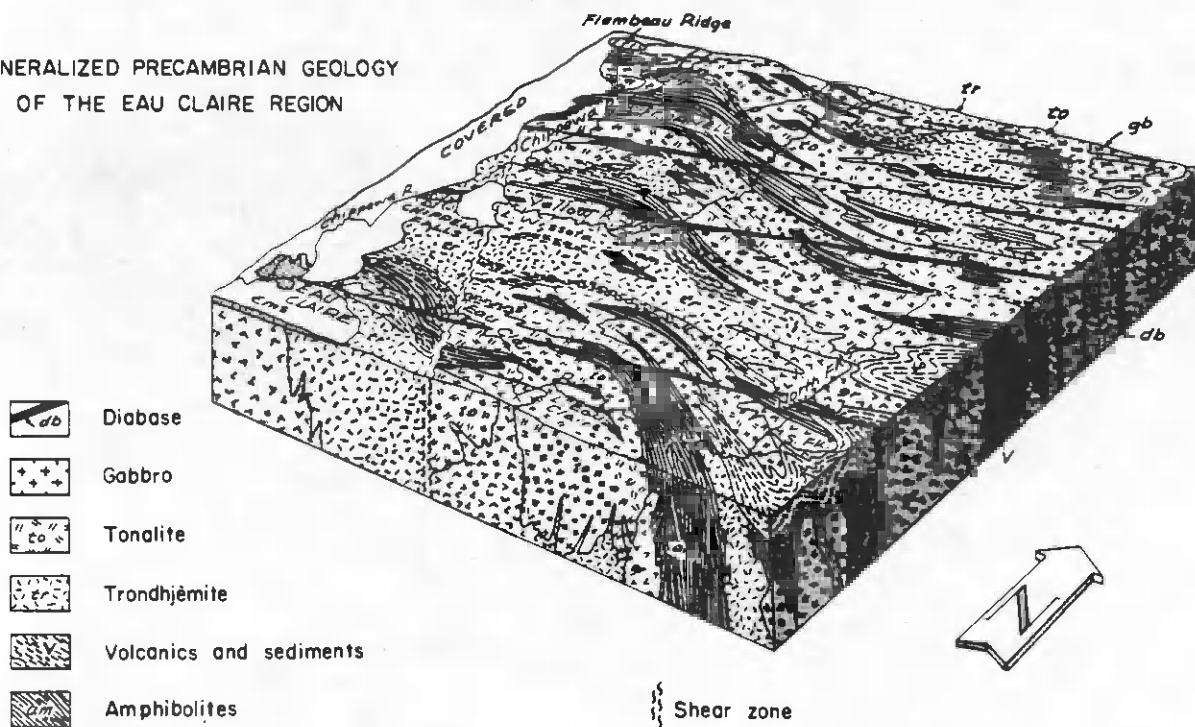




FIELD TRIP 4

The Precambrian Geology & Tectonics of Marathon County, Wisconsin

GENERALIZED PRECAMBRIAN GEOLOGY
OF THE EAU CLAIRE REGION



May 10, 1980

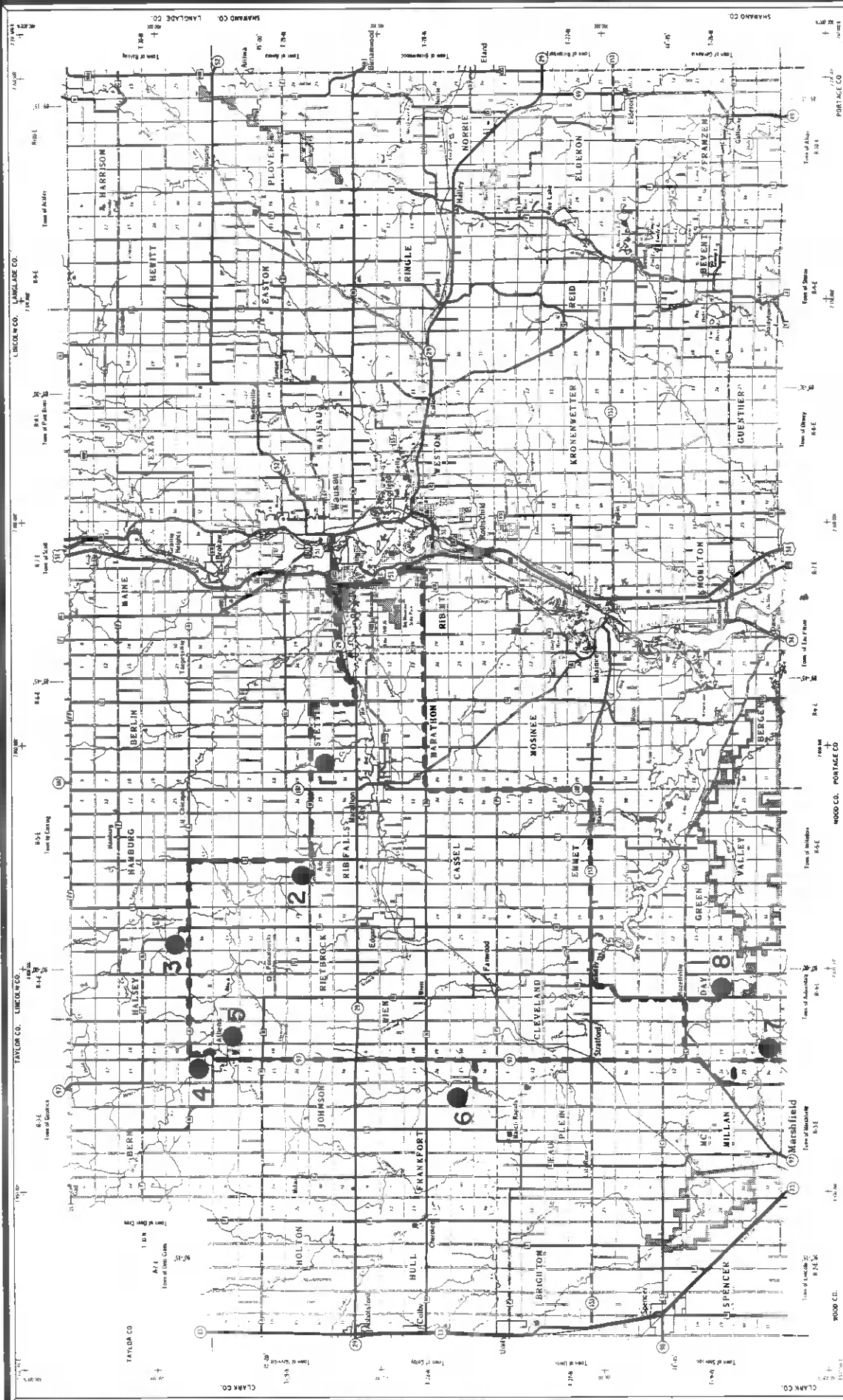
University of Wisconsin-Eau Claire

FIELD TRIP GUIDEBOOK FOR
THE MIDDLE PRECAMBRIAN GEOLOGY OF MARATHON COUNTY, WISCONSIN
Leaders

Gene L. LaBerge and Elizabeth Palmer

Special Paper
THE PRECAMBRIAN GEOLOGY AND TECTONICS OF
MARATHON COUNTY, WISCONSIN
by Gene L. LaBerge

Prepared for the 26th Annual Meeting of the
INSTITUTE ON LAKE SUPERIOR GEOLOGY
Eau Claire, Wisconsin, 1980



1987
J. M. J. M.
of Jan. 1, 1987

MARATHON CO.

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1945-1950	1950-1955	1955-1960	1960-1965	1965-1970	1970-1975	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2005	2005-2010	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050	2050-2055	2055-2060	2060-2065	2065-2070	2070-2075	2075-2080	2080-2085	2085-2090	2090-2095	2095-2100

LEGEND

Country	Population (millions)	Area (sq. miles)	Capital	Language	Religion	Government	Notes
Algeria	20.0	919,590	Algiers	Arabic	99% Muslim	Presidential	
Angola	12.0	480,000	Luanda	Portuguese	99% Catholic	Presidential	
Argentina	35.0	2,780,000	Buenos Aires	Spanish	90% Catholic	Presidential	
Australia	18.0	7,740,000	Canberra	English	95% Christian	Parliamentary	
Austria	8.0	83,850	Vienna	German	90% Catholic	Parliamentary	
Brazil	140.0	8,511,000	Brasilia	Portuguese	70% Catholic	Presidential	
Canada	30.0	9,970,000	Ottawa	English/French	70% Christian	Parliamentary	
China	1,200.0	9,596,960	Beijing	Mandarin	95% Buddhist	One-party	
France	59.0	212,000	Paris	French	80% Catholic	Parliamentary	
Germany	80.0	357,000	Berlin	German	80% Christian	Parliamentary	
India	850.0	3,287,000	New Delhi	Hindi/English	70% Hindu	Parliamentary	
Italy	57.0	301,000	Rome	Italian	90% Catholic	Parliamentary	
Japan	125.0	377,000	Tokyo	Japanese	90% Buddhist	Constitutional Monarchy	
South Korea	45.0	100,000	Seoul	Korean	90% Buddhist	Presidential	
Spain	40.0	505,000	Madrid	Spanish	60% Catholic	Parliamentary	
United States	250.0	3,797,000	Washington D.C.	English	70% Christian	Presidential	
United Kingdom	55.0	93,000	London	English	70% Christian	Parliamentary	
USSR	280.0	17,098,000	Moscow	Russian	90% Orthodox	One-party	

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Special Paper

THE PRECAMBRIAN GEOLOGY AND TECTONICS OF
MARATHON COUNTY, WISCONSIN

by Gene L. LaBerge

INTRODUCTION

This paper is taken, in part, from a more extensive report on the geology of Marathon County by Paul Myers and me in preparation for the Wisconsin Geological Survey. More details on the geology are presented in that paper. The interpretations expressed here do not necessarily reflect those of the Wisconsin Survey. They are based upon nine field seasons of mapping by me and six by Myers, in addition to extensive reconnaissance mapping by Myers in Eau Claire and Chippewa Counties.

I consider this field trip (and all others) to be a forum for discussion on the geology of the area. This paper and stop descriptions are presented as background material for the discussion. The trip is designed to show representative examples of the geology of Marathon County, particularly those exposures that bear on the structural and tectonic setting. Some of the exposures visited present problems and elicit questions regarding the tectonic setting. These problems and questions probably will not be fully answered; however, I hope the trip stimulates others to ponder these questions, and to propose alternate solutions.

ACKNOWLEDGEMENTS

This paper is based on field mapping by Paul Myers and me that has been funded by the Wisconsin Geological Survey since 1969. Their continued support is greatly appreciated. Some of the ideas expressed herein are the outgrowth of numerous discussions with Paul Myers during the course of the project and are hereby acknowledged.

Review comments by Mike Mudrey on this and an earlier version of the manuscript have been most helpful. Paul Myers also reviewed the manuscript and offered helpful suggestions. Their assistance is acknowledged with gratitude.

GENERAL GEOLOGY

Marathon County is situated near the southern margin of the exposed Precambrian Shield. Its regional setting in the Precambrian of Wisconsin is shown in Figure 1. The bedrock is predominantly Precambrian igneous and metamorphic rocks with a few scattered outliers of Paleozoic sandstone that unconformably overlie the Precambrian rocks (Figure 2). Early Precambrian(?) gneisses and Middle Precambrian (± 1900 m.y.) volcanic rocks are intruded by numerous syn- to post-tectonic Middle Precambrian (± 1850 m.y.) (Van Schmus, 1976) plutons ranging in composition from quartz diorite to granite. The volcanic rocks range in composition from basalt to rhyolite and occur as isolated pendants and blocks in the plutonic rocks. Stratigraphic and structural relationships of the volcanic rocks within individual blocks and correlation between blocks is uncertain because of lack of exposures and deformation.

Eastern Marathon County is underlain by the Wolf River batholith, a large anorogenic pluton of Late Precambrian (1500 m.y.) age (Van Schmus and others, 1975). The circular Wausau and Stettin syenite bodies west of Wausau

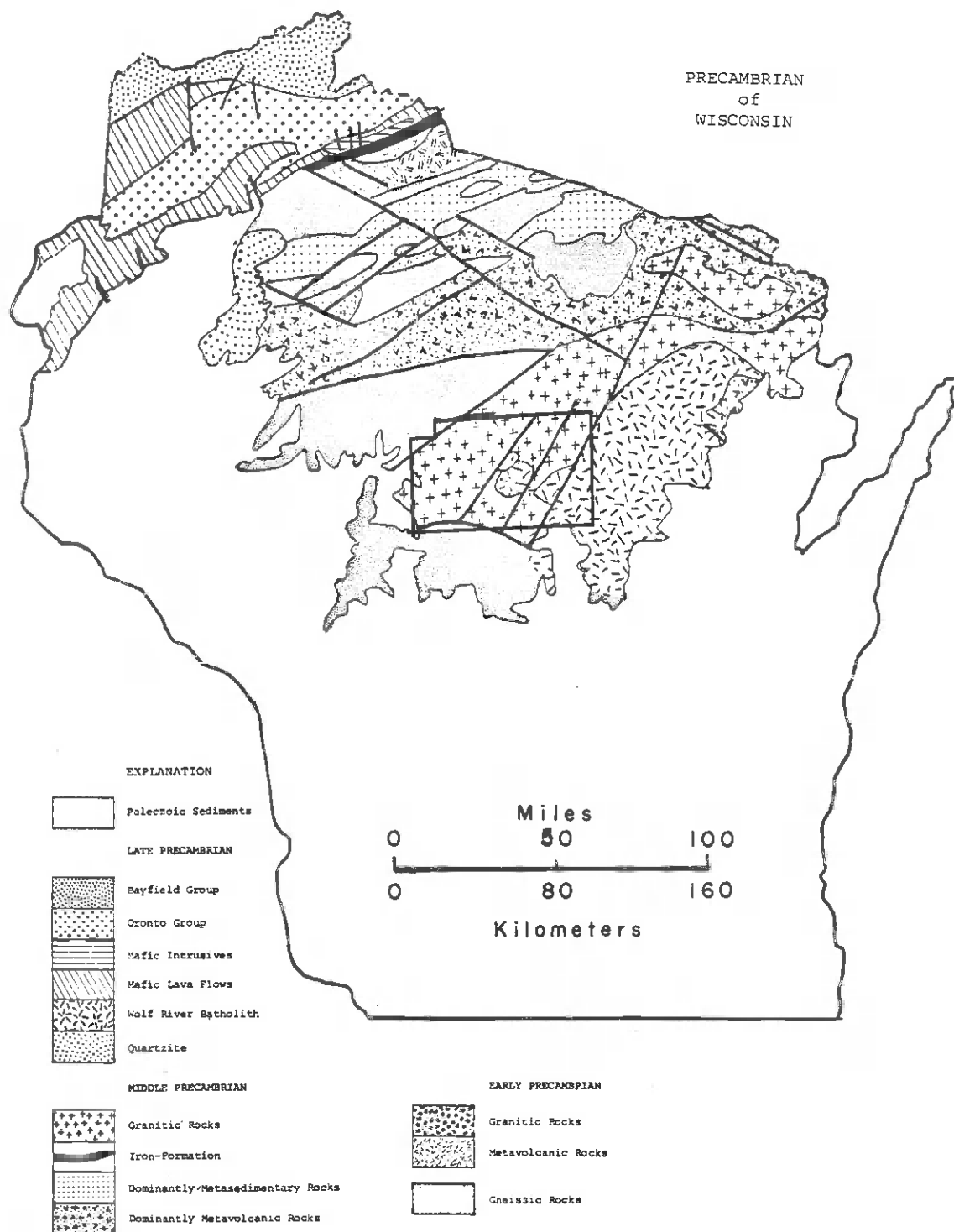


Figure 1. Generalized geological map of Precambrian rocks in northern Wisconsin. Marathon County is outlined in the central part of the state. (Data in part from Sims, 1976.)

are probably related to the Wolf River batholith (Myers, 1976). Several small quartz monzonite porphyry plugs and diabase dikes are also of Late Precambrian age.

Several large northeast and northwest zones of cataclasis dominate the structural geology (Figure 2). Major shear zones and spatially related ultramafic bodies separate gneissic rocks from the greenschist facies Middle Precambrian volcanic-plutonic complex. Similar cataclastic zones within the Middle Precambrian complex have the same orientation as the major boundary fault zones. Field relationships suggest a long history of shearing before, during and after emplacement of the plutonic rocks.

Three ages of glacial drift were recognized by LaBerge (1971). Mickelson and others (1974) confirmed the existence of the three drifts and showed that they range in age from pre-Wisconsin to late Woodfordian. Figure 3 summarizes the geological events recognized in and adjacent to Marathon County.

EARLY(?) PRECAMBRIAN

Gneisses and Schists. Medium- to coarse-grained quartzofeldspathic biotite- and hornblende-bearing gneisses, schists and migmatites underlie northwestern Marathon County and occur as isolated blocks along the southern edge of the county. The gneissic rocks are poorly exposed and consist mainly of large frost-heaved blocks and widely scattered outcrops. The gneisses range in composition from granite to quartz diorite and have a conspicuous foliation and lineation. Biotite or hornblende or both comprise 15-40 percent of the rock and some phases are garnetiferous. The common occurrence of hornblende, and locally garnet, suggests that they have been metamorphosed to amphibolite facies.

