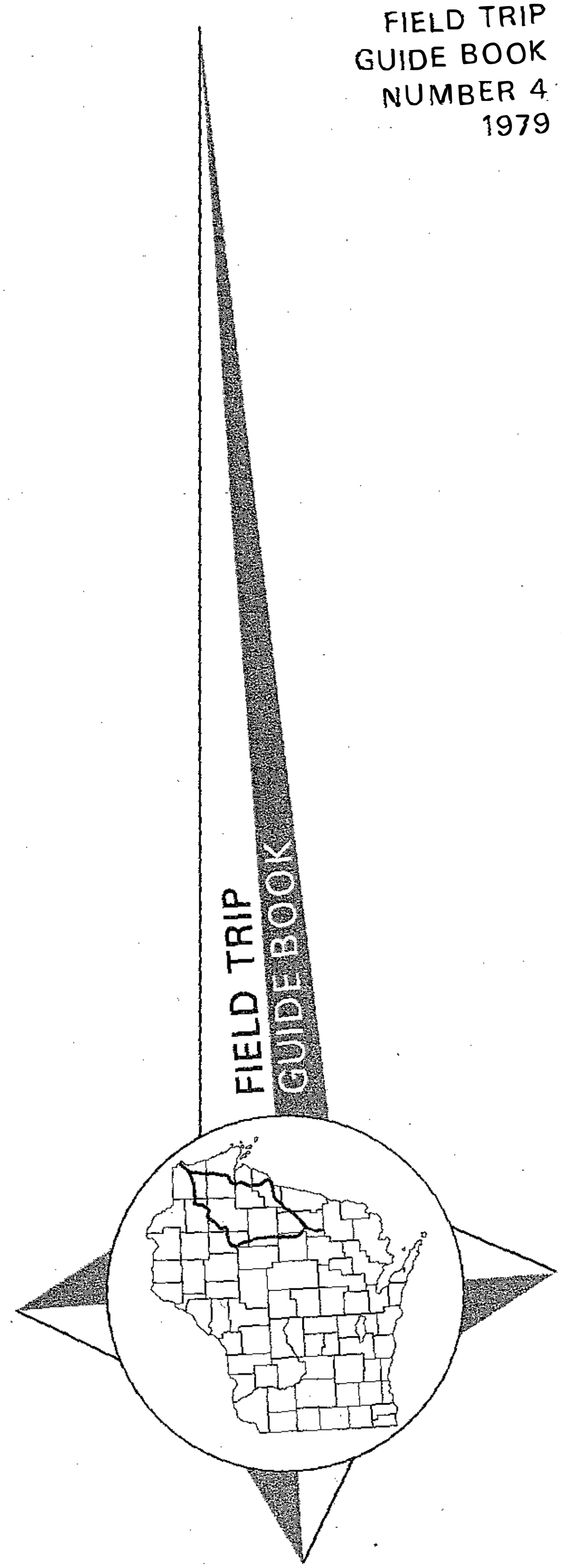
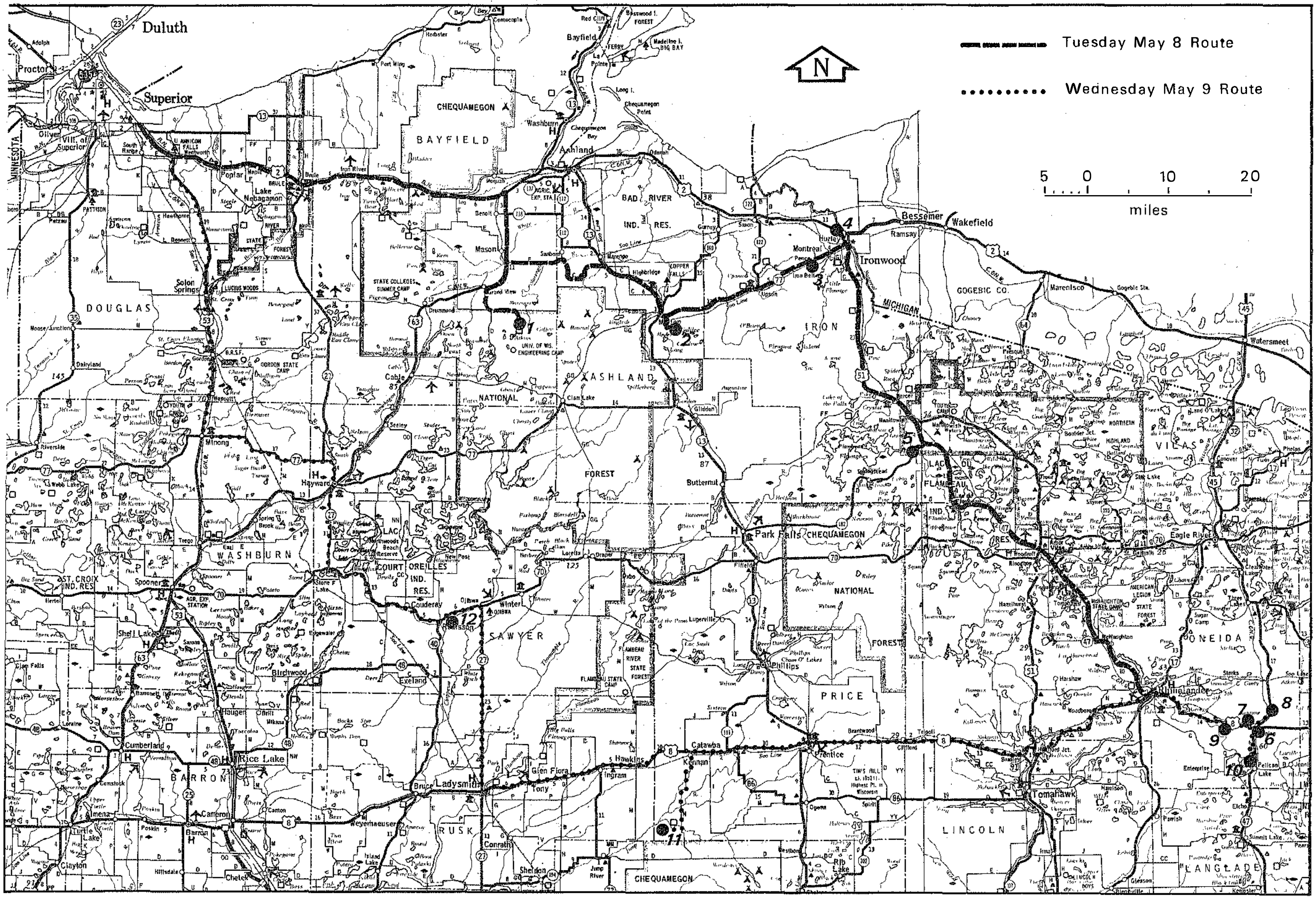
FIELD TRIP
GUIDE BOOK
NUMBER 4
1979

UNIVERSITY OF WISCONSIN-EXTENSION
GEOLOGICAL AND NATURAL HISTORY SURVEY
Meredith E. Ostrom, State Geologist and Director

# MIDDLE PRECAMBRIAN GEOLOGY OF NORTHERN WISCONSIN




Prepared for:
TWENTY-FIFTH ANNUAL MEETING
INSTITUTE ON LAKE SUPERIOR GEOLOGY
UNIVERSITY OF MINNESOTA-DULUTH
DULUTH, MINNESOTA
MAY 8-13, 1979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Enterprise
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Spirit
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Webb Lake
Dairyland
Riverside
Moose Junction
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Pattison
Superior
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Ramsay
Gogebic Sta.
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Chequamegon Point
Long I.
Madeline I.
Big Bay
La Pointe
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Port Wing
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St. Croix Ind. Res.
Lac du Flambeau Ind. Res.
Flambeau River State Forest
Northern Highland State Forest
American Legion State Forest
Gordon State Camp
Lucius Woods
State Colleges Summer Camp
Univ. of Wis. Engineering Camp
Agric. Exp. Sta.
Agr. Exp. Station
Lincoln Boys
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Field Trip Guidebook
Number 4

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

# MIDDLE PRECAMBRIAN GEOLOGY OF NORTHERN WISCONSIN

Road Log and Geological Stop Descriptions
Gene L. LaBerge and M.G. Mudrey, Jr.

Edited by
M.G. Mudrey, Jr.
Geological and Natural History Survey

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Duluth, Minnesota

May 8 - 13, 1979

(meeting concurrently with the Thirteenth Annual Meeting,
North-Central Section, Geological Society of America)

David G. Darby, Chairman, Field Trip Committee
University of Minnesota-Duluth

Available from the Wisconsin Geological and Natural History Survey, University of Wisconsin-Extension, 1815 University Avenue, Madison, Wisconsin 53706.

1979

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ILLUSTRATIONS



SPECIAL EVENT

TUESDAY, May 8, 1979 - Evening

Field trip banquet at Holiday Acres, Rhinelander, Wisconsin

After dinner addresses:

Discussion of Massive Sulfide Deposits by J.M. Franklin

Discussion of the Crandon Deposit by E.R. May and Paul G. Schmidt

## INTRODUCTION

M.G. Mudrey, Jr.[1]

Northern Wisconsin is blessed with an abundance of sand and gravel resources deposited by the last major glacial advance. This is a mixed blessing, in that bedrock exposures are few and far between. A fair average would be about one small outcrop per township. Since the 1920's and extensive exploration for iron deposits, bedrock studies in northern Wisconsin have been few. In the late 1960's, Gene LaBerge and Paul Myers working for the Geological and Natural History Survey initiated detailed-reconnaissance mapping in the central part of the state. Renewed interest in the Precambrian geology of northern Wisconsin was spurred in 1968 with the discovery near Ladysmith in Rusk County of a small, but rich massive sulfide ore body. Additional discoveries since then include the Pelican River deposit near Rhinelander in Oneida County, and the Crandon deposit in Forest County. In addition, numerous theses and dissertations have studied the various Precambrian and Pleistocene units. Although present detailed coverage is sparse (less than five percent of Wisconsin is mapped in any detail), the general framework and distribution is known or can be inferred from geophysical studies.

This trip is designed to show the lithologies which illustrate changing environments in the Middle Precambrian, with predominantly sedimentary rocks in the north, and extrusive and intrusive igneous rocks in the south. Classical localities of Middle Precambrian iron-formation, conglomerates within the Middle Precambrian, the environment of volcanogenic massive sulfide accumulation and granitic plutons will be visited in road cuts, quarries, and natural exposures. To cover the terrane, we must travel over 500 miles. Some of the exposures are well studied, whereas others are having been identified in the past few years.

Because of the non-ferrous base-metal interest in northern Wisconsin, several of the stops will concentrate on the general rock types in the volcanic pile, and their relation to known ore deposits. In addition, at the field trip banquet Tuesday evening in Rhinelander Jim Franklin of the Geological Survey of Canada will give a general summary on Precambrian massive sulfide deposits and their enclosing rocks and Ed May and Paul Schmidt of Exxon, U.S.A., will present their observations on the largest zinc-copper find to date in Wisconsin, the Crandon deposit near Little Sand Lake in Forest County.

The weather this time of year can be nasty, but usually is crisp and invigorating. Stops will not be particularly strenuous. We will assemble for prompt 8:00 a.m. departure on Tuesday, May 8, 1979, and proceed with field stops to Rhinelander, Wisconsin, for an overnight stop, and journey back to Duluth with field stops the next day. We plan on returning to Duluth about 6:00 p.m. on Wednesday, in time for you to join the activities of the Twenty-Fifth Annual Institute on Lake Superior Geology and the Thirteenth Annual North-Central Section of the Geological Society of America.

Monday evening, before the trip, an informal technical/social gathering is scheduled in Duluth. The geologic framework will be discussed, and all participants will have the opportunity to get acquainted before the Tuesday morning departure.

WELCOME TO BADGER LAND!

Table 1. Time-Stratigraphic Framework of Precambrian Rocks in Wisconsin

| Era | System | Stratigraphic Units | Lithology and Depositional Environment | Intrusive Rocks | Approximate Age |
|---|---|---|---|---|---|
| Paleozoic | | | | | |
| Late Precambrian | Upper Keweenawan | Bayfield Group | semimature at base grading upward to mature clastic rocks deposited mainly in shallow water | | 600-1,100 m.y. |
| | | -------------- | | | |
| | | Oronto Group | immature clastic rocks deposited mainly in shallow water | | 600-1,100 m.y. |
| | | --disconformity-- | | | |
| | Middle Keweenawan | Portage Lake and Powder Mill volcanics south of Lake Superior and Chengwatana volcanics in northwest and along St. Croix River | mafic and intermediate lavas and interbedded sedimentary rocks | gabbroic and granophyric complexes near Mellen and Mineral Lake south of Lake Superior | 1,120 m.y. |
| | | --disconformity-- | | | |
| | Lower Keweenawan | Bessemer Quartzite along Gogebic Range | immature clastic rocks deposited mainly in shallow water | | 1,200 m.y. |
| | | | | rapakivi massif and associated granite, syenite and anorthosite in northeast (Wolf River area) | 1,500 m.y. |
| | | --unconformity?-- | | | |
| | | Quartzite at Baraboo, Barron and as isolated outliers in north | clastic rocks deposited mainly in shallow water | | 1,765 m.y. |
| | | --unconformity-- | | | |
| | | rhyolite inliers in south | subaerial tuffs and breccias | epizonal, post-tectonic granite in south and isolated plugs in north | 1,765 m.y. |
| | | --regional unconformity-- | | | |
| 1,800 m.y. | | | | | |
| | | | | epizonal to mesozonal, syntectonic granites | 1,880-1,820 m.y. |

| | | | | |
| --- | --- | --- | --- | --- |
| | positions uncertain | | | |
| Middle Precambrian | basaltic to felsic volcanic and volcaniclastic rocks in north | submarine flows, tuffs, and volcanic sediments | *model lead ages from massive sulfide deposits are 1,830 m.y. Physical correlation with other units is difficult at best. May correlate with Tyler Formation in north.* | |
| Middle Precambrian | kyanite-staurolite-garnet bearing schists and associated quartzo-feldspathic gneiss near Park Falls to Mercer (including Powell kyanite locality) | | *metamorphic studies suggest 685° C at 7.5 Kbars. This area has been correlated with the Gogebic Range.* | |
| Middle Precambrian | basaltic to felsic volcanic and volcaniclastic rocks in extreme northeast (Florence area) | submarine flows, tuffs, and volcanic sediments | *uranium-lead ages on zircon from gneisses are around 1,850-1,900 m.y. Some volcanic rocks (Quinnesec) have been correlated with the Lower Precambrian and with the Middle Precambrian. Stratigraphic relations in this area are not clear.* | |
| Middle Precambrian | Tyler Formation on Gogebic Range | clastic rocks deposited mainly in deep water | (=Baraga Group of Michigan) | (=Animikie Group of Minnesota); age uncertain probably 2,050-1,850 m.y. |
| Middle Precambrian | --local unconformity?-- | | | |
| Middle Precambrian | Ironwood Iron-formation on Gogebic Range | iron formation | | |
| Middle Precambrian | Palms Formation on Gogebic Range | immature clastic rocks deposited in shallow water | (=Menominee Group of Michigan) | |
| Middle Precambrian | --regional unconformity?-- | | | |
| Middle Precambrian | Bad River Dolomite on Gogebic Range | stromatolitic dolomite | (=Chocolay Group of Michigan) | |
| Middle Precambrian | --regional unconformity-- | | | |
| 2,600 m.y. | | | | |
| Early Precambrian | volcanics and associated sediments south of Gogebic Range | submarine flows, tuffs and agglomerates | epizonal granite south of Hurley | 2,710 m.y. |
| Early Precambrian | --unconformity?-- | | | |
| Early Precambrian | gneiss, migmatite and amphibolite in south and western end of Gogebic Range | high-grade migmatites | | 2,800 m.y.+ |

