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Meredith E. Ostrom, State Geologist and Director

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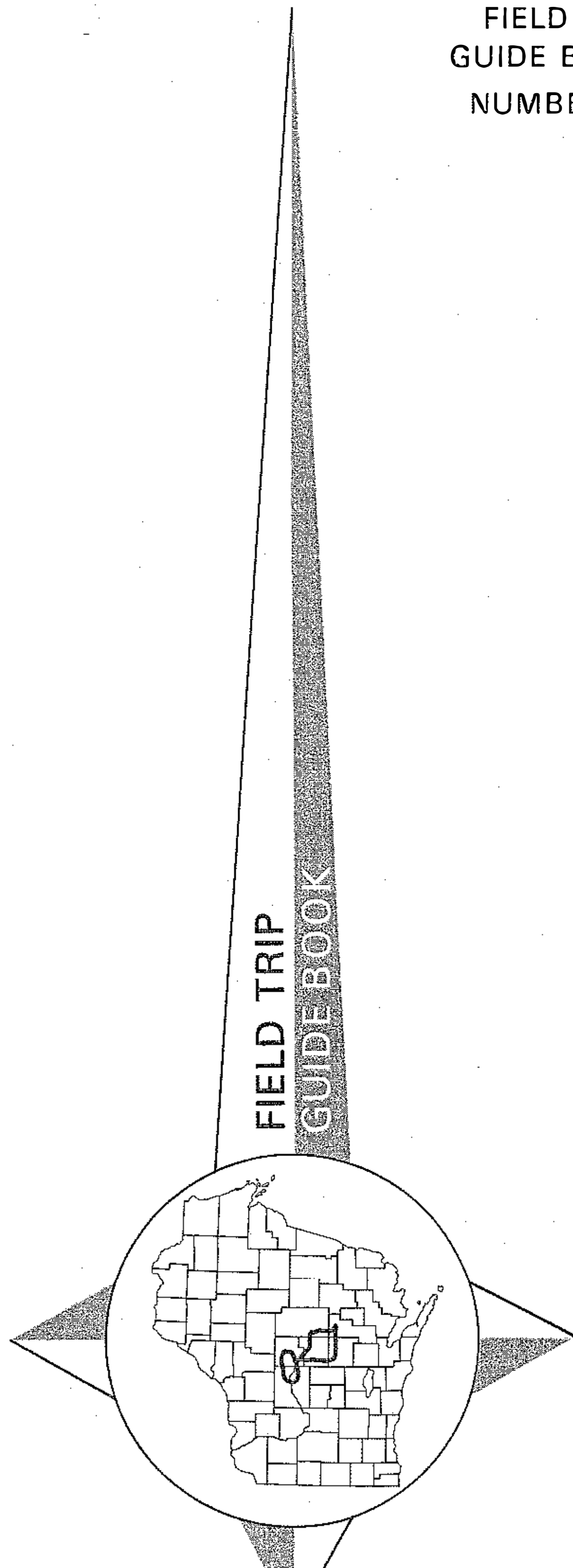

THE WOLF RIVER BATHOLITH AND BARABOO INTERVAL IN CENTRAL WISCONSIN

Prepared for

THE THIRTY-SECOND ANNUAL MEETING

INSTITUTE ON LAKE SUPERIOR GEOLOGY

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THE WOLF RIVER BATHOLITH AND BARABOO INTERVAL IN CENTRAL WISCONSIN

by

J.K. Greenberg, B.A. Brown, L.G. Medaris, and J.L. Anderson

Discussion and Geological Stop Descriptions in Two Parts

Part I. J.K. Greenberg, L.G. Medaris, and J.L. Anderson

Part II. B.A. Brown and J.K. Greenberg

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GENERAL INTRODUCTION

Three major episodes of post-Penokean anorogenic tectonism and magmatism have been recorded in the Proterozoic history of Wisconsin. In order of decreasing age these are (1) the Baraboo interval, including magmatism, sedimentation, and deformation about 1760 to 1650 Ma, (2) intrusion of the Wolf River batholith and related plutons about 1500 Ma, and (3) Keweenawan rifting, magmatism, and sedimentation about 1000 Ma. The earlier two of these anorogenic events are the focus of the present guidebook. The emphasis on anorogenic activity has resulted both from current investigations and renewed interest in post-Penokean tectonic problems.

The metasedimentary rocks of the Baraboo interval and the plutonic rocks of the Wolf River batholith are classic topics of investigation in the Precambrian terrane of the Lake Superior region. The Baraboo Range has been known for almost a century as the archtypical example of Precambrian quartzite and of cleavage development. The Wolf River batholith is noteworthy as a well-documented occurrence of associated granite, monzonite, and anorthosite, which was produced by a Late Proterozoic anorogenic magmatic event of continental extent. Stops that have been selected for the two-part field trip do not include the frequently visited exposures at Baraboo, nor some of the better known outcrops of the Wolf River batholith. Rather, it is the desire of the authors to bring attention to some of the more diverse and less well understood examples of anorogenic rocks in central Wisconsin.

PART I - THE WOLF RIVER BATHOLITH

Introduction

For information on the Wolf River batholith there is no better source than the work of J. L. Anderson and colleagues (see reference list) upon which most of the background information here is based. Additional pertinent data and interpretations for the Tigerton anorthosite are available from Weis (1965) and Gnat (1984), for the 1760 Ma anorogenic magmatism and comparisons with the Wolf River batholith from Anderson and others (1980) and for tectonism associated with 1500 Ma anorogenic magmatism in Wisconsin from Greenberg and Brown (1986b).

The one day of the field trip which is devoted to the Wolf River is far from a comprehensive survey. The diversity of rock types and the quality of outcrops which will be examined should compensate for the limited time available. The field trip will begin near the southern contact of the batholith at Waupaca and travel north to near its center at Bowler (see the back-cover map). Stops enroute include several enigmatic outcrops in and around Waupaca, a quarry in Waupaca adamellite, a variety of Wolf River lithologies at Little Falls (lunch stop), and the Tigerton anorthosite at Bowler. From Bowler the trip proceeds west to the last two stops, near the batholith margin, where foliated Red River adamellite is featured at the first stop (in eastern Marathon County), and several textural variants of the Red River adamellite, are exhibited at the second, just north of Stevens Point.

General Characteristics of the Batholith

The Wolf River batholith is a large, anorogenic rapakivi massif, which in present-day terminology would be classified as an A-type granite. The batholith has an age of 1485 Ma and is related to a major anorogenic magmatic event (1410 to 1490 Ma) extending from Labrador to southern California. The batholith is composed predominantly of granitic rocks and smaller quantities of monzonite (mangerite) and anorthosite (fig. 1). Such an association of granite, monzonite, and anorthosite is common in anorogenic massifs of rapakivi affinity and represents a cogenetic, but not necessarily comagmatic, suite of rocks.

Rapakivi texture, that is mantling of alkali feldspar by plagioclase, is a conspicuous textural feature which occurs variably, but extensively, in the batholith. In addition, the Wolf River batholith is distinguished by a number of features which it shares in common with other rapakivi massifs, including

1) relatively high contents of alkalis (particularly K), Si, and F and low contents of Ca, Mg, and Al;
2) a predominance of alkali feldspar over plagioclase;
3) the common occurrence of porphyritic texture with phenocrysts of ovoidal to subhedral alkali feldspar and, to a lesser extent, plagioclase and euhedral quartz;
4) relatively high Fe/Mg, which is expressed mineralogically in the form of Fe-rich ferromagnesian silicates, including annitic biotite, ferroedenitic to hastingsitic hornblende, and locally ferroaugite, ferrohypersthene, and fayalite;
5) occurrence of fluorite, allanite, and zircon as accessory minerals; and
6) field characteristics which are typical of epizonal plutons.

Distribution of Plutonic Rocks

The Wolf River batholith underlies an area of approximately 9300 km^2 in the southeastern part of the exposed Precambrian shield in Wisconsin. The slightly younger (1456 Ma) and probably cogenetic Wausau and Stettin syenite complexes are located three to ten miles west of the batholith. In addition to the exposed plutons, other 1500 Ma granitic rocks in the subsurface of Wisconsin and adjoining northern Illinois are either known from drilling or inferred from geophysical measurements.

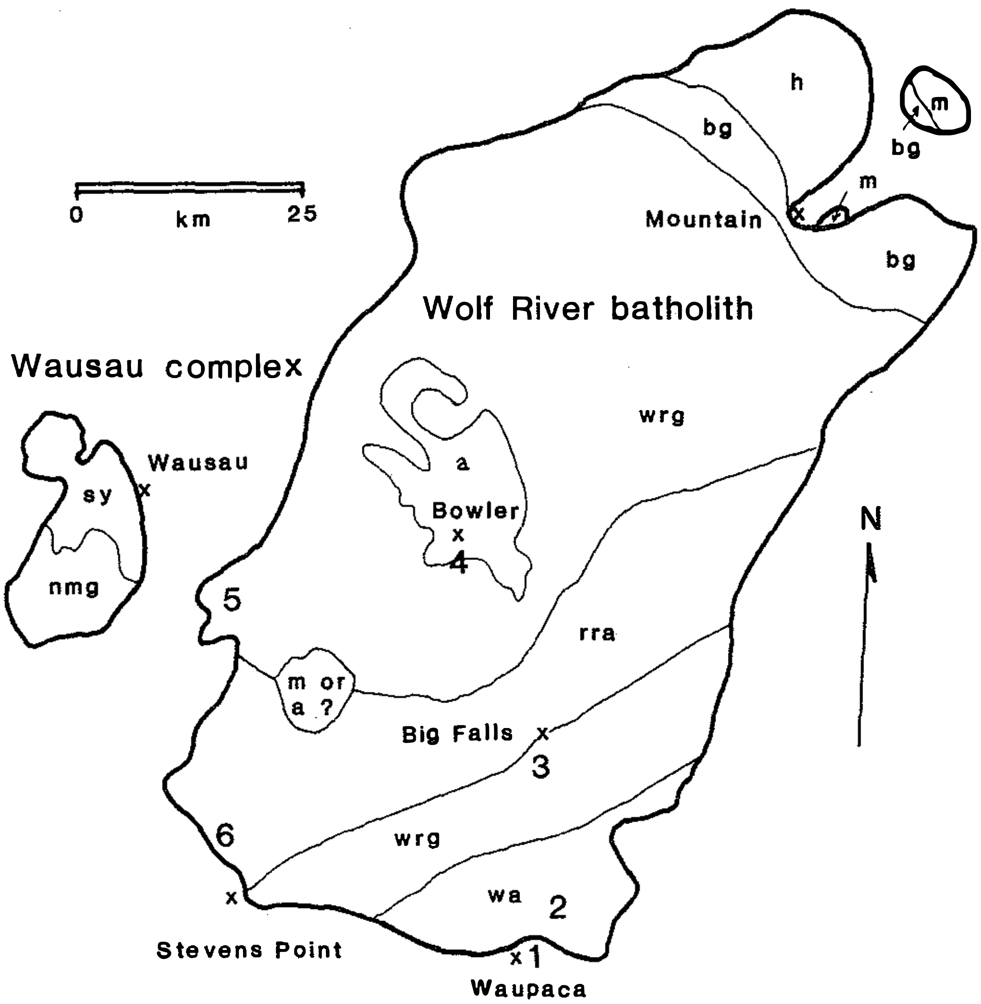


Figure 1. Geologic map of the 1500 Ma Wolf River batholith and Wausau plutonic complex. Small x's indicate the location of towns; numbers 1 to 6 represent the location of field trip stops. Letter symbols for plutons are as follows: m-monzonite, h-Hager granite/porphyry/felsite, bg-Belongia granites, wrg-Wolf River granite, a-anorthosite, rra-Red River adamellite, wa-Waupaca adamellite, sy-syenites, nmg-Nine Mile granite.