Reconnaissance geologic mapping to the west and north of Marathon County suggests that the gneisses are part of a high-grade metamorphic terrane that extends at least 60 miles to the west. Gneissic rocks extend in a northeasterly direction along the northern part of Marathon County at least to Prairie Dells in Lincoln County (about 13 km northeast of Merrill). The gneisses closely resemble those of the "Chippewa Amphibolite Complex" described by Myers (1974, and this conference) from exposures along the Chippewa and Eau Claire Rivers. Known exposures of Precambrian rocks between Marathon and Chippewa and Eau Claire Counties are dominantly high-grade metamorphic rocks. The gneissic rocks have a distinctive aeromagnetic pattern of gently curving anomalies, compared with a blotchy pattern of magnetic highs and lows in the remainder of Marathon County (Figure 9). The Bouguer Anomaly Gravity Map of Ervin and Hammer (1974) shows the gneisses as a distinct area of zero to minus 40 milligals, compared with minus 40 to minus 90 milligals in the remainder of Marathon County. Therefore, the known geology, aeromagnetism and gravity all suggest that the gneisses in Marathon County are part of a large "block" as shown on Figure 1.

Gneissic rocks in and on the periphery of Marathon County are strongly lineated, with mineral lineations and fold axes plunging 20°-60° west in the plane of the foliation (Figure 8). For example, lineations and fold axes along the Rib River near Goodrich (in Taylor Co.) plunge 30°-40° west; fold

PERIOD OR ERA	GEOLOGICAL EVENTS
Pleistocene	Woodfordian Drift (Late Wisconsin) Merrill Drift (Early Wisconsin) Wausau Drift (Pre-Wisconsin?)
Paleozoic	Unconformity Scattered Upper Cambrian(?) Sandstone Outliers
Late Precambrian	Unconformity Diabase Dikes (1200 m.y.) Quartz Porphyry Plugs Wolf River Batholith (1500 m.y.)
Middle Precambrian	Unconformity Emplacement of Post-tectonic Plutons (1765 m.y.) Emplacement of Syn-tectonic Plutons (1850 m.y.) Major Faulting in Central Wisconsin Volcanic-sedimentary Sequence (1900 m.y.) Unconformity Metamorphism to Amphibolite Facies? Early Sedimentary-volcanic Sequence?
Early Precambrian	Unconformity Gneisses, Migmatites, Amphibolites some greater than 2800 m.y. old

Figure 3. Table showing an outline of geological events recognized in central Wisconsin.

axes in gneisses near Marshfield plunge about 20° west; strong mineral lineation in amphibolites along the Little Eau Claire River in southeastern Marathon County plunge 60° southwest; fold axes in migmatitic gneisses at Greenwood (in Clark Co.) plunge 35° west; and fold axes at Neillsville (in Clark Co.) plunge 70° west.

No published radiometric ages are available from the gneisses in Marathon County, and therefore their age is uncertain. However, Van Schmus and Anderson (1977) reported an age of more than 2800 m.y. for migmatitic gneisses at Pittsville (25 km south of Marathon County). Structural studies of gneisses at several localities in central Wisconsin, and radiometric dating led Maass and Medaris (1977) to conclude that the gneisses in central Wisconsin are mainly of Middle Precambrian age. Myers (1978, and this conference) showed that amphibolites and gneisses in Eau Claire and Chippewa Counties had undergone two periods of metamorphism and deformation prior to being included in 1850 m.y. old plutons. Thus, there appears to be more than one age of gneissic rocks in the region. This point will be discussed further under the section on structure.

MIDDLE PRECAMBRIAN

METAVOLCANIC ROCKS

Volcanic rocks occur as xenoliths, screens and pendants in intrusive rocks and as relatively continuous areas in northern and eastern Marathon County. They range in composition from basalt to rhyolite and exhibit a wide variety of textures and primary structures, including pillow lavas, massive flows, flow breccias, welded tuffs, tuffs and volcanogenic sediments. The rocks have undergone little metamorphism except near larger plutons, and consequently, primary textures and structures are well preserved where the rocks are not highly deformed. The volcanic sequence has been extensively disrupted by faulting and intrusion, forming isolated blocks surrounded by plutonic rocks. This, coupled with the generally poor exposure, precludes establishing the original volcanic stratigraphy. U/Pb age determinations on zircons in rhyolite on the east edge of Wausau indicate that volcanic rocks in this area are 1900 m.y. old (Van Schmus, 1975).

Mafic and Intermediate Metavolcanic Rocks. Basaltic rocks, including tuffs and pillowed and massive flows, are exposed in several large areas in eastern, northern and southern Marathon County, and in a number of smaller roof pendants within plutons. Pillow lavas are relatively widespread and indicate that many of the basalts are the result of subaqueous eruptions. Although pillow lavas are widespread, most outcrops are frost-heaved and therefore cannot be used for top determinations. Porphyritic and amygdaloidal basalts are also common in the sequence. The basalts have been converted to chlorite-rich schists along zones of intense deformation.

In thin section the undeformed rocks consist of randomly oriented epidote, actinolite, chlorite, sodic plagioclase and quartz, indicating greenschist facies metamorphism. Primary textures, including a fine felty groundmass with porphyritic or glomeroporphyritic or amygdaloidal textures, are preserved in places. Adjacent to larger granitic plutons the basalts have been metamorphosed

to amphibolites or hornblende or pyroxene hornfels in others. In some roof pendants the andesites occur between basaltic and rhyolitic rocks. Because the volcanic rocks are present in scattered blocks, the original extent and thickness of units is unknown. Andesites are locally interbedded with "graywacke" and conglomerate suggesting subaqueous deposition. In eastern Marathon County the andesites are interbedded with dacites, and the sequence becomes progressively more rhyolitic to the northwest.

Felsic Metavolcanic Rocks. Felsic volcanic rocks underlie that part of Wausau east of the Wisconsin River and occur extensively to the east and north. They also occur in several roof pendants elsewhere in the county (Figure 2). A wide variety of volcanic rock types are represented, including water-laid (bedded) tuffs, welded tuffs, pyroclastic breccias, flow breccias, massive and flow-banded rhyolites, lahars and volcanogenic sediments of several types. Lithic tuff with some interbedded volcanogenic sediment is the most common rock type. Pyroclastic breccias with clasts up to at least 20 cm are present in several localities, and were probably deposited near vents.

Flow-banded rhyolite (Figure 4), lahars (Figure 5) and welded tuffs (Figure 6) are well preserved in Wausau and along the Rib River east of Athens. Relict spherulites, perlitic cracks and intensely welded vitric fragments (Figure 6) suggest that some of these rocks probably were originally obsidian. Near Brokaw volcanic conglomerate, sandstone, and siltstone are interbedded with welded tuffs and lava flows. The conglomerates consist mainly of boulders up to 20 cm in diameter of volcanic rocks in a matrix of finer volcanic fragments. However, boulders of quartzite and granite are also present in some layers. The volcanic sandstones consist of round sand-size volcanic fragments, quartz grains, and scattered quartzite pebbles. These units range in thickness from a few meters to several tens of meters and have a very restricted distribution between the lava flows or ash flows.

Except for local development of sericite in deformed areas, the felsic volcanic rocks show little or no evidence of metamorphism. The extremely fine grain size and preservation of primary features such as shard structures also indicates a general lack of recrystallization. Where the rocks have been deformed, they may be converted to sericite schists or the volcanic fragments may be extensively deformed, as discussed later under the section on structure.

The felsic volcanic rocks are interpreted to be mainly aquagene tuffs with interbedded sediments. Thus they are mainly similar in origin to the subaqueous mafic and intermediate rocks. However, the welded tuffs, flow banded rhyolites and lahars are probably of subaerial origin. The volcanic sandstones and conglomerates north of Wausau are believed to be alluvial facies of the volcanic rocks. Their restricted distribution and inter-layered welded tuffs may indicate that they are valley-fill deposits on the flanks of a volcano. Therefore, the subaerial felsic volcanic rocks may represent volcanic islands in a basin of unknown dimensions.

The only age determinations on volcanic rocks in Marathon County are from a rhyolite along Wis. Hwy. 52 near the eastern city limits of Wausau. Van Schmus and others (1975) report a U/Pb age on zircons of 1900 m.y. for these rocks. I assume the other volcanic rocks are part of the same general period of volcanism.

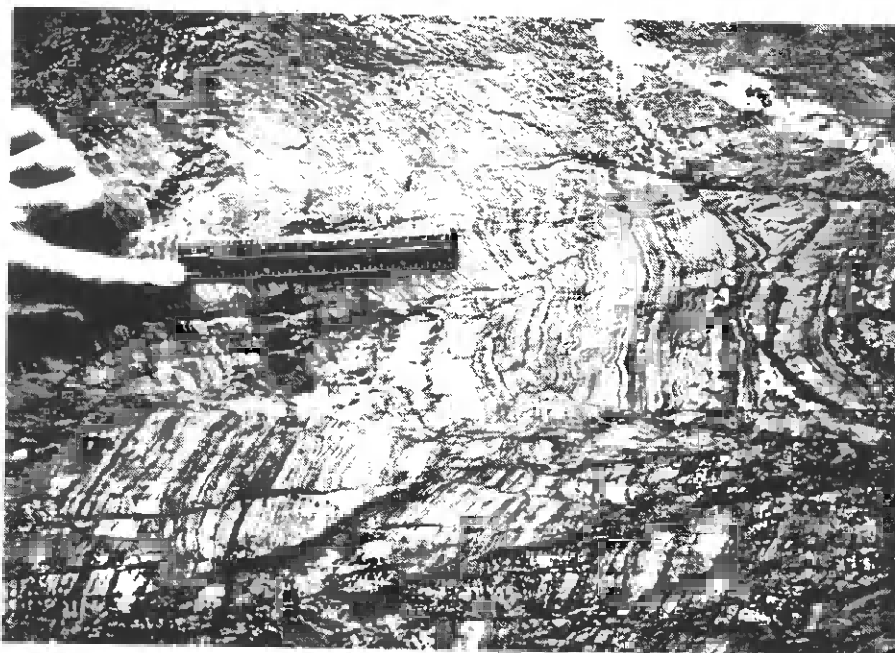


Figure 4. Flow banded rhyolite along Rib River east of Athens.

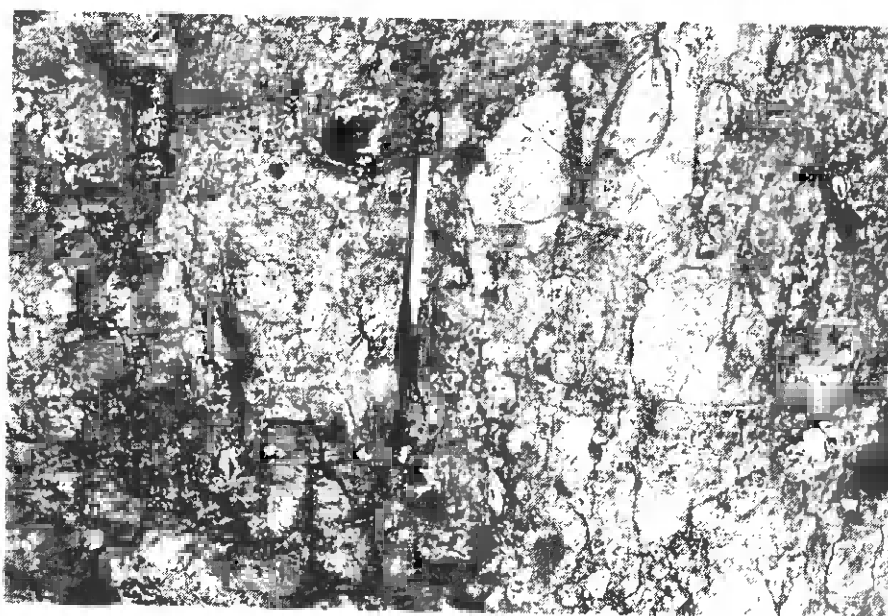


Figure 5. Volcanic mudflow (lahar) deposits at Highland Grove School in Wausau. Note the mixture of clasts in a fine tuffaceous matrix.

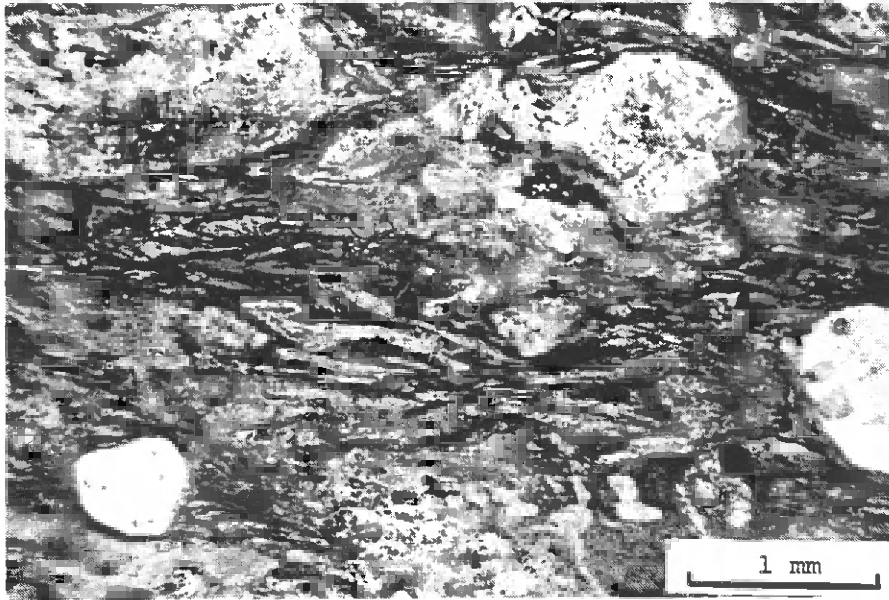


Figure 6. Welded tuff showing flattened and welded shard fragments along with rounded phenocrysts. Sample is from Wausau.

Metasedimentary Rocks. Graywacke and slate associated with volcanic rocks in north central Marathon County (between Athens and Merrill) were named the "Hamburg Slates" by Weidman (1907). Mapping by LaBerge and Myers indicates a much more limited distribution of metasedimentary rocks, and further indicates that they are extensively and complexly interbedded with volcanic rocks. Most of the sedimentary rocks are not sufficiently exposed to allow delineation of discrete units. The coarser sediments are graywackes composed of quartz, plagioclase and rock fragments. The finer-grained sediments were metamorphosed to chlorite and/or sericite slates or phyllites.

Well bedded argillite and graywacke with interbedded tuff is exposed along CTH-W north of Wausau (Sec. 12, T.29N., R.7E.). The rock is medium to fine grained, with layers ranging in thickness from about 1-30 cm. Excellent examples of graded bedding and soft sediment deformation ("slump structures") are exposed. Several units of rhyolitic lapilli tuff are interbedded with the graywacke-argillite. Some of the argillite units are composed mainly of volcanic fragments. Conglomeratic units within and at the top of this sequence (along the Wisconsin River at the west end of the bridge at Brokaw) may be volcanic conglomerates. Welded tuffs, flow breccias and lahars exposed along the west side of the Wisconsin River (Sections 2, 3, & 11, T.28N., R.7E.) and in the 3M Company Quarry (NW $\frac{1}{4}$, Sec. 11, T.28N., R.7E.) are interbedded with the conglomerates and stratigraphically overlie the graywacke-argillite sequence on the east side of the Wisconsin River. The sedimentary units, therefore, are underlain, interbedded with, and overlain by volcanic rocks. They are interpreted to be facies of the volcanic sequence in the area.

An isolated area of metagraywacke and conglomerate surrounded by, and interbedded with felsic to intermediate volcanics is located northwest of Stratford (Sections 34, 35, 36, T.28N., R.3E., and Sec. 31, T.28N., R.4E.). A prominent magnetic high is associated with the sedimentary units. The metagraywacke is fine to medium grained and medium to massively bedded. No graded bedding was observed. The conglomerate contains boulders up to 30 cm of quartzite, iron-formation, felsic and mafic volcanic rocks and some plutonic rocks. The present landowner reported that a mining company from Michigan drilled exploratory holes for iron ore in the area during the late 1950's.

Thus, sedimentary rocks, mainly graywackes and slates or argillites, are widely distributed throughout the county and are characteristically associated with volcanic rocks. However, no large, continuous area of sedimentary rocks was demonstrated in the present mapping program. The widespread association of sediments with the volcanic rocks, however, is helpful in interpreting the environment in which the rocks accumulated.

INTRUSIVE ROCKS

The volcanic rocks have been intruded by more than twenty stock-like plutons in Marathon County. Most of the plutons range in composition from quartz diorite to granite; however, several gabbroic intrusions are also present. Discordance of the plutons, low metamorphic grade of the volcanic rocks, and generally meagre contact metamorphic effects suggests crystallization of the intrusions at shallow levels in the earth's crust with little subsequent erosion. The plutons would probably be classed as upper mesozonal.

Gabbroic Intrusions. Several small gabbroic intrusions of diverse texture, and presumably of diverse age, are present in Marathon County. Most intrusions are metamorphosed and somewhat deformed.

A mass of metagabbro underlying approximately 20 km² is exposed along the Eau Claire River in the vicinity of Callon (east of Wausau). Most of the intrusion is massive gabbro with a sub-ophitic texture, but conspicuously layered gabbro is present locally. Although the flanking volcanic and granitic rocks are extensively deformed, the gabbro mass is largely undeformed. Inclusions of schistose volcanic rocks and deformed granite occur in the gabbro suggesting that the gabbro is younger than the deformational event affecting the surrounding rocks.

