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Meredith E. Ostrom, State Geologist and Director

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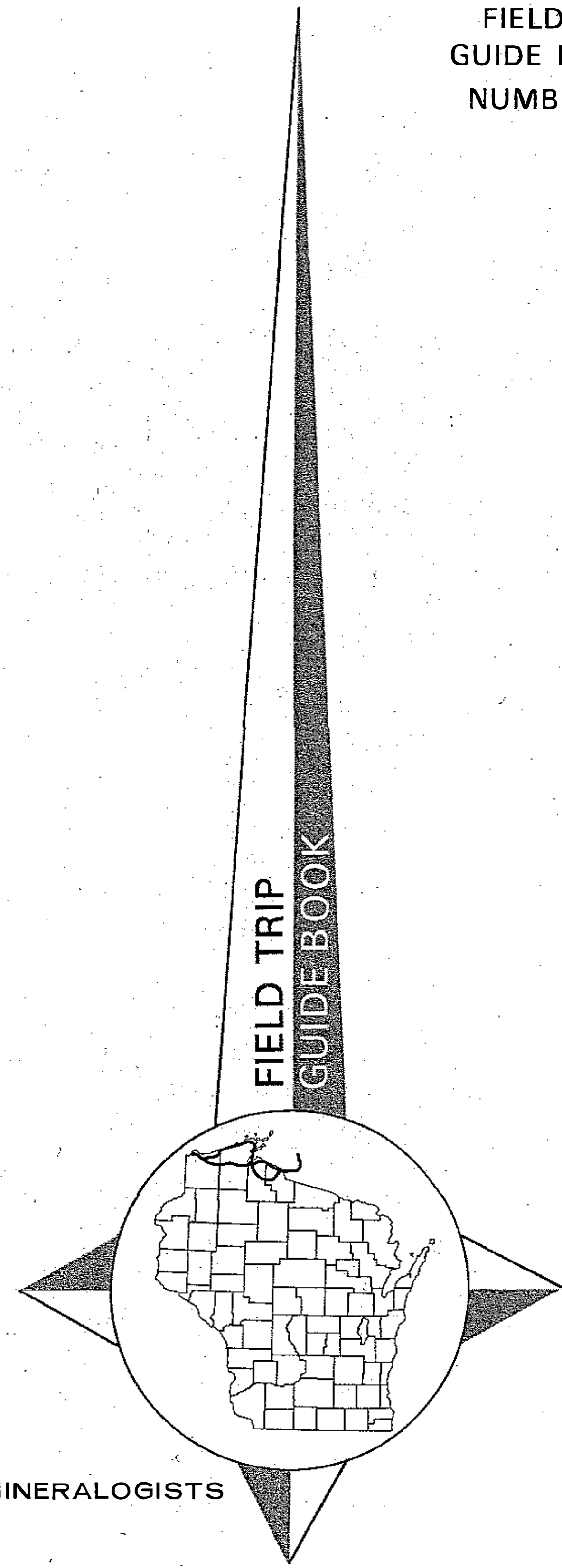

PRECAMBRIAN PETROLEUM POTENTIAL ALONG THE MIDCONTINENT TREND

Prepared for

SIXTEENTH ANNUAL FIELD CONFERENCE
GREAT LAKES SECTION
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
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PRECAMBRIAN PETROLEUM POTENTIAL ALONG THE MIDCONTINENT TREND
(companion volume to Geoscience Wisconsin Volume 11)

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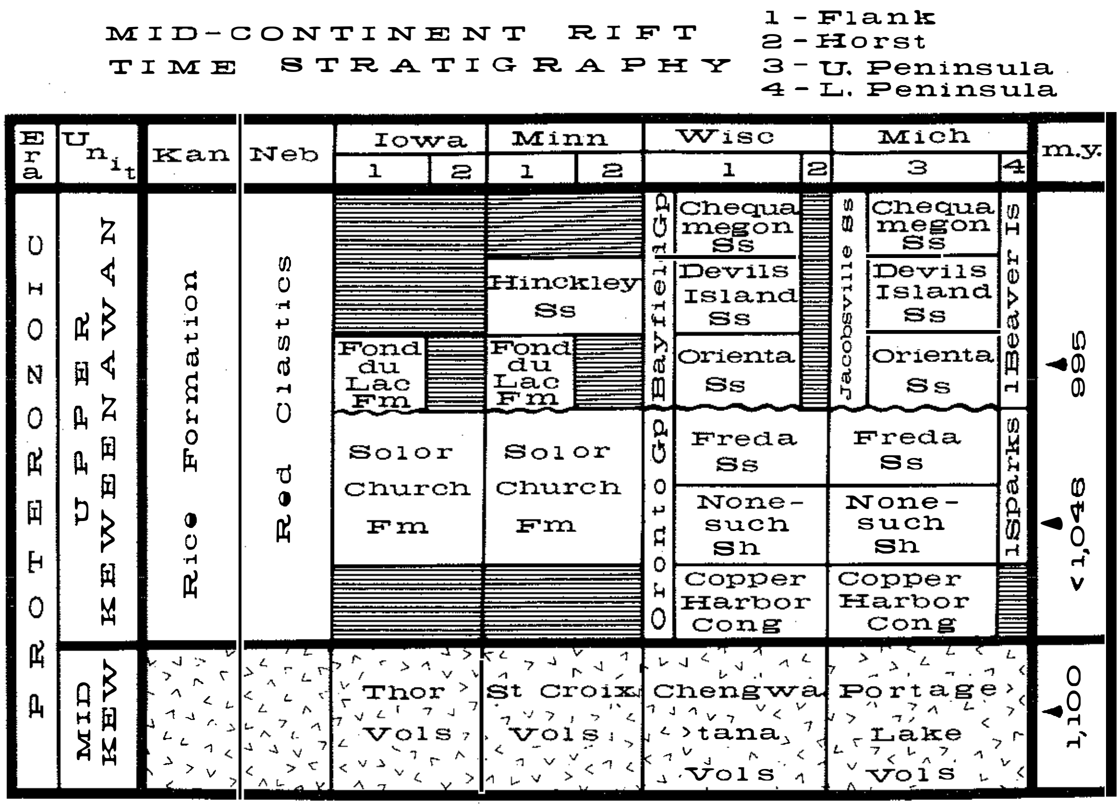
INTRODUCTION

Recognition that economically recoverable oil and gas occur in the Proterozoic in China, Siberia, possibly Australia, and northwestern Montana is causing industry to reexamine the North American Precambrian for petroleum potential. Indigenous petroleum is known from the Nonesuch Shale Formation in the Lake Superior area. This occurrence has attracted about half a dozen companies into the area at some level of exploration. Over 200,000 acres of land have been leased for petroleum exploration in Wisconsin. Several million more acres have been leased along the Midcontinent trend in Minnesota, Iowa, and Kansas. Several thousand line-miles of seismic surveys have been undertaken, including speculative surveys such as that by Geosource, and proprietary surveys by Grant Geophysical and others. Grant-Norpak, Inc. conducted a marine survey in Lake Superior for about a dozen clients in 1984.

Seven factors are normally examined when petroleum potential for an area is evaluated. These include source bed characterisitics, nature of hydrocarbons, thermal maturation, petroleum migration possibilities, reservoir characteristics, reservoir seals, and structural style of tectonic evolution. Information to evaluate these factors and to understand the evolution of the Keweenawan and its petroleum potential is presented in the field trip and the accompanying Geoscience Wisconsin Volume 11.

The final event in the formation of the Precambrian crust in this region was the development of the Midcontinent Rift System (Wold and Hinze, 1982). Rifting was accompanied by the massive upwelling of mantle-derived magma with



Stratigraphic terminology and time relationships along Midcontinent Rift Trend. Reproduced from A.B. Dickas, 1986, Comparative Precambrian stratigraphy and structure along the Mid-continent rift: American Association of Petroleum Geologists Bulletin, v. 70, no. 3 (March 1986), p. 227.

solidification of mafic plutonic rock at depth and widespread volcanism and clastic sedimentation at the surface in a series of coalesced basins (Morey, 1978; Weiblen and Morey, 1980; Green, 1977; Dickas, 1986).

Rock within the rift system can be divided into three lithotectonic assemblages that partially overlap in space and time. The oldest assemblage consists of predominantly sedimentary rock and possible coeval low-alumina tholeiitic sills, which did not significantly deform or metamorphose their country rock. The main stage of tectonic activity consisted of predominantly igneous rock in at least two separate successions of lava flows and from plutonic rocks that were emplaced over a relatively short time span, 1,100 to 1,000 Ma. These were emplaced into an evolving rift system that extended from Lake Superior at least as far as southern Kansas. The uppermost lithotectonic assemblage consists of two suites of clastic sedimentary rock of alluvial to fluvial origin. The older suite, which locally is intercalated with the uppermost lava flows, consists of lithic sandstone and shale that were deposited in a number of fault-bounded basins along the axis of the rift. The younger suite consists of arkosic and quartzose sandstone deposited in a large half-graben-like basin along the flanks of the rift. These predominantly sedimentary assemblages mark the gradual cessation of crustal separation and magmatism.

Dominantly vertical faulting continued intermittently throughout the time of active sedimentation and into the Paleozoic Era. This most recent tectonic event is characterized by the development of an axial horst along the main rift trend and subsequent subsidence of the rifted region to form the major embayments that existed during the Paleozoic Era.

Correlation of units in the uppermost lithotectonic assemblage is one of controversy because of lack of exposures and key beds between areas that have been well studied (Morey and Ojakangas, 1982). The Nonesuch Formation, the presumed source bed, is generally conceded to pinch out to the southwest of its type locality in Michigan, and is only a few meters thick in northwestern Wisconsin (Daniels, 1982). Some feel that the stratigraphic interval represented by the Nonesuch is replaced by unknown, but correlative petroleum source beds to the southwest in Minnesota and Iowa (Lee and Kerr, 1984). Others feel that this correlation is unwarranted. It has been proposed that the Devils Island Formation and the overlying Chequamegon Formation that are the uppermost units of the Bayfield Group are in fact Paleozoic and correlate, at least in part, with the Jacobsville Sandstone (Ostrom and Slaughter, 1967). Some have assigned an Early Cambrian age to these units. Others assign these same units to the Middle Proterozoic.

Structures, including folds and faults, are recognized in uppermost Keweenwan rock; however, there is some question as to the age of deformation. Some have noted that in Paleozoic rock overlying the Keweenawan sequence in the Twin Cities Basin and the River Falls Syncline that at least some of the structures are as young as Middle Ordovician. How much of the deformation along the Midcontinent Rift is Proterozoic in age, and how much represents minor isostatic adjustment of the rift remains to be resolved.

Petroleum factors have been evaluated for the rift. Estimates range from optimistic to pessimistic (Hatch and Morey, 1985).

It is the intent of the field trip organizers to illustrate the principal lithologies in the upper Keweenawan, the deformational history, and to present a synthesis based on available public data. Many of the points of controversy may be resolved in the future by additional work, whereas others will remain.

GEOLOGIC ROAD GUIDE FOR GREAT LAKES SECTION OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS FIELD TRIP TO UPPER KEWEENAWAN ROCKS IN NORTHWESTERN WISCONSIN AND UPPER MICHIGAN, SEPTEMBER 20-21, 1986

Richard A. Paull, Rachel K. Paull, M.G. Mudrey, Jr., and Albert B. Dickas

A significant part of the material that follows is modified from Paull and Paull (1980).

The road guide that follows is logged in the direction of travel of the 1986 SEPM field trip. The log is broken into several discrete segments.

GEOLOGIC ROAD LOG FOR SEPTEMBER 20, 1986; SUPERIOR, WISCONSIN, TO PRESQUE ISLE RIVER PARK, MICHIGAN, AND ASHLAND, WISCONSIN.

LOG SEGMENT 1: SUPERIOR TO ASHLAND, WISCONSIN.

Mileage

0 Junction Highway 53 (Business) with Highway 2 and 53 in Superior, Wisconsin and on the shore of Superior Bay. The bay is protected by southeastward trending Minnesota Point, reported to be the longest freshwater sand bar in the world. This feature, and the northwestward trending companion bar of Wisconsin Point that defines Allouez Bay a few miles ahead, developed during the last 3,000 years. The narrow gap between the 2 points was the natural outlet for the St. Louis and Nemadji rivers. It is now maintained by dredging to provide access to the harbors at Duluth and Superior. Some of the largest taconite loading docks in the world are located here. Railroad cars dump their loads directly into giant hoppers that store the ore until it can be transferred to a Great Lakes carrier. With this type of automation, the Great Northern docks are capable of handling more than 15 million tons of taconite pellets annually.

Superior, at the western end of Lake Superior, has a long and colorful history. French trappers and explorers passed this way during the mid-1600s, and a trading post was established here by 1680. The Hudson's Bay Company took over the trading post in 1787, when the English gained temporary control of this region. The first town site was developed near the mouth of the Nemadji River a few years after the Chippewa made peace with the United States in 1847. A fort was built here during the early 1860s when an Indian war seemed imminent. The town boomed during the 1890s, in response to iron mining activity in Minnesota and a lumbering boom throughout the region. By 1900, an iron smelter and a shipbuilding industry helped make Superior the second largest city in Wisconsin.

Although this heyday passed, Superior is still a busy port city, with major ship-loading facilities for moving iron ore from Minnesota mines, wheat from prairie states, and coal from Wyoming and Montana.

Superior is situated on a lowland plain bordering Lake Superior. This plain is composed of thick reddish clay till, which overlies thin sandy till, sand, and gravel overlying the Precambrian sandstone. This till was deposited in the Lake Superior basin 9,500

Mileage

to 11,500 years ago, when the Superior Lobe of the Laurentide Ice Sheet filled the basin. As the Superior Lobe melted back, Lake Superior briefly stood at the Duluth level, with drainage southward through the Bois Brule River in eastern Douglas County, Wisconsin, into the St. Croix River, and on to the Mississippi.

As lake level dropped, streams flowing into the basin cut deep valleys in the soft glacial clay.

The poorly drained lake plain climbs gradually southward for about 10 miles toward the Keweenawan basalt of the Douglas Copper Range. Here, at an elevation of about 1,100 feet, the highest beaches of the Duluth stage of Lake Superior are still recognizable.

Turn southeast on Highway 2 and 53.

3 Cross the Nemadji River. Normally this river carries a heavy load of eroded clays.

Moccasin Mike Road goes north from U.S. 2, at the east edge of Superior, to provide access to Wisconsin Point. A road extends along the length of this feature to the shipping canal, which separates this point from the longer spit that extends from the Minnesota shore (Minnesota Point).

7 Junction with Highway 13, which goes northeasterly along the Bayfield Peninsula. We will return to this intersection on September 21.

Highway 2 continues across the Lake Superior lowland. The underlying bedrock is sandstone and shaly sandstone of the uppermost Keweenawan Bayfield Group. In this area, bedrock is covered by thick, reddish clay till. These deposits obscure bedrock irregularities to form a flat, poorly drained plain that slopes gently toward Lake Superior.

13 Junction with Highway 53 (south). Near the southeast corner of this intersection, a quarry is developed in the Amnicon gabbro, which intruded Middle Keweenawan volcanics at this locality.

Highway 2 crosses the trace of the Douglas Fault near this intersection.

14 Junction with Highway U is immediately east of the boulder-strewn course of the north-flowing Amnicon River. The road leads to Amnicon Falls State Park; we will visit this important locality on our last stop on September 21.