Within the Wolf River batholith, eleven distinctive lithologic units are recognized (fig. 1) which, with the exception of volumetrically subordinate syenite, monzonite, and anorthosite, are mostly granite and adamellite (fig. 2). The granitic plutons have intruded older Proterozoic plutonic and volcanic rocks along the western margin of the batholith and on the east are overlain noncomformably by Paleozoic sedimentary rocks. Hypabyssal syenite, granite, and porphyry (Hager units) are distributed in a roughly concentric band at the northeastern end of the batholith, where Proterozoic plutonic, volcanic, and sedimentary rocks have been intruded. The only other rocks recognized as possibly equivalent to the Hager units are those exposed in Waupaca. As discussed later in the guidebook, geologic relationships at Waupaca are not well understood.

Petrogenesis

Relationships among the different plutons of the batholith and their petrogenesis have been discussed in detail by Anderson (1975, 1980) and Anderson and Cullers (1978). It is sufficient for the purpose of this guidebook to

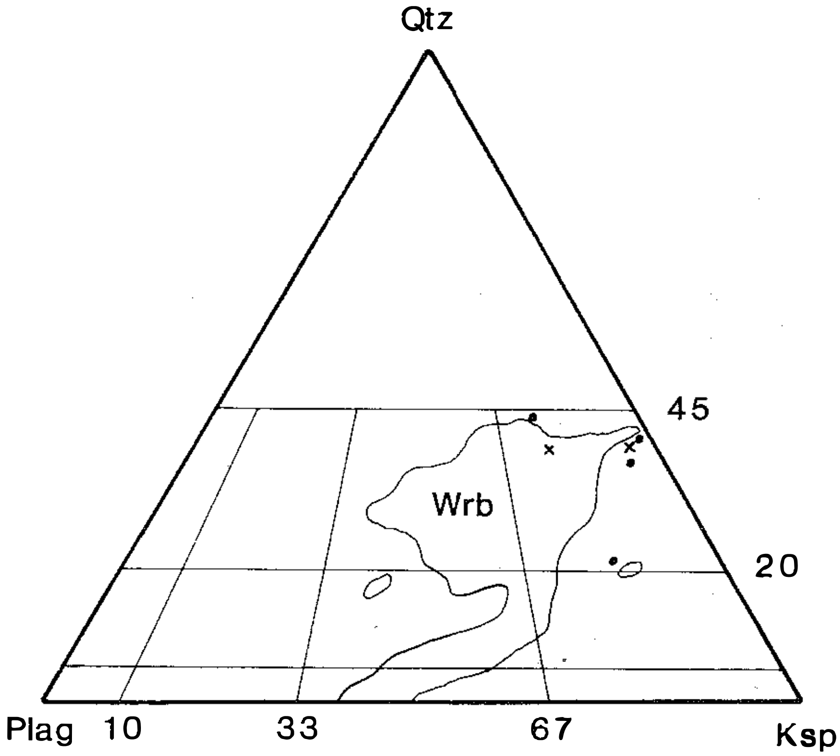


Figure 2. Modal quartz-plagioclase-potassium feldspar ternary diagram (modified from Anderson and Cullers, 1978). Small x's represent the two samples of Waupaca quarry granite reported in Anderson and others (1980). Dots represent two samples from the Waupaca city park (a dark gray and a pink variety), a sample of foliated rock from the river-bank outcrop (lowest quartz of the four from Waupaca), and a sample from the Waupaca quarry (plots with one of the Anderson and others samples). The enclosed fields represent Wolf River batholith granitic units and monzonite.

Table 1.
Major and Trace-Element Compositions of Waupaca Area and Comparison Samples

	1	2	3	4	5	6	A	B	C	D	E
in Wt. %											
SiO_2	69.20	63.50	64.90	65.00	71.60	64.30	73.05	72.82	63.44	70.59	77.32
TiO_2	0.33	0.62	0.48	0.47	0.17	0.20	0.19	0.19	0.85	0.37	0.21
Al_2O_3	13.90	15.00	15.60	16.00	12.50	16.60	13.17	13.56	15.40	13.61	1.32
Fe_2O_3*	2.49	4.78	3.65	3.76	2.14	2.24	1.61	1.68	6.69	3.22	1.83
MnO	0.06	0.10	0.07	0.08	0.06	0.05	--	--	0.15	0.07	0.05
MgO	0.57	1.70	0.98	0.95	0.24	0.53	0.25	0.24	0.29	0.17	0.10
Na_2O	3.23	3.14	3.99	4.15	3.64	3.73	3.05	3.14	4.21	3.57	2.21
K_2O	5.15	4.09	4.67	3.96	5.56	8.26	5.19	5.80	5.19	5.49	5.07
CaO	1.54	3.08	2.69	2.89	0.69	0.61	0.91	0.75	2.66	1.29	0.88
P_2O_5	0.33	0.33	<0.01	0.01	0.05	0.04	--	--	--	--	--
LOI	0.40	1.25	0.50	0.90	0.35	0.85	--	--	--	--	--
TOT	97.20	97.59	97.53	98.17	97.00	97.41	97.46	98.23	98.88	98.38	99.99
in ppm											
Rb	245	174	171	128	211	218	160	176	136	141	207
Sr	229	381	344	409	106	150	120	100	160	93	54
Y	36	29	32	20	41	88	--	--	--	--	--
Zr	236	245	296	257	244	399	--	--	--	--	--
Nb	34	30	29	23	28	53	--	--	--	--	--
Ba	810	936	994	904	632	707	739	778	2110	1353	--
Be	<1	1	<1	8	<1	<1	--	--	--	--	--
Li	33	34	20	22	30	15	25	20	16	22	18
Sc	11.1	3.6	4.6	10.8	7.4	7.0	--	--	--	--	--
La	19.4	66.0	56.7	50.2	55.8	41.9	--	63	90.3	--	-
Ce	45	124	109	99	112	86	--	134	193	--	--
Nd	19	44	40	41	37	32	--	--	--	--	--
Sm	4.3	7.4	6.7	7.1	6.9	5.8	--	10.3	18.3	--	--
Eu	0.9	0.9	0.8	1.2	1.3	1.2	--	0.78	5.8	--	--
Tb	0.8	0.9	0.7	0.7	0.5	0.6	--	2.10	2.4	--	--
Ho	1.0	1.4	1.1	1.4	1.2	1.0	--	--	3.4	--	--
Yb	2.1	3.7	3.8	3.1	3.3	2.8	--	4.8	7.0	--	--
Tm	0.3	0.6	0.7	0.6	0.5	0.5	--	--	--	--	--
Lu	0.3	0.6	0.6	0.5	0.5	0.4	--	0.76	1.1	--	--
Th	2.3	21.6	22.6	12.5	14.2	12.0	--	23.9	--	--	--

1. Sample WP-85-1 granite from Granite Street, Waupaca
2. Sample WP-85-2 light gray porphyry from Waupaca City Park
3. Sample WP-85-3 dark gray syenite porphyry from Waupaca City Park
4. Sample WP-85-4 foliated adamellite from Highway K
5. Sample WP-85-5 granite from Waupaca City quarry
6. Sample WP-85-6 foliated "syenite" from Waupaca City Park river bank

A Sample 70-12 granite from Waupaca City quarry (Anderson and others, 1980)
B Sample 70-13 granite from Waupaca city quarry (Anderson and others, 1980)
C Sample GR17B monzonite, northeastern WI (Anderson and Cullers, 1978)
D Sample 72M Hager granite, northeastern WI (Anderson and Cullers, 1978)
E Sample 50M Hager porphyry, northeastern WI (Anderson and Cullers, 1978)

outline briefly some important chemical and physical characteristics of the Wolf River batholith and its member units. Most of the plutons in the batholith are undifferentiated, although the Belongia granite has formed by differentiation from the Wolf River granite. The undifferentiated plutons probably originated by partial melting of lower crustal material at pressures of about 7 to 10 kb (depths of 25 to 36 km), and the more evolved felsic granitic plutons crystallized at emplacement depths of less than 4 km. With respect to a

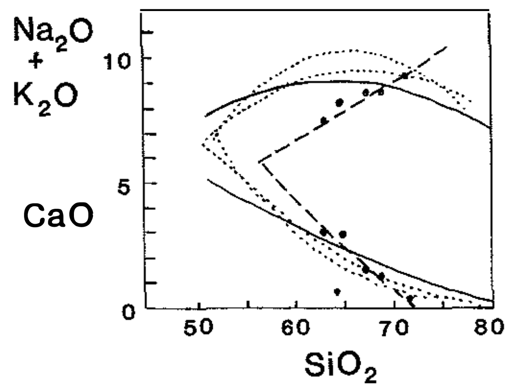


Figure 3. Peacock diagram (modified from Anderson and Cullers, 1978) comparing the trend of six Waupaca samples (dots and corresponding dashed lines) with the more alkaline trends of the Wolf River batholith (solid lines) and the Nigerian younger granites and White Mountain magma series (two pairs of dotted curves).

