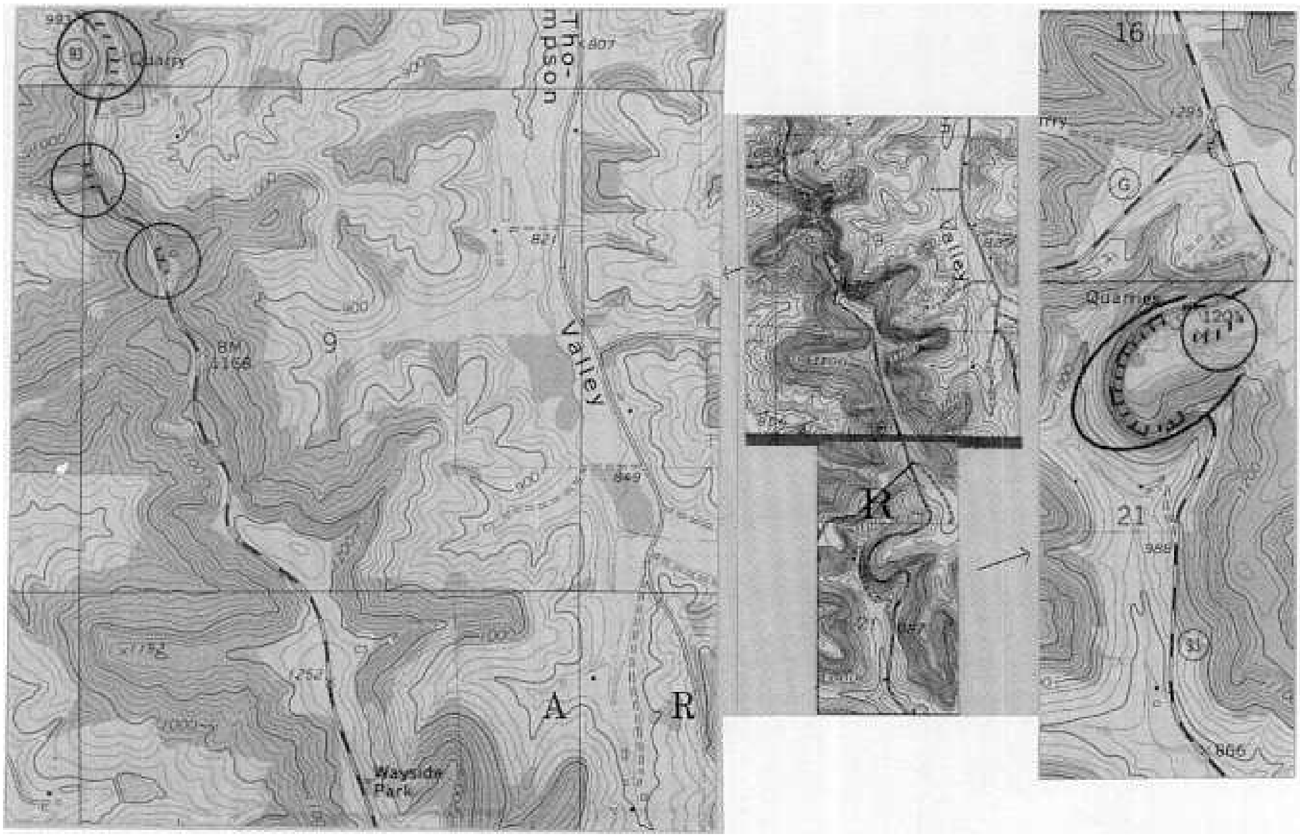
Significance: The contact relationship and characteristics of mineralogy, lithology, texture bedding, fossils, and sedimentary structures of the Wonewoc and Lone Rock Formations are well shown. Examine these features closely.

On the basis of your examination is the contact sharp or transitional? Is it an erosional unconformity? What is your evidence? What is your interpretation of the environment of deposition of the Ironton Member? Birkmose Member? Tomah Member? Reno Member? How do these relationships of texture, composition bedding, fossils, and sedimentary structures compare to what you have seen of previous exposures?

References: M. E. Ostrom, 1970.

Title: Arcadia South

Location: Composite section from outcrops and quarries located along State Highway 93 and extending from 1.8 miles to 3.5 miles south of its intersection in Arcadia with State Highway 95 in the SE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 9, T.20N., R.9W., Trempealeau County (Tamarack 7.5-minute topographic quadrangle, 1973).



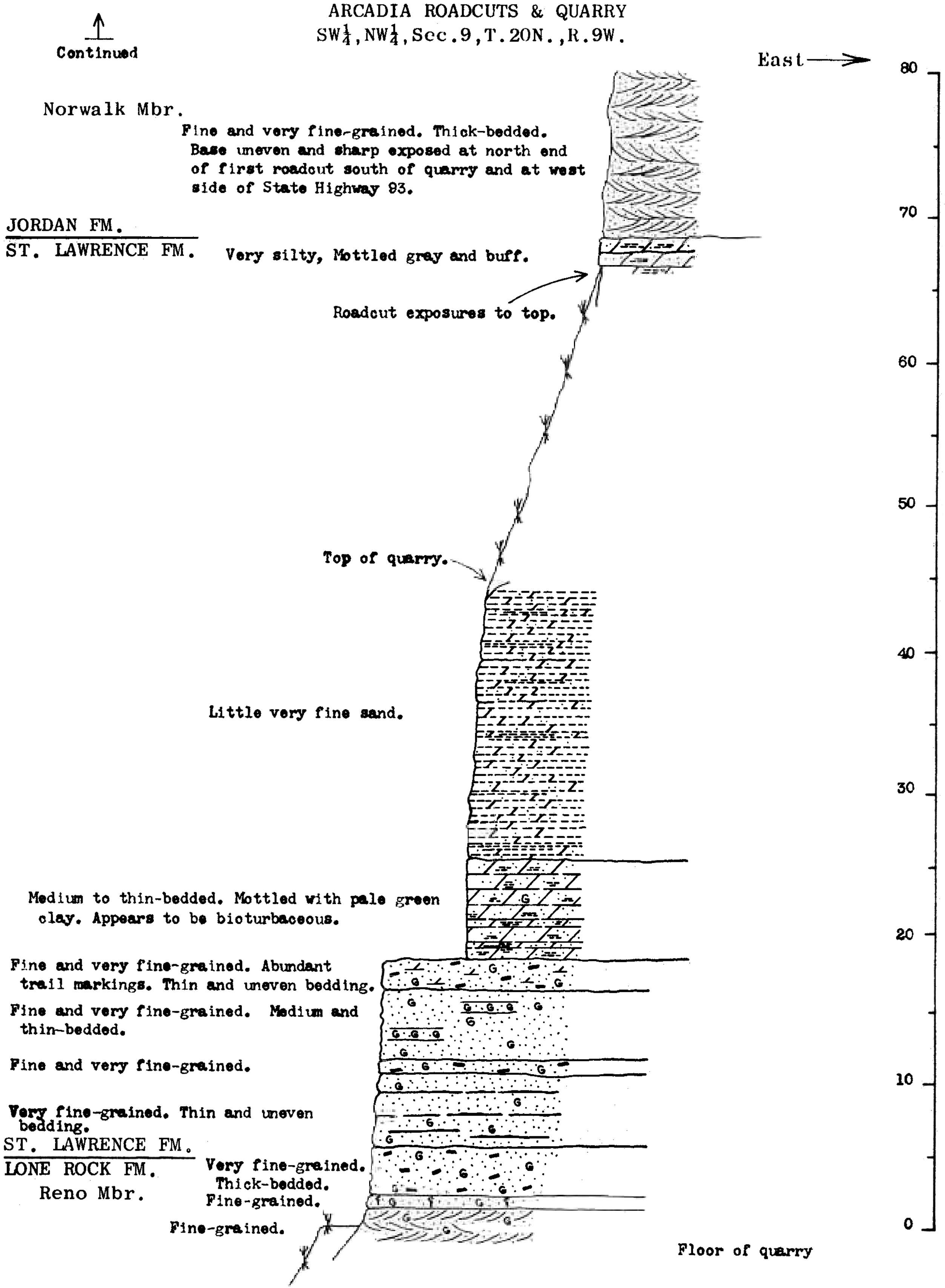
Author: M. E. Ostrom (modified from Twenhofel, et al, 1935, Nelson, 1956, Mitby, 1967, and Ostrom 1970).

Description: This stop displays the St. Lawrence and Jordan formations to good advantage and it also illustrates one of the problems in the Upper Cambrian Stratigraphy in Wisconsin, namely determining the limits and relationships of the Black Earth Dolomite and Lodi Siltstone members of the St. Lawrence Formation.

Nelson (1956) studied these units in the Upper Mississippi Valley area. He defined the Black Earth as ".....sandy dolomite and interbedded dolomitic siltstone and fine-grained sandstone" and in the vicinity of Black Earth and Madison and at localities along the Mississippi Valley as dolomite that is "....generally massive, brown to buff, slightly glauconitic...(with) ...algal structures locally." The Lodi Member consists of "....siltstone, generally dolomitic, and dolomitic sandstone."

The fact that his definitions indicate both the Black Earth and the Lodi

ARCADIA ROADCUTS & QUARRY
SW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 9, T. 20N., R. 9W.



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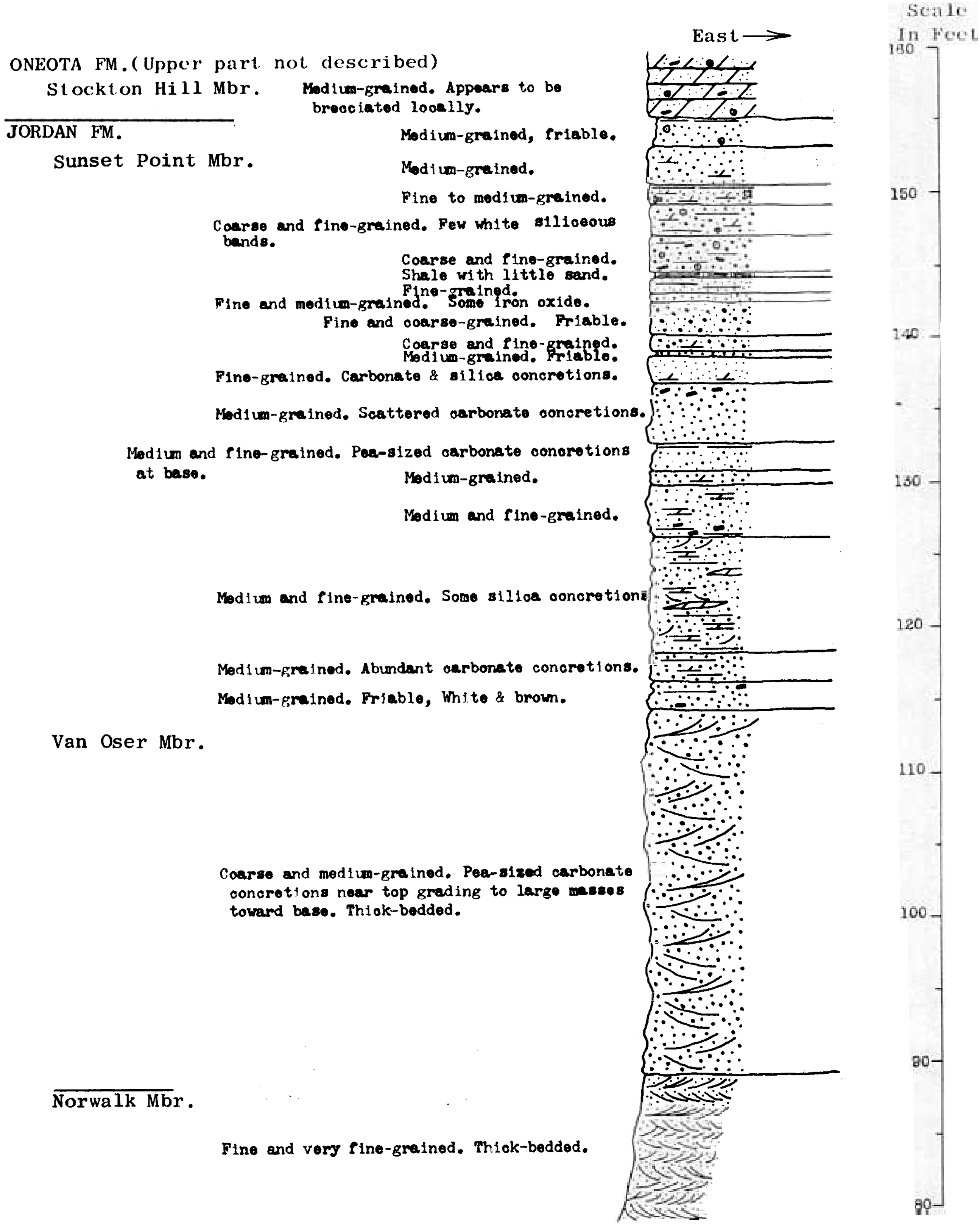

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can consist of dolomitic siltstone and fine-grained sandstone is reason why it is commonly very difficult to distinquish the two members as can be seen at this exposure. Here Nelson assigned the lower 17 feet of the St. Lawrence to the Lodi the middle 12-foot portion to the Black Earth, and an overlying 15-foot section to the Lodi for a total thickness of about 44 feet. Close examination of the outcrop reveals that if a Black Earth Dolomite occurs here it is probably the 7 feet of very silty dolomite in the interval from 19 feet to 26 feet above the base of the exposure. However, there does not appear to be any marked difference in lithology such as would suggest the presence of Black Earth lithology rather than Lodi. The Wisconsin Geological and Natural History Survey recognizes the Black Earth as a medium to thick-bedded, medium to coarsely-crystalline dolomite that is locally silty, sandy and glauconitic with fossil algae and with the possible exception of several thin beds assigns all of the St. Lawrence Formation of this exposure to the Lodi Member. The Norwalk Member of the Jordan Formation consists of very fine and fine-grained non-silty sandstone which is thick-bedded to thin-bedded. At this exposure it is separated from the underlying silty and dolomitic Lodi by a sharp and uneven surface interpreted to indicate post-Lodi erosion. At the majority of outcrops of this interval in Wisconsin the contact appears to be completely gradational. However, the fact that the Norwalk and Van Oser constitute a thick body of sandstone similar in character to the Galesville and others of the Cambrian and Ordovician sandstones of this region suggests that the Jordan probably had a similar origin, namely that it formed on an erosion surface by a process of coalescing of beach deposits in a transgressing sea, but that in at least this area erosion was a minor factor.

The Van Oser Member of the Jordan Sandstone is characterized by medium-grained sandstone with some coarse and a little fine. Contact of the Van Oser with the Norwalk is commonly though not always sharp. At this exposure the contact is slightly uneven. Contact relations of overlying beds will best be examined at subsequent stops.

Field study by McGannon (1960) led him to propose the name Stockton Hill Formation for those strata between the Lone Rock Formation below and Jordan Formation above. The top of the Lone Rock is marked by 3 feet of flat-pebble conglomerate overlain by 0.7 feet of "wormstone", a burrowed, glauconitic, calcareous, silky fine-grained sandstone. McGannon's Stockton Hill Formation extends 36.7 feet upward to 6.4 feet below the top of the quarried section. The lower 24.1 feet are assigned to the Lodi Member; the upper 12.6 feet to what he has named the Red Wing Member. The upper 6.4 feet which he assigned to the Jordan Formation contains from 28 to 50 percent carbonate and from 35 to 50 percent of silt and finer particles which does not conform to other descriptions of the Jordan. Contact of fine-grained Jordan Sandstone containing only minor carbonate and silt can be observed in the first roadout above the quarry and west of Highway 93. It is believed this is the actual contact. The Wisconsin Geological and Natural History Survey retains the name St. Lawrence Formation for what McGannon proposes to call the Stockton Hill Formation and assigns all of the St. Lawrence at this exposure to the Lodi Member.

The Jordan Sandstone is divided on the basis of composition, texture, and bedding characteristics, into three members, the lower Norwalk, the middle Van Oser, and the upper Sunset Point. These can be traced throughout southwestern Wisconsin and into eastern Minnesota and Iowa.

The Jordan Sandstone is overlain by the Oneota Dolomite Formation of the Prairie du Chien Group.

Quarries in the Oneota Formation are located along Highway 93 south of the Jordan Sandstone outcrops and at the crest of the ridge which forms the Skyline Drive. The Oneota is a primary source of crushed stone used for construction throughout much of southern Wisconsin. This is a "portable operation", namely the crushing and processing equipment is portable as opposed to stationary.

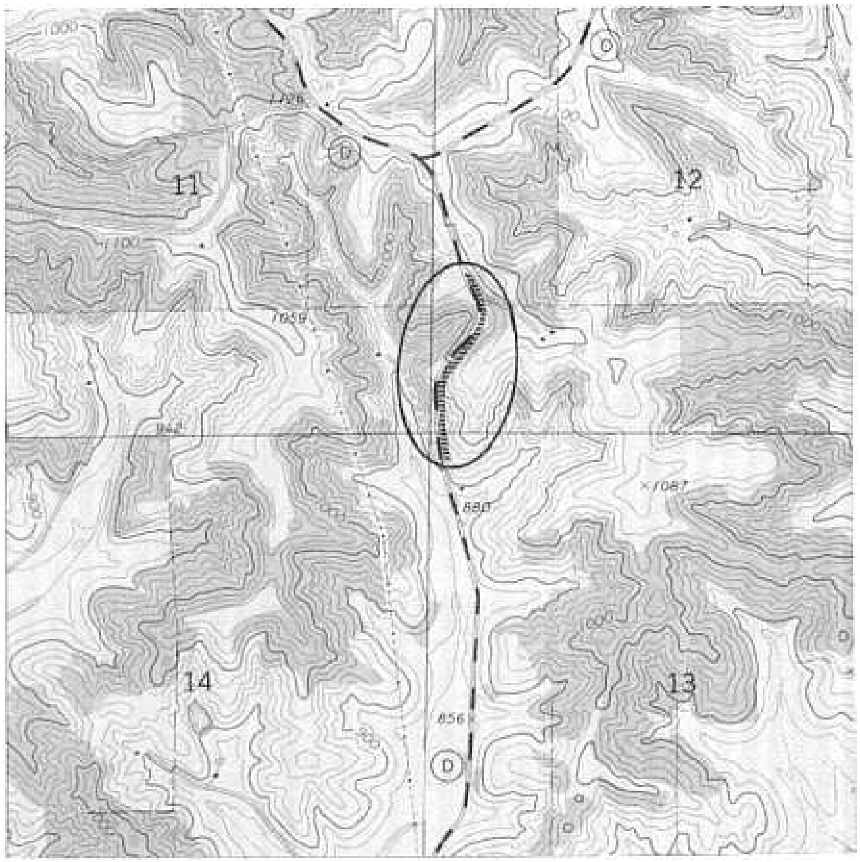
Significance: This stop illustrates the contact relationship of the Lone Rock Formation with the St. Lawrence Formation and of the second cycle with the third cycle. It also illustrates a major use of Wisconsin's dolomite formations.