The route from here to Poplar, Wisconsin, traverses Middle Keweenawan lava flows, which are largely covered by poorly drained clay till.

16 Wentworth, about 240 feet above the present level of Lake Superior, provides a good view of the lowland we traversed.

Mileage

17 Cross the Middle River. About 2 miles north along this drainage, steeply south-dipping, Upper Keweenawan Freda Sandstone and rock of the overlying Bayfield Group are exposed. Overturning of these beds was caused by the Douglas Fault, which brought Middle Keweenawan volcanics up and over the younger sedimentary rock.

21 Cross the Poplar River at Poplar. The route ahead climbs several beaches of glacial Lake Superior.

22 Maple, Wisconsin. A high shoreline of the Duluth beach (about 1,080 feet in elevation) provides a fine view northward over the Lake Superior lowland to Lake Superior.

29 Cross the Bois Brule River. From the mid-1600s well into the 1800s, this river was part of an important canoe route for French and English explorers, missionaries, and fur traders traveling between Lake Superior and the Mississippi River. The Bois Brule rises near the headwaters of the St. Croix River at Solon Springs, Wisconsin, about 30 miles southwest of here. Because the St. Croix is a tributary of the Mississippi, only a short, low-level portage was required to use this waterway. Although they didn't know it, these early travelers were following the south-flowing spillway of glacial Lake Superior. The highest elevation along the portage controlled the maximum level for the Duluth stage of the lake. When eastern outlets at lower elevations became free of ice, the lake dropped abruptly.

30 Brule, Wisconsin, and the junction with Highway 27.

31 Douglas/Bayfield County line.

37 Cross the Iron River, in an area of gently rolling glacial collapse topography just above the highest beach of Lake Superior.

38 Enter Iron River. This village was founded in 1887 near a mineral spring. Although it is in a region of beautiful lakes in a late Wisconsinan collapse depression, it was too remote to prosper in the days when health spas were in vogue.

The route ahead crosses onto a late Wisconsin till. The knobby, pitted till is sandy and thick, and it forms an attractive countryside mantled with birch, pine, maple, and bracken.

50.5 Village of Ino in an area of red-clay till.

56 A vista of the Bayfield Peninsula and the bordering lake plain.

57 Junction Highway 63 (south) as Highway 2 descends the lowland extending inward from Chequamegon Bay.

63 Junction Highway 13 (north) to the Bayfield Peninsula. We will follow this route on September 21, 1986. Cross Fish Creek east of the University of Wisconsin Experimental Station. The axis of the Lake Superior syncline crosses the highway in this general area.

Mileage

64 Cross the reedy sloughs of Fish Creek once again, where it enters Chequamegon Bay. The old ore docks and the Lake Superior District Power Company Plant dominate the view of the bay.

65 Ashland/Bayfield county line; enter Ashland County. A wayside park is north of the highway. The route continues over a poorly drained lowland underlain by Upper Keweenawan Sandstone and shale, which are covered by clay till.

66 Enter the historic port city of Ashland, Wisconsin, where rich iron ore from the Penokee-Gogebic Range to the south was loaded onto boats destined for eastern mills.

To the north, across Chequamegon Bay, is the high-standing Bayfield Peninsula. The bay, and Ashland's harbor, are protected by Chequamegon Point and Long Island. Both of these features were once part of the same sand spit that nearly closed the mouth of Chequamegon Bay. This sand bar is the legendary dam constructed by the Chippewa god Nanabozho, to trap the Great Beaver of Lake Superior.

This locale is also the "Shining Big-Sea-Water" setting for Longfellow's poem, "The Song of Hiawatha." However, it is unlikely that Hiawatha, a legendary hero of the Iroquois, ever ventured into this region because this was the stronghold of the Chippewa's Nanabozho, a traditional enemy of the Iroquois.

Intersection of Highway 2 and Highway 13 in downtown Ashland; turn south on Highway 13 toward Mellen, Wisconsin.

LOG SEGMENT 2: ASHLAND-MELLEN-HURLEY, WISCONSIN, BY WAY OF HIGHWAY 13 AND 77

Mileage

0 Intersection of Highway 13 and Highway 2 in Ashland, Wisconsin. Turn south on Highway 13 toward Mellen, Wisconsin.

1 Northland College is west of the highway.

6 Cross the White River.

11 Junction of Highway 13 and 112 (west) in an area of flat, poorly drained clay till.

13 Cross the Marengo River and enter the village of Marengo.

16 Community of North York.

18 Village of High Bridge. Silver Creek has eroded a deep valley in the glacial deposits at this locality.

20 The route ascends to a rolling, morainal surface from the relatively subdued landscape of the Lake Superior lowland. The Upper Keweenawan

sedimentary bedrock underlying this lowland is covered with sediment deposited during various ancestral stages of Lake Superior. Sandy shoreline deposits in this area establish that one of the Duluth stages was about 500 feet above the present level of Lake Superior.

The Lake Superior lowland extends inland from Chequamegon Bay for about 30 miles.

22 The highway is now on late Wisconsin till, which overlies Middle Keweenawan volcanics.

23 The large roadcut on the west side of the road provides an exposure at the northern edge of the Mellen gabbro body. Here, red and gray granitic rock (Mellen Granite) encloses angular blocks of dark gabbro. Although the gabbro fragments are surrounded by granitic rock, there is little evidence of assimilation in this intrusive breccia.

Glacially polished and striated exposures of Mellen gabbro occur on both sides of the highway for the next mile.

24 Junction of Highway 13 and 169; turn northeast on 169 toward Copper Falls State Park, and cross the Bad River.

25 The abandoned quarry of the American Black Granite Company is north of the highway. There were numerous gabbro quarries operating in the Mellen area during the mid-1930s, when 2,000 tons of rock a month were shipped. The products varied from small fragments for terrazo to huge blocks weighing up to 100 tons. The larger blocks were taken by rail to Ashland, where they were cut and polished at a finishing plant before being shipped all over the United States.

The Upper Keweenawan Mellen gabbro body was intruded along the regional trend of the Keweenawan volcanics. The northwesterly dipping intrusion persists for about 40 miles, and it is up to 15,000 feet thick. The composition of the rock varies from gabbroic at the base to granitic at the top. In the Mellen area the gabbroic body and adjacent Keweenawan volcanics are intruded by the younger Mellen granite. Because it is similar in composition and intrusive relationships to the Duluth gabbro, the Mellen gabbro is considered to be the same age (about 1 billion years old).

26 Pass Loon Lake, and turn left (north) on Highway J. The route traverses an area of irregular till.

27 <u>STOP 1: COPPER FALLS STATE PARK:</u> Three waterfalls are the center of attraction at this park, and all are accessible by trails. The nearest is Copper Falls, where the Bad River plunges 29 feet over resistant, north-dipping Middle Keweenawan basaltic lava flows. A quarter-mile downstream from Copper Falls, the Tyler Forks, a tributary of the Bad River, drops 30 feet over Brownstone Falls to reach the narrow, lava-lined gorge of the Bad River. The Tyler Fords cascades are upstream from Brownstone Falls. Here, a grouping of five small waterfalls tumble over a series of resistant lava ledges.

Mileage

Where the Bad River first enters the lava gorge, erosion is quite efficient, and the rapids here have retreated 4 feet upstream in the last 6 years.

Downstream, a short distance below the confluence of the Tyler Forks with the Bad River, a succession of near-vertical, Upper Keweenawan sedimentary rocks are exposed. These rocks consist of the Copper Harbor conglomerate at the base, which is in fault contact with Middle Keweenawan basalts upstream, an overlying poorly exposed interval of Nonesuch shale, and the reddish Freda Sandstone at the top. The Copper Harbor is the most resistant unit in this sequence, and it forms a narrows along the Bad River known as Devils Gate.

North of the main parking area, at the head of the trails to the falls, a large cliff of till and fluvial sand and gravel is exposed. Striations on basaltic bedrock indicate the late Wisconsin ice sheet move south into this area.

While at Copper Falls, notice that the park buildings are made of Mellen gabbro, whereas the walkways are paved with the Lower Proterozoic Tyler Slate.

An overview of Upper Keweenawan stratigraphy will be presented at this stop.

Upon leaving Copper Falls State Park, return to Highway 13 via Highway J and Highway 169.

30 Junction of Highway 169 and 13; turn south on 13.

31 Junction of Highway 13 and 77 in Mellen, Wisconsin. This community was once a major quarrying center for an attractive building stone that carried the trade name "black granite."

32 Leave Mellen.

The Minneapolis, St. Paul, and Sault Ste. Marie Railroad (the "Soo" line), south of Mellen, uses the Bad River gap through the Penokee-Gogebic Range. Highway 77 follows the Penokee-Gogebic Iron Range northeastern for 36 miles from Mellen to Hurley, Wisconsin.

The prominent ridge south of the highway is the western end of the Penokee-Gogebic Range, and it is the surface expression of a narrow band of steeply dipping (55 to 65° north), resistant, Early Proterozoic (Animikean) sedimentary rock. Although the range is less than a mile wide, it persists for 80 miles in an east-northeasterly direction, for 8 miles west of Mellen, Wisconsin, to Lake Gogebic in Michigan.

The south face of the range here rises 100 feet above Pleistocene material overlying older Precambrian rock. On the north the resistant rock of the range dips steeply toward a narrow valley formed on the less resistant slate of the Tyler Formation at the top of the Animikean succession. Along this side of the range, the relief between valley floor and ridge crest is 250 feet, and at Mt. Whittlesey, southeast of Mellen, the relief is 550 feet. North-dipping ridges of resistant Keweenawan volcanics form the range that parallels the trend of the Penokee-Gogebic on the north of this slate valley.

34 Roadcuts expose north-dipping beds in the Tyler Slate. The hills north of the highway are composed of Mellen Gabbro.

37 Ashland/Iron County line; enter Iron County.

39 Roadcuts provide an opportunity to examine exposures of glacially polished slate and graywacke in the Tyler Slate. The highest part of the Penokee-Gogebic Range is visible to the southwest. The range of volcanic rock is well defined to the north.

40 Cross Tyler Forks River.

45 Cross the Potato River, which flows northward through a gap in the Penokee-Gogebic Range; and enter the Village of Upson. Junction with Highway 22 (north); continue northeasterly on Highway 77.

The unconformity between the steeply (65°) north dipping Palms Formation and the metamorphosed amygdaloidal volcanics of the Archean metavolcanic sequence is exposed along the Potato River 0.3 mile upstream.

Upson village park, a short distance north of the highway, provides access to Upson Falls. Here, the Potato River cascades over steeply north-dipping, resistant quartzite beds within the Early Proterozoic Tyler Formation. The valley in this area is flat and poorly drained, but it supports a dense stand of second-growth timber.

49 Cross the Minneapolis, St. Paul, and Sault Ste. Marie Railroad and proceed into the village of Iron Belt. To the north the parallel trending ranges are composed of resistant Keweenawan lava. Highway 77 and the Soo line follow the valley developed on relatively nonresistant Tyler Slate.

51 Roadcuts expose steeply north-dipping Tyler Slate.

52 The hoist structure in the woods south of the highway marks the site of the Plummer Mine, and it is a photographer's joy. The Palms Formation is exposed south of the mine, and the waste piles provide abundant samples of the productive iron-formation.

53 Village of Pence.

56 Town of Montreal and the dumps of the Montreal Mine. The first iron ore from this historic community was shipped in 1886. The most important mine in the area was the Montreal, and it followed steeply north-

Mileage

dipping hematite deposits to a depth of 4,335 feet. The hoists that hauled ore from this depth moved at 1,800 feet per minute. This was the deepest iron mine in the work, and 46 million tons of ore was extracted before it closed in 1962. Snow is now the important commodity in Montreal, and it attracts great numbers of skiers each winter.

Iron ore was discovered in the western part of this range in 1848, but development was slow until the 1880s. The main ore mined in the Penokee-Gogebic was a soft hematite that formed after Animikean rock was tilted northward by the formation of the Lake Superior syncline duing Keweenawan time. This tilting allowed oxygen-rich water to percolate down the upturned edges of the ore-bearing strata. These waters were selectively funneled into trough-like areas, where transverse faults or dikes cut through the Ironwood Iron Formation. At such locations, and near the contact of the Ironwood with the impervious Palms Formation, the siliceous iron formation was altered to soft hematite by the removal of silica. Mines followed these ore horizons downdip to considerable depths. With the development of taconite pelletization, soft ores from underground mines were no longer profitable. By 1961 only three mines were operating. When the last load of ore was shipped in 1967, an era ended.

Cross the West Fork of Montreal River.

Gile Falls is located a short distance south along Kobogan Street. Here, the West Fork of Montreal River plunges over steeply north-dipping quartzite beds in the Palms Formation. This is the basal unit in the Early Proterozoic sedimentary succession in this part of the Penokee-Gogebic Iron Range.

Continue on Highway 77.

58 The mine dumps of the Cary Mine lie south of the highway. This was the last operating property on the Penokee-Gogebic Range. When it closed in 1965, it ended underground iron mining in Wisconsin.

59 Junction of Highway 51 and Highway 77 in Hurley, Wisconsin.

In 1884 Hurley had a population of 7,000 rough, bawdy, brawling lumberjacks, miners, and assorted camp followers. Although things are quieter in town today, there are still a few taverns left.

Turn north on Highway 51 toward Ironwood, Michigan.

LOG SEGMENT 3: HURLEY, WISCONSIN, TO WAKEFIELD, MICHIGAN

Mileage

0 Hurley, Wisconsin, and the junction of Highway 77 and Highway 51. Turn north on Highway 51.

Highway 51 and the Chicago and Northwestern Railroad enter Hurley from the south through a gap in the Penokee-Gogebic Range.

Mileage

The high-standing Penokee-Gogebic is interrupted in several places by gaps such as this one. These features were eroded by north-flowing streams, which became established on an erosional surface during the early part of the Cambrian or after Paleozoic deposition ended. As the streams eroded downward, they eventually encounted the buried edge of the tilted Early Proterozoic rock that forms the present-day Penokee-Gogebic Range. Although Pleistocene debris may have filled these gaps, post-glacial erosion removed the debris to expose the old channels.

1 Junction of Highway 51 and 2; turn east on Highway 2. Road cuts at this intersection expose slate and graywacke of the Tyler Formation, dipping steeply to the north. A drumlin, about 10 feet high and 100 feet wide extends from this hill 2 miles south to the Cary Mine area. Leave Iron County, Wisconsin; enter Gogebic County, Michigan.

This river was called Kawasiji-Wangesepi (White Falls River) by the Chippewas for the spectacular waterfalls between Hurley and Lake Superior. These include Peterson (or Interstate), Saxon, and Superior Falls, and they provide spectacular exposures of Keweenawan rock.

2 State of Michigan Travel Information and Rest Area.

3 Ironwood, the former commercial center for the Gogebic iron-mining area is now a recreational center. Mt. Zion Community Park is north of here along Greenbush Avenue. This site is on a glacially polished knob of Lower Keweenawan basalt with a good overview of this part of the Penokee-Gogebic Iron Range. Drumlins extend southward from all the basalt knobs in this area.

9 Bessemer, Michigan. The resistant, rounded knobs of Lower and Middle Keweenawan volcanics looming above town to the north are part of the volcanic ranges. The Penokee-Gogebic Iron Range in this area forms a subdued ridge to the south. Highway 2 follows along a lowland valley developed upon relatively nonresistant Early Proterozoic slate.