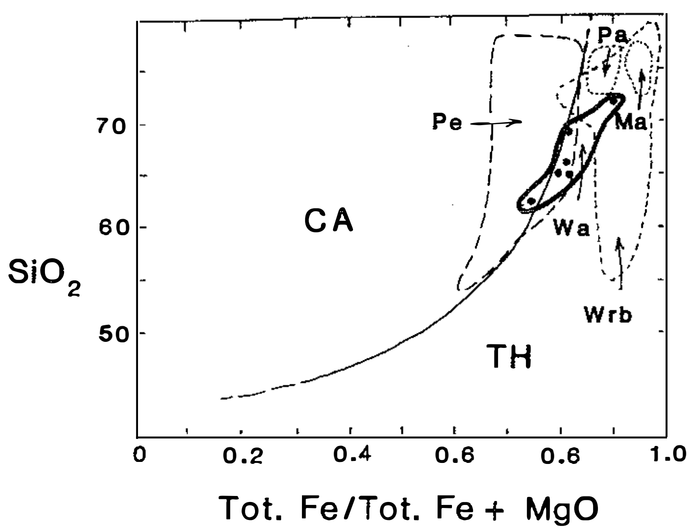


Figure 4. Plot of silica versus an iron/magnesium ratio (modified from Anderson and others, 1980). The solid curved line divides the CA-Calcalkaline field from the TH-tholeiitic field. Labeled fields are as follows: Pe-Penokean granitic rocks, Pa-peraluminous 1760 Ma granites, Ma-metaluminous 1760 Ma granites, Wa-Waupaca sample field (heavy line) from this study, Wrb-Wolf River batholith granitic rocks.

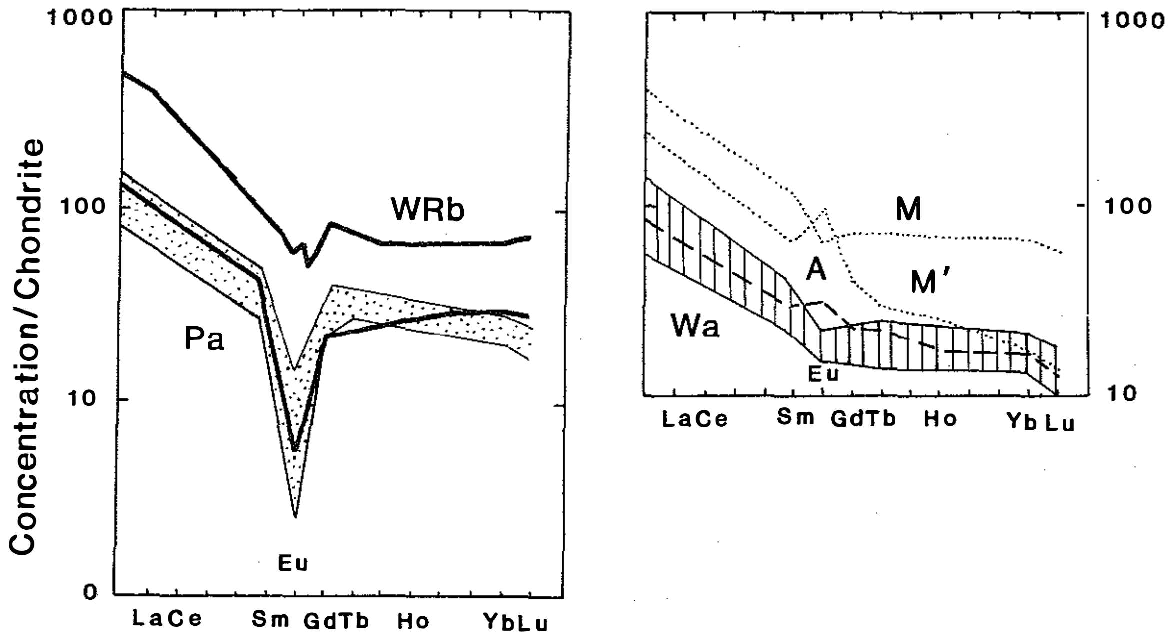


Figure 5. Plots of chondrite normalized rare-earth data (modified from Anderson and Cullers, 1978 and Anderson and others, 1980). Field within solid lines on left diagram represents combined patterns of Wolf River batholith granitic rocks. Dotted field on the left diagram represents Pa-peraluminous 1760 Ma granites. Dotted-line patterns on the right diagram represent two monzonite samples (M and M'). Dashed-line pattern on right diagram represents A-Tigerton anorthosite. The vertical-lined field on the right diagram represents the combined patterns of six Waupaca samples from this study.

generally alkaline, though not peralkaline, character and high Fe/Mg, the Wolf River batholith is similar to other continental anorogenic plutonic series (figs. 3, 4). Trace element contents and rare earth element patterns (fig. 5, Table 1) preclude derivation of the granitic units from either the associated anorthosite or monzonite. The anorthosite-granite suite may have been generated by ponding of tholeiitic magma at the base of continental crust; anorthosite was derived by crystallization from the tholeiitic magma and granite originated by partial melting of the lower crust, which was induced by the addition of heat from the ponded magma.

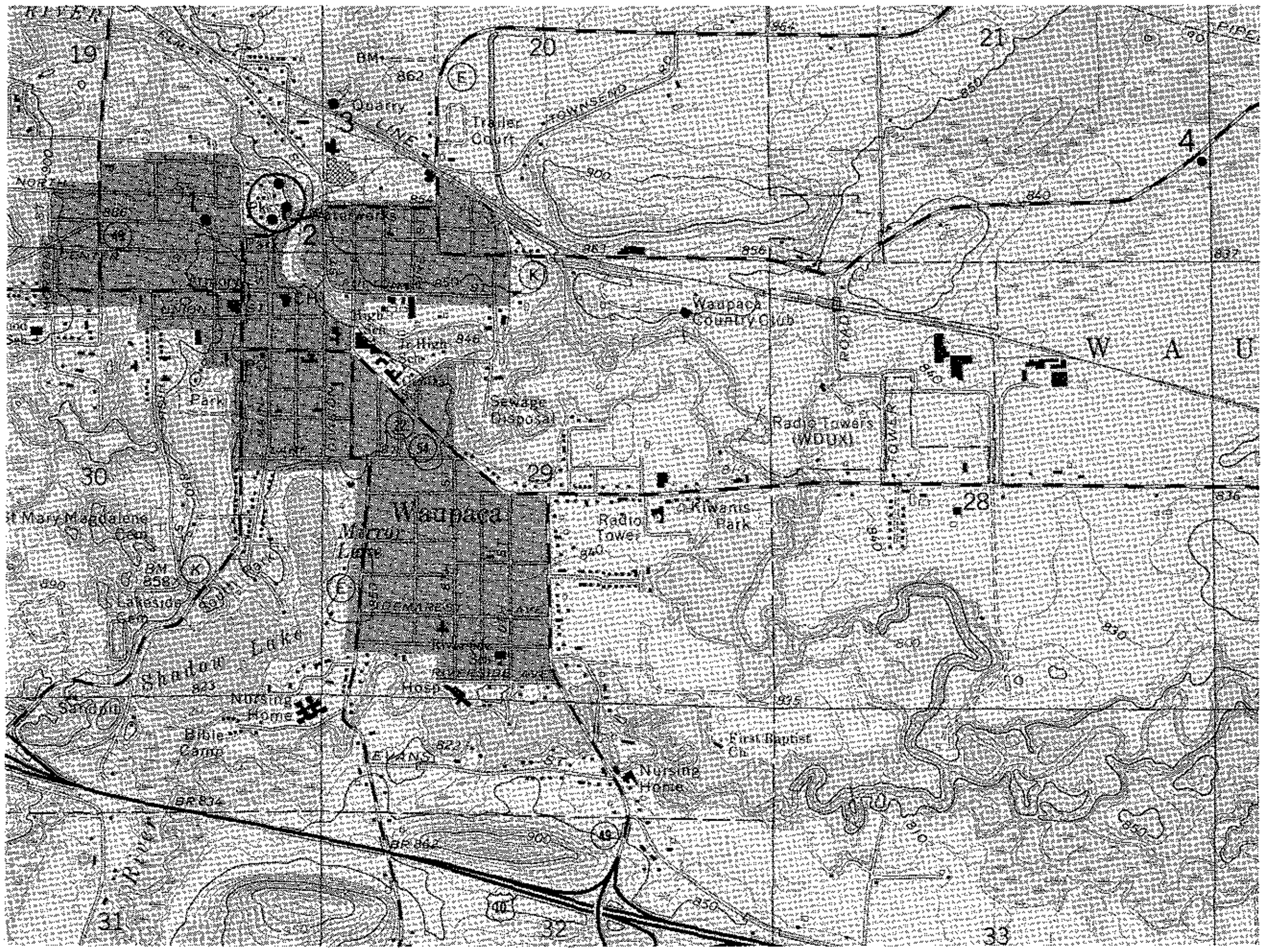
Associated Tectonism

The Wolf River batholith and other associated 1500 Ma intrusions were generated at a time when the region was relatively stable. Magmatism at 1500 Ma was both preceded and followed by other periods of anorogenic magma- tism, each of which was indicative of a particular stage in the progressive evolution of the crust (Greenberg and Brown, 1984). The Wolf River batholith was not syntectonic in the sense of having been contemporaneous with regional metamorphism and deformation, although its intrusion may have had a substantial effect on the surrounding country rocks. Metamorphic effects in the country rocks which may be associated with intrusion of the batholith include the development of staurolite, sillimanite, garnet, and andalusite in aluminous rocks and hornblende, cummingtonite, garnet, and pyroxene in mafic rocks. In addition, certain distinctive structural features, such as overprinting of foliations and cataclasis occur in country rocks in the vicinity of the batholith. Possible explanations for tectonic features associated with 1500 Ma magmatism in Wisconsin are discussed in Greenberg and Brown (1986b).

Outcrops of all rock types within the Wolf River batholith are typically massive and fractured along sets of widely-spaced joints. A planar fabric due to alignment of crystals, usually feldspar phenocrysts, occurs at various locations, commonly near the margins of plutons, and has probably resulted from igneous flow. Only in a few exposures near contacts with country rocks or interplutonic contacts have the granitic plutons obviously been modified by subsolidus deformation. This type of deformation is evidenced by cataclasis and attenuation of grains within foliation planes which are roughly parallel to the aforementioned contacts. Such relationships indicate that the subsolidus deformation occurred during emplacement of the batholith and probably was not related to later tectonism.