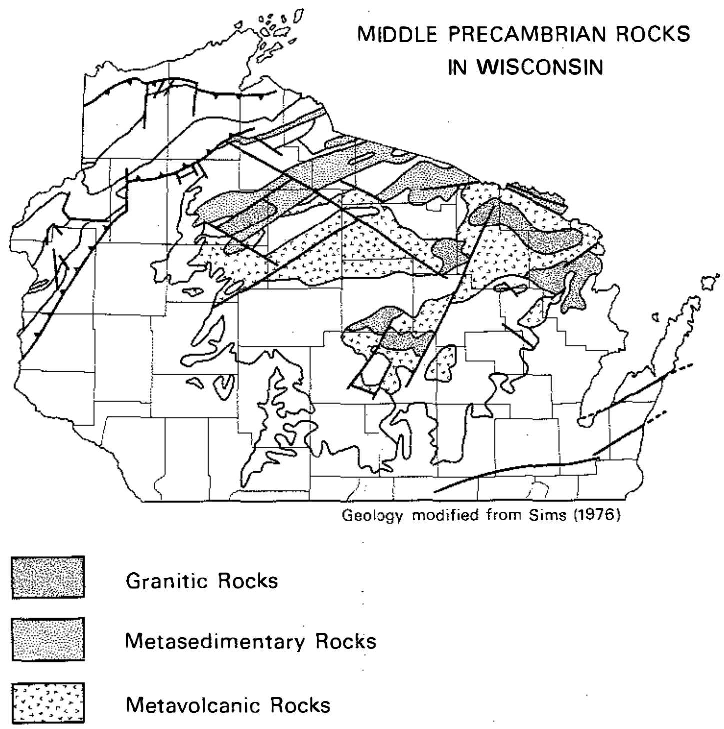


Figure 1. Map of northern Wisconsin showing distribution of various lithologies in the Middle Precambrian. Metasedimentary rocks include slates, conglomerates, iron-formations, and carbonates. These rocks are least deformed and metamorphosed in the extreme northwest. To the south, these rocks contain kyanite and various other higher metamorphic grade minerals. The metavolcanic rocks include mafic to felsic lavas and associated pyroclastic and epiclastic materials. The granitic rocks include epizonal granodiorite to granitic plutons, and alkali-rich post-tectonic granites.

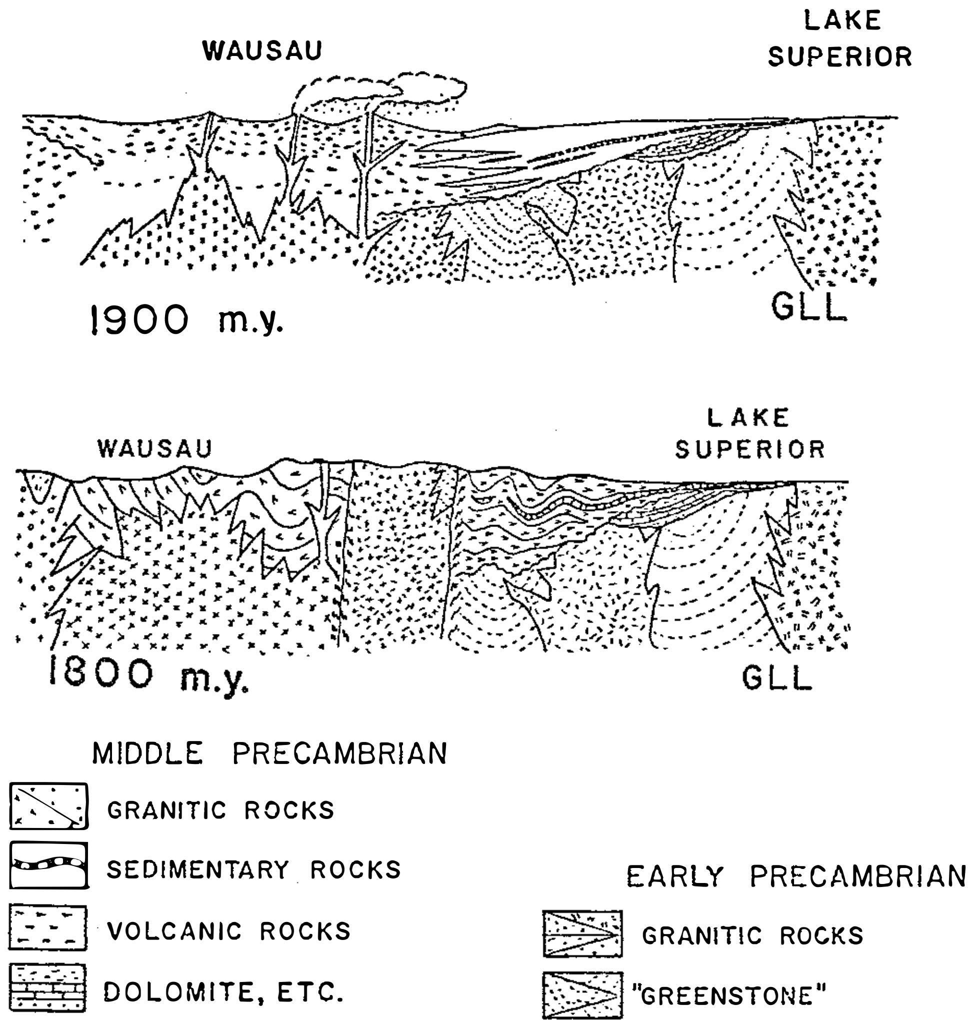


Figure 2. Schematic cross sections showing inferred lithologic -- structural relations during the "Penokean" event of Middle Precambrian age. The upper diagram illustrates a north (right-side) -- south (left-side) section from Lake Superior to central Wisconsin near Wausau during the Middle Precambrian about 1,900 m.y. ago. To the north, platform sediments including carbonates and iron-formation were deposited, while to the south, deeper water sediments and volcanics were accumulating. The lower diagram illustrates the cross-section after cessation of tectonism about 1,800 m.y. ago. To the north the sequence is little deformed, whereas to the south the sequence is folded, and in the extreme south the sequence was moved to shallow structural levels along major faults or shear zones in an apparent host-graben arrangement.

Tuesday, May 8, 1979

Geologic Road Log for Ashland, Bayfield, Iron, and Vilas Counties

This leg of the trip visits the dominantly sedimentary part of the Middle Precambrian. The first stop is about two hours after starting. Lunch will be at Stop 2 on Mt. Whittesey. The last stop will be about 4:00 with a 90 minute deadhead trip to Holiday Acres in Rhinelander.

| Mileages | |
|---|---|
| 63 | Follow U.S. 2 from Superior to the intersection with U.S. 63 turn right (south) on U.S. 63. |
| 14 | Proceed on U.S. 63 to intersection with Bayfield County D in Grand View. Turn left (south) on County D. Note: There are several approaches to stop 1. Directions are given for the best route, however roads may be closed by washouts. The alternate direction given below is longer, but is generally a better maintained road. |
| 3.2 | Proceed on County D to intersection with U.S. Forest Rd. 377 at Chequamegon National Forest Sign. Turn left (east) on Forest 377. |
| 2.6 | Proceed on Forest 377 to intersection with Forest 378. Turn right (south) on 378. |
| 3.1 | Proceed on Forest 378 intersection Forest 198 (straight ahead) and 202 (cross road). Continue straight ahead (east) on Forest 198. |
| 1.3 | Proceed on Forest 198, crossing Marengo River and then turning right onto unmarked road parallel to Forest 198. |
| 0.2 | Proceed on unmarked road to bridge with gate over Marengo River. Park vehicles in area left (north) of road. |
| 1900 ft. | Cross bridge on foot, entering private land. Follow quarry road, keeping to right at branches of road, into quarry. |
| | Stop 1. Grand View Quarry -- Bad River Dolomite |
| 10.4 | Return to Grand View. |

## Alternate Route From Grand View to Stop 1

| | |
|---|---|
| 4.8 | Proceed on County D to intersection with Forest 201 (Atkins Lake Road). Turn left (east) on Forest 201. |
| 4.0 | Proceed on Forest 201 to intersection with Forest 202. Turn left (north) toward Marengo Lake on Forest 202. |
| 1.5 | Proceed on Forest 202 to intersection with Forest 198 (right) and 378 (left). Turn right (east) on Forest 198. |
| 1.3 | Proceed on Forest 198, crossing Marengo River and then turning right onto unmarked road parallel to Forest 198. |
| 0.2 | Proceed on unmarked road to bridge with gate over Marengo River. Park vehicles in area left (north) of road. |
| 1900 ft. | Cross Bridge on foot, entering private land. Follow quarry road, keeping to right at branches of road, into quarry. |
| | Stop 1. Grand View Quarry -- Bad River Dolomite |
| 11.8 | Return to Grand View. |

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| | |
|---|---|
| 4.8 | Follow U.S. 63 north from Grand View to intersection with County E. Turn right (east) on County E. |
| 7.4 | Proceed on County E to intersection with Ashland County C (E turns left). Continue straight ahead on County C. |
| 1.3 | Proceed south on County C to crossroad intersection with Midway Road. Turn left (east) on Midway Road. |
| 2.3 | Proceed east on Midway Road and rejoin County C. Continue straight ahead (east) on County C. |
| 2.4 | Proceed east on County C to intersection with State 13. Turn right (south) on State 13. |
| 9.9 | Proceed south on State 13 to intersection with State 77 in Mellen south of railroad tracks. Turn left (east) on State 77. |
| 0.4 | Proceed east on State 77 to intersection with County P (Lake Drive). State 77 turns left (north) over railroad tracks. Continue straight ahead on County P (Lake Drive). |
| 1.6 | Proceed on Lake Drive. Road jogs left. Stay on Lake Drive. Road jogs left. Stay on Lake Drive towards Camp Galike. Turn left on third dirt road to left (east). This may be marked "Mellen Fire Tower Road." |

1.5 Proceed on dirt road to flagged area. Hike 100 yards north of road into cleaning. Note: There is a locked gate on the Fire Tower Road. The key is available from the Head Ranger, Copper Falls State Park, about 3 miles northeast of Mellen on State 169.

Stop 2. Mt. Wittlesey. Ironwood Iron formation

Afternoon, May 8

3.1 Return to County P and State 77 in Mellen.

21 Follow State 77 east from Mellen to Pence (mileage that follows is calculated from sign on west city limits of Pence.

0.4 Proceed into Pence on State 77 to intersection with Spruce St. Proceed south one block, and park on Whiteside Street. Out crop is located on south side of Whiteside Street, at the intersection with Spruce Street, under a large tree.

5.1 Return to State 77, and continue east towards Hurley. Enter Hurley. Stop sign at intersection of State 77 and Fifth Ave. Turn left (north) onto Fifth Avenue.

0.5 Follow Fifth Avenue to intersection with U.S. 51. Turn left (west) onto U.S. 51.

1.1 Follow U.S. 51 northbound, taking overpass towards U.S. 2 westbound. Stop at large outcrop on right (east) side of road immediately after crossing the overpass.

2.5 Return to southbound U.S. 51 by taking U.S. 2 <u>westbound</u> to cross-over (about 0.5 miles) and reverse direction to <u>east-bound</u> U.S. 2, and taking the exit ramp to southbound U.S. 51. Next leg of trip mileage is measured from intersection of U.S. 51 and State 77 in Hurley.

26.6 Proceed south on U.S. 51 to intersection of U.S. 51 and State 47 in Manitowish. Turn right (south) on State 47.

3.9 Follow State 47 to intersection with State 182. Turn right (west) on State 182.

1.2 Follow State 182 to large outcrops on both sides of road.

Stop 5. Bear River - Powell Kyanite

1.2 Return to State 47. Turn right (south) on State 47.

50 Follow State 47 southbound towards Rhinelander and intersection U.S. 10.

Wednesday, May 9, 1979

Geologic Road Log For Oneida, Price and Sawyer Counties

This leg of the trip visits the dominantly volcanogenic part of the Middle Precambrian basin near Monico in Oneida County, with incidental stops at granite localities. We will start with a short trip to Monico and examine volcanic rocks, and spend the last half of the morning deadheading to our lunch stop in Price County. One afternoon stop will be made in Sawyer County. We plan on arriving in Duluth - Superior around 6:00 p.m.