What is the major difference between the Lone Rock and St. Lawrence Formations? The St. Lawrence and Jordan Formations? Where would you place the contact of the Lone Rock with the St. Lawrence? The St. Lawrence with the Jordan? The Jordan with the Oneota? What were their environments of deposition and what is the supporting evidence? What similarities and differences can you make between the same lithotopes of the 3 cycles you have seen? How do you interpret these differences? Why have the quarries in the Oneota Dolomite been developed in this area? (consult a geologic map of the state). What environmental and economic problems are associated with quarrying? Portable versus stationary operations?

References: Twenhofel, Raasch, and Thwaites, 1935; Melby, 1967; Nelson, 1956; McGannon, 1960; Ostrom, 1970.

Title: Whitehall

Location: Road cuts north of Whitehall on County Highway "D" and 1.7 miles north of its juncture with State Highway 53 in the SW$\frac{1}{4}$, SW$\frac{1}{4}$, Sec. 12, T.22N., R.8W., Trempealeau County (Pleasantville 7$\frac{1}{2}$-minute topographic quadrangle, 1973).



Author: M. E. Ostrom (modified from Ostrom, 1966 & 1970)

Description: Exposure of geologic section beginning with Lone Rock Formation at top and extending downward to Eau Claire Formation at base.

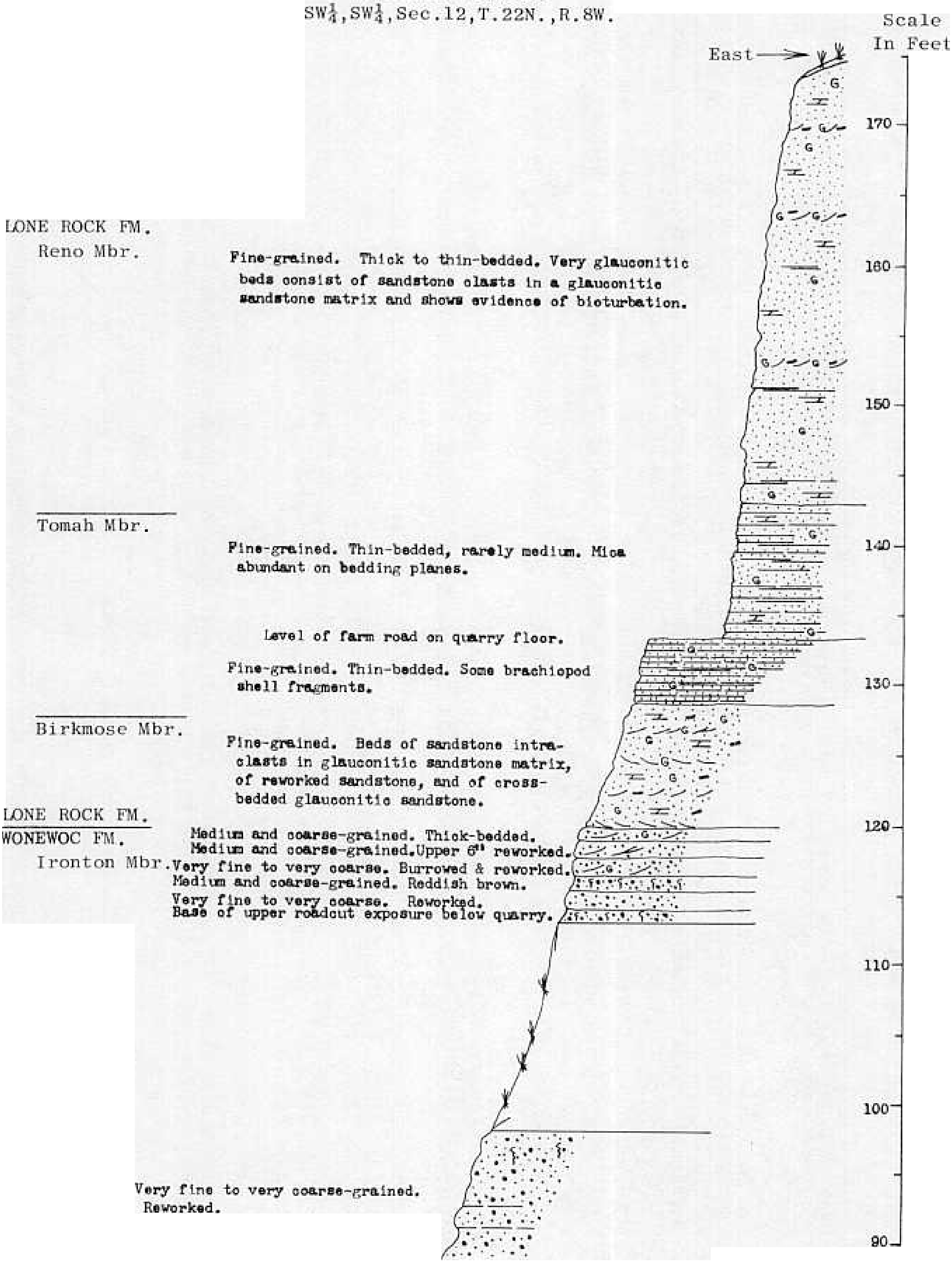
This is an excellent exposure to show the interrelationships of the various lithostratigraphic units beginning with the Eau Claire Formation and extending upward into the Lone Rock Formation. The section is complete except for about 15 feet of covered interval midway in the Ironton Member.

Beginning with the sharp and unconformable contact of Galesville on Eau Claire near the base, one can proceed upwards through the remainder of the section without evidence of major erosional break.

Regionally the Eau Claire Formation thins to the east until in the vicinity of Wisconsin Dells it is not recognized. North and northwest of the Dells what is believed to be thin Eau Claire can be seen at Friendship Mound, north of

WHITEHALL ROADCUT

SW$\frac{1}{4}$,SW$\frac{1}{4}$,Sec.12,T.22N.,R.8W.



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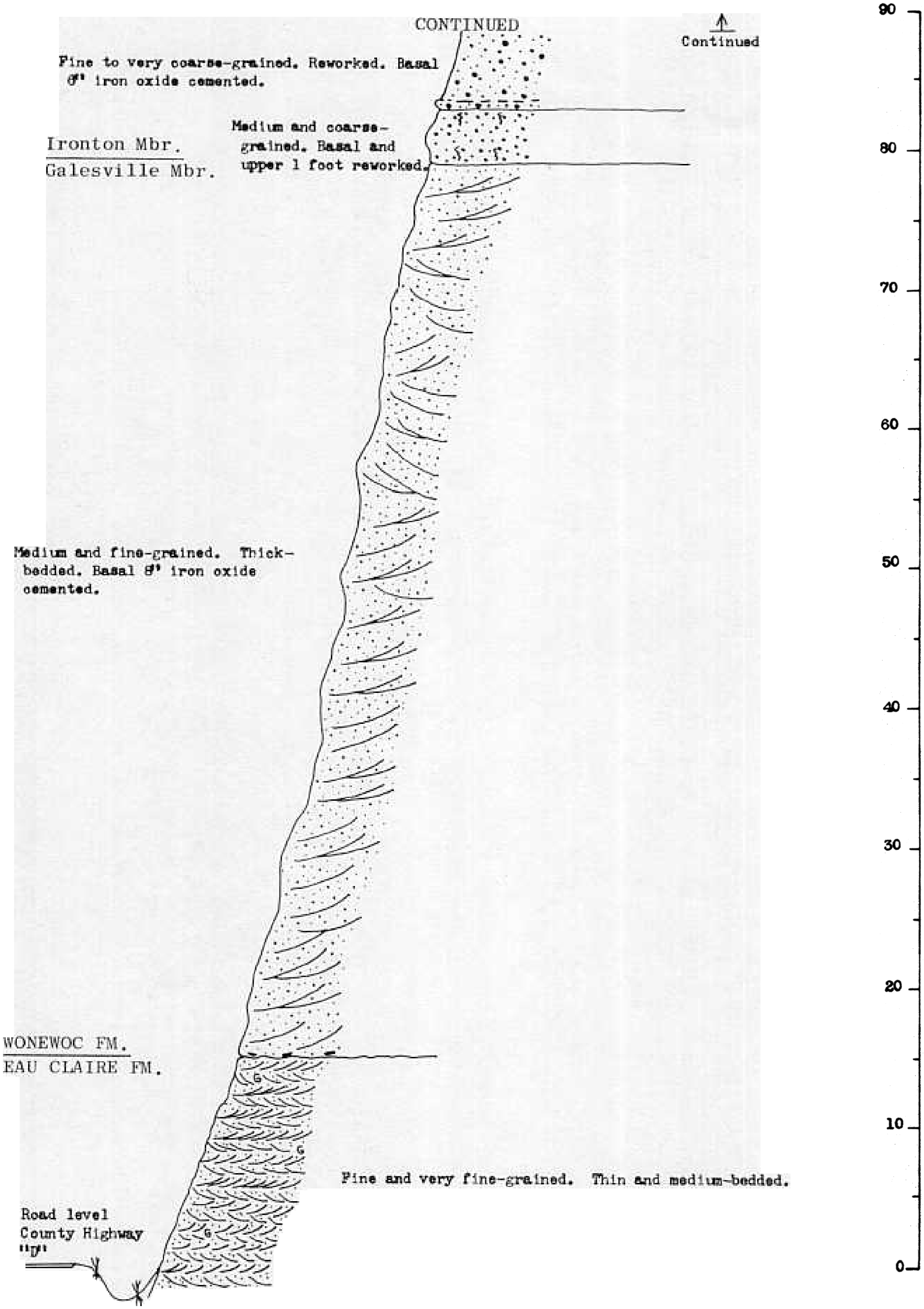


CONTINUED
Continued
Fine to very coarse-grained. Reworked. Basal 6" iron oxide cemented.
Medium and coarse-grained. Basal and upper 1 foot reworked.
Ironton Mbr.
Galesville Mbr.
Medium and fine-grained. Thick-bedded. Basal 8' iron oxide cemented.
WONEWOC FM.
EAU CLAIRE FM.
Fine and very fine-grained. Thin and medium-bedded.
Road level
County Highway
"D"
90
80
70
60
50
40
30
20
10
0

Friendship, and at Sheep Pasture bluff located south of Mauston.

At Friendship Mound there is a one-foot bed of fine-grained, silty, iron-oxide, cemented sandstone that separates two thick-bedded, medium-grained, well-sorted sandstone units. The upper of these two units is positively identified as the Galesville Sandstone. At Sheep Pasture Bluff the situation is similar except that the thickness assignable to the separating unit is 7 feet and it contains only minor iron exide. Also at Sheep Pasture Bluff, sandstone clasts occur in the base of the Galesville. The possibility exists that the separating unit is the Eau Claire Formation thinned by pre-Galesville erosion and that the lower sandstone unit is the Mt. Simon Sandstone.

A study of the Mt. Simon Sandstone by Asthana (1968) indicates that its feldspar content ranges from 3 percent to 40 percent and averages 18 percent. On the other hand it is known from numerous analyses of the Galesville Sandstone that it seldom contains more than 1 percent feldspar. Asthana determined that the feldspar content of the sandstone unit below the Eau Claire is higher than that above by a factor of 2 at Sheep Pasture Bluff and of 9 at Friendship Mound. This sharp decrease in feldspar content corresponds to a similar difference between the feldspar content of the Mt. Simon and Galesville sandstones elsewhere and is interpreted to indicate that at these exposures the Eau Claire is much reduced in thickness probably due to post-Eau Claire erosion. Thus, it appears that the Eau Claire thins eastward and that thinning is due to pre-Galesville erosion.

The Eau Claire-Galesville contact marks the end of one transgressive/regressive sequence and the beginning of the transgressive phase of the subsequent sequence. The Galesville Sandstone formed during transgression as the result of a process of coalescing of littoral zone deposits. Rather persistent high energy conditions are indicated by a noticeable lack of clay, silt and very fine sand and a total lack of fossils.

Above and transitional with the Galesville is the Ironton Member. The Ironton is interpreted to have formed in an environment located seaward of the beach where high and low energy conditions alternated. Whereas the Galesville is thick-bedded, the Ironton is medium-bedded and even-bedded. Silt and other fine particles are abundant in certain beds. Burrows are common and fossils are present locally. Also, there is commonly carbonate cement and glauconite in the upper few feet of the unit. Alternate beds are commonly well-sorted, clean, medium and coarse-grained, cross-bedded quartzarenite on the one hand and poorly-sorted, reworked and burrowed quartzarenite on the other. Emrich (1966) traced certain of the burrowed beds for as much as 100 miles in the outcrop area of western Wisconsin which is interpreted to signify a broad and flat shelf bottom on which the effects of storm or quiet were widely impressed.

The Ironton Member thins toward the Wisconsin Dome to the east. At this exposure the Ironton is about 40 feet thick. Traced east and south it thins to disappearance as can be seen at exposures south of Lone Rock in the south bluff of the Wisconsin River. Further to the southeast in northeastern Illinois the Ironton increases to a maximum of 150 feet in thickness (Buschbach, 1964; Emrich, 1966). The Ironton thickens westward into Minnesota. It is assigned a Franconian age on the basis of fossils.

At this exposure the Ironton is in sharp contact with and lithologically markedly different from the overlying fine-grained glauconitic, shaly and thin-bedded Lone Rock Formation of the Tunnel City Group. The Tunnel City Group consists of two distinct facies in the Upper Mississippi Valley area, namely a glauconitic facies, the Lone Rock Formation, and a nonglauconite facies, the Mazomanie Formation (Trowbridge & Atwater, 1934; Wanenmacher et al, 1934; Twenhofel et al, 1935; Ericson, 1951; Berg, 1954; Ostrom, 1966, 1967). The Lone Rock facies intertongues with and is laterally and vertically transitional with the Mazomanie facies in the direction of the Wisconsin Dome (Ostrom, 1966). The Mazomanie facies can be seen at the Mazomanie and Lone Rock stops.

Abundant burrows and trails in the Lone Rock indicate prolific animal life. Thin bedding and fine particles suggest persistent low energy conditions. Occasional beds, up to 2 feet thick and rarely up to 8' thick, of sandstone clasts in a greensand matrix suggest occasional episodes of high energy such as storms. The environment of Lone Rock deposition is interpreted to have been located seaward of that of the Ironton in an area of deeper water and lower overall available energy as attested to by thin beds, fine sediment, abundant fossils and lateral persistence of beds.

The similarity of the lower part of the Lone Rock Formation at this site to the lower part of the Eau Claire at the Eau Claire County Highway "II" stop is believed to be significant. In both cases the upward change is from transitional beds characterized by medium and persistent beds of medium and coarse-grained quartzarenite to fine-grained, shaly glauconitic sandstone with abundant trail markings on bedding surfaces. The two units are interpreted as the manifestation of a single environment repeated by two episodes of transgression separated by a minor regression which is marked by the Galesville Sandstone and the erosion surface at its base (Ostrom, 1964).

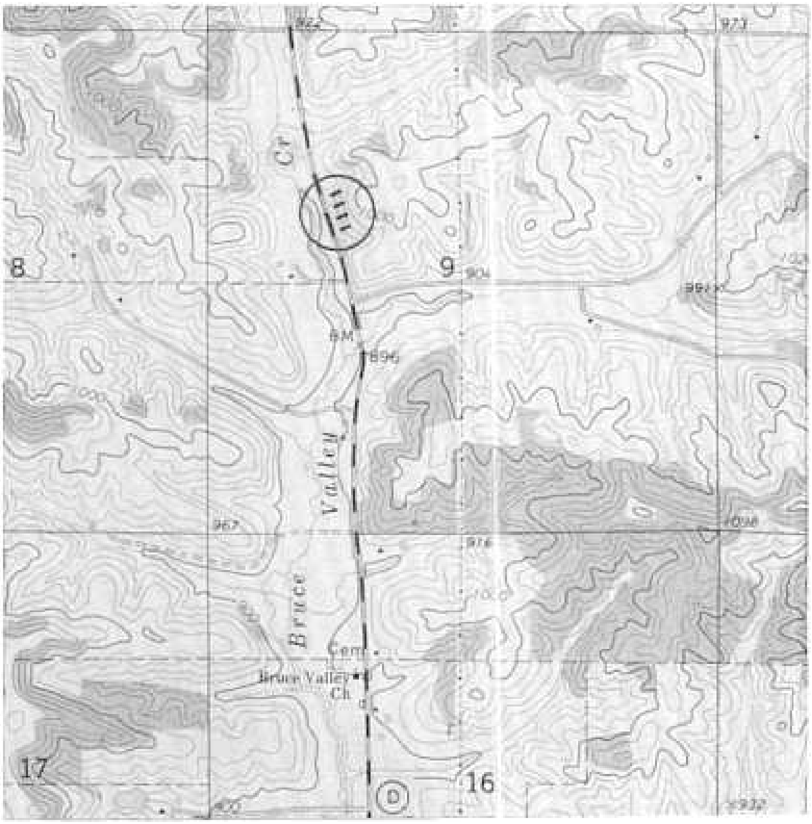
Significance: This stop illustrates the contact relationship of the first and second "cycles" as described in the discussion of the Bruce Valley Quarry Stop. Also, it affords an opportunity to examine and compare three "lithotopes" of the second cycle equivalent to lithotopes of the first cycle seen at previous stops (Irvine Park, Mt. Simon, Eau Claire County Highway "II", Strum, and Bruce Valley Quarry).

How do you interpret the contact between the Eau Claire and Wonewoc Formation? Between the Galesville and Ironton members? Between the Wonewoc and Lone Rock Formations? What are the mineralogical and lithological differences between the various members and functions? What do they signify in terms of source of sediments and environments of deposition? What are differences and similarities of texture, bedding, sedimentary structures, and fossil content of the various members and formations? What do they signify in terms of environments of deposition?

References: Trowbridge and Atwater, 1934; Wanenmacher, Twenhofel, and Raasch, 1934; Twenhofel, Raasch, and Thwaites, 1935; Ericson, 1951; Emrich, 1966; Berg, 1954; Buschbach, 1964; Ostrom, 1964, 1966, 1967, 1969 & 1970; Asthana, 1968.

Title: Bruce Valley Quarry

Location: Abandoned quarry located at east side of County Highway "D" 1.2 miles north of Bruce Valley Church in the NE$\frac{1}{4}$, SE$\frac{1}{4}$, NW$\frac{1}{4}$, of Sec. 9, T.23N., R.8W., Trempealeau County (Pleasantville 7.5-minute topographic quadrangle, 1973).