Several gabbroic masses are present in southwestern Marathon County. A relatively unmetamorphosed mass situated north of Marshfield consists of coarse-grained ophitic gabbro and anorthositic gabbro. This mass produces a prominent oval aeromagnetic anomaly.

A gabbroic mass along the Little Eau Pleine River (Secs. 23, 24, T.26N., R.3E., and Secs. 17, 18, 19 & 20, T.26N., R.4E.) consists of granular plagioclase and hornblende with numerous strongly foliated zones of amphibolite. This gabbroic mass is much more deformed and metamorphosed than the one north of Marshfield, and therefore appears to be older.

Ultramafic Intrusions. Several small, widely scattered ultramafic bodies composed mainly of talc and serpentine are located in Marathon County. The ultramafic rocks are poorly exposed, rendering it difficult to determine their size and shape. They are located along major zones of cataclasis, and thus it is likely that the bodies are elongated parallel to the strike of the zones.

A small ultramafic body occurs with the metagabbro mass along the Little Eau Pleine River (NE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 20, T.26N., R.3E.). It is composed mainly of serpentine and talc, but contains numerous relict olivine crystals. The main exposure of the serpentinite is in a pit where quarrying was attempted. The mineralogy and texture of the rock indicate that it has not been as intensely metamorphosed or deformed as the associated metagabbro. Therefore, it probably represents a separate intrusion rather than an ultramafic differentiate of the gabbroic mass. A similar serpentine-talc body exposed in a roadcut south of Rozellville (NW $\frac{1}{4}$, NW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 27, T.26N., R.4E.) also contains abundant relict olivine and has only 39.4 percent SiO₂. Thus, it is probably a serpentinitized dunite. Feldspathic pyroxenites consisting of serpentinitized pyroxene and plagioclase and retaining their igneous texture are exposed in the SE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 2, T.29N., R.3E. and NE $\frac{1}{4}$, NE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 27, T.30N., R.4E. along a major fault zone in northwestern Marathon County. Therefore, they appear less deformed than the ultramafic bodies in southern and eastern Marathon County.

Granitic Intrusions. The volcanic-sedimentary sequence and gneisses have been intruded by numerous stock-like plutons of granite. Most of the plutons are compositionally zoned and contain pendants, screens and xenoliths of volcanic and older plutonic rocks.

Quartz diorite intrusions are typically small, heterogeneous and generally highly contaminated with inclusions of volcanic rocks, gabbro, pyroxenite, and metasedimentary rocks. A conspicuous east to northeast trending cataclastic foliation is present in most of the plutons. Mineralogically, they contain strongly zoned plagioclase (about An₃₀), 20-30 percent quartz, 10-30 percent hornblende or biotite or both, and minor microcline.

Intrusions ranging in composition from quartz monzonite to granite intrude the volcanic rocks and dioritic bodies. Typically, the margins are highly contaminated, but the cores are relatively homogeneous. Some quartz monzonites appear to be gradational into quartz diorites, but dikes of quartz monzonite in the dioritic rocks suggest fracturing and intrusion of the peripheral dioritic rocks by later phases of the intrusion. The quartz monzonites generally have a pervasive cataclastic foliation which, in places, is truncated by non-foliated granites (Figure 7), suggesting that the granites are later.

The granitic plutons range in size from about 5-130 km². Many have concentric zoning with a granitic core and quartz monzonite to quartz diorite border. Narrow but distinct contact metamorphic halos were observed around several intrusions where the felsic volcanic rocks were recrystallized to a massive saccharoidal rock and mafic volcanic rocks were recrystallized to hornblende hornfels. Excellent examples of intrusion breccias are exposed on the margins of some intrusions.

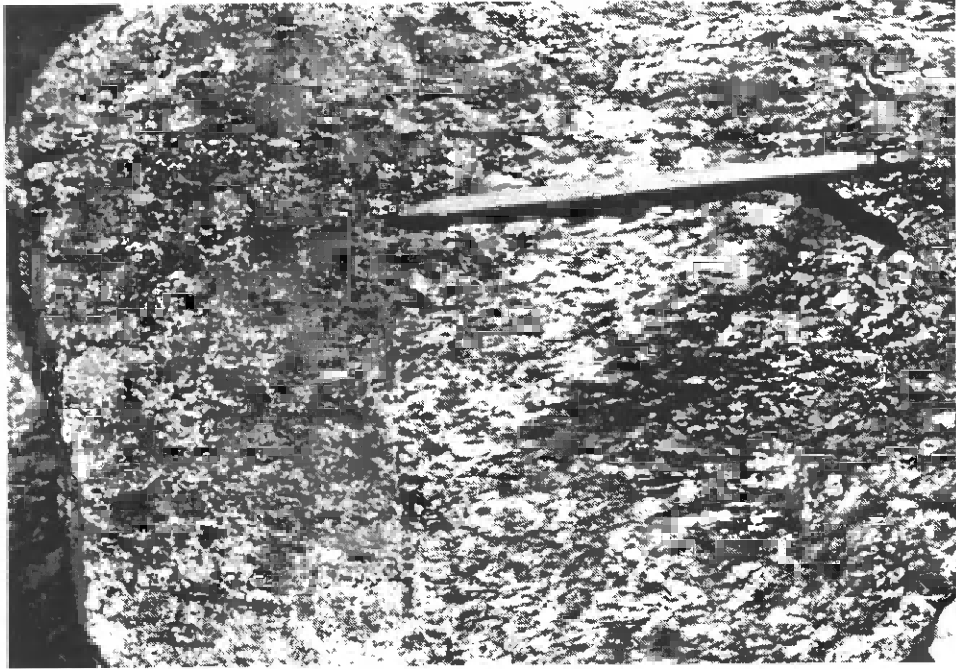


Figure 7. Foliated quartz monzonite on right (with foliation parallel with the pencil) cut by a massive granite on left. The pencil point is approximately on the contact.

The granitic intrusions exhibit a wide variety of textures and mineralogy. Quartz monzonites tend to be porphyritic with phenocrysts of plagioclase (An₂₀₋₃₀) or microcline or both in a finer matrix of quartz, feldspar and mafic minerals. Hornblende is common in quartz monzonites, comprising as much as 20 percent of the rocks. Biotite is also common. Granites generally contain fewer mafic minerals, with biotite the most common variety. Individual plutons may be recognized by their mineralogy, or texture, or both. The intrusions also differ in color. Quartz monzonites are typically gray and weather to a buff color whereas granites range from pink to deep brick red. The variety of textures exhibited by the granitic rocks presumably reflects differences in the environment (temperature and pressure) and chemistry (especially H₂O) at the time of crystallization.

The Middle Precambrian volcanic-plutonic portion of Marathon County is situated on one of the major gravity lows in the state (up to minus 90 milligals) (Ervin and Hammer, 1974). The gravity low is significantly greater than that over the gneissic area described above. This indicates that the area is underlain mainly by granitic rocks. The general gravity low suggests that the volcanic pendants (at least the mafic ones) are relatively shallow features in the granitic rocks. The aeromagnetic map of the area (Zeitz and others, 1977) is consistent with this interpretation. The granites have a low, flat magnetic expression whereas the gabbros and volcanics produce magnetic highs. (This is the reverse of the magnetic pattern described elsewhere in northern Wisconsin by Mudrey and Karl (1977).) The blotchy magnetic

pattern indicates a patchy distribution of volcanic rocks in an area composed largely of granitic rocks.

Only a few radiometric ages are available from plutonic rocks in Marathon County. Van Schmus and others (1976) obtained a U/Pb age of 1850 m.y. on zircons from the Kalinke quartz monzonite in northeastern Marathon County.

The granitic rocks in Marathon County (with the exception of the Wolf River Batholith and syenite bodies near Wausau, described below) are believed to be related to a single igneous event. All are intruded into what may reasonably be interpreted as a single (but complex) volcanic-sedimentary sequence. The various plutons show similar, widespread cataclastic foliation, and many have gradational contacts from quartz diorites to granites. It is conceivable that the various granitic rocks are co-extensive at depth and form a large composite batholith. If this interpretation is correct, the various stock-like plutons may be cupolas on this large batholith. Numerous 1850 m.y. old plutons also intruded the gneissic rocks in central Wisconsin (Van Schmus, 1976).

Chemical analyses of 19 granitic rocks and 8 volcanic rocks from the county indicate that they are calc-alkaline. Because the volcanic and plutonic rocks have a similar age, have undergone a similar structural history, and are chemically similar and are spatially related, I suggest that they may be co-genetic.

LATE PRECAMBRIAN

The Late Precambrian is represented in Marathon County by widely distributed igneous rocks, including quartz monzonites, granites, syenites, and several types of diabase dikes. The quartz monzonites and granites are part of a large batholith whereas the syenites are small, circular bodies. The diabase dikes may represent the youngest Precambrian rocks in the area.

The Wolf River Batholith. The Wolf River Batholith is a major Late Precambrian batholith underlying at least 3500 km² in eastern Marathon County and adjoining parts of northeastern Wisconsin (Van Schmus and others, 1975). U/Pb age on zircons indicates that the batholith is 1500 m.y. old (Van Schmus and others, 1976). The western margin of the batholith was mapped during this survey.

The major rock type of the Wolf River Batholith exposed in Marathon County is a coarse-grained porphyritic quartz monzonite which extends from the northeastern corner of the county approximately two-thirds of the way across the county. The southeastern part of Marathon County is underlain by a medium-grained porphyritic quartz monzonite which extends southwest as far as Stevens Point. Anderson (1975) and Anderson and Cullers (1978) concluded that the Wolf River Batholith is chemically related to alkalic intrusions, and thus is significantly different from the Middle Precambrian plutons to the west.

The contact between the western edge of the Wolf River Batholith and the Middle Precambrian rocks is, in part, a major fault zone along the

Eau Claire River. At Eau Claire Dells and to the northeast near Hogarty (Figure 1), the Wolf River Batholith has metamorphosed the sheared volcanic and plutonic rocks (discussed later) to hornblende and pyroxene hornfelses. However, farther southwest along the contact a zone of cataclastic foliation more than 1.5 km wide cuts the Wolf River Batholith (Figure 2). The strike and dip of the foliation is consistent with that in the older rocks and suggests a recurrence of the deformation after emplacement of the Wolf River Batholith.

The Syenite Plutons. Two elliptical, concentrically zoned alkalic plutons intruded the Middle Precambrian volcanic-plutonic complex just west of Wausau (Myers, 1976, this conference). These plug-like plutons are about 1500 m.y. old and are chemically related to the Wolf River Batholith (Van Schmus and others, 1976).

Wausau Syenite Pluton. The Wausau syenite pluton is approximately 12 x 27 km in plan, elongate concordantly northeast, and consists of a wall zone of foliated amphibole syenite, an intermediate zone of xenolith-rich quartz syenite and a core of quartz monzonite (the "Ninemile granite"). The southern half of the Wausau syenite pluton was intruded and partially assimilated by the Ninemile pluton. A nearly complete ring of very large, lensoidal quartzite xenoliths marks the outer part of the intermediate zone. The larger quartzite xenoliths form a ring of prominent hills, including Rib Mountain, Mosinee Hill and Hardwood Hill. An intrusion breccia marks the contact between the resistant quartzite on the tops of the hills and the more readily eroded syenite exposed on the lower slopes. Quartzite is accompanied by smaller xenoliths of schistose metavolcanics and metadiorite(?). The northern part of the Wausau syenite pluton appears to be repeated (by low angle faulting?) on opposite sides of the Rib River. Xenolith lithology, size and relative abundance vary extensively within the pluton, although metavolcanic rocks, quartzite, schist and metadiorite are dominant. Xenoliths of contrasting lithology are chaotically mixed, especially in the intermediate zone. Mixing probably involved considerable vertical transport of clasts during intrusion. (This interpretation is significant and will be referred to later.) Long dimensions of xenoliths are concentric about the core. Biotitized mafic xenoliths are ubiquitous in the quartz syenite. The amphibole and pyroxene syenites of the wall zone possess a distinct flow lineation in most places.

The Ninemile pluton forms the core of the Wausau Syenite and appears to have breached the southern part of the circular complex and spread into a large oval area to the southwest. Although the contact between the quartz monzonite core and the surrounding syenite is discordant, it appears to be gradational in most places. Quartz monzonite in the space formerly occupied by the circular core margin contains abnormally abundant mafic xenoliths. It is probable that the xenolith-contaminated "caldera-rim"(?) persisted within the upwelling magma without appreciable lateral dispersal or complete assimilation.

The Ninemile pluton is a coarse, equigranular hornblende-biotite quartz monzonite similar in appearance to the Wolf River Granite. The pluton is elliptical and underlies 218 km². A peripheral zone 2-3 km wide is marked by

numerous "rotten granite" quarries indicating that in this zone the rock has almost completely lost its coherence.

Stettin Syenite Pluton. The Stettin syenite pluton is oval in plan with dimensions of 6 x 9 km; it is concentrically zoned and elongate northeasterly. The pluton intruded mafic volcanic rocks on the west and felsic volcanic rocks and associated sedimentary rocks on the east. The pluton is divided into five main, subconcentric units: (1) lensoidal syenite, (2) nepheline syenite, (3) tabular syenite, (4) amphibole syenite, and (5) pyroxene syenite. Lensoidal syenite, banded nepheline syenite and tabular syenite are confined to the wall zone. Flow lineated amphibole and pyroxene syenites of the intermediate zone enclose a nearly circular core of pyroxene syenite that is rimmed by nepheline syenite. The pluton was intruded between two northeast-trending shear zones, with apophyses extending outward along the foliation. The concentric cylindrical structure suggests subvolcanic intrusion of the Stettin and Wausau plutons.

Diabase Dikes. Both pyroxene and olivine diabase dikes are present in Marathon County. They are characteristically undeformed and unmetamorphosed and may represent the youngest igneous rocks because they intrude all older rocks in the area. The dikes range up to 30 meters wide, and those with exposed contacts trend east or northeast. Most diabase dikes have no magnetic "signature," but one prominent dike exposed in the "rotten granite" quarries south of Rib Mountain has an associated aeromagnetic low that can be traced for more than 100 km from northern Shawano County westward across most of Marathon County. Thus, at least this dike is reversely polarized. Where exposed, it is a medium-grained pyroxene diabase about 15 meters wide with a chilled margin. A fine-grained olivine diabase is exposed in the northwestern corner of the county. The relative age of the olivine and pyroxene diabases are not known.

STRUCTURAL GEOLOGY

Regional Setting. Marathon County is on the southern margin of a large Middle Precambrian volcanic-sedimentary basin that extends across northern Wisconsin into Minnesota and Michigan. Although Middle Precambrian rocks are widely distributed over the area, their relationship from one area to another is largely unknown. Sedimentary rocks are dominant on the iron ranges to the north, but relatively unmetamorphosed volcanic and plutonic rocks predominate in Marathon County. The contacts between these low-grade rocks and gneisses, migmatites and amphibolites extensively developed in central Wisconsin are exposed in several places in the county. Maass and Medaris (1977) interpret the gneisses to be mainly Middle Precambrian in age, also. Contacts between the Middle Precambrian rocks, the 1500 m.y. old Wolf River Batholith, and related syenite plutons are also well exposed in Marathon County. Therefore, an understanding of the structural geology of this area is important to a wide variety of rocks over a large region.

Folding. Although nearly 4500 km² are mapped in Marathon County, no clear-cut structural evidence for large-scale folding was established. In much of the county the trend of distinctive lithologies in the volcanic rocks is N.60°E. to east-west. However, top indicators are lacking in most of the

volcanic rocks, and the massive nature and broken surfaces of most outcrops and/or foliation prevents determination of the dip and strike of the layering. Minor folds were observed in a few widely scattered locations, and in different roof pendants, so their significance regarding pre-intrusive folding is uncertain. Pillow lavas are widely distributed, but top determinations can be made only at two localities. The other pillow occurrences are all frost-heaved blocks, or boulders picked from fields and piled by area farmers.

The general distribution of volcanic rocks in Marathon County, however, may be the result of a large synclinal fold. In the eastern part of the county basalts are more abundant to the southeast (near Ringle) (Figure 2) with an increase in intermediate and felsic rocks toward Wausau. Rhyolites predominate at Wausau. North and northwest of Wausau intermediate and mafic rocks again predominate. West of Wausau pillow lavas exposed along Artus Creek (NE $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 29, T.29N., R.6E.) indicate tops to the southeast, suggesting that the basalts dip beneath the rhyolites in the Wausau area. Assuming that the basalts underlie the rhyolites, the distribution of volcanic rocks suggests a northeast-trending synclinal structure with its axis approximately at Wausau. However, the mafic to felsic sequence appears to have been duplicated at least twice by faulting southeast of Wausau. One proposed fault is parallel to and approximately 1.5 km west of the Eau Claire River, juxtaposing basalts on the west with rhyolites on the east. The sequence also appears to be repeated along a fault zone extending from Rothschild northeasterly along Little Sandy Creek. The complex pattern of volcanic rocks west of the Wisconsin River suggests that the succession has been repeated by faulting (or folding) in that area as well.

In addition to the large-scale folding and faulting, the volcanic rocks have been extensively segmented and disrupted by intrusions. However, the general sequence of volcanic rocks in roof pendants is consistent with the broad pattern outlined above. This suggests that the intrusions have engulfed the rocks without extensively altering the general fold pattern.