12 Wakefield intersection the Highway 28; turn left (north).

LOG SEGMENT 4: WAKEFIELD, MICHIGAN, TO LAKE SUPERIOR VIA HIGHWAY 519

1 Turn on Highway 519 and head north toward Lake Superior.

5 Poor outcrop of Jacobsville Sandstone on west side of road, 0.1 mile south of Johnson Creek bridge and adjacent east side. The Jacobsville is considered a time equivalent of the Bayfield Group in Wisconsin.

14 Enter Porcupine Mountain Wilderness State Park.

17 Park entrance ranger station. Follow "Falls-Picnic Area" sign (16 miles) to parking lot. STOP 2. PRESQUE ISLE STATE PARK: At this site, the lower section of the Freda Sandstone outcrops above (south) of the main falls. Between the falls and the swinging bridge

Mileage

found downstream, Nonesuch Formation outcrop is well exposed. This stop provides an opportunity to examine the potential source rock for the well publicized Keweenawan oil and gas play initiated in Wisconsin in the fall of 1983.

34 Return to Highway 2 junction in Wakefield and turn west on Highway 2 to the Wisconsin State line.

LOG SEGMENT 5: JUNCTION HIGHWAY 51 AND 2 WEST OF IRONWOOD, MICHIGAN, TO ASHLAND, WISCONSIN.

Mileage

0 Cross the Montreal River, and leave Gogebic County, Michigan, to enter Iron County, Wisconsin.

Junction of Highway 2 with Highway 51 (south). Continue west on Highway 2 toward Ashland, Wisconsin.

West from here, Highway 2 generally follows the route of the Chicago and Northwestern Railroad. This railway once carried iron ore from the Penokee-Gogebic Range to Ashland, Wisconsin, through a pass through the relatively resistant Lower to Middle Keweenawan Portage Lake Volcanics. Late Wisconsin till covers the basalt in this area.

Chippewa legends describe a magnetic rock body in this area so powerful that it disarmed a raiding band of Dakotas with the latest in metal weapons. Several generations of prospectors have not found this ore body yet.

4 Cross West Fork of the Montreal River.

11 Highway 122 exit to Saxon, in an area covered by a Late Wisconsin till; the Lake View moraine, which is about 100 feet wide, crosses the highway 0.1 mile north of the junction and 0.5 mile west of the junction at Lake View Cemetery.

14 Turn right (north) on Highway 122.

16.3 Turn left (west) on Highway B (unmarked gravel road).

16.65 Park at sharp turn to right.

STOP 3. PARKER CREEK: Proceed on foot about 0.5 mile upstream (45-minute walk) in Parker Creek.

A short side trip north on Highway 122 provides an opportunity to see several spectacular waterfalls on the Montreal River. To view the 80 foot plunge of Saxon Falls over Middle Keweenawan basalt, go 2 miles north on Highway 122 to Highway B, and then east for about 2 miles to the Lake Superior District Power Company's hydroelectric plant. The 50-foot drop of Superior Falls over a resistant unit in the Upper Keweenawan Freda Sandstone is best viewed from another power generating station located off a continuation of Highway 122 in Michigan. In the canyon between Saxon and Superior Falls, the Copper Harbor conglomerate is eroded into picturesque spires and irregular rock masses.

19 Return to Highway 2.

Highway 2 continues west on an upland across till, deposited 9,800 years ago, during the Marquette advance. The beach of the Duluth stage of Lake Superior about 500 feet above modern lake level occurs 0.5 mile west of the Lake View Cemetery.

21 Junction Highway 169 to Gurney and Potato River Falls. Stream erosion at the falls exposes the Upper Keweenawan Copper Harbor Conglomerate, Nonesuch Shale, and Freda Sandstone in a spectacular setting, but it is not a suitable locality for large groups.

24 Iron/Ashland County line; enter Ashland County and the Bad River Indian Reservation. The sandy rise in this area is another part of the high shoreline of glacial Lake Duluth. This ancient lake formed in the western end of the Lake Superior basin when the retreating Late Wisconsinan (Greatlakean) ice blocked eastern outlets. This old shoreline is about 500 feet above the present level of Lake Superior. It is also about 45 feet higher than the same shoreline in the Duluth-Superior area. The Duluth beach slopes downward to the west due to the unequal rebound of the land surface when the mass of glacial ice melted.

The view ahead overlooks a low lake plain, which extends inland from Chequamegon Bay. This poorly drained, often swampy lowland is covered by clay till deposits, which obscure underlying Upper Keweenawan sandstone and shale.

The highway descends to cross the covered trace of the Keweenaw Fault. This fault places resistant Middle Keweenawan basaltic lavas against less resistant Upper Keweenawan sedimentary rock in this area.

32 Odanah, near the marshy junction of the Bad and White Rivers, was once a thriving lumbering center. Commercial interests and the U.S. government cooperated in a crash program to denude this area before it was officially designated an Indian Reservation.

Cross the Bad River, and then cross Beartrap Creek.

39 Leave the Bad River Indian Reservation.

Chequamegon Bay comes into view as the highway descends toward Ashland, Wisconsin.

42 Enter Ashland; our port of call for the evening of September 20.

LOG SEGMENT 6: GEOLOGIC STOPS IN AN AREA SOUTHWEST OF ASHLAND, WISCONSIN.

Mileage

0 Turn left (south) on Highway 112.

6 STOP 4. WHITE RIVER DAM: Exposures of Freda Formation below the dam.

12 Return to Ashland on Highway 112.

END OF LOG FOR SEPTEMBER 20, 1986

LOG SEGMENT 7: GEOLOGIC ROAD LOG FOR SEPTEMBER 21, 1986; ASHLAND, WISCONSIN, TO SUPERIOR, WISCONSIN, VIA THE BAYFIELD PENINSULA. JUNCTION HIGHWAY 2 AND HIGHWAY 13 WEST OF ASHLAND TO AMNICON FALLS STATE PARK.

Mileage

0 Junction Highway 2 and Highway 13 (north) to Bayfield on the western edge of Ashland, Wisconsin. Bayfield is the major port providing entry to the Apostle Islands National Lakeshore. This rapidly developing recreational area will ultimately include 20 of the 22 islands at the end of the Bayfield Peninsula, and 10 miles of adjacent mainland shoreline. The bedrock islands of the Apostle Group, like the adjoining peninsula, are formed of reddish brown, uppermost Precambrian Bayfield sandstone.

Chippewa legend credits the islands to stones that Manitou threw at an escaping deer. However, most geologists believe they are the surviving remnants of ridges between preglacial valleys, which were modified by wave action during various stages of glacial Lake Duluth and Lake Superior.

The Apostles are noted for picturesque shorelines, where sandy beaches are interspersed with wave-sculptured sandstone cliffs containing pillars, caves, and arches. Devils Island provides some of the best examples of these erosional forms.

Madeline Island, largest and most popular of the Apostle Islands, can be reached by daily boat service from Bayfield during the summer months. Among other attractions, this island provides an excellent exposure of the Bayfield sandstone at the abandoned Ashland Brownstone Company quarry. Several other quarry sites, which produced this famous building stone, are present along Highway 13 between Ashland and Bayfield.

Additional information on the Apostles and a schedule of boat trips are available at National Park Service offices in Bayfield and at Little Sand Bay.

8 Village of Washburn, Wisconsin.

16 STOP 5. VAN TASSELLS POINT, PIKE QUARRY: Abandoned. Typical of the many quarries in operation in this area in the late 1800s. Source of Chequamegon "brownstone" used in construction throughout the Midwest.

Mileage

21 Bayfield, Wisconsin, gateway to the Apostle Islands National Lakeshore. Site of annual apple festival.

24 Red Cliff, Wisconsin, on the southern edge of the Red Cliff (Chippewa) Indian Reservation.

41 Cornucopia, Wisconsin. Turn left on Siskiwit Fall Road, bear right at 0.3 mile to small concrete bridge. STOP 6. SISKIWIT FALLS: Outcrop of gently southeast dipping Devils Island Formation. Note the extremely high quartz content, flaggy bedding, and well rounded mature quartz grains.

42 Turn right at the stop sign onto Highway C. Continue into Cornucopia.

Junction with Highway 13. Turn left (west).

50 Herbster, Wisconsin.

57 Port Wing, Wisconsin.

91 Intersection of Highway 13 and Highway U; turn south on Highway U.

94 STOP 7. AMNICON FALLS STATE PARK. Turn into the parking area at Amnicon Falls State Park for stop. At this locality, the Amnicon River cuts into the bedrock to expose the steeply dipping Douglas Fault, which brings Middle Keweenawan basaltic lava up and over latest Precambrian sandstone of the Bayfield Group. Although the fault is not topographically impressive at this locality, southwest of here the lava rises 350 feet above the Lake Superior Lowland to form the front of the Douglas Copper Range.

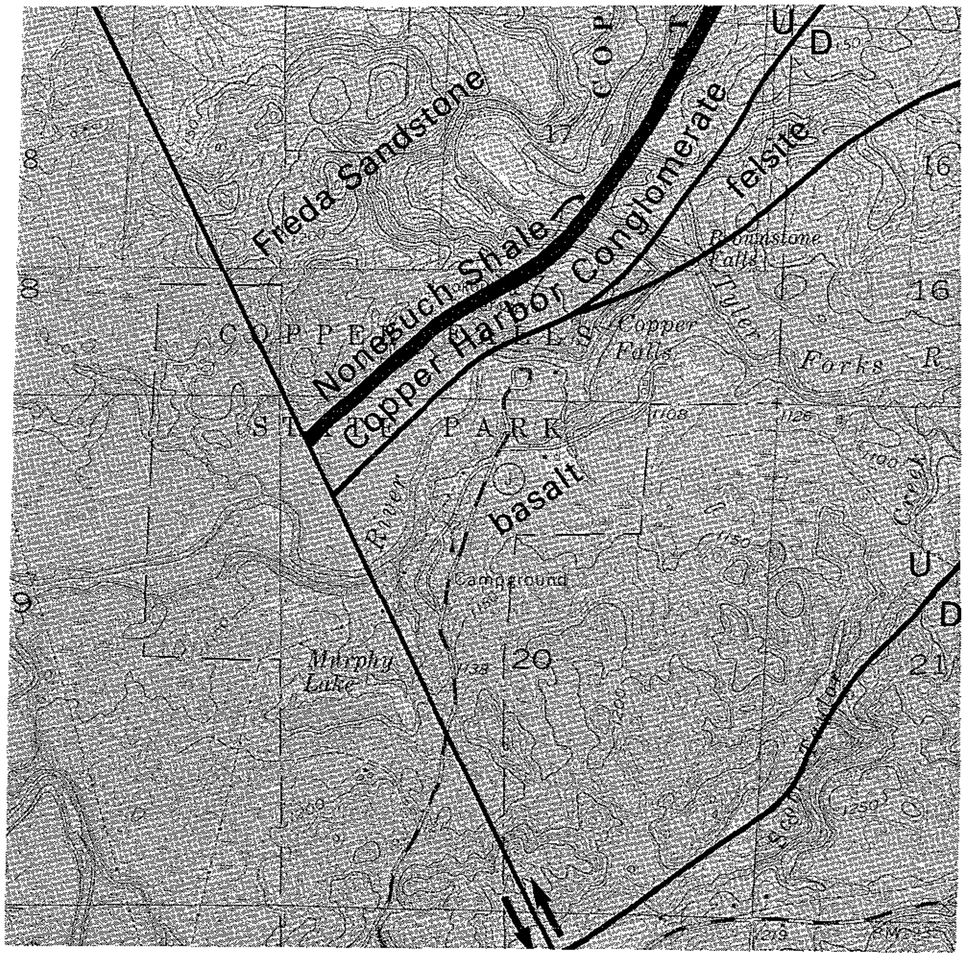
There are two falls in Amnicon Falls State Park. The upper falls drops about 35 feet over a resistant lava unit; the lower one drops 20 feet over lava into a gorge cut into sandstone of the Bayfield Group. The fault is a short distance downstream from the lower falls because stream action has caused the lava to recede from the original fault line. The sandstone gorge below the falls is eroding rapidly, and rockfalls and slides are active. The sandstone dips about 5 to 10 degrees south toward the center of the Lake Superior syncline, while the lava dips more steeply (30 to 40°) in a similar direction. Upstream from the falls and near the southern edge of the park, there is a reddish gabbroic body intruded into Keweenawan lavas.

Although there was extensive exploration for copper in the Keweenawan lavas of Wisconsin, no commercial deposits were found. However, native copper does occur at several localities in the Douglas Copper Range.

After examining the Douglas Fault, proceed 1 mile south along Highway D to Highway 2, and turn westward along Highway 2 to Superior, Wisconsin. The return route is described at the beginning of this geologic road guide.

Title: Copper Falls State Park - Oronto Group AS 45/02E/17B

Location: Northwest of Mellen on Highway 169. SE1/4, Sec. 17, T. 45 N., R. 2 E., Ashland County, Wisconsin. (Mellen and High Bridge 7 1/2-minute topographic quadrangles, 1967 and 1984, respectively).



Author: M.G. Mudrey, Jr.

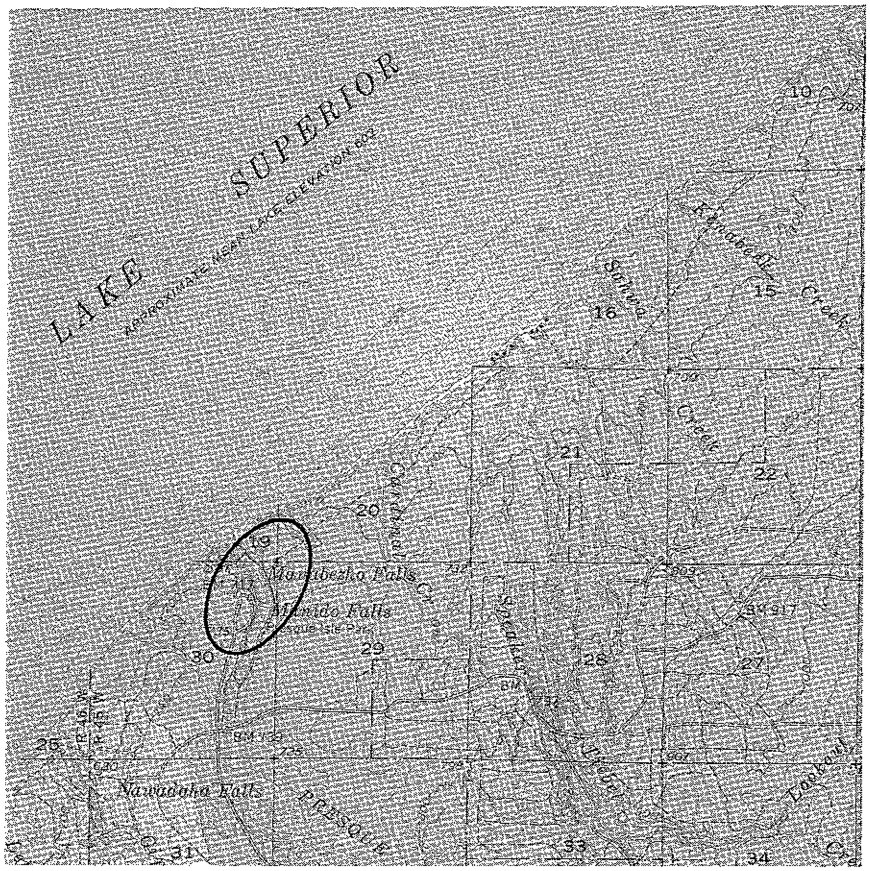
Description: Copper Falls is formed where the Bad River cuts through the resistant ridge of Keweenawan lava flows. Downstream, 0.6 km from Copper Falls at the contact between basalt to the south and rhyolite to the north, the Tyler Forks River joins the Bad River at Brownstone Falls, which occurs at the contact between basalt to the south and rhyolite to the north. The conglomerate of the Copper Harbor Formation is exposed in the lower gorge at Devils Gate about 200 m downstream from Brownstone Falls. The conglomerate is 129 m thick; at the Montreal River the conglomerate is 515 m thick. Northwest of the conglomerate is the black shale of the Nonesuch Formation; northwest of the Nonesuch is the sandstone of the Freda Formation. There is black shale distributed through 141 m of section, but only 20 m are considered Nonesuch Formation. Above the interval with black shale, the sediment is red shaley arkose.