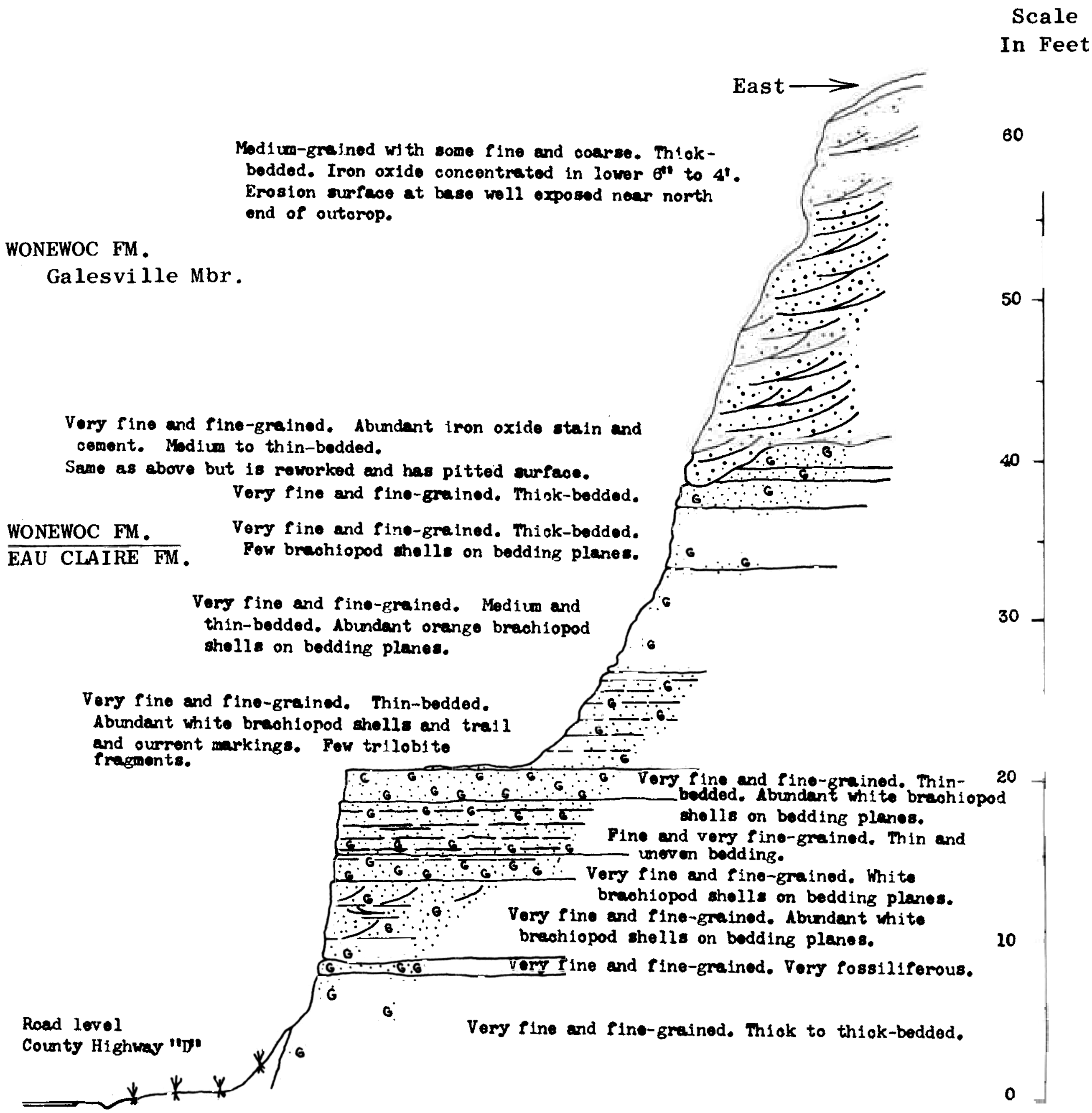
Author: M. E. Ostrom (modified from Ostrom, 1970)

Description: At this stop the contact of the Eau Claire Formation with the overlying Galesville Formation is marked by an unconformity which is especially well shown near the top at the north end of the quarried face. The unconformity is interpreted to signify retreat of the sea and subareal erosion. The Galesville is believed to have formed by a process of intermingling of beach deposits during the succeeding transgressive episode (Ostrom, 1964) during which the sea advanced over the eroded land surface.

Close examination of this contact indicates sharp and marked lithologic and/or textural change and often erosion of the top of the Eau Claire. The lower few feet of the Galesville quite often contains clasts of Eau Claire sandstone and shale. An excellent example of these features will be seen at the Galesville stop, the type section of the Galesville Formation.

Additional discussion of the relationships and significance of the rocks shown at this exposure is given in the discussion of the Irvine Park Stop.

Bruce Valley Quarry
NE$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 9, T. 23N., R. 8W



Horizontal to vertical scale approx. 1:2

Significance: Previous stops at Irvine Park, Mt. Simon, Rest Haven Gardens Town Road, and Strum have established a sequence of lithologic types that is repeated five times in the Cambrian and Ordovician sections of Wisconsin. The repetition is interpreted (Ostrom, 1964) to signify a cyclical pattern of geologic events, environmental conditions, sedimentation, and rock formation. Each cycle consists of four major rock types called lithotopes and is commonly bounded at top and bottom by an erosion surface which marks an unconformity. The basal unit of a cycle is an orthoquartzite sandstone such as the Mt. Simon, which was deposited in a shallow nearshore marine environment as the sea advanced over the eroded land surface.

This is succeeded by a transitional zone, such as in the upper 40 feet of the Mt. Simon, which consists primarily of alternating beds of poorly-sorted silty sandstone which has been disturbed by burrowing animals and of well-sorted coarse-grained and cross-bedded sandstone. Commonly small phosphatic brachipod shells are present and rarely trilobites are present. This unit is interpreted to have formed offshore in an area of deeper water, slow to no deposition, and alternating periods of higher and lower wave and current activity.

It is overlain by a unit, such as the Eau Claire Formation, which consists of calcareous and shaly fine-grained, fossiliferous, glauconitic, and thin-bedded sandstone and of pale green shale that is calcareous, sandy, and silty with scattered glauconite, and is locally fossiliferous. This unit is interpreted to have formed in a low energy area of slow but essentially continuous deposition on a continental shelf area seaward of the zone previously described. Occasional storm episodes produced high energy which caused materials to be torn from the bottom and incorporated in overlying sediment layers.

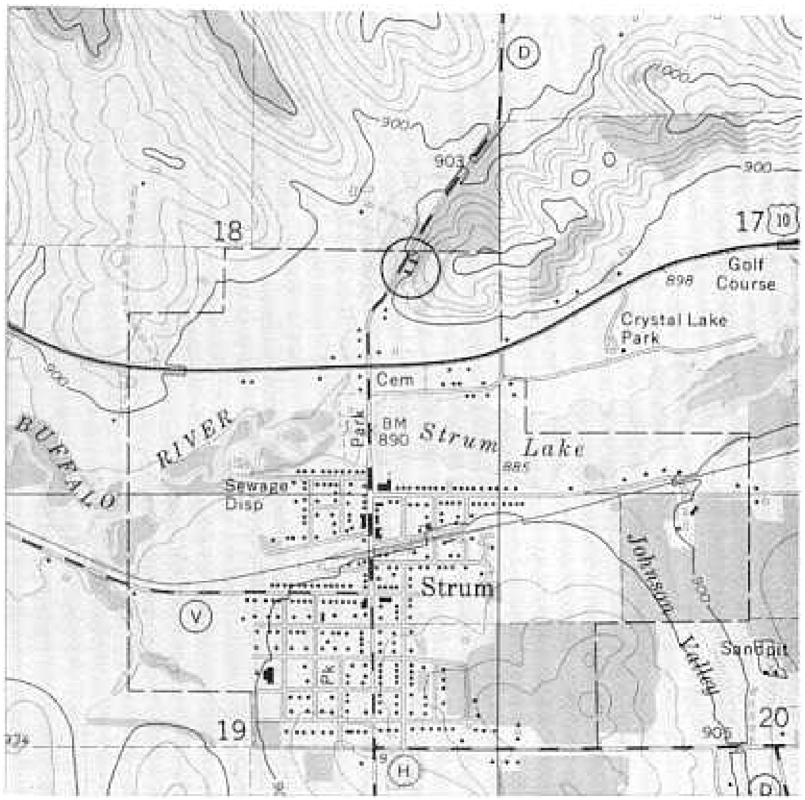
The fourth unit of a cycle is not present in the first cycle. It consists of carbonate rocks formed as layers of fossil debris and reef interbeds on top of other shelf sediments. If one traces the Eau Claire Formation south into Illinois and Missouri it is overlain by such a deposit, namely the Bonneterre Dolomite Formation.

At this exposure the contact of the first cycle with the second cycle is well exposed. How do you interpret this contact? Why is there no carbonate rock at the top of the first cycle? How was the abrupt lithologic change from one cycle to the next produced? Examine the Galesville Sandstone closely. How does it differ from the Mt. Simon Sandstone? In what ways is it similar to the Mt. Simon? How do you explain glauconite in the Eau Claire Formation?

References: Twenhofel, Raasch, and Thwaites, 1935; Ostrom, 1964 and 1970.

Title: Strum North

Location: Abandoned quarry at east side of County Trunk Highway "D" 0.2 miles north of its junction with Highway 10 at the north edge of the Village of Strum in the NE$\frac{1}{4}$, NE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 18, T.24N., R.8W., Trempeleau County (Strum 7.5-minute topographic quadrangle, 1973).



Author: M. E. Ostrom (modified from Ostrom, 1966 and 1969, and Morrison, 1968).

Description: This stop is one of the better exposures of the Eau Claire Formation in Wisconsin and is intended to show characteristics of lithology and paleontology As one proceeds eastward across Wisconsin this lithology is lost. It is believed that the Eau Claire lithology is at least in part laterally transitional with that of the Galesville and Mt. Simon as was described by Twenhofel, Raasch, and Thwaites (1935). It is also believed that its disappearance eastward is in part due to pre-Galesville erosion as is discussed under the Bruce Valley Quarry Stop. In support of this latter contention it must be stated that Twenhofel, Raasch, and Thwaites (op. cit) indicated the Eau Claire can be subdivided into two faunal zones in this area and that traced eastward these disappear, first the upper and then the lower, suggesting a cut-off at the top of the Eau Claire. If the Eau Claire was deposited during transgression as is now believed, then it is difficult to explain an apparent off-lap of beds except by post-Eau Claire erosion.

CAMBRIAN SYSTEM
(ST. CROIXAN SERIES - DRESBACHIAN STAGE)
ELK MOUND GROUP
EAU CLAIRE FORMATION (57.5')

13.	49.5-57.5'	8.0'	Sandstone, light yellowish-gray, fine and very fine-grained, very glauconitic, weathers as thick-bedded unit but is thin- to medium-bedded. Contains fossil fragments, especially oboloid brachiopods.
12.	43.0-49.5'	6.5'	Sandstone, light yellow-brown, fine and very fine-grained, little glauconite, thin- to thick-bedded, few green shale partings. Abundent Crepicephalus and other darker fossils materials including brachiopods. Grades down to
11.	37.5-43.0'	5.5'	Sandstone, yellow-brown, fine and very fine-grained, trace of glauconite, mostly thick-bedded. Contains Crepicephalus in upper thin-bedded portion - Cedaria in lower part.
10.	36.5-37.5'	1.0'	Siltstone, clayey, gray-green interbedded with fine-grained sandstone.
9.	35.0'-36.5'	1.5'	Sandstone, light yellow-gray, fine- and very fine-grained, glauconitic, appears thick-bedded but weathers thin-bedded near top. Contains trilobite fragments.'
8.	33.0-35.0'	2.0'	Sandstone, similar to above but thinner bedded and more irregularly bedded with clay partings. Abundant trilobite fragments.
7	29.0-33.0'	4.0'	Sandstone, bright yellowish-gray, fine and very fine-grained, glauconitic, thick-bedded but weathers thin-bedded near top. Contains trilobite fragments.
6	25.5-29.0'	3.5'	Sandstone, clayey, yellowish-brown, mottled gray, thin and irregular bedding, soft, with thin clay seam at bottom.
5.	22.5-25.5'	3.0'	Sandstone, yellowish-gray, fine and very fine-grained, glauconitic, thick-bedded, hard, may thin to less than 2 feet.
4.	17.5-22.5'	5.0'	Sandstone, light gray-brown, fine to very fine-grained, slightly glauconitic, micaceous, thin-bedded, irregular bedding in upper 1 foot.
3.	13.5-17.5'	4.0'	Claystone, very silty, dark gray, micaceous, bedded, interbedded with few very fine-grained sandstone layers. Very soft.
2.	6.0-13.5'	7.5'	Sandstone, light gray-brown, fine to very fine-grained, thin-bedded with thicker beds in top, slightly glauconitic, micaceous, abundant animal trails.
1.	0.0- 6.0'	6.0'	Sandstone, light gray-brown, fine to very fine-grained, thin-bedded, slightly glauconitic, micaceous, numerous trails markings. Trace of Cedaria throughout.

Quarry floor.

Significance: The Eau Claire Formation is the oldest major fossil-bearing formation in Wisconsin. Rocks of Precambrian age were first studied in the Upper Mississippi Valley area from where all of the formation names were taken. Although early subdivisions were based on lithology, later study produced a classification based on paleontology and especially on zonation using trilobite. Thus, the Eau Claire was subdivided in ascending order into the Cedaria, Crepicephalus, and Aphelaspis zones. The youngest, or Aphelaspis zone, is not present in this area. Sketches of Cedaria and Crepicephalus are shown below. What is the significance of focal zones? Find the contact of the two zones at this stop. How do you interpret such contacts? Supposedly, the zones do not overlap. Why is there no overlap? Or can you demonstrate overlap? What is the environmental, geological and ecological significance of such a contact?

References: Twenhofel, Raasch, and Thwaites, 1935; Thwaites, 1935; Ostrom 1964, 1966, and 1970; Morrison, 1968.

St. Lawrence and Jordan formations (Upper Cambrian) south of Arcadia, Wisconsin

M. E. Ostrom, Wisconsin Geological and Natural History Survey, 3817 Mineral Point Road, Madison, Wisconsin 53705

LOCATION

Composite section from outcrops and quarries located along Wisconsin 93 (Fig. 1) and extending from 1.8 mi (2.9 km) to 3.5 mi (5.6 km) south of its intersection in Arcadia with Wisconsin 95, in the W½,NW¼,Sec.9,T.20N.,R.9W., Trempeauleau County (Tamarack 7½-minute Quadrangle, 1973).

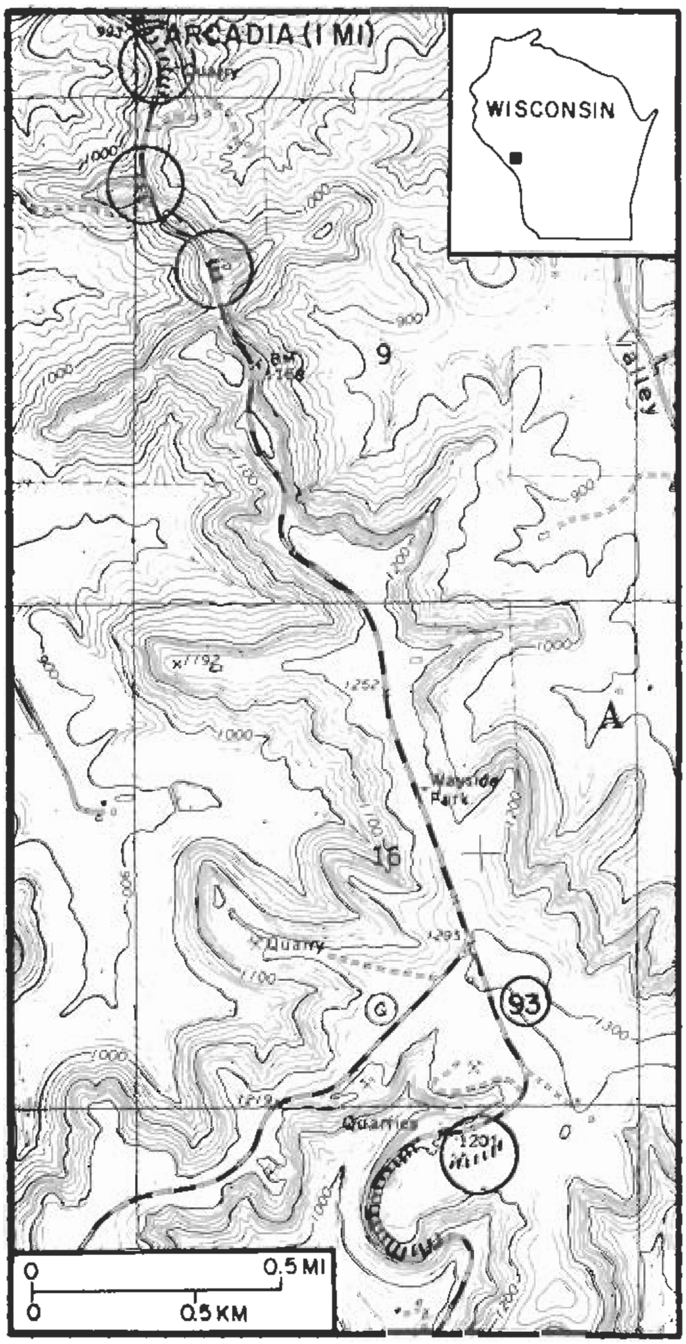


Figure 1. Map showing location of exposures discussed in text.

SIGNIFICANCE

This stop is an excellent exposure of the St. Lawrence and Jordan formations (Fig. 2). It also illustrates one of the problems in the Upper Cambrian stratigraphy in Wisconsin, namely determining the limits and relationships of the Black Earth Dolomite and Lodi Siltstone members of the St. Lawrence Formation. This stop illustrates the contact relationship of the Lone Rock Formation with the St. Lawrence Formation and of the second and third cycles of sedimentation in the Cambro-Ordovician of Wisconsin. It also illustrates a major economic use of Wisconsin's dolomite formations.

DESCRIPTION

Nelson (1956) studied these units in the upper Mississippi valley area. He defined the Black Earth as " . . . sandy dolomite and interbedded dolomitic siltstone and fine-grained sandstone. In the vicinity of Black Earth and Madison, and at localities along the Mississippi Valley, it generally is massive, brown to buff, slightly glauconitic . . . (with) . . . algal structures locally" (p. 173). The Lodi Member consists of " . . . siltstone, generally dolomitic, and dolomitic sandstone" (p. 173).

The fact that his definitions indicate that both the Black Earth and the Lodi can consist of dolomitic siltstone and fine-grained sandstone is the reason why it is commonly very difficult to distinguish the two members. Here Nelson assigned the lower 17 ft (5 m) of the St. Lawrence to the Lodi, the middle 12-ft (3.7 m) portion to the Black Earth, and an overlying 15-ft (4.5 m) section to the Lodi for a total thickness of about 44 ft (13 m). Close examination of the outcrop shows that if a Black Earth Dolomite occurs here, it is probably the 7 ft (2.1 m) of very silty dolomite in the interval from 19 ft (5.8 m) to 26 ft (7.9 m) above the base of the exposure. However, there does not appear to be any marked difference in lithology to suggest the presence of Black Earth rather than Lodi. The Wisconsin Geological and Natural History Survey recognizes the Black Earth as a medium to thick-bedded, medium to coarsely crystalline dolomite that is locally silty, sandy, and glauconitic, with fossil algae. With the possible exception of several thin beds, all of the St. Lawrence Formation at this exposure is assigned to the Lodi Member.