Title: Waupaca Area Plutonic Rocks

Location: T. 22 N., R. 12 E. (Waupaca 7½-minute topographic quadrangle).



Author: J. K. Greenberg (1986)

Precambrian bedrock at Waupaca is exposed in several outcrops along the southern and eastern sides of a hill in the SE¼ of Sec. 19 (loc. 1 and 2), in a quarry near the center of the western section line just within Sec. 20 (loc. 3), and just northeast of town along highway K, SW¼ of Sec. 22 (loc. 4).

Location 1 - Granite Street

The outcrop along Granite Street consists of a pink fine- to medium-grained porphyritic granitic rock which is rich in clots of mafic minerals (biotite ± hornblende). The rock is massive with no obvious preferred mineral orientation. Quartz veins and pegmatitic segregations occupy discontinuous fractures. Textures in thin section indicate extensive reaction and replacement of mineral phases. Hornblende has been partially converted to aggregates of biotite, epidote ± sphene. The finer-grained matrix minerals, particularly quartz, appear to have been recrystallized into equigranular mosaics. Phenocrysts of plagioclase and potassic feldspars have been replaced by sericite and other feldspars. Chemically and mineralogically this is a true granite with moderate enrichment in mafic minerals and thus Mg, Fe, Ca (relative to silica) and the trace elements Rb, Sr, Y, Zr, and Nb (fig. 2 and Table 1).

Location 2 - City Park and River Bank

The ornamental park outcrop (no hammers please) varies from lighter-colored gray and pinkish granitic rocks (similar to location 1) to darker, almost black fine- to medium-grained porphyries. A relatively low quartz content and appropriate chemistry identify these more mafic rocks as adamellite to monzonite (fig. 2, Table 1). In one place, a darker variant intrudes the pinker rock. Granite pegmatites, generally striking about N 60° W to N 35° W and dipping about 60° to the NE, transect both lighter and darker rock types (fig. 6). A foliation-lineation fabric is variably developed in the darker rocks which occupy the center and eastern part of the park. Aligned and somewhat distorted hornblendes, patches of biotite, and to a lesser extent, feldspar laths define the steeply dipping foliation (striking N-S to N 20° E) with a steeply dipping linear component (20° to 60° E). Foliation is faint or absent in the pink granitic rocks in the western part of the outcrop.

In the woods covering much of the northern and eastern exposure area, gray porphyries are cut by narrow vertical pegmatite and aplite dikes with a N-S orientation. The dikes increase in abundance eastward toward the river. A highly foliated gray gneiss is in contact with the less deformed gray intrusive rocks on the east near the river (see the location map). The gneissic banding is defined by mafic-rich and aplitic quartzand feldspar-rich layers which range in thickness from 1 cm to 1-2 mm. The overall texture is cata-

Figure 6. Photo of granite pegmatite cutting dark gray rock at the Waupaca city park. Craig for scale.

clastic to recrystallized cataclastic with some post-foliation growth of randomly-oriented amphibole (Note that a similar gneissic rock, but without the random amphiboles, is exposed in the upper part of the Waupaca ademellite quarry, Stop 2.). The easternmost outcrop of the park hill exposure is on the western river bank. This is a highly-laminated gneissic rock exhibiting a fabric orientation (N 20° W to N 10° E) and intensity of deformation similar to the wooded outcrop described above, but it is composed almost entirely of quartz, alkali feldspar, and hematite-stained muscovite. Biotite is a minor phase. Quartz veins and lensoidal quartz segregations are locally abundant in the river-bank outcrop.

The park-hill outcrops described above range from relatively-undeformed porphyritic rocks with phenocrysts of hornblende and feldspars in a granoblastic matrix of feldspar, biotite, and quartz (fig. 7) to rocks which have variably recrystallized strain-fabrics defined by aligned mafic minerals and quartzofeldspathic layers. The quartz and feldspar comprising the layers are typically segregated by size. Much of the lithologic variation observed across the outcrops can be explained by differences in grain size and the relative abundance of hornblende and biotite. Recrystallization and the breakdown of hornblende and feldspars may be indicative of metamorphic changes that correspond to the change from pristine igneous textures to mechanical-strain induced fabrics.

Chemical variation is recorded in the contrast between analyses of granite at location 1 and the more mafic rocks at the park. For example, with a decrease in SiO_2 there is an accompanying change in Rb/Sr ratios from greater than 1 (Rb > Sr) in the granite to less than 1 for the park hill samples (Table 1). Accordingly, Al_2O_3, MgO, TiO_2, CaO, and Fe_2O_3* are all more abundant in the darker rocks. A sample from the river bank exposure (#6,

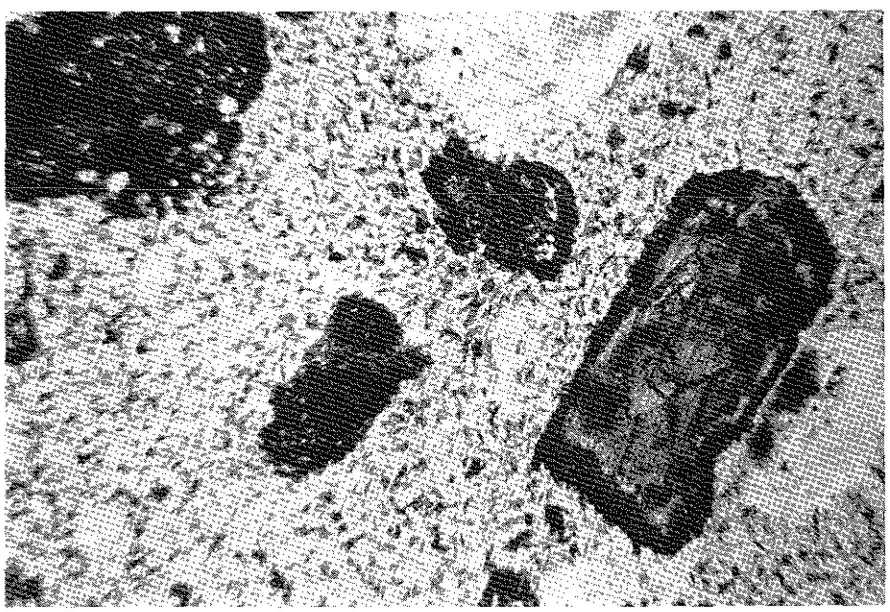


Figure 7. Photomicrograph of gray porphyritic rock from the Waupaca city park. Plane light. Long dimension about 6 mm.

Table 1) is exceptional. This rock has a very high K_2O/Na_2O ratio and elevated Zr, Y and Nb relative to the other Waupaca samples.

Location 3 - Waupaca City Quarry

In years past, the term "Waupaca Granite" referred to an ornamental dimension-stone supposedly from Waupaca. However, this "granite" is in fact the Waupaca adamellite member of the Wolf River batholith which was quarried from a site 6 km north of Waupaca (described in Stop 2 of this guidebook). There is a granite quarry in the city of Waupaca located along the Soo Line railroad tracks.

The quarry outcrop consists entirely of a massive, homogenous pink-granite. Some scattered quartz veins and fracture-like planar concentrations of muscovite are noticeable upon close examination. These features are not penetrative across the exposure and exhibit no obvious preferred orientation.

This granite is medium- to fine-grained, typically an equigranular (tends more rarely to porphyritic) xenomorphic to granoblastic mosaic of quartz, potassic feldspar (perthite and microcline) and sodic plagioclase. Muscovite is also relatively abundant as scattered grains (to 6% of total volume). Biotite, chlorite, and hematite are minor phases. The muscovite appears to have grown as either a late- or post-magmatic phase. Anderson and others (1980) indicate that chemical compositions argue against a metamorphic origin for the muscovite. The occurrence of myrmekite and other replacement textures involving feldspars and biotite probably do indicate subsolidus disequilibrium.

Samples from the quarry are compositionally similar to some of the more differentiated members of the Wolf River batholith (Belongia granite, for example) and the peraluminous types of 1760 Ma granite in Wisconsin (Anderson and others, 1980). The study by Anderson and others (1980) included two samples from Waupaca, which although unlocated, are probably from the quarry (see Table 1).

Location 4 - Waupaca Highway K Outcrops

There is a series of small outcrops northeast of Waupaca on County Highway K. Although of diverse texture, the rocks in these outcrops are not unlike the more mafic foliated varieties at the city park. Variations along Highway K range from coarser-grained adamellite with orthoclase phenocrysts and a foliation defined by aligned biotite and quartz segregations to finer-grained syenitic types with a less-pronounced gneissic foliation. Foliations trend approximately N 20° W to less commonly N 30° W. Mineral lineations are present but are of poorer expression than those at the city park. A chemical analysis of one medium-grained foliated sample from Highway K (Table 1) plots essentially among other Waupaca area samples on variation diagrams. This is the only sample with Na_2O greater than K_2O.

Further northeast along Highway K a field of frost-heaved blocks marks the first unequivocal identification of a known Wolf River batholith lithology, the Waupaca adamellite. Along with this unit there are blocks of what appear to be a strongly foliated version of Waupaca adamellite. Other layered, gneissic rocks similar to those in the Waupaca area are also exposed in the field.

Discussion: It is unfortunate that radiometric ages have not been determined for any of the lithologies at Waupaca. Among the few major outcrops there are characteristics similar to granitic rocks crystallized during the Penokean orogeny (approximately 1870 to 1820 Ma), the post-orogenic 1760 Ma granites, and the 1500 Ma Wolf River batholith. The mineralogy and general appearance of the porphyries at the city park are most like the 1500 Ma Hager porphyry or the monzonite associated with the Wolf River batholith. The relatively fine-grained granite in the Waupaca city quarry and the aplitic veins in the city park area are all muscovite bearing and are most similar to some of the peraluminous types of 1760 Ma granite. This is the correlation attributed to the quarry granite by Anderson and others (1980). The more foliated and layered rocks at the city park, river bank, in the woods, and along Highway K are structurally most like older syntectonic Penokean or perhaps Archean gneissic units. The age ambiguity is further apparent on various geochemical diagrams where Waupaca samples overlap some of the fields and trends defined by the various age groups of granitic rocks (for example, figs. 4, 8). Chemical plots may also suggest that the Waupaca samples define their own distinct trends (figs. 3, 4, 5, 8). Thus, in certain ways including rare earth element patterns (fig. 5) all Waupaca area samples can perhaps be envisioned as cogenetic with chemical variation related to relatively wide variation in mineral proportions. Even if cogenetic, there is still no satisfactory way of estimating age from composition. Zircons do appear to be of sufficient abundance in many Waupaca samples to provide U/Pb isotopic ages.

