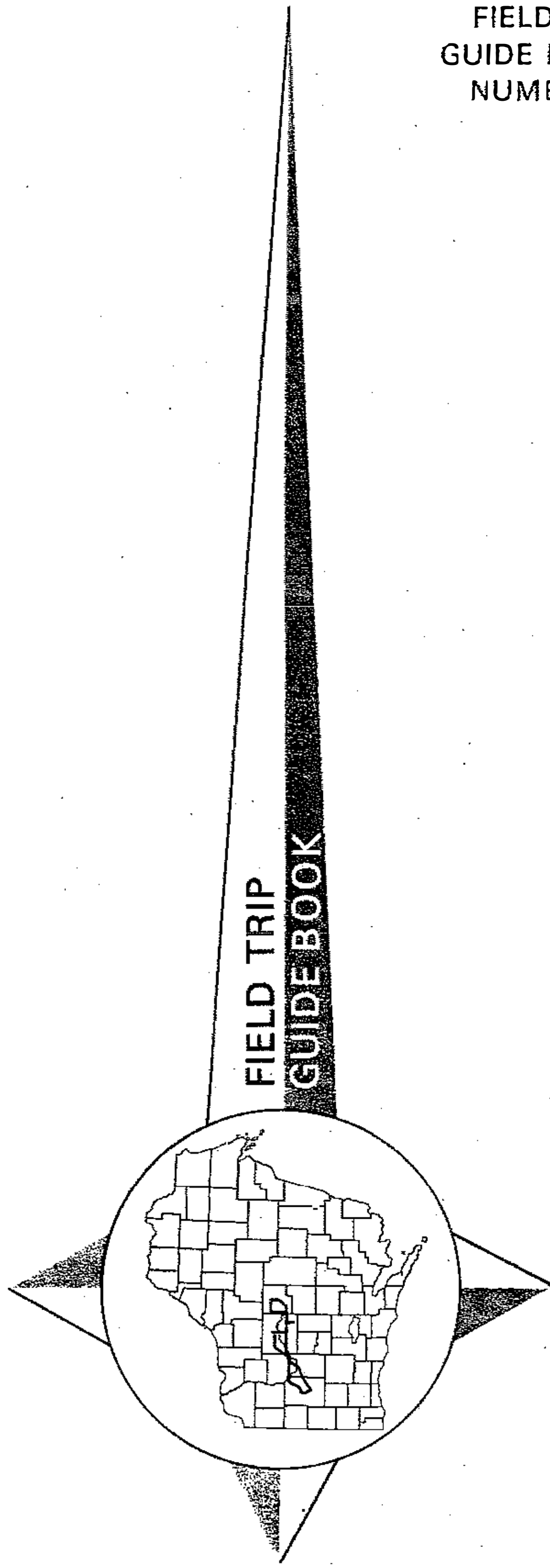
UNIVERSITY OF WISCONSIN-EXTENSION
GEOLOGICAL AND NATURAL HISTORY SURVEY
Meredith E. Ostrom, State Geologist and Director

FIELD TRIP
GUIDE BOOK
NUMBER 8
1983

MIDDLE PROTEROZOIC TO CAMBRIAN ROCKS IN CENTRAL WISCONSIN: ANOROGENIC SEDIMENTARY AND IGNEOUS ACTIVITY



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Field Trip Guide Book
Number 8

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

MIDDLE PROTEROZOIC TO CAMBRIAN ROCKS IN CENTRAL WISCONSIN:

ANOROGENIC SEDIMENTARY AND IGNEOUS ACTIVITY

Discussion and Geological Stop Descriptions

J.K. Greenberg and B.A. Brown

Prepared for

Seventeenth Annual Meeting
NORTH-CENTRAL SECTION
GEOLOGICAL SOCIETY OF AMERICA

University of Wisconsin-Madison
Madison, Wisconsin

April 28 - May 1, 1983

(meeting concurrently with the North-Central Section of the Paleontological Society, the Pander Society and the Great Lakes Section of the Society of Economic Paleontologists and Mineralogists)

Michael G. Mudrey, Jr., Field Trip Chairman
Wisconsin Geological and Natural History Survey

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PREFACE

Several of the field excursions in conjunction with this Seventeenth Annual Meeting of the North-Central Section of the Geological Society of America serve to amplify presentations given in stuffy rooms of technical sessions by moving into the dynamics of a Wisconsin spring day.

Don Mikulic and Joanne Kluessendorf will convene a half-day symposium on the hematitic and calcareous oolitic strata at the Ordovician-Silurian boundary, and then will lead interested participants to locales where these provocative relations may be examined. Jeff Greenberg and Bruce Brown have organized a symposium on the geology and tectonic setting of Baraboo-type Proterozoic metasedimentary rocks, and then will lead interested participants on a lengthy excursion to focus on newly recognized relations of the anorogenic part of the Middle Proterozoic. Lee Clayton and Tim Kemmis have coordinated a symposium on recognition of till facies with a round-robin excursion to examine the Quaternary record in southeastern Wisconsin organized by Dave Mickelson.

Lloyd Pray, Charlie Byers and Bob Dott will conduct a trip which illustrates relations or Ordovician stratigraphy, including contributions from their students in the past few years in southwestern Wisconsin. Gene Smith will rerun his trip to the Precambrian inliers in south-central Wisconsin with a newly prepared road log and technical data on the granites and rhyolites.

The local field trip committee thanks the North-Central Section of the Geological Society of America, the North-Central Section of the Paleontological Soceity, the Pander Society and the Great Lakes Section of the Society of Economic Paleontologists and Mineralogists for the opportunity to demonstrate geological relations in southern Wisconsin.

All printed field trip materials were provided in camera-ready form by the respective authors. The Wisconsin Geological and Natural History Survey is responsible for arranging details of printing. The committee also thanks Meredith E. Ostrom, Director and State Geologist of the Wisconsin Geological and Natural History Survey, for providing assistance and support for the field trips.

We welcome you to Badger land, and hope that you find the geology, companionship and tour rewarding!

Michael G. Mudrey, Jr.
Field Trip Chairman

INTRODUCTION

Bedrock over much of Wisconsin has been obscured by glacial cover. Fortunately, the rocks of interest on this field trip have been somewhat resistant to erosion, and often protrude through the glacial deposits. Even so, all but two of the planned field trip stops are located in excavations. Extreme caution is suggested for all participants. Please do not linger near or attempt to climb steep pit faces. Also, please respect the time allotted for each stop. Sample collecting is permitted at each stop, but is limited in order to keep hammer damage to a minimum at stop 1, the Skillet Creek-Baraboo outcrop; at stop 5, the Veedum pit; and at stop 8, the Necedah outcrop on private property. Don't forget to bring along rain gear and water-proofed boots.

The field trip will begin immediately after the technical sessions in Madison (by 5 pm Friday) and proceed to a single stop at Baraboo for 20 minutes before continuing on to Wisconsin Rapids for the night. Dinner Friday <u>will</u> <u>not</u> be provided; therefore be prepared to eat on your own. After dinnertime, there will be an informal get-together and introduction for the trip. Lunch will be provided on Saturday as a break in the five planned stops. A banquet is included for Saturday evening and will be followed by a time of discussion with opportunity to hassle the field trip leaders. Sunday will conclude the trip with two stops and lunch. Participants will return to Madison by 1 pm.

The authors of the guidebook thank Sherri Taylor for contribution on the geology of Hamilton Mound. We also acknowledge the aid given by the field trip drivers. Drs. Carla Montgomery and Randy Van Schmus have worked closely with the authors in an attempt to determine the ages of some of the igneous units associated with the Baraboo interval. Irene D. Lippelt assisted the authors in preparation and editing of the manuscript.

BARABOO INTERVAL SEDIMENTATION

Rocks of the Baraboo interval, a sequence of Proterozoic quartz-rich metasedimentary rocks are exposed throughout much of the upper midwest. Prior to deposition of this sequence, the Precambrian evolution of the region included formation of the Archean craton to the north, tectonism during the Early Proterozoic Penokean Orogeny, and post-orogenic felsic magmatism.

The Baraboo syncline in south-central Wisconsin is considered a type locality for rocks of the Baraboo interval. Some other well known exposures are the Sioux Quartzite in Minnesota, Iowa, and South Dakota and the Barron Quartzite in northwestern Wisconsin. The rocks in this sequence can be distinguished from both younger and older Proterozoic metasedimentary rocks by their distribution (fig. 1), their petrologic and tectonic character, and their probable time of deposition. The term, Baraboo interval (Dott, 1983), is used in this guide in reference to the period of time when the Baraboo-type sediments were deposited. Unconformable relationships and isotopic ages of associated igneous units bracket the depositional interval between about 1760 m.y. ago and 1500 m.y. ago. The sedimentation is interpreted as one manifestation of regional anorogenic tectonism, which included rhyolite-granite magmatism 1760 m.y. ago, widespread uplift and possibly deformation 1630 m.y. ago, and alkalic intrusion 1500 m.y. ago.

The major intent of this field guide is to present background and descriptions of several important exposures of Baraboo interval units. Some of these exposures are key in establishing stratigraphic relationships. Unconformities between Proterozoic basement and overlying Cambrian sandstone are also well demonstrated at some of the field trip stops.

The sedimentary sequence within the Baraboo interval consists dominantly of orthoquartzite, quartzite conglomerate, and micaceous quartzite, with lesser amounts of phyllite (argillite), micaceous conglomerate, metachert, and iron formation. Carbonate rocks (dolomitic) are known only within the upper part of the succession at Baraboo (Dalziel and Dott, 1970). Of all the rock types in the interval, only iron formation and dolomite will not be seen on the field trip.

There is now strong evidence from rocks in northeastern Wood County, western Portage County, Baraboo (Weidman, 1904, thin section 6903), and the Sandhill Wildlife Refuge (stop 6) suggesting that subaerial rhyolite volcanism took place within or immediately preceeding Baraboo-interval deposition.

Other exposures visited on the field trip demonstrate various temporal relationships including: (1) quartzite and micaceous conglomerate overlying post-tectonic granite (Vesper, stop 2); (2) Cambrian sandstone unconformable on the Proterozoic metasedimentary units and post-tectonic granite (Hamilton Mound, stop 7; Veedum, stop 5; Sandhill, stop 6; and Cary Mound, stop 4); and (3) the effects of granitic magmas intruding quartzite (Hamilton Mound, stop 7; Necedah, stop 8; Cary Mound, stop 4; and perhaps Powers Bluff, stop 3). Intrusive relationships can also be observed for the McCaslin, Waterloo, and Baraboo Quartzites (figs. 1 and 2) which are within the Baraboo interval but are not included in this guide. Fracture cleavage development at Powers Bluff and Hamilton Mound and more intense differentiated cleavage in Baraboo phyllite at Skillet Creek (stop 1) are possible manifestations of deformation

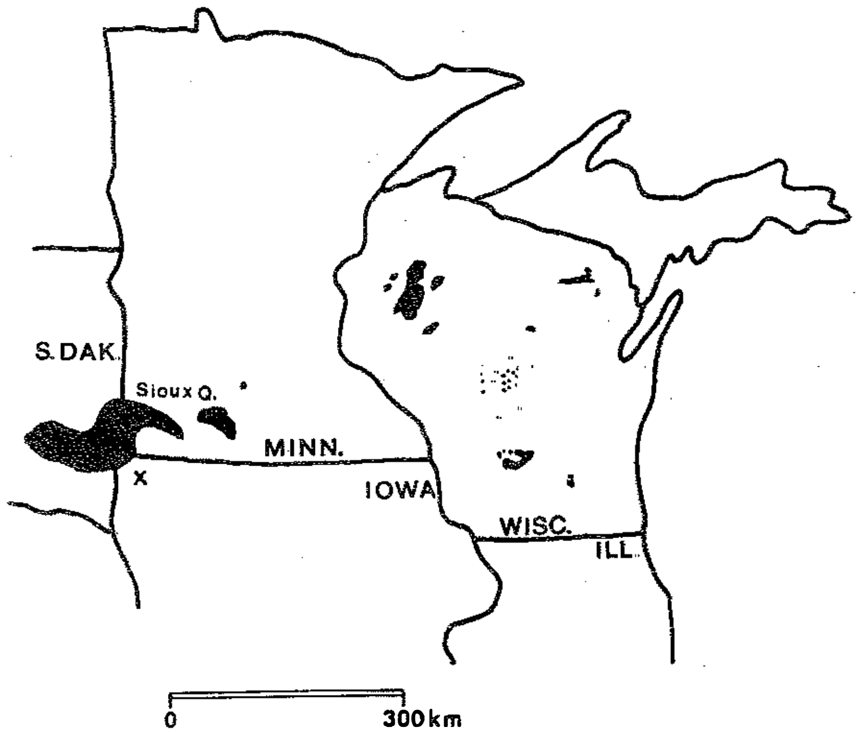


Figure 1. Distribution of Baraboo interval exposures in the upper midwestern U.S. shown in black. X marks the location of 1500 m.y. old granitic rock in subcrop of Sioux Quartzite.

1630 m.y. ago or later. Quartzite brecciation which is a common brittle deformation feature is well displayed at both Hamilton Mound and Necedah.

Distribution and Character of Baraboo Interval Sediments in Wisconsin

The best known and most widely studied rocks belonging to the Baraboo interval in Wisconsin are the red quartzites. These include the Baraboo Quartzite (Wiedman, 1904; Dalziel and Dott, 1970; Dott and Dalziel, 1972; and Dott, 1983), Barron and Flambeau Quartzites (Campbell, 1981), McCaslin Quartzite (Olson, 1983), and quartzite exposed in the Waterloo area of southeastern Wisconsin. It has long been known that the quartzite at Baraboo was overlain by a sequence of argillaceous and ferruginous sediments (Wiedman, 1904; Dalziel and Dott, 1970). Until now, little attention had been given to the possibility that the argillaceous and ferruginous sediments and quartzites which occur scattered throughout central Wisconsin (Wiedman, 1907), might also belong to the Baraboo interval. It has also been known for many years that quartzite, slate, and iron formation of Precambrian age underlie the Paleozoic rocks covering a large area of southeastern Wisconsin, Thwaites (1931, 1940).

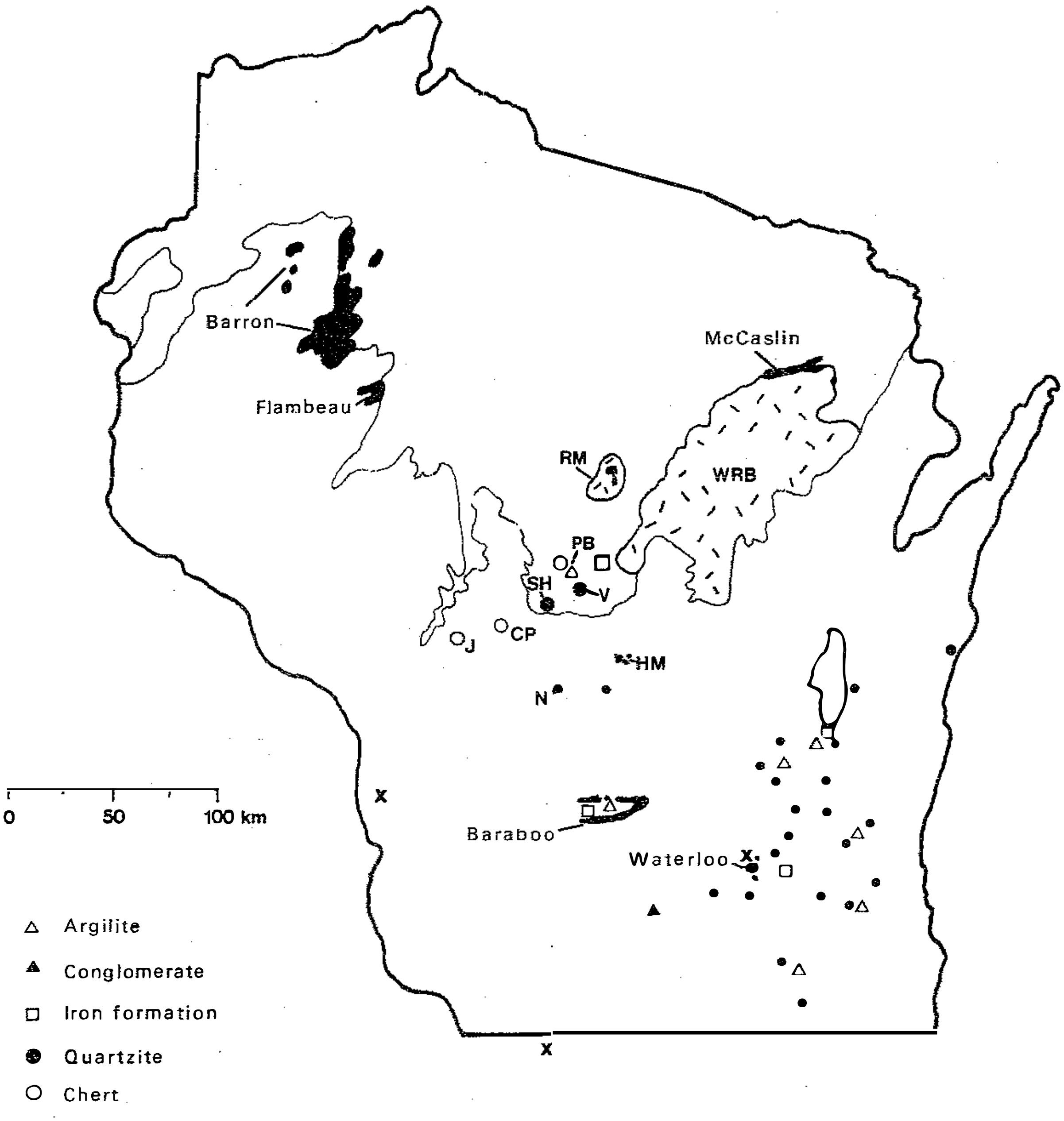


Figure 2. Distribution of Baraboo interval metasedimentary rocks in Wisconsin. X marks location of 1500 m.y. old intrustive rocks outside of Wolf River Batholith (WRB). Abbreviations: RM - Rib Mountain, PB - Powers Bluff, V - Veedum, CP - City Point, J - Jackson county chert, N - Necedah, HM - Hamilton Mound.