Faulting. The Middle Precambrian volcanic-plutonic complex in Marathon County is bounded on all sides by major zones of cataclastic rocks (Figure 8). A zone of cataclastic rocks 1-5 km wide extends from the northeast corner of the county southwest down the Eau Claire River and Little Eau Claire River Valleys about 61 km to Lake DuBay near the south edge of the county. There it curves northwesterly and continues northwest up the Eau Pleine River Valley about 32 km to Stratford where it curves southwest again toward Neillsville. Thus, the zone makes a large sygmoid curve that has been traced for over 120 km. The Wolf River Batholith lies east of and has locally metamorphosed the deformed rocks. A complex area of gneisses, migmatites and amphibolites (and local low-grade metamorphic rocks) lie south of the segment along the Eau Pleine River. At least five ultramafic bodies occur along this belt of cataclastic rocks.

A similar broad zone of cataclastic rocks extends in a southwesterly direction along the northern edge of the volcanic-plutonic terrane in Marathon County. It, too, separates gneisses, migmatites, and amphibolites on the north from the low-grade rocks to the south. The fault zone has been traced from near Merrill southwest through Athens to Milan where foliation curves in a

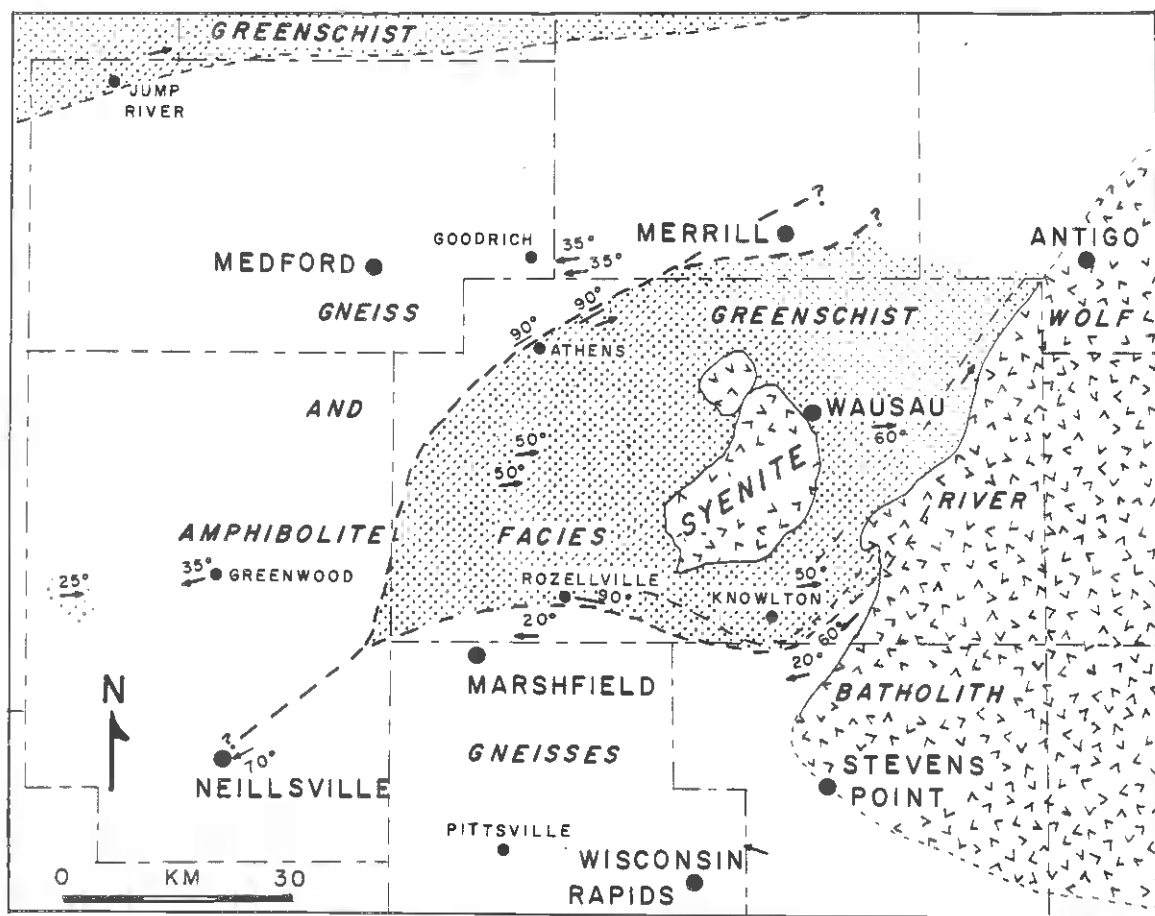


Figure 8. Simplified map of structural relationships in central Wisconsin showing the orientation of linear features in the gneissic rocks and low grade metamorphic rocks. Boundary faults are shown in dashed lines. Outliers of greenschist facies volcanic rocks are widely distributed in the areas labelled gneiss and amphibolite.

more southerly direction. Several ultramafic bodies also occur along this northern zone of cataclastic rocks. Cataclastic foliation in southwestern Marathon County strikes nearly north-south, suggesting that the two major bounding fault zones may join near the southwest corner of the county. However, the combination of glacial and Paleozoic cover effectively masks the Precambrian in that area. Gneisses, some of them migmatitic, are exposed at Greenwood, approximately 22 km west of the low-grade rocks at the western edge of Marathon County. This suggests that the low grade rocks do not extend to the west. These two major cataclastic zones coincide with aeromagnetic and gravity lineaments. Magnetic lows and local highs parallel

the structures (Figure 9). The northern cataclastic zone separates a prominent gravity low (over Marathon County) from significantly higher gravity values over the gneisses, suggesting that the structures involve considerable thickness of crust.

In addition to the major boundary fault zone numerous cataclastic zones are present within the volcanic-plutonic terrane. Their trend is parallel to the major bounding faults. The zones range up to several km wide and consist of branching and recombining zones of intensely deformed rocks, including mylonites, within a broader zone of less deformed rocks.

Cataclastic zones cut the gneissic rocks at Goodrich Dells on the Rib River (Elizabeth Palmer, verbal communication, 1979). Thus, cataclasis in the gneisses is not restricted to the boundary fault zones. It appears to be present in numerous zones throughout the area, cutting greenschist facies volcanics, plutons and gneisses. Therefore, recognition and an understanding of cataclastic rocks are important to understanding the structural and tectonic history of central Wisconsin.

Cataclastic rocks have a superficial resemblance to regionally metamorphosed rocks, for which they are often mistaken. They differ in several important ways: (1) they have a linear distribution and cut non-deformed rocks; (2) they grade across strike into rocks that are not cataclastically deformed, numerous examples of which are present in Marathon County; (3) they possess a weak to prominent foliation and lineation; (4) they are markedly inequigranular with shattered grains, and some rocks show recrystallization of the fine matrix.

The cataclastic zones typically consist of a network of braided zones of intense cataclasis several mm to many meters wide bordering lens-shaped pods of relatively undeformed rock. Therefore, there is a wide disparity in the degree of cataclasis over short distances along and across the zones. The lensoidal pattern is present on all scales from thin section to map units. The cataclastic zones cross plutonic and volcanic rocks alike, with the result that an extremely wide variety of cataclastic rocks have been produced. A brief description of the major rock types mapped is presented here.

Flaser gneiss is a medium to coarse grained rock with foliation produced by the cataclastic degradation of plutonic rocks. It is characterized mesoscopically by a pervasive lensoidal structure produced by intersecting shear planes (Figure 10). Microscopically, the rock is markedly inequigranular with relatively undeformed porphyroclasts of feldspar and quartz in a fine grained matrix of crushed material. Individual fragments tend to be crushed and boudinaged, with larger fragments typically assuming a lensoidal shape (Figure 11). Biotite, chlorite, epidote, and magnetite formed during cataclasis are concentrated along braided surfaces that intersect at angles of 10-30 degrees. This imparts a streaky appearance to the rocks. Lineation due to elongation of mineral grains is common in the plane of foliation. Flaser gneiss grades on one hand into undeformed plutonic rocks, and with continued cataclasis into mylonite or phyllonite.

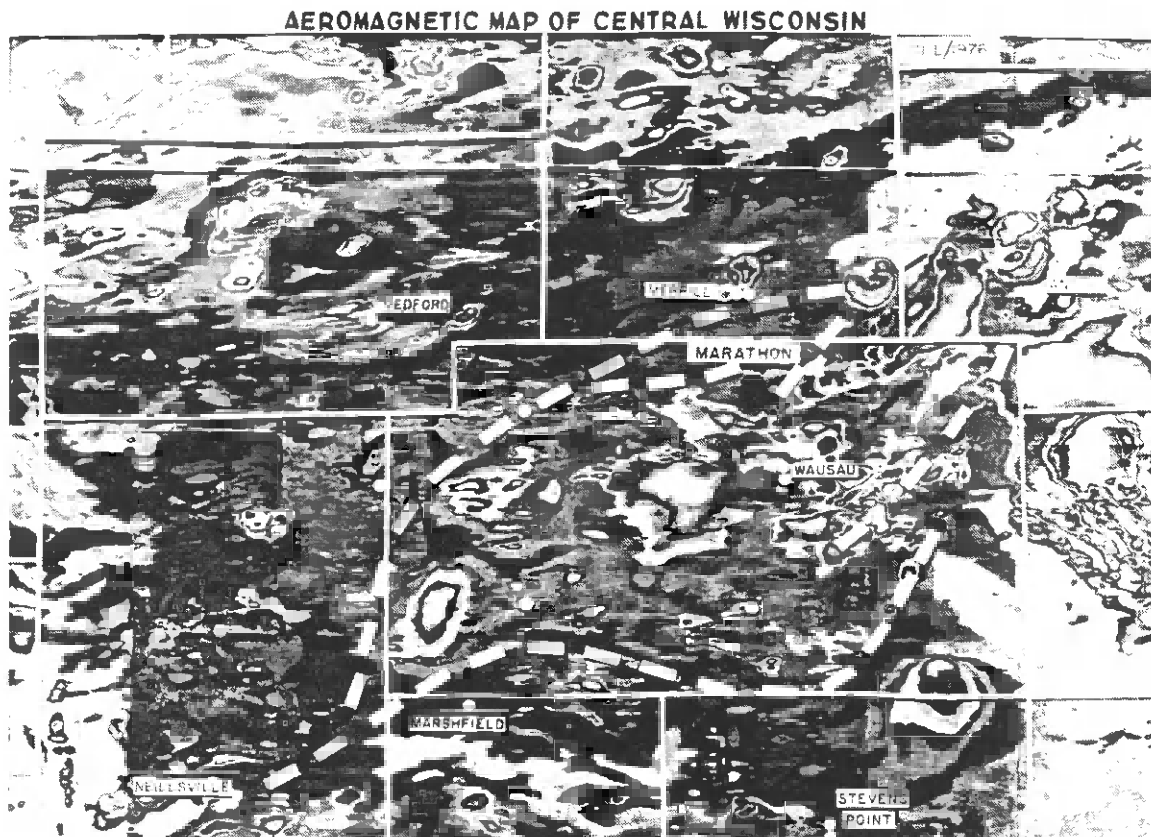


Figure 9. Photograph of the aeromagnetic map of central Wisconsin. Note the coincidence of the major boundary faults (dashed white lines) with aeromagnetic lineaments. Note also the distinctive magnetic pattern of that portion of Marathon County enclosed within the dashed lines. (Magnetic data from Karl, 1973-75.)

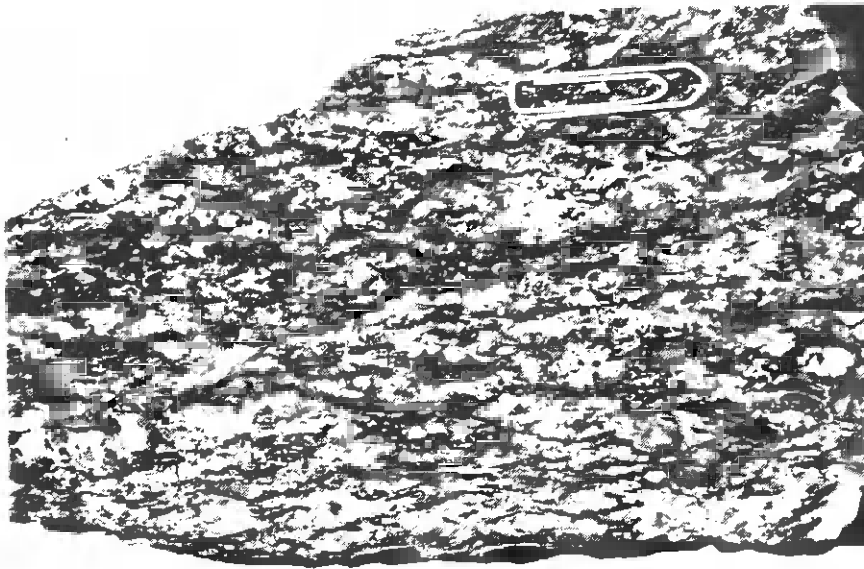


Figure 10. Quartz monzonite flaser gneiss showing typical lensoidal structure produced by intersecting shear planes.

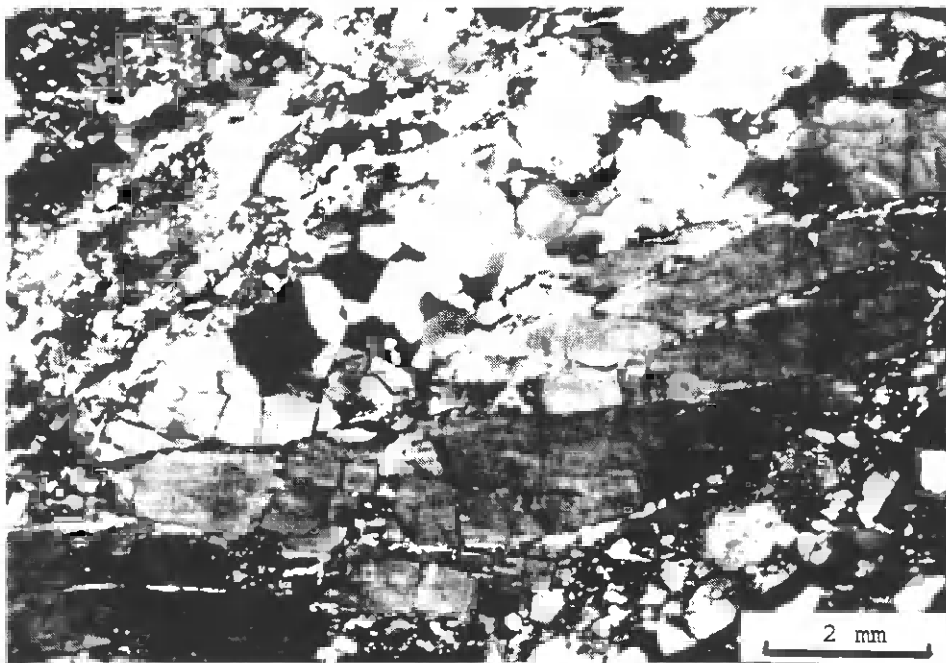


Figure 11. Photomicrograph of a typical flaser gneiss showing the fractured porphyroclasts, matrix and lensoidal structure.

Mylonite is typically a flinty, laminated rock (Figures 12 and 13) consisting mainly of finely crushed material (Figure 14), and may be compositionally banded. Like flaser gneiss, mylonite is very inequigranular, but has a greater percentage of crushed matrix. Foliation surfaces are closely spaced and typically intersect at less than 10 degrees. Streaky lineation in the direction of tectonic transport is produced by "trains" of fine grained minerals in the plane of cataclastic foliation. Detached fold axes and intrafolial folds within mylonites indicate local folding. Polygonization and increase in grain size of the fine matrix indicates recrystallization of mylonites locally. While the parent rock for most flaser gneisses can be determined, the protolith for mylonites is much more difficult to ascertain (Figure 15). Mylonites in Marathon County have been derived from a wide variety of volcanic and plutonic rocks. Whereas felsic mylonite is commonly a hard, flinty rock owing to its high silica content, mylonite derived from intermediate and mafic rocks tends to be more chloritic and schistose. Felsic and intermediate to mafic mylonites are commonly intercalated.

Deformed Volcanic Rocks. Volcanic rocks react differently to stress than do plutonic rocks. Indeed, the literature on deformed volcanic rocks is extremely vague and meagre. The presence of a wide variety of volcanic rocks interspersed with cataclastically deformed plutonic rocks in Marathon County provides an excellent opportunity to compare features in deformed volcanic and plutonic rocks. Most of the deformed volcanic rocks are strongly foliated due to the extensive development of layer silicates. Felsic volcanic rocks tend to be sericitic whereas intermediate and mafic rocks are chloritic. In some rhyolites the phenocrysts are rotated into the plane of foliation and boudinaged (Figure 16). Deformation of rhyolitic tuffs results in flattening and/or elongation of the volcanic fragments (Figure 17). In some rhyolites the strain appears to have been taken up by recrystallization and flowage of the matrix, leaving relatively euhedral phenocrysts in a highly foliated sericitic matrix. Evidently the nature of the pre-existing volcanic rock (e.g. a tuff vs. a lava flow, or a porphyritic vs. a non-porphyritic rock) affects the behavior of the rock during deformation. Deformation of fragmental andesites has produced spectacular examples of elongated fragments. In some areas the long dimension is 10 times the cross-sectional diameter of the lineated fragments. Boudinaged hornblende and plagioclase phenocrysts accompany the lineated fragments in several localities, suggesting dislocation rather than simple flattening.