Besides the primary age of units, another major related problem at Waupaca is the nature of deformation. How can the distribution of massive rocks relative to those with foliations, both cataclastic and recrystallized, be explained? At least three possibilities are recognized: (1) the foliated rocks could be earlier units (Penokean or Archean?), exposed now as surrounding wall-rocks or as inclusions within the intrusive units; (2) the different foliated units could represent different ages of deformation, possibly both pre- and syn-intrusion; (3) all the observed strain could have been imposed on older units and some marginal phases of the intrusive rocks during emplacement.

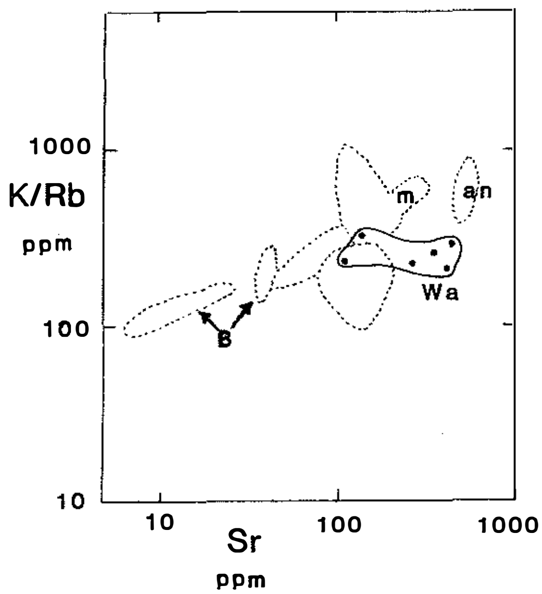
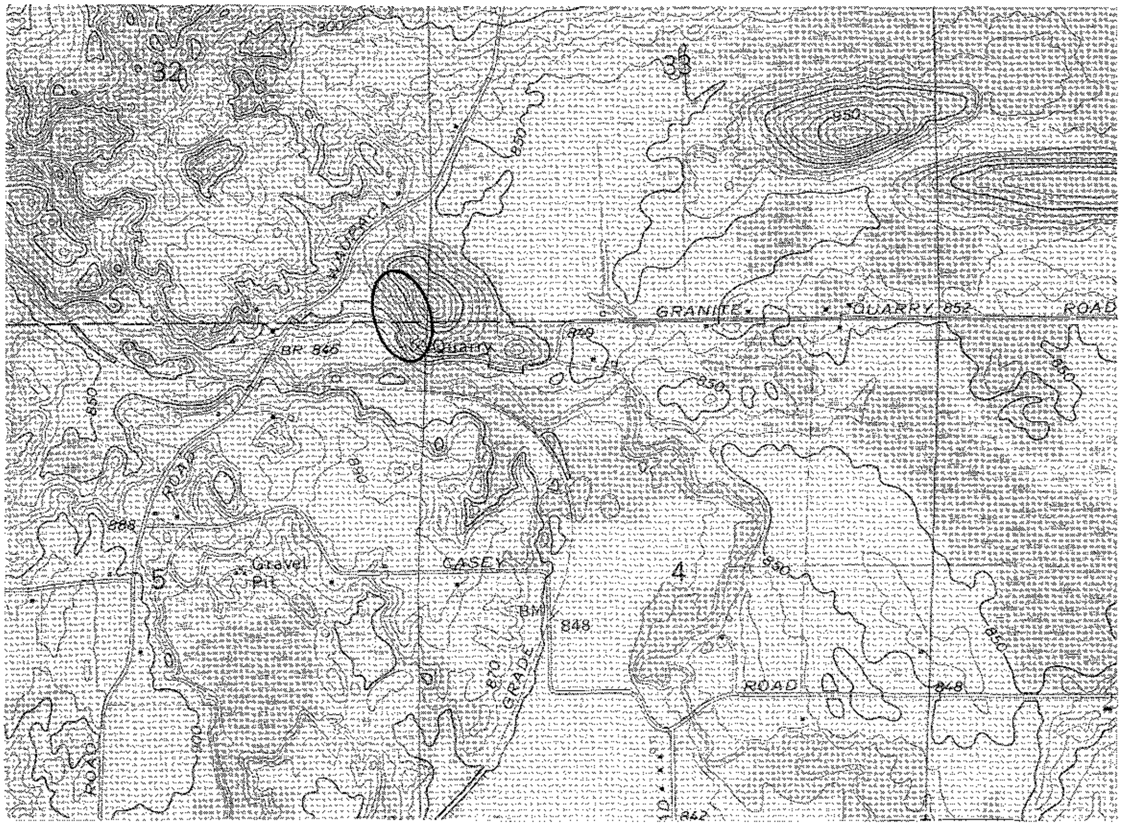


Figure 8. Plot of K/Rb versus Sr (modified from Anderson and Cullers, 1980). Black dots and solid-line field represent Wa-Waupaca area samples (this study). Dotted-line fields represent Wolf River batholith samples, including B-Belongia granites, m-monzonite, and an-Tigerton anorthosite.

Title: Quarry in Waupaca Adamellite

Location: Quarry is on the north side of Granite Quarry Road, NW¼, NW¼, Sec. 4, T. 22 N., R. 12 E., Waupaca County (Ogdensburg 7½-minute topographic quadrangle).



Authors: J. L. Anderson and L. G. Medaris, Jr. (1986)

Description: This quarry is located in the Waupaca adamellite, which forms the southernmost pluton in the Wolf River batholith. The Waupaca adamellite intrudes gneiss (perhaps Archean), an outcrop of which occurs on the hill above the quarry wall. The northern contact of the adamellite with the Wolf River granite is not exposed, so its relative age with respect to the other lithologic units in the batholith is unknown.

The Waupaca adamellite is characterized by rapakivi texture (fig. 9) and is equivalent to wiborgite of the classical rapakivi massifs in Finland. Approximately 70 to 80 percent of the coarse ovoidal alkali feldspar grains are mantled by plagioclase. The adamellite is massive, coarse-grained, and inequigranular, with anhedral quartz, hornblende, and biotite occurring interstitially to the large ovoidal feldspar. Accessory minerals include apatite, zircon, ilmenite, magnetite, allanite, sphene, and fluorite.

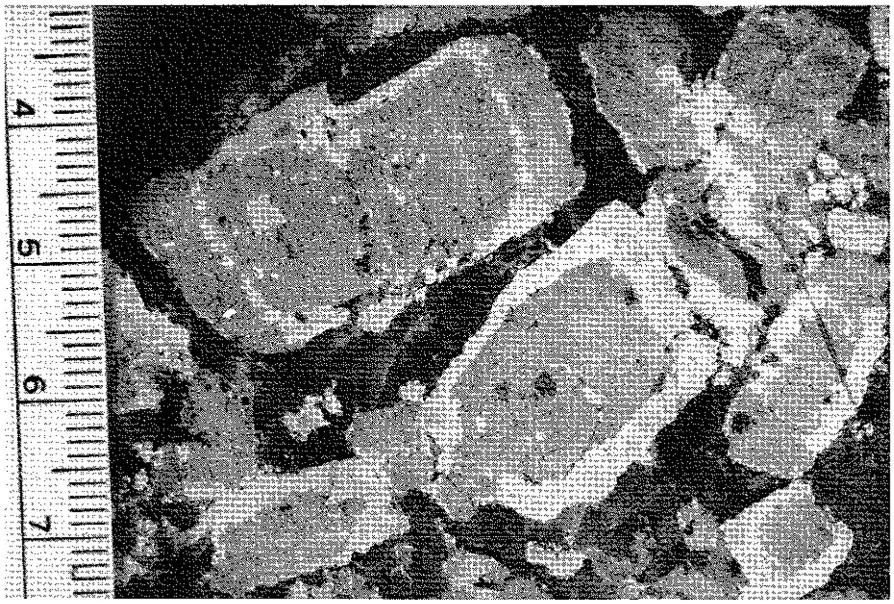


Figure 9. Rapakivi texture in Waupaca adamellite. Scale in centimetres.

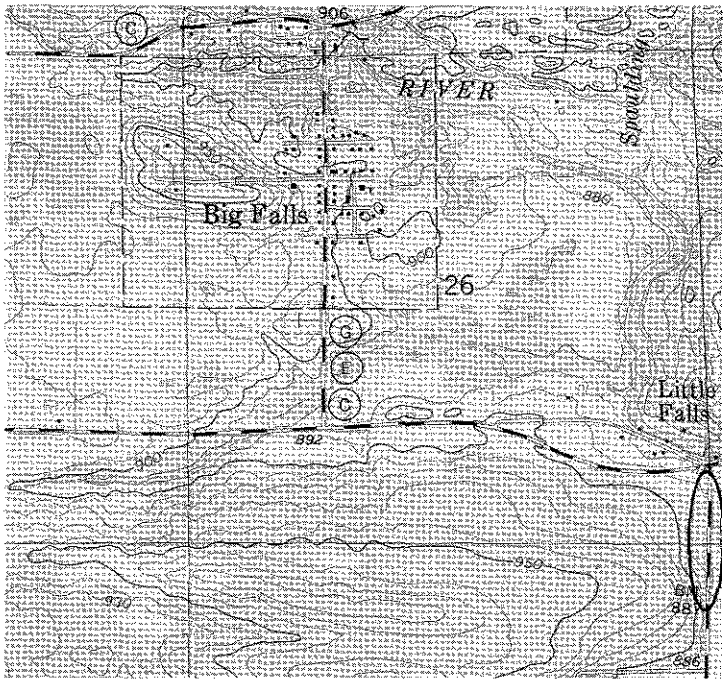
The Waupaca adamellite is a member of the suite of undifferentiated granite to adamellite plutons in the batholith. Although there is some compositional overlap with the Red River adamellite, the Waupaca adamellite is one of the most aluminous plutons (13.75 to 14.70%) within the undifferentiated suite, has the highest values for CaO/CaO + Na_2O (0.32 to 0.42), has the highest contents of K_2O + Na_2O (8.60 to 9.23%), and has intermediate values of FeO/FeO + MgO (0.86 to 0.89). The one sample (from this quarry) of Waupaca adamellite which has been analyzed for the rare earth elements contains the greatest concentration of these elements among samples from the undifferentiated plutons.