Recent field mapping in central and northern Wisconsin, along with a reexamination of rock samples and well cuttings in the Wisconsin Geological Survey collections have confirmed that many of the metasedimentary rocks from these outlying occurrences are similar in composition and texture to the rocks of the Baraboo region, and were also deposited during the same time period, the Baraboo interval. The lack of continuous exposure makes strict correlation of units impossible, but physical similarity, spatial distribution, and apparent time of deposition argue strongly that these rocks are part of the same sedimentary package as the "red" quartzites of Dott (1983).

The distribution of rocks assigned to the Baraboo interval in Wisconsin is shown in figure 2. Also shown in figure 2 is the distribution of the six distinct facies: red to pink quartzite, micaceous and feldspathic quartzite, conglomerate, argillaceous rocks, iron formation, and chert.

Quartzite

Quartzite typically consists of greater than 90 percent quartz grains. In examples where texture has not been destroyed by recrystallization, grain size is comparable to medium to fine sand, and sorting is moderate. Quartz grains are generally well rounded. Minor constituents include iron oxides, zircon, rutile, and apatite. Matrix, represented by fine grained phyllosilicates, (sericite, muscovite, pyrophyllite) typically constitutes less than 10 percent of the rock. Where matrix content is higher than 10 percent, the rock is classified as a micaceous quartzite.

Cross bedding, current lineation, and ripple marks are common sedimentary structures in the quartzites. In areas where deformation is not intense, these structures have been used as paleocurrent indicators, (Campbell, 1981; Dott, 1983; and Olson, 1983). From what limited data are available, the dominant direction of transport in Wisconsin is generally to the south.

Quartzite in the strict sense is present as a major or minor lithology in all known areas of exposure and subcrop of Baraboo interval metasedimentary rocks. It is the dominant lithology in the Baraboo, Barron, Waterloo, and Sioux Quartzites (Dott, 1983), and is the dominant lithology of the McCaslin, Rib Mountain, and Necedah Quartzites of northern Wisconsin.

Argillite

Meta-argillite beds, now more properly called slates and phyllites, are common throughout the sequence. Phyllitic beds less than 1 cm thick are reported at Baraboo (Dalziel and Dott, 1970) and at McCaslin Mountain (Olson, 1983). Thick argillaceous sequences, several tens of meters thick, are known only in the upper part of the section at Baraboo, at Powers Bluff, and in the subsurface, particularly in the Fond du Lac area.

At Baraboo, the quartzite is overlain by the Seeley Slate (100 m), the Freedom Formation (carbonate & iron formation, 300 m), the Dake Quartzite (70 m), and the Rowley Creek Slate (50 m). The units overlying the quartzite are not exposed, and are known only from drill core from the center of the Baraboo syncline. The Seeley is gray to green in color with fine stratification marked by variation in color and texture. This unit, and argillaceous units in the lower part of the overlying Freedom Formation, appear similar in texture and composition to the argillite exposed at Powers Bluff. The Rowley Creek Slate is an iron-rich chlorite bearing slate. Rocks similar to the Rowley Creek have not been found in central Wisconsin although rocks similar to both the Rowley Creek and Seeley Slates occur in the subsurface of southeastern Wisconsin.

The mineral composition of the argillites is predominantly quartz and kaolin. Metamorphosed agrillites such as occur at Waterloo (Geiger and others, 1982) and McCaslin Mountain (Olson, 1983) have developed porpbyroblasts including garnet, sillimanite, andalusite, and chloritoid.

The dominant sedimentary structure in the argillites is fine lamination, suggesting a quiet depositional environment. No grading or turbidite structures have been observed in sequences containing abundant argillite beds.

Argillite is present throughout the outcrop and subcrop area of Baraboo interval metasediments in Wisconsin. In most areas it is a minor lithology, present only as thin beds in quartzite.

Micaceous Quartzite

Quartzite containing up to 30 percent or more matrix occurs at Baraboo and at several localities in central Wisconsin. The most logical source for the matrix is the breakdown of feldspars in originally arkosic rocks, or the breakdown of unstable rock fragments such as fine volcanic debris.

The close association of rhyolite flows and breccias with quartzite at Sandhill (stop 6) suggests that contemporaneous rhyolitic volcanism may have contributed sediment into the depositional environment of Baraboo interval rocks. Re-examination of thin sections from rocks collected by Wiedman (1904) at Baraboo also suggests that conglomerate beds containing volcanic fragments may be present in the lower part of the Baraboo Quartzite.

Although primary detrital feldspar is unknown in the Baraboo interval rocks of Wisconsin, it is possible that rocks such as the very micaceous quartzites at Vesper (stop 2) and Veedum (stop 5) may have originally been arkoses or quartz wackes.

Conglomerate

Several types of conglomerate occur in the Baraboo interval rocks of Wisconsin. Pebble conglomerates containing quartz pebbles ranging from 5 to 10 mm up to 2 to 3 cm in diameter occur as discontinuous lenses in the Baraboo, Waterloo, McCaslin, and Barron Quartzites. These conglomerate lenses have been interpreted by Dott (1983) as evidence for a fluvial depositional environment.

In central Wisconsin, coarser (up to 10 cm in diameter) clasts commonly occur in a very micaceous matrix. Clasts of quartz, chert, jasper, and rhyolite are common. The presence of angular to subangular rhyolite clasts is further evidence for volcanism contemporaneous with sedimentation in this region.

Minor occurences of intraformational conglomerates, consisting of argillite rip-ups have been reported in the Flambeau Quartzite by Campbell (1981).

Chert

Chert is a distinct lithology but not a common rock type in the Baraboo interval. The only documented occurrences are in the Freedom Formation of the

Baraboo syncline, at Powers Bluff in Wood County, and at several minor exposures in Wood and Jackson Counties. The cherts are essentially aphanitic, consisting of fine quartz with color variation and banding defined by slight variations in grain size and content of opaques (iron oxide). The chert at Powers Bluff is blue-gray to pink in color, showing prominent banding 3 to 5 cm thick. Cherts exposed in Jackson County east of Black River Falls and Wood County north of City Point (fig. 2) are identical in character to the Powers Bluff chert, as are samples collected by Wiedman (1904) from the Freedom Formation. At Baraboo, the cherts of the Freedom Formation are associated with ferruginous argillites. The Powers Bluff chert is associated with interbedded ferruginous and carbonaceous argillite, which contains distinct nodules of chert identical in texture and composition to the bedded chert.

Ferruginous Quartzite and Iron Formation

Major iron formations such as occur in the northern Penokean terrane of northern Wisconsin and Upper Michigan (fig. 3) are not known in the Baraboo interval rocks. Iron formations known to be associated with Baraboo interval sediments are generally thin, of limited areal extent, and are not presently of economic grade. Many rocks of this group, however, are sufficiently iron rich to be called iron formation, and their expression for dip-needle magnetic surveys caused much interest among early iron prospectors. The iron rich beds of the Freedom Formation were even mined in the early days, (Wiedman, 1904). Ferruginous quartzite occurs in central Wisconsin and ferruginous slate is present in the argillite sequences of Powers Bluff and in the Seely slate. Iron formation and ferruginous slate occur in wells in the Fond du Lac area, in Jefferson County, and in Waukesha County.

Although exposure is poor and continuity is non-existent, a pattern is evident in the distribution of the six facies described above. True quartzites appear to be most abundant in the north (Barron, McCaslin, Rib Mountain) and in the south (Baraboo, Necedah, Waterloo, subsurface). Argillite is very minor and iron formation and chert are not known in the extreme north. Fine clastic and chemical sedimentary rocks are most abundant in the upper part of the section in the south. In central Wisconsin, thick sequences of quartzite are not present; instead, sedimentary rocks which are cherty, argillaceous, and ferruginous appear to directly overly basement.

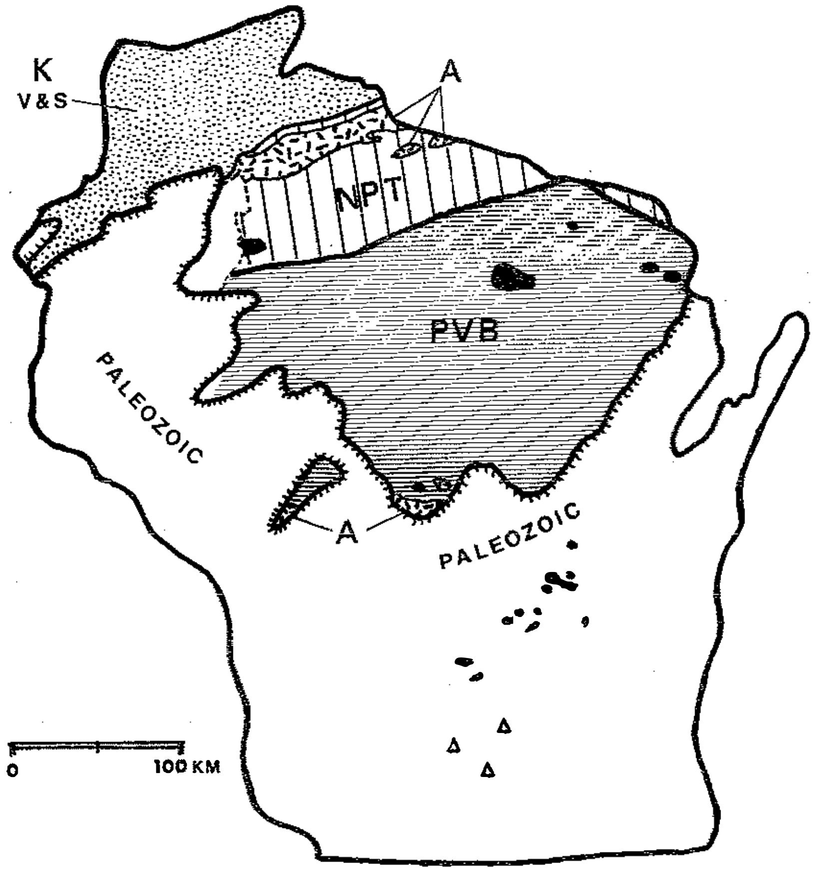


Figure 3. Major Precambrian tectonic-chronologic divisions in Wisconsin. 1760 m.y. old granite and rhyolite shown in black. Subsurface data as triangles; K v & s area - Keweenawan volcanic, sedimentary units; Archean terranes marked by A and random dash patterns; NPT area - northern Penokean terrane; PVB area - Penokean volcanic belt.

TECTONIC AND DEPOSITIONAL SETTING

Pre-Baraboo Interval

In Wisconsin, three major periods of tectonism occurred prior to the Baraboo interval. Two Archean terranes were developed about 3000 to 2500 m.y. ago (Van Schmus and Anderson, 1977; Sims, 1980). An Archean terrane representing the southern margin of the Superior Shield trends east-west across northwestern Wisconsin. An isolated Archean block in central Wisconsin constitutes a second terrane (fig. 3). Sedimentation and volcanism took place south of and in part on the cratonic margin during the Early Proterozoic, approximately 1900 m.y. ago. These units were deformed, metamorphosed, and intruded by plutons as part of the second major period of tectonism, the Penokean Orogeny (Goldich and others, 1961). This orogeny produced two distinct 1850 m.y. old terranes (fig. 3), the northern Penokean terrane, developed on the rifted craton margin, and The Penokean volcanic belt, which problably developed similar to island arc complexes, on simatic crust south of the craton (Greenberg and Brown, 1983).

A separate episode of post-tectonic granite and rhyolite magmatism took place 1760 m.y. ago in Wisconsin. This third pre-Baraboo interval tectonic period represents a change from Penokean conditions which produced a wide spectrum of calc-alkaline magmas, including more mafic plutons (Anderson and others, 1980). The felsic type of magmatism represented by 1760 m.y. old granite annd rhyolite is considered to be indicative of the early phase of cratonization (conversion to relatively stable continental sial; Rogers and Greenberg, 1981).

As mentioned previously, Baraboo interval sedimentation followed 1760 m.y. old magmatism without any intervening process, except erosion. Smith (1978) proposed a folding event between rhyolite volcanism and deposition of the quartzose sediments. Available structural and metamorphic data oppose this view and indicate that rhyolite and quartzite most likely underwent the same tectonic episode(s). This relationship can be seen as a parallelism of structural fabrics in rhyolite and quartzite at Baraboo, northern Wood County, and Sandhill Wildlife Refuge (stop 6).

Environment of Deposition

The distribution of facies in the Baraboo interval sedimentary rocks of Wisconsin suggests three possible depositional models. The first possiblility is that the Baraboo interval was a time of gradual marine transgression from south to north (Dott, 1983). In this model (fig. 4 a), central Wisconsin remained above sealevel during deposition of the fluvial orthoquartzites, and became submerged as the marine argillites and ferruginous carbonates and cherts were deposited. In the second model, (fig. 4 b), the ferruginous beds of central Wisconsin are lateral equivalents of the quartzites to the north and south, and a complex basin geometry caused the basin in central Wisconsin to be starved for coarse clastic sediment. While orthoquartzites accumulated in the north, south, and west; chemical sediments, locally derived clastics, and minor volcanic debris were accumulating within tectonically (?) controlled restricted environments. A third model, (fig. 4 c), allows the possibility of unconformities in the sequence. In this model, argillites, cherts, and thin micaceous and pebbly quartzites were deposited throughout the basin. These were later eroded and a transgression as in the first model occurred, depositing an upward fining fluvial to shallow marine sequence.