Morning, May 9

Mileages

| | |
|---|---|
| 14 | Follow U.S. 8 east from Rhinelander to the intersection with U.S. 45 and U.S. 47 south in Monico. |
| 1.0 | Continue east on U.S. 8, crossing on bridge over Chicago and Northwestern Railroad tracks and U.S. 45 to north. About 0.2 miles east of intersection of U.S. 45 to north, take County V to the right, and park. Outcrop is located at intersection of U.S. 45 and County V. |
| | Stop 6. Monico East - Mafic Pillow Basalt. |
| 0.2 | Return westbound on U.S. 8 to intersection with U.S. 45 north. Turn right (north) on U.S. 45. |
| 0.5 | Proceed to Lake Road, and turn left (west) onto Lake Road. |
| 0.6 | Proceed on Lake Road, crossing Baade Road and stopping behind house on left (south). |
| | Stop 7. Monico Gravel Pits (Baade and Lake Roads)--Intermediate to felsic pillow lavas. |
| 0.6 | Return to U.S. 45 and turn left (north) on U.S. 45. |
| 0.9 | Proceed to small, abandoned farm on right (east) side of road. |
| | Stop 8. Witte Farm - Coarse Felsic Agglomerate. |
| 1.4 | Return south to U.S. 8. Turn right (west) on U.S. 8. |
| 2.4 | Proceed west on U.S. 8 to intersection with old U.S. 8 and Leith Road. Proceed on old U.S. 8. |
| 0.7 | Proceed to flagged area. Small outcrops on both sides of road. |
| | Stop 9. Monico West -- Section 26 - pyritic tuff. |
| 0.7 | Return to U.S. 8 and proceed east on U.S. 8. |

| | |
|---|---|
| 1.6 | Proceed east on U.S. 8 to intersection U.S. 45 (southbound). Turn right (south) on U.S. 45. |
| 2.5 | Proceed to Wayside on west (right) side of highway. Outcrop in wayside.<br>Stop 10. Beck Tower Wayside Park - Late red granite. |
| 2.5 | Return north to U.S. 8. Turn left (west). |
| 14 | Proceed on U.S. 8 west to Rhinelander. |
| 44 | Continue west on U.S. 8 to Prentice. |
| 18 | Continue west on U.S. 8 to junction with Price County N near Kennan. Turn left (south) on County N. |
| 10.2 | Proceed on County N to junction with road to Big Falls County Park road. Turn right (west). |
| 1.0 | Proceed on park road to park entrance and turn left (south) into park. |
| 0.2 | Proceed to pavillion. Outcrops in river west of pavillion.<br>Stop 11. Big Falls County Park on the Jump River, Price County - Granite and Pyritic tuff. |

Afternoon, May 9

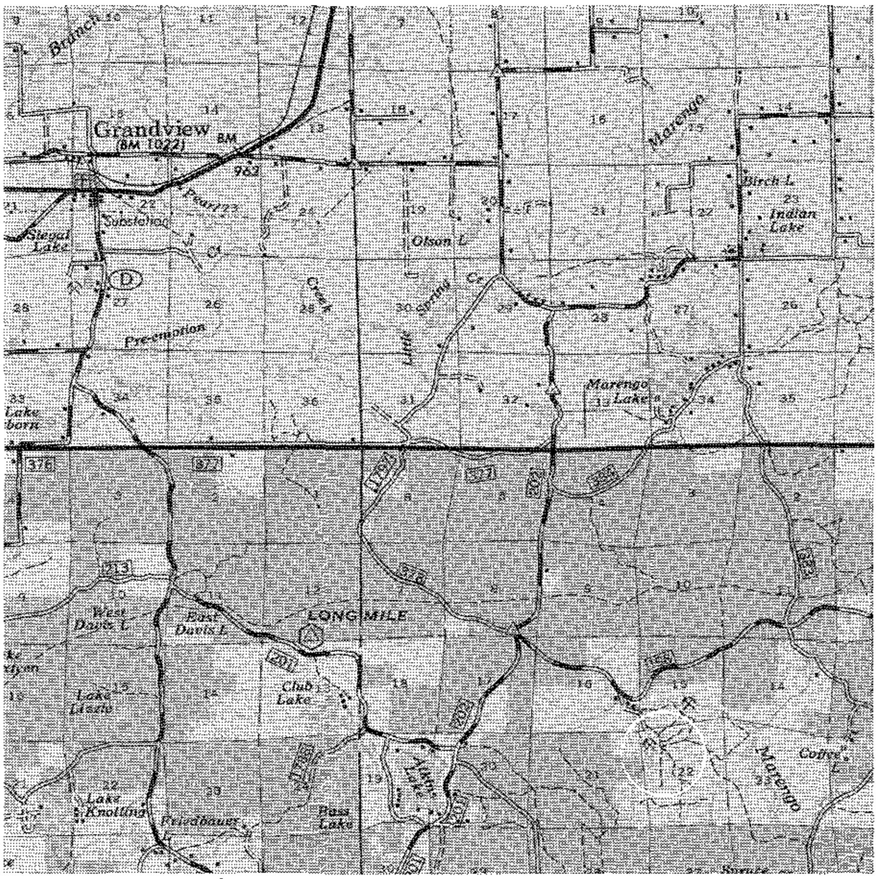
| | |
|---|---|
| 11.9 | Return to Kennan and junction of County J and N. Turn left (west) on County J. |
| 0.9 | Follow County J to U.S. 8. Turn left (west) on U.S. 8 to Ladysmith. |
| 27 | Follow U.S. 8 through Ladysmith to intersection with State 77. Turn right (north) on State 27. |
| 23 | Follow State 27 to Ojibwa to intersection with State 70. Turn left (west) on State 70. |
| 4.4 | Follow State 27 and 70 west. Turn left (south) on gravel road. |
| 0.7 | Proceed on gravel road. Turn left (east) on asphalt road, cross bridge. |
| 0.4 | Proceed to junction with Swede Road. Turn right. |
| 0.25 | Proceed to junction with Birch Lane. Turn right. |
| 0.6 | Follow Birch Lane. Turn right crossing bridge and park. Walk 350 feet along trail to river.<br>Stop 12. Arpin Dam in Radisson - Late Porphyritic Granite. |

| | |
|---|---|
| 1.25 | Return to intersection with asphalt road. |
| 1 | Continue west on asphalt road into Radisson and intersection with State 40. Turn right (north) to intersection with State 70 and 27. |
| 29 | Follow State 27 to Hayward. |
| 77 | Follow State 77 to Minong and U.S. 53 to Duluth. |
| 540.2 mi. | End of Log |

GEOLOGICAL STOP DESCRIPTIONS

Title: Grand View Quarry -- Bad River Dolomite

Location: Johnson & Johnson Quarry, Grand View. NW¼, NW¼, NW¼, Sec. 22, T.44N., R.5W., Bayfield County. (Chequamegon National Forest, ½ inch = 1 mile, 1968)

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Author: Gene L. LaBerge (1978)

Description: This quarry provides one of the largest and most excessible exposures of the Bad River Dolomite in Wisconsin. The formation was named by Van Hise and Leith (1911) from exposures along the Bad River at Penokee Gap southwest of Mellen. According to Aldrich (1929), it unconformably overlies the Lower Precambrian greenstones and granites to the south. In the eastern part of the Gogebic Range the Sunday Lake Quartzite conformably underlies the dolomite, but both the dolomite and quartzite are missing in the central part of the district, presumably due to erosion prior to deposition of the overlying Palms Formation (Irving and Van Hise, 1892). Thus, there appears to have been gentle folding or arching along a north-south axis causing erosion of the Bad River Dolomite and Sunday Lake Quartzite prior to deposition of the Palms Formation, the basal unit of the Animikie Series (James, 1958) in this area.

The exposures in the quarry are fairly typical of the formation. The bedding dips 35°- 75° north, along with all other Middle Precambrian units on the Gogebic Range in Wisconsin. Komatar (1972) estimates a minimum thickness of 550 feet in this area, thinning to about 310 feet eight miles to the east. Aldrich (1929) reports that the lower part of the formation is mainly a dolomitic limestone with a much more siliceous upper part. The silica occurs as lenses of sandy dolomite or cross-bedded sandstone (now quartzite), and as beds, pods and irregular masses of chert (Komatar, 1972). The chert ranges in color from light gray to black, presumably due to included organic matter. Algal structures up to nearly 1 meter in diameter, some with black chert layers alternating with dolomite, are present in the formation (Figure 1).

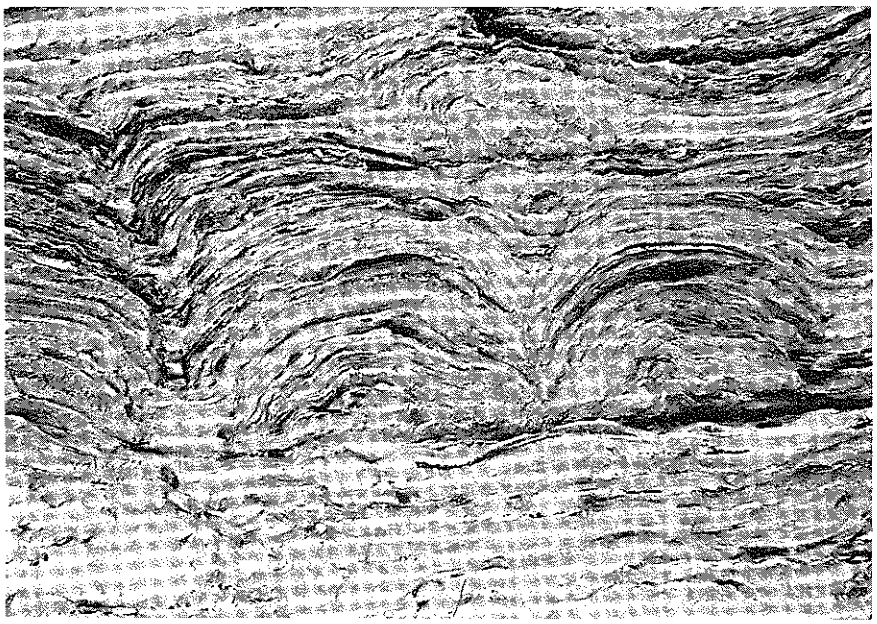

Figure 1. Algal structures in the Bad River Dolomite. Photo is of a large glacial erratic near Clam Lake, about 10 miles southeast of Grandview.

Several mafic dikes striking N.80°E. and dipping 84°S. are exposed in the quarry (Komatar, 1972). These are presumably Keweenawan diabase dikes.

Mineralogically, the formation consists of medium-grained granular carbonate with lenses, pods and patches of quartz. A reaction rim of pale green tremolite typically occurs between the quartz and carbonate. The tremolite is also present in layers of massive, randomly oriented crystals and as radial aggregates several inches in diameter.

The mineral assemblage in the Bad River Dolomite and associated Palms and Tyler Formation indicate that the area was metamorphosed to greenschist facies during the Penokean orogeny about 1700 m.y. ago (Komatar, 1972). He reports that the metamorphic grade increases from quartz-albite-muscovite-chlorite subfacies on the east to quartz-albite-epidote-almandine subfacies in the Grandview area. This metamorphism was associated with only slight deformation.

Intrusion of the Mellen gabbro produced widespread contact metamorphism superimposed on the earlier regional metamorphism. K/Ar ages (Komatar, 1972) date this event at 1050±40 m.y.

Discussion: The Bad River Dolomite was deposited on an erosion surface of Lower Precambrian greenstones and granites. The presence of algal structures, sandy dolomite and interbedded layers of sand indicate deposition in a shallow marine environment. The increase in sand content upward in the formation suggests either a shallowing of the basin or a change in source area providing more coarse clastics to the basin. The unit is similar in all respects to the Kona and Randville dolomites in the Marquette and Menominee districts of Michigan respectively, with which it is generally correlated.

The absence of the Bad River Dolomite in the central part of the Gogebic suggests a gentle upwarp in that area resulting in erosion of the formation prior to deposition of the overlying Palms Formation. Gentle folding and greenschist facies metamorphism occurred during the Penokean orogeny.

The major northward tilting of the units and contact metamorphism associated with emplacement of the Mellen gabbro occurred during Late Precambrian time.

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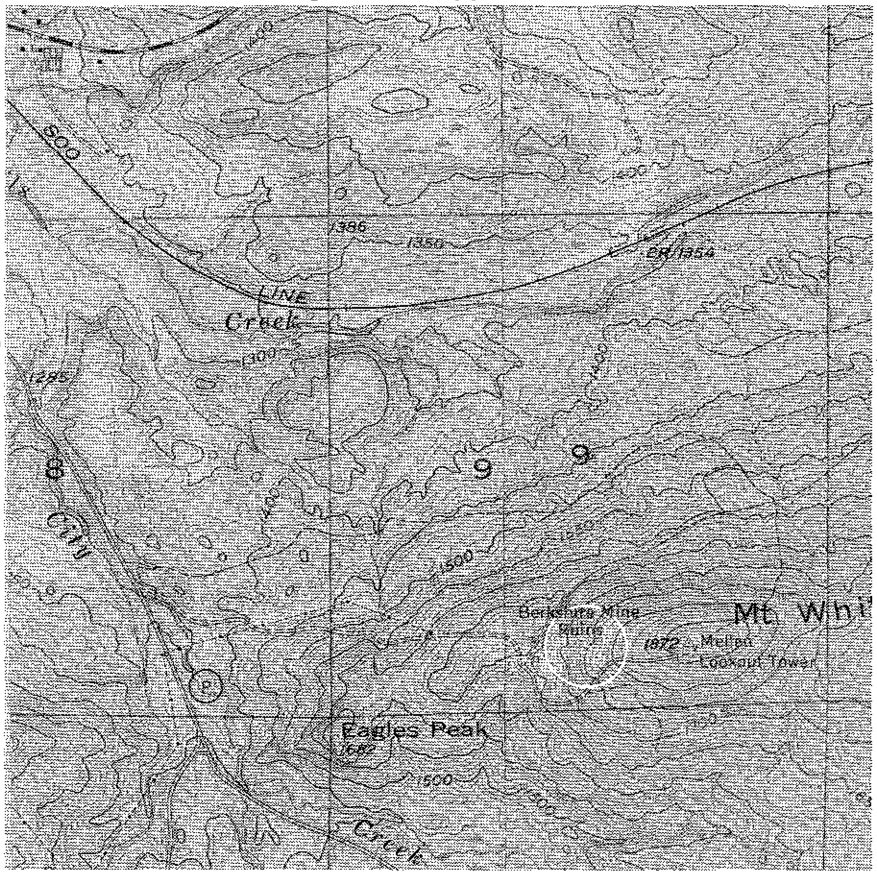
AS 44/2W/9B

Title: Mount Whittlesey - Ironwood Iron-formation

Location: Berkshire Mine, SW¼, SW¼, SE¼, Sec. 9, T.44N, R.2W., Ashland County. (Mt. Whittlesey 7½-minute topographic quadrangle, 1967) (Get key from Ranger at Copper Falls State Park)




Author: Gene L. LaBerge (1978)

Description: The Ironwood Iron-formation ranges from about 450-950 feet in thickness and extends for approximately 60 miles across Michigan and Wisconsin in a west-southwesterly direction from west of Lake Gogebic, Michigan, to west of Mineral Lake in Wisconsin. It lies conformably between the Palms Formation and the Tyler Formation. The prominent hill here (Mt. Whittlesey) results from the resistant nature of the exposed metamorphosed iron-formation. The lowlands west and east of the hill are the result of cross-faults of Late Precambrian age that offset the Middle and Upper Precambrian strata (Aldrich, 1929).