Ferromagnesian phases in the Waupaca adamellite are relatively Fe-rich, as they are elsewhere in the batholith. In a sample from this quarry, Fe/Fe + Mg is 0.77 in biotite and 0.84 in amphibole, which is close to ferroedenite in composition. Individual plagioclase grains exhibit normal zoning and range in composition from An_{13-24}; plagioclase mantles on alkali feldspar also range in composition from An_{13-24}. The bulk composition of perthitic alkali feldspar is Or_{74} Ab_{23} An_3. The compositions of coexisting ilmenite, magnetite, and biotite indicate a crystallization temperature of approximately 745 °C and an oxygen fugacity of $10^{-16.7}$ bars.

At this quarry some portions of the adamellite have been extensively altered to epidote and chlorite, which imparts a green color to hand samples.

Title: Outcrops at Little Falls (1986)

Location: Southwest of Big Falls on the south bank of the Little Wolf River at the intersection of County Trunk Highways C and E, SE¼, SE¼, Sec. 26, T. 25 N., R. 12 E., Waupaca County (Big Falls 7½-minute topographic quadrangle).



Authors: J. L. Anderson and L. G. Medaris, Jr. (1986)

Description: Three lithologic units of the Wolf River batholith (Wolf River granite, Wiborgite porphyry, and Red River adamellite) may be examined in excellent outcrops along the Little Wolf River.

The Wolf River granite is the oldest granitic pluton in the batholith and the largest, accounting for approximately 50% of the exposed area. The red, coarse-grained granite consists of large (1-3 cm) ovoidal to subhedral alkali feldspar with interstitial plagioclase (An_{15-20}), quartz, biotite, hornblende, and accessory minerals, including apatite, zircon, allanite, ilmenite, magnetite, sphene, and fluorite. Only 3 to 10 percent of the alkali feldspar grains are mantled by plagioclase. Texturally, the Wolf River granite resembles the pyterlite variety of the Finnish rapakivi granites.

Field, petrologic, and geochemical data indicate that in the northeastern part of the batholith a differentiated granitic suite (Belongia coarse and Belongia fine granite) has been produced by fractional crystallization of the Wolf River granite. The Wolf River granite crystallized at a temperature of approximately 700 °C and an oxygen fugacity of $10^{-17.9}$ bars, based on the compositions of coexisting ilmenite, magnetite, and biotite.

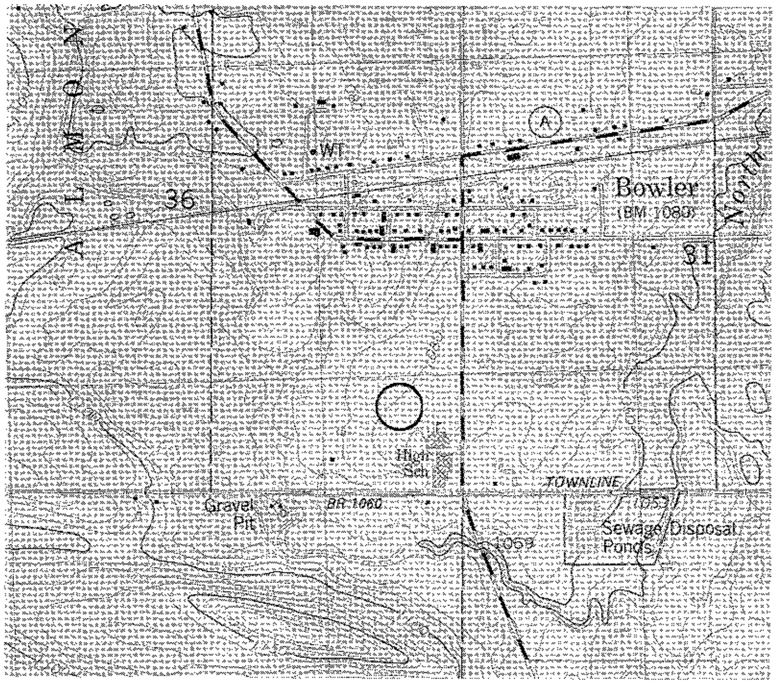
The <u>Wiborgite porphyry</u> is a granite porphyry which contains extensive rapakivi and less abundant anti-rapakivi mantling of feldspars. The porphyry contains 45 to 70 percent phenocrysts of mantled alkali feldspar and lesser amounts of plagioclase (An_{17-24}), quartz, biotite, and hornblende in a medium- to coarse-grained matrix of the same minerals and accessory phases. The porphyry occurs as large, massive dikes up to 5 km long and 1 km wide within the Wolf River granite.

The <u>Red River adamellite</u> is the youngest of the undifferentiated plutons in the batholith. The adamellite is porphyritic and contains coarse-grained phenocrysts (1-20 percent) of subhedral to rectangular alkali feldspar and lesser amounts of euhedral plagioclase (An_{17-27}), euhedral quartz, and clusters of biotite ± hornblende. The medium-grained matrix consists of anhedral quartz, two feldspars, biotite, ± hornblende, ilmenite, ± magnetite, sphene, allanite, apatite, zircon, and fluorite. Texturally, the Red River adamellite is similar to the porphyritic varieties of the Finnish rapakivi granites.

The compositions of coexisting ilmenite, magnetite, and biotite yield a temperature of approximately 760 °C and an oxygen fugacity of $10^{-16.3}$ bars for crystallization of the Red River adamellite.

Title: Anorthosite near Bowler

Location: Outcrop in schoolyard on west side of County Trunk Highway J, approximately ½ mile south of Bowler, SE¼, SE¼, Sec. 36, T. 28 N., R. 12 E., Shawano County (Bowler 7½-minute topographic quadrangle).



Authors: J. L. Anderson and L. G. Medaris, Jr. (1986)

Description: Anorthosite occurs as a centrally located large mass and as smaller inclusions in the Wolf River granite. The rock varies from anorthosite to gabbroic anorthosite and consists predominantly of coarse-grained (1-20 cm) blue-gray plagioclase, which ranges in composition from $An_{37.5-63.5}$ (Gnat, 1984). The texture is porphyritic granoblastic, or cataclastic; coarse-grained plagioclase is set in a medium-grained matrix of plagioclase and interstitial clinopyroxene (salite to augite), orthopyroxine (hypersthene to bronzite), hornblende, magnetite, and ilmenite. Pyroxenes are typically surrounded or replaced by hornblende.

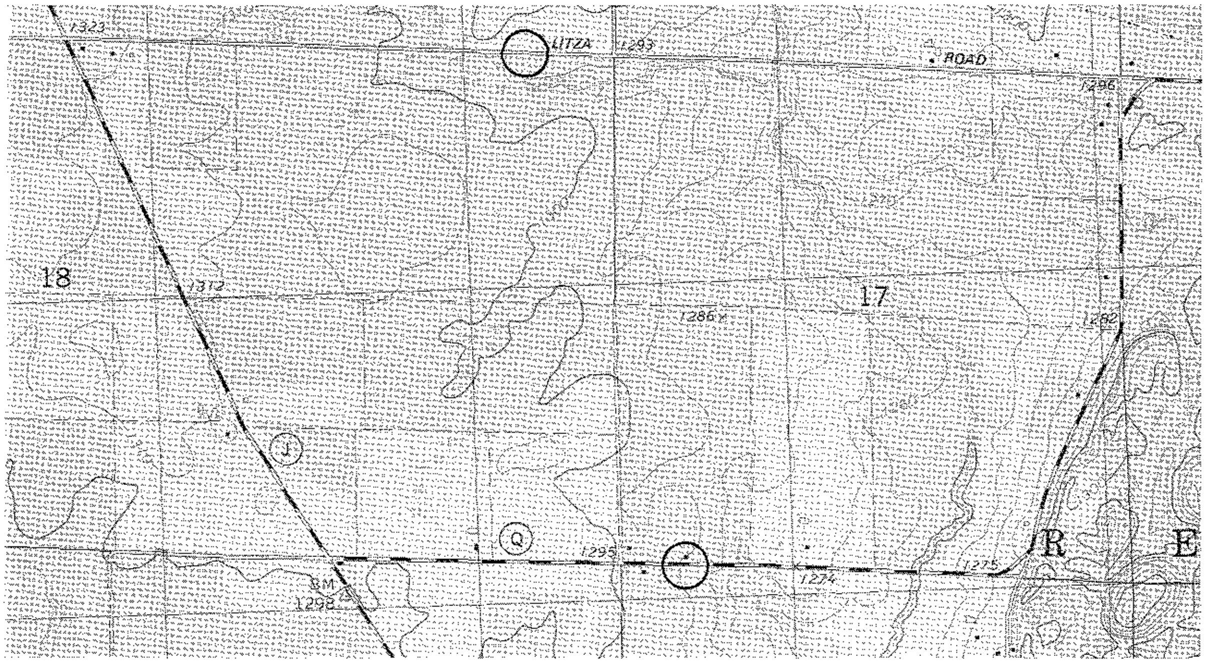
Anorthosite at the Bowler locality varies from anorthosite to gabbroic anorthosite and is intruded locally by pegmatite. The anorthosite tends to be porphyritic, with coarse-grained plagioclase phenocrysts situated in a medium-grained matrix, in which plagioclase displays well developed 120° grain boundaries. Augite is either surrounded by hornblende or replaced by an assemblage of hornblende, cummingtonite, and iron-titanium oxides, and biotite occurs on hornblende and iron-titanium oxides (fig. 10).

Figure 10. Photomicrograph of porphyritic anorthosite. Interstitial pyroxene is rimmed by hornblende, biotite occurs on opaque oxides, and the groundmass texture is a mosaic of plagioclase. Long dimension is 6 mm.