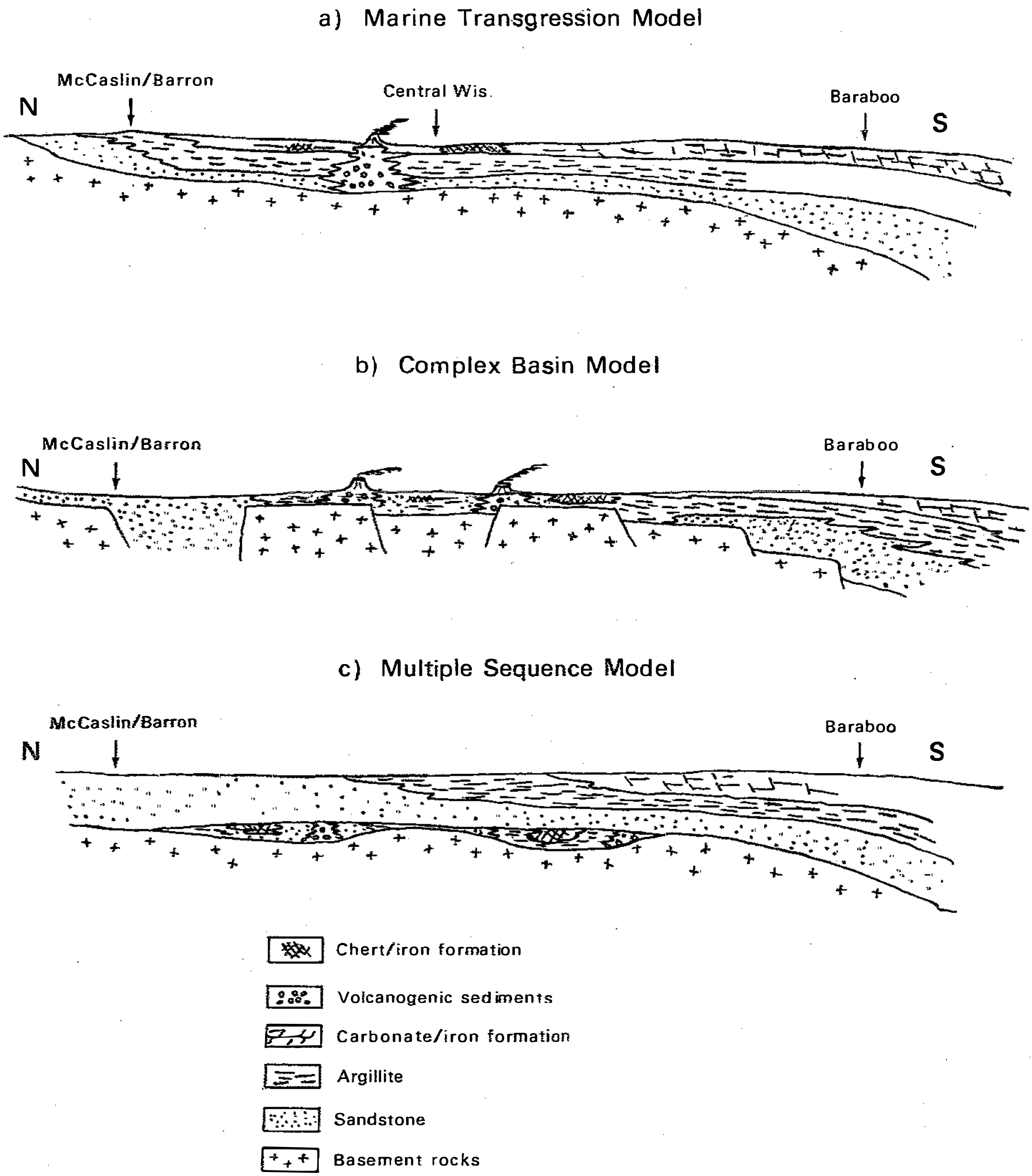


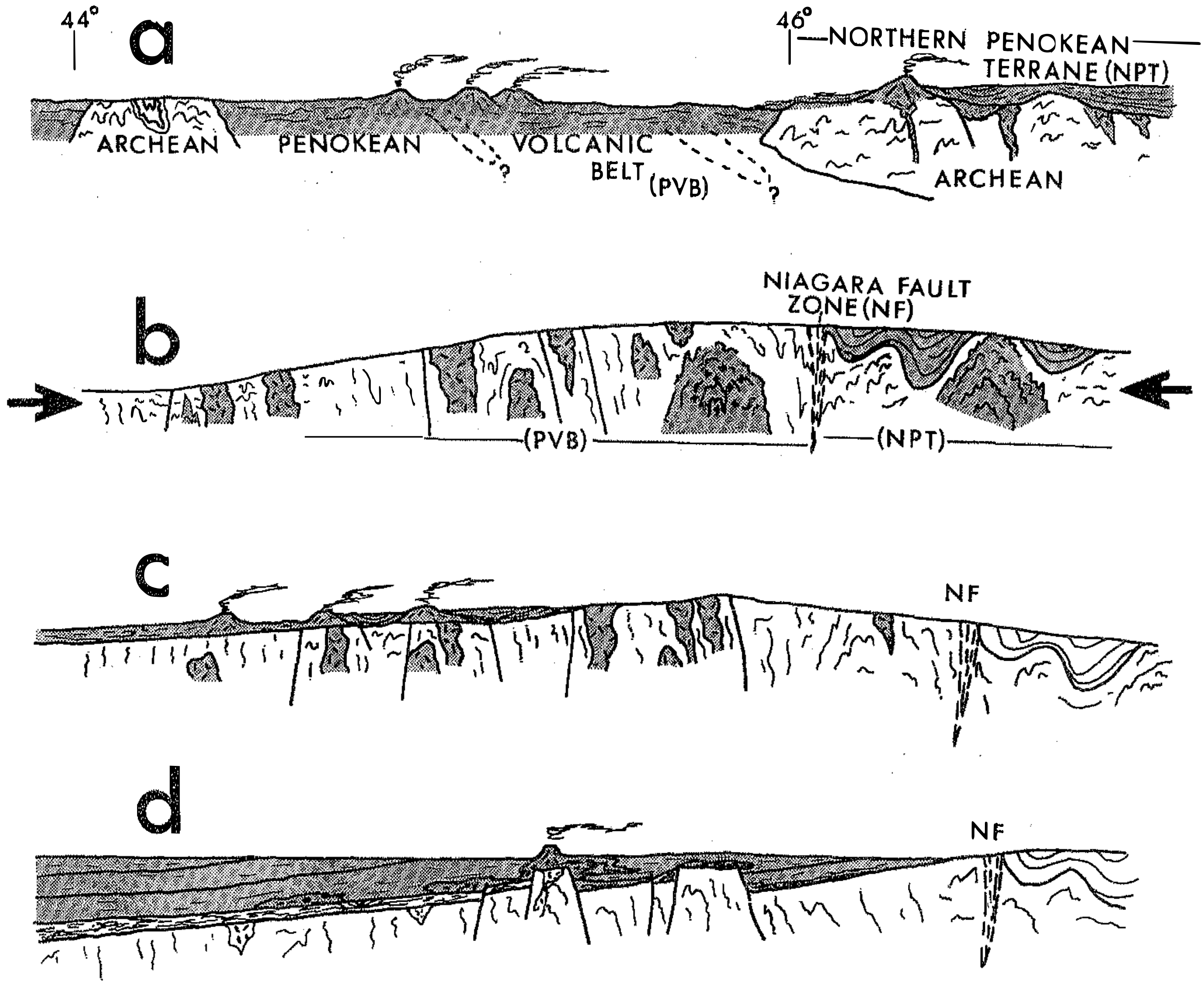
Figure 4. Alternative models for deposition of Baraboo interval rocks in Wisconsin.

Post Depositional Deformation and Metamorphism

Deformation of Baraboo interval rocks, particularly in south-central Wisconsin, has been attributed to collisional orogeny south of Wisconsin, perhaps in northern Illinois, 1630 m.y. ago (Dott and Dalziel, 1972; Dott, 1983). However, there is little support for the proposition of orogenic activity in Wisconsin at that time. At present, 1630 m.y. ago is known only as a Rb-Sr isotopic overprint on rock units with earlier primary ages (Sims and Peterman, 1980). There are known magmatic rocks in the region dated as 1630 m.y. old; nor can any known metamorphism be assigned this age. The suggestion of a subduction-zone collision boundary in southern Wisconsin and northern Illinois requires higher grades of metamorphism and more intense deformation of Baraboo interval rocks in the south than in central or northern Wisconsin. In fact, more intense metamorphic conditions are now depicted by high T/P mineral phases found where 1500 m.y. old alkalic intrusion has taken place (McCaslin Mountain, Olson, 1983; Waterloo, Geiger and others, 1982; Rib Mountain, Ansfield, 1967). This is regardless of distance from any proposed collision. The intensity of deformation appears to decrease towards the west (Barron and Sioux Quartzites as examples), away from 1500 m.y. old alkalic intrusion.

A likely explanation of the 1630 m.y. old "event" is that it was a time of widespread uplift throughout the Lake Superior region which reset Rb-Sr isotope systems (Sims and Peterman, 1980). If deformation of Baraboo interval sedimentary units, such as the production of the syncline at Baraboo, occurred 1630 m.y. ago, then the dynamic process could be envisioned as a result of mostly vertical, gravity-type tectonics (fig. 5 e). Thin section evidence from Waterloo (Geiger and others, 1982) and the Deer lookout tower hill (Mancuso, 1960), Sec. 2, T. 34 N., R. 16 E., show that the growth of high T/P static metamorphic minerals (andalusite, sillimanite, and garnet) followed the development of a tectonic foliation. The timing of the observed features may begin with local folding during 1630 m.y. old uplift, later overprinted by thermal metamorphism and additional tectonic strain during 1500 m.y. old intrusion (Brown and Greenberg, 1980; Greenberg and Brown, ms, 1982).

We believe that the lack of orogenic characteristics after about 1850 m.y. ago and the nature of magmatism both prior to and following deposition of the Baraboo interval sequence strongly indicates that an epicontinental, anorogenic environment existed throughout the region for most of the Proterozoic. A generalized impression of the tectonic history 1850 to 1500 m.y. ago across (north-south) Wisconsin is shown in figure 5 a to 5 f.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44°
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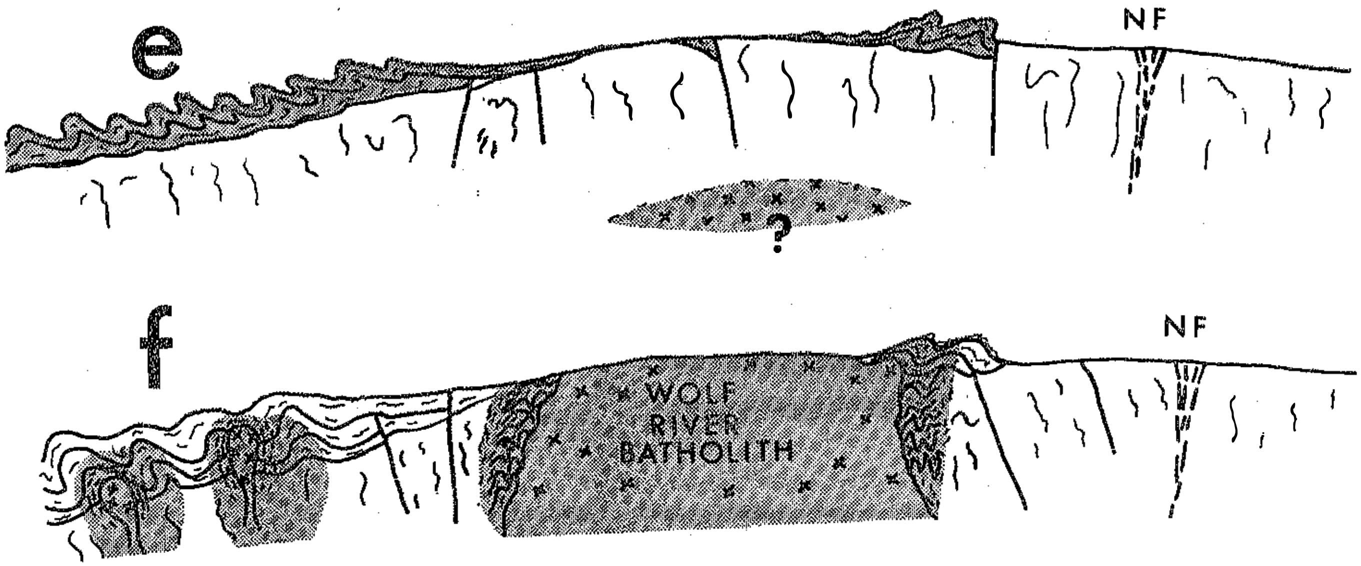
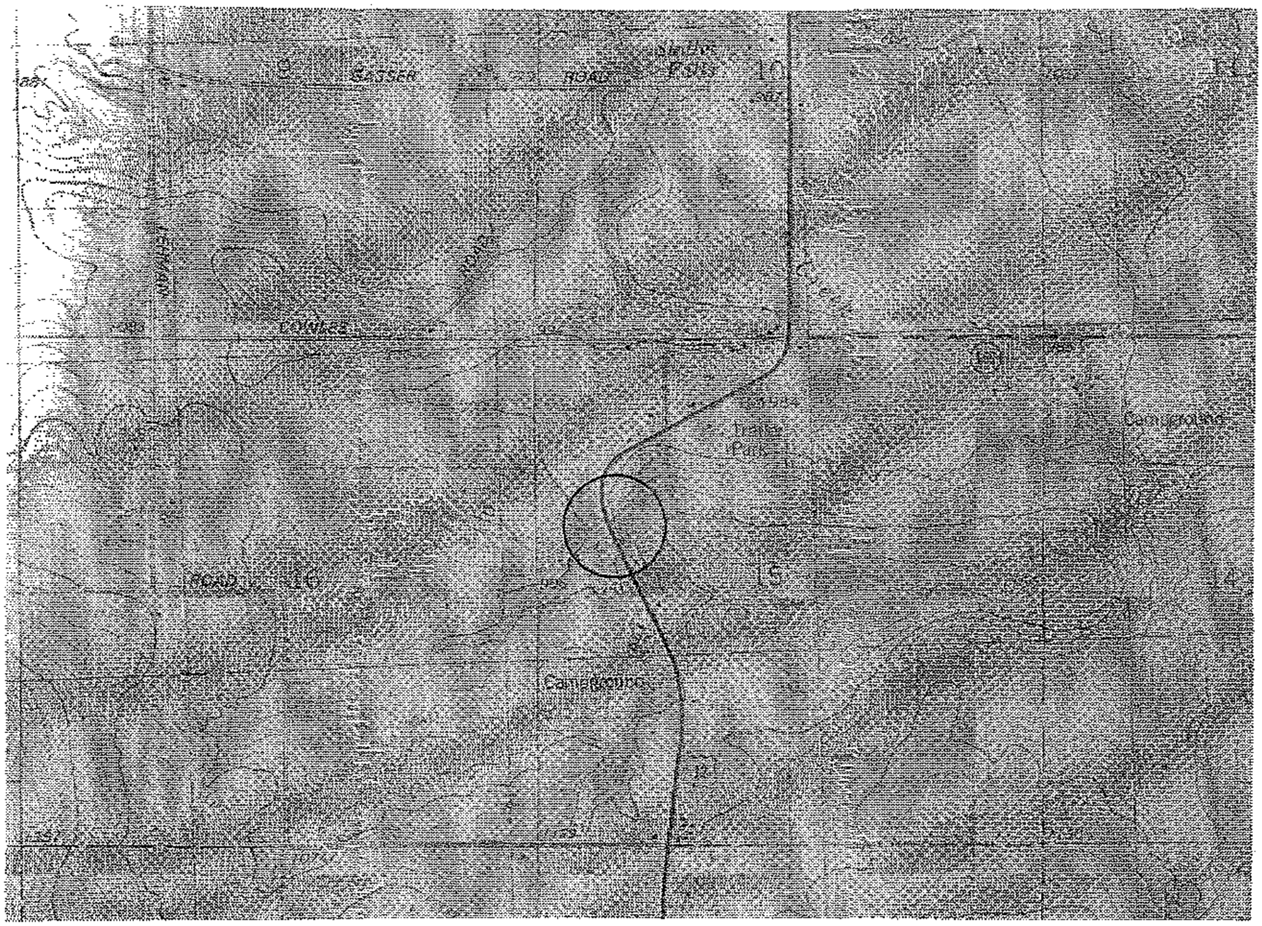


Figure 5. Hypothetical cross sections along 89° 30' N longitude, explaining the tectonic development of northern Wisconsin from about 1900 to about 1500 m.y. ago. Shading indicates magmatism, deformation, or metamorphism associated with the specific time period of each section.

a.) Pre-deformational formation of two Penokean terranes, about 1900 m.y. ago;
b.) Penokean orogeny and collision (?) of terranes about 1850 m.y. ago;
c.) 1760 m.y. old felsic plutonism and volcanism during cratonization of the region;
d.) Waning of felsic magmatism and the deposition of Baraboo interval sediments from about 1760 m.y. ago to about 1630 m.y. ago;
e.) Uplift and gravity induced deformation of Baraboo interval units 1630 m.y. ago;
f.) Intrusion of alkalic plutons throughout the region about 1500 m.y. ago. Localized deformation attended intrusion and was followed by mostly thermal metamorphism.