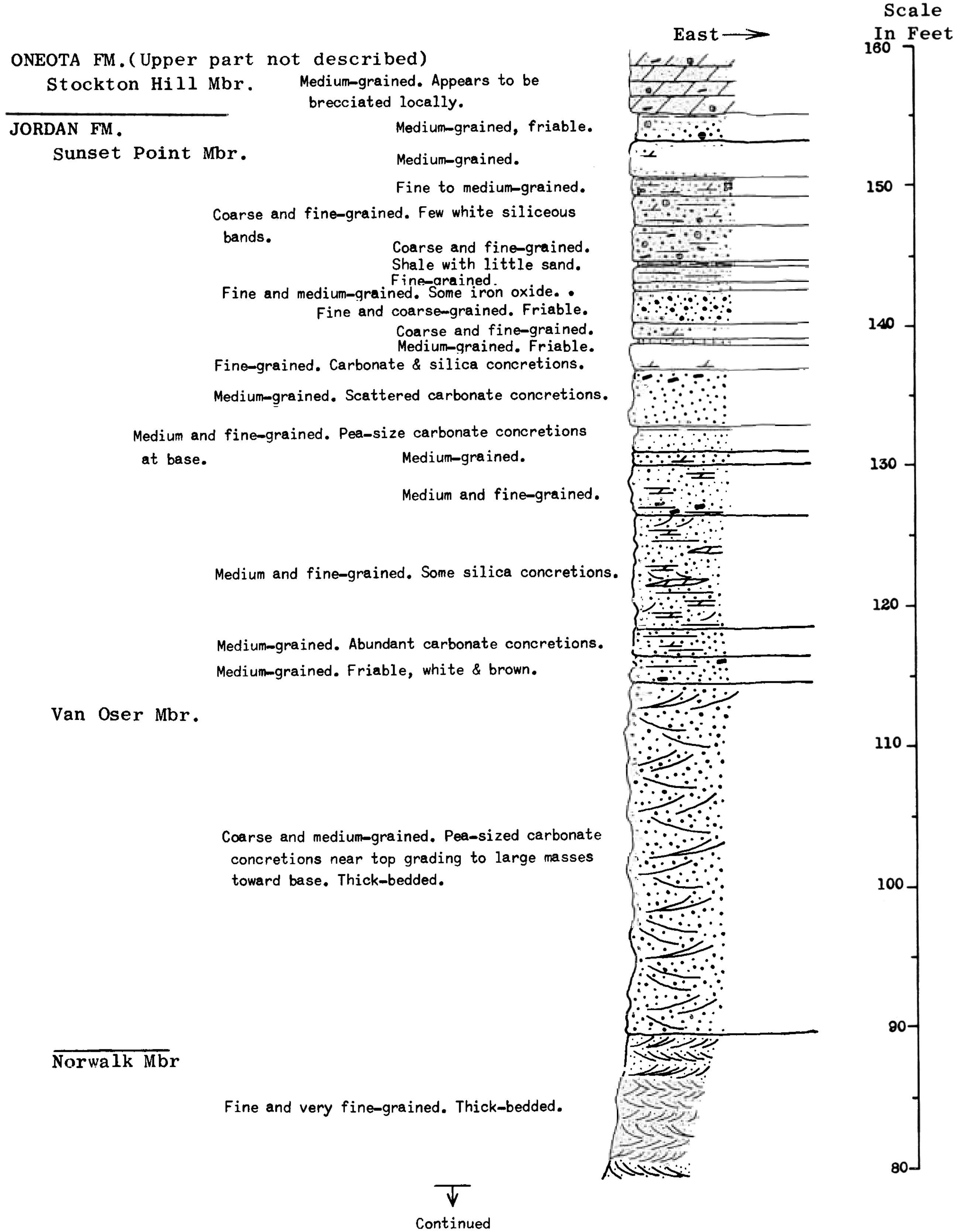
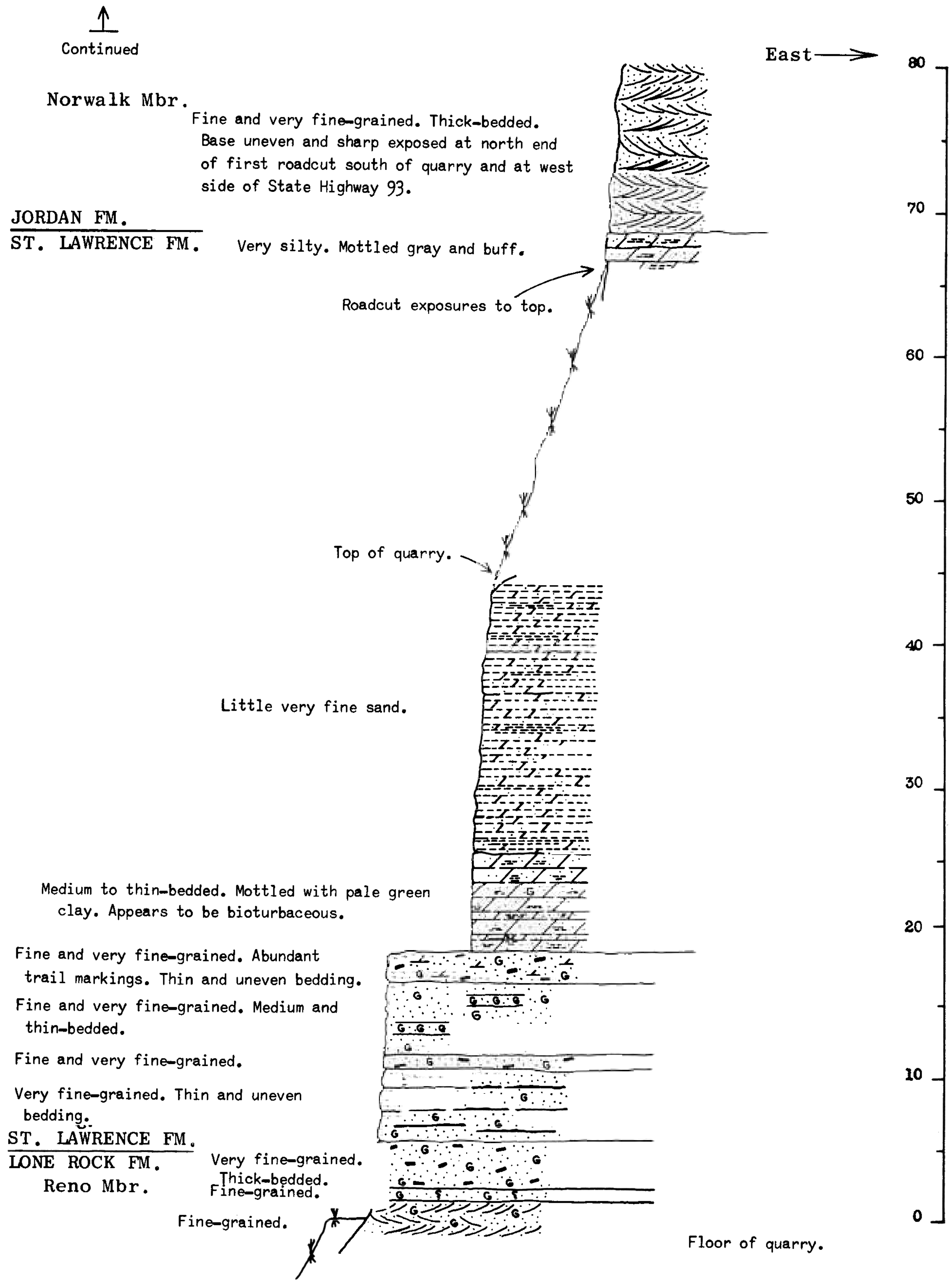


Figure 2. Stratigraphy of Cambrian rocks exposed in NW¼,Sec.9,T.20N.,R.9W., Tamarack 7½-minute Quadrangle (Fig. 1).


Continued
East
80
70
60
50
40
30
20
10
0
Norwalk Mbr.
Fine and very fine-grained. Thick-bedded. Base uneven and sharp exposed at north end of first roadcut south of quarry and at west side of State Highway 93.
JORDAN FM.
ST. LAWRENCE FM.
Very silty. Mottled gray and buff.
Roadcut exposures to top.
Top of quarry.
Little very fine sand.
Medium to thin-bedded. Mottled with pale green clay. Appears to be bioturbaceous.
Fine and very fine-grained. Abundant trail markings. Thin and uneven bedding.
Fine and very fine-grained. Medium and thin-bedded.
Fine and very fine-grained.
Very fine-grained. Thin and uneven bedding.
ST. LAWRENCE FM.
LONE ROCK FM.
Reno Mbr.
Very fine-grained.
Thick-bedded.
Fine-grained.
Fine-grained.
Floor of quarry.

The Norwalk Member of the Jordan Formation consists of very fine and fine-grained nonsilty sandstone, which is thick bedded to thin bedded. At this exposure it is separated from the underlying silty and dolomitic Lodi by a sharp and uneven surface interpreted to indicate post-Lodi erosion. At the majority of outcrops of this interval in Wisconsin, the contact appears to be completely gradational. The Norwalk and Van Oser members constitute a thick body of sandstone similar in character to the Galesville Formation(?) and other Cambrian and Ordovician sandstones of this region. This suggests that the Jordan probably had a similar origin, namely that it formed on an erosion surface by a process of coalescing of beach deposits in a transgressing sea. In at least this area, erosion was a minor factor.

The Van Oser Member of the Jordan Sandstone is characterized by medium-grained sandstone, with some coarse and a little fine. The contact of the Van Oser with the Norwalk is commonly, though not always, sharp. At this exposure the contact is slightly uneven. Contact relations of overlying beds are best examined elsewhere.

Field study by McGannon (1960) led him to propose the name Stockton Hill Formation for those strata between the Lone Rock Formation below and Jordan Formation above. The top of the Lone Rock is marked by 3 ft (1 m) of flat-pebble conglomerate overlain by 0.7 ft (0.2 m) of "wormstone," a burrowed, glauconitic, calcareous fine-grained sandstone. McGannon's Stockton Hill Formation extends 36.7 ft (11.2 m) upward to 6.4 ft (2 m) below the top of the quarried section. The lower 24.1 ft (7.3 m) are assigned to the Lodi Member; the upper 12.6 ft (3.8 m) to what he has named the Red Wing Member. The upper 6.4 ft (2 m), which he assigned to the Jordan Formation, contains from 28 to 50 percent carbonate and from 35 to 50 percent silt and finer particles, although this does not conform to other descriptions of the Jordan. The contact with fine-grained Jordan Sandstone containing only minor carbonate and silt can be observed in the first roadcut above the quarry and west of Wisconsin 93. It is believed that this is the actual contact. The Wisconsin Geological and Natural History Survey retains the name St. Lawrence Formation for what McGannon proposes to call the Stockton Hill Formation and assigns all of the St. Lawrence at this exposure to the Lodi Member.

The Jordan Sandstone is divided on the basis of composition, texture, and bedding characteristics into three members: the lower Norwalk, the middle Van Oser, and the upper Sunset Point. These can be traced throughout southwestern Wisconsin and into eastern Minnesota and Iowa.

The Jordan Sandstone is overlain by the Oneota Dolomite Formation of the Prairie du Chien Group.

Quarries in the Oneota Formation are located along Wisconsin 93 south of the Jordan Sandstone outcrops and at the crest of the ridge that forms the Skyline Drive. The Oneota is a primary source of crushed stone used for construction throughout much of southern Wisconsin. This is a "portable operation;" the crushing and processing equipment is portable, as opposed to stationary.

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Cambrian stratigraphy at Whitehall, Wisconsin

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LOCATION

Road cuts north of Whitehall on Trempealeau County Highway "D" and 1.7 mi (2.7 km) north of its juncture with Wisconsin 53 in the SW¼,SW¼,Sec.12,T.22N.,R.8W., Trempealeau County, on the Pleasantville 7½-minute Topographic Quadrangle, 1973) (Fig. 1).

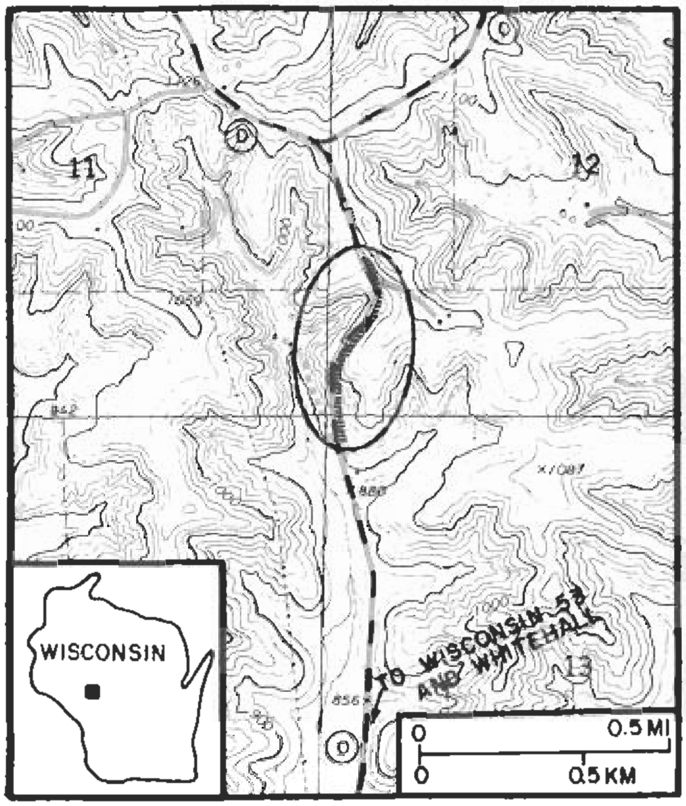


Figure 1. Map showing location of exposures discussed in text.

SIGNIFICANCE

This stop illustrates the contact relationship of the first and second sedimentary cycles in the Cambro-Ordovician rocks of Wisconsin (Ostrom, 1964, 1970). Also, it affords an opportunity to examine and compare three "lithotopes" of the second cycle equivalent to lithotopes of the first cycle, which can be seen at Irvine Park, Mount Simon, and Strum.

DESCRIPTION

This is an excellent exposure to show the interrelationships of the various Cambrian lithostratigraphic units, beginning with the Eau Claire Formation at the base and extending upward into the Lone Rock Formation (Fig. 2). The section is complete except for about 15 ft (4.5 m) of covered interval midway in the Ironton Member.

Beginning with the sharp and unconformable contact of Galesville on Eau Claire near the base, one can proceed upward through the remainder of the section without evidence of major erosional break.

Regionally, the Eau Claire Formation thins to the east until, in the vicinity of Wisconsin Dells, it is not recognized. North and northwest of the Dells, what is believed to be thin Eau Claire can be seen at Friendship Mound, north of Friendship, and at Sheep Pasture bluff located south of Mauston.

At Friendship Mound there is a 1-ft (0.3 m) bed of fine-grained, silty, iron-oxide–cemented sandstone that separates two thick-bedded, medium-grained, well-sorted sandstone units. The upper of these two units is positively identified as the Galesville Sandstone. At Sheep Pasture Bluff the situation is similar except that the thickness assignable to the separating unit is 7 ft (2 m) and it contains only minor iron oxide. Also at Sheep Pasture Bluff, sandstone clasts occur in the base of the Galesville. A possible interpretation is that the separating unit is the Eau Claire Formation, thinned by pre-Galesville erosion, and that the lower sandstone is the Mount Simon.

A study by Asthana (1969) indicates that the feldspar content of the Mount Simon Sandstone ranges from 3 to 40 percent and averages 18 percent. On the other hand, it is known from numerous analyses of the Galesville Sandstone that it seldom contains more than 1 percent feldspar. Asthana determined that the feldspar content of the sandstone unit below the Eau Claire is higher than that above by a factor of 2 at Sheep Pasture Bluff and of 9 at Friendship Mound. This sharp decrease in feldspar content corresponds to a similar difference between the feldspar content of the Mount Simon and Galesville sandstones elsewhere and is interpreted to indicate that at these exposures the Eau Claire is much reduced in thickness, probably due to post–Eau Claire erosion. Thus, the Eau Claire apparently thins eastward due to pre-Galesville erosion.

The Eau Claire–Galesville contact marks the end of one transgressive/regressive sequence and the beginning of the transgressive phase of the subsequent sequence (Ostrom, 1964). The Galesville Sandstone formed during transgression as the result of a process of coalescing of shallow marine near-shore deposits. Rather persistent high-energy conditions are indicated by a noticeable lack of clay, silt, and very fine sand, and the paucity of fossils.