Minor Structure. Mesoscopic structures are widespread in Precambrian rocks in central Wisconsin, and their pattern is informative regarding the structure of the area. Reconnaissance mapping north, west and south of Marathon County (in Lincoln, Taylor, Clark, Wood, and Portage Counties) and farther west in Chippewa and Eau Claire Counties (Myers, 1974, 1978, and this conference) disclose a consistent pattern of linear features in gneissic rocks in central Wisconsin. Axes of minor folds, mineral lineations and elongation of mafic xenoliths(?) plunge at a relatively low angle to the west in most of the gneissic rocks (Figure 8). In gneisses in and near Marathon County, fold axes and lineations plunge west at 30-40° in the plane of the foliation. Maass and Medaris (1977) interpret these to be Middle Precambrian (Penocean) structures. Lineations in the gneisses steepen to near vertical near the



Figure 12. Outcrop of mylonite about 1.6 km southwest of Athens along the boundary between the gneisses and greenschist facies rocks.

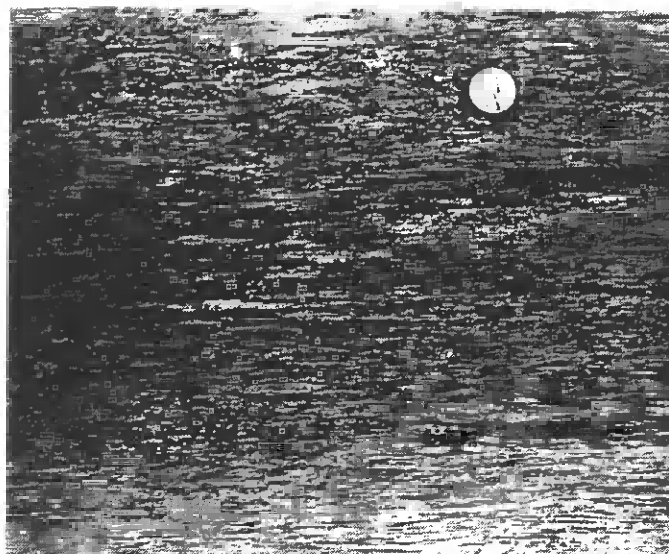


Figure 13. Photograph of mylonite showing the typical streaky and lensoidal character.

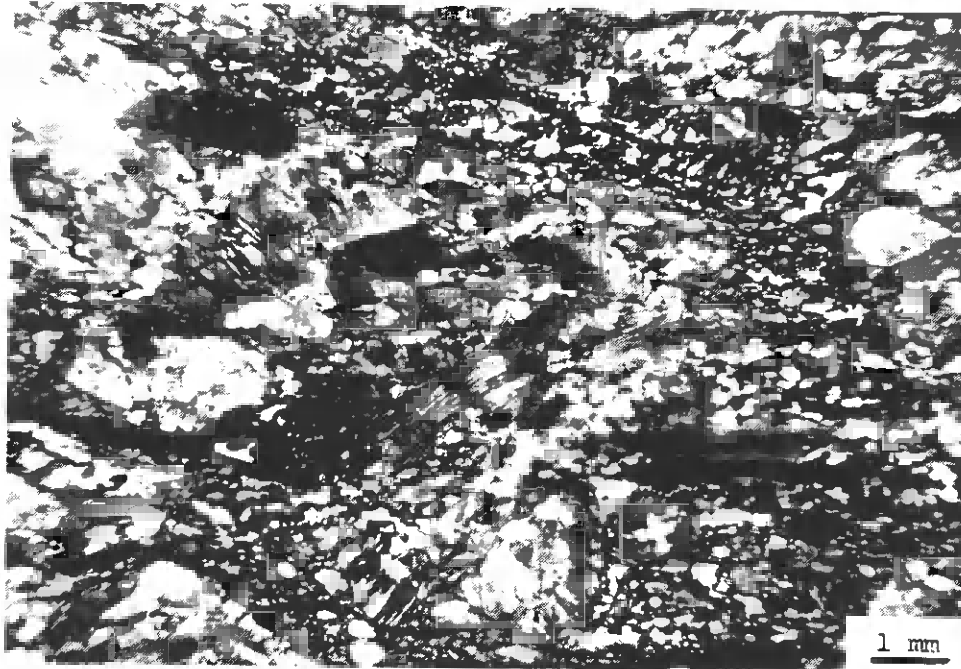


Figure 14a. Photomicrograph of typical mylonite from Marathon County showing the abundance of fine material and the close spacing of shear planes.

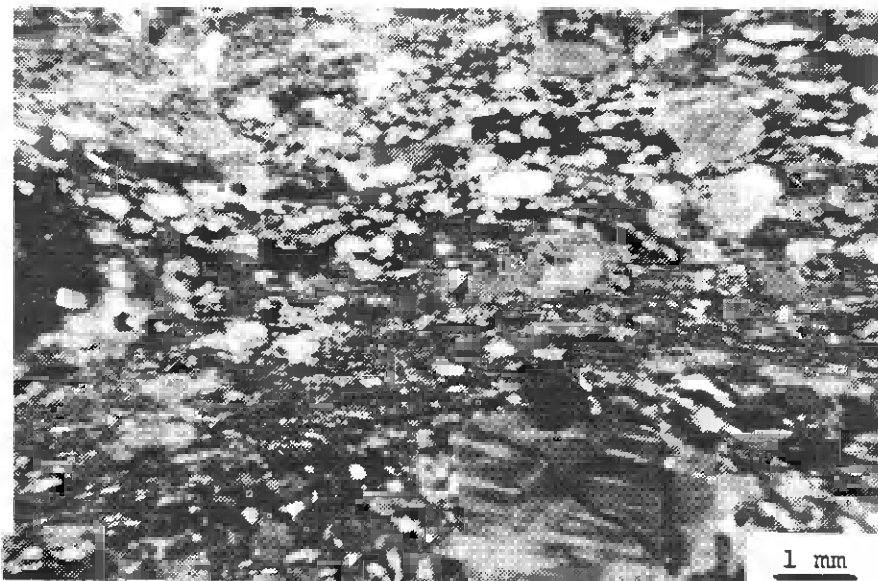


Figure 14b. Photomicrograph of typical mylonite from the Brevard Zone in the southern Appalachians.



Figure 15. Photographs showing the progressive cataclastic degradation from an undeformed granite (top) to mylonite (center) to ultramylonite (bottom). The protolith for the mylonite can be established where the transition is exposed.

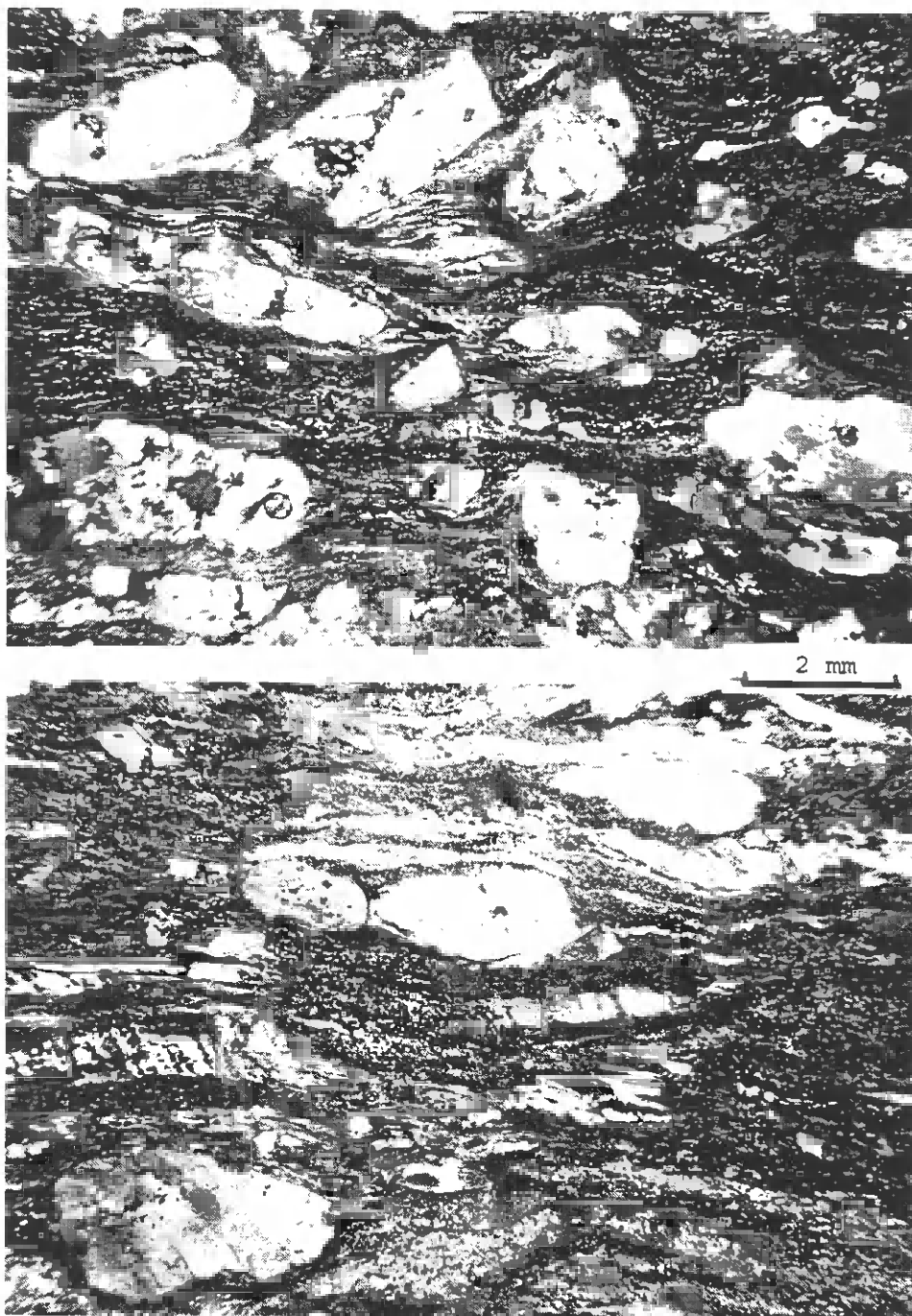


Figure 16. Deformed felsic volcanic rocks showing a foliated sericitic matrix and boudinaged phenocrysts that have been rotated into the plane of foliation. Note the crenulation folds in the matrix of the lower photograph.

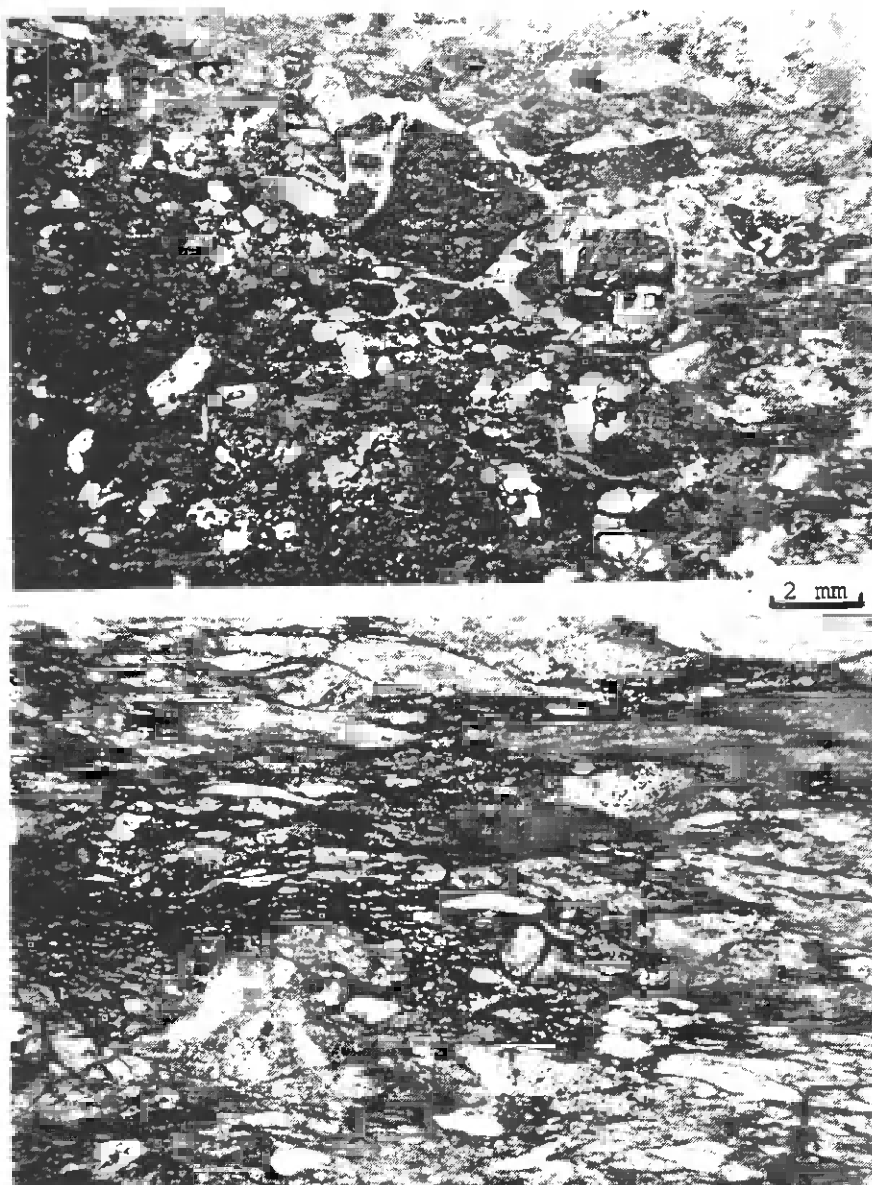


Figure 17. Photographs of felsic tuff showing the elongation of deformed fragments. Upper photo is undeformed tuff with angular, equant clasts. Lower photo shows typical lenticular longitudinal section in a deformed tuff.

major boundary fault zones where the gneisses are in contact with greenschist facies volcanic-plutonic rocks in Marathon County.

Lineations are also present in the deformed volcanic and plutonic rocks. Elongated clasts and boudinaged phenocrysts plunge east at 50° or steeper in most of the volcanic pendant. Several minor fold axes also plunge steeply east to nearly vertical. Lineations including streaking and elongation of minerals and xenoliths are also present in many plutonic rocks. Boudinaged quartz veins occur in both volcanic and plutonic rocks. Most measured lineations in plutonic rock are nearly vertical; however, some with a steep easterly dip were recorded. Crenulation folds are locally present, indicating multiple deformation. Westerly dipping lineations are conspicuously absent in the low-grade rocks. Thus, the orientation of minor structures suggests that the two terranes have different structural histories.

Furthermore, Myers (1978) shows isolated patches of volcanic rocks and volcanogenic sediments lying unconformably on the amphibolite facies rocks along the Eau Claire River in eastern Eau Claire and western Clark Counties. (Note that this is a different Eau Claire River than the one in eastern Marathon County.) The unconformity between the amphibolite facies gneisses and greenschist facies volcanogenic rocks has been folded about an axis that plunges 30° east (Myers, 1978). This indicates that the low-grade rocks were deposited on a basement of amphibolite facies rocks. Furthermore, it argues against the suggestion by Maass and Medaris (1977) that the amphibolite facies rocks are simply more highly metamorphosed equivalents of the greenschist facies rocks in Marathon County.

While the minor structures in the volcanic-plutonic terrane have a different orientation than those in the surrounding high-grade rocks, the nature of the deformation within the low-grade rocks must be considered. For example, the deformation in the volcanic-plutonic terrane may be due to (1) emplacement of the plutonic rocks, or (2) deformation later than, and not necessarily related to, the plutonic activity. If the deformation is related to emplacement of the plutonic rocks, cataclasis around each intrusion should be related spatially and in orientation to that pluton. Foliation trends may be expected to "wrap around" the plutons. If the deformation is not related to the plutonic activity, the deformation would be through-going and have a consistent pattern throughout the terrane.

Strike and dip of numerous cataclastic zones within the volcanic-plutonic terrane are similar to those of the major boundary faults. Cataclastic zones with a consistent trend cut volcanic and plutonic rocks alike. A pervasive cataclastic foliation with a consistent regional trend (east or northeast) is present in most of the Middle Precambrian plutons in Marathon County. The absence of pervasive cataclastic foliation in Late Precambrian plutons is a major distinction between them and Middle Precambrian rocks.

The age of the deformation is difficult to establish. However, a general pattern of deformation and intrusion was recognized by LaBerge (1976), in which the oldest plutons (quartz diorites) typically are more intensely deformed than quartz monzonites that intrude them. Granitic plutons are generally less cataclastically deformed than quartz monzonites, and in places

(Figure 7) truncate cataclastic foliation in quartz monzonites. In eastern Marathon County a cataclastic foliation in 1900 m.y. old (Van Schmus, 1975) rhyolite is truncated by the 1850 m.y. old (Van Schmus, 1976) Kalinke quartz monzonite. The western margin of the pluton is not foliated, but the eastern margin is extensively foliated along the Eau Claire River shear zone. South-east of Wausau granitic plutons cut the cataclastic foliation in a similar foliated quartz monzonite. Similar relationships throughout the county suggest that deformation occurred over an extended period of time, and intrusions were emplaced during this time. The cataclastic rocks of the Eau Claire River zone were metamorphosed by the 1500 m.y. old (Van Schmus and others, 1973) Wolf River Batholith. A 1.5 km wide zone of cataclasis within the Wolf River Batholith along the Little Eau Claire River suggests subsequent deformation of the batholith as well. Since the Eau Claire River zone is parallel to other cataclastic zones as much as 36 km west of the Wolf River Batholith, it is unlikely that significant cataclastic deformation was produced by emplacement of that batholith.