STOP 1

Title: Skillet Creek - quartzite and phyllite



Location: SW 1/4 NW 1/4 Sec. 15, T. 11 N., R. 6 E. The exposure is on the east side of U.S. Hwy. 12, 0.6 km south of the junction with State Hwy. 159. (North Freedom 7 1/2 minute topographic quadrangle). CAUTION: Traffic on Hwy. 12 is heavy, and there is a blind curve just north of the outcrop!

Author: B. A. Brown, (1983; after Dalziel and Dott, 1970, supplementary stop G)

Description: This outcrop provides an opportunity to examine both the quartzite and phyllite facies of the Baraboo quartzite. Pink quartzite, dipping north at 15°, is exposed at the southern end of the outcrop. Good examples of sedimentary structures typical of the Baraboo Quartzite, including cross-bedding (fig. 6) and ripple marks, are present at this exposure. Dalziel and Dott (1970) refer to this exposure as an excellent example of the paleocurrent indicators which suggest a southward sediment transport direction at Baraboo. Locally, cross-bedding in individual sets of laminae shows contortion, particularly oversteepening which Dalziel and Dott attributed to synsedimentary deformation.

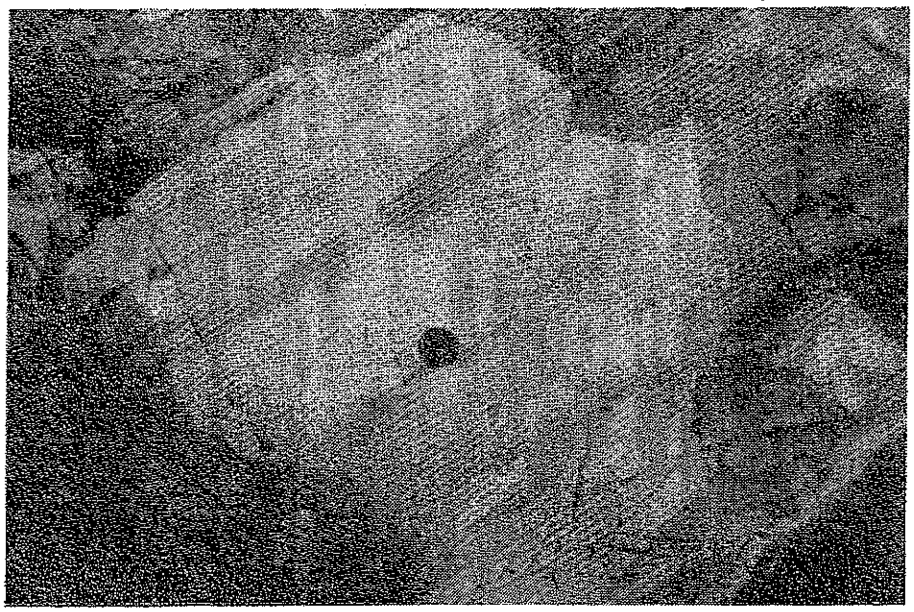


Figure 6. Cross-bedding in Baraboo Quartzite, lower part of exposure near road. Lens cap is 5 cm in diameter.

Figure 7. Boudinaged and folded beds of quartzite interlayered with phyllite, upper part of exposure, above massive quartzite. Long dimension is approximately 2 m.

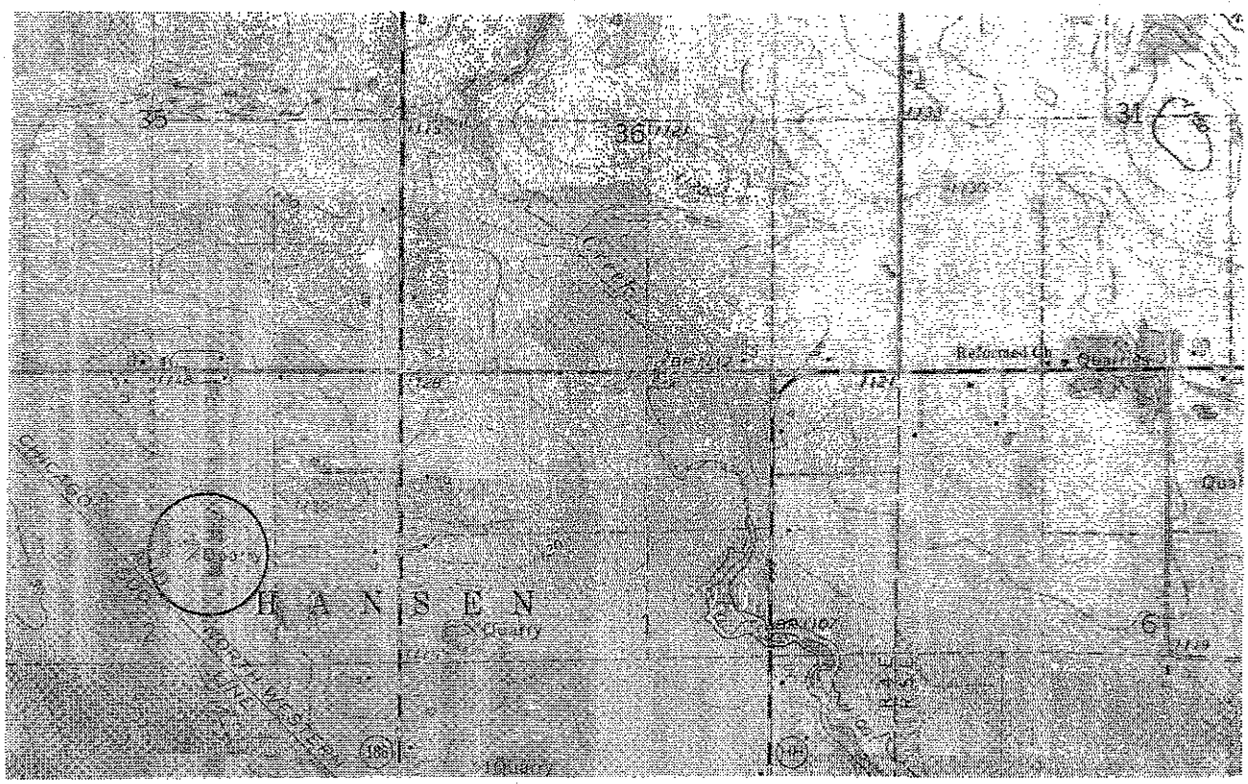
At the north end of the exposure and on top of the cliff, argillaceous beds up to 2 m in thickness occur interbedded with thin (0.5 m or less) beds of quartzite, (fig. 7). The thin quartzite beds within the less competent phyllite provide some spectacular examples of boudinage and parasitic folding. The S_1 cleavage, related to the formation of the Baraboo Syncline, is nearly parallel to bedding at this location. Later crenulation cleavages and small scale conjugate kinks cut the S_1 foliation at high angles. Late veins of white quartz cut the thin quartzite beds at a high angle to bedding. In thin section (fig. 8), crenulation in the phyllite is quite apparent. Mineralogy is quartz, muscovite ± pyrophyllite, indicating a maximum of upper greenschist facies metamorphism.

This is an exemplary teaching outcrop and field trip stop, please keep hammering and destructive sampling to a minimum.

Figure 8. Photomicrograph of crenulated phyllite. Note crenulations at high angle to phyllitic foliation. Field of view is about 8 mm in long dimension.

STOP 2

Title: Vesper - abandoned granite quarry



Location: This small granite-quartzite quarry is located on the Marty property about 0.7 km west of Hwy 186 in Wood County in the SW 1/4 NE 1/4 Sec. 2, T. 23 N., R. 4 E. (Sherry 7 1/2 minute topographic quadrangle).

Author: J. K. Greenberg (1983)

Description: Quartzite (fig. 9) and red granite had been removed from this exposure. The red granite is similar in appearance to that quarried north of Wausau. This was a small-scale operation and its history is unknown.

This granite is associated with an overlying (?) quartzite, correlated with other quartzites of the Baraboo interval. Granite more commonly occurs together with Baraboo interval quartzite in an intrusive relationship (Baxter Hollow, near Baraboo; McCaslin Mountain; Waterloo; Hamilton Mound, stop 7; and perhaps Cary Mound, stop 4.). The exact contact in this quarry lies within a covered zone (a meter or two wide) between exposed granite and exposed quartzite. The inferred contact strikes northeast, the same orientation as the regional structural grain, as seen in major foliation and aeromagnetic trends.

Quartzite

The type of quartzite northwest of the quarry and nearest the access road is light-colored, buff, gray, or pinkish. This appears in hand specimen to have been a clean, well-sorted orthoquartzite. However, microscopic examination shows that mica is abundant in almost all samples as a supporting matrix for rounded quartz grains (fig. 10). Because of this, weathered quartzite resembles a Paleozoic sandstone on some surfaces where disintegration has left the quartz grains free from matrix. This quartzite typically has a uniform fine- to medium-grain size, but rounded quartz and quartzite clasts of various sizes (0.5 to 7 cm) occur sporadically in certain areas (beds?) of the exposure. Bedding and a weak tectonic fabric show-up only faintly.

Southeast of the light-colored quartzite and closer to the granite, there is a few meter-wide bed of dark red micaceous conglomerate and quartzite. The red color is caused by large quantities of disseminated hematite. This rock is about 20 percent matrix composed of sericite, hematite, muscovite, and silt-sized quartz in pebble conglomerate. Some of the sericite-muscovite is segregated into clots that may have been derived from feldspar or feldspar-rich material. Finer-grained rocks in the unit show better sorting of clasts and are 30 to 60 percent matrix, totally matrix supported. The clasts in this hematitic facies of the quartzite are predominantly quartzite, metachert, and single quartz grains. The only metamorphic or deformational features observed are large muscovite grains which may have crystallized at the expense of sericite, and also some crushing-granulation of larger clasts. Most quartz grains show moderate strain with undulatory extinction. Quartz recrystallization was not observed.

Quartzite nearest the granite continues to be micaceous, but is less hematitic and is reddish to greenish in color. Evidence for interaction with the granite is lacking. There is no indication of intrusion (dikes, assimilation, thermal overprint, and so forth); nor is there any evidence of deriving the quartzite locally from eroded granite. The lack of positive evidence for a zone of weathering on the granite does not exclude this possibility, however. The high concentration of sericitic matrix in the basal quartzite may suggest granitic weathering products.

Granite

The granite in the quarry gives no more clues to the nature of the unconformity than does the quartzite. There are no inclusions, quartz veins, pegmatites or zonations of any kind noticeable across the exposed granite. Weathering or fracturing are not more pronounced within 2 m of the contact with quartzite than they are 20 m away. Again, this does not rule out the possibility of granite as the basement for Baraboo interval deposition here, and there is no reason to suspect that the granite intruded quartzite. A faulted contact is possible, but this too lacks supporting data.

The only variability noted in the red granite was a few pink aplitic masses. Overall, the granite is a massive, equigranular medium- to coarse-grained, two feldspar type, averaging about 3 percent chloritized biotite plus opaques as mafic phases. Large perthites appear to be early crystallized phases, some of which have been replaced along their margins with albitic plagioclase. Fluorite is a rare interstitial phase and zircons are abundant. Quartz and microcline are more common in aplite samples.

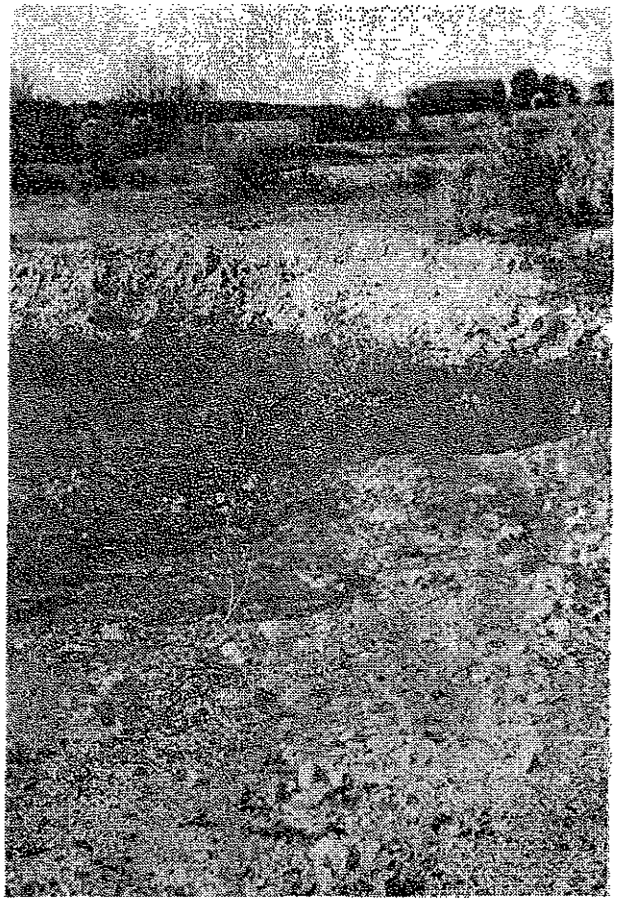


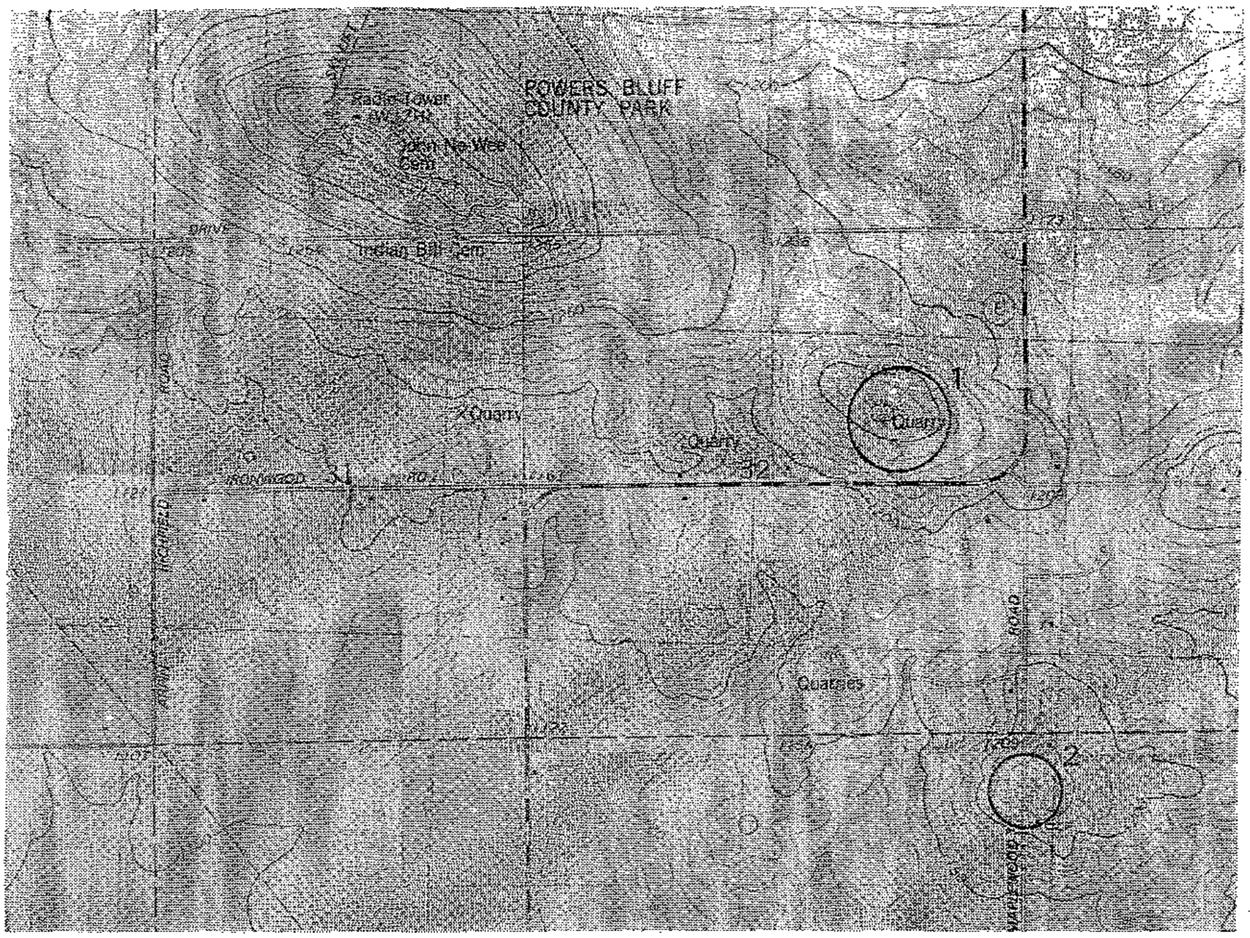
Figure 9. View of quartzite pit perpendicular to bedding, looking north from hematitic, micaceous conglomerate toward finer-grained quartzite.