Overlying and transitional with the Galesville is the Ironton Member. The Ironton is interpreted to have formed in an environment located seaward of the beach, where high- and low-energy conditions alternated. Whereas the Galesville is thick bedded, the Ironton is medium bedded and even bedded. Silt and other fine particles are abundant in certain beds. Burrows are common and fossils are present locally. Also, there is commonly

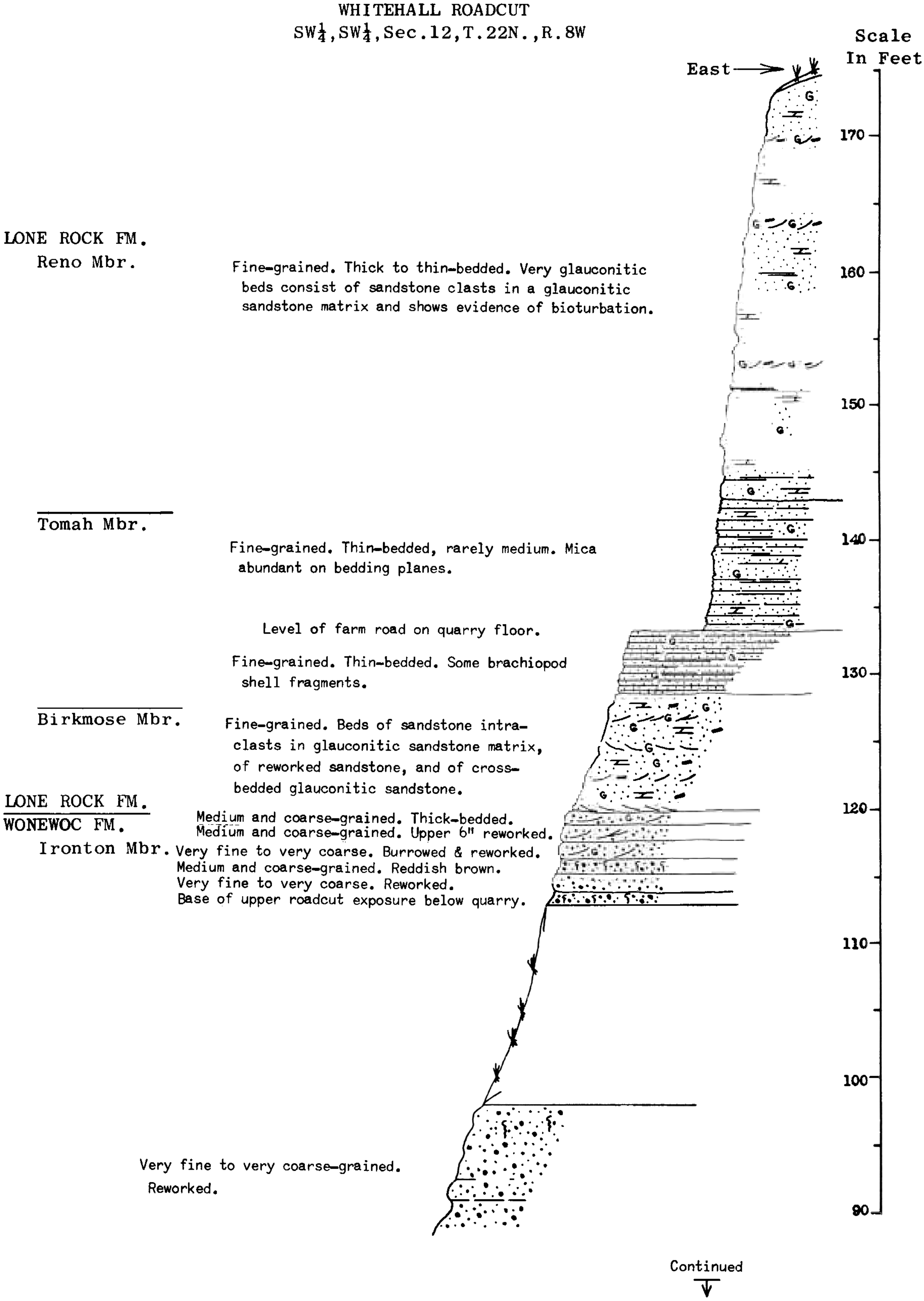
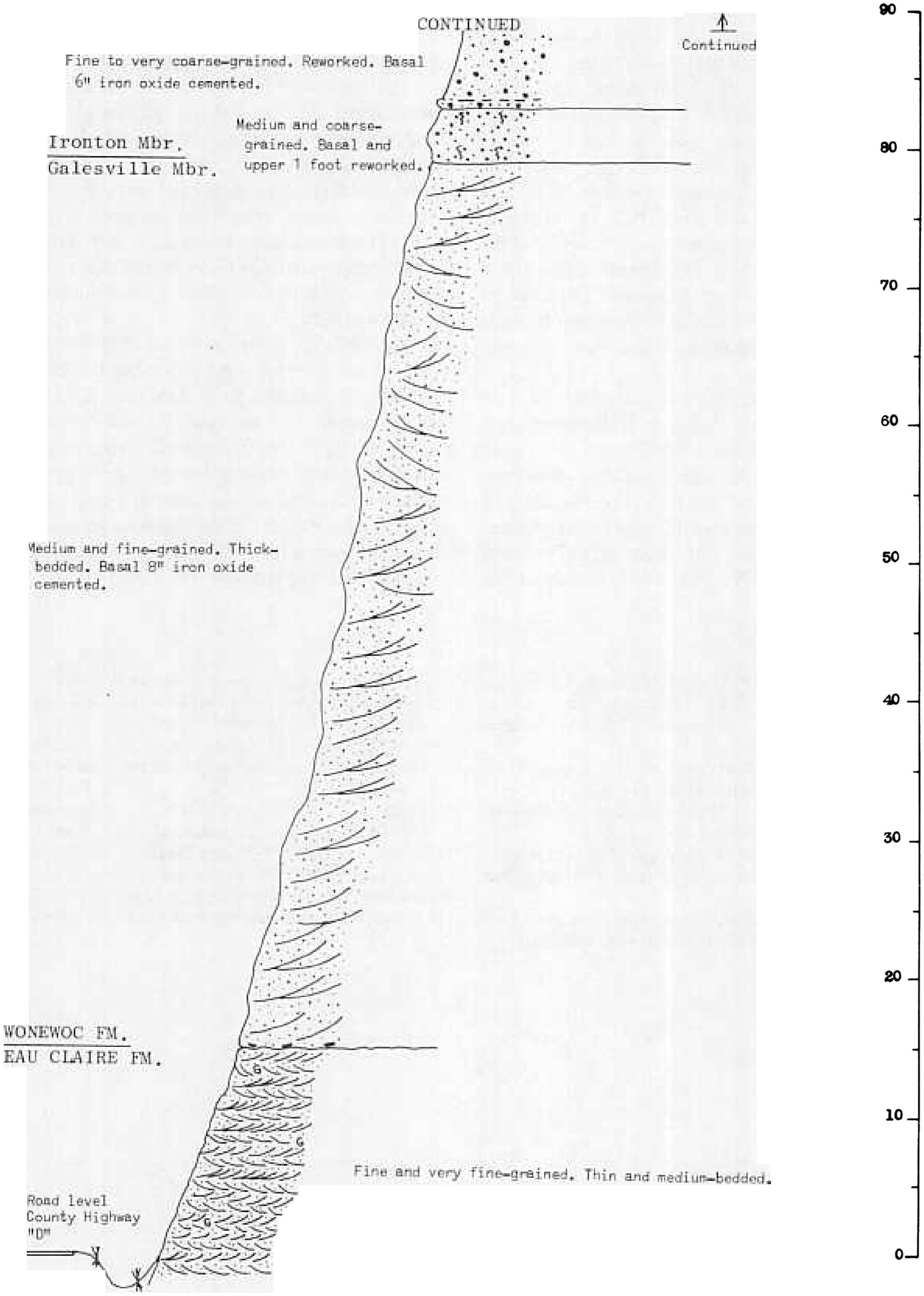


Figure 2. Stratigraphy of Cambrian rocks exposed in SW¼,Sec.12T.22N.,R.8W., Pleasantville 7½-minute Quadrangle (Fig. 1).


CONTINUED
Continued
Fine to very coarse-grained. Reworked. Basal 6" iron oxide cemented.
Medium and coarse-grained. Basal and upper 1 foot reworked.
Ironton Mbr.
Galesville Mbr.
Medium and fine-grained. Thick-bedded. Basal 8" iron oxide cemented.
WONEWOC FM.
EAU CLAIRE FM.
Fine and very fine-grained. Thin and medium-bedded.
Road level County Highway "D"
G
90
80
70
60
50
40
30
20
10
0

carbonate cement and glauconite in the upper few feet of the unit. Beds alternate between well-sorted, clean, medium- and coarse-grained, cross-bedded quartzarenite and poorly sorted, reworked and burrowed quartzarenite. Emrich (1966) traced certain of the burrowed beds for as much as 100 mi (160 km) across western Wisconsin, which suggests a broad and flat shelf bottom on which the effects of storm or quiet were widely impressed.

The Ironton Member thins eastward toward the Wisconsin Arch. At Whitehall, the Ironton is about 40 ft (12 m) thick. Traced east and south it thins to disappearance in the bluffs of the Wisconsin River south of Lone Rock. In northeastern Illinois, the Ironton thickens again to a maximum thickness of 150 ft (46 m) (Buschbach, 1964; Emrich, 1966). The Ironton also thickens westward into Minnesota. It is assigned a Franconian age on the basis of fossils.

At Whitehall the Ironton is in sharp contact with the overlying fine-grained glauconitic, shaly and thin-bedded Lone Rock Formation of the Tunnel City Group. The Tunnel City Group consists of two distinct facies in the upper Mississippi valley area, namely a glauconitic facies, the Lone Rock Formation, and a nonglauconite facies, the Mazomanie Formation (Trowbridge and Atwater, 1934; Wanenmacher and others, 1934; Twenhofel and others, 1935; Ericson, 1951; Berg, 1954; Ostrom, 1966, 1970). The Lone Rock facies intertongues with and is laterally and vertically transitional with the Mazomanie facies in the direction of the Wisconsin Arch (Ostrom, 1966).

Abundant burrows and trails in the Lone Rock indicate prolific animal life. Thin bedding and fine particles suggest persistent low-energy conditions. Occasional beds, up to 2 ft (0.6 m) thick and rarely up to 8 ft (2.4 m) thick, of sandstone clasts in a greensand matrix suggest occasional episodes of high energy such as storms. The environment of Lone Rock deposition is interpreted to have been located seaward of that of the Ironton in an area of deeper water and lower overall available energy, as attested to by thin beds, fine sediment, abundant fossils, and lateral persistence of beds.

The similarity of the lower part of the Lone Rock Formation at this site to the lower part of the Eau Claire is believed to be significant. In both cases the upward change is from transitional beds characterized by persistent beds of medium and coarse-grained quartzarenite to fine-grained, shaly glauconitic sandstone with abundant trail markings on bedding surfaces. The two units are interpreted as the manifestation of a single environment repeated by two episodes of transgression separated by a minor regression, which is marked by the Galesville Sandstone and the erosion surface at its base (Ostrom, 1964).

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Late Cambrian Eau Claire Formation at Strum, Wisconsin

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LOCATION

Abandoned quarry at east side of County Trunk Highway D 0.2 mi (0.3 km) north of its junction with U.S. 10 at the north edge of the village of Strum in the NW¼,NE¼,SE¼,Sec.18, T.24N.,R.8W., Trempealeau County, Wisconsin, Strum 7½-minute Quadrangle (Fig. 1).

Figure 1. Location of exposure at Upper Cambrian Eau Claire Formation in abandoned quarry north of Strum, Wisconsin.

SIGNIFICANCE

This is one of the better, and certainly one of the most accessible, exposures of the Eau Claire Formation in Wisconsin (Ostrom, 1978). The Eau Claire Formation was named by Wooster (1882, p. 109) in referring to "Eau Claire Trilobite Beds" exposed in Eau Claire, Wisconsin. It is assigned to the Upper Ironton Dresbachian Stage on the basis of its trilobite fauna. In ascending order the trilobite assemblage zones in the Dresbachian are the *Cedaria, Crepicephalus, Aphelaspis,* and *Dunderbergia.* The Eau Claire strata in the region have been characterized faunally by the presence of the Upper Cambrian trilobite genera *Cedaria* and *Crepicephalus* (Ulrich, 1914, p. 354). The *Aphelaspis* Zone is known only from outcrops in the city of Hudson at the west edge of Wisconsin in the east bluff of the St. Croix River. The *Dunderbergia* Zone is not present in Wisconsin. In addition to being faunally zoned, the Eau Claire Formation has been subdivided on the basis of lithology. Morrison (1968, p. 21) subdivided the formation into five distinct lithologic units principally on the basis of bedding character and clay content. The lithologic units are:

E. Upper Massive Beds (±20 ft; 6 m). Sandstone; fine and very fine grained, light yellowish gray to brownish and greenish gray, massive and submassive, glauconitic; exposed near Strum and near Whitehall.

D. Upper Thin Beds (±15 ft; 4.5 m). Sandstone; fine and very fine grained, greenish gray; thin bedded; very glauconitic; usually missing.

C. Lower Massive Beds (±25 ft; 8 m). Sandstone, fine and very fine grained, light greenish gray to light brownish gray, thick to massive bedded; may be very glauconitic; few very argillaceous irregularly bedded units separating the more characteristic massive beds.

B. Lower Thin Beds (±20 ft; 6 m). Sandstone, fine and very fine grained, light greenish gray; thin and thick bedded; glauconitic and micaceous.

A. Shaley Beds (±15 ft; 4.5 m). Sandstone shale; dark gray to greenish gray, sandstone very fine and fine grained; very thin bedded; beds less than 3 in (8 cm) thick; very argillaceous.

The Eau Claire Formation is comformable with the underlying Mount Simon Formation. It is believed to represent a transgressive shallow marine shelf depositional environment deposit (Ostrom, 1966; 1970). The formation is unconformable with the overlying Galesville Member of the Wonewoc Formation (Ostrom, 1970). The Eau Claire thins from a thickness of about 90 ft (27 m) in the subsurface of western Wisconsin to zero in outcrops at Sheep Pasture Bluff in Juneau County and at Friendship Mound in Adams County. Thinning is attributed to postdepositional erosion, which produced the unconformity.

At the Strum North exposure the section (Fig. 2) extends from the upper part of lithologic Unit A to near the top of Unit C. In addition, both the *Cedaria* and *Crepicephalus* faunal zones are present and readily distinguishable. The faunal break between the two zones occurs near the base of Unit C. One can speculate that in Wisconsin the reason for the almost complete absence of the overlying *Aphelaspis* Zone, and the complete absence of the succeeding *Dunderbergia* Zone, is that they were removed partially or completely by post–Eau Claire and pre-Galesville erosion. The Eau Claire Formation is succeeded by the Galesville Sandstone Member of the Wonewoc Formation. The Galesville Sandstone is interpreted to have formed in a broad and shallow beach/nearshore environment that transgressed over the eroded Eau Claire surface. The unconformable relationship is clear in an exposure in

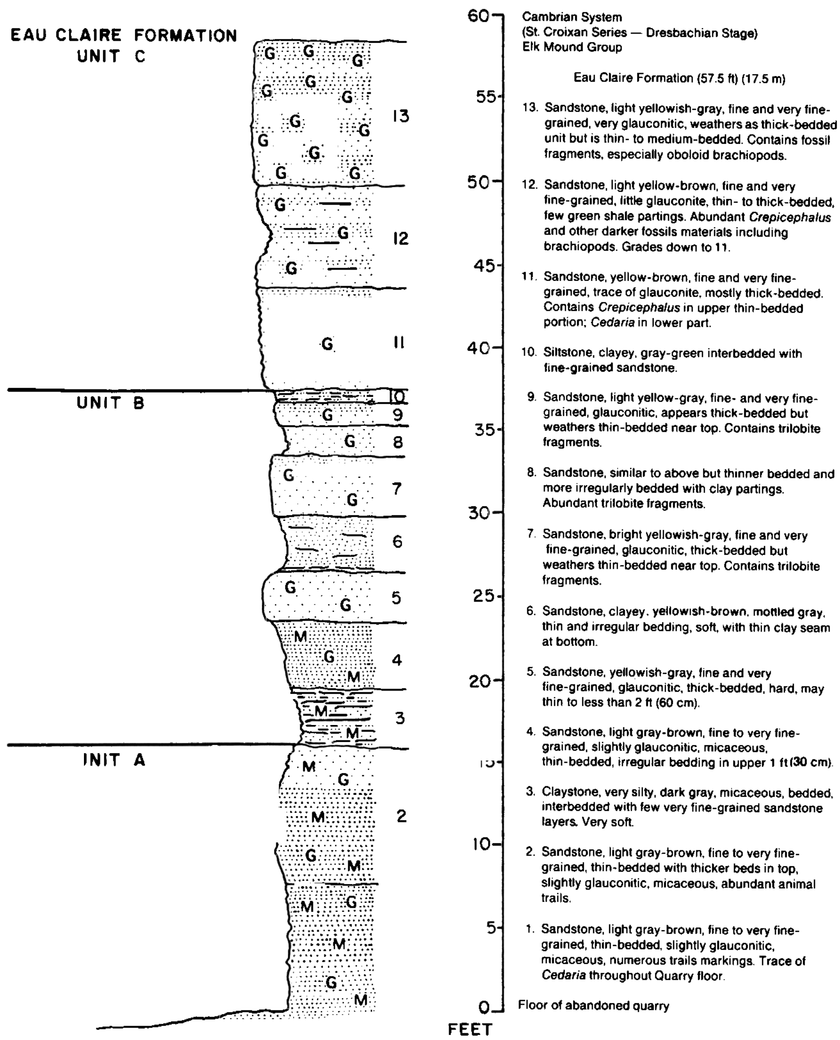

Figure 2. Section exposed in abandoned quarry north of Strum, Wisconsin.

the face of an abandoned quarry in the east bluff of Bruce valley located at the east side of County Highway D about 5 mi (8 km) south-southeast of Strum (NE¼SE¼NW¼Sec.9,T.23N.,R.8W., Trempealeau County, Wisconsin) and in the type section of the Galesville Sandstone, which is in a high and precipitous cliff cut by Beaver Creek where it passes through the city of Galesville about 32 mi (51 km) south of Strum (NE¼NW¼Sec.33, T.19N.,R.8W., Trempealeau County). The Galesville Sandstone is essentially unfossiliferous and is conformable with the overlying Ironton Sandstone, which contains the *Elvinia* fauna of the Franconian Stage. The lack of distinctive fossils in the Galesville Sandstone, its unconformable relationship with the underlying Eau Claire Formation, the eastward thinning and disappearance of the Eau Claire Formation and the conformable relationship of the Ironton Sandstone, which contains the Franconian *Elvinia* fauna, suggest that the Galesville Sandstone should be assigned to the Franconian rather than to the Dresbachian. Viewed from another perspective, it should be noted that no Dresbachian fossils are known to occur above the base of the Galesville Sandstone, which is transitional with strata containing a Franconian Fauna. From this perspective, one can reasonably assign the Galesville to the Franconian rather than to the Dresbachian as has been done traditionally.

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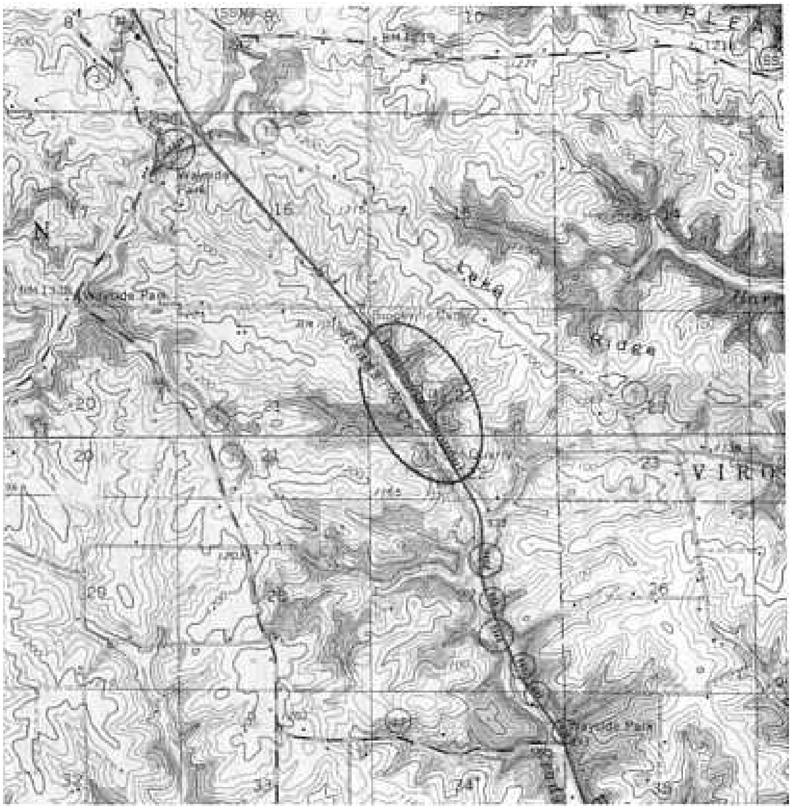
Title: Reads Creek

Location: Exposures in stream and roadcuts along Reads Creek and U. S. Highway 14 between Viroqua and Readstown commencing about 1.5 miles southeast of Viroqua with a roadcut at the north side of Highways 27 and 82 and about 0.1 mile west of junction with U. S. 14 in the NW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 16, T.12N., R.4W., Vernon County (Viroqua 15-minute topographic quadrangle, 1965) and ending with roadcuts just south of the Wayside Park in the SE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 27, T.12N., R.4W., Vernon County (Viroqua 15-minute topographic quadrangle, 1965).