The iron-formation exposed here shows the bedding characteristics typical of Middle Precambrian iron-formations of the Lake Superior region. Two basic styles of bedding are readily apparent -- one is a laminated rock consisting of alternating layers about 1 cm thick of recrystallized chert and iron oxides. This is commonly referred to as "banded" or "even-bedded" or "slaty" iron-formation. The other bedding type present is a thick and irregularly-bedded variety with beds up to 15 cm or more thick. The thicker beds are cherty with abundant sand-size clasts (granules or oolites) of chert in a chert matrix. The clasts commonly are somewhat ferruginous, whereas the matrix is more pure

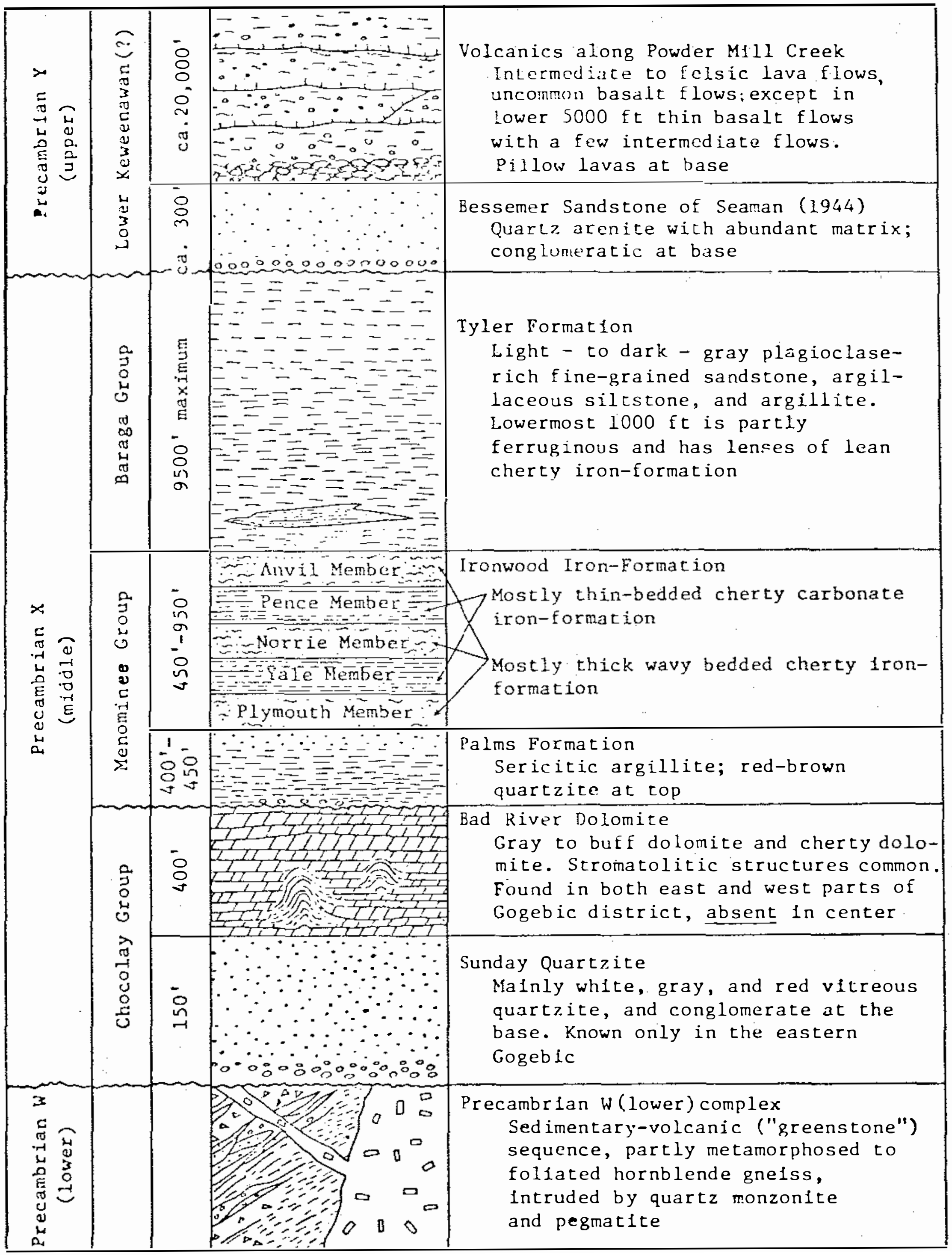



Figure 1. Generalized stratigraphic section in central and western Gogebic Range (from Schmidt and Hubbard, 1972, p. A3).

chert. These cherty units are highly irregular in shape and are separated by layers composed mainly of iron oxides. Intra-formational conglomerates are relatively common in the "wavy" or "irregularly" bedded or "cherty" iron-formation.

These different bedding styles represent different intensities of wave action in the basin during iron-formation deposition. Or alternatively, they represent alternately shallow and deep water conditions, with the thin-bedded variety representing deep (quiet) waters and the wavy bedded units indicating shallow (agitated) waters.

These bedding differences were used by Hotchkiss (1919) as a basis of subdividing the formation into five members based on the dominant bedding style. He recognized three units with dominantly wavy bedding (Plymouth, Norrie, and Anvil) separated by two units of mainly thin-bedded iron-formation (the Yale and Pence). These units can be recognized over much of the 60-mile length of the range, and are roughly correlative with the lower cherty, lower slaty, upper cherty and upper slaty members of Biwabik Iron-formation in Minnesota.

The iron-formation here has been metamorphosed to grunerite grade, and consists of quartz, grunerite, magnetite and minor hematite and garnet, with minor dolomite, ankerite and siderite co-existing with the grunerite (Laybourn, 1979). Minnesotaite is the stable iron-silicate present in the iron-formation east of Ballou Creek (about 2 miles east of here), and iron-rich pyroxenes (ferrohypersthene and ferroaugite) appear from Mellen westward (Laybourn, 1979). The metamorphic facies are produced by contact metamorphism related to the Mellen and Mineral Lake gabbro complexes.

Economic Geology: Iron ore was discovered on the Gogebic Range at Bessemer, Michigan in 1873, and over 300 million tons of natural ore was mined before operations ceased in 1966 (Schmidt and Hubbard, 1972). Most of the mining operations were done between Hurley, Wisconsin, and Wakefield, Michigan, on the eastern part of the range. Natural ores that are economically exploitable have been worked out.

Marsden (1978) reports that major reserves of taconite ore in the Ironwood Iron-formation remain on the western end of the Gogebic range where the rocks have been more highly metamorphosed. The intensity of metamorphism increases progressively westward from biotite grade to pyroxene grade (Marsden, 1978). The area of interest for development of magnetite taconite extends from near Upson southwestward for 21½ miles to just west of Mineral Lake. Outcrop width of the iron-formation is 1000-1500 feet over much of this length, but folding in the Mt. Whittlesey area produce an outcrop width of 2500 feet locally (Marsden, 1978).

Marsden (1978) estimates the total reserves of magnetic taconite in Wisconsin to be 4,171,000,000 metric tons, of which 3,711,000,000 metric tons are in the Ironwood Iron-formation of the Gogebic Range. The other taconite reserves are the Agenda deposit (Sec. 22, 23, 24, T.42N., R.1E.), 160,000,000 tons; the Butternut deposit (Sec. 20, 21, 28, 29, T.49N, R.1W), 48,000,000 tons; and the Pine Lake deposit (Sec. 21, 22, 23, 26, 27, 28, T.44N, R.3E.), 184,000,000 tons. The latter three deposits are not in the Ironwood Iron-formation, but appear to be in lateral equivalents (Allen and Barrett, 1914).

Thus, the Middle Precambrian of northern Wisconsin contains one of the largest undeveloped taconite reserves in North America.

Discussion: Mineralogically, the iron-formation is generally referred to as "oxide facies," implying that it was deposited as oxides with the chert. LaBerge (1964) showed that the magnetite is almost entirely secondary. Dimroth (1975) points out that the mineral facies are diagenetic (or metamorphic) and do not reflect the depositional environment. Thus, unless we can prove that the present mineralogy is the original mineralogy, there is no basis for interpreting the depositional environment from the mineralogy. The Facies concept of James (1954) should be restricted to a descriptive rather than interpretative concept. The present mineralogy of iron-formations is the product of the depositional, diagenetic, metamorphic, and in many cases, the weathering environment; it should not be assumed that the present mineralogy is the original mineralogy.

The subdivision of the Ironwood into members based on the dominance of granular (cherty) or laminated (slaty) iron-formation (Hotchkiss, 1919) works well in the eastern two-thirds of the Gogebic. However, subdivision of the formation into the various members in the western third of the district is difficult. In part, this may be due to the higher metamorphic grade in the western end of the district, but there seems to be a real change in the stratigraphy as well. Morey (1972, p. 209) shows a similar relationship for the western Mesabi, where subdivision into the cherty and slaty members is difficult. This may suggest a change in the Animikie Basin to the southwest. The presence of a thicker succession, interbedded clastics and volcanic rocks in iron formation in the Cuyuna district (Marsden, 1972) may indicate a change from platform to deeper basin to the southwest.

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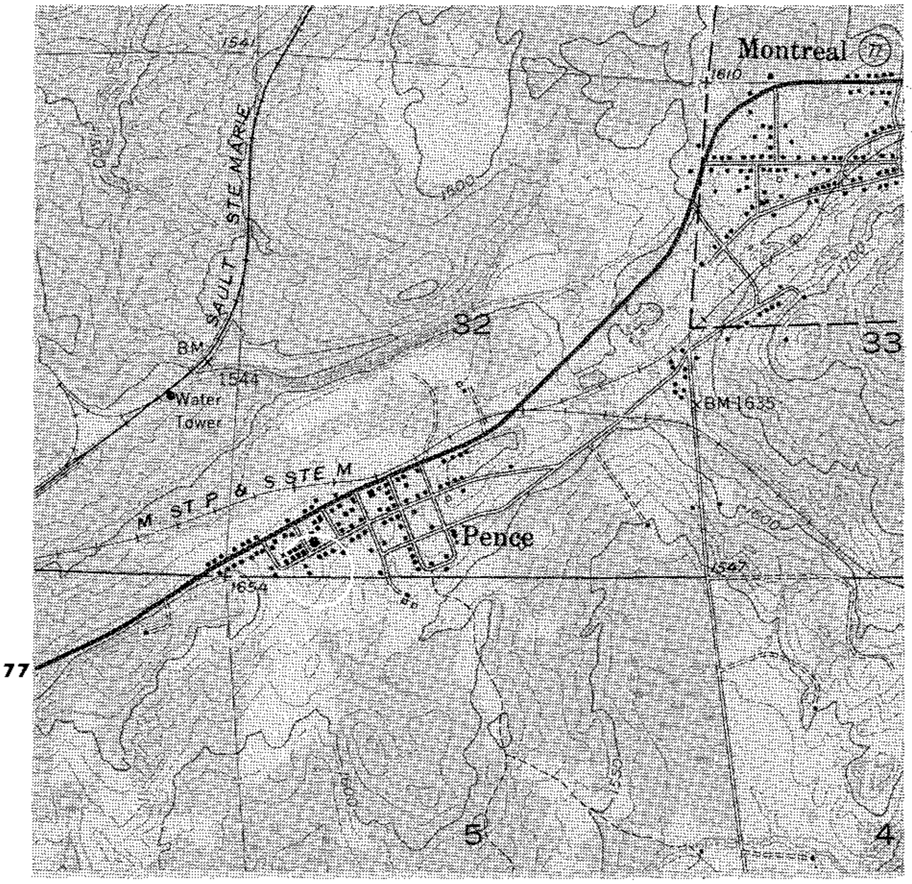
Title: Pence--Basal Palms Formation

Location: Intersection of Whiteside Street and Spruce Street in Pence, Wisconsin. SE¼, SW¼, Sec. 32, T.46N., R.2E., Iron County. (Iron Belt 7½-minute topographic quadrangle, 1956).




Author: Gene L. LaBerge (1978)

Description: The Palms Formation is the basal unit of the Middle Precambrian Animikie Group (James, 1958), and unconformably overlies the Bad River Dolomite and Sunday Lake Quartzite of the Chocolay Group (Cannon and Gair, 1970). According to Aldrich (1929), the Palms is continuous throughout the Gogebic range, averages about 450 feet in thickness, and contains a basal conglomerate, a "quartz-slate" unit, and an upper quartzite unit.

At this locality the basal Palms rests on Lower Precambrian granite, the older Bad River Dolomite and Sunday Lake Quartzite evidently having been removed by post-Bad River - pre-Palms erosion. Both west and east of here the Bad River Dolomite and Sunday Lake Quartzite are present between the Palms and the underlying Early Precambrian granite and greenstone. The following generalized description is taken mainly from Aldrich (1929).

The basal conglomerate of the Palms is up to about six feet thick and appears to be derived mainly from the immediately underlying rock types (Aldrich, 1929). It was deposited on an uneven erosion surface, and thus varies in thickness locally. The larger clasts are well rounded at some localities, and very angular at others according to Aldrich (1929). Here the clasts consist of quartz, chert, granite, and felsic and melfic volcanics, are moderately well rounded and range up to about 8 cm in diameter. The outcrop is slightly phosphatic.