The name Copper Falls comes from a small copper prospect in a small ravine about 200 m south of the concession building. The working was begun by the Ashland Mining Company in August 1864 and closed in February 1866. Copper in a quartz vein in diabase was prospected. Apparently the property was reopened at the turn of the century.

<u>Discussion</u>: Although faults complicate the local geology, the essentially conformable relationship between the Oronto Group and Keweenawan flows can be seen. The lower parts of the Oronto Group, the Copper Harbor and the Nonesuch, are significantly thinner here than at localities to the east.

Title: Presque Isle State Park - Nonesuch Formation

Location: Mouth of the Presque Isle River, Sec. 19 and 30, T. 50 N., R. 45 W., Gogebic County, Michigan (Thomason 15-minute topographic quadrangle, 1956).



Authors: M.G. Mudrey, Jr. and P.A. Daniels, Jr. (modified from Hite, 1968 and Daniels, 1982)

Description: The Nonesuch is more drab in color and generally of greater textural and compositional maturity than the underlying or overlying red bed sequences. Generally, the Nonesuch is a medium gray to black shale to medium sandstone. The finest grained rock is the darkest in color. The bedding ranges from massive-appearing to evenly laminated with many laminae less than 1 mm thick. Thin, rhythmic grain-size alternations are common in microscale, and many show graded bedding and dewatering features such as clastic dikes. The rock is rich in organic material and is petroliferous in the White Pine area. The Nonesuch averages about 180 m in thickness, and generally thins to the southwest. In the White Pine area about 40 km east of Presque Isle State Park, the Nonesuch thickens basinward at more than 4 m/km. Structural attitude varies from overturned in the Porcupine Mountain area to about 10 degrees in the White Pine and Presque Isle River areas, and 75 degrees in Wisconsin.

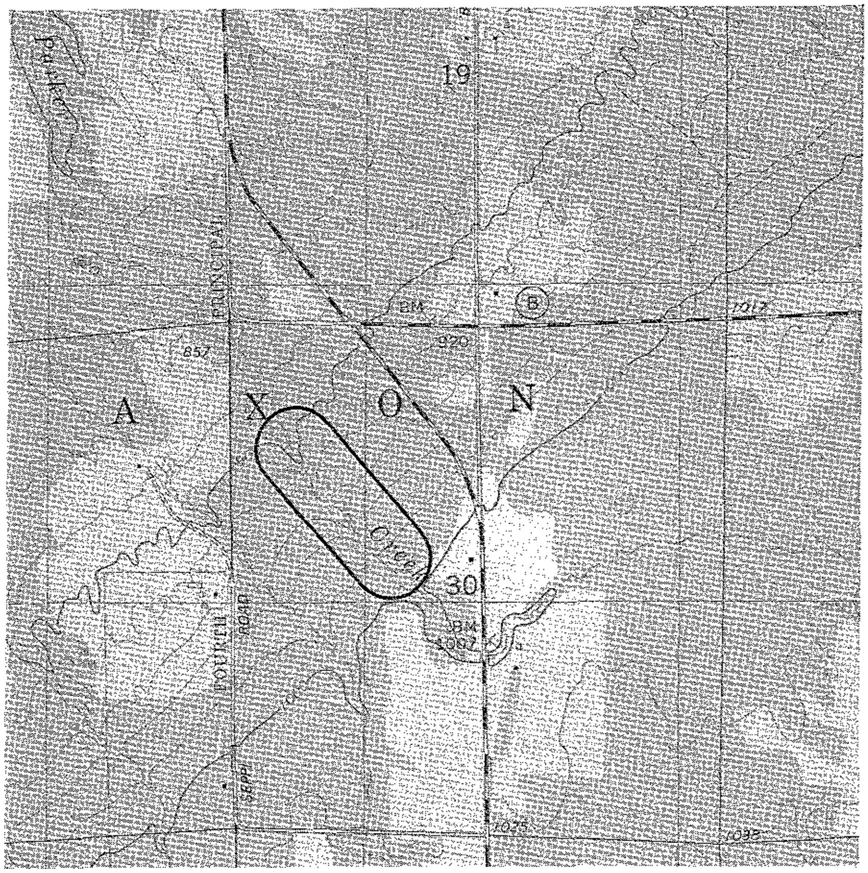
The Nonesuch possesses a great variety of sedimentary features. Both horizontal stratification and cross stratification occur. Laminated stratification is the most common; lenticular, wavy or irregular, and ripple stratification also occur. Units rarely exceed 60 cm in thickness, and the thicker beds are coarser sandstone and conglomerate. Alternating laminae of fine gray sandstone and black shaley siltstone less then 0.5 cm thick are common. The cross-stratification is of two types, planar cross stratification and rib and furrow. Both of these types are abundant on the Presque Isle River in Michigan. Shrinkage cracks and disturbed bedding occur locally and sometimes abundantly. Sediment and current transport data support a dominant flow regime to the west-southwest during deposition of the Nonesuch in the Presque Isle area.

Discussion: The sedimentary structures indicate that the depositional environment of the Nonesuch Formation was that of a standing body of water, with perhaps significant variation in water depth. Salinity was at least high enough to precipitate gypsum.

The initial formation of this water body could have occurred either due to subsidence along the rift, creating a closed topographic low that would then act as local base level, or perhaps, more likely, the disruption of regional drainage pattern by some type of damming.

Title: Parker Creek - Oronto Group IR 47/01E/30

Location: Approximately 300 m upstream to the southeast from the northwest corner of section 30. NW1/4, Sec. 30, T. 47 N., R. 1 E., Iron County, Wisconsin (Oronto Bay 7 1/2-minute topographic quadrangle, 1980).



Author: M.G. Mudrey, Jr. (modified from Myers, 1971 and Rosenberry, 1924)

Description: Approximately 600 m of continuous exposure from the last Keweenawan lava flow, through the Copper Harbor and Nonesuch Formations into the lower 300 m of the Freda area exposed along Parker Creek (also known as Davis Creek). Because the upper reaches of the creek tend to run parallel to the bedding, the Copper Harbor appears to be much thicker than normal.

All of the units trend N. 60 degrees E., 85 degrees NW. There are a few, very minor flexures and faults in the wall of the valley, but the section appears to be continuous with no repetition by faulting.

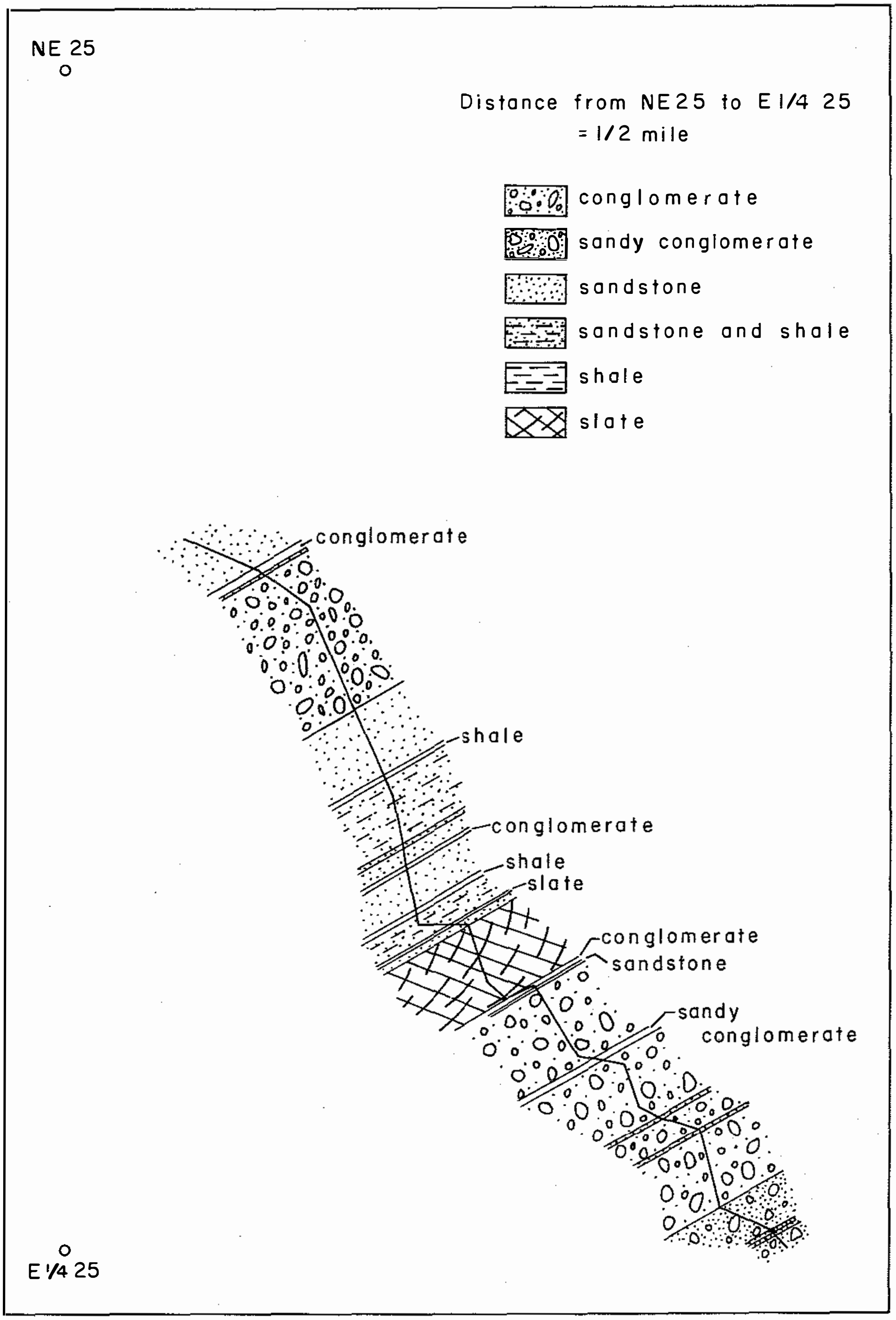
Approximately 200 m of Copper Harbor Formation are exposed in the upper reaches of the creek. The unit appears to consist of five main conglomeritic zones about 30 to 60 m in thickness, interbedded with coarse, sandy conglomerate. Both lithologies are clast-supported conglomerate. The Copper Harbor is relatively typical, consisting of rounded cobbles of Keweenawan volcanic rock and granite and iron formation from the underlying Early Proterozoic and Archean succession.

About 310 m of Nonesuch Formation is exposed. The Nonesuch consists of several dark colored slate units, interbedded with sandy slate. The lower contact of the Nonesuch and the Copper Harbor is gradational in that the nonconglomerate interbeds become finer grained and more abundant as the upper contact with the Nonesuch is approached. Bedding is clearly defined in the Nonesuch, and local cross bedding and deformation structures can be recognized. The upper contact of the Nonesuch with the Freda is also gradational in that sand beds become more common and slate beds less so.

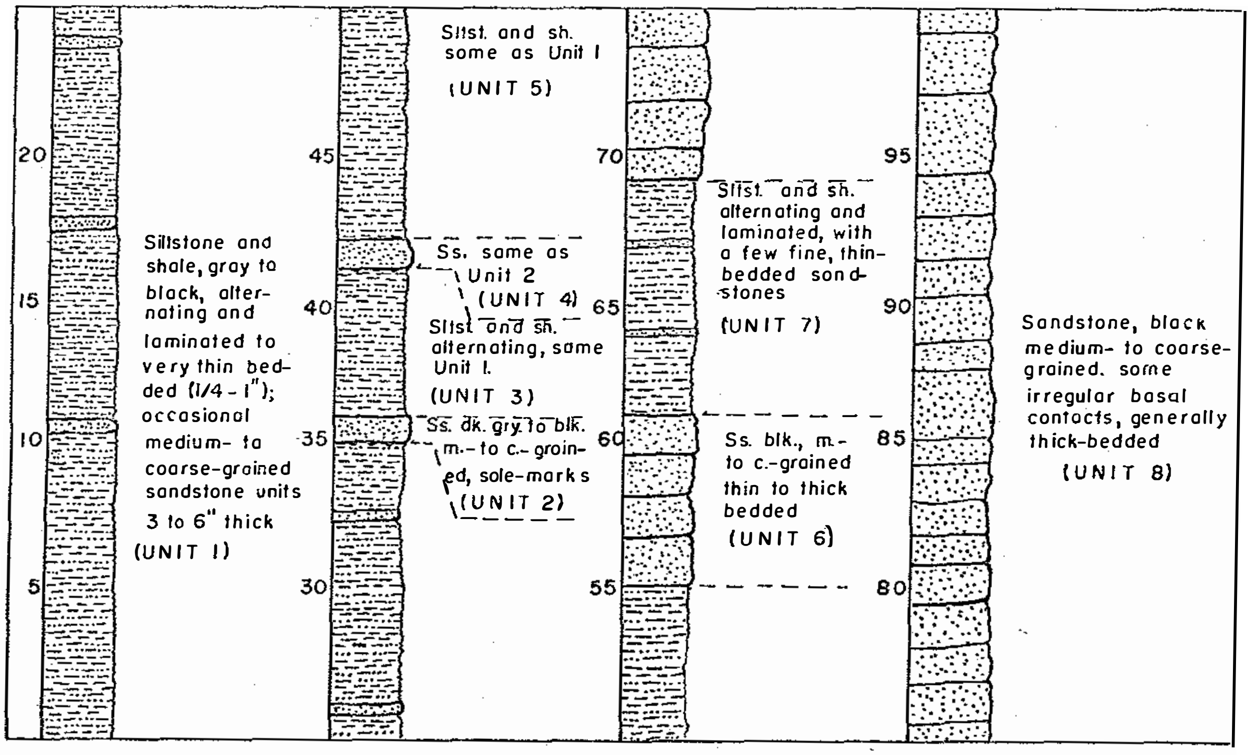
The lower member of the Freda Formation is a thick bedded, fine- to medium-grained sandstone that is strongly stained with iron. Local pebble zones are common. The middle Member of the Freda is seen only at the northernmost outcrop in the creek. It is much better exposed in Spoon Creek to the west. This member consists of siltstone and very fine-grained sandstone with occasional shale and cross-stratified fine-grained sandstone beds. Bedding is more pronounced in the middle member compared to the lower member. The upper member of the Freda is best seen at the mouth of the Montreal River to the east, particularly at Superior Falls in Michigan. The upper member consists of thick bedding units of micaceous siltstone, very fine-grained, laminated sandstone with abundant scours and and current direction indicators, and slightly conglomeritic, fine-grained sandstone with bedding poorly developed. The White River location is probably in the upper member.