Author: M. E. Ostrom (modified from Ostrom, 1965).

Description: Roadcut on north side of Highway 27-82 about 0.1 mile west of junction with U. S. Highway 14 located 1.5 miles southeast of Viroqua in the NW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec. 16, T.12N., R.4W., Vernon County (Viroqua 15' topographic quadrangle, 1965).

Here a lithologic sequence similar to those seen at Whitehall, Arcadia, and Coon Valley can be seen. It begins at the base with quartz sandstone believed to be the Tonti of Templeton and Willman (1963) and to be lithologically analagous with the Galesville and Van Oser seen at previous stops. This is overlain by a discontinuous and thin layer of poorly-sorted sandstone which is succeeded by 4.5 feet of greenish gray shale. At this stop the poorly-sorted sandstone and the shale are distinct units whereas at previous stops the two lithologies were interbedded. The overlying 4.0 feet of the Pecatonica Member of the Platteville Formation is lithologically analagous with the basal Oneota of previous stops.

The poorly-sorted sandstone and the shale is assigned to the Glenwood Member. The poorly-sorted sandstone attains a maximum thickness of nearly 8 feet near Beetown in Grant County, southwestern Wisconsin, and eastward toward New Glarus in Rock County it thins irregularly due to an uneven basal surface. Its upper contact with the shale is even. In western Wisconsin the shale can be separated into a lower non-calcareous greenish-gray portion and an upper calcareous grayish-brown shale (Templeton & Willman, 1963). The shale and its two subdivisions thin to disappearance eastward to New Glarus, the lower shale persisting the furthest (Ostrom, 1969). In the New Glarus area the shale is absent and the poorly-sorted sandstone is in direct contact with the overlying Pecatonica Dolomite Member of the Platteville Formation. The basal bed of the Pecatonica has been assigned the name Chana by Templeton and Willman. This bed attains a maximum thickness of 20 inches in Wisconsin and consists of sandy dolomite with scattered phosphate pellets in its base. Its occurrence is coincident with the Pecatonica Dolomite.

Although the Glanwood has been assigned to the Platteville by many investigators the reasoning behind such an assignment is questionable. Briefly it can be said that neither lithology nor persistence of beds justify its assignment to the Platteville.

ORDOVICIAN SYSTEM

<u>Platteville Formation</u>

Pecatonica Member (+4 feet)

0' 4'	4'	Dolomite, light yellowish brown, fine- and medium-crystalline, dense, thin- and medium-bedded. Sandy with phosphate pellets in base (Chana member of Templeton & Willman, 1963).

<u>St. Peter Sandstone Formation</u>

Glenwood Member (6.4 feet)

4' - 5.5'	1.5'	Shale, brownish green, slightly dolomitic, silty.
5.5' -10.0'	4.5'	Shale, greenish-gray
10.0' -10.2'	0.2'±0.2'	Sandstone, poorly-sorted, with grains from very coarse sand down to silt.

Tonti Member +15 feet)

10.4' -25.4'+	+15'	Sandstone, light yellowish gray, medium and fine-grained, massive-bedded, cross-bedded.

BASE OF EXPOSURE AT ROAD LEVEL

Proceed southward on Highway 14 for 3.2 miles, 0.3 miles southeast of quarry at east side of highway.

Roadcut on left (east) side of Highway 14 about 4.5 miles southeast of Viroqua in the center of the NE$\frac{1}{4}$, Sec. 27, T.12N., R.4W., Vernon County (Viroqua 15-minute topographic quadrangle, 1965).

At this stop a St. Peter "channel" is exposed. Here the St. Peter Sandstone can be seen to fill what is believed to have been a stream erosion channel cut in the surface of the Oneota Dolomite at a time when the sea had retreated far to the southeast. The sand filling the channels is believed to have been deposited when the sea once again advanced over the land. Each new advance of the sea is marked by the deposition of quartz sand. In the case of this outcrop the erosion surface is an obvious feature because it developed in a resistant rock having a lithology much different from the sandstone deposited on it. In other instances with other cycles the lack of an obvious erosion surface can be explained as the result of that surface having been cut in silts and sands not markedly different from the sands deposited on them by the advancing sea. In such a case it would be difficult if not impossible to identify the surface as being one of erosion.

FROM HERE WALK DOWN HIGHWAY TO FIRST OUTCROP ON WEST SIDE OF HIGHWAY 14.

Roadcuts on both sides of Highway 14 about 4.8 miles southeast of Viroqua in the NW$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 27, T.12N., R.4W., Vernon County (Gays Mills 15' topographic quadrangle, 1966).

This stop differs from those at Arcadia and Coon Valley in that the Sunset Point Member is thinner by three quarters. The name Sunset Point was proposed by Raasch (1952) as a replacement for the name Madison which was previously used for this unit. The exposure here is significant because supposedly the Madison Sandstone does not extend beyond the Madison area. Raasch recognized the Sunset Point in Vernon County and assigned it this name because he believed the name Madison to be preempted for use elsewhere.

ORDOVICIAN SYSTEM

Prairie du Chien Group

Oneota Formation (+32.6 feet)

111.9' - 114.9'	3.0'	Dolomite, gray, finely-crystalline, slightly porous, has "chiton" zones 8" and 20" above base; also scattered white oolitic chert nodules.
111.2' - 111.9'	0.7'	Dolomite, gray, finely-crystalline, dense, thickness varies from 5" to 8"; locally appears to contain cryptozoa.
108.6' - 111.2'	2.6'	Dolomite, massive, gray, medium- and coarsely-crystalline, dense, oolotic, little oolitic white chert 6" above base. Oolites abundant in base and rare in top.
105.6' - 108.6'	3.0'	Dolomite, very light brownish gray, medium- and coarsely-crystalline, dense to slightly porous, medium- to thin-bedded and irregularly-bedded, otherwise massive.

103.8' -	105.6'	1.8'	Dolomite, light gray, medium-crystalline, slightly sandy, massive, with porosity that may be due to fossils (first ledge below top of bluff west side of road). Upper surface has algal structures although this does not show at edges.
101.0' -	103.8'	2.8'	Dolomite, light gray, medium-crystalline, very sandy, has white discontinuous chert bed through midportion. Very sandy 8" below top.
99.6' -	101.0'	1.4'	Dolomite, light gray, finely-crystalline, massive, very oolitic.
99.3'	99.6'	0.3'	Dolomite "breccia".
98.5'	99.3'	0.8'	Algal Dolomite.
97.9'	98.5'	0.6'	Dolomite, brownish gray, medium-crystalline, dense with much green clay in top.
97.2'	97.9'	0.7'	Sandstone, very dolomitic, few oolites, some "green speckled" beds, (clay). Has some clay and finely-crystalline dolomite clasts. Locally much green clay.
96.7' -	97.2'	0.5'	Sandstone, light gray streaked yellowish brown, poorly-sorted, predominantly medium-grained with much fine and very little coarse, silty trace green clay.
95.2'	96.7'	1.5'	Dolomite, light gray, medium-crystalline, massive slightly porous, appears to contain cryptozoa; clastic in upper 6".
93.2'	95.2'	2.0'	Dolomite, very light yellowish brown, medium-crystalline, dense, very oolitic, thin- and medium-bedded where weathered horizontally streaked with thin brown closely spaced and crinkly partings. Lower 2" no oolites.
92.4'	93.2'	0.8'	Sandstone, ripclast, very light yellowish gray to light gray, poorly-sorted, very fine to very coarse clasts of finely-crystalline dolomite and of green shale.
90.4' -	92.4'	2.0'	Dolomite, light yellowish brown, medium-crystalline, very sandy, contains oolitic chert, massive-bedded.
89.6'	90.4'	0.8'	Sandstone ripclast with clasts of dolomitic sandstone and of sandy oolitic dolomite.

88.8' - 89.6'	0.8'	Sandstone, very pale light greenish gray, medium- and fine-grained, massive-bedded, many fucoidal (?) markings. Very argillaceous in basal 6". Upper contact uneven and has very sandy dolomite deposited in depressions.
87.3' - 88.8'	1.5'	Dolomite, light grayish brown, sublithographic to very finely-crystalline, dense, much very fine sand. Beds uneven.
85.8' - 87.3'	1.5'	Sandstone, same as in #18
82.3' - 85.8'	3.5'	Dolomite, gray, massive- to thin-bedded, discontinuous beds, sandy (locally a dolomitic sandstone). Appears brecciated and has considerable distortion of bedding. Highly silicified and brecciated in basal 3" to 12". Laterally beds are even, medium- to thin-bedding, and continuous. (Top of lower ledge west side of road)

CAMBRIAN SYSTEM
Trempealeau Group

Jordan Formation

Sunset Point Member (13.2 feet)

70.3' - 82.3'	12.0'	Sandstone, light gray, medium-grained, massive-bedded and cross-bedded with some green clay along cross beds.
69.3' - 70.3'	1.0'	Dolomite, gray, finely-crystalline, massive-bedded, sandy, some porosity along bedding planes Very sandy at base - slightly sandy at top.
68.1' - 69.3'	1.2'	Sandstone, light yellowish gray, medium- and fine-grained with little coarse, poorly-sorted, silty, very dolomitic, scattered clasts.
65.6' - 68.1'	2.5'	Sandstone ripclast; coarse sand matric, sandy dolomite pebbles, with scattered specks of green clay. Pebbles are flattened and rounded.
64.5' - 65.6'	1.1'	Sandstone, very light gray, coarse- to fine-grained with trace very coarse, poorly-sorted, trace green clay, massive, slightly dolomitic; good reference bed.
63.8' - 64.5'	0.7'	Sandstone, mottled brown and light yellowish brown, fine- to coarse-grained, poorly-sorted, locally cross-bedded.
63.3' - 63.8'	0.5'	Sandstone, light yellowish gray, very fine-grained dolomite, streaked light brown.

62.5' - 63.3'	0.8'	Sandstone ripclast; same as #25
59.0' - 62.5'	3.5'	Sandstone, light yellowish brown, medium- and fine-grained with some coarse, poorly sorted, cross-bedded, becomes finer-grained upward.
58.9' - 59.0'	0.2/0.1'	Sandstone, brown and yellowish brown, fine- to coarse-grained, poorly-sorted, very argillaceous, iron-enriched in base, scolithic.
58.5' - 58.9'	0.5/0.2'	Sandstone, light gray, very coarse- to very fine-grained, trace silt, poorly-sorted, conglomeratic.
		Van Oser Member - +15.0 feet
43.5' - 58.5'	15.0'	Sandstone, light yellowish gray to light yellowish brown, medium-grained, with some fine and trace of coarse, well-sorted, massive-bedded and cross-bedded.

BASE OF EXPOSURE

Return to cars and proceed southeast on Highway 14 to Wayside opposite County Highway "J" in the SW$\frac{1}{4}$, NO$\frac{1}{4}$, Sec. 35, T.12N., R.4W., Vernon County. (Gays Mills 15-minute topographic quadrangle, 1966). Walk north about 0.4 miles to first outcrop located at the east side of Highway 14 in SE$\frac{1}{4}$, SE$\frac{1}{4}$, Sec. 27, T.12N., R.4W. Description begins at base of Sunset Point Member which forms prominent ledge at top of exposure.

CAMBRIAN SYSTEM
Trempealeau Group

Jordan Formation

		Van Oser Member (23.5 feet)
39.5' - 43.5'	4.0'	Sandstone, light yellowish brown, medium- and coarse-grained, some poorly-sorted, especially in upper 0" to 8". Weathers as a reentrant. Cross-bedded.
27.5' - 39.5'	12.0'	Sandstone, light gray, medium-grained with little coarse, massive-bedded. Upper 1" contains rounded sandstone concretions that have both siliceous and calcareous cement. Commonly iron-enriched in upper few inches. Shows evidence of burrowing in upper part. Cross-bedded. Discontinuous shale partings throughout.
27.0' - 27.5'	0.5'	Sandstone, pink, dolomitic, medium- and fine-grained with little coarse; ledge former.
20.0' - 27.0'	7.0'	Same as #3, with less cement and only a trace of coarse sand, massive, forms reentrant.

0.0' - 20.0'	+20.0'	Sandstone, very light yellowish brown to light yellowish gray, fine-grained, thin- and medium-bedded, horizontally laminated with very low-angle cross-beds. In lower 8' sandstone is fine- and very fine-grained, silty, thin- and medium-bedded and has some burrowed beds.

BASE OF EXPOSURE

Walk to exposure located at the east side of Highway 14 opposite its junction with County Highway "J" just south of the Wayside in the NE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 34, T.12N., R.4W., Vernon County (Gays Mills 15-minute topographic quadrangle, 1966).

At this outcrop the Norwalk Member of the Jordan Formation and underlying Lodi Member of the St. Lawrence Formation are exposed. The contact of the two members is believed to be about 3 feet above road level and is marked by the change downward from very fine-grained sandstone with minor silt and very little calcareous cement to siltstone that is calcareous and which contains very fine sand and thin beds of gray dolomite. There is a transition zone of about 4 feet which is assigned to the Norwalk. Estimated thickness of the Norwalk in this area is 35 feet.

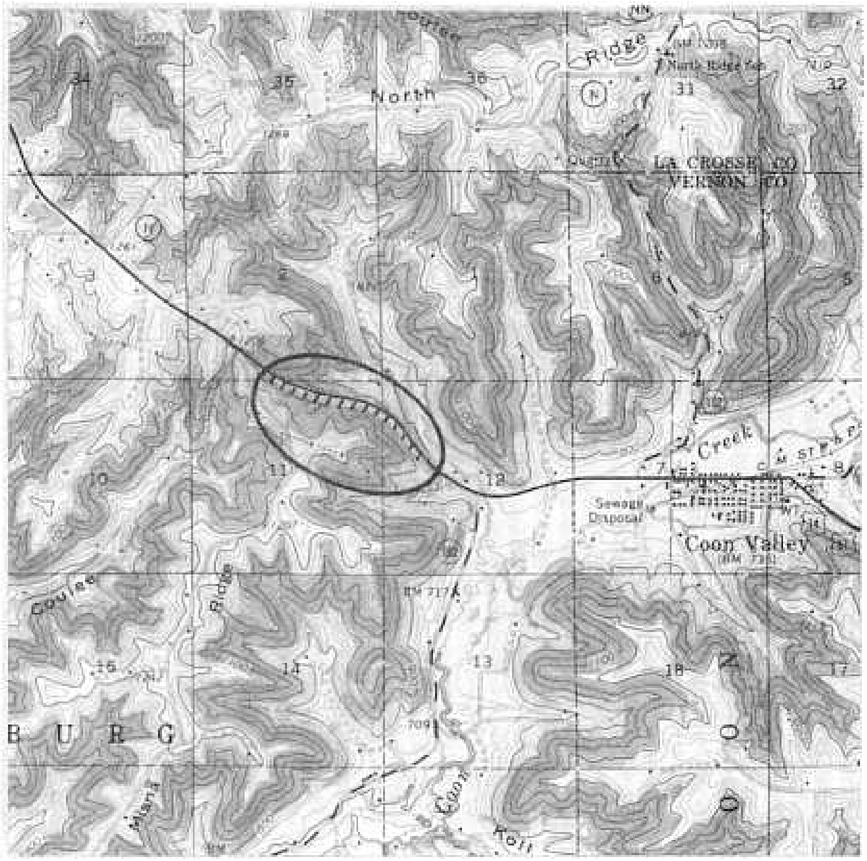
Significance: Two cycles of sedimentation are represented in this series of exposures. Each is similar to the other, but there are distinct differences. In addition, each differs from older cycles seen at previous stops.

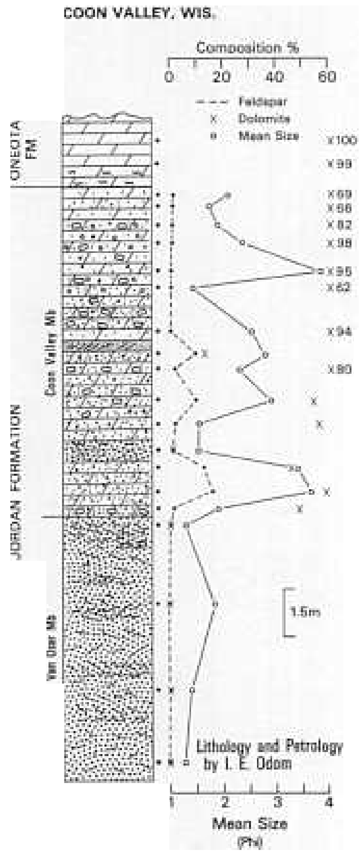
What are the differences between the two cycles seen here? How do you explain the differences? How do the two cycles seen here differ from older cycles seen at previous stops? How do you explain the differences? What fossil evidence is there at this stop and what is its significance? Do you agree with the description of the pre-St. Peter erosional uncomformity?

References: Raasch, 1952; Templeton & Willman, 1963; Ostrom, 1965.

Title: Coon Valley West

Location: Type section of the Coon Valley Member of the Jordan Foundation located on the south side of U. S. Highway 14 two miles west of the City of Coon Valley in the NW$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 11, T.14N., R.6W., Vernon County (Stoddard 15-minute topographic quadrangle, 1965).





Author: M. E. Ostrom (modified from Odom and Ostrom, in press).

Description: The Coon Valley Member is the uppermost of four members which comprise the Jordan Formation in central and western Wisconsin, eastern Minnesota and northern Iowa. The basal member is a very fine-grained sandstone called the Norwalk. It is overlain by the Van Oser, a medium to fine-grained sandstone, which is considered to be the basal member of the upper Jordan Formation. In most areas, the Van Oser is in sharp contact with the overlying thinly bedded, dolomitic sandstones, sandy dolomites and sandstones containing coarse to fine poorly sorted quartz sand, abundant intraclasts, sand-cored oolites, and shale interbeds. This lithic unit ranges in thickness from 52 feet at Genoa to 11 feet in east Madison, Wisconsin, and is named the Coon Valley Member. In and near Madison the Van Oser Member contains a local facies of very fine-grained, highly feldspathic (20 - 40%), dolomitic and non-dolomitic sandstone called the Sunset Point Member. At its type section, the

Sunset Point is underlain by the Van Oser Member and overlain by the Coon Valley Member; but just a few miles to the east, the Sunset Point is both overlain and underlain by the Van Oser. No lithic correlation of the Sunset Point Sandstone is found in western Wisconsin.

Following is a description of the Coon Valley type section from Odom and Ostrom (in press):

ORDOVICIAN SYSTEM

Oneota Formation

68.0'-75.0'+	7.0'+	Unit 14-Dolomite, gray massive, vuggy, some very fine sand in lower one foot. (7' + ft.)
67.0'-68.0'	1.0'	Unit 13-Dolomite, gray, abundant stromatoliths. (1 ft.)