Overlying the basal conglomerate, and comprising about 400 feet of the formation is the thin-bedded "quartz-slate" unit characteristic of the Palms. It consists of alternating quartz-rich and argillaceous beds 1-3 cm thick with ripple marks, cross-bedding and scour-and-fill features common. The quartz-rich beds are composed mainly of quartz, although some are quite feldspathic. Quartz grains range from angular to well rounded, with the larger grains generally the most rounded (Aldrich, 1929). Argillaceous layers consist mainly of fine sericite, chert, chlorite and magnetite. A general coarsening of grain size of argillaceous materials and the appearance of octahedra of magnetite west of the Tyler Forks River is evidently due to contact metamorphism produced by the Upper Precambrian Mellen Gabbro.

The uppermost 50 feet of the Palms consists of a vitreous quartzite composed of medium-grain, well-rounded quartz. Minor mica is present on bedding planes. The quartzite varies from white, green, brown to red (Aldrich, 1929).

The Palms is overlain conformably by the Ironwood Iron-formation. This represents an abrupt transition from clastic sedimentation in the Palms to chemical sedimentation (with virtually no clastics) in the Ironwood. A similar abrupt transition is present throughout most -- but not all -- of the Lake Superior region.

<u>Discussion</u>: The Palms Formation is an important part of understanding the geometry of the Animikie Basin. It is generally correlated with the Pokegama and Kakabeka Formations of the Mesabi and Gunflint districts respectively on the north shore of Lake Superior, and the Siamo and Ajibik Formations of the Marquette district (Cannon and Gair, 1970). The Kakabeka Formation is mainly a conglomerate and generally only a few feet thick (Goodwin, 1954). The Pokegama is mainly a quartzite and up to 167 feet thick (Morey, 1972). These formations underlie the iron-formation in their respective districts. The general thickening of the clastic sequence beneath the iron-formation suggests a deeper (or older) basin to the south, or alternately that the sea was transgressing northward onto the craton at the onset of iron-formatin deposition. In the Marquette district, the Siamo Slate and Ajibik Quartzite are 1,000 feet thick in the Neguanee area, but thin markedly to only about 100 feet near Michigamme at the western end of the district (Boyum, 1970).

Thus, the nature and thickness of the formations underlying the major iron-formation differs from place to place within the basin and must reflect local differences in the pre-iron-formation history of the Animikie basin. In the Gogebic district, the Palms has some features typical of shallow water deposition, and some (the quartz-slate) which appears to have similarities to deeper water deposition, perhaps transitional into a graywacke-type environment farther south.

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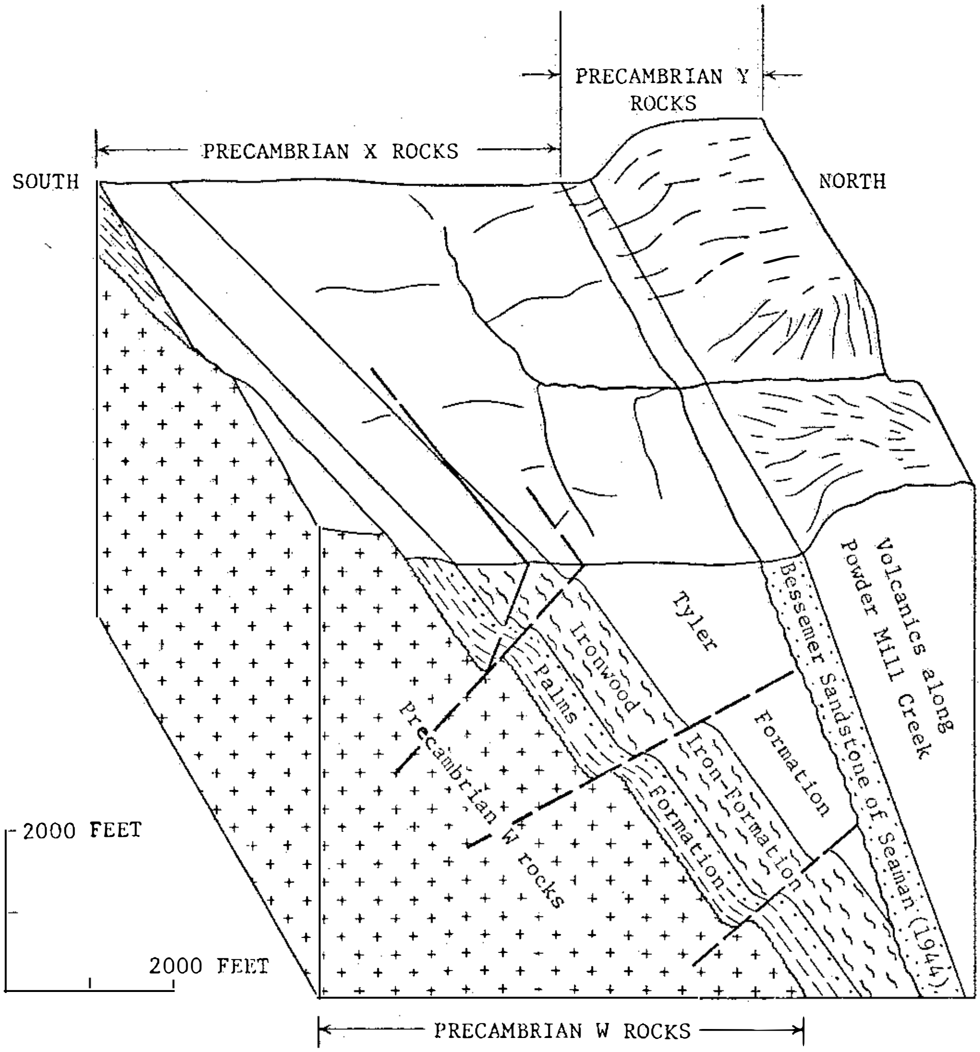
Title: Hurley Overpass. Tyler Formation.

Location: Junction U.S. Highway 2 and U.S. Highway 51 north of Hurley, Wisconsin. SE¼, SE¼, NE¼, Sec. 14, T.46N., R.2E., Iron County. (Ironwood 7½-minute topographic quadrangle, 1975)

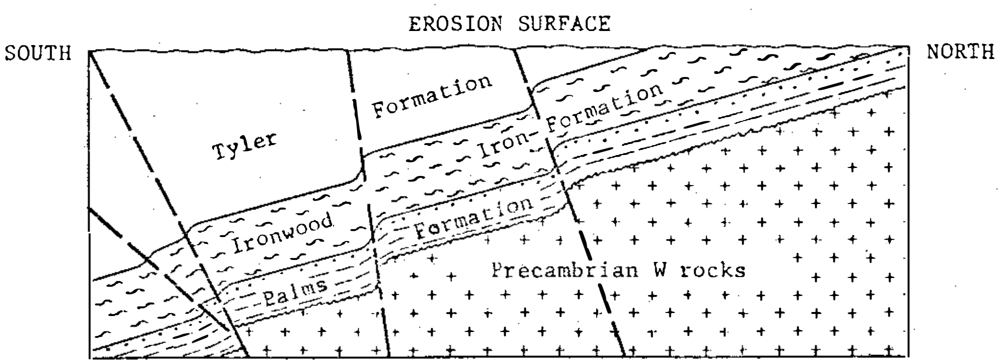

Author: Gene L. LaBerge, 1978

Description: This exposure is characteristic of most of the Tyler Formation which conformably overlies the Ironwood Iron-formation, and is the youngest Middle Precambrian unit recognized on the Gogebic Range. The unit is generally referred to as the Tyler "slate," although Alwyn (1976) reports that the formation is about one-third slate and two-thirds graywacke sandstone. Alwyn (1976) reports that the Tyler formation is approximately 7,000 feet thick in this area, but increases in thickness westward to about 12,000 feet near Mellen. Schmidt and Hubbard (1972) report that the Tyler has been completely removed by pre-Keweenawan erosion to the east. Because of its stratigraphic relations, the Tyler is generally correlated with the Virginia and Rove formations in Minnesota and with the Michigamme formation in Michigan (Leith, Lund, and Leith, 1935; James, 1960).

Sedimentological studies led Alwyn (1976) to conclude that the Tyler formation was derived mainly from a granitic terrane and that sediment transport was northward into the Animikie basin. Thus, he postulates a granitic landmass south of the Gogebic range shedding abundant clastics. The presence of probable Middle Precambrian submarine volcanics near Mercer approximately 20 miles to the south




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

(Allen and Barrett, 1914; Dutton and Bradley, 1970) suggest that the granitic landmass must have been narrow. Assuming that the volcanics near Mercer are correlative with those in the Ironwood Iron-formation in the eastern Gogebic range (Aldrich, 1929), limits on the size of the landmass would suggest that it must have been tectonically uplifted to continue to provide the source of sediments for the Tyler Formation.

The dip of the Tyler Formation at this location is 70° NW. Graded beds and other primary structures indicate that the beds are right-side up (Schmidt and Hubbard, 1972). Cleavage in the shaly layers dips less steeply than the bedding (about 30° NW). According to Schmidt and Hubbard (1972), this cannot be a Keweenawan axial plane cleavage because that cleavage would dip more steeply than the bedding. If this is an axial plane cleavage, it must have formed during an earlier deformation, presumably the Penokean Orogeny.

Discussion: Schmidt and Hubbard (1972) point out that the basal Keweenawan dips more steeply northward than the Middle Precambrian Tyler and Ironwood Formations, suggesting that the Middle Precambrian was dipping south during early Keweenawan time. The cleavage to bedding relationship at this stop also suggests that the Tyler Formation was dipping south at the time the cleavage formed. Thus, the present orientation of the units is a result of subsidence of the Lake Superior syncline during Keweenawan time, as shown for most of the Gogebic range, suggesting that a block approximately 60 miles long and perhaps 10-15 miles wide rotated northward nearly 90° with no obvious internal deformation.

The tilting of this block occurred after deposition of the Oronto Group (of early Late Keweenawan time (Craddock, 1972)) because of the Freda sandstone dips near vertically along the Montreal River on the Michigan-Wisconsin border. This suggests that the Tyler and other Middle Precambrian rocks were buried beneath at least 12 miles (20 kms) of Keweenawan basalts and sandstones during the Late Precambrian. However, the low metamorphic grade of the Tyler at this locality is difficult to reconcile with the interpretation of having been buried to a depth of 12 miles. Either an unusually low geothermal gradient of burial was too short to affect much recrystallization, or heretofore unrecognized structures in the Keweenawan sequence give an exaggerated apparent depth of burial. The last alternative seems most likely. Most recognized faults (and the most obvious ones) on the Gogebic are cross-faults; however, mine mapping (Hotchkiss, 1919) has demonstrated the presence of bedding faults and strike faults in the Ironwood Iron-formation. The strike faults duplicate the section in places. I suggest that strike faults (or perhaps thrust faults) exist in the Keweenawan duplicating the section to give an exaggerated thickness of Late Precambrian rocks and therefore an exaggerated apparent depth of burial for the Tyler Formation in this area. Perhaps the question should be raised whether the cleavage may be related to these postulated thrust faults, and therefore of Keweenawan age. Resolution of this problem is pertinent to an understanding of both the Middle and Late Precambrian geology of the Lake Superior region.

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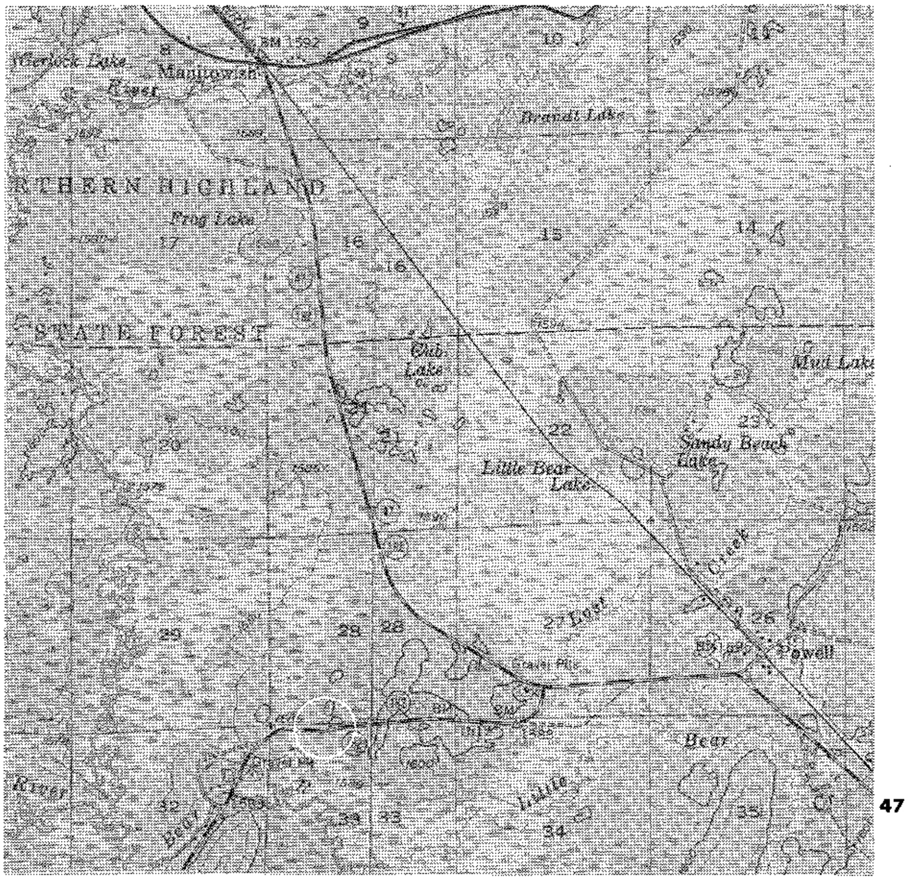
Title: Bear River-Powell Kyanite

Location: On State Hwy. 182 approximately 1 mile west of State Hwy. 47. SE¼, SW¼, Sec. 28, T.42N., R.4E. (Wilson Lake, 7½-Minute Topographic Quadrangle, Vilas County).




Author: Gene L. LaBerge (1978)

Description: This exposure is part of a sequence of upper amphibolite facies gneisses and schists that occur as widely scattered outcrops along the Flambeau River flowage. Magnetic surveys and diamond drilling suggest that this sequence of rocks continues eastward into northern Michigan, and the occurrence of iron-formation, pellitic rocks and volcanics has served as a basis for correlating these rocks with the much lower-grade rocks on the Gogebic range (Allen and Barrett, 1915). James (1955) includes this area in the core of his "Watersmeet node," an elongate area of high-grade regional metamorphism, and Dutton and Bradley (1970) show that metamorphic intensity decreases in directions from this high-grade center.