<u>Discussion</u>: Clearly, the Oronto Group represents a single depositional episode, the individual formations representing various environments within that episode. All of the units appear to be gradational. The Freda appears to thicken from its type locality near Freda, Michigan, to the Montreal River and west. The Nonesuch, conversely, appears to thin toward the west from Presque Isle State Park. At Copper Falls State Park the dominant shale unit appears to be less than 20 m thick; however, the shale-bearing interval is about 140 m thick.

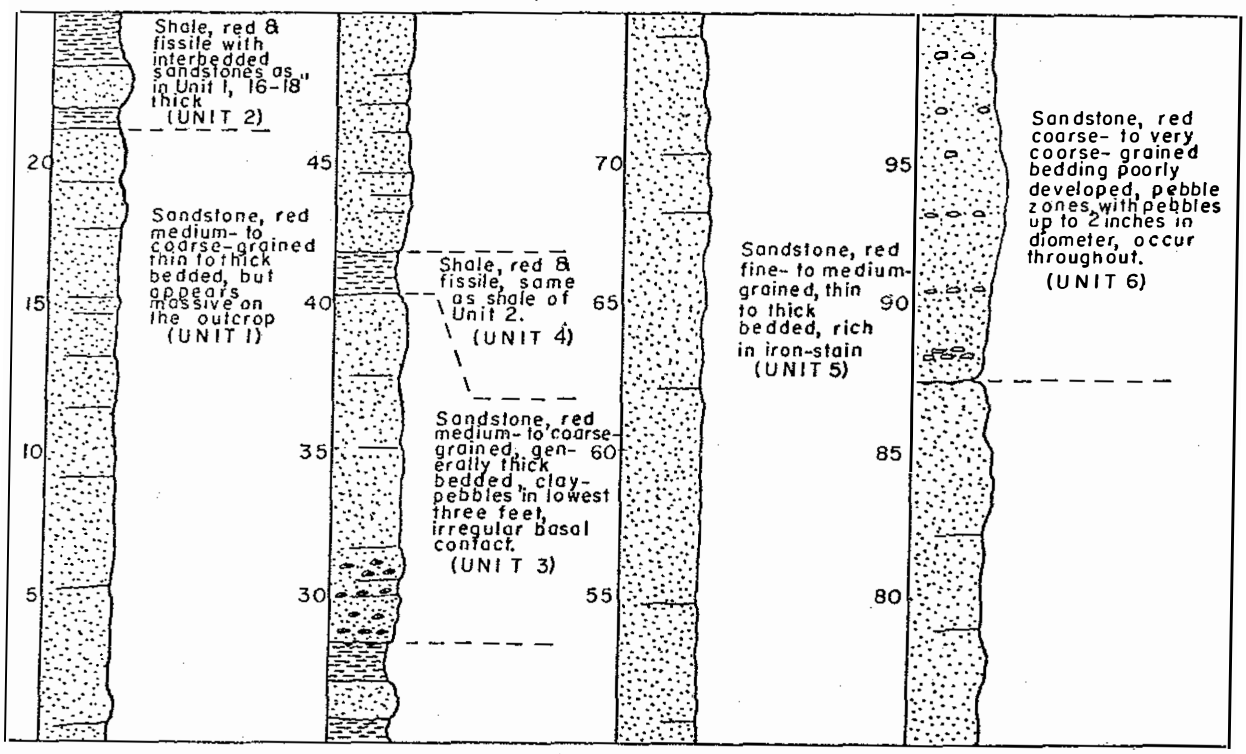
All along the Gogebic Range, the Early and Middle Proterozoic units dip northwest at a steep angle. Reconstruction of the thickness of the section results in an estimate that is too thick, 20 km of section from Hurley to Lake Superior. In Michigan this is easy to understand as the Keweenaw and associated faults clearly repeat parts of the section; however, in Wisconsin because of poor exposure, the faults are not readily recognized. As will be seen and discussed at White River, there is at least one major anticline known in outcrop at Marble Point, and at least one major syncline with the Freda. A more reasonable estimate for the total thickness of the Oronto Group would be 5 km.



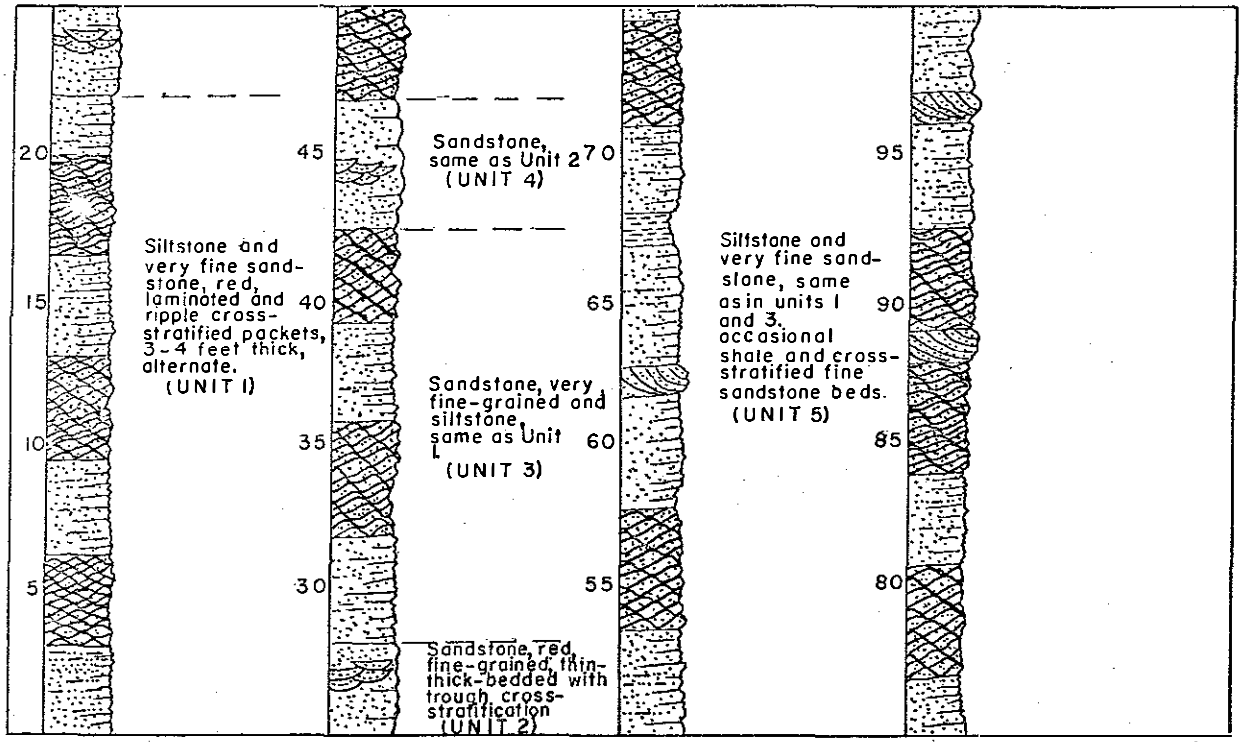
Sketch of geology in Parker Creek from Rosenberry (1924).



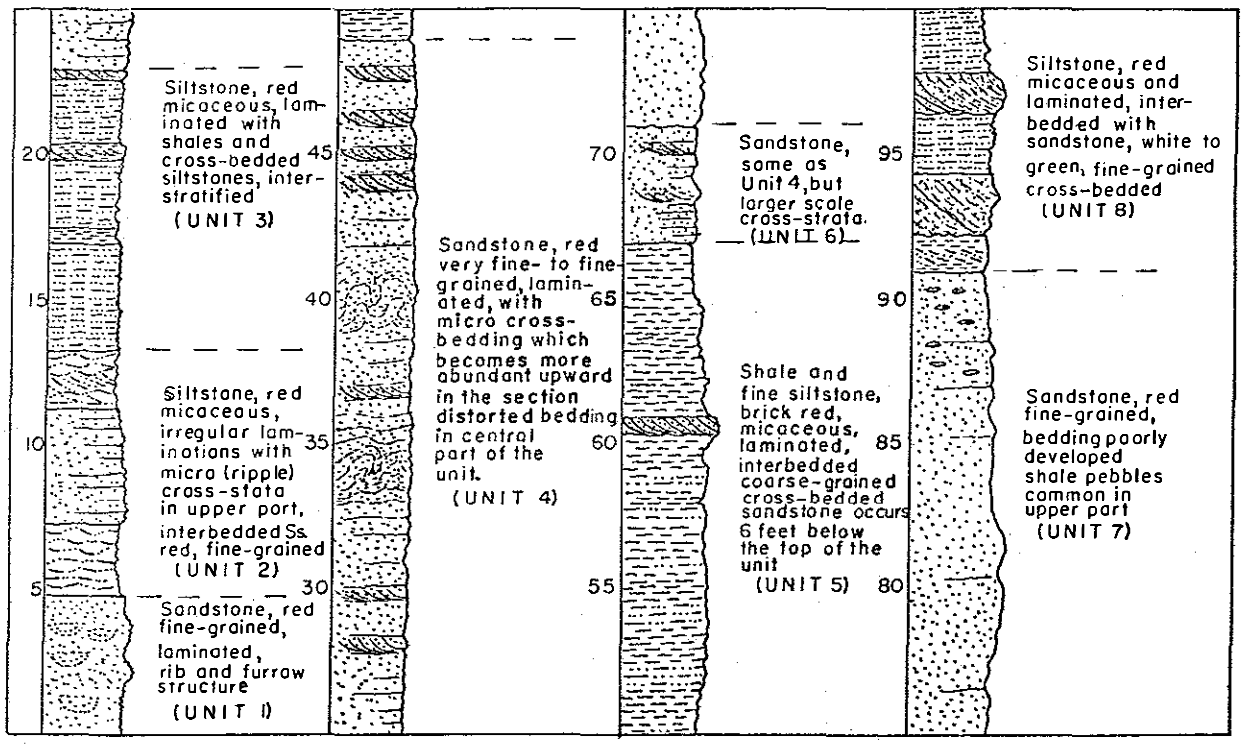
Stratigraphic section showing 100 feet of typical Nonesuch Formation (figure 20 of Hite, 1968).



Stratigraphic section showing 100 feet of typical Lower Freda Formation (figure 30 of Hite, 1968).



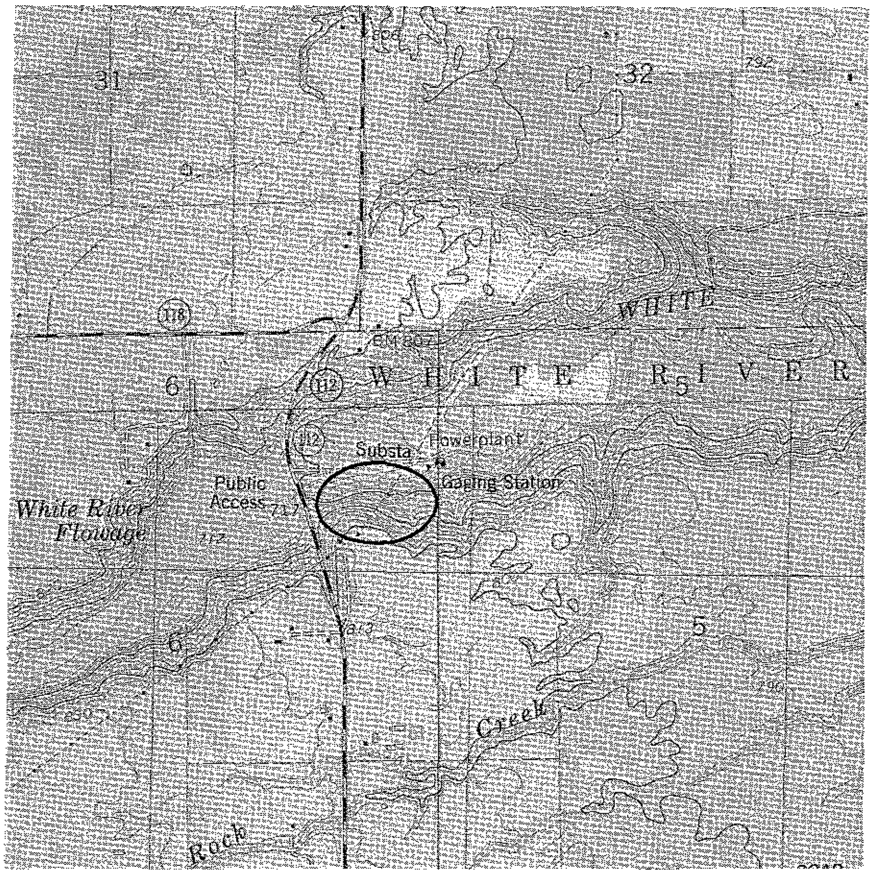
Stratigraphic section sh•wing 100 feet of typical Middle Freda Formation (figure 33 of Hite, 1968).



Stratigraphic section showing 100 feet of typical Upper Freda Formation (figure 42 of Hite, 1968).

Title: White River - Freda Formation AS 46/04W/06B

Location: Exposures on banks and bed of White River below reservoir dam and on both sides of bridge on Highway 112 about 6 km south of Ashland. NE1/4, NE1/4, Sec. 6, T. 46 N., R. 6 W., Ashland County, Wisconsin (Ashland West and Sanborn 7 1/2-minute topographic quadrangles, 1975 and 1984, respectively).



Author: M.G. Mudrey, Jr. (modified from Thwaites 1912, from which much of the descriptive narrative is taken, and Myers, 1971)

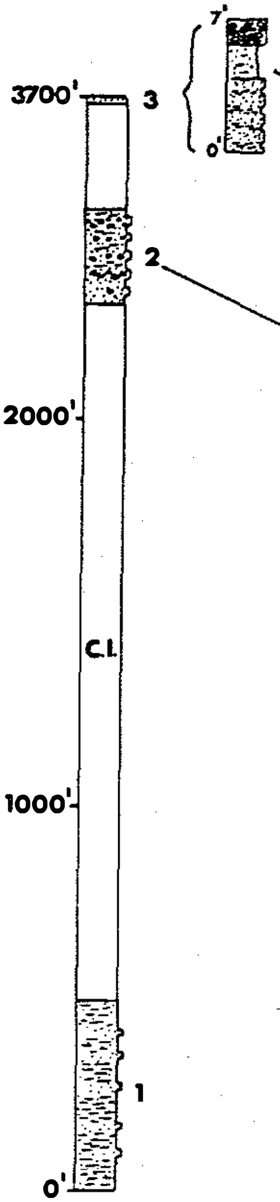
Description: Thwaites (1912) mapped 100 m of Freda Sandstone in this vicinity. The Freda consists of coarse red and green arkose alternating in rather thin beds with red and green micaceous shale. Some poorly developed ripple marks and mud cracks can be observed, and parting lineation and other scour features. The bedding trends N. 50 degrees to 65 degrees E., 25 degrees to 28 degrees SE.

Discussion: The Freda Sandstone was named by Lane and Seaman from outcrops along Lake Superior at Freda, Michigan. Hamblin (1965) and Hubbard (1975) proposed changing the name to the Freda Formation, principally because the unit consists of over 10 percent siltstone. Hite (1968) divided the Freda into upper, middle, and lower members, which can be lithologically recognized, but not regionally mapped because of the poor outcrop. The unit thickens from 1,500 m in the type locality to over 3,700 m on the Michigan-Wisconsin state line.