Thus, I believe the deformation within the volcanic-plutonic terrane is a tectonic event contemporaneous with but not necessarily related to emplacement of the plutons. The consistent orientation of minor structures suggests that it is a regional orogenic deformation that pre-dates emplacement of the Wolf River Batholith. This deformation does not appear to be restricted to Marathon County, for lineations in greenschist facies volcanic rocks exposed along the Jump River in northwestern Taylor County (40 km NW of Athens) also dip steeply to the east. Mudrey (1979, written communication) also recorded east-plunging lineations in volcanic rocks near Monico in Oneida County. This is similar to the lineations in Marathon County but distinctly different from the shallow westerly dip of lineations in the intervening gneissic rocks. Therefore, it appears to have regional significance in this part of the Lake Superior region.

Xenoliths in some intrusions also have a bearing on the possible age of the gneissic rocks. Biotite schist and quartzite, mixed in various proportions with volcanic and mafic and ultramafic intrusive rocks, occur as xenoliths in the Wausau Syenite and less abundantly in other plutons. Quartzite inclusions are restricted to the 1500 m.y. old (Van Schmus, 1976) Wausau Syenite complex. A quartzite xenolith in quartz syenite 3.2 km northwest of Wausau (SE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 21, T.29N., R.7E.) contains up to 12 percent sillimanite. Xenoliths of volcanic and plutonic rocks in the same intrusion are virtually unmetamorphosed, suggesting that the sillimanite may have been produced by an earlier metamorphic event, and not by contact metamorphism by the syenite. This suggests an upward transport of the quartzite from a high-grade metamorphic terrane at depth, perhaps the basement on which the volcanic rocks were deposited. The absence of quartzite xenoliths in older (1850 m.y. old) plutons suggests either a very restricted occurrence of the quartzite in the basement or that the quartzite is younger than the 1850 m.y. old plutons and was intruded only by the syenite. In the latter case, quartzite would represent foundered blocks from above and the sillimanite would necessarily be the result of contact metamorphism by the syenite. However, it seems unlikely that quartzite (with a specific gravity of 2.7) would sink in a magma that carried ultramafic xenoliths (with a specific gravity of about 3.4) upward. Therefore, I favor the interpretation that the sillimanite-bearing quartzite was carried upward from a high-grade metamorphic basement although I recognize that an alternative

interpretation is possible. Since thick quartzites are uncommon in Early Precambrian sequences, the quartzite is more likely Middle Precambrian.

The question then arises whether the gneisses represent a deeper level (higher pressure-temperature) of the volcanic sequence, or whether they represent an older basement on which the volcanics were deposited. Mapping by LaBerge and Myers in and around Marathon County shows that structures in the gneisses have a different orientation than those in the low-grade volcanic rocks. The general westerly plunge of lineations in the gneisses compared with easterly plunging lineations in the low-grade rocks indicates that the gneisses and low-grade rocks have been subjected to different stresses. While it is possible that both strain patterns may be produced by a single period of deformation, I believe the differences in regional patterns and unconformable relationships described by Myers (1978) are best explained by assuming two periods of deformation separated by erosion.

TECTONIC SPECULATION

If the gneisses are Middle Precambrian (as suggested by Maass and Medaris, 1977, and Van Schmus, 1979, oral communication) and the low-grade volcanic-plutonic terrane is also Middle Precambrian (as dated by Van Schmus, 1975, 1976) and if the two sequences were subjected to different periods of deformation, then there are two periods of metamorphism and deformation represented in the rocks of Marathon County. If this interpretation is correct, it has considerable regional significance.

The postulated two Middle Precambrian deformations may be represented throughout much of the Lake Superior region. It has long been recognized that a mild flexuring and erosion occurred during deposition of the Middle Precambrian sedimentary rocks exposed on the various iron ranges (cf. Van Hise and Leith, 1911). For example, the sequence of rocks containing the Kona, Randville and Bad River Dolomites (the Chocolay Group of the Marquette Range Supergroup of Cannon and Gair, 1970) underwent gentle flexuring and erosion prior to deposition of the less deformed rocks of the Menominee and Baraga Groups. The deformation following deposition of the Baraga Group is generally referred to as the Penokeyan Orogeny (Goldich, 1961). Deformation attributed to the Penokeyan Orogeny increases in intensity southward in the Lake Superior region. If, indeed, two periods of Middle Precambrian deformation are present, the gneisses and amphibolites in central Wisconsin may be a manifestation of the post-Chocolay--pre-Menominee deformation and the deformation in the low-grade volcanic-plutonic rocks may represent the "Penokeyan Orogeny." If only one Middle Precambrian deformation is present, the gneisses would presumably be Early Precambrian in age. This problem remains unresolved. Regardless of the age of the gneisses, it is probable that they represent the basement on which the volcanic rocks were deposited, for relatively small isolated areas of low-grade volcanogenic sediments (of Middle Precambrian age?) occur within an area of dominantly gneisses in Eau Claire County. Therefore, I believe that the volcanics are a discrete, younger sequence than the high-grade rocks.

SUMMARY

Gneissic rocks in northwestern and extreme southern Marathon County are probably the oldest rocks in the area, although they have not been dated radiometrically. They may be, at least in part, Early Precambrian (more than 2500 m.y.) or earlier Middle Precambrian rocks that underwent amphibolite facies metamorphism and deformation. If the high-grade rocks are Middle Precambrian, as suggested by Maass and Medaris (1977), they may correlate with rocks of the Chocōlay Group of the Marquette Range Supergroup farther north in the Lake Superior region. Deformation of these rocks would then be post-Chocōlay--pre-Menominee Group. The more intense metamorphism and deformation in central Wisconsin may correlate with the gentle regional flexuring of Chocōlay Group rocks (LaBerge and Mudrey, 1979) that occurred on the iron ranges to the north. Erosion of these gently deformed rocks occurred on the iron ranges, but much deeper erosion must have occurred in central Wisconsin to expose the amphibolite-facies gneissic rocks.

The deposition of Menominee Group sedimentary rocks on the iron ranges may correlate with the onset of volcanism in central Wisconsin, where greenschist facies volcanic rocks rest unconformably on amphibolite facies rocks. Most of the volcanic rocks are subaqueous, indicating the presence of one or more basins. The volcanic rocks were then extensively intruded by granitic plutons and deformed. The presence of high-grade rocks juxtaposed with greenschist facies rock and the preponderance of vertical lineations, including boudinage structures that indicate vertical movement on the boundary faults, suggests that the gneisses were uplifted along large faults. Then the general synclinal structure of the volcanic rocks in Marathon County may result from relative subsidence of the volcanic rocks into a "graben-like" structure (Figure 18). Intrusion of numerous plutons and deformation of those plutons

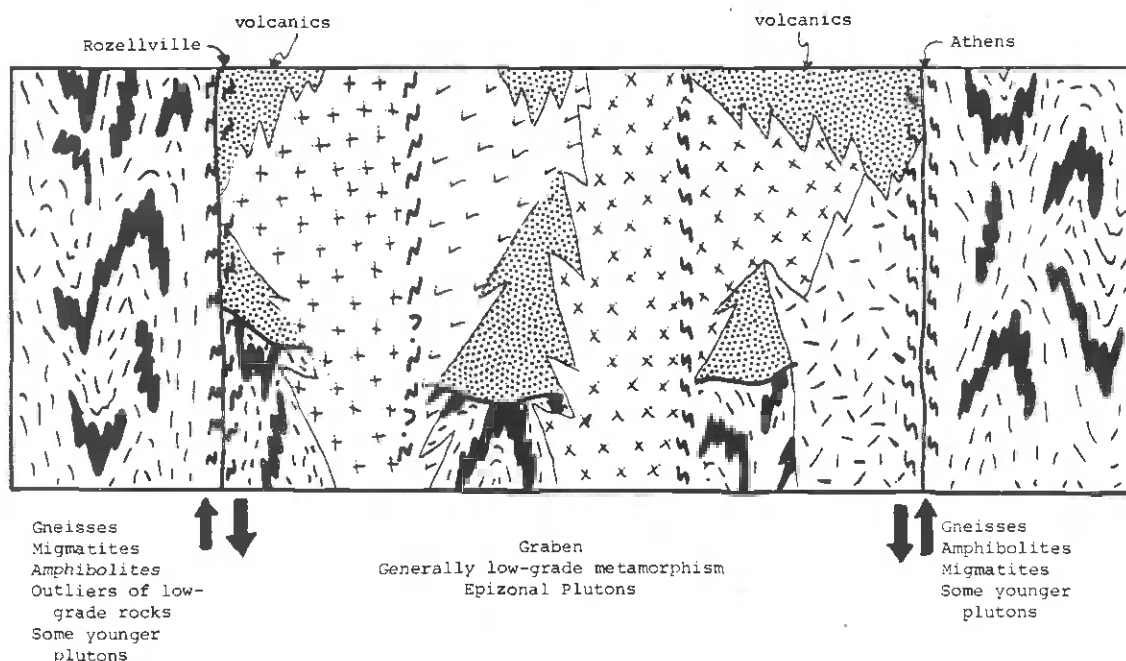


Figure 18. Idealized north-south cross-section across western Marathon County showing the postulated graben structure.

suggests that the major deformation of the area continued throughout most of the plutonic activity. This deformation and plutonic activity may correlate with the post-Menominee event known as the Penokean Orogeny (Goldich, 1961).

Presumably the area was again elevated above sea level and subjected to erosion although evidence for this is largely lacking in the area. Emplacement of the anorogenic Wolf River Batholith and related syenite intrusions about 1500 m.y. ago was the next major event in the area. The final Precambrian event recorded in the area is the intrusion of pyroxene and olivine diabase dikes, which cut all older rocks in the county.

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GEOLOGICAL STOP DESCRIPTIONS

Title: Artus Creek - Pillow basalts.

Location: In pasture along the east side of Artus Creek. NE $\frac{1}{4}$, NW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 29, T.29N., R.6E. (Marathon 15 minute quadrangle, Marathon County.) (Get permission from Harold Theis (pronounced "Tice"), R. R. 2, Marathon, WI, Phone: 715-845-2667.)

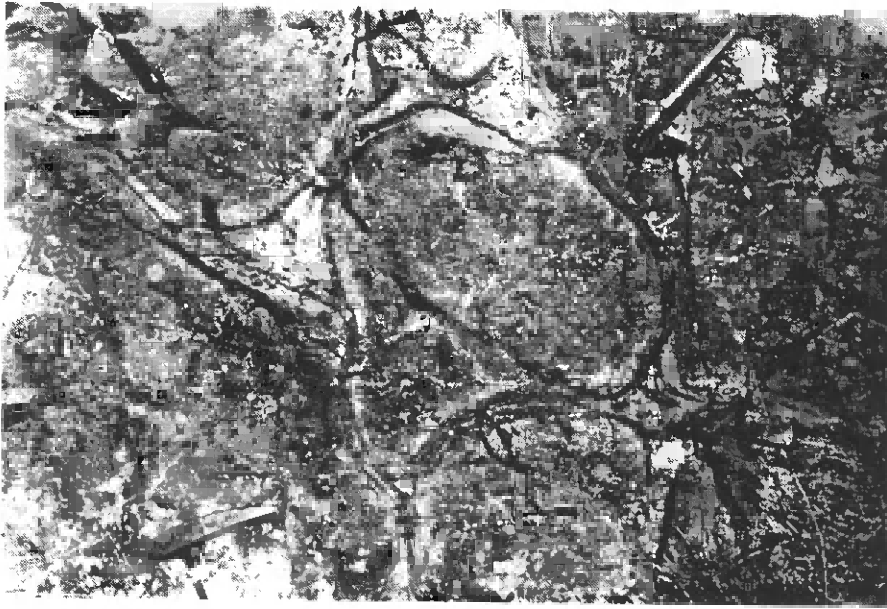
Author: Gene L. LaBerge (1980)

Description: This stop contains the best exposures of pillow basalts in Marathon County. Due to the irregular fracture pattern on the surface of the outcrop, the pillows are not very evident. However, they are well exposed on several small south-facing ledges farther from the road.

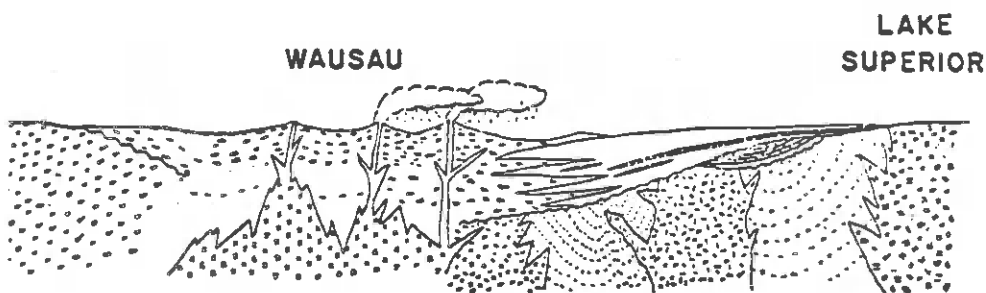
The pillows range in size from less than one foot to at least three feet in diameter. Pillows are widely used for top determination in mapping volcanic rocks. The accompanying photo, taken at this stop, shows the classical domal top and pointed bottom of the pillow. While the dip of the flows is readily determined from pillows, they do not show the strike. This must be determined by tracing a distinctive lithology (or pillowed unit). Where exposures are as limited as they are in Marathon County, it is extremely difficult to determine the strike of the basalts.

The greenstones here consist of sodic plagioclase, actinolite, epidote, chlorite, and minor carbonate and quartz. Epidote and actinolite are the dominant minerals in some samples. At the time of formation the selvages (rinds) around the pillows were probably a hydrated basaltic glass (palagonite); however, they are now dominantly quartz and epidote. The mineralogy suggests that the rocks have undergone greenschist facies metamorphism.

Significance: Pillowed basalts are widely distributed in an east-west trending "belt" across northern Wisconsin. They are abundantly exposed near Pembine in Marinette County, and sporadically exposed to the west of there, including the Monico area in Oneida County (Mudrey, 1979). The Bouguer Anomaly Gravity Map of Wisconsin (Ervin & Hammer, 1974) suggests that these rather heavy rocks (a resulting gravity high) extend almost continuously from the Michigan border west beyond Ladysmith in Rusk County. Rhyolites are also present at most localities along this belt, indicating a long belt of volcanic activity. The widespread occurrence of pillows indicates a submarine origin for most of the volcanics.



Middle Precambrian pillow lavas along Artus Creek. Pencil points at the top of the pillow.



MIDDLE PRECAMBRIAN



GRANITIC ROCKS



SEDIMENTARY ROCKS



VOLCANIC ROCKS



DOLOMITE, ETC.

EARLY PRECAMBRIAN



GRANITIC ROCKS



"GREENSTONE"

Generalized north-south cross-section in northern Wisconsin showing the postulated relationship between volcanic rocks in north central Wisconsin and iron-formations and other sediments to the north.

Radioactive age dating on these rocks indicates that they were formed between 1900 m.y. and about 1825 m.y. ago (Van Schmus, Thurman and Peterman, 1975; Sims, 1976). Thus, they are approximately the same age as the iron-formation and graywacke on the Gogebic Range, and must, therefore, have formed as part of the same basin of deposition -- the Animikie Basin (LaBerge, 1977) (see diagram).

The volcanic rocks in Marathon County have been extensively intruded by granitic rocks and are separated from the main volcanic belt by a large wedge-shaped mass of gneisses and amphibolites that appear to be older. However, the volcanic rocks here are believed to be related to those farther north in Wisconsin because they are of the same age, and were formed mainly in a subaqueous environment. At the succeeding stops, we will examine the relationships between these various rock sequences.

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Ervin, C. P. and Hammer, S., 1974, Bouguer Anomaly Gravity Map of Wisconsin; Wis. Geol. Nat. Hist. Survey.

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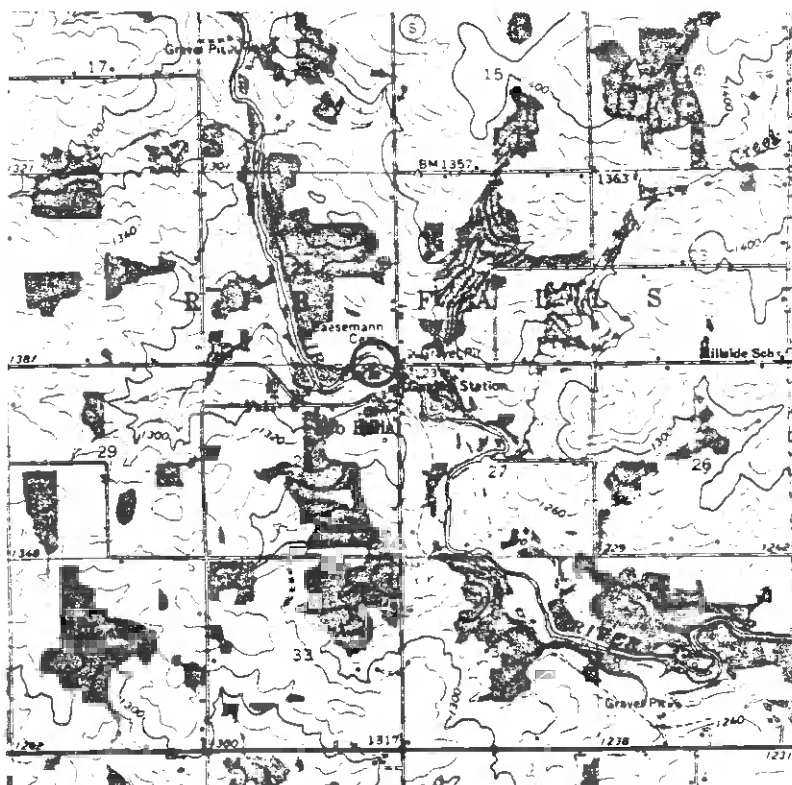
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Title: Rib Falls - Deformed intrusion breccia.