Main lithologies present include amphibolites, quartzo-feldspathic gneisses and schists, some of which contain staurolite and kyanite ±sillimanite (Black, 1977). Exposures here are mainly garnet-staurolite-kyanite-bearing schists, although sillimanite is present in small amounts. The sillimanite occurs as incipient crystal clusters in the kyanite. Black (1977) concluded that the mineral assemblage kyanite-staurolite-muscovite + sillimanite suggests metamorphism at 685°C and a pressure of about 7.5 Kb. This indicates that the rocks were metamorphosed at a depth of 25 kilometers and at temperatures at or near minimum melting range (Black, 1977).

The rocks have been intensely folded about an east-northeast trending fold axis with a prominent east-northeast foliation. Quartz boudins, intrafolial folds, disconnected fold hinges and limbs, and augen and other features of transposed bedding are common and obliterate most primary features of the rocks (Black, 1977). The sequence probably represents a highly deformed and metamorphosed pile of mafic to felsic volcanic rocks and graywackes.

The high-grade rocks are bounded on the north by a sequence of less deformed, and less metamorphosed mafic-intermediate volcanics, iron-formation and slate (Allen and Barrett, 1915; Black, 1977). The boundary between these sequences contains a prominent zone of electrical conductivity called the Flambeau Anomaly (Sternberg and Clay, 1977). The anomaly is evidently produced mainly by highly graphitic rocks that extend a minimum of 17 kilometers into the crust. The conductive zone extends west-southwesterly more than 100 km to near Couderay in Sawyer County.

Discussion: Allan and Barrett (1915) interpreted the boundary between the greenstones on the north and the high-grade rocks on the south as an unconformity. Black (1977) interprets the boundary as a major fault with the south side uplifted. The proposed fault may correlate with Sims' (1976) postulated boundary between a 2650-2700 m.y. old granite-greenstone terrane to the north and an older gneiss terrane to the south (Black, 1977). The Flambeau Anomaly appears to be in-folded or in-faulted along the boundary between the greenstones (of unknown age) and high-grade metamorphic rocks (also of unknown age).

Thus, the more recent interpretations of the geology in this area raise the question of whether the high-grade metamorphic rocks exposed here are really correlative with the Tyler Formation of the Gogebic. The stratigraphic position of the greenstones to the north is also debatable. Alwyn's (1976) interpretation of a granitic landmass south of the Gogebic as a source area for the Tyler coupled with the recent recognition of major faults and the Flambeau Anomaly suggests that the geology may be far more complex than heretofore recognized.

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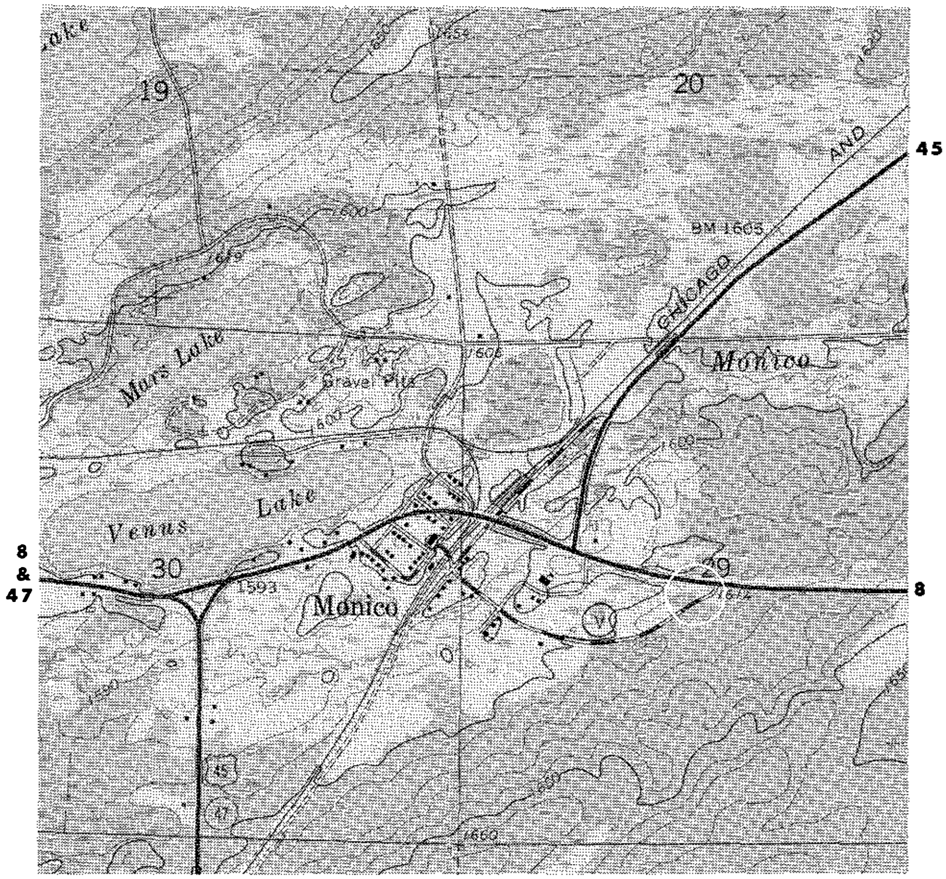
<u>Title</u>: Monico East - Mafic Pillow Basalt

<u>Location</u>: Intersection of U.S. 8 and County V, center of Sec. 29, T.36N., R.11E., Oneida County (Monico 7½-minute topographic quadrangle, 1965).




<u>Author</u>: M.G. Mudrey, Jr. (1978)

<u>Description</u>: A large outcrop is in the southwest corner of the intersection. The rock consists predominantly of sulfide-bearing, gray-green, chloritic pillow basalt trending N. 85° E., and dipping 80° SE. The two-foot thick by three-foot long pillows are slightly stretched and top to the south. Original pyroxene has altered to hornblende and chlorite. Plagioclase is extensively altered. The southeast edge of the outcrop is a ten-foot thick massive flow or sill. Diabasic texture in this unit is well developed.

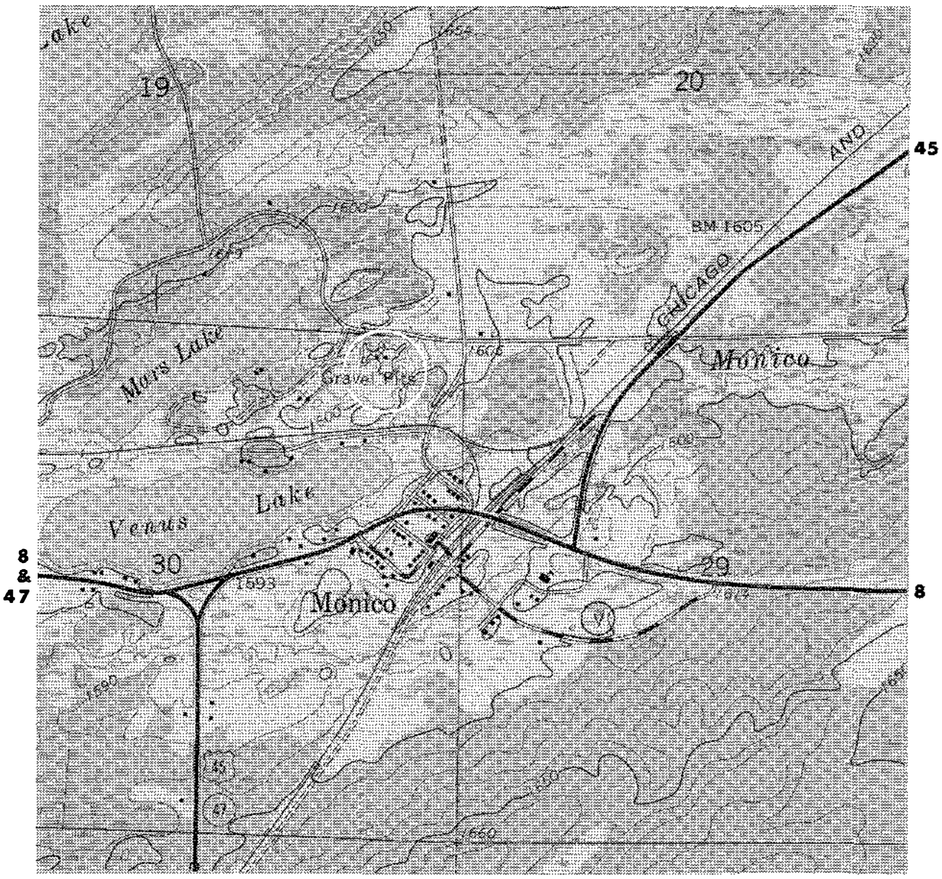
<u>Discussion</u>: Two supracrustal sequences characterize the Middle Precambrian succession in northern Wisconsin and Michigan, a dominantly sedimentary unit including iron formations to the north, and a dominantly volcanic sequence including massive sulfide deposits to the south. Inasmuch as bedrock exposures are poor south of the Gogebic Range area, geologic maps of northern Wisconsin are based dominantly on geophysical interpretation. Units defined in the few areas of outcrop are extrapolated into the poorly exposed areas. The belt of rocks from Ladysmith on the west to Pembine on the east appears to be dominantly volcanic, with few intrusives. The volcanics in the Monico area are among the least deformed and better exposed in this belt. Pillows and other indicators of subaqueous deposition are evident in the volcanic rocks exposed in the Monico area. These features are well preserved because of the low metamorphic grade. The sequence around Monico appears

to young to the south, and the sequence is known to be repeated by faulting that trends east-northeast. This particular outcrop appears to lie stratigraphically above the massive sulfide deposit at Pelican River to the west, and possibly above the Crandon deposit to the east. It is representative of the basaltic rocks in the Monico area.

ON 36/11E/30

Title: Monico Gravel Pits - Andesite Pillow Lava

Location: Exposures are at the top of the hill behind houses on Baade and Lake Roads, and on the north side of the gravel pit to the west, NE¼, NE¼, Sec. 30, T.36N., R.11E., Oneida County (Monico 7½-minute topographic quadrangle, 1965).




Author: M.G. Mudrey, Jr. (1978)

Description: The outcrops consist of pillowed, fine grained, light gray andesite with sparse to abundant quartz and plagioclase phenocrysts. The pillows appear to top south. Schriver (1973, p. 25) describes the rocks as amygdaliodal basalt. In the gravel pit, the amygdule fillings have weathered out, leaving a pock-marked vesicle texture. Amygdules constitute up to three percent of the rock, range in size up to three mm, and have a globular shape, but are generally undeformed. A chlorite rim encloses the amygdule filling of epidote or epidote and quartz. The groundmass consists predominantly of epidote and actinolite less than 0.05 mm in size. Plagioclase phenocrysts are largely altered to epidote and calcite and appear to be around $An_{25-30}$.

Schriver (1973, p. 30, no. 16) reports the following chemical data:

| | | Molecular Norm (Irvine-Baragar) | |
|---|---|---|---|
| $SiO_2$ | 53.5 | Q | 20.5 |
| $TiO_2$ | 0.7 | Or | 0.3 |
| $Al_2O_3$ | 14.0 | Ab | 10.1 |
| $FeO_T$ | 9.3 | An | 15.3 |
| MnO | 0.1 | Wo | 12.9 |

| | | | |
|---|---|---|---|
| MgO | 6.9 | En | 25.5 |
| CaO | 10.6 | Fs | 12.0 |
| $Na_2O$ | 2.1 | Mt | 2.1 |
| $K_2O$ | 0.1 | Il | 1.3 |
| Total | 97.3 | | |

Other analyses of this unit several miles to the southwest contain more silica and potassium, and might more properly be termed dacite.

Other outcrops of this unit may be found on the hills to the southwest and to the northeast. Mapping in 1978 by Mudrey suggests that this unit can be traced along an east-northeast strike about 3/4 mile. Mapping also suggests that this unit overlies the tuffaceous agglomerate unit to the east and south.

Discussion: Intermediate to felsic Middle Precambrian volcanism characterizes the northern Wisconsin volcanic belt. May (1977) describes the host rocks associated with the Flambeau deposit near Ladysmith, and Schmidt and others (1978) describe similar rocks associated with the Crandon deposit. Recently, Bowden (1978) described a similar sequence of rocks at the Pelican River deposit. Present mapping and geophysics suggest that the sequence of volcanic rocks immediately around Monico are close to the same stratigraphic position as the rocks at Pelican River. This exposure probably lies stratigraphically beneath the Pelican ore body, although definitive mapping has not been completed.

References Cited:

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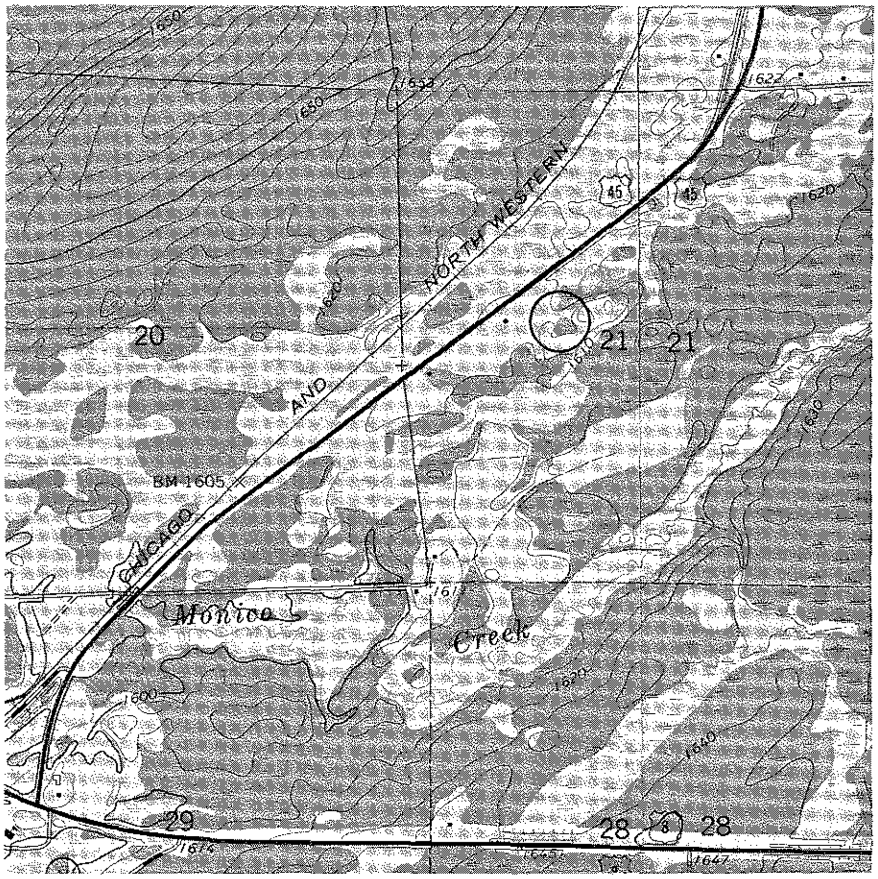
Schmidt, P.G., Dolence, J.D., Lluria, M.R., and Parsons, G., III, 1978, Geology of the Crandon massive sulfide deposit in Wisconsin: Skillings' Mining Review, v. 67, no. 18, p. 1, 8-11.