Discussion: As discussed in the introduction to this guidebook, it has been demonstrated that the three main rock types in the Wolf River batholith (granite, monzonite, and anorthosite) are not all comagmatic, although they may be cogenetic. Gnat (1984) has suggested that the anorthosite has evolved from a high-alumina tholeiite parent by means of open-system fractionation and plagioclase accumulation in a periodically replenished and tapped magma chamber. In addition, geochemical data are consistent with monzonite having been derived from anorthosite through fractional crystallization of plagioclase, hypersthene, augite, and apatite (Anderson and Cullers, 1978).

Title: Litza Road/Highway Q - foliated Wolf River batholith

Location: Roadside outcrops along Litza road and a parallel east-west stretch of County Highway Q--SE¼ (southern section line), sec. 7, T. 27 N., R. 9 E. and SW¼, sec. 17, T. 27 N., R. 9 E., Marathon County (Bevant 7½-minute topographic quadrangle).



Author: J. K. Greenberg (1986)

Description: Several good examples of what is probably Red River adamellite with strong foliation fabrics (tending to cataclastic) are shown on the Bedrock Geologic Map of Marathon County (LaBerge and Myers, 1983). This area is within 4 km of the western contact of the batholith with deformed county rocks. One of the small exposures in the road bank of Litza Road displays a well-foliated host "granite" and tectonically layered inclusions (fig. 11). The pluton's foliation here is defined by feldspar phenocrysts both aligned (undeformed) and also elongated in the plane of deformation (striking approximately N 50° to 60° E). Mafic minerals (mostly biotite) and quartz here and in many of the other exposures are also deformed. The inclusions along Litza Road are composed almost entirely of size-segregated quartz and feldspar, grains of which are elongate rectangular to rod like. Recrystallization with the annealing of preexisting strain features has been partial to complete (as seen in thin section, fig. 12). Any evidence of the inclusions' original identity has been modified by the deformation and recrystallization. A felsic volcanic rock is a likely candidate if the inclusions are xenolithic. Fragmented aplites are a possible explanation if these are autolithic inclusions.

The road bank-backyard outcrop on Highway Q exhibits a fabric which may be more indicative of igneous flow in the Red River adamellite than any subsolidus deformation. Feldspar laths here are aligned with variable orientations (average alignment near N 30° E) and there is little obvious distortion of grains. Cataclasis, therefore, is not developed here as along Litza Road or as seen elsewhere near the Wolf River batholith margin.

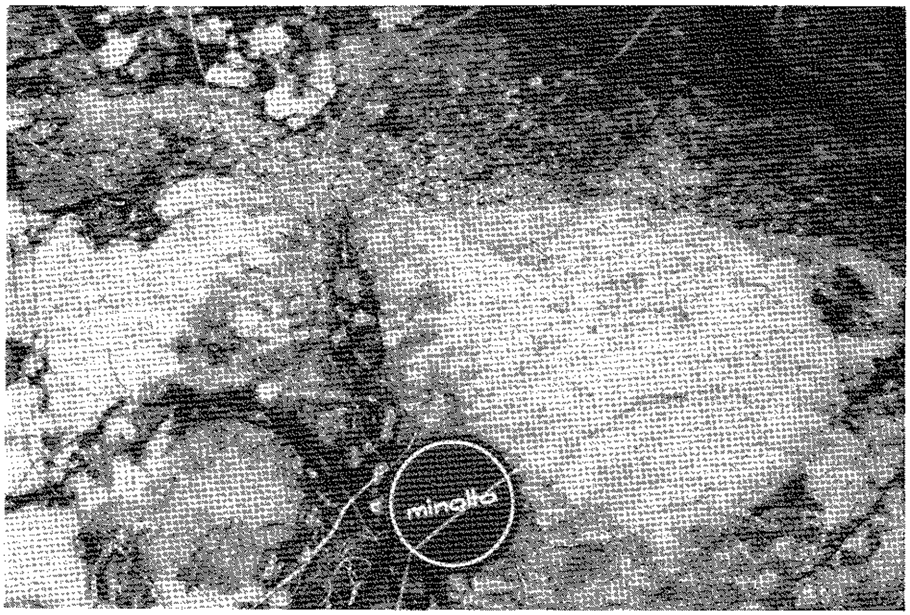


Figure 11. Litza Road outcrop of foliated Red River adamellite (?) with equivalently-foliated felsic inclusion.

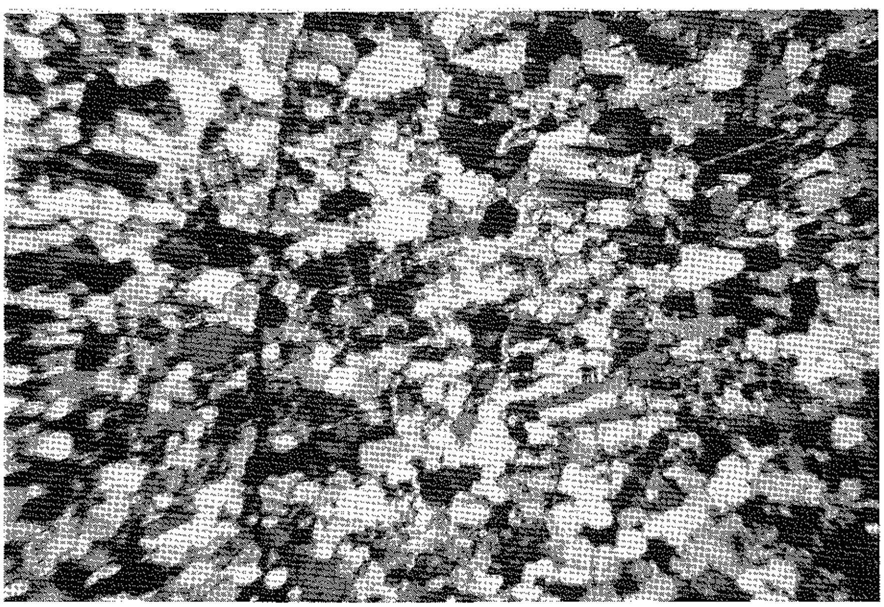
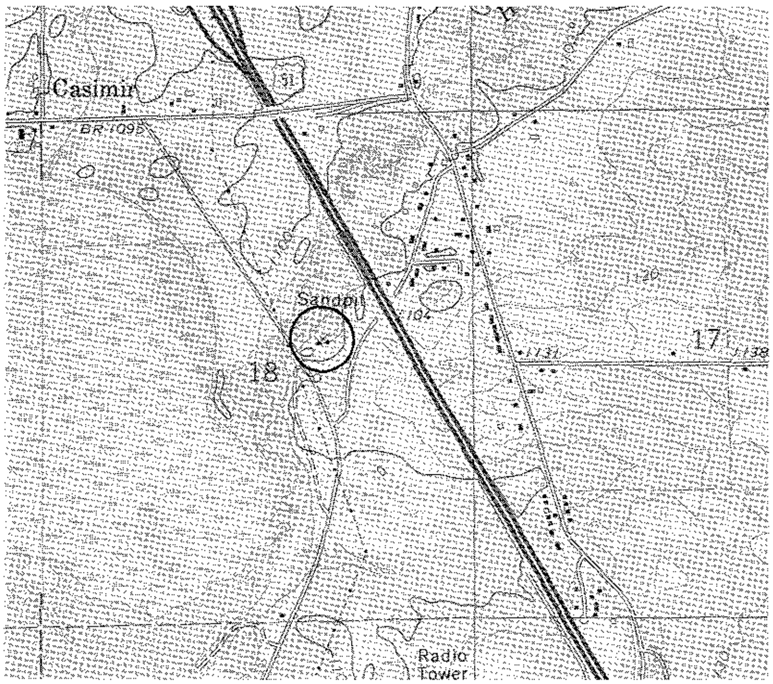


Figure 12. Photomicrograph of felsic inclusion from Litza Road outcrop. The foliation fabric has been preserved after recrystallization.

Title: Casimir Sand Pit - Red River Adamellite

Location: Road side pit near the center of sec. 18, T. 24 N., R. 8 E., about 0.5 km from U.S. Highway 51, Portage County (Stevens Point 7½-minute topographic quadrangle).



Author: J. K. Greenberg (1986)

Description: A post-Cambrian (Pleistocene most likely) eolian erosion surface is exposed in the sand pit south of Casimir. At present, only unconsolidated sand and ventifacts remain as vestiges of a Cambrian basal conglomerate. The underlying Precambrian basement in the form of Wolf River batholith granitic rocks is still intact although wind blasted and frost heaved. Several variants of the Red River adamellite occur together at this location. Medium- to coarse-grained porphyritic granite is the dominant rock type, but pegmatites, including some that are zoned with quartz cores (fig. 13) are also abundant. Other less common types include a feldspar cumulate and aplites. Intrusive relationships among the various rock types are complex with pegmatites probably youngest and aplites typically occurring as reacted inclusions in porphyritic variants.

The pit exposure is within about 3 km of the mapped contact between the Wolf River batholith and older plutonic rocks (Greenberg and Brown, 1986a). In spite of the proximity to the batholith's margin, only a weak structural fabric is evident here. Feldspar phenocrysts are crudely aligned along a N 70° E trend. In two places where it could be measured, a second foliation striking N 50° W is defined by subtle orientations of matrix biotite and quartz. The second northwest-trending foliation is roughly parallel to the batholith margin at this location. The same foliation trend is also evident in an adjacent metagabbro or country-rock about 5½ km west of the pit.

Figure 13. Float block of quartz-cored pegamatite in the Casimir sand-pit exposure.

Discussion: A speculative explanation for the two foliations in the pit may be that the phenocryst alignment represents original igneous-flow conditions, whereas the matrix was only later deformed after magmatic crystallization was complete. Of all the rock types in the pit, only the aplitic inclusions exhibit significant recrystallization. The fact that the two foliations are weakly developed here may be related to the general lack of recrystallization.

Recrystallization is a nearly pervasive phenomenon associated with rocks near the margin of the Wolf River batholith. This conclusion has been made for many country-rock units (Greenberg and Brown, 1986b) and has also proven true for inclusions in the Wolf River batholith as well as for some marginal phases of the batholith itself. The recrystallization textures are commonly manifested in relatively strain-free mosaic fabrics. In many cases, recrystallization has not been complete and earlier cataclastic and/or intergranular-reaction textures are still evident. It may be reasonably inferred that the heat of intrusion from the batholith directly facilitated the observed recrystallization. It is perhaps less obvious whether or not many of the other features indicative of metamorphism and deformation near the Wolf River batholith are intrusion related (Greenberg and Brown, 1986b). At Waupaca, (Stop 1) the interpretation of batholith-related tectonism is certainly tenuous. Along Litza Road and Highway Q in Marathon County (Stop 5) and here in the Casimir pit exposure the cause and effect relationship between batholith intrusion and deformation-recrystallization is much more certain.