Figure 10. Micrograph of matrix-supported conglomerate. Long dimension about 8 mm.

Rb-Sr data including mineral separates on the coarse-grained and aplitic rocks indicate that the isotopes were reset with a high initial ratio (0.734) 1479 ± 32 m.y. ago (C. Montgomery, unpub. data). This date in Wisconsin coincides only with the widespread intrusion of alkalic magmas, including the Wolf River batholith. The isotopic resetting may therefore represent the thermal effects of this magmatic episode. Preliminary results of U-Pb zircon dating indicate that the granite near Vesper intruded about 1900 m.y. ago (W. R. Van Schmus, unpub. data). If this date is confirmed, it would establish that "younger-looking" post-tectonic granites can in fact be older than the major 1850 m.y. old episode of deformation and metamorphism in northern Wisconsin. The early date also supports the conclusion that the quartzite is probably younger than the granite.

STOP 3

Title: Powers Bluff - quartzite quarry



Location: NE 1/4 of Sec. 32, T. 24 N., R. 4 E. (Arpin 7 1/2 minute topographic quadrangle).

Author: B. A. Brown (1983)

Description: This small quarry (locality 1) presents the best known exposure of argillite of the Baraboo interval sedimentary sequence. Approximately 50 meters of argillite are exposed in the pit. The argillite strikes roughly east-west and is bounded on the north and south by beds of chert. A large exposure of chert is located in Powers Bluff County Park, to the northwest of the quarry. To the south and east of the quarry, pebbly and micaceous quartzites occur interbeded with chert and argillite in a road cut (locality 2). Cambrian sandstone of the Elk Mound Group is exposed in several small pits and cuts in the area surrounding the prominent ridge known as Powers Bluff.

Figure 11. Bedding in cherty quartzite at Powers Bluff County Park. Lens cap is 5 cm in diameter.

The bedded cherty quartzite is the dominant lithology at Powers Bluff (fig. 11). The chert occurs in 5 to 10 cm thick beds and varies in color from nearly white to dark bluish gray to red. Beds exposed on the south slope of the bluff are particularly ferruginous and are dark red in color. In thin section (fig. 12), the chert is aphanitic, consisting of an aggregate of very fine quartz grains, occasionally cut by coarser quartz veins.

The argillite (fig. 13) is finely laminated (5 to 10 mm) and varies in color from brown to greenish gray, with some zones of red and black. The red zones are highly ferruginous and the black bands are carbonaceous. The argillite shows fine banding in thin section, (fig. 14), and the mineralogy is quartz and kaolinite with varying amounts of iron oxide. Nodules of chert are found scattered in zones within the argillite.

Coarser clastic rocks occur at locality 2, where pebble conglomerate (clasts up to 5 mm) is interbedded with chert and argillite and fine- to medium-grained pink quartzite.

The structure of the Powers Bluff area has not been mapped in detail. The limited data available suggest that the bedding strikes northwest-southeast, parallel to the trend of the topographic ridge. Dips vary from steep (75 to 80°) N, to steep to the south. Local variation in strike, particularly in the quarry (locality 1), suggests folding about steep northeast trending axial surfaces. A distinct cleavage trends N 20° E and is near vertical.

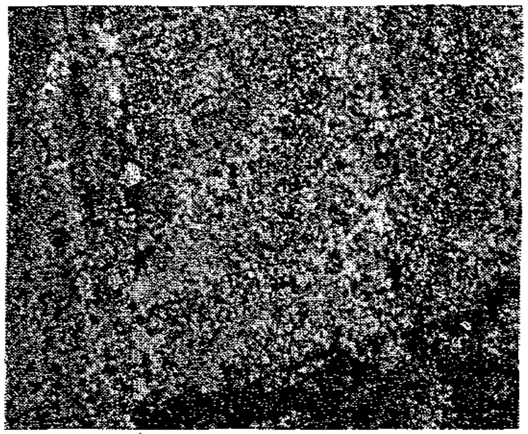


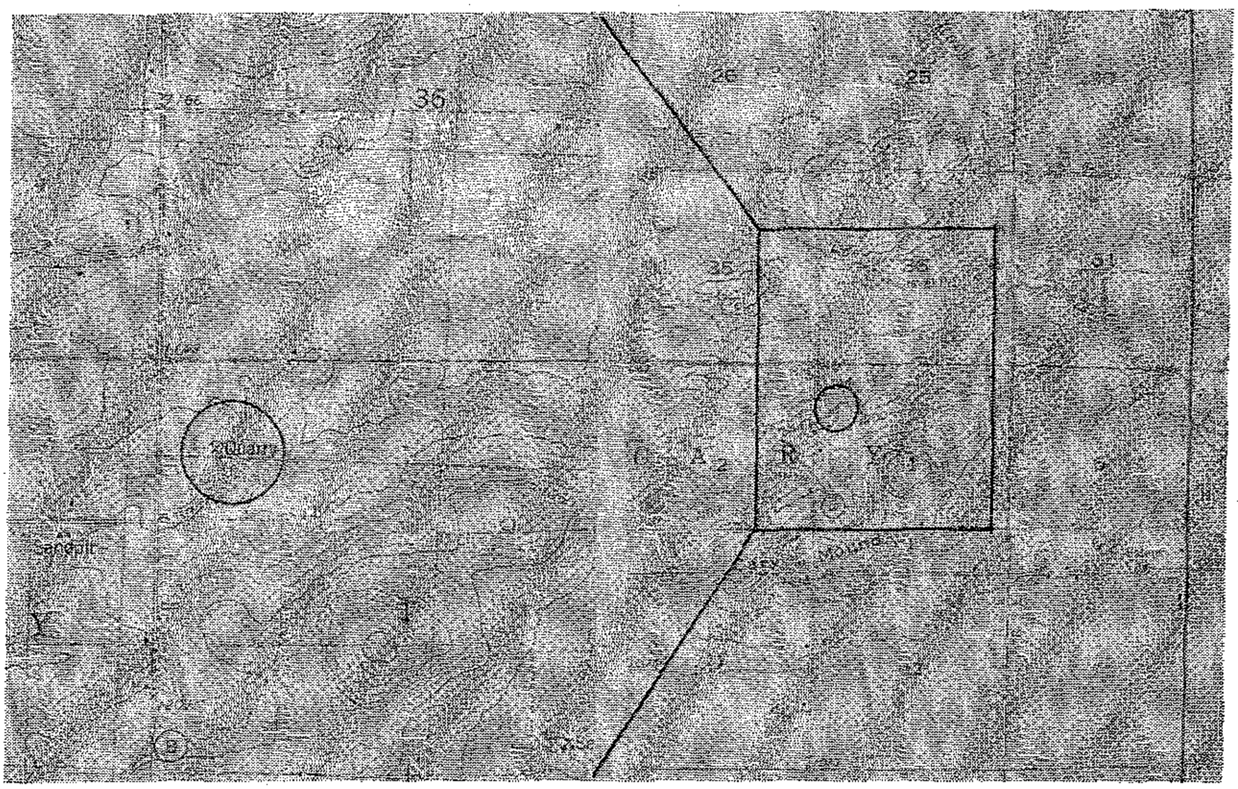
Figure 12. Photomicrograph of cherty quartzite. Rock consists almost entirely of very fine quartz grains. Long dimension of field of view is 8 mm.

Figure 13. Hand specimens of argillite from Powers Bluff quarry. Clockwise from top: folded ferruginous argillite, carbonaceous argillite, banded kaolin-rich argillite.

Figure 14. Photomicrograph of argillite. Note apparent offset of quartz vein and quartz-rich band along cleavage planes. Long dimension of field of view is 8 mm.

STOP 4

Title: Cary Mound - granite quarry on Highway B



Location: Cary Mound, located in northeast Wood County, is a circular hill rising nearly 100 m above much of the land to the south. The hill is underlain by bedrock composed of post-tectonic granite exposed on slopes, in quarries, and in creek beds. The field trip stop is in one of two active quarries at Cary Mound. This quarry is on Wood County Highway B, about 4 km west of State Highway 13 at NW 1/4 NW 1/4 Sec. 1, T. 23 N., R. 2 E. (Lake Manakiki 7 1/2 minute topographic quadrangle).

Author: J. K. Greenberg (1983)

Description: The Highway B quarry has exposed granophyric granite, one of the four major types of granitic rock at Cary Mound (Sherwood, 1976). The other types, porphyritic granophyre, spherulitic granophyre, and an equigranular red granite, outcrop at various places on the Mound. The granite body as a whole is a high-level (epizonal) post-tectonic pluton. This pluton is generally similar to other red granites in the region, but is most similar to the granophyric and chemical nature of the 1760 m.y. suite of granites in Wisconsin (Anderson and others, 1980). Outcrops of Precambrian rocks around

Cary Mound include Archean gneisses near Pittsville (about 6 km to the southeast) and other variably deformed granitic and metavolcanic rocks assumed to be about 1850 m.y. old. Cambrian sandstone commonly overlies Precambrian rocks at higher elevations, particulary on prominent ridges and hills. This is true for Cary Mound, as seen in the field trip quarry (fig. 15). Baraboo interval metasedimentary rocks, mostly quartzites, are locally exposed throughout this area. Quartzite is found at Cary Mound, but not in place. Although quartzite is not in place, large (to 3 m across) loose blocks occur with granite in the quarry. Several undeformed, intermediate to mafic dikes also occur in the quarry cutting the granite along a N 40° W orientation. These are possibly Keweenawan (about 1000 m.y. old) dikes, because of their fresh mineralogy and unaltered diabasic textures.

Figure 15. Southwest quarry wall at Cary Mound showing sandstone unconformable on granite.

Granite

W. R. Van Schmus (1980, and unpub. data) has obtained U-Pb isotopic ages of zircon from granophyric granite exposed in the other active quarry in Cary Mound, as well as from coarse-grained granite at the base of the Mound. These data indicate ages near 1850 m.y. for both types of rock. The granophyric granite is medium- to fine-grained, contains few primary mafic minerals (typically less than 4 percent ferrohastingsite plus biotite), and has conspicuous quartz veinlets and whisps of chlorite on fracture surfaces. The chlorite-filled fractures and quartz veinlets may be the combined effects of mafic dike intrusion and subsolidus magmatic fluids. In thin section, the granite is characterized by complex micrographic and myrmekitic intergrowths of quartz and feldspars. Chemically, Cary Mound granitic rocks are silicic (about 75 percent SiO_2) and very similar to calc-alkaline granites with no extremes of major or trace element concentrations (table 1).

Table 1. - Chemical Analyses of Cary Mound Granite

Oxides	1	2	3	4
SiO_2	75.57	76.00	76.71	75.47
TiO_2	0.16	0.19	0.17	0.11
Al_2O_3	13.13	13.07	12.24	11.40
Fe_2O_3*	1.91	2.32	1.87	---
FeO	---	---	---	1.97
MgO	0.09	0.06	0.52	0.06
CaO	0.44	0.12	0.25	0.55
Na_2O	3.70	3.69	5.23	3.50
K_2O	5.14	5.10	1.45	4.50
Trace Elements				
Li	---	---	---	3
Rb	113	111	29	88
Sr	31	34	29	41
Ba	1402	1504	479	1347
Zr	325	419	386	---
Y	47	39	60	---

Oxides in weight percent, trace elements in part per million.
* Total iron as Fe_2O_3.

1. Sample CM-RCG, coarse-grained red granite.
2. Sample CM-B1, granophyric granite.
3. Sample CM-Q1-6, ferrohastingsite granophyre.
4. Sample 74-8, red granite, from Anderson and others (1980).

On the south face of the quarry there is a wide zone (striking N 40° E) of contaminated intrusive rock that grades horizontally from fresh red granite into a gray quartz-rich rock containing scattered muscovite and chlorite-sericite-fluorite-pyrite veinlets. Very little unaltered feldspar occurs in the most quartz-rich rock. The origin of this silicified zone is a problem not obvious from the exposure. One explanation might be the presence of the quartzite blocks in the quarry. Assimilated quartzite may have created a zone of mixing and metasomatic activity similar to that at Hamilton Mound (stop 7). Another complicating factor is the introduction of pyrite into the granite along mafic dikes and fractures near the dikes. Are dikes also the source of pyrite in the silicified zone? Further investigation may answer this and clarify the role of late magmatic to post-magmatic activity at Cary Mound.

Quartzite

Unfortunately, the large quartzite blocks in the quarry were moved out of place prior to investigation. Sherwood (1976) makes no mention of quartzite (or Cambrian sandstone) in her thesis, probably because the Highway B quarry was not in existence during her study. The quartzite now observed is white-pink in color with a vague banding, perhaps preserved bedding. Scattered patches of hematite and aluminous minerals (sericite-muscovite, chlorite, and sillimanite) can also be seen in hand specimen. In thin section (fig. 16), the quartzite is fine-grained (average 0.1 mm across) with no penetrative deformational fabric. Sedimentary features have been destroyed. Quartz grains form a low-strain mosaic and comprise over 95 percent of the rock. A few large remnant grains were observed to be strained and only partially recrystallized. Hematite, muscovite-sericite, and sillimanite make up 2 to 3 percent of most samples. Chlorite is rare whereas zircon is unusually common. The patches of sericite and sillimanite may have been derived from feldspar or detrital phyllosilicates.

The high degree of static recrystallization and static sillimanite growth in some sections is indicative of high T/P metamorphism. This is additional evidence that the quartzite at Cary Mound was intruded at some time under low-strain conditions, analogous to metamorphosed quartzite at Waterloo (Geiger and others, 1982), Rib Mountain (Ansfield, 1967), and McCaslin Mountain (Olson, 1983).

Sandstone

The Highway B quarry is a good place to examine the unconformity between Elk Mound Group Cambrian sandstone and Precambrian basement. The west face of the quarry exposes about 4 m of irregularly bedded quartz sandstone. Bedding thicknesses vary from a few mm to several cm. Lenticular bedding is common near the base of the unit. Fresh sandstone ranges from poor to moderately well sorted. Grains from thin sections higher in the quarry face are a fine to medium, well-rounded sand, but their sphericity is quite variable. Many grains have thin discontinuous overgrowths in contact with silica cement. Sericite, clay, and hematite comprise the remainder of the sparse matrix material.

Sand to pebble-sized fragments of weathered granophyric granite and clear quartz granules are disseminated throughout the lower sandstone beds (fig. 17). The quantity of matrix clay also increases toward the unconformity. The unconformity itself is a sharp to diffuse transition from poorly sorted, clay-rich sandstone containing abundant weathered granitic rock fragments into the highly weathered and fractured granophyric granite (fig. 18). Evidence, including weathered basal sandstone, may also suggest that the unconformity served as a zone of post-depositional alteration, permeable to ground water (Bultz, 1981). In some places, there is a meter or more of the altered granophyre above fresh, unaltered rock.

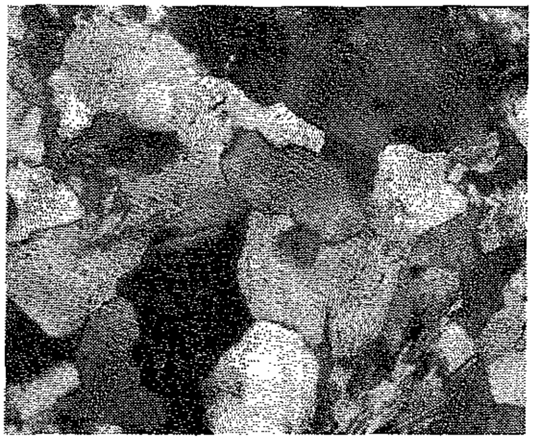


Figure 16. Micrograph of sillimanite in Cary Mound quartzite. Long dimension is about 2.5 mm.