Schriver, G.H., 1973, Petrochemistry of Precambrian greenstones and granodiorites in southeastern Oneida County, Wisconsin: Unpub. M.S. Thesis, University of Wisconsin-Milwaukee, 83 p.

ON 36/11E/21

Title: Witte Farm - Coarse Felsic Agglomerate

Location: 1.4 miles north of intersection of U.S. 8 and U.S. 45. Outcrop located 400 feet east of highway behind abandoned house. SE¼, NW¼, Sec. 21, T.36N., R.11E., Oneida County (Monico 7½-minute topographic quadrangle, 1965).




Author: M.G. Mudrey, Jr. (1979)

Description: Three-foot long, angular, dacite clasts range in size from inches to several feet are set in an amphibole-bearing tuff or graywacke. Within the clasts, sparse euhedral plagioclase phenocrysts ($An_{20}$) up to 1.8 mm in maximum dimension are set in a flow banded matrix which wraps around the crystals. The rock is intensively altered, and sericite extensively replaces plagioclase. The groundmass consists predominantly of quartz, muscovite, and calcite. Blood red hematite is present, along with local concentrations of epidote and chlorite.

The matrix for the clasts consists of altered mineral grains 0.3 to 0.4 mm in size. A few relict (? pyroxene (?) and amphibole crystals remain, but the grains in the matrix consist predominantly of epidote-chlorite-muscovite-quartz granules. Calcite occurs abundantly as granules and in veins. Blood red hematite is sparse, and reflict glass shards can be seen in thin sections.

The trend of bedding is N. 70°-75° W. and dips 85° SW. About 700 feet to the northeast, intermediate pillow lavas appear to top south, however the bedding trend at this locality is N. 60° W. This is the only area of the quadrangle in which folding has been suggested.

A small body of intrusive granodiorite can be found about one thousand feet north.

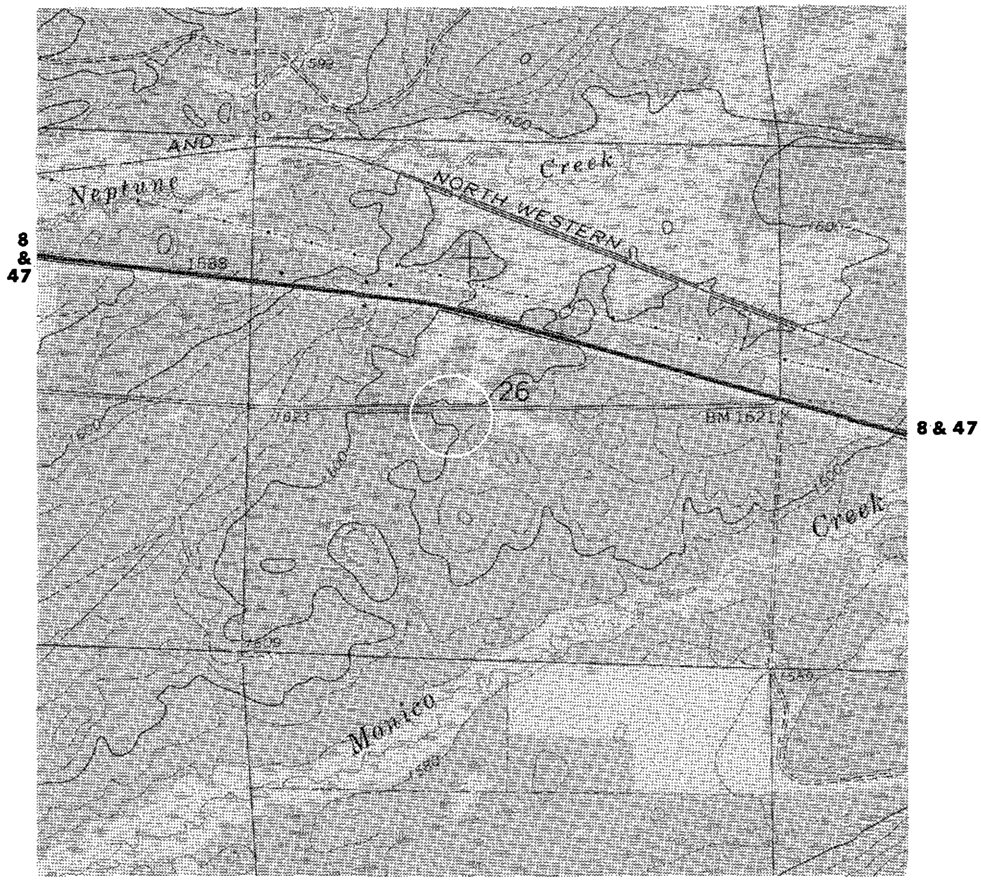
Discussion: Sangster (1972) noted the close spatial association between felsic agglomerates (or coarse pyroclastics) and massive sulfide ores, and that these agglomerates were a characteristic feature of many mining regions. Sangster (1972, p. 3) remarks that "the author / Sangster / once remarked to his colleagues that whenever he stood on the outcrop containing the largest fragments of acid pyroclastic in any given mining camp, he could invariably hear the mine mill nearby. His colleagues immediately dubbed this distinctive lithology 'millrock' and since then, 'millrock' has been observed close by most massive sulfide deposits in Precambrian volcanic rocks." The interpretation of this distinctive lithology is still open. Millrock is generally found in, or close to volcanic units in which the massive sulfides occur. The belt of rocks from the Pelican deposit, about 7 miles west, to several miles east of this locality has been extensively explored since the early 1970's. Although only the Pelican deposit has been announced as a possible massive sulfide deposit, the intensity of exploration attests to the favorable terrane.

References Cited:

Sangster, D.F., 1972, Precambrian volcanogenic massive sulfide deposits in Canada: A review: Geological Survey of Canada Paper 72-22, 44 p.

Title: Monico West - Section 26 Pyritic Tuff

Location: Old U.S. 8 west of Monico, SE¼, NW¼, Sec. 26, T.36N., R.10E., Oneida County (Monico 7½-minute topographic quadrangle, 1965).




Author: M.G. Mudrey, Jr. (1978)

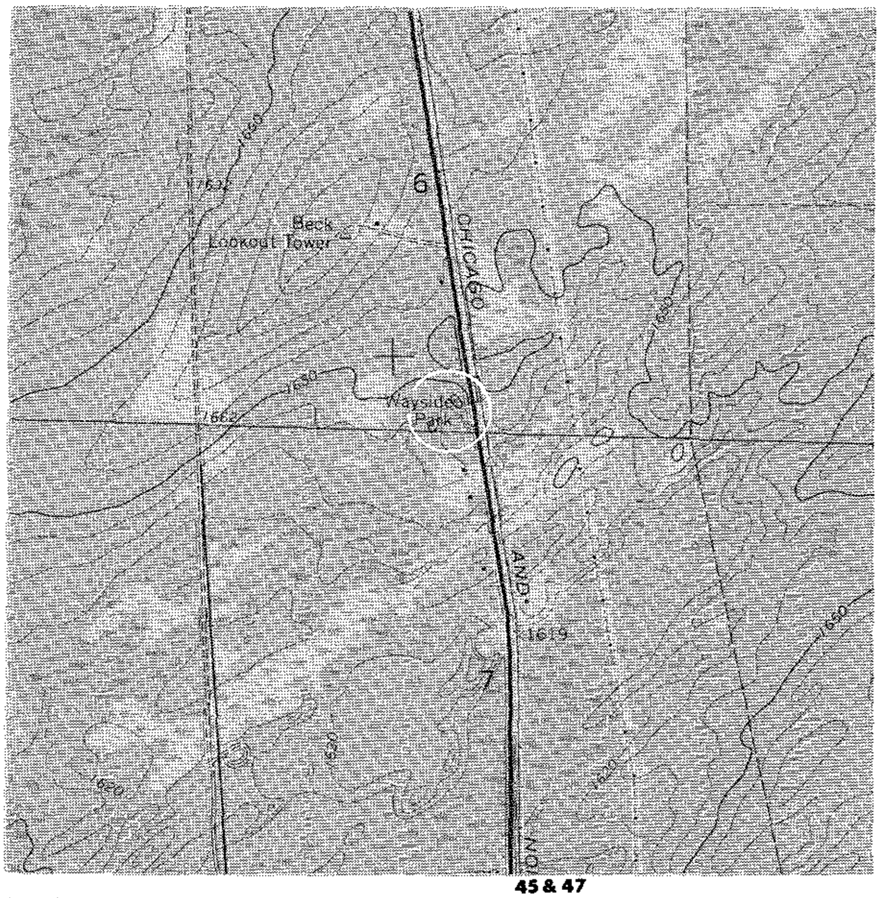
Description: The low outcrop on the north side of the road is a fine, light-gray, pyritic, indistinctly bedded lithic-crystal tuff which trends N. 60°-70° E. and dips vertically. The crystals consist of millimeter-sized, sericitized plagioclase. Most of the crystals are euhedral and embayed and corroded. Less altered lithic fragments contain minor amphibole. Actinolite, chlorite, and epidote are the dominant alteration minerals. Prehnite (?) and hematite are sparse.

The low ledge on the south side of the road consists of beds of gray, fine-grained, chloritic crystal tuff and bedded, light gray, aphanitic ash. The tuff is similar to the tuff on the north side, but matrix is more abundant, and the crystals sparser. Chlorite in the ash is berlin blue in thin section. This volcaniclastic unit varies considerably from fine tuffs and ashes to lapilli tuff. The unit is 3,000 to 4,000 feet thick and can be traced along strike at least three miles.

Discussion: Massive sulfide ore bodies consist mainly of sulfide-rich tuff, and grade distally into pyritic tuffs. These lithologies usually do not crop out because the sulfides weather readily. Therefore, the sulfide-rich outcrop here is unusual. It illustrates the general lithology and composition of the distal ends of a massive sulfide ore body. Some outcrops in the area contain more sulfide than this one. A recent road cut in Sec. 21, T.36N., R.11E. contains abundant sulfidic and sericitic schists, and may represent the lateral equivalent of the mineralized zones at Little Sand Lake. The trend of bedding at this locality and at the Crandon deposit near Little Sand Lake in Forest County is slightly north of due west, and on projection this locality could be essentially the same stratigraphic horizon as that at Little Sand Lake. Intervening between the two, however, is the granite body at Jennings (exposed at Beck Tower Wayside). Wisconsin aeromagnetic data suggest a northwest-trending fault immediately west of the Little Sand Lake deposit, therefore, this particular exposure probably is not directly correlatible with Little Sand Lake, but does illustrate many of the rock types spatially associated with the host rocks for the massive sulfide deposit.

Title: Beck Tower Wayside Park - Jennings Granite

Location: 2½ miles south of Monico on U.S. 45 and State 47, SW¼, SE¼, Sec. 6, T.35N., R.11E., Oneida County (Monico 7½-minute topographic quadrangle, 1965).




Author: M.G. Mudrey, Jr. (1978)

Description: This outcrop is a coarse, red, biotite granite and exhibits spheroidal weathering. Another outcrop is present 500 feet to the northeast in a railroad cut. Fresher outcrops of the same granite are found near Jennings, about 6 miles east. According to Venditti (1973, p. 46), the rock contains euhedral orthoclase, microcline and microperthite (40 percent), subhedral to euhedral oligoclase ($An_{27}$, 23 percent), anhedral quartz (31 percent), and minor amounts of interstitial biotite (3 percent). The biotite is pleochroic and light brown to dark brown, is sagenitic, and altered to chlorite. The grain size is 4-5 mm and shows no cataclastic textures at this outcrop, although outcrops near Jennings show narrow, well developed mylonitic zones.

Venditti (1973, p. 90, no. 24) reports the following analysis:

| | |
|---|---|
| $SiO_2$ | 73.1 |
| $TiO_2$ | tr |
| $Al_2O_3$ | 15.5 |
| $FeO_T$ | 1.5 |
| MnO | tr |
| MgO | tr |

| | |
|---|---|
| CaO | 1.5 |
| $Na_2O$ | 3.0 |
| $K_2O$ | 4.3 |
| Total | 98.9 |

Van Schmus and others (1975, p. 1259, no. D1356) report a Rb-Sr age of 1,580 m.y. from this locality. Van Schmus (in press) reports a U-Pb zircon age of 1,765± 10 m.y. from this locality.

Discussion: The potassic granitic intrusives in the Middle Precambrian of northern Wisconsin are all post-tectonic, and their ages cluster around 1,765 m.y. The younger 1,600 m.y. Rb-Sr age represents a wide-spread alteration of Rb-Sr ages that is not fully understood.

Van Schmus (in press) has divided the Middle Precambrian igneous activity into two pulses. The older one began with mafic to felsic volcanism 1,850± 20 m.y. ago, and was followed immediately by tonalitic to granitic plutonism 1,840 - 1,820 m.y. ago. Structural studies by Maas (1977) indicate that these rocks were emplaced during the main phase of the Middle Precambrian thermotectonic event. The second pulse consisted predominantly of phyolitic and granophyric granite and occurred about 1,765± 10 m.y. ago. No plutonic units have been found so far with zircon ages in excess of 1,850, nor have any been found with ages on the order of 1,615 - 1,630 m.y., the time of widespread alteration of the Rb-Sr isotopic systems in the region.