Location: West side of CTH-S at junction with CTH-U on north side of Rib River. NE corner, Sec. 28, T.29N., R.5E., Marathon County (Marathon 15 minute quadrangle).



Author: Gene L. LaBerge (1980)

Description: The volcanic sequence in Marathon County has been extensively invaded by zoned stocklike granitic intrusions. Many intrusions show extensive development of intrusion breccias. The exposure consists mainly of quartz diorite with abundant quartz, plagioclase and chloritized mafics. Mafic to intermediate volcanic(?) xenoliths ranging from about 2 cm to several meters are present in several zones. The xenoliths show a wide range in assimilation in the intrusive phase. Some are readily recognizable as fine-grained volcanic(?) rocks; others are expressed as mafic-rich clots in the quartz diorite. Several late granitic (less mafic) dikes cut the quartz diorite and the volcanic xenoliths.

Plagioclase in the quartz diorite ranges from An₂₀₋₃₅ and shows prominent zoning, and some resorption rims. Quartz occurs as + 5-8 mm grains (phenocrysts?) and as similar sized clots of finely polygonal quartz.

Much of the quartz diorite has a pervasive cataclastic foliation that strikes N.45°E. and dips vertically. Several prominent vertical, N.45°E. shear zones cross the outcrop area. They appear to be most pronounced where mafic

rocks are more abundant. Some of the zones may be sheared mafic dikes. However, in other zones the mafic material is extensively mixed with lensoidal patches of plutonic rock, suggesting that they were initially mafic-rich intrusion breccias. Lensoidal (boudinaged) blocks of relatively unsheared plutonic rocks are separated from one another by a network of braided shear planes.

Significance: Features exposed here and variations on this theme are typical of many Middle Precambrian plutons in Marathon County. Intrusion breccias are common and widespread. Xenoliths and country rocks are generally metamorphosed only to greenschist facies. Plutons are typically zoned, with a xenolith-rich quartz diorite margin and a more granitic core. Inner portions of plutons commonly intrude outer, more mafic zones, suggesting multiple injections from a differentiating magma. Quartz diorite is the common intrusive phase in intrusion breccias into mafic/intermediate volcanics whereas granite is more common with felsic volcanic xenoliths. This suggests that the composition of the magma is at least partially controlled by assimilation of intruded material.

Individual plutons are relatively small, and are mineralogically distinct from neighboring plutons, and roof pendants of volcanic rocks more than ten kms long are present.

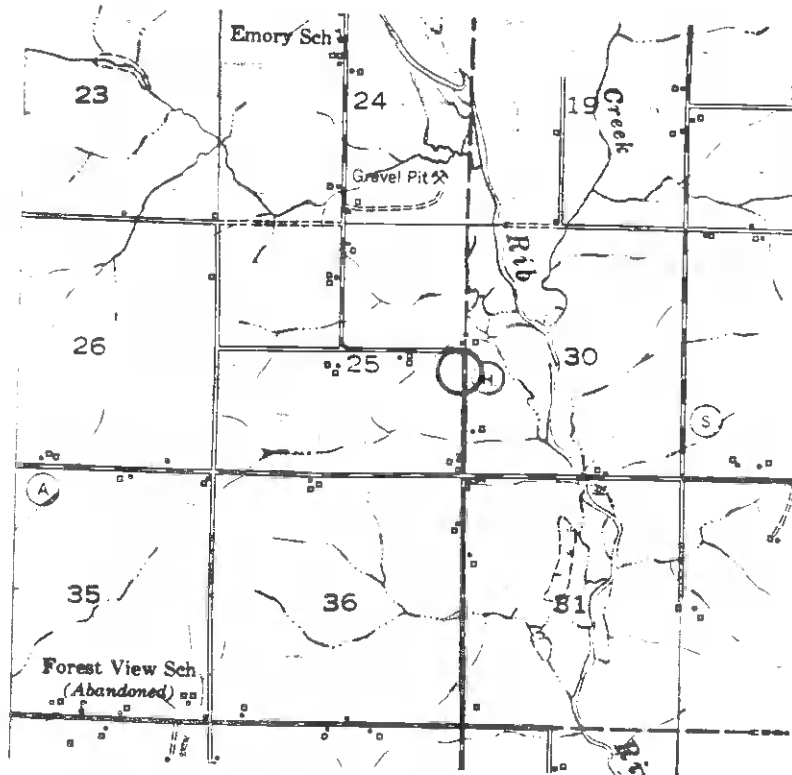
Most of Marathon County is included in a major gravity low in central Wisconsin (Ervin and Hammer, 1974). This suggests that the area is underlain predominantly by granitic rocks, probably a large batholith. The surficial geology suggests a composite batholith just being unroofed by erosion. The markedly cross-cutting relationships of the plutons, common intrusion breccias, low-grade regional metamorphism of the volcanics, prominent zoning in the plagioclases all indicate emplacement of the batholith at upper mesozonal to epizonal depths in the crust.

References:

Ervin, C. P. and Hammer, S., 1974, Bouguer Anomaly Gravity Map of Wisconsin: Wis. Geol. Nat. Hist. Survey.

Title: Rib River at Emory School - Ultramafics at contact of gneiss terrane.

Location: NW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 30, T.30N., R.5E., Hamburg 15' quadrangle.



Author: Paul E. Myers, UW-Eau Claire (1978). (Revised by LaBerge & Palmer, 1980.)

Summary of Features: A small, ENE-trending, lenticular body of massive metaperidotite(?) separates hornblende-biotite-tonalite-gneiss to the north from phyllites of sedimentary parentage to the south. The ultramafic rock was apparently emplaced along a major fault which raised more highly metamorphosed tonalite gneisses on the north.

Discussion: Muscovite phyllite with foliation and subparallel relict bedding N74°E, 75°N and subordinate cleavage N35°E, 74°NW is probably derived from a felsic volcanic rock. Relict quartz and feldspar clasts (staining show presence of both potassium feldspar and plagioclase) and bedding are best seen on horizontal surfaces toward their fault contact with the ultramafic rock. The phyllites contain streaked lensoids of K-feldspar and diamond-shaped hematite replacements. A conspicuous lineation formed by the intersection of foliation and cleavage plunges N36°W at 68-74°.

Biotite-hornblende tonalite pencil gneisses along Rib River north of here have lineations plunging N50-65°W at 55-65°. Foliation, where present, dips steeply NNW.

The coarse-grained ultramafic rock is composed of relict pyroxene(?) which appears to have been altered to an amphibole and chlorite. The presence of plagioclase suggests that this may be a feldspathic pyroxenite. Some specimens are near gabbro in composition. Another massive mafic unit composed of amphibole, epidote, and sphene outcrops 6.6 km southwest of here (NW¼, Sec. 33, T.30N., R.4E.). At both localities the mafic rocks parallel the fault contact between gneissic rocks on the north and low-grade metavolcanic and metasedimentary rocks on the south. The restricted occurrence of ultramafic rocks between the two terranes suggests that they lie along major high-angle faults and were emplaced during or after faulting. Their lack of foliation suggests the latter. Although the ultramafic body is about 300 meters wide here, it was not observed in outcrop along the Rib River just east of here. Shape and extent of the body are unknown.

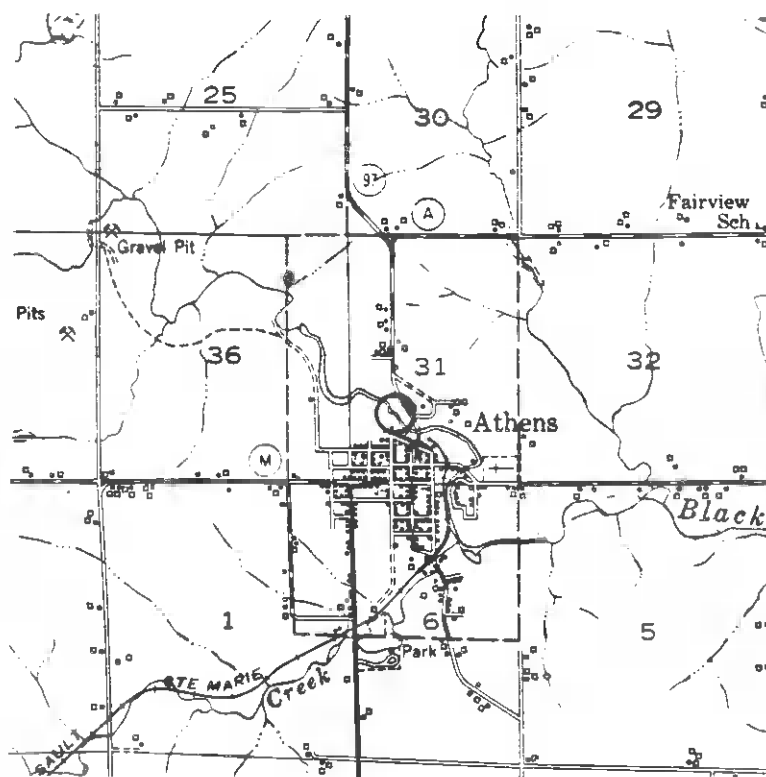
A prominent magnetic low parallels the fault contact between the gneisses and low-grade rocks for nearly 60 km along the northern edge of Marathon County (Zeitz, Karl, and Ostrom, 1977). It is not known whether the magnetic low is due to "demagnetization" of rocks along the fault zone, or whether a number of reversely-polarized mafic and ultramafic rocks are present.

References:

Zeitz, I., Karl, J. H., and Ostrom, M. E., 1977, Preliminary aeromagnetic map covering most of the exposed Precambrian terrane in Wisconsin: U.S. Geol. Survey Misc. Field Studies Map 888.

Title: Black Creek, Athens - Quartzofeldspathic gneisses.

Location: Along Black Creek valley west of Wis. Hwy. 97 in Athens. NE $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 31, T.30N., R.4E. (Marathon County) (Athens 15 minute quadrangle).



Authors: Gene L. LaBerge and Elizabeth Palmer, 1980.

Description: Quartzofeldspathic gneisses of variable composition crop out at a number of places in northwestern Marathon County. This exposure illustrates several phases of the gneisses, but numerous other phases are present.

The southeastern end of the exposure consists of a felsic rock with lensoidal, medium-grained quartz-feldspar fragments in a finer-grained micaceous quartzofeldspathic matrix. Muscovite and biotite laths wrap around the lensoidal fragments. The rock appears to be a metamorphosed felsic tuff with the clasts elongated in the plane of foliation. A more mafic (amphibolitic) rock occurs northwest of the felsic rock. The composition, fine grain size, and weakly foliated character of the mafic rock suggest that it was derived from a mafic flow or dike. The mafic rock is bounded on the north (near the old dam) by a felsic rock rich in potassium feldspar. It contains large feldspar fragments and microcline in the recrystallized groundmass. It appears to be a sheared and recrystallized potassic plutonic rock or gneiss.

Foliation here strikes about N.70°E. and dips vertically. Clasts in the gneissic rocks are elongated vertically in the plane of foliation. Farther

from the contact with the greenschist facies rocks, fold axes and mineral lineations in the gneisses plunge westerly. For example, at Goodrich Dells on the Rib River eight miles northeast of here, mineral lineations, fold axes and mafic clots plunge west at 35° - 70° within the $N.85^{\circ}E.$ foliation. This is in contrast to the east-plunging lineations in the greenschist facies rocks along Hamann Creek which we will see later on this trip.

Significance: The northwestern corner of Marathon County is underlain by a variety of quartzofeldspathic gneisses, amphibolites and locally migmatites. Reconnaissance mapping to the west and north suggests that the gneisses are an extension of the complex high-grade metamorphic terrane that extends at least 60 miles to the west. The lithologies closely resemble those of the "Chippewa Amphibolite Complex" described by Myers (1974) from exposures in Chippewa and Eau Claire Counties. Known exposures of Precambrian rocks in Clark County (between Marathon and the Chippewa-Eau Claire area) are dominantly high-grade metamorphic rocks, although scattered outliers of low-grade metavolcanic and metasedimentary rocks are present. A distinctive aeromagnetic and gravity pattern is also present in this four-county area. Thus, the gneisses in Marathon County are evidently part of a large "block" of gneisses as shown in Figure 1.

The age of these gneisses is unknown since no radiometric ages are available. However, Myers (1980, this conference) shows that similar gneisses in the Chippewa River valley have undergone two periods of deformation and metamorphism prior to 1850 m.y. Van Schmus and Anderson (1977) report that similar gneisses south of Marathon County have radiometric ages ranging from 1850 m.y. to more than 2800 m.y. Maass and Medaris (1976) interpret the rocks to be Middle Precambrian in age. Reconnaissance by Myers (1978) indicates that low grade volcanic and sedimentary rocks unconformably overlie the high grade terrane along the Eau Claire River in Clark County. Thus, the high grade rocks must be older than greenschist facies volcanics.

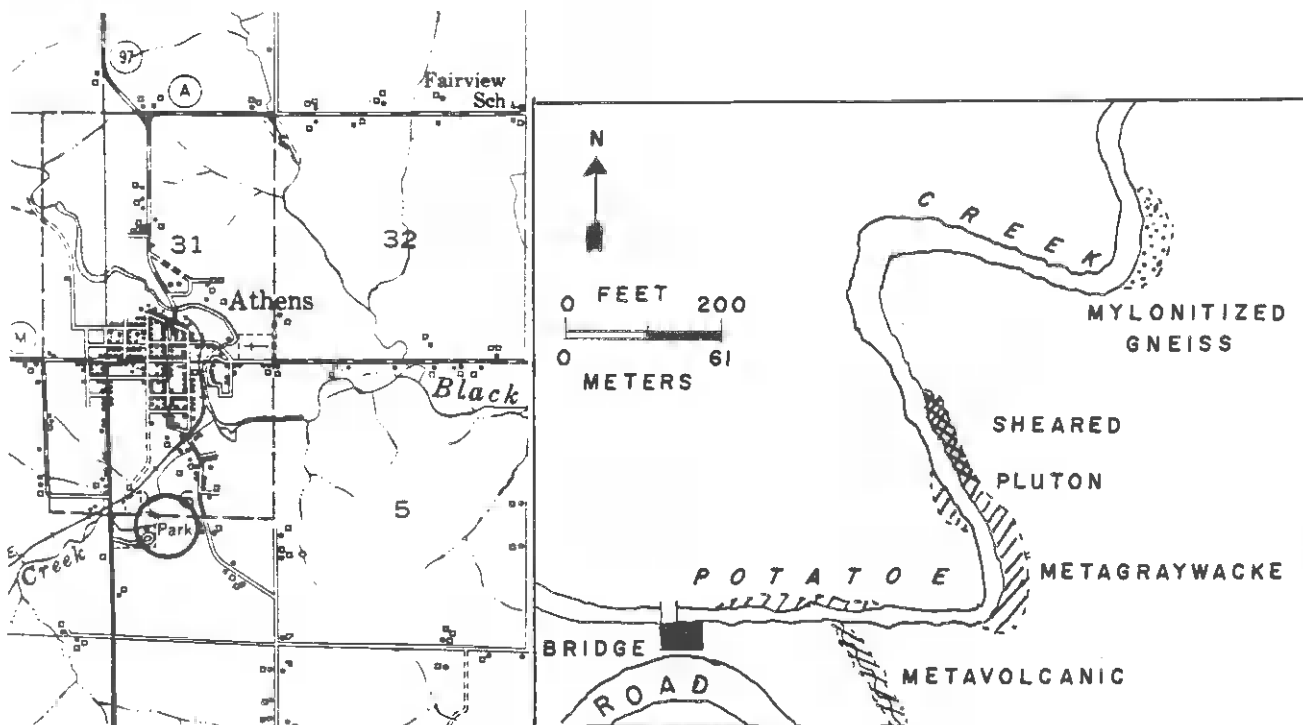
If the gneissic rocks are Middle Precambrian as suggested by Maass and Medaris (1976), they must represent an earlier deformed and metamorphosed sequence than that which we find in most of Marathon County.

References:

- Maass, R. and Medaris, L. G., 1976, Penokean Structures and Plutonic Rocks in Portage and Wood Counties, Wisconsin: 22nd Annual Inst. on Lake Superior Geology, St. Paul, p. 38.
- Myers, P. E., 1974, Precambrian Geology in Guidebook for 38th Annual Tri-State Geological Field Conference, Eau Claire, pp. 1-3.
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- Myers, P. E. and Cummings, M. L., 1980, Early and Middle Precambrian Amphibolites, Plutonic Rocks, Metavolcanics, and Metasediments of the Chippewa Valley, Wisconsin: Guidebook for 26th Annual Inst. on Lake Superior Geol., Eau Claire.
- Van Schmus, W. R., and Anderson, J. L., 1977, Gneiss and Migmatite of Archean Age in the Precambrian Basement of Central Wisconsin: Geology, vol. 5, pp. 45-48.

Title: Athens County Park - Sheared rocks.

Location: NE $\frac{1}{4}$, NW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 6, T.29N., R.4E. (Athens 15 minute quadrangle)
Marathon County.



Authors: Gene L. LaBerge and Elizabeth Palmer, 1980.