Figure 17. Micrograph of sandstone with fragment of granophyre. Long dimension is about 8 mm.

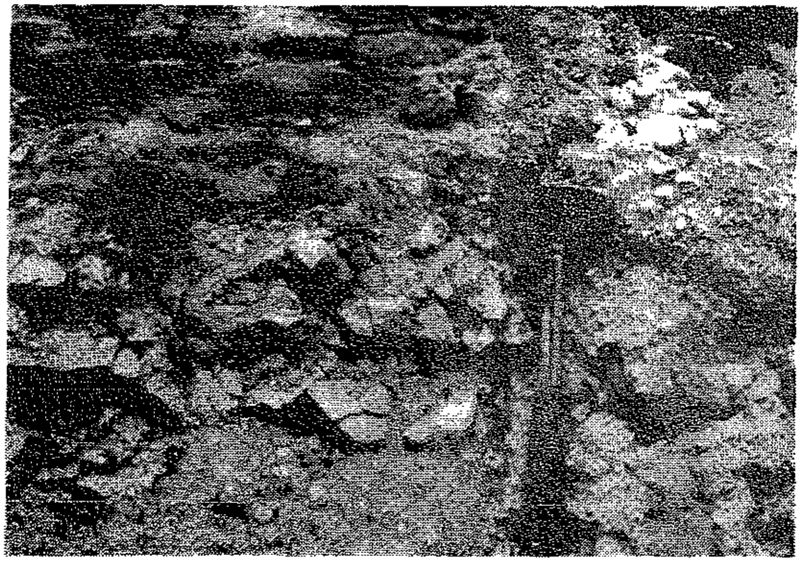
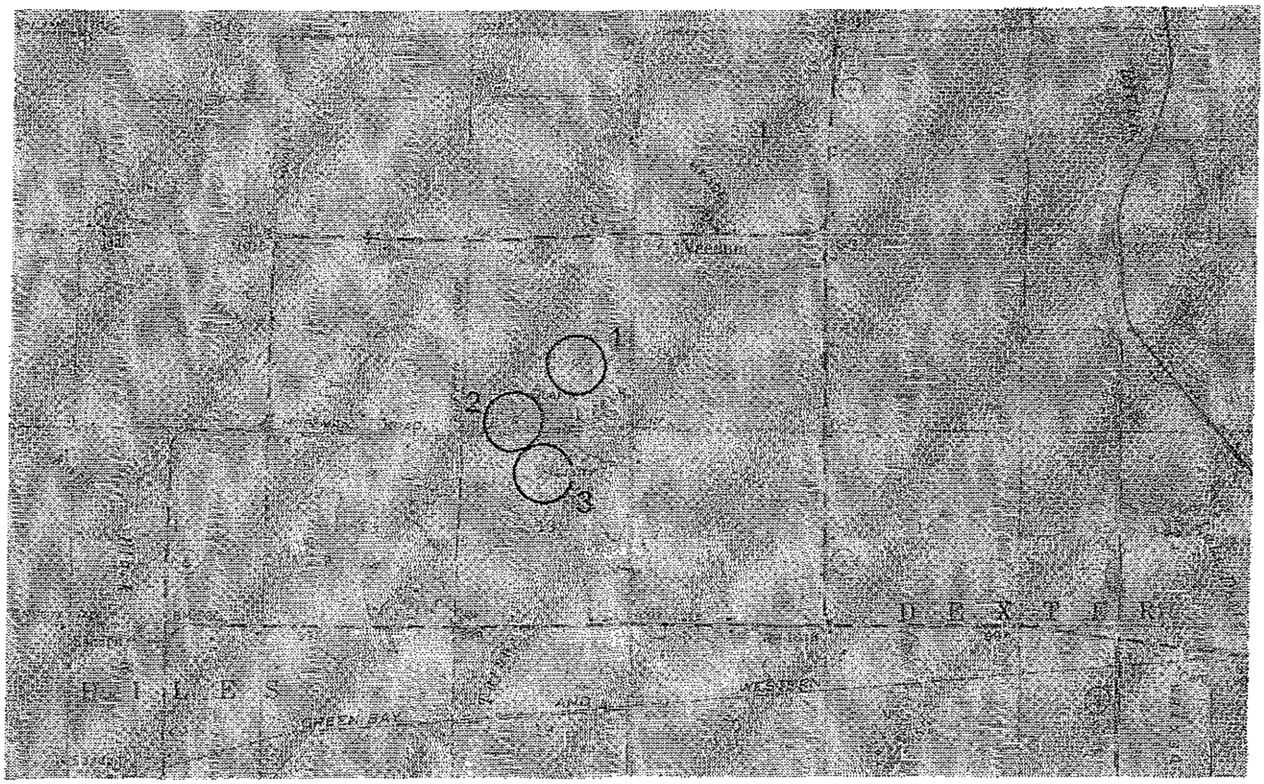


Figure 18. Close-up of sandstone-granite unconformity. Hammer head marks the contact between lenticular sand beds and fractured and bleached granophyre.

STOP 5

Title: Veedum - abandoned sandstone quarries



Location: Three small quarries are located in the S 1/2 of Sec. 7 and N 1/2 of Sec. 18, T. 22 N., R. 3 E., 1.5 to 2 km southwest of Veedum in Wood County. (Pittsville 15 minute topographic quadrangle).

Author: B. A. Brown (1983)

Description: Road material quarries have been developed in basal sandstone beds of the Cambrian Elk Mound Group, at localities 1, 2, and 3. The sandstone is generally 3 to 4 meters thick and the floor of the pits consists of Precambrian rocks.

In the quarry at locality 1, a 10 to 20 cm thick bed of Cambrian conglomerate overlies red, sericite-rich quartzite (fig. 19). The conglomerate bed contains 1 to 3 cm pebbles of quartzite varying from red to green in color and floating in a matrix of medium to coarse sand. Beds near the contact are commonly cemented by iron oxides. The steeply dipping quartzite (figs. 20 and 21) contains bands rich in fine micas, partly altered to clay, which may have been derived from the breakdown of feldspar in an originally arkosic sediment.

Figure 19. Contact of Cambrian conglomerate with micaceous quartzite at Veedum, locality 1.

The quarry at locality 2 illustrates sandstone, with beds containing pebbles of 1 cm or less, overlying red quartzite with distinct green bands and zones. The green color is due to fine grained chromium-rich mica (S. W. Bailey, unpub. data). The chromium in the micas is possibly derived from the weathering of Penokean-age mafic intrusions which occur in the pre-quartzite basement rocks of central Wisconsin.

The 2800 m.y. old (Van Schmus and Anderson, 1977) gneiss basement on which the quartzite was deposited is exposed in the bed of Turner Creek on the south side of Hoffman Road, and was encountered at a depth of 3 to 4 meters below the floor of the quarry at locality 3 during drilling. Little is known about the structure of the quartzite in the Veedum area, except that it shows strain and a well developed foliation, (fig. 21). The foliation and bedding in the quartzite vary widely in strike, but dip steeply, usually in excess of 50°. Although no contact between the two rock types has been found, the quartzite is probably preserved in fault blocks or infolded with the gneiss.

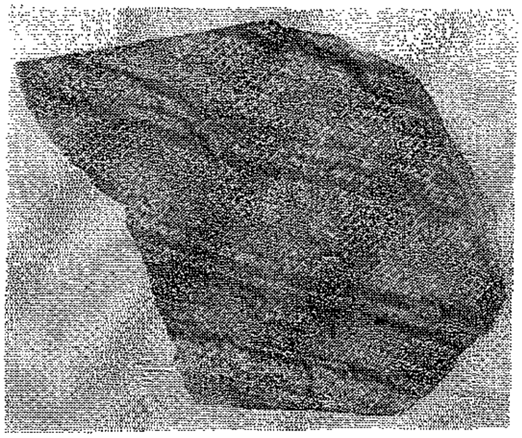


Figure 20. Hand specimen of micaceous, clay-rich quartzite from Veedum, locality 1. Dark beds are quartz-rich, lighter beds are rich in sericite partially altered to clay.

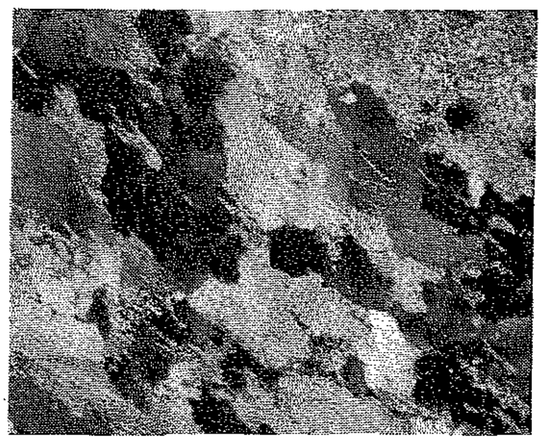
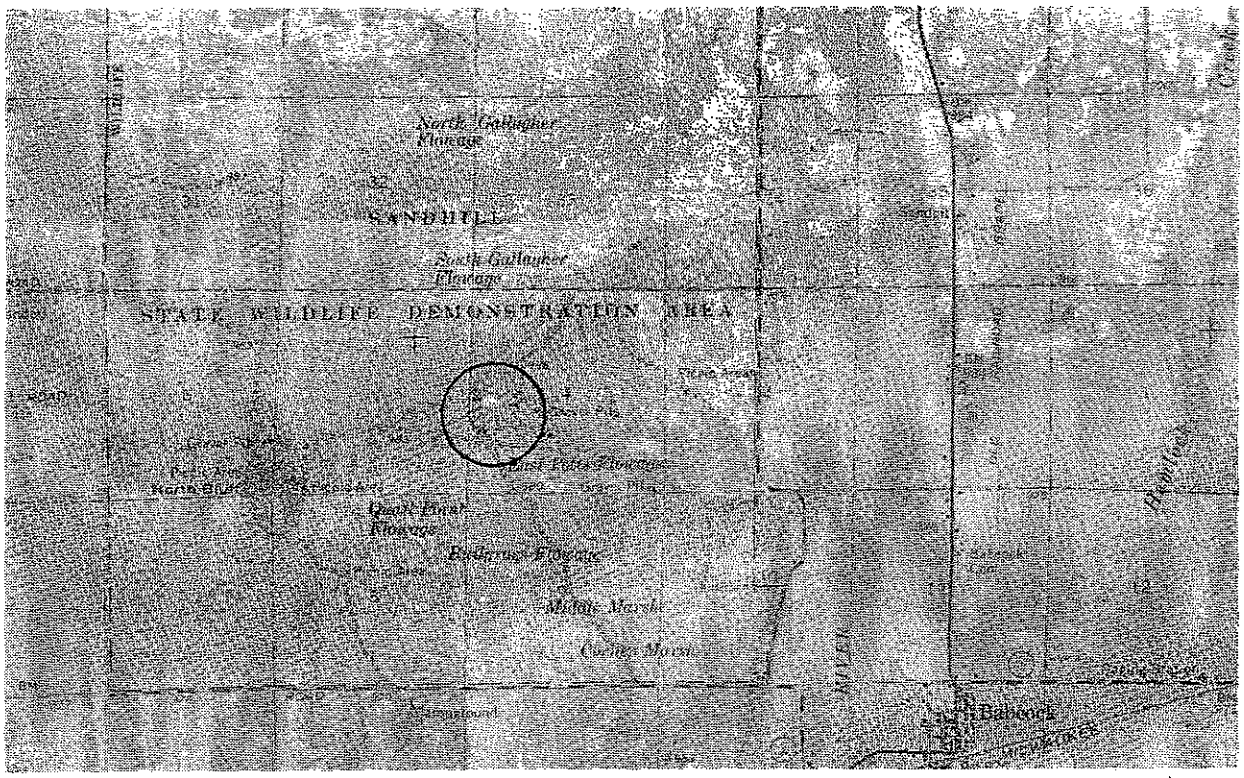


Figure 21. Photomicrograph of sample shown in Figure 20. Note foliation defined by micas parallel to long dimension of strained quartz grains. Field of view is 2.5 mm in long dimension.

STOP 6

Title: Sandhill Wildlife Refuge - crushed stone quarry



Location: The quarry is in an area of Precambrian outcrop about 4 km northwest of the entrance to the Sandhill Wildlife Refuge on Wood County Highway X. This is at NW 1/4 SW 1/4 Sec. 4, T. 21 N., R. 3 E. (Pittsville 15 minute topographic quadrangle).

Author: J. K. Greenberg (1983)

Description: The quarry of interest in the Refuge is a shallow pit operated by the Wisconsin Department of Natural Resources for crushed stone used in local levy and road construction. The pit is within the small area of outcrops which rise above the generally low, sandy and marshy topography. North Bluff, the largest outcrop, is a hill west of the quarry composed of flow-banded rhyolite and rhyolite breccia.

The most significant aspect of the quarry exposure is the direct contact of subaerial rhyolite and Baraboo interval quartzose metasedimentary rocks. This is a more enlightening association of rhyolite with quartzite than that at Baraboo where the two units are typically separated by a few to several meters. There is also an excellent example of Cambrian sandstone lapping upon the Precambrian rocks in the Sandhill pit (Fig. 22). Outside the Refuge, 5 km to the southeast of the quarry, a northwest trending hill, South Bluff, exposes 30 m or so of a highly indurated Cambrian orthoquartzite.

Figure 22. Pit face at Sandhill showing unconformable contact between steeply dipping rhyolite breccia and overlying Cambrian sandstone.

Rhyolite

The volcanic rocks at Sandhill are referred to here as rhyolite, because of preserved textures and quartz-sericite mineralogy. A general correlation can be made between this rock and 1760 m.y. old rhyolites exposed to the south and east in central Wisconsin (Smith, 1978). The rhyolite occurs primarily as a flow-banded rock and breccia. Lithologic variation, banding, and a weakly developed cleavage are all nearly parallel, strike N 80° E and are vertical to dipping 75° NW. The cleavage, or foliation, is defined mostly by sericite oriented between quartz-rich layers. Post-breccia quartz veins transect the layering.

Sandhill rhyolite is distinctly weathered and colorful with rose pink, flow-banded rocks and light to dark gray matrix in breccias. Exposed surfaces also have a chalky-white bleached appearance. An attempt to determine the age of the rhyolite by the Rb-Sr method yielded data indicating chemical disturbance (C. Montgomery, unpub. data), probably as a result of the weathering. Sr values for these rocks are very low and may suggest a leaching of Sr. The timing of the weathering is unknown. However, subaerial volcanic rocks are known to undergo coloration changes and possess other weathering characteristics as a result of late magmatic fluid alteration. The occurrence in the rhyolite of hollow, parallel tubes, lined with secondary quartz (fig. 23), may have some significance in this regard. These might be late magmatic features related to gaseous fluid activity and brecciation.

Little or no tectonic fabric is apparent in thin sections of the rhyolite. Flow-banded samples and fragments in breccia retain spherulitic textures with some axiolites and probable microlites recrystallized as feldspar-quartz aggregates. Some of the breccia fragments have a spotted appearance with ragged patches of altered feldspar in a fine-grained quartz mosaic. A cherty matrix of fine-grained quartz is common in most breccia samples (fig. 24). Quartz veins are abundant and do not appear to be recrystallized. Although sericite is fine-grained and was not easily observable, it is a constituent of matrix material, is concentrated in some bands, and is found between clasts in breccia. No coarse-grained micas were observed in any of the samples. One rhyolite breccia sample from North Bluff contains conspicuous clots of sericite and a few embayed quartz grains.

Quartzite

The quartz-rich metasedimentary rocks in the pit vary from phyllite and fine-grained micaceous quartzite to granule and pebble conglomerate. The high sericite content of these rocks is analogous to that recognized elsewhere in the Baraboo interval (Vesper, stop 2; Veedum, stop 5; Baxter Hollow, Baraboo; Dake Quartzite, Baraboo). Bedding can be distinguished on the basis of grain-size and color variation. Pebble beds are often thin layers between finer-grained beds. Graded bedding is obscure but, where apparent, seems to indicate a top direction away from the rhyolite (tops toward the northwest). Quartzite at the contact with rhyolite is generally more micaceous than that up (?) section. There is no reason to suspect that the contact represents a major unconformity, that is, of major tectonic significance. The components of the sedimentary rocks are compatible as erosion products of rhyolite. In addition, the same deformational features are present in both units. The weak foliation-cleavage in the rhyolite is seen in quartzite as a weak alignment of sericite concentrations and stretching of quartz grains. In some areas, the foliation dips 5 to 10° more steeply than the beds. Neither rhyolite nor quartzite could have been metamorphosed beyond the lower greenschist facies. One explanation of these observations is that rhyolite volcanism was soon followed by deposition of sediments in this section of the Baraboo interval.