Daniels (1982) reviewed published data on the Freda and augmented that with his own observations. The Freda is a realively immature sedimentary rock. The sandstone is generally micaceous, highly cross-bedded, angular to subrounded, and fine- to very coarse-grained. Textural and compostional maturity is highly variable. Minor conglomerate is known low in the section. Sedimentary structures in the Freda include small channels, micro-cross-lamination, intraformational mudclast conglomerate, multiple-generation mudcracks, festoon trough cross-stratification, graded beds, various ripple mark types, large ball and pillow and other loading and soft-sediment deformation structures and tabular cross-beds. Daniels (1982) interprets these features to suggest shallow water deposition. Textural maturity, notably the high percentage of rock fragments, heavy minerals, and feldspar indicate incomplete weathering and short transport distances.

Exposures of Oronto Group sedimentary rocks south of White River dip at steep angles to the north; at White River dip is to the south. The preferred interpretation would be a syncline to the south, and an anticline to the north, probably passing to the northeast toward Marble Point on the Lake Superior shoreline. Because the Bayfield Group sedimentary rock is nearly horizontal, this deformation of the Oronto Group must have occurred prior to deposition of the Bayfield Group. Some have argued that the deformation was contemporary with development of the medial horsts such as the St. Croix; however, there are no firm data requiring such an interpretation.

STRATIGRAPHIC COLUMN OF EXPOSURES ON THE WHITE RIVER (FREDA SANDSTONE), ASHLAND COUNTY, WISCONSIN.



Attitude: Strike N 58 E; Dip 20 SE; Section measured immediately below reservoir

Pebbly ss; contact w siltstone sharp; appears to be x-bedded; abundant vol R.F.; feldspathic; poorly sorted

Grayish red (10R 4/2) siltstone; highly indurated; birdseye leaching

Medium grained sandstone with thin interbeds of siltstone (¼-½"thick); color (dry) is grayish red (10R 4/2); locally leached to light olive gray (5Y 5/2). Mudcracks having long dimension 2½-3", width of crack 2mm.

Attitude: Strike N30 E, Dip 13 SE
Hard red siltstones; thin units of coarse ss 3' thick. Exposure located above reservoir
Cross-bedding

Covered Interval

Attitude: Strike N25 E, Dip 15 SE

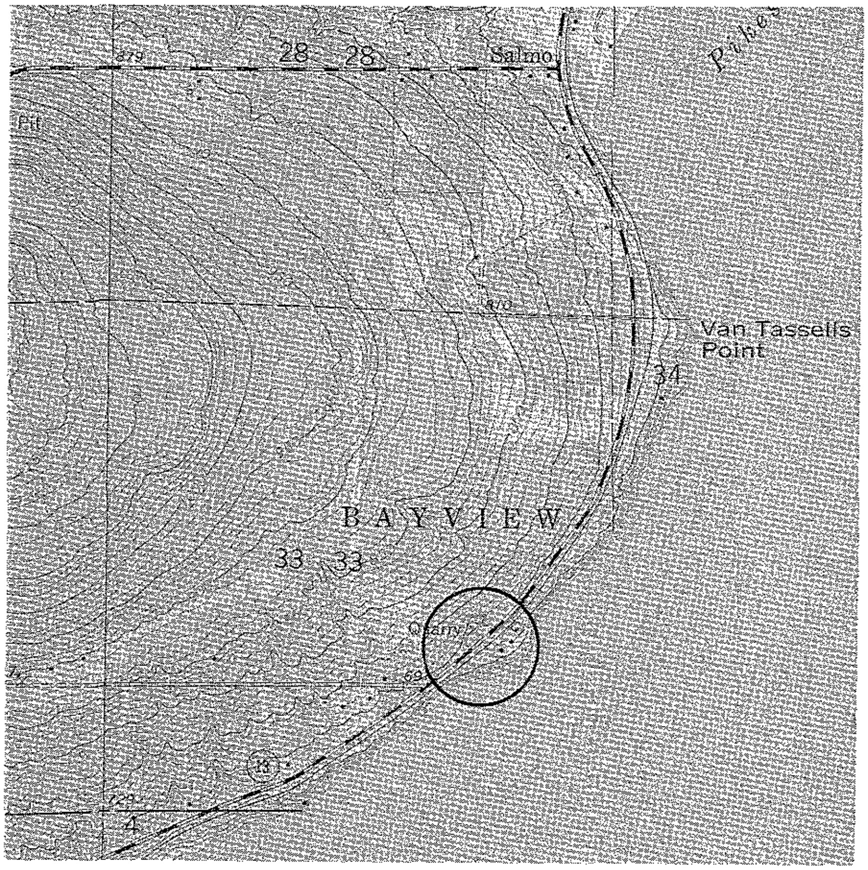
Soft grayish red siltstones; interbedded with soft sandstone; units of hard sandstone present No coarse zones observed. No mudcracks observed.

No conglomerate anywhere in section; just hard grayish red siltstone and volcanic ss; shallow water (fluvial?) sedimentary structures

Stratigraphic column at White River (page 231 of Myers, 1971).

Title: Van Tassells Point, Pike Quarry - Chequamegon Formation BA 50/04W/33

Location: Pike Quarry, also known as Green House Quarry, adjacent to Highway 13, near Salmo, 3 km south of Bayfield, NE1/4, SE1/4, Sec. 33, T. 50 N., R. 4 W., Bayfield County, Wisconsin (Mt. Ashwabay and Bayfield 7 1/2-minute topographic quadrangle, both 1975).



Author: M.G. Mudrey, Jr. (modified from Thwaites 1912, and Myers, 1971)

Description: This quarry was opened by Captain R.D. Pike about 1888 and was operated until 1897. Three quarry openings were cut; the lowest on the lake shore provided soft stone, the upper contained clay pockets, and the middle opening is the stop. This section is the greatest continuous single exposure known of the Chequamegon Formation.

Myers (1971) describes the quarry beds as consisting of fine- to medium-grained, grayish red (10R4/2), quartzose sandstone. The grains are subangular to subrounded. The bedding surfaces are gritty to coarse grained, but are thin and discontinuous. The lakeshore exposure consists of grayish red (10R4/2), medium- to fine-grained sandstone with scattered small pebbles.

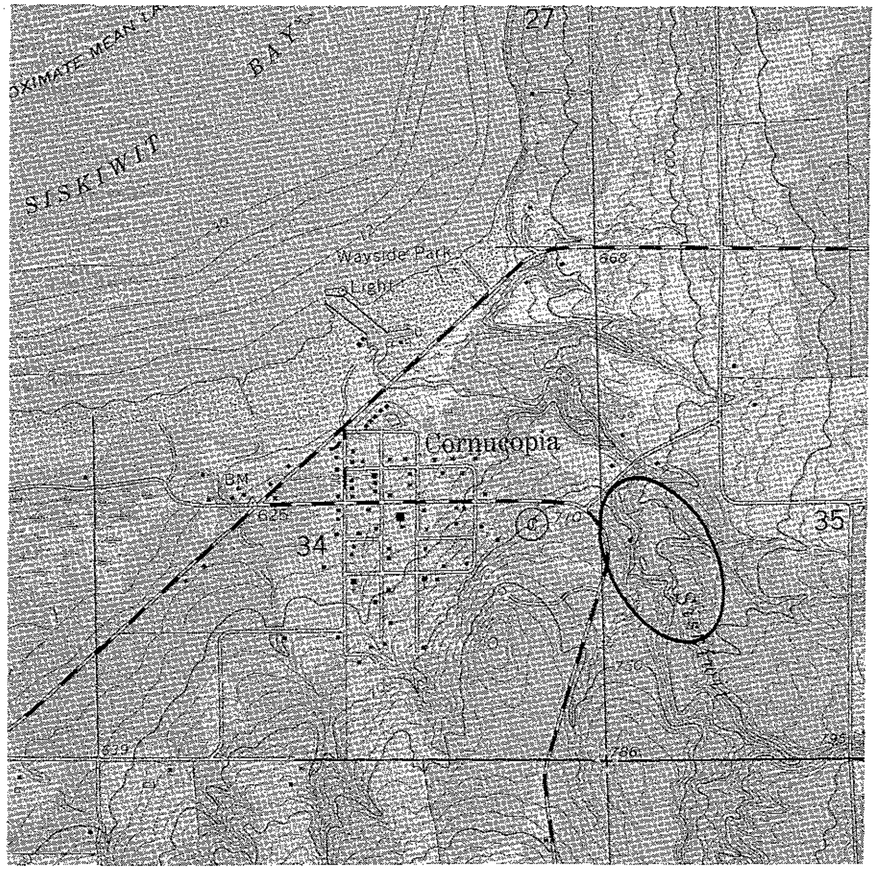
The lower exposures appear to be better sorted that the main quarry horizon. Four cross bedding determinations were made: 25 degrees N. 15 degrees W., 12 degrees N. 85 degrees E., 9 degrees S. 30 degrees E., and 12 degrees N. 45 degrees E.

Discussion: The Chequamengon Formation is not correlated elsewhere in the Lake Superior Keweenawan succession. The highest part of the Minnesota section, the Hinckley Formation, is generally correlated with the Devils Island Formation of Wisconsin, which presumably underlies the Chequamegon. Ostrom (1967) suggested that the Chequamegon, and possibly the Devils Island, may in fact be Cambrian units and correlated them with facies in the Mt. Simon Formation. The lower contact of the Chequamegon with the Devils Island is not exposed. Mudrey (1979) has suggested that the Chequamegon and Orienta Formations may be the same unit, and that the Devils Island is either a synclinal feature, or the section has been repeated by faulting. Examination of the marine seismic records in the Apostle Islands area may resolve the stratigraphic postion of the Chequamegon.

Section at Pike's Quarry (after Thwaites, 1912, p. 36).	Thickness (in feet)
Weathered and broken brownstone	23
Thin bedded and cross bedded red shaley sandstone with yellow streaks	6
Heavily bedded brownstone with very few clay pockets (the best quarry rock)	33
Unexposed [original emphasis] below level of railway track	15
Heavily bedded brownstone in lake cliff, the top much broken up	35
Thin bedded, red, shaley sandstone	8
Heavy layer of brownstone	8
Gray to deep red, yellow, and white sandstone, varies from shaley to with much cross bedding, the coarser phases having the lighter colors	12
Heavily bedded coarse pebbly brown sandstone	20
Total thickness, about	150

Title: Siskiwit Falls - Devils Island Formation BA 51/06W/35

Location: At bridge on Siskiwit Falls Road where it crosses Siskiwit River, 0.5 km east of Cornucopia. NW1/4, SW1/4, Sec. 35, T. 51 N., R. 6 W., Bayfield County, Wisconsin (Cornucopia 7 1/2-minute topographic quadrangle, 1964).



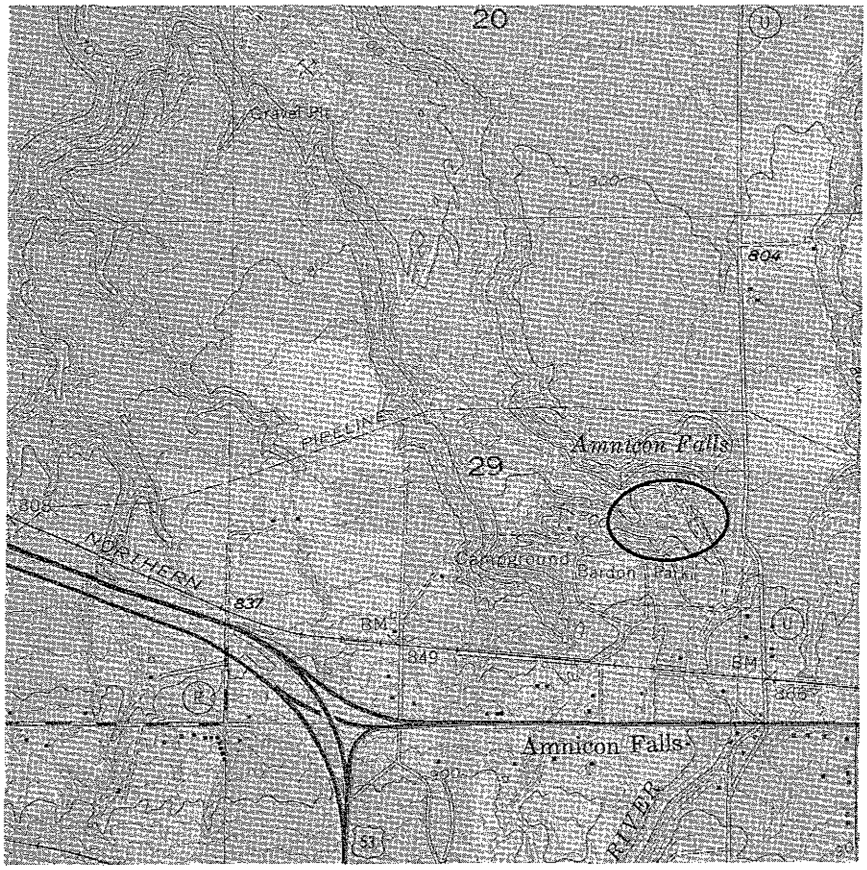
Author: M.G. Mudrey, Jr. (modified from Myers, 1971 from, which much of the discussion is taken)

Description: Six m of section are exposed in the rapids, forming Siskiwit Falls, one of three known exposures of Devils Island Formation in Bayfield County and the only one readily accessible. Myers (1971) describes the sandstone at this exposure as moderate reddish orange (10R6/6), very well sorted, fine-grained, thinly bedded sandstone with thin (less than 1 cm), moderate reddish brown and grayish red interbeds of very fine-grained sandstone. These zones have a crinkled profile suggesting penecontemporaneous deformation due to differential loading. Sedimentary structures are abundant; the most prominent are current ripple marks with short wave lengths (5 cm). Also present are minor rectilinear mud cracks that occur in the very fine-grained sandstone. Cross bedding is well developed. The overall trend of bedding is N. 40 degrees 2 E., 08 degrees SE.

Discussion: Thwaites (1912) named the Devils Island Sandstone for exposures of a very distinctive, thinly bedded, quartz-rich sandstone cropping out on Devils Island. From this locality, the sandstone can be traced along a narrow belt for 70 km to the southwest. The Devils Island Formation is a fine- to medium-grained quartz sandstone containing more than 99 percent quartz. Clay matrix generally constitutes less than 1 percent of the sandstone. The sandstone is texturally uniform; no shale beds or coarse-grained beds are known anywhere in the sequence. The lower contact of the Devils Island with the Orienta is not well exposed. The upper contact is best displayed on Devils Island, where it appears to be gradation with the overlying Chequamegon. Although the contact is not exposed, the two formations appear to be intercalated in such a manner that in passing from red Chequamegon Sandstone to orange Devils Island Sandstone, orangish beds become increasingly prevalent until the true Devils Island is encountered. Ostrom (1967) identified a difficulty with that interpretation, in that there is difficulty in understanding the depositional environment of going from a mature sandstone like the Devils Island to a significantly less mature unit like the Chequamegon. In part this is the reason that he has advanced for considering at least this section of the Bayfield Group to be Cambrian.

Title: Amnicon Falls State Park - Douglas Fault Ds 48/12W/29B

Location: Amnicon Falls State Park, NE1/4, SE1/4, sec. 29, T. 48 N., R. 12 W., Douglas County, Wisconsin (South Range 7 1/2-minute topographic quadrangle, 1975).