Description: This stop illustrates some of the complex and diverse lithologies developed along the major fault zones in Marathon County. Movement on the faults have evidently juxtaposed rocks of varied parentage and in various stages of cataclastic degradation, producing extremely variable, complex zones.

At the south end of the exposure at the bend in the creek (refer to sketch map), the rock is schistose, and may be a metagraywacke. It is variable in composition, with quartz, plagioclase, biotite, muscovite and hornblende the dominant minerals. Exposures in the small creek entering Potatoe Creek from the south at the south edge of the map appear to be deformed felsic volcanic rocks.

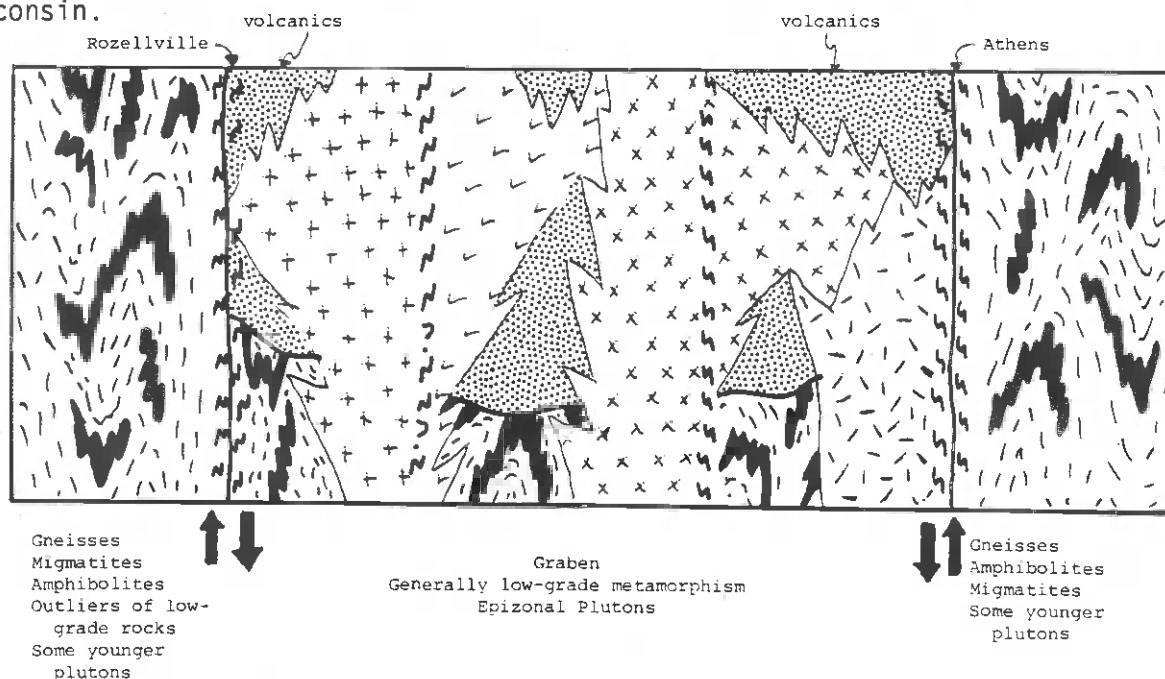
North (downstream) from the schistose rock are several exposures of well foliated biotite-rich flaser gneiss. The biotite encloses lens-shaped porphyroclasts of quartz and feldspar and emphasizes the lens-structure. This rock appears to be a highly sheared pluton, or perhaps a sheared gneiss. The larger grains show cataclastic degradation and alteration to sericite and carbonate. Deformed felsic volcanic rocks are intimately mixed with the biotite flaser gneiss.

Exposures of fine-grained pink, mylonitized granitic gneiss and several large quartz veins are present about 60 meters northeast of the park boundary. These appear to have been phaneritic rocks that have been cataclastically degraded.

Significance: A major structural boundary passes through Athens trending about N60°E. South of the lineament are volcanic rocks and granites that have been only slightly metamorphosed. North of the lineament the rocks are high grade gneisses, amphibolites and migmatites (LaBerge, 1977). Along the lineament are mylonites, phyllonites and other intensely sheared rocks along with a number of mafic to ultramafic bodies. The width of the shear zone ranges up to nearly 2 km and consists of numerous braided zones of intense cataclasis separated by lens-shaped "pods" of relatively undeformed rock. In places, the deformation affected mainly the low-grade volcanic and sedimentary rocks. A variety of rocks appear to have been involved in the deformation here. A similar cataclastic zone along the south side of Marathon County (see County map) brings gneisses into contact with low-grade volcanics and intrusions.

The presence of low-grade metamorphic rocks bounded on the north and south by gneisses and separated by broad cataclastic zones containing mafic and ultramafic bodies indicates large scale block faulting. The low-grade volcanics and granites appear to occupy a graben-like structure with horsts of gneisses uplifted on both the north and south. The diagram illustrates these relationships across this part of Marathon County.

These large scale faults appear to have been active over several hundred million years of time, and represent the major structural features in central Wisconsin.



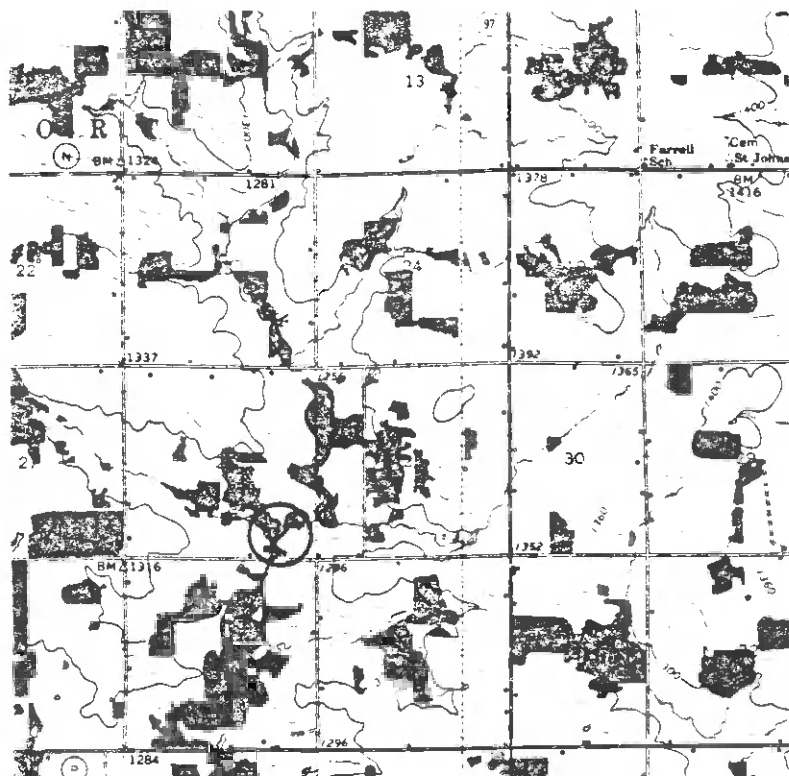
North-south cross-section across Marathon County.

References:

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

Title: Hamann Creek - Lineated andesite.

Location: Along Hamann Creek in SE¼, Sec. 26, T.28N., R.3E. Marathon County.
(Stratford 15 minute quadrangle) (Get permission from Roger Bohman,
Rt. 1, Stratford; phone 715-687-2343.)



Author: Gene L. LaBerge

Description: This exposure is representative of the intermediate volcanic rocks in Marathon County. The main rock type is a tuffaceous andesite with clasts about 1 cm in diameter, but clasts up to 10 cm long are present a short distance upstream from the bridge. Sandy textured "graywacke" is interbedded with the tuff locally. Exposures in the pasture to the north are significantly more siliceous than the outcrop near the bridge. Phenocrysts of plagioclase and hornblende are visible in places.

The rock displays a prominent foliation and lineation. Foliation and layering appear to strike about N.85°E. Foliation dips 60°-80°S. Lineation consists of elongation of volcanic clasts, extreme "smearing" of mafic minerals and boudinaged plagioclase (Figure 1). Lineation dips about 50°E in the plane of foliation. South of the road exposures along the creek are dominantly graywacke. Approximately one-half mile south along the creek are exposures of a spectacularly deformed conglomerate.

Significance: The exposure is part of a large roof pendant of volcanics, and exemplifies the type of deformation within the pendant. Rocks in the immediate area and elsewhere in Marathon County have a conspicuous mineral lineation and boudinaged mineral grains. Volcanic, plutonic and sedimentary rocks are lineated, suggesting that at least part of the deformation post-dates emplacement of the plutons. The foliation and lineations have occurred in mappable zones that have been traced for more than 90 kms. These features are interpreted to indicate that the area has been subjected to shearing stresses and that the stress was taken up along shear zones in places, and by pervasive cataclasis in other places.

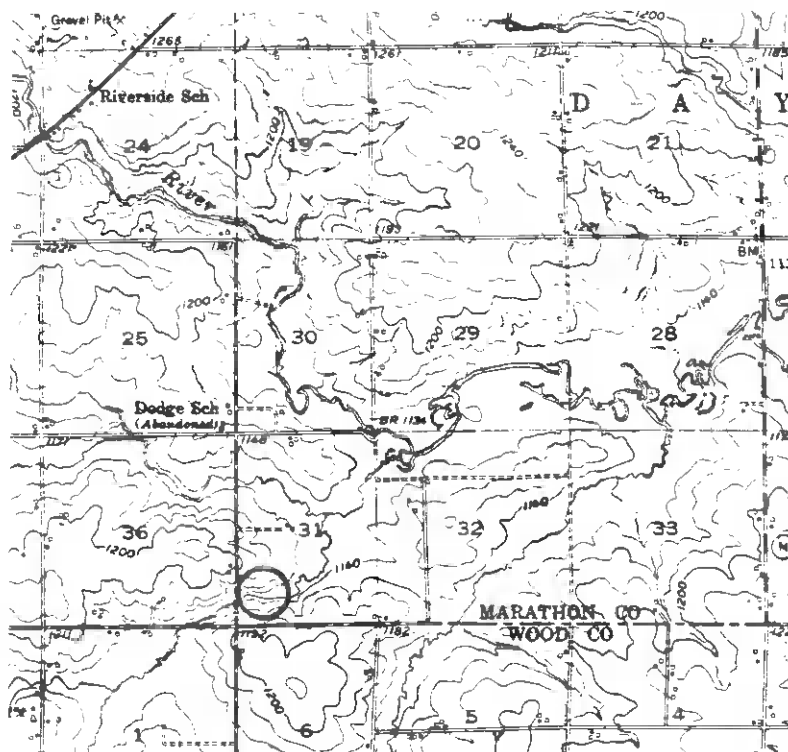
The lithologies exposed here and to the south indicate that these are largely subaqueous volcanics. Welded rhyolitic tuffs, flow banded rhyolites, and lahars (not visited on this trip) indicate that the felsic volcanics are at least partially subaerial. The other supracrustal rocks are probably subaqueous, indicating a sizeable Middle Precambrian basin in Central Wisconsin.



Lineated andesite showing alignment and boudinaging of phenocrysts (the black lines on the white lensoidal grains). Note also the zones of more intense deformation near left and right margins bounding areas of less deformation (left edge and center of photo).

Title: Little Eau Pleine River - Gneiss.

Location: N $\frac{1}{2}$, SW $\frac{1}{4}$, Sec. 31, T.26N., R.4E. Marathon County, Marshfield 15 minute quadrangle. (Get permission from Norbert Kolbeck, Rt. 2, Auburndale, WI, Box 148; Phone 715-384-8798.)



Author: Gene L. LaBerge

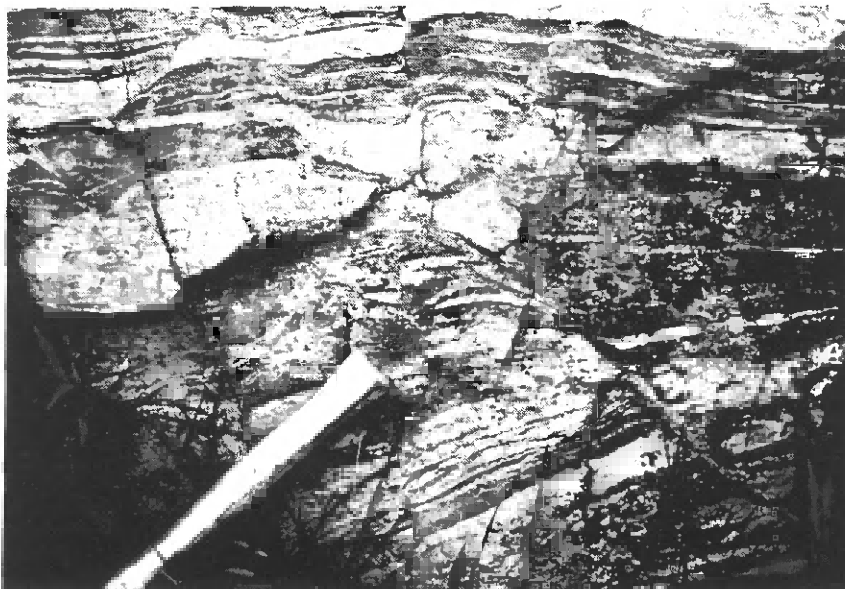
Description: Isolated blocks of high grade metamorphic rocks are present in rocks more typically metamorphosed to greenschist facies. This exposure represents a small block of gneiss and migmatite bounded on the north by a zone several hundred feet wide of ferruginous, sheared(?) quartz. Across the valley to the south the rocks are non-foliated granites and quartz monzonites that extend at least several miles south into Wood County. Other high grade metamorphic blocks include an amphibolite (metagabbro?) mass at the junction of Wis. Hwy. 97 and CTH-T in contact with a relatively unmetamorphosed ultramafic rock. The major rock type in the area is a prominently foliated quartz diorite.

This exposure is a small block (lens?) of high grade gneiss of approximately granodiorite composition. Some migmatite is present at the western end of the exposure. Small scale folds are relatively common in the gneiss with near horizontal fold axes. This is in contrast to the near vertical fold axes in low grade metasedimentary rocks about 3 miles northeast of here. Thus, it is anomalous in metamorphic grade and structurally anomalous with its surroundings.

Significance: An arcuate zone of extremely complex geology extends along the southern boundary of Marathon County. The zone consists of a wide variety of rock types, including volcanic, plutonic, sedimentary and metamorphic rocks with no apparent pattern. Most of the rocks have a prominent foliation and lineation. Rocks of very different metamorphic grade are in contact with one another, such as greenschist facies volcanics and sediments in contact with gneisses and amphibolites. Several ultramafic bodies (probably dunites) are present in the zone. Both shallow and vertical fold axes are present, along with a pervasive cataclasis (and local recrystallization) in plutonic rocks.

The mixture of lithologies and disparate metamorphic grade in a broad zone of complex structure suggests tectonic mixing of the various rock types. The area is suggestive of a megamélange, with a relatively deep level in the structure exposed along the southern part of Marathon County.

Van Schmus and Anderson (1977) dated migmatitic gneisses west of Pittsville (27 km south of this locality) at more than 2800 m.y. The gneisses may be the basement on which the Middle Precambrian volcanics were deposited. However, the structural complexity along the southern edge of Marathon County indicates a large-scale fault contact between the two terranes.



Migmatitic gneiss characteristic of the high-grade rocks exposed along the southern edge of Marathon County.

References:

Van Schmus, W. R., and Anderson, J. L., 1977, Gneiss and Migmatite of Archean Age in the Precambrian Basement of Central Wisconsin: Geology, vol. 5, pp. 43-48.

Title: Wild Creek, Rozellville - Ultramafic rocks.

Location: Ditch outcrop on east side CTH-M at the brink of the hill 1.5 miles south of Rozellville. (Farmhouse directly across the road to the west.) W $\frac{1}{2}$ corner, Sec. 22, T.26N., R.4E., Marathon County. (Marshfield 15 minute quadrangle)



Author: Gene L. LaBerge

Description: The outcrop consists primarily of a talc-serpentine rock. Relict olivine is visible in many samples. A chemical analysis of this rock shows that it contains only 39.4 percent SiO₂, and thus it probably represents an altered dunite. It is one of at least four such intrusions known along this zone. Outcrops in the yard on the west side of the road and in the creek to the north consist of mafic volcanic rocks with poorly preserved pillow structures indicating tops to the south(?). Exposures in the fields to the southeast are a strongly foliated quartz diorite (tonalite) that appears to be a relatively highly metamorphosed rock. (It contains braided zones of amphibolite up to several feet wide that may have been produced by metamorphism of shear zones in the quartz diorite.) Similar quartz diorite and amphibolite underlie at least 50 km² in this area and is associated with the gneiss exposed at the previous stop.

Foliation in this area trends N.60°W. and dips vertically. The axis of a minor fold exposed 1.2 km north along CTH-M plunges vertically and would suggest right lateral movement.

Significance: This and other ultramafic rocks occur along a zone of strongly foliated rocks of highly variable composition. The volcanic rocks to the north are believed to be part of the greenschist facies terrane present in most of Marathon County. The foliated and recrystallized tonalites, quartz monzonites and gneisses to the south appear to be part of a higher grade metamorphic terrane to the south. However, largely undeformed (and unmetamorphosed?) plutons are present several km to the southwest in Wood County, and relatively low grade mafic volcanic rocks are also present in places. Therefore, there exists here a complex zone of mixed rock types, which basically mark the boundary between the greenschist facies terrane in Marathon County and a higher grade terrane to the south. We do not know the ages of any of the rocks, except that all have been interpreted to be Middle Precambrian.