Thin sections of the quartzite and conglomerate confirm macroscopic observations. Color variation and banding is mostly defined by hematite-rich segregations. Larger clasts are almost exclusively single quartz grains and quartz aggregates. The few patches of sericitic material noticed may have been feldspar-rich prior to alteration. Most samples are at least 40 percent matrix, composed of sericite with zircons, clinozoisite, and muscovite as disseminated detrital grains. Although quartz clasts show some elongation, they do not exhibit much strain.

Sandstone

The Cambrian-Precambrian unconformity at Sandhill is an impressive feature. The east face in the quarry shows debris-laden sandstone swept against vertical beds of rhyolite. The majority of the Cambrian rock (term used loosely) is friable to the point of being unconsolidated. Near the unconformity in particular, the sandstone is full of large cobble and boulder size angular blocks of rhyolite and distinct purple-pink blocks of chert. There are also rounded clasts of rhyolite, quartzite, and vein quartz of various sizes, all floating in poorly sorted sand and clay. Coarse-grained matrix sand here is well rounded.

Figure 23. Tube-like voids in Sandhill rhyolite.

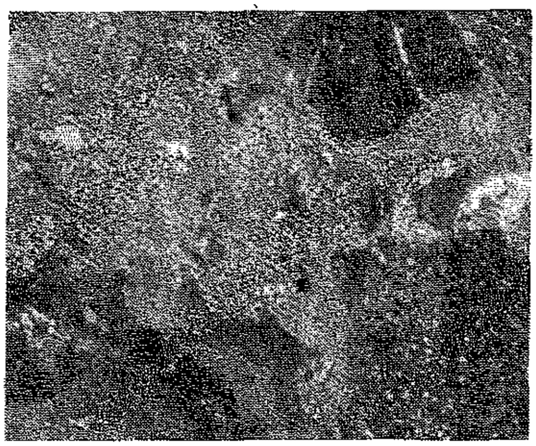


Figure 24. Micrograph of rhyolite breccia, volcanic fragments in cherty matrix. Long dimension is about 8 mm.

Away from the unconformity, certain beds, or layers, in the sandstone are fairly well sorted. These layers include several of poorly sorted sand surrounding well sorted rhyolite fragments. Within the beds containing rhyolite fragments, there are thin (1 to 5 cm) layers and lenses of green and maroon silty shale, and some layers of well sorted medium-grained sand. Near the top of the pit face, some flaggy layers of medium-grained sand contain 50 percent clay matrix.

The Proterozoic and Paleozoic sandstones at Sandhill may be somewhat analogous. Both contain predominantly quartz in various concentrations with aluminous phyllosilicates. Both may have derived material locally from weathered rhyolite. However, the great maturity and high degree of sorting in the Baraboo interval rocks contrasts with the nature of the Cambrian sandstone. Contrasting maturity may support the concept that weathering was different in the Early to Middle Proterozoic than it was in the Paleozoic; but not necessarily. Note that an immature, rhyolite-bearing conglometate (fig. 25) correlated into the Baraboo interval occurs in northwestern Wood County (Sec. 23, T. 24 N., R. 4 E.). The possibility of high-energy storm deposition in the Cambrian can be inferred from the Sandhill exposure in comparison to similarities at Baraboo (Dalziel and Dott, 1970) and Hamilton Mound (stop 7).

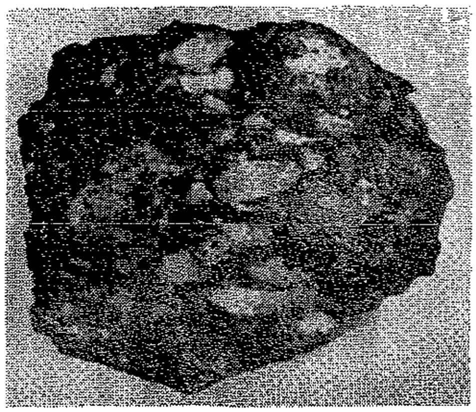
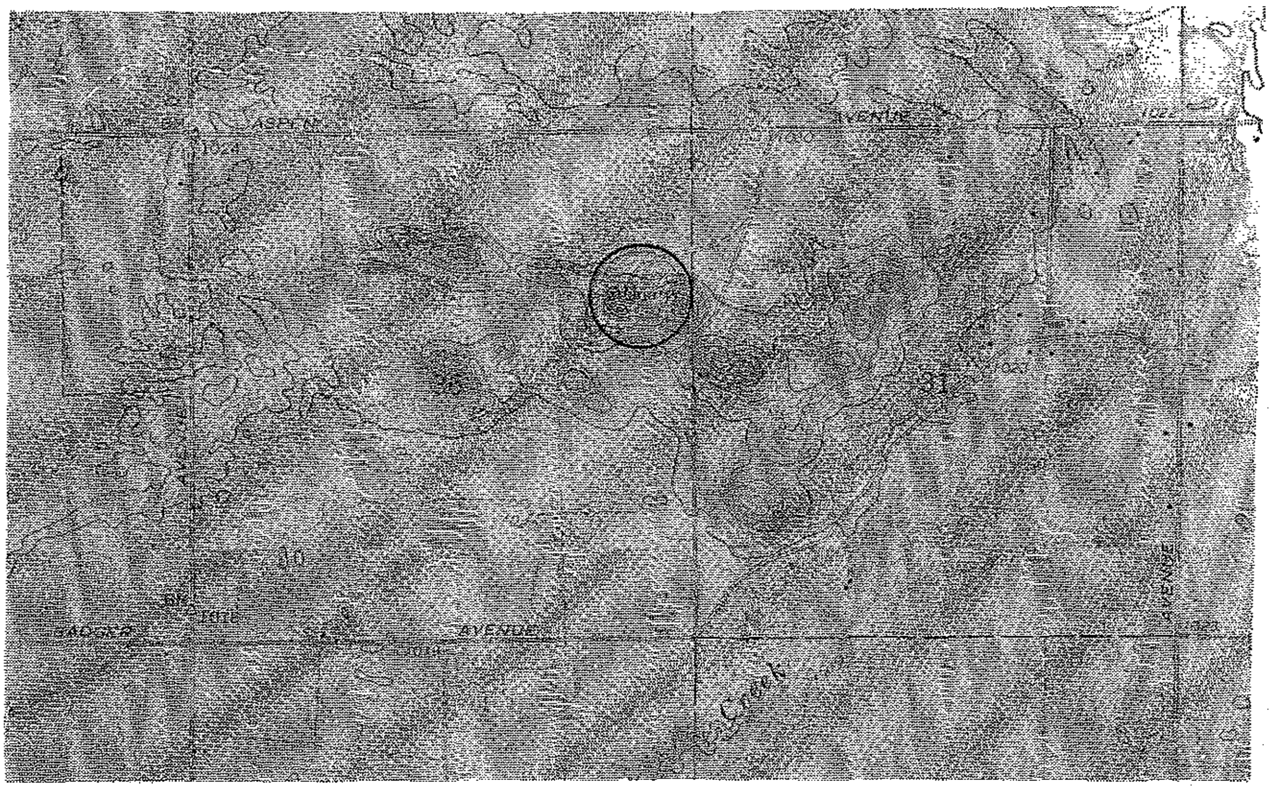


Figure 25. Hand specimen of rhyolite-bearing quartzite conglomerate from Wood County. The foliation plane is near horizontal. Long dimension about 18 cm.

STOP 7

Title: Hamilton Mound(s) - crushed stone quarry



Location: The mound (or mounds) occupies much of Sec. 36, T. 20 N., R. 6 E. and Sec. 31, T. 20 N., R. 7 E. in northern Adams County about 8 km east of Highway 13. The quarry is at SE 1/4 NE 1/4 Sec. 36, T. 20 N., R. 6 E. (Coloma NW, 7 1/2 minute topographic quadrangle).

Author: J. K. Greenberg (1983)

Description: Hamilton Mound is one of several prominent ridges oriented roughly east-west in central Wisconsin. Unlike the many Cambrian sandstone exposures, this complex of ridges is an inlier composed of folded Proterozoic quartzite similar to that at Baraboo. The main ridge possesses only a veneer of Paleozoic sandstone a few meters thick, and even thinner Pleistocene glacial cover. Since the early 1930's, the quartzite has been quarried for road material, currently by the Adams County Highway Department. From the occurrence of feldspars in thin sections of quartzite, Ostrander (1931) speculated that intrusive rocks might exist beneath the area of exposure. Later quarrying did uncover a granitic intrusion below quartzite and a complicated zone of granite-quartzite contamination.

After Ostrander (1931), no studies of Hamilton Mound had taken place until our recent work in 1981 as a part of the regional investigation of Baraboo interval metasedimentary rocks. Work by S. M. Taylor and C. W. Montgomery (abstract, 1983) on Rb-Sr geochronology and some aspects of the geology, as well as U-Pb zircon analysis by W. R. Van Schmus (unpub. data) are other studies inspired by the recent interest at Hamilton Mound.

Quartzite

Quartzite at Hamilton Mound was originally a homogeneous, fine- to medium-grained quartz sand. Major compositional variation was in the content of clay (or feldspar?), now either metamorphosed to mica or realtered to kaolin after mica. Sericite plus clay as matrix constitute from 1 or 2 percent to about 25 percent of the quartzite. Typical samples contain 5 to 10 percent sericite, 90 percent or so recrystallized quartz grains, and traces of hematite, chlorite, zircon, and other rare detrital minerals. Small feldspar grains (under 1 mm) are commonly observed in quartzite near the granite intrusion. Chlorite, zircon, sericite, and clay are also somewhat concentrated near the intrusion.

Bedding orientations of quartzite on the ridges at Hamilton Mound define a series of moderately tight folds, striking N 75° W to east-west. Bedding is generally right-side up, except on the southernmost ridge where the quartzite is apparently overturned to the south. The vertical amplitudes of the major folds are estimated as being several tens to a few hundreds of meters. Folding is inferred to be relatively tight because of bedding dips and the frequency between fold hinges is about equal to the amplitude.

Recrystallization was locally intense at Hamilton Mound, but bedding features, especially cross-bedding, and less commonly ripple marks, can be observed. Note particularly that some bedding laminations are intricately slumped and faulted. Unfortunately the nature of cross beds does not allow the determination of sediment transport directions. Some modified bedding laminations and other bands in the quartzite which are not obviously bedding-related constitute a tectonic fabric. This fabric or foliation is well defined in places by sericite and quartz segregations, but it is not a penetrative feature.

A fracture cleavage is locally well developed and obvious when at a high angle to bedding (fig. 26). Quartz crystals embedded in clay have grown in this fracture cleavage. Similar quartz crystals and clay are found as constituents of brecciated quartzite which occurs on several of the ridge tops. Similar breccia occurs at Baraboo, Waterloo, Necedah (stop 8), and at two small exposures of quartzite in Wood and Clark Counties. Post-deposition intrusions are known at all but the smaller areas, and this may imply a breccia-intrusion relationship. At Hamilton Mound, planar zones of intense strain and cataclasis occur near the quartzite-intrusive contact. Within these zones, there are microstylolites between quartz grains (fig. 27) and microbrecciation which may be small-scale equivalents of the larger breccias. In addition, Taylor and Montgomery (1983) have also observed porphyritic granite fragments in breccia surrounded by quartzite at Hamilton Mound. It is conceivable that brecciation was induced by strain and hydrothermal activity during intrusion.

A definite influence of granitic intrusion on the quartzite is color alteration. Although Hamilton Mound quartzite away from the intrusion is

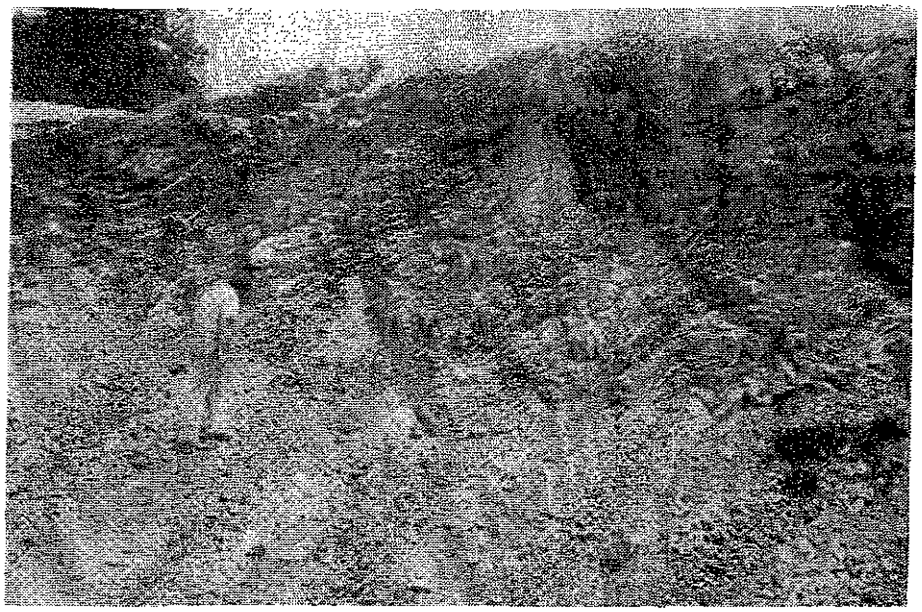


Figure 26. Excavation face at Hamilton Mound showing steeply dipping beds in quartzite cut by nearly horizontal fracture cleavage.

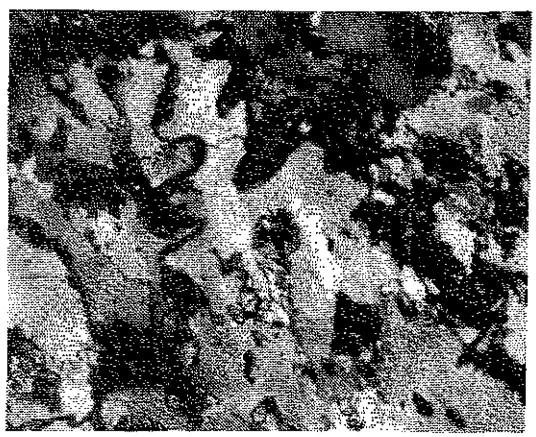


Figure 27. Micrograph of intensely deformed quartzite from near the intrusive contact. Microstylolite developed between quartz grains. Long dimension is about 6 mm.

characteristically pink-red (as seen on the ridge southeast from the quarry ridge), quartzite in proximity to the granitic rock is distinctly greenish. The color change is probably explained by the reduction of iron in hematite during the introduction of heat. Similar color variations can be seen at Necedah and at Baxter Hollow (Baraboo).

Intrusion

From the present extent of exposure, there is no certain way of knowing the original igneous character of the granitic intrusion at Hamilton Mound. Contaminated igneous material is of two types. The more original appearing rock is nearer the pit entrance and is composed of bright red-orange phenocrysts (to 2 cm in length) of potassium feldspar and plagioclase, colored by hematite inclusions. Some larger quartz grains also occur as clasts in a matrix of highly strained quartz (to 50 percent of total), chlorite, opaques, and sericite (fig. 28). Much of the sericite may have been derived from altered feldspars. Zircons are common. Larger inclusions in the granitic rock are composed of quartz, biotite, chlorite, and sericite. These inclusions are unlike the overlying quartzite and may be remnants of digested basement rocks. Chemical analyses of samples of the porphyritic granite are consistent with a granitic intrusion contaminated by mafic and aluminous material (S. Taylor, unpub. data). Initial U-Pb zircon data from the porphyritic granitic rock suggest 1760 m.y. (W. R. Van Schmus, unpub. data) as a possible age that would further associate Baraboo-interval sedimentation with 1760 m.y. old magmatism. Preliminary Rb-Sr analyses (Taylor and Montgomery, 1983) indicate that whatever the original age, the granite at Hamilton Mound was isotopically reset 1585 ± 30 m.y. ago, an age overlapping the uncertainties of both the 1630 m.y. old regional disturbance and the 1500 m.y. old episode of alkalic magmatism.