Author: M.G. Mudrey, Jr. (modified from Thwaites 1912, and Myers, 1971, from which much of the descriptive narrative is taken)

Descriptions: Amnicon Falls is formed by the Amnicon River flowing off the resistant Keweenawan lavas onto the soft, flat-lying Orienta Formation. The contact between the two is the Douglas Fault, readily visible at the falls and in the ravines adjacent to the fault. The fault is best exposed on the east side of the river below the falls, where fault breccia and gouge are present along the south-dipping thrust. The orientation of the Douglas Fault, as inferred from the faulted base of the volcanic flows, is a strike of N. 85 degrees E., 37 degrees SE. Other faults of small throw but similar geometry can be seen down stream from the falls. South of the fault the lavas trend N. 60 degrees E., 40 degrees SE. North of the fault sandstone of the Orienta Formation is horizontal. The fault zone includes fractured massive volcanic rock underlain by a zone of fault gouge and breccia that is

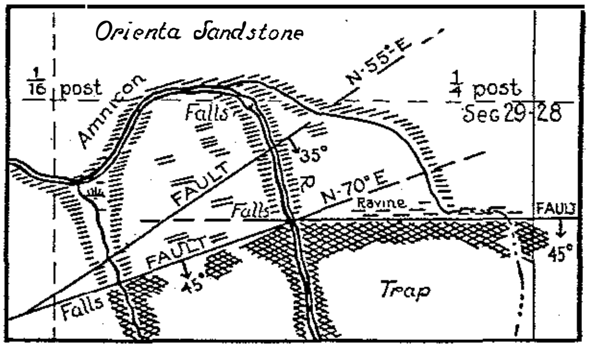
2.5 m thick. The gouge and breccia zone is composed of crushed basalt in a finer matrix. The clasts are weathered, angular to subangular, and range up to 1 m in diameter. The base of the gouge zone is a 6-cm thick layer of silicified, fine-grained sandstone, exhibiting prominent slickensides. This unit strikes N. 80 degrees E., and dips range from 45 degrees to 82 degrees to the south.

North of the steeply dipping clastic beds lies a fine- and medium-grained sandstone unit. Rounded volcanic pebbles are scattered in the sandstone for a distance of 30 m from the conglomerate, but their distribution is restricted to the bedrock bench on the valley floor.

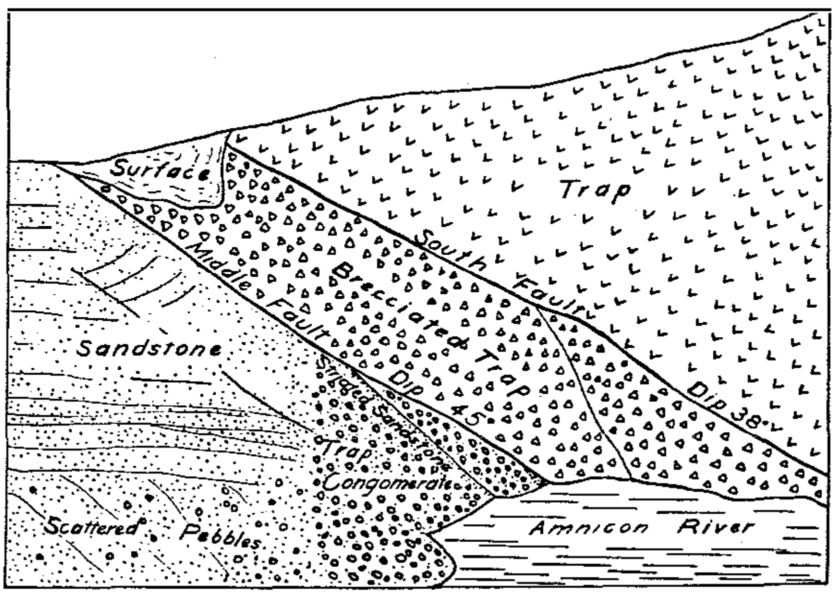
Myers (1971) reported three potassium-argon age determinations. The basalt cobble from the conglomerate yielded an age of 970 Ma, a rhyolite cobble yielded an age of 995 Ma, and a sample of aphanitic basalt 100 m upstream from the falls yielded an age of 720 Ma.

There is a suggestion that the steeply dipping conglomerate beds become finer toward sand within 30 m to the north of the fault. This can only be seen during low flow of water in the river.

<u>Discussion</u>: The Douglas Fault is the northern bounding fault of the St. Croix horst. At the surface, the Keweenawan volcanic rock has been thrust over Orienta Sandstone. Gravity, magnetic, and seismic data suggest 3,000 to 5,000 m of offset may have occurred. The fault can be traced for nearly 40 km across Wisconsin and Minnesota. Because of the minor faults seen in the Orienta Sandstone near the fault, some have argued that the fault is younger than deposition of the Bayfield Group. The observation that no thick, extensive fanglomerate is known adjacent to the fault, and that the conglomerate beds appear to fine within very short distances, leads me to argue that relief on the scarp was never great.



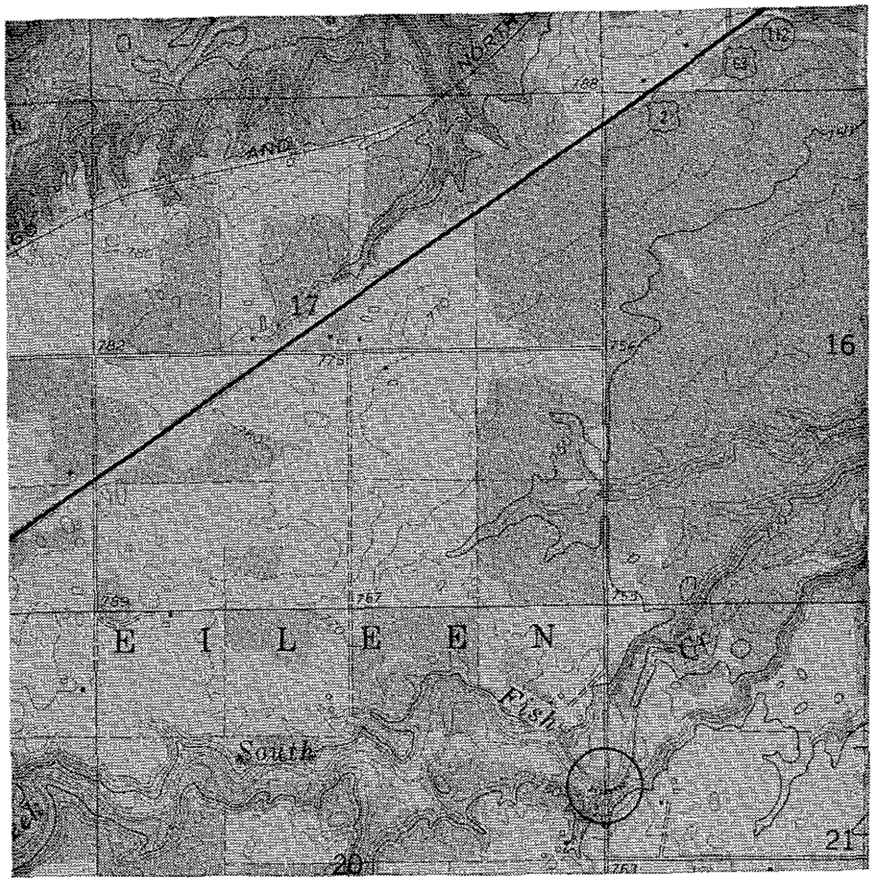
Sketch map of Amnicon River area (figure 10 of Thwaites, 1912).



Sketch from photograph showing fault, in Key to Plate XVIII B of Thwaites (1912).

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)

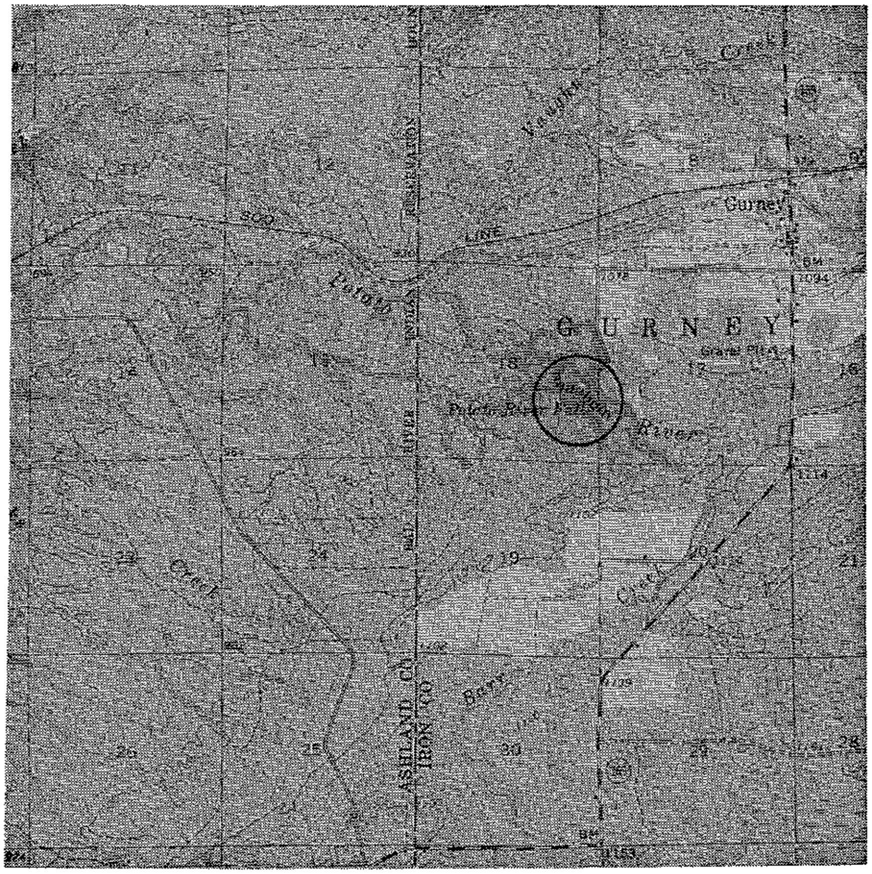
11.0' Sandstone, grayish red to reddish brown, uniformly fine-grained, hard, cross-bedded with parting lineation. Much leaching. Penecontenporaneous deformation. Current ripple marks found in float.

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?

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).

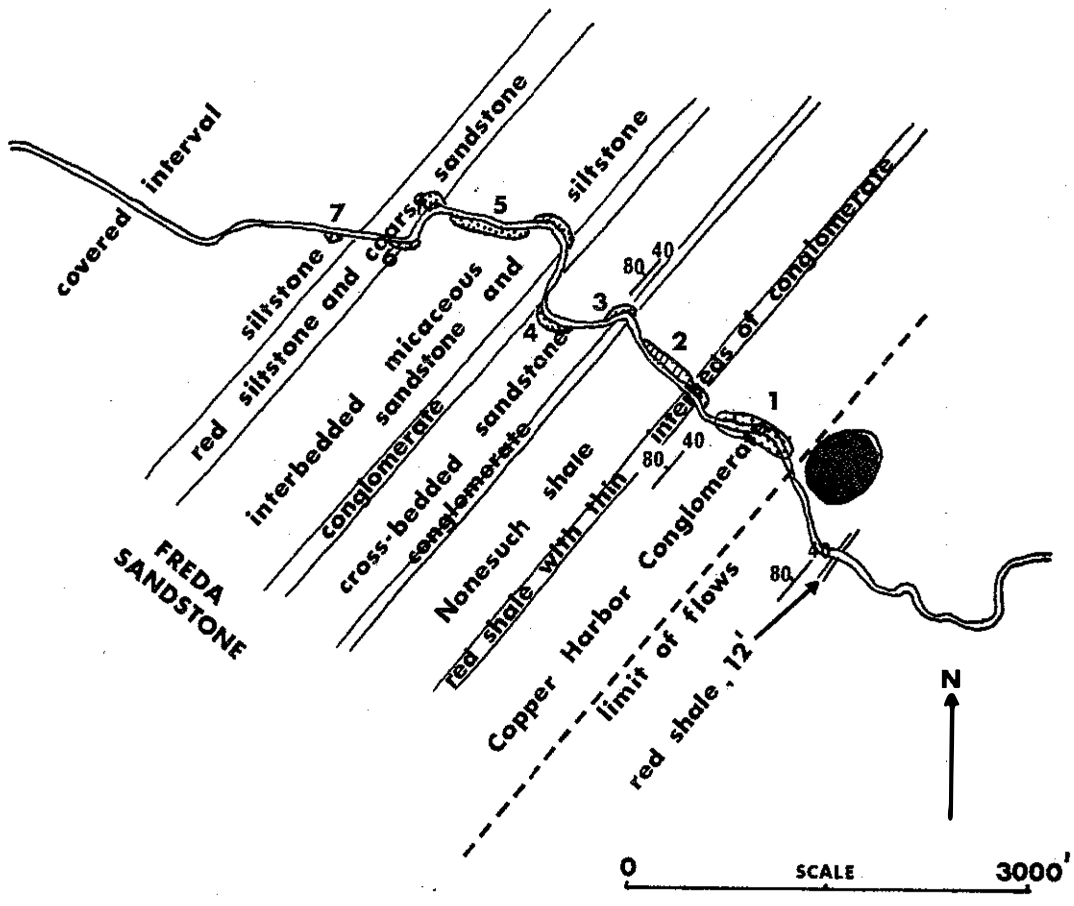


Author: M. E. Ostrom (modified from Myers, 1931)

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.

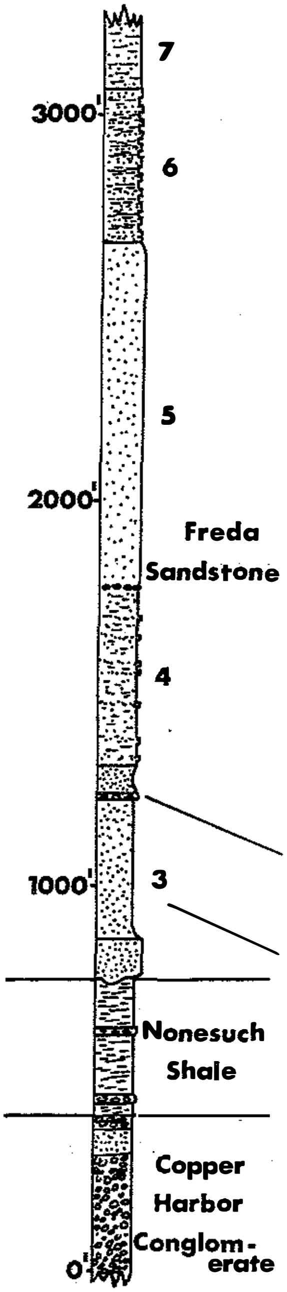
Significance: Exposure affords opportunity to examine the three formations which comprise the Oronto Group of the Upper Keweenawan Series, i.e. the Copper Harbor Conglomerate, Nonesuch Shale, and Freda Sandstone and their lithologies, mineralogies, contact relationships, sedimentary structures, and other 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?



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.