After emplacement of the late granites, major faulting occurred (LaBerge and Myers, 1976 and LaBerge, 1977), and has been recently studied to the south in Marathon County. Late faulting is recognized in north-central Wisconsin as seen in the mylonitic samples from Jennings. Extent and magnitude of the faulting in north-central Wisconsin is not known.

References Cited:

LaBerge, G.L., 1977, Major structural features in central Wisconsin and their implications to the Animikie Basin (abs.): 23rd Annual Institute on Lake Superior Geology (Thunder Bay, Ontario).

LaBerge, G.L., and Myers, P.E., 1976, The Central Wisconsin Batholith (abs.): 22nd Annual Institute on Lake Superior Geology (St. Paul, Minnesota).

Maas, R.S., 1977, Structure and petrology of an Early and Middle Precambrian gneiss terrane between Stevens Point and Wisconsin Rapids, Wisconsin: Unpub. M.S. Thesis, University of Wisconsin-Madison, 128 p.

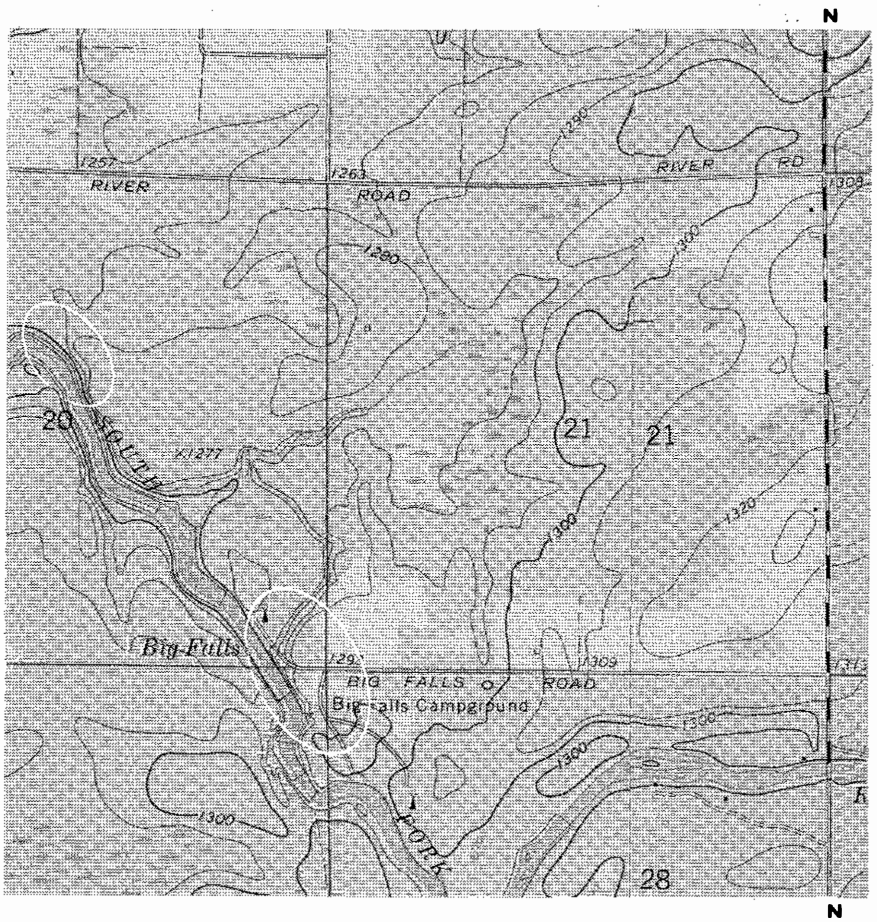
Van Schmus, W.R., in press, Chronology of igneous rocks associated with the Penokean orogeny in Wisconsin: Geological Society of America Memoir.

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: Geological Society of America Bulletin, V. 86, p. 1255-1265.

Venditti, A.R., 1973, Petrochemistry of Precambrian rocks in southeastern Oneida County, Wisconsin: Unpub. M.S. Thesis, University of Wisconsin-Milwaukee, 93 p.

Title: Jump River at Big Falls County Park

Location: Along the Jump River in NE¼, NE¼, Sec. 29, and SE¼, Sec. 20, T.34N., R.2W., Price County. (Jump River Fire Tower, Topographic Quadrangle, 1970).




Author: Gene L. LaBerge

Description: The main rock type exposed here is a weakly foliated quartz monzonite of presumed Middle Precambrian age. Foliation strikes approximately east-west and dips vertically. Late stage aplite dikes along with minor pegmatite and vein quartz cut the main quartz monzonite body.

Downstream from the main park area the rock has been extensively sheared to flaser gneiss and mylonite. The main cataclastic foliation is oriented approximately east-west with a vertical dip and is about one-half mile wide. Within the cataclastic zone are smaller mylonitic zones that strike N.30°E. and about 40°SE.

Pyritic tuffaceous andesitic(?) greenstone crops out at the major bend in the river approximately three-quarters of a mile downstream from the park. Good preservation of primary textures suggests the rocks have undergone only greenschist or lower amphibolite facies metamorphism. A number of exposures of mafic rocks are present along the river between the tuffaceous greenstone and quartz monzonite. They appear to be somewhat metamorphosed and sheared.

Discussion: This exposure is along a major structural feature in Wisconsin, the "Jump River lineament" (Myers, 1974). The lineament is expressed topographically and on both the Bouguer anomaly gravity map (Ervin and Hammer, 1974), and the aeromagnetic map (Zietz, Karl, and Ostrom, 1978). Where exposed, the lineament consists of cataclastic rocks. North of the lineament of the rocks are dominantly volcanic rocks in the greenschist and/or lower amphibole facies with numerous more or less foliated granitic plutons. This forms a major east-west volcanic belt of Middle Precambrian rocks across Wisconsin from the Michigan border westward to the Keweenawan overlap (Sims, Cannon, and Mudrey, 1978). (Note that the "Jump River Fault" of Sims, Cannon, and Mudrey (1978) does not coincide with the "Jump River lineament" of Myers (1974).)

South of the lineament, gneisses, amphibolites, schists and migmatites are the predominant rock types for nearly 30 miles. Relatively unmetamorphosed volcanic and plutonic rocks are common in Marathon County and are in fault contact with the gneisses (LaBerge, 1977). Little or no work has been done on the high-grade rocks; however, they appear to be mainly amphibolite grade with few, if any, primary features preserved. Cummings and Myers (1978) and Myers (1977) have studied similar rocks in the Eau Claire area that are evidently part of this terrane, and they concluded that the rocks are at least in part Early Precambrian. Probable Middle Precambrian granitic rocks intrude the higher-grade rocks, and isolated patches of low-grade metavolcanic and metasedimentary rocks are present in places (Myers, 1978a, b). The low grade metamorphic rocks are probably Middle Precambrian in age, but no age determinations are available on the higher grade rocks. Thus, we do not know whether the high-grade rocks represent an Early Precambrian basement on which simply more highly metamorphosed Middle Precambrian rocks. The "horst-graben" pattern in Central Wisconsin is suggestive of basin and range structure. The implications of this structure, as well as its timing, has important bearing on our interpretation of the tectonic development of the Animikie Basin. As indicated here, the emplacement of at least some of the granitic plutons occurred prior to final displacement along the fault zones. If this is a Penokean age pluton, the faulting must be either late Penokean or post-Penokean in age.

References Citied:

Cummings, M.L., and Myers, P.E., 1974, Eau Claire River at Big Falls: Wisconsin Geological and Natural History Survey, Geology of Wisconsin Outcrop Description EC 27/8W/13, 10 p.

Evin, C.P., and Hammer, S., 1974, Bouguer anomaly gravity Map of Wisconsin: Wisconsin Geological and Natural History Survey, scale 1:500,000, 2 sheets, separate text.

LaBerge, G.L., 1977, Major structural features in central Wisconsin and their implications on the Animikie Basin (Abs.): 23rd Annual Institute on Lake Superior Geology (Thunder Bay, Ontario), p. 23.

Myers, P.E., 1977, Eau Claire River at Little Falls: Wisconsin Geological and Natural History Survey, Geology of Wisconsin Outcrop Description EC 27/8W/19, 6 p.

Myers, P.E., 1978a, North Fork of the Eau Claire River at Knight Pool: Wisconsin Geological and Natural History Survey, Geology of Wisconsin Outcrop Description EC 26/5W/10, 2 p.

Myers, P.E., 1978b, Eau Claire River at Confluence of North and South Forks: Wisconsin Geological and Natural History Survey, Geology of Wisconsin Outcrop Description EC 26/5W/29, 2 p.

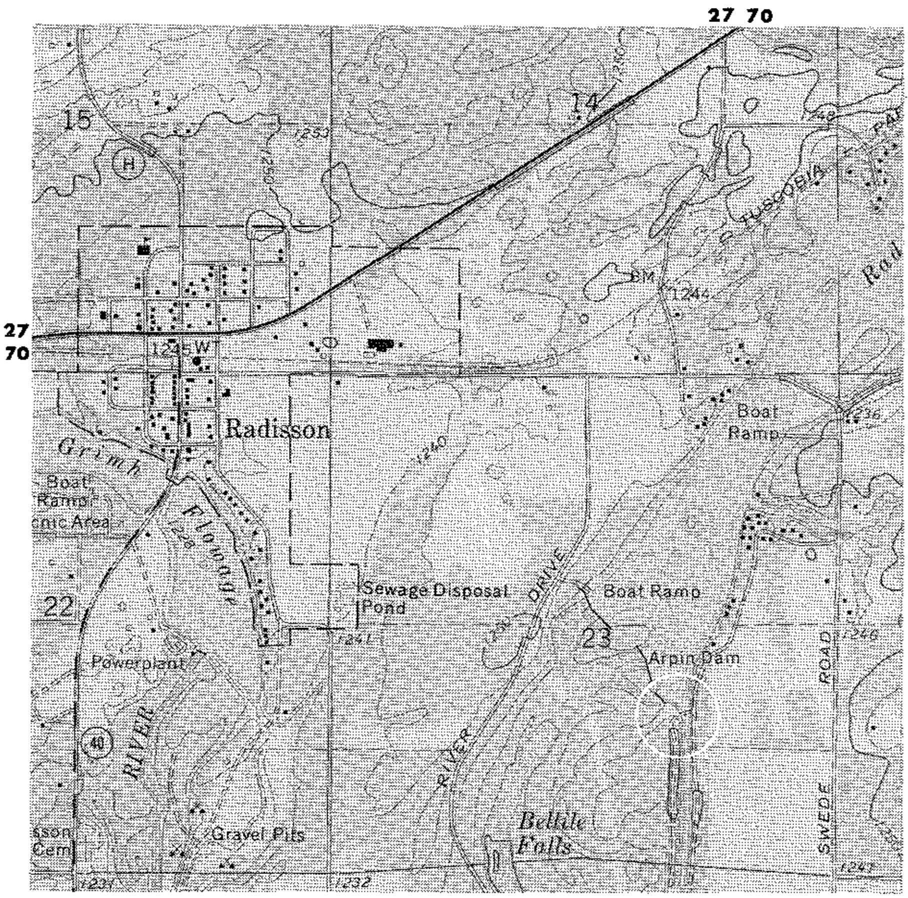
Sims, P.K., 1976, Presidential address - Precambrian tectonics and mineral deposits, Lake Superior Region: Economic Geology, v. 71, no. 6, p. 1092-1118.

Sims, P.K., Cannon, W.F., and Mudrey, M.G., Jr., 1978, Preliminary geologic map of Precambrian rocks in part of northern Wisconsin: U.S. Geological Survey Open-file Report 78-318, scale 1:250,000, 2 sheets.

Zietz, I., Karl, J.H., and Ostrom, M.E., 1978, Preliminary aeromagnetic map covering most of the exposed Precambrian terrane in Wisconsin: U.S. Geological Survey Miscellaneous Field Study MF-888, scale 1:250,000.

Title: Arpin Dam in Radisson - Late Porphyritic Granite

Location: River channel downstream from Arpin Dam, one mile southeast of Radisson, NW¼, SE¼, Sec. 23, T.38N., R.7W., Sawyer County (Radisson 7½-minute topographic quadrangle, 1972)




Author: M.G. Mudrey, Jr. (1978)

Description: Outcrops are reasonably abundant in the vicinity of Radisson. The bedrock consists of a coarse, hornblende-granodiorite with inch-sized microcline megacrysts generally aligned N. 50° E. Medium-granied aplite dikes up to one-foot wide trend N. 15°-35° E. The granodiorite consists of subhedral to euhedral microcline set in a groundmass of sutured quartz grains, subhedral plagioclase ($An_{15-20}$), minor brown biotite slightly altered to chlorite, and green hornblende with trace amounts of apatite, epidote and zircon are found. The aplite dikes consist of equal amounts of subhedral plagioclase ($An_{20}$), microcline, and anhedral quartz. Trace quantities of muscovite, chlorite and zircon are present. Van Schmus (in press) reports an U-Pb zircon age of 1,765 10 m.y. for a sample from Grimh Flowage, about 0.6 miles west of this locality.

Discussion: This granodiorite, the Jennings granite, other alkalic granites, and the rhyolites of south-central Wisconsin are all late Penokean and yield ages around 1,765 m.y. For the most part, the granitic rocks are little deformed, but all yield Rb-Sr ages around 1,600 m.y. The 1,600 m.y. age is widespread. However, there appears to be no rock units or major structures related to this resetting in northern Wisconsin. Smith (1978) has determined that the Baraboo

Quartzite and the rhyolites of southern Wisconsin were metamorphosed and deformed about this time. The 1,600 m.y. age is pre-Wolf River and associated rapakivi granites, syenites and anorthosites. Some of the faulting in the area may be related to this 1,600 m.y. thermal event.

The Radisson granodiorite is similar to the Rockville Granite of Minnesota, both in petrography and in age (Keighin and others, 1972, p. 240).

References Cited:

Keighin, C.W., Morey, G.B., and Goldich, S.S., 1972, East-Central Minnesota: in P.K. Sims and G.B. Morey, editors, The Geology of Minnesota (G.M. Schwartz Volume): Minnesota Geological Survey, p. 240-255.

Smith, E.I. 1978, Precambrian rhyolites and granite in south-central Wisconsin: Field Relations and geochemistry: Geological Society of American Bulletin, v. 89, p. 875-890.

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