CAMBRIAN SYSTEM
Jordan Formation

Coon Valley Member (37 feet)

65.5'-67.0'	1.5'	Unit 12-Dolomite, grayish brown, massive, sandy. (1.5 ft.)
64.5'-65.5'	1.0'	Unit 11-Sandstone and Sandy Dolomite, brown, medium-grained, friable, (1 ft.)
61.5'-64.5'	3.0'	Unit 10-Dolomite, grayish-brown, massive, contains abundant coarse sand. (3 ft.)
56.5'-61.5'	5.0'	Unit 9-Dolomite, grayish-brown, massive, vuggy, moderately sandy, scattered intraclasts. (5 ft.)
54.5'-56.5'	2.0'	Unit 8-Dolomite, brownish-gray, very sandy, sand ranges from coarse to fine-grained, massive, numerous clasts. irregular upper contact. (2 ft.)
51.5'-54.5'	3.0'	Unit,7-Sandstone, brown, poorly sorted, contains large sandstone and sandy dolomite intraclasts. Irregular upper contact. (3 ft.)
47.5'-51.5'	4.0'	Unit 6-Sandstone and Sandy Dolomite, brown, fine-grained, thinly bedded, moderately well sorted, friable locally. (4 ft.)
42.5'-47.5'	5.0'	Unit 5-Dolomite and Dolomitic Sandstone, brown, fine to medium grained, poorly sorted, intraclasts throughout but especially abundant at base, vuggy in upper 2'.(5 ft.)
38.5'-42.5'	4.0'	Unit 4-Sandstone and Sandy Dolomite, brown, coarse to fine-grained, poorly sorted, thinly bedded, intraclasts and green shale streaks in upper 2', white sand lenses in lower 2'. (4 ft.)
32.0'-36.5'	4.5'	Unit 2-Sandstone, brown, coarse to fine-grained, very dolomitic thinly to massively bedded, cross bedded locally, moderately well sorted in upper 2-1/2 feet, poorly sorted in lower 2'. (4.5 ft.)

30.0'-32.0'	2.0'	Unit 1-Sandstone, brown, coarse to fine, poorly sorted thinly bedded at base, numerous clasts in upper 1', secondary calcite in lower few inches (2 ft.)

Van Oser Member (30 feet)

0.0'-30.0'	30.0'	Sandstone, white, iron-stained in upper 2', medium-grained massive to highly cross bedded, well sorted, secondary calcite in upper 2 ft. (30 ft.)

Norwalk Member (9 feet)
Van Oser Member (11 feet)
Norwalk Member (21 feet)

St. Lawrence Formation (19 feet)
Lone Rock Formation (+11 feet)

BASE OF EXPOSURE

The feldspar and dolomite content and mean grain size is shown by an accompanying diagram (Odom and Ostrom, in press).

Significance: This exposure shows clearly the lithologic character of three of the members of the Jordan Formation as well as the contact relationships and lithologic character of the enclosing formations.

Note especially the lithology of the various units. Have you seen them before? What sedimentary structures can you identify? Fossils? What is their significance? What were the environments of deposition of the different units? Beach? Tidal? Reef? What was the direction and possible character of the source of sediment? How do you explain the high feldspar content in the Coon Valley Member as shown by the accompanying diagram? Although you have not seen the Sunset Point, how might you explain its local distribution in the area of Madison? In forming your answer consider the direction of sediment transport and any geologic features which coincides with that direction.

References; Odom and Ostrom in press)

Title: Valley Sand and Gravel Pit

Location: Sec. 5, 6, T. 6 N., R. 20 E., Hales Corners 15' Quadrangle, Waukesha County Permission is needed to enter this pit. It can be obtained from Valley Sand and Gravel.

Author: David M. Mickelson (after Whittecar, 1976).

Description: This pit is in the core and flanks of a drumlin formed by ice of the Lake Michigan Lobe during mid-Woodfordian time. The southern part of the pit is in the south flank of the drumlin and exposes numerous deformation features (Whittecar, 1977; Whittecar and Mickelson, 1977). Gravels underlie till throughout much of the core, demonstrating that this drumlin form is primarily an erosional feature. A large clastic dike or diapir of fine sand has warped gravels upward about 40 feet from their originally flat lying position. Were the gravels frozen at the time of deformation? The answer to this question is not known, but one can hypothesize that ice advanced over a thin permafrost layer (gravels saturated and frozen) and underlying saturated but unfrozen sands were forced upward by differential pressures.

The till above the gravels is typical of the mid-Woodfordian advance of the Lake Michigan Lobe. Note that some of the till (especially its lower contact with the gravels) is deformed with the folding. A very similar till above seems to truncate this structure and follow the drumlin form. The relationships in the pit have led Whittecar and Mickelson (1977) to suggest the following sequence of events.

1. Deposition of outwash gravels previous to and during the advance of mid-Woodfordian ice (see Waukesha Gravel Pit).

2. Ice advance over the gravels and deposition of basal till on a zone near the ice margin. Much of this till is conformable (doesn't cross-cut) the gravels.

3. Further ice advance and thickening of ice over the area. Partial erosion of the tills and gravels producing the drumlin form and deformation of the gravels.

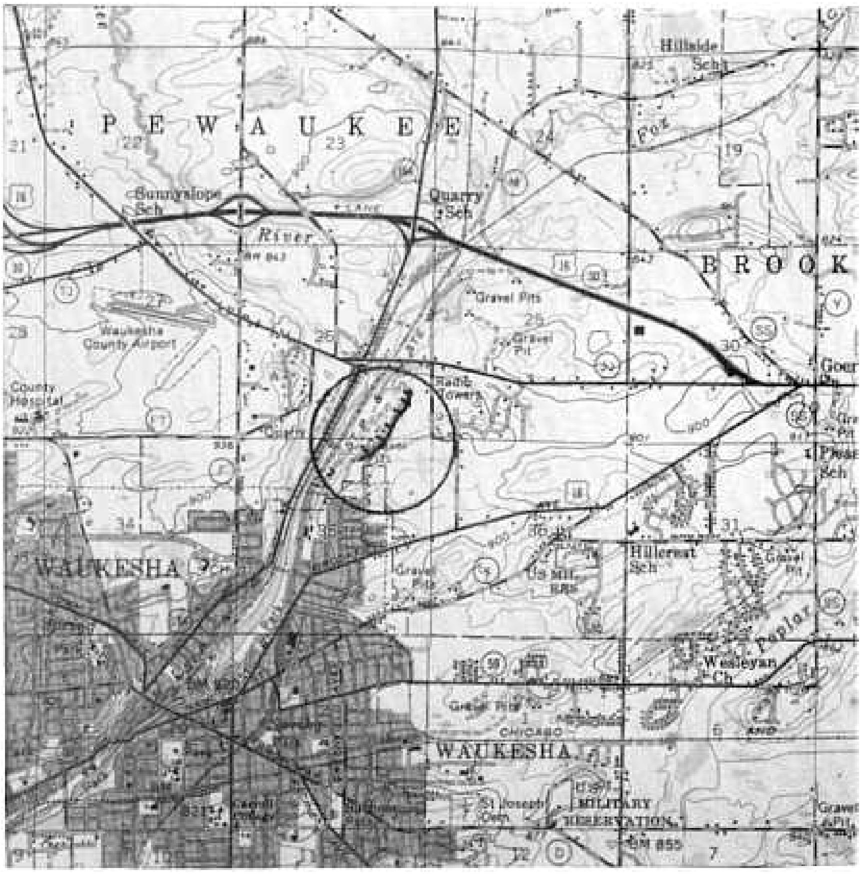
4. Retreat of ice and deposition of a basal till layer over the drumlin form. This till cross-cuts the structure of the gravels.

Significance: Exposure is one of best for illustrating cross-cutting relationships of tills deposited during advance and retreat. The southern part of the pit usually illustrates this best. This type of drumlin, cored with gravel, proves that in some drumlins the form is due to sub-glacial erosion of preexisting material.

References: Alden, 1905; 1918

Title: Waukesha Lime and Stone Co. Pit

Location: SE 1/4, Sec. 26, T. 7 N., R. 20 E., Waukesha 15' Quadrangle, Waukesha County. Permission is necessary to enter and should be obtained from Mr. Douglas Dewey.



Author: David M. Mickelson (after Whittecar, 1976)

Description: Quarry is primarily for dolomite (Niagaran) but exposures in glacial deposits (a drumlin) are excellent. As in the Valley Sand and Gravel Pit, the drumlin is cored with sand and gravel. In the northern part, gravels are flat-lying beneath a thick till unit. The upper part of the unit is buff-to brown, sandy till and below this is grey, sandy till. Do these tills represent two different glacial advances? How might one determine this?

In the pit face just south of the quarry a large overturned fold is present in the gravel (Whittecar and Mickelson, 1977). This style of folding is different than that seen in the Valley Sand and Gravel Pit. This folding (and possible faulting) is due to compression due to ice flow.

In most pits there is no way to determine if the gravels were deposited by the ice that formed the drumlins or if it pre-existed. Here, in the pit face south of the fold there is a paleosol beneath the upper tills. Examine the buried soil carefully. Note that it is developed in a thin silt unit just above gravels. Weathering in the soil and underlying gravels is intense. Although this soil has not been dated, a log from gravels in a nearby drumlin is dated at 30,800 years B.P. (Whittecar, 1977; Black and Rubin, 1968). In Illinois and Wisconsin, the mid-Wisconsin (40,000-22,000 years B.P.) or Farmdalian (31,000-22,000 years B.P.) was a warm period of time when the soil could have developed. An older, red silty till underlies the gravels and can be seen at the south edge of the quarry atop dolomite. This till probably correlates with one of several red silty tills in southern Wisconsin, but sufficient work has not been done to document this.

Significance: Sand and gravel and a paleosol in the care of the drumlin demonstrate that the drumlin is an erosional form. The shape itself is due to subglacial erosion of preexisting material and deposition of till produced a veneer over the eroded form (see Valley Sand and Gravel).

Title: Mineral Creek, Iowa — Prairie du Chien Group contact relationships

Location: Roadcut at east side of Iowa state highway 76 in valley of Mineral Creek, about 1.2 miles north of the village of Hanover, in the SE1/4 SE1/4 NW1/4, sec. 23, T. 99 N., R. 6W., Allamakee County, Iowa. (Dorchester, Iowa, quadrangle, 7.5-minute series, topographic, U.S. Geological Survey, 1971) (fig. 1).

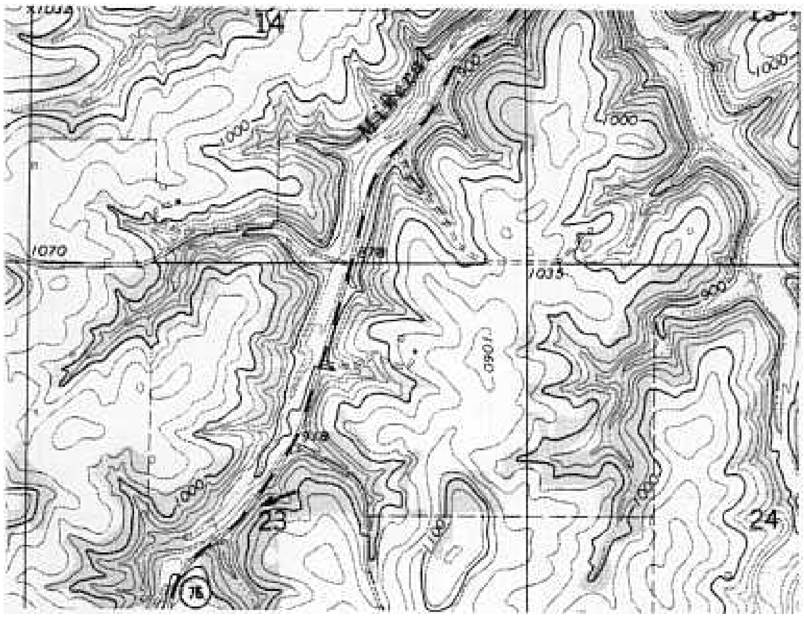


Figure 1. Location of roadcut in Lower Ordovician strata showing unconformable contact relationship between the Oneota Formation and overlying New Richmond sandstone, 1.2 miles north of Hanover, Iowa.

Author: M.E. Ostrom, 1987 (modified from Ostrom and others, 1970, p. 77).

Description: The Mineral Creek exposure is part of a more extensive section exposed along Iowa state highway 76 and in the valley of the Iowa River in secs. 11-14 and 23, T. 99 N., R. 6W. (fig. 2).

At this exposure the Hager City Member of the Oneota Formation consists of buff to gray, medium-crystalline, thick-bedded dolomite that dips to the north at approximately 6 degrees. More than 45 ft of the Hager City Member is exposed downslope and north of the outcrop. It is unconformably overlain by the New Richmond Member of the Shakopee Formation. The New Richmond Member consists of reddish brown, medium-grained, well sorted, friable, cross-bedded sandstone. Approximately 30 ft of the New Richmond is exposed up-slope to the south and east of the outcrop.

Significance: This excellent and accessible exposure shows the unconformable erosional relationship between the Hager City Member and the overlying New Richmond Member.

The erosional relationship between the Oneota Formation and Shakopee Formation was first noted by Ulrich (1924), who designated the contact as the boundary between the Ozarkian and Canadian Systems. The contact was considered to be transitional by Powers (1935), Heller (1956), and Shea (1960), who interpreted it to signify continuous deposition with the Prairie du Chien Group. Ostrom (1964, 1970) agreed with Ulrich's interpretation on the basis of the erosional unconformity separating two of five depositional cycles that occur in Cambrian and Lower and Middle Ordovician rocks in the upper Mississippi valley area. Regional study by Davis (1968) confirmed this relationship.

Figure 2. Unconformable contact of New Richmond sandstone with underlying Oneota Formation in roadcut on Iowa state highway 76, 1.2 miles north of Hanover, Iowa (from Ostrom and others, 1970).

The lithologic character of the formations at this exposure is similar to that in a roadcut along Iowa state highway 76, about 13 miles to the north and northeast of Wilmington, Minnesota (Ostrom, 1987). However, in contrast to the Wilmington exposure, the contact relationship here is distinctly angular. Thus, at this exposure, in addition to a distinct lithologic change and a small amount of relief on the Oneota surface, the slightly dipping Oneota (fig. 3) is truncated. Also, fragments of Oneota dolomite are common in the lower 5 ft of the New Richmond Member.

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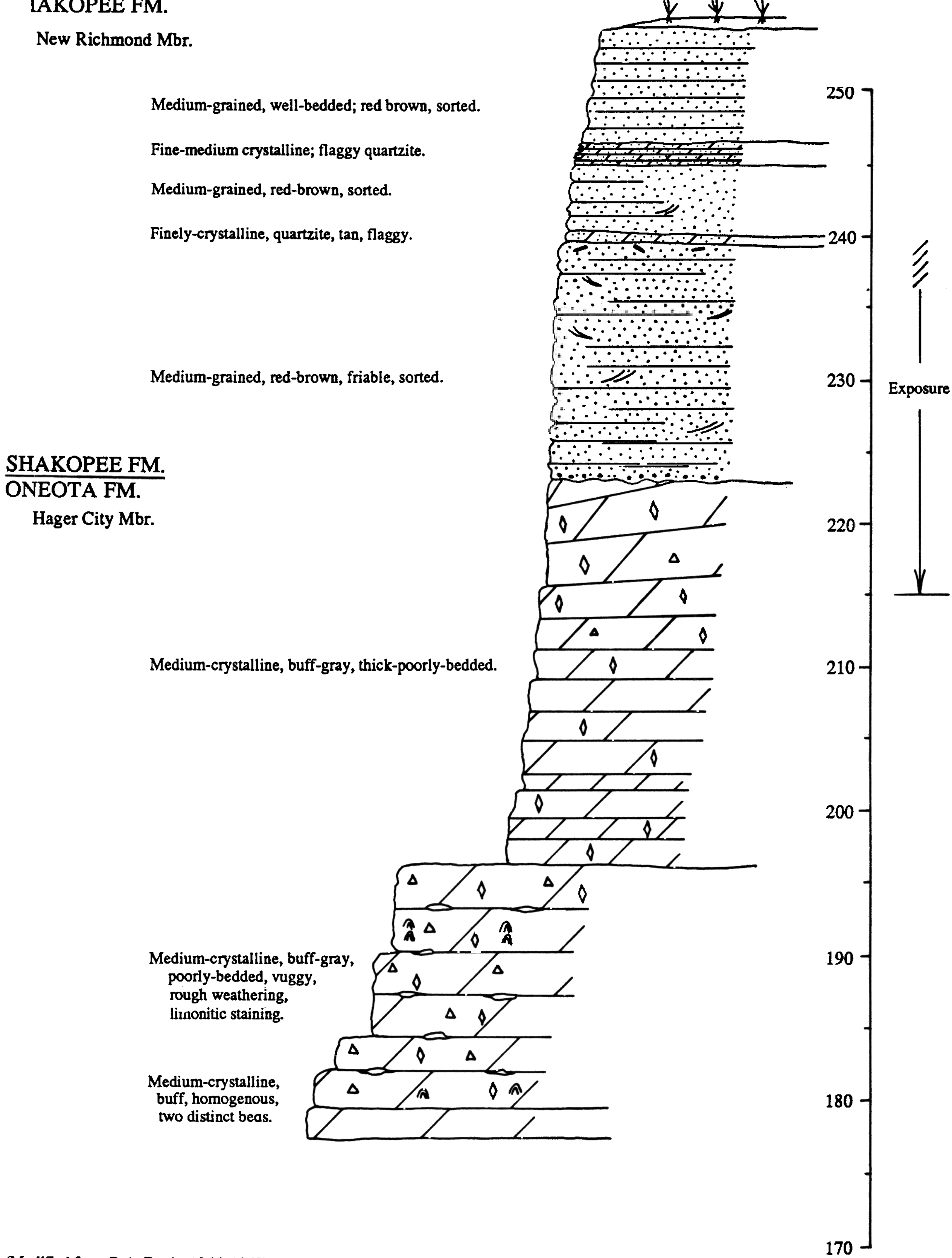

(Modified from R.A. Davis, 1966; 1969)

Figure 3. Description of roadcut in Lower Ordovician strata north of Hanover, Iowa, showing contact of Oneota Formation with Shakopee Formation.

Natural History, v. 16, p. 421-448.
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UWEX UNIVERSITY OF WISCONSIN—EXTENSION

Title: Waukon Junction, Iowa -- Lower Ordovician New Richmond Member

Location: Roadcut at west side of Iowa state highway 364, 0.3 miles northeast of its junction with Iowa state highway 76, and 2 miles southwest of Waukon Junction, in the NW1/4 NE1/4 SW1/4, sec. 16, T. 96 N., R. 3W., Allamakee County, Iowa (Harpers Ferry, Iowa-Wisconsin, quadrangle, 7.5-minute series, topographic, U.S. Geological Survey, 1983) (fig. 1).