At the far end of the quarry, quartzite and magma appear to be very complexly mixed. The gray foliated rock which is exposed here grades vertically from a highly deformed micaceous quartzite down into a very quartz-rich banded rock containing large amounts of fresh fine-grained feldspar (microcline and plagioclase), biotite, and less common hornblende. It is here, across the zone of transition or mixing, that laminations with the appearance of sedimentary features have been contorted into a tectonite foliation (fig. 29, and mentioned above). Enigmatic round inclusions (xenoliths?) of mafic material with reaction rims occur in the mixed zone. U-Pb analyses by W. R. Van Schmus (unpub. data) determined that zircons from this mixed zone are 2500 m.y. old. One interpretation is that these zircons and inclusions in the magma represent basement assimilated and brought up from below. Another possibility is that the Hamilton Mound quartzite contains detrital zircons derived from eroded Archean basement.

All thin sections of quartzite and intrusive rock collected from within or near the mixed zone have the high-strain deformational fabric, associated with the quartzite-intrusion contact. Unusually strain-free grains, feldspar and biotite in particular, appear to be late magmatic (metasomatic?) phases that grew during or after deformation. Rare dikelets of granitic rock containing tourmaline are also known to post-date deformation (Taylor and Montgomery, 1983). These observations, along with the previously mentioned brecciation, suggest both a forceful intrusion and a substantial chemical interaction between magma and overlying quartzite.

Figure 28. Micrograph of contaminated porphyritic granite. Strained quartz and chlorite surround phenocrysts. Long dimension is about 8 mm.

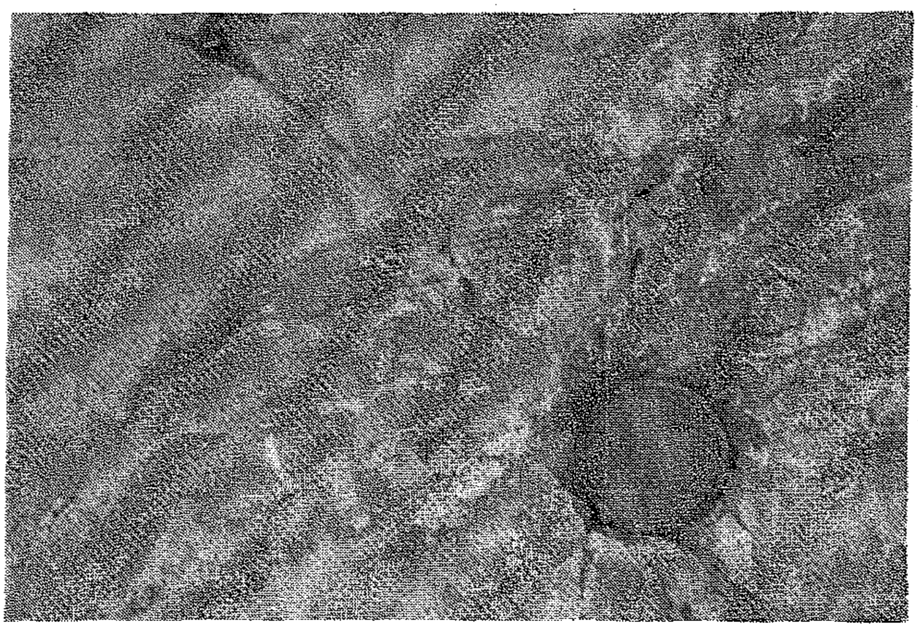


Figure 29. Distorted laminations and inclusions with reaction rim, from the quartzite-intrusion mixing zone at Hamilton Mound. Lens cap is 5 cm in diameter.

Sandstone

A thin cap of sandstone sits atop poorly exposed quartzite along one wall of the quarry (fig. 30). This sandstone, like most other exposures in the area, is correlated with the Upper Cambrian Elk Mound Group. Further differentiation into a particular formation is not possible. The sands are interpreted as having been deposited on a topographic high of the eroded Precambrian.

Just above the quartzite, the sandstone is very poorly sorted with almost regularly spaced alternations of rubbly conglomerate beds and finer sand beds (fig. 30). The rubbly conglomerate contains large angular blocks (to 1 m across) of quartzite. Away from the unconformity, the beds become thinner, with better sorting and flaggy parting.

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

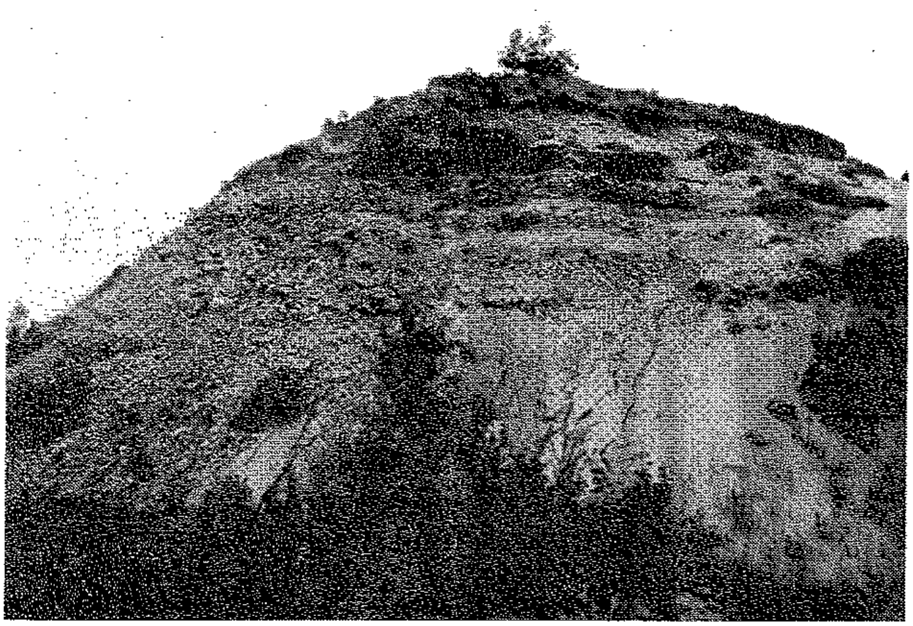
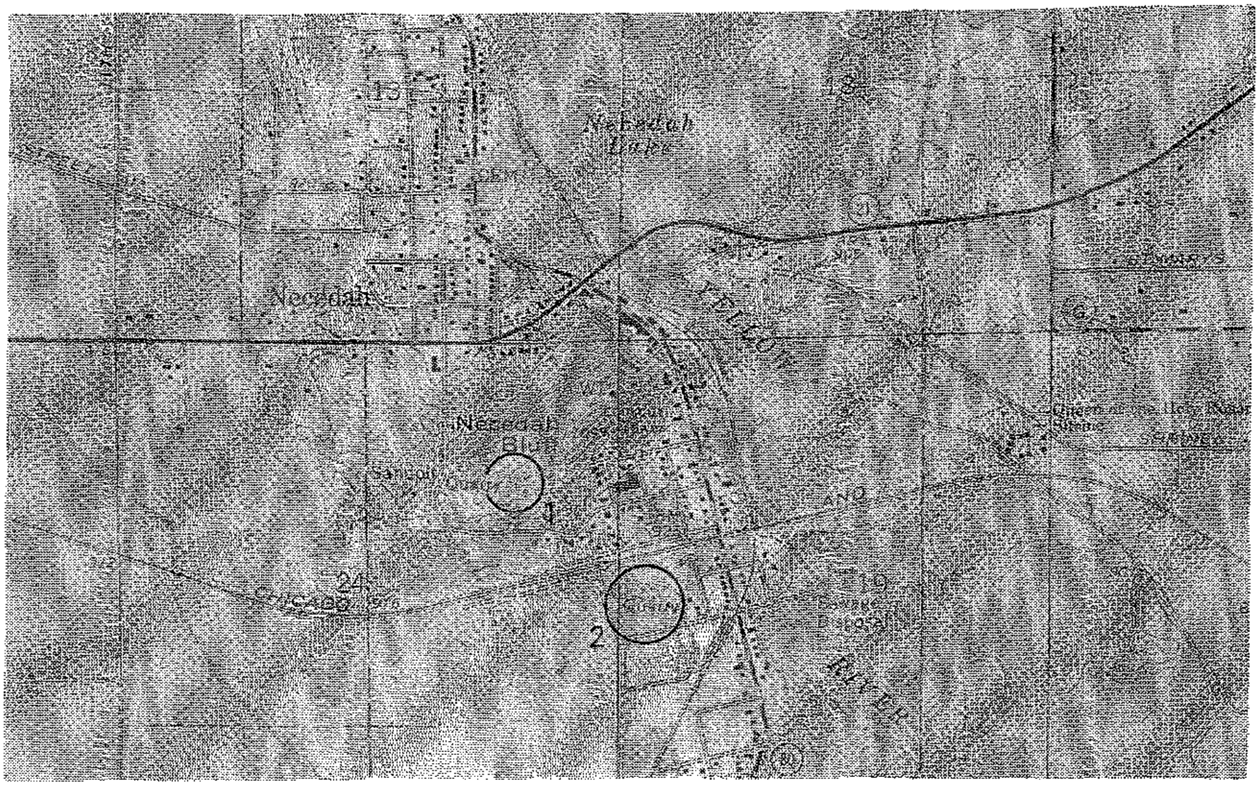


Figure 30. Excavation face at Hamilton Mound showing quartzite blocks in Cambrian sandstone overlying quartzite. Sandstone beds become more regular and flaggy to the right of the photo. Horizontal dimension is about 10 m.

STOP 8

Title: Necedah - quartzite quarries



Location: NE 1/4 Sec. 24, T. 18 N., R. 3 E., and NW 1/4 Sec. 19, T. 24 N., R. 4 E. (Necedah 7 1/2 minute topographic quadrangle).

Author: B. A. Brown (1983)

Description: Necedah Bluff is a hill of quartzite which rises 60 m above the surrounding terrane. Quartzite is exposed on the flanks of the bluff, and in a large quarry on the southwest end of the bluff (locality 1). Quartzite is also exposed in a quarry on a small hill south of the Chicago & Northwestern railway tracks (locality 2), 0.5 km south of the bluff.

The quartzite at Necedah is similar in appearance and composition to quartzite exposed at Baraboo and Hamilton Mound. It is predominantly pink to red in color, but locally varies to gray, black, or light green. The iron content of individual beds is an important factor in determining the intensity of red color. The gray to green and black colors probably result from reduction of iron, as at Hamilton Mound. Bedding strikes east-west and dips steeply (80°) to the north. The only primary sedimentary structure identified at Necedah is cross bedding (fig. 31) which is typical of all exposures of the quartzite facies in Wisconsin. In thin section the quartzite appears to have originally been a medium- to fine-grained sandstone. Most grains show sutured boundaries and varying degrees of strain. Fine muscovite and sericite are commonly present between grains.

The most striking structural feature of the Necedah Quartzite is the extensive brecciation. All of the quartzite observed in the active quarry (locality 1) is a brecia consisting of angular quartzite blocks up to 30 cm across, floating in a matrix of white vein quartz (fig. 32). Vugs in the breccia are filled with white clay into which late euhedral quartz crystals have grown. Similar breccias are observed at Baraboo, Hamilton Mound, Waterloo, and at several minor exposures in Wood and Clark Counties.

At Hamilton Mound and in the Waterloo area, the breccias are found in zones discordant to bedding and are closely associated with known igneous intrusions into the quartzite sequence. Although no intrusive rock has been observed at Necedah, a well located near locality 2 reports red granite at a depth of 50 m. Early exploratory drilling for iron in the Necedah area encountered diorite and granite at depth. The presence of intrusive rocks at depth, the local reduction of iron, the late hydrothermal effects such as growth of quartz and muscovite, and the presence of extensive brecciation suggest the possibility of an intrusion into the quartzite much like the situation at Hamilton Mound (stop 7).

Necedah Bluff probably represents a high hill on the Precambrian surface that stood above the sea level during Cambrian time. Wells to the north of the bluff penetrate up to 60 m of sandstone of the Elk Mound Group before hitting quartzite. A well in the southern part of the town of Necedah penetrates 20 m of conglomerate with quartzite clasts, probably analogous to Cambrian basal conglomerates flanking the basement highs at Hamilton Mound (stop 7) and Sandhill (stop 6).

Figure 31. Distorted cross-bedding in quartzite (locality 2). Quarter for scale.

Figure 32. Quartzite breccia in large quarry (locality 1). Note abundant white vein quartz which forms matrix.

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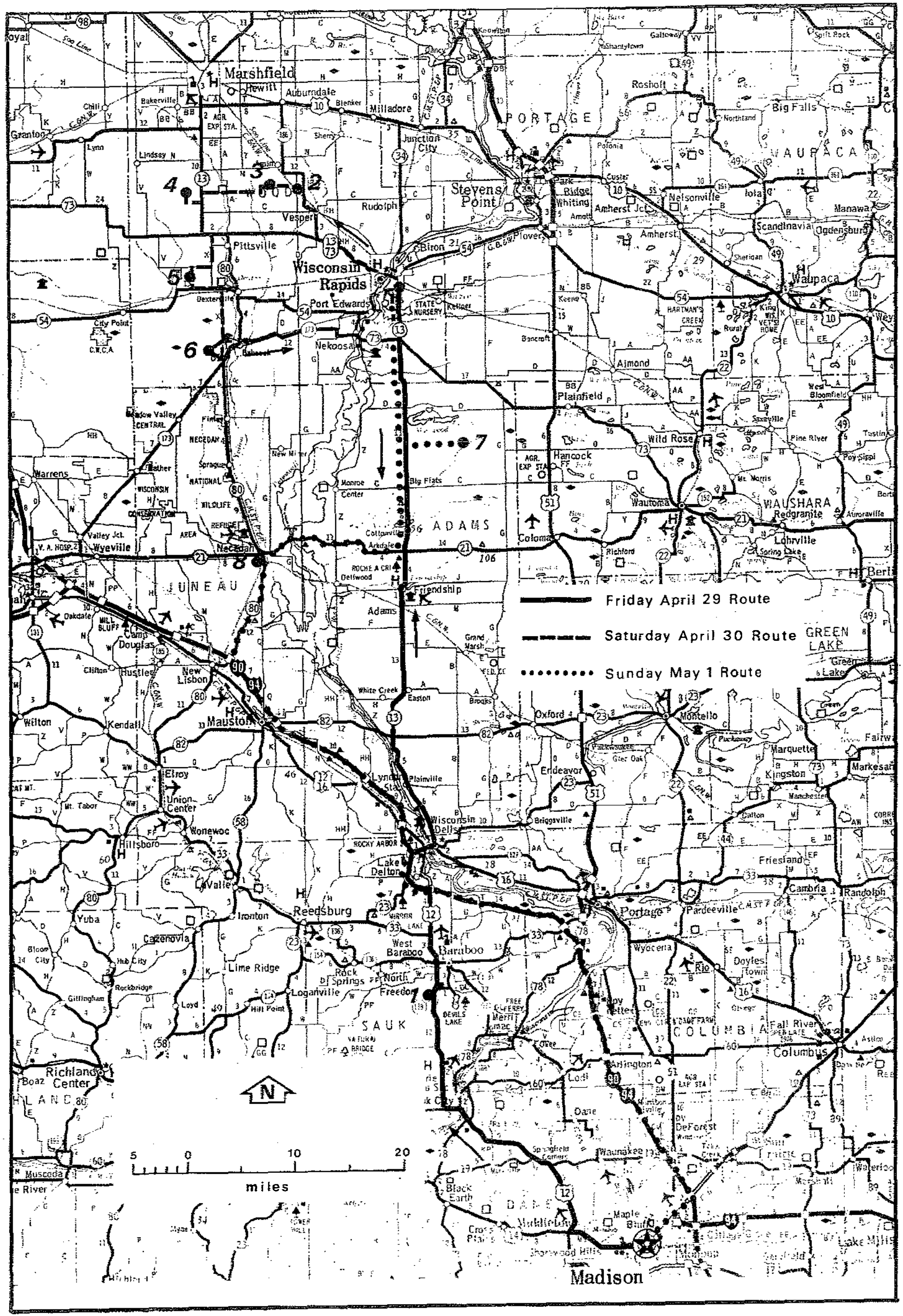
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