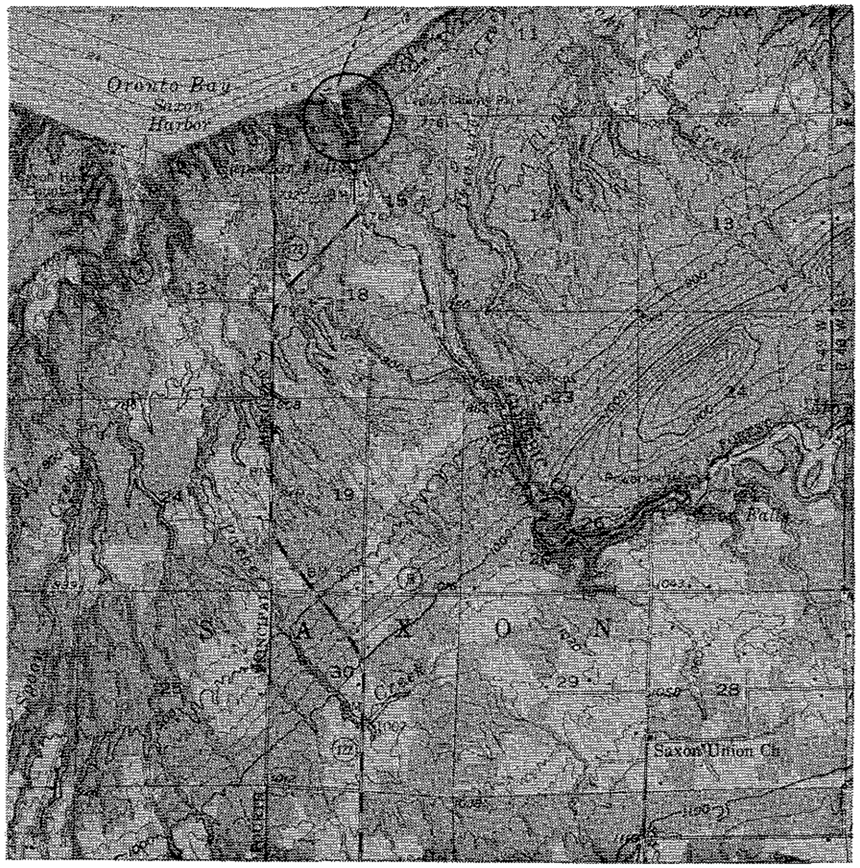
Zone of interbedded sandstone and siltstone (minor). Siltstone units 3-6" thick; leaching and minor copper staining. Basal 20' consists of hard grayish red sandstone and siltstone. Some evidence of cut and fill; contact with Nonesuch may be minor diastem

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: 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. $\pm$)

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.

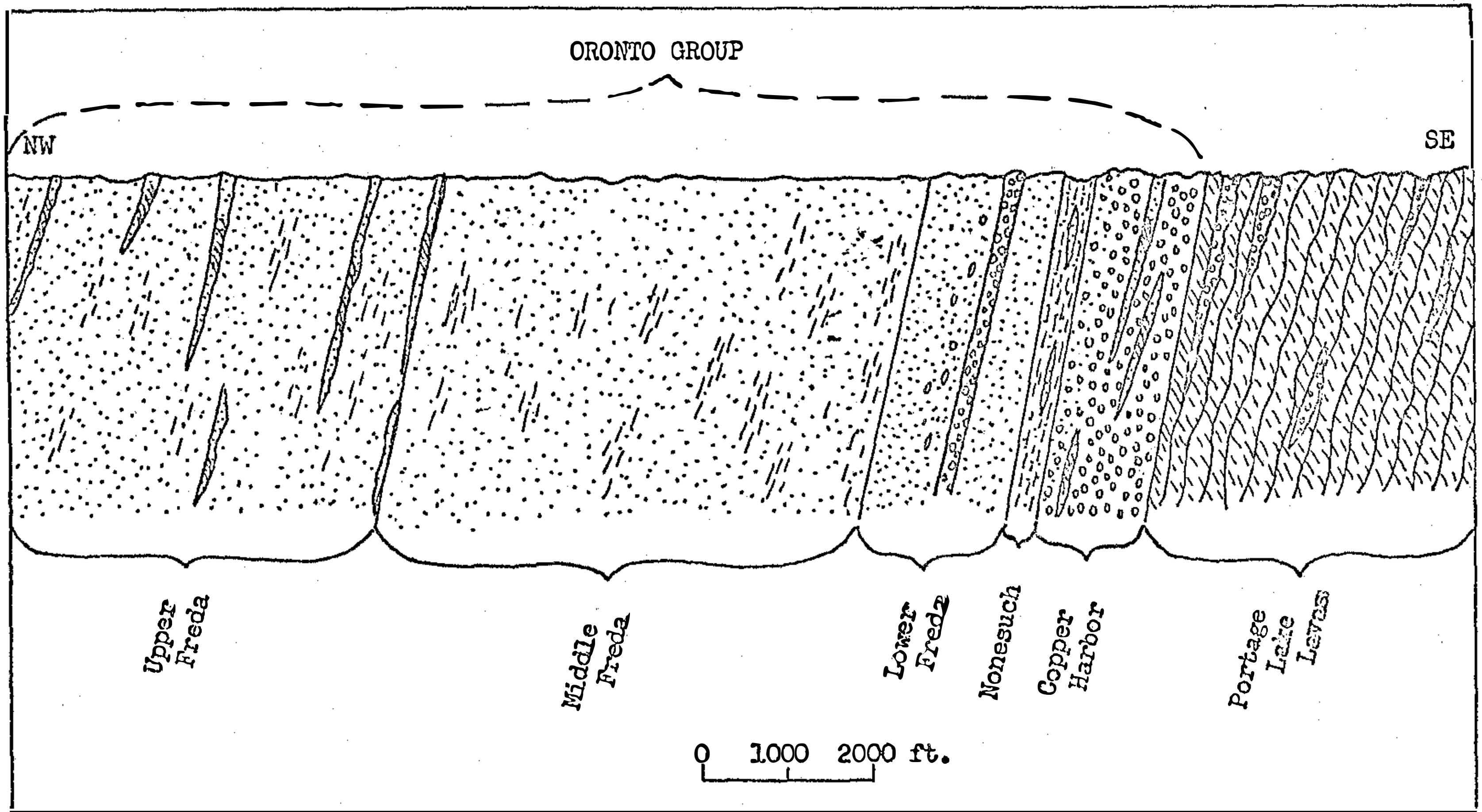
A detailed description of the Freda Sandstone section from Superior Falls downstream to the Superior Power Station (modified from Hite, 1968, p. 111):

PRECAMBRIAN

Upper Keweenawan

Freda Sandstone Formation (100.0 ft.)

0.0' - 9.0'	9.0'	8.	Siltstone, red, micaceous and laminated, interbedded with white to green feldspathic sandstone, fine-grained, thin-bedded.
9.0' -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.
33.0' -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

Aldrich, H.R., 1925, VI. General geology, in Wisconsin Geological and Natural History Survey Township Report T. 45 N., R. 2 W. (1924), p. 36-69.

Daniels, P.A., Jr., 1982, Upper Precambrian sedimentary rocks: Oronto Group, Michigan-Wisconsin, in Wold, R.J., and Hinze, W.F., eds., Geology and tectonics of the Lake Superior basin: Geological Society of America Memoir 156, p. 107-133.

Dickas, A.B., 1986, Comparative Precambrian stratigraphy and structure along the Mid-continent rift: American Association of Petroleum Geologists Bulletin, v. 70, no, 3, p. 227.

Eckert, K.B., 1982, The sandstone architecture of the Lake Superior region: Michigan State University, Lansing, unpublished Ph.D. dissertation, 504 p.

Green, J.C., 1977, Keweenawan plateau volcanism in the Lake Superior region, in Baragar, W.R.A., ed., Volcanic regimes in Canada: Geological Association of Canada Special Paper 16, p. 407-422.

Hamblin, W.K., 1965, Basement control of Keweenawan and Cambrian sedimentation in the Lake Superior region: American Association of Petroleum Geologists Bulletin, v. 49, p. 950-959.

Hatch, J.R., and Morey, G.B., 1985, Hydrocarbon source rock evaluation of Middle Proterozoic Solor Church Formation, North American Mid-Continent Rift System, Rice County, Minnesota: American Association of Petroleum Geologists Bulletin, v. 69, no. 8, p. 1208-1216.

Hite, D.M., 1968, Sedimentology of the Upper Keweenawan sequence of northern Wisconsin and adjacent Michigan: University of Wisconsin, Madison, unpublished Ph.D. thesis, 217 p.

Hubbard, H.A., 1975, Keweenawan geology of the North Ironwood, Ironwood and Little Girls Point quadrangles, Gogebic County, Michigan: U.S. Geological Survey Open File Report OF 75-152, 23 p.

Irving, R.D., 1880, The Keweenawan or copper-bearing system, in Geology of Wisconsin, v. III., p. 185, 205-206.

Lee, C.K., and Kerr, S.D., 1984, Midcontinent--a frontier oil province: Oil and Gas Journal, August 13, 1984, p. 144-150.

Morey, G.B., 1978, Metamorphism in the Lake Superior region, U.S.A., and its relation to crustal evolution, in Fraser, J.A., and Heywood, W.W., eds., Metamorphism in the Canadian Shield: Geological Survey of Canada Paper 78-10, p. 283-314.

Morey, G.B., and Ojakangas, R.W., 1982, Keweenawan sedimentary rocks of eastern Minnesota and northwestern Wisconsin, in Wold, R.J., and Hinze, W.F., eds., Geology and tectonics of the Lake Superior Basin: Geological Society of America Memoir 156, p. 135-146.

Mudrey, M.G., Jr., 1979, Geologic summary of the Ashland 2° quadrangle: Wisconsin Geological and Natural History Survey Open-file Report WOFR 79-1, 39 p.

Myers, W.D., II, 1971, The sedimentology and tectonic significance of the Bayfield Group (Upper Keweenawan?), Wisconsin and Minnesota: University of Wisconsin, Madison, unpublished Ph.D. thesis, 269 p.

Ostrom, M.E., 1967, Paleozoic stratigraphic nomenclature of Wisconsin: Wisconsin Geological and Natural History Survey Information Circular 8, chart and text.

Ostrom, M.E., and Slaughter, A.E., 1967, Correlation problems of the Cambrian and Ordovician outcrop areas of the Northern Peninsular [sic] of Michigan: Annual Field Excursion, Michigan Basin Geological Society, p. 1-5.

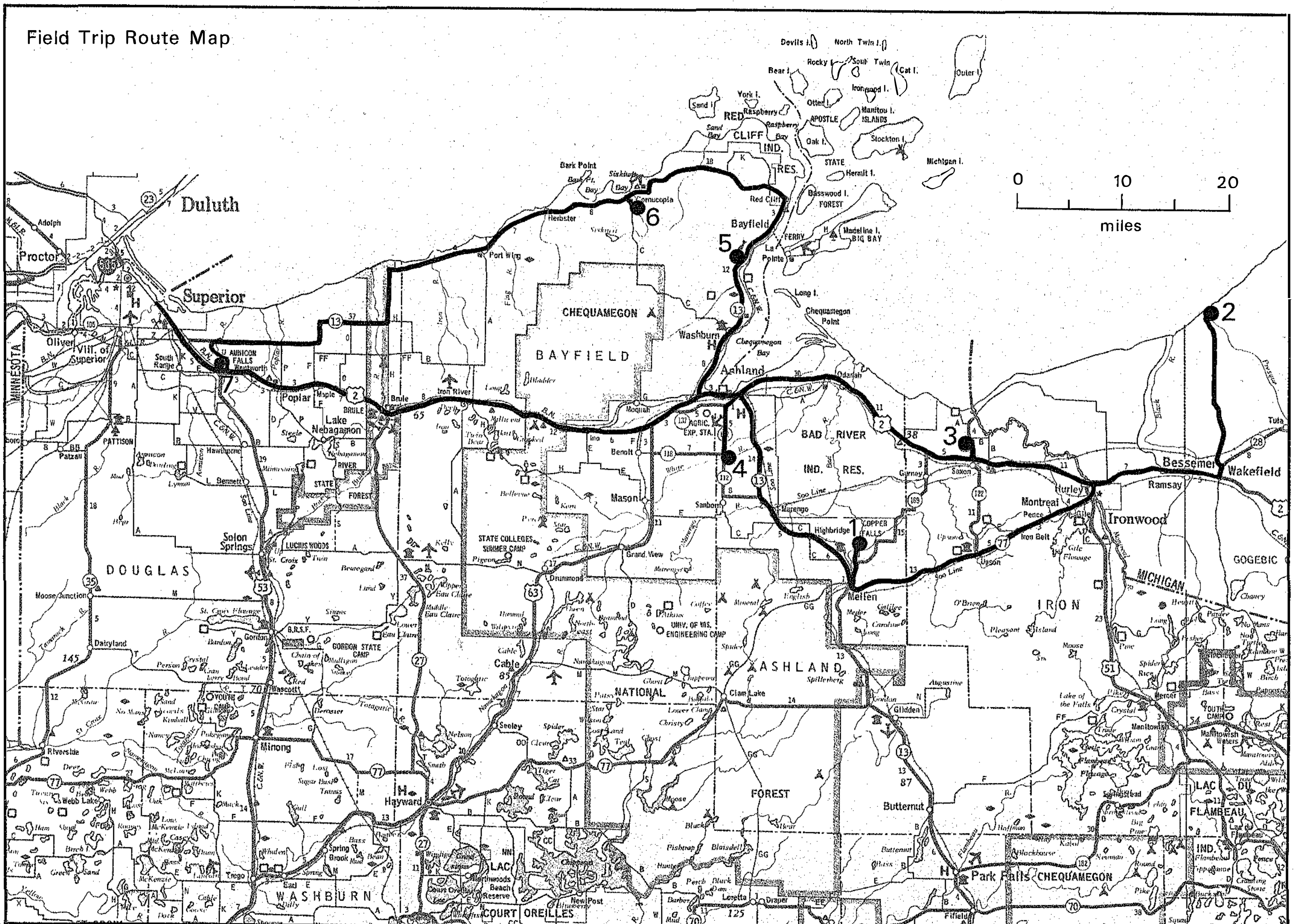
Paull, R.K., and Paull, R.A., 1980, Field Guide to Wisconsin and Upper Michigan: Kendall/Hunt Publishing Co., Dubuque, Iowa, 260 p.

Rosenberry, S.C., 1924, VI. General geology, in: Wisconsin Geological and Natural History Survey Township Report T. 47 N., R. 1 E. (1924), p. 17-28.

Thwaites, F.T., 1912, Sandstones of the Wisconsin coast of Lake Superior: Wisconsin Geological and Natural History Survey Bulletin 25, 117 p.

Weiblen, P.W., and Morey, G.B., 1980, A summary of the stratigraphy, petrology and structure of the Duluth Complex: American Journal of Science, v. 280-A, pt. 1, p. 88-133.

Wold, R.J., and Hinze, W.F., eds., 1982, Geology and teconics of the Lake Superior Basin: Geological Society of America Memoir 156, 280 p.


Field Trip Route Map
0
10
20
miles
Duluth
Superior
Proctor
Oliver
Ashland
Bayfield
Washburn
Cornucopia
Herbster
Port Wing
Brule
Iron River
Poplar
Lake Nebagamon
Solon Springs
Gordon
Minong
Hayward
Cable
Drummond
Mason
Mellen
Hurley
Ironwood
Bessemer
Wakefield
Montreal
Saxon
Gurney
Odanah
Park Falls
Glidden
Butternut
Clam Lake
DOUGLAS
BAYFIELD
ASHLAND
IRON
WASHBURN
GOGEBIC
CHEQUAMEGON
NATIONAL
FOREST
BAD RIVER
IND. RES.
RED CLIFF IND. RES.
APOSTLE ISLANDS
Madeline I.
Chequamegon Bay
MINNESOTA
MICHIGAN
COPPER FALLS
AMNICON FALLS
1
2
3
4
5
6
7