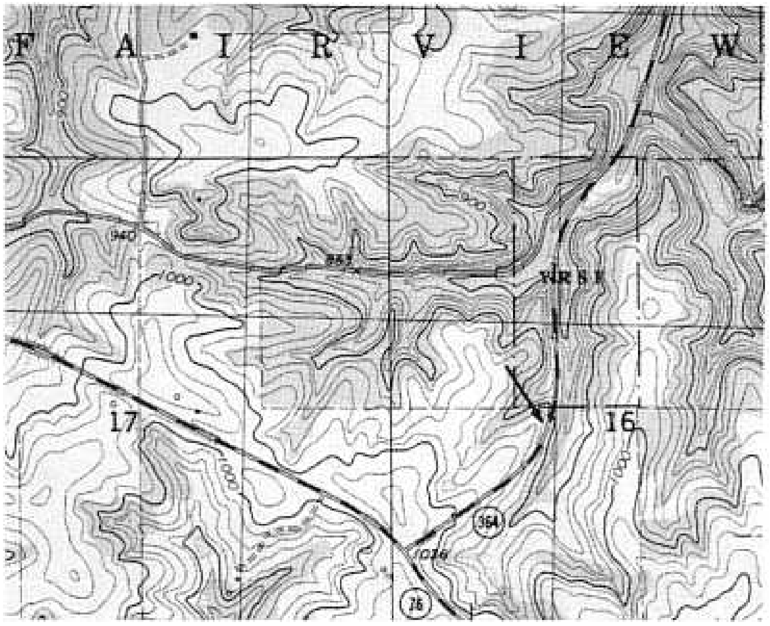

Figure 1. Location of roadcut in Lower Ordovician strata southwest of Waukon Junction, Iowa, showing New Richmond Member.

Author: M.E. Ostrom, 1987 (modified from Ostrom and others, 1970, p. 70-73).

Description: In northeast Iowa and southwest Wisconsin the New Richmond Member of the Shakopee Formation grades from predominantly quartz sandstone in the west, such as near Hanover, Iowa (roadcut along Iowa state highway 76 in the SE1/4 SE1/4 NW1/4, sec. 23, T. 99 N., R. 6W, Allamakee County) and near Wilmington, Minnesota (roadcut along Minnesota state highway 76 in the SE1/4 NE1/4 SE1/4, sec. 11, T. 101 N., R. 6W., Houston County), to the interbedded sandstone and dolomite that occurs at this exposure and persists to the east (quarries in Wisconsin along Grant County highway X in Wisconsin at the base of the Mississippi River bluff at Bagley and Wyalusing).

The New Richmond Member is overlain by the Willow River Dolomite and underlain by the Oneota Formation. At this exposure, the Oneota Formation consists of buff to gray, medium-crystalline, poorly bedded, and vuggy dolomite assigned to the Hager City Member. In the upper 5 ft of this exposure, the Hager City contains rounded quartz sand grains that appear to have filtered down to concentrate in solution cavities during deposition of the overlying New Richmond sandstone.

Significance: This is an excellent exposure of a complete and accessible section of the New Richmond Member (fig. 2). The Oneota Formation is separated from New Richmond sandstone by an unconformity developed during an episode of regression that led to subaerial or very shallow marine erosion. Similar erosional unconformities mark the contacts between four other depositional cycles in the Cambrian and Lower and Middle Ordovician strata of this region (Ostrom, 1964, 1970).

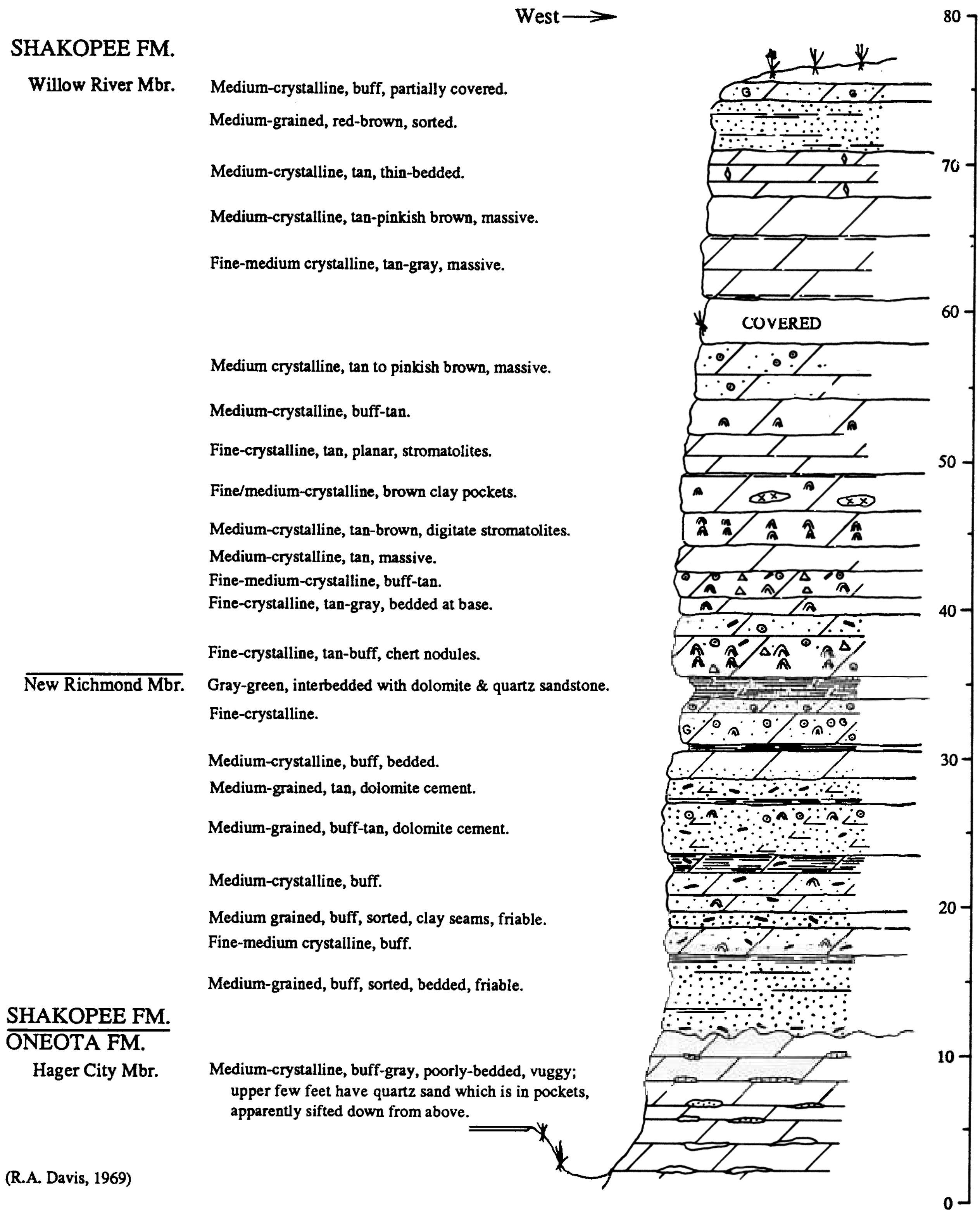

Figure 2. Description of Lower Ordovician strata in roadcut on Iowa state highway 364, 2 miles southwest of Waukon Junction in the NW1/4 NE1/4 SW1/4, sec. 16, T. 96 N., R. 3 W., Allamakee County, Iowa.

depositional cycles, the New Richmond Member (in exposures to the west) was deposited in a highly energetic near-shore, shallow marine environment characterized by thick-bedded, cross-bedded, quartz sandstone. At this exposure and in areas to the east, the New Richmond Member is characterized by interbeds of sandy algal dolomite, dolomite, shaly quartz sandstone, and sandy shale. Oolites and intraclasts are common in the dolomite and in the dolomitic sandstone. This lithology is interpreted as having formed in a less vigorous shallow marine environment situated seaward of the highly energetic near-shore shallow marine environment. The absence of a distinct thick sandstone sequence suggests that the pre-New Richmond erosional surface formed under shallow marine conditions. The 1 ft of pale green shale that occurs here in the top of the New Richmond is common in exposures to the east, but tends to be less distinct to the west. Traced to the east into south-central Wisconsin near Pine Bluff (Dane County), the New Richmond Member is less than 4 ft thick and consists predominantly of sandy dolomite.

The New Richmond Member is conformable with the overlying Willow River Dolomite. The Willow River consists of different dolomite lithologies ranging from sandy, oolitic, and algal dolomite to dolomite. According to Davis (Ostrom and others, 1970) the carbonates are "dolomitized algal biolithite, grain sparite, intrasparite, and oosparite." Carbonate mud was apparently present in small quantities or was recrystallized to coarser textures. Algal stromatolites comprise a large portion of the section here and at the quarry at Wyalusing, Wisconsin. Davis (1966) interprets this as being an algal bank separating a shallow bay to the east from a normal marine shelf to the northwest.

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UWEX UNIVERSITY OF WISCONSIN—EXTENSION

Title: Wilmington, Minnesota -- Lower Ordovician New Richmond Member

Location: Roadcut at east side of Iowa state highway 76, 2.75 miles south of intersection with Minnesota state highway 44, and 200 feet south of bridge over east-flowing tributary stream to Winnebago Creek and a secondary gravel road in the SE1/4 NE1/4 SE1/4, sec. 11, T. 101 N., R. 6 W., Houston County, Minnesota (Wilmington, Minnesota, quadrangle, 7.5-minute series, topographic, U.S. Geological Survey, 1965) (fig. 1).

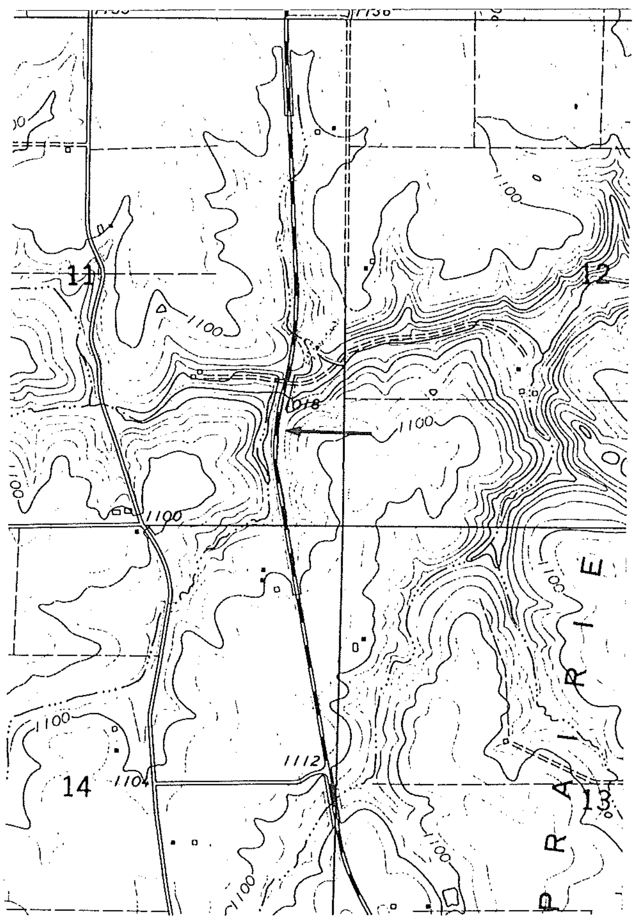

Figure 1. Location of roadcut in strata of the Lower Ordovician Prairie du Chien Group, 1.85 miles northeast of Wilmington, Minnesota.

Author: M. E. Ostrom, 1987 (modified from Ostrom and others, 1970, p. 70-73).

Description: At this exposure 29 ft of the New Richmond Member of the Shakopee Formation unconformably overlies 20 ft of the Oneota Formation. The New Richmond consists predominantly of light reddish brown to light brown, medium-grained, thin- to medium-bedded, well sorted, cross-bedded, friable, rounded quartz sandstone. Shaly partings occur in the lower few inches and in beds 15 ft and 25 ft above its base. Well formed ripple marks are common in the lower 12 ft (fig. 2).

The Oneota Formation consists of gray, medium-crystalline, thick-bedded, dense dolomite with some brecciated zones and abundant sparry calcite.

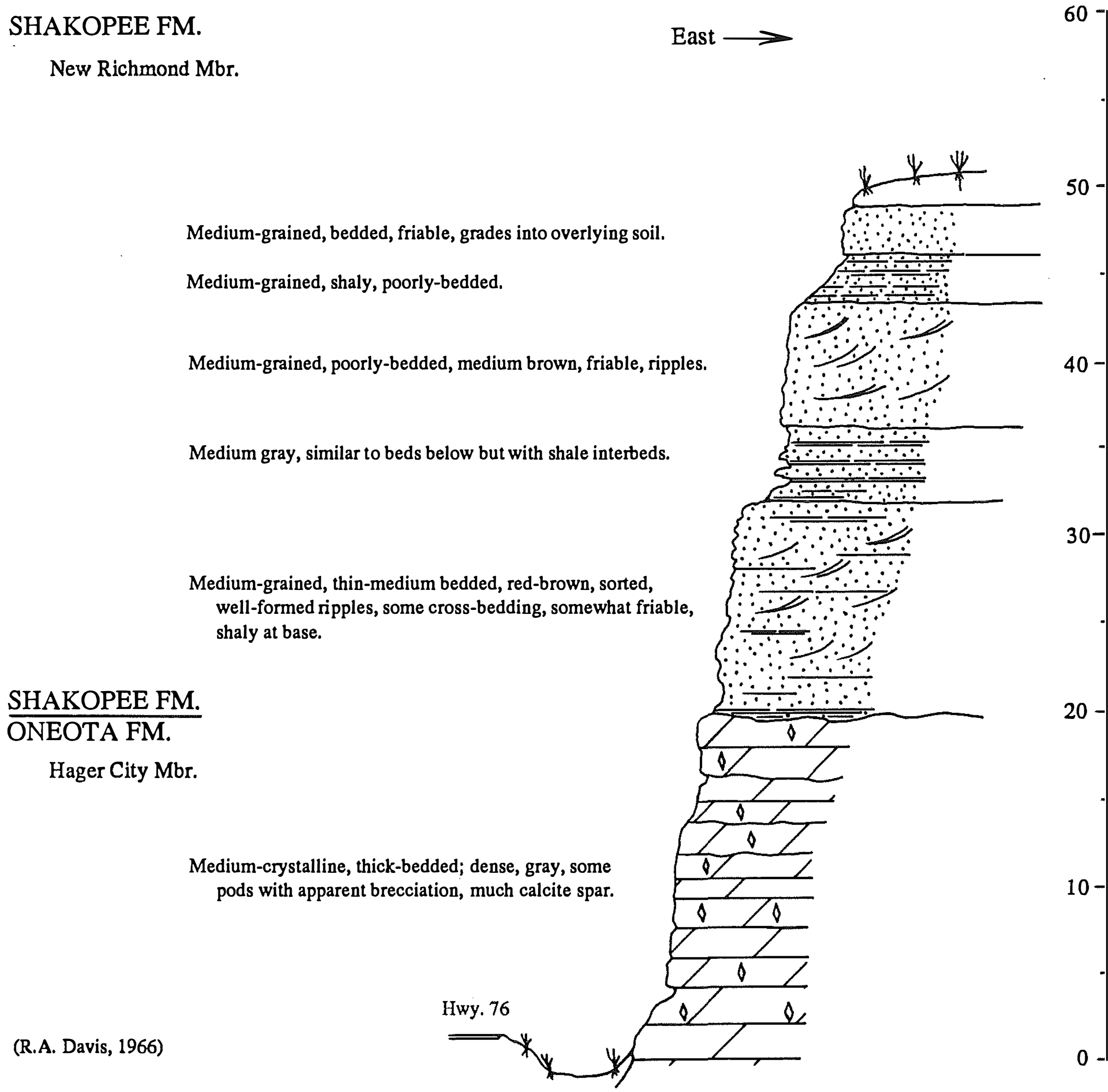

Figure 2. Description of roadcut in Lower Ordovician strata near Wilmington, Minnesota, in the SE1/4 NE1/4 SE1/4, sec. 11, T. 101 N., R. 6 E., Houston County, Minnesota (Wilmington 7 1/2-minute Quadrangle) at east side of Minnesota state highway 76 and about 200 feet north of farm access road and 250 feet north of bridge over east-flowing tributary stream to Winnebago Creek.

Significance: The unconformable contact of the Oneota Formation with the overlying New Richmond sandstone is readily accessible in this exposure. Ulrich (1924) was the first to recognize and describe this erosional unconformity; he designated it as the boundary between the Ozarkian and Canadian Systems. Later Powers (1935), Heller (1956), and Shea (1960) interpreted the contact as transitional and as representing continuous deposition within the Prairie du Chien Group. Ostrom (1964, 1970) defined the contact between the Oneota and New Richmond as an erosional unconformity on the basis of exposures in southwest Wisconsin as well as a concept of repetitive depositional cycles. Subsequent regional study of this relationship by Davis (1968) confirmed the presence of the unconformity.

At this exposure, the upper surface of the Oneota Formation is slightly undulating and makes an abrupt lithic change to sandstone of the New Richmond Member. Near Lanesboro, Minnesota, 30 miles to the northwest, large fragments of Oneota dolomite occur in the basal New Richmond Member. About 1.5 miles north of Hanover, Iowa, in a large roadcut exposure at the east side of Iowa state highway 76 an angular relationship between the Oneota and the New Richmond is clearly shown (fig. 3). This same relationship is shown in abandoned quarry exposures at the north side of Wisconsin state highway 179, approximately 2.7 miles east of Eastman, Wisconsin (SW1/4 NW1/4 NE1/4, sec. 17, T.8N., R.5W., Vernon County), and at the south side of county highway X at Wyalusing, Wisconsin (SW1/4 NW1/4 SW1/4, sec. 31, T.6N., R.6W., Grant County).

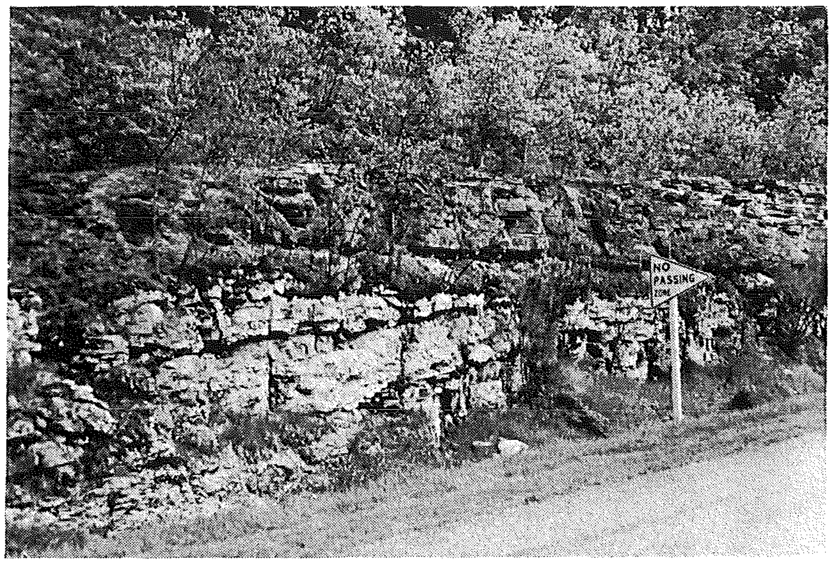

Figure 3. Unconformable contact of New Richmond sandstone with underlying Oneota Formation in roadcut at east side of Iowa state highway 76 about 7 miles north of Hanover, Iowa (Ostrom and others, 1970).

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