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PART II - THE BARABOO INTERVAL ROCKS OF CENTRAL WISCONSIN

Introduction

The second day of the field trip will be spent examining rocks of the Baraboo interval (1760-1500 Ma). Outcrops have been selected to illustrate the diversity of sedimentary rocks deposited during this time, and to show the relationship of the sediments to contemporary intrusive and extrusive igneous rocks as well as to older basement rocks.

The Baraboo interval was named by Dott (1983) for the classic outcrops of Proterozoic quartzite around Baraboo in south-central Wisconsin (fig. 14). Dott originally defined the Baraboo interval as a period of widespread continental to shallow marine sedimentation during which some of the earliest red-bed sequences were deposited. The interval was defined from a sedimentological/stratigraphic perspective, based on Dott's work on the Baraboo, Barron, and Sioux Quartzites.

Greenberg and Brown (1983, 1984) redefined the Baraboo interval as a period of anorogenic magmatic and sedimentary activity which took place on continental crust stabilized after the Penokean orogeny (1850 Ma). Baraboo interval sedimentation was an integral part of a series of anorogenic tectonic events which began with the eruption of rhyolites and emplacement of related granitic rocks at about 1760 Ma (Smith, 1978; 1983), continued with clastic sedimentation, regional uplift and deformation (1630 Ma), and ended with 1500 Ma magmatism (Wolf River batholith). This series of events is interpreted to be part of a general process of "cratonization" which affected the crust after orogenesis here in Wisconsin and in other areas worldwide (Greenberg and Brown, 1984; Rogers and others, 1984).

Baraboo Interval Sedimentation

At the time the Baraboo interval was first defined (Dott, 1983), it was thought that the Baraboo, Barron, and Sioux Quartzites, predominantly red quartz arenites, were, with the exception of slates and carbonate iron formation from the top of the Baraboo section, the dominant, if not only, important rocks representative of this period. Mapping in central Wisconsin has shown that a diverse suite of rocks, including argillaceous rocks, iron formation, bedded chert, and micaceous or feldspathic quartzites and conglomerates are also important constituents of the Baraboo interval stratigraphic record (Brown, 1986).

Based on his study of the orthoquartzites, Dott (1983) interpreted the Baraboo sediments as predominantly fluvial deposits formed in a coastal plain environment which was succeeded by a shallow marine environment. The marine transgression is represented by the argillaceous and chemical sediments of the upper part of the Baraboo section. Dott visualized the Baraboo, Barron, and Sioux quartzites as a broad sand blanket, much like the Cambrian sandstones of the region. Greenberg and Brown (1984) suggested two alternative models for Baraboo interval sedimentation based on their observation that lithologies other than orthoquartzite were more widely distributed than previously known. In particular, the occurrence of marine sediments overlying older basement without a significant underlying orthoquartzite section introduced a complexity that could not be explained by the sand blanket model of Dott (1983).

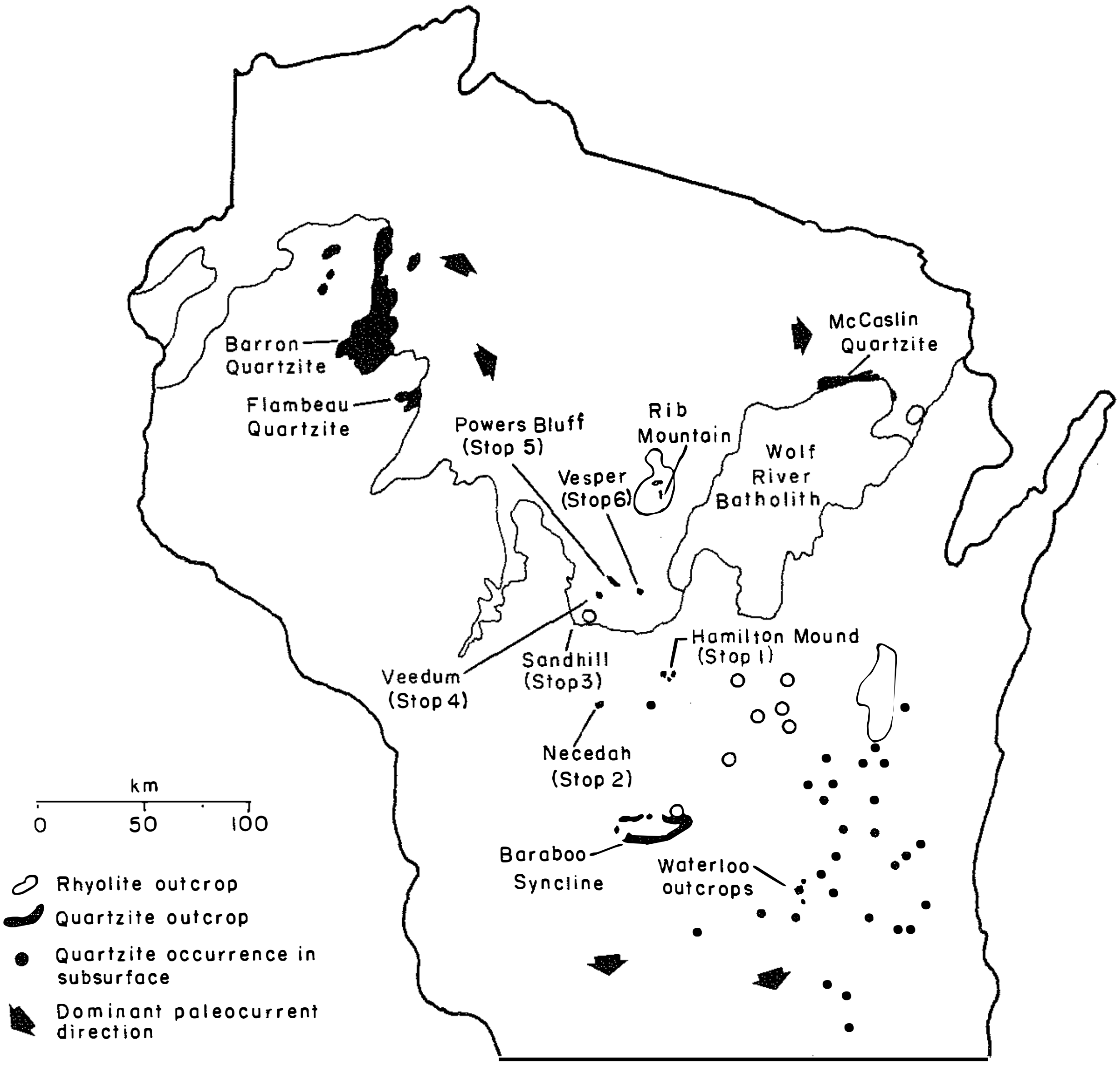


Figure 14. Map of Wisconsin showing location of Baraboo interval rocks.

The observed stratigraphy of Baraboo interval rocks in Wisconsin may be better explained by a complex basin/marine transgression model in which thick orthoquartzites accumulated in local basins, controlled by basin and range-type faulting (Greenberg and Brown, 1984). The entire region was subsequently covered by the transgressing marine environment which deposited argillaceous and chemical sediments in central Wisconsin and above the orthoquartzites at

Baraboo. This model, (fig. 15a) is consistent with the observation that marine facies directly overlie basal conglomerate and volcanogenic sediments in central Wisconsin whereas orthoquartzite was deposited both in the north (McCaslin, Rib Mountain, Barron) and in the south (Baraboo, Waterloo, southeast Wisconsin subsurface). At the time the orthoquartzites were deposited, central Wisconsin was a positive area where only locally derived sediments accumulated until late in the period of sedimentation, when marine conditions covered this region. Morey (1984) has suggested that deposition of the Sioux Quartzite of Minnesota may also have been controlled by local fault-bounded basins.

Additional support for the complex basin model is provided by limited paleocurrent data (Olson, 1984). Measurements in northern Wisconsin (Barron, McCaslin) suggest eastward transport in the quartzites, those in the south (Baraboo, Sioux) suggest southward transport (fig. 1). A regional southward transport would be expected in a fluvial dominated coastal plane with source to the north and shoreline to the south. Paleocurrent data for the Barron (Johnson, 1985) indicate a change to a bipolar-bimodal pattern in the upper part of the section, consistent with transition to tidal-dominated shallow marine conditions.

Rb-Sr dating of biotites in northern Wisconsin by Peterman and others (1985) suggests that periodic uplift of crustal blocks occurred in the region throughout Baraboo interval time. At present, evidence is accumulating which favors deposition of the Baraboo interval sediments on relatively unstable crust subject to epeirogenic activity, rather than a stable continental margin coastal plane (Greenberg and Brown, 1984; Rogers and others, 1984).

Greenberg and Brown (1984) introduced a second model which involved multiple sedimentary sequences. In this model (fig. 15b), the marine and volcanogenic sediments of central Wisconsin would represent an early sequence, partially removed by erosion. These rocks were in turn covered by the fining-upward transgressive sequence described by Dott (1983). The distribution of lithologies seen today is the product of erosion and later uplift, in which overlying orthoquartzites were removed from central Wisconsin. The complex basin model is favored for reasons already presented, in particular the marked similarity of the cherty, argillaceous, and ferruginous sediments of central Wisconsin to the Seeley and Freedom formations at Baraboo, which in the multiple sequence model would belong to a younger depositional series. Because the Baraboo interval lasted over 200 Ma, and a small fraction of these sediments are exposed, the possibility of multiple sequences cannot be dismissed. Also, no evidence has been found to suggest a major unconformity of regional extent within the Baraboo interval sequence. However, more work needs to be done before a comprehensive sedimentary/tectonic model can be proposed.

Structure of the Baraboo interval rocks

Very little is known about the regional structural geology of the Baraboo interval rocks. Detailed structural studies have only been conducted on the rocks of the Baraboo Syncline. Most of these studies have been concerned primarily with the evolution of the syncline and the problems of deformation mechanics and cleavage development (Van Hise, 1893; Dalziel and Dott, 1970; Jank and Cambray, 1986; Hempton and others, 1986). The timing of the folding of the Baraboo interval rocks has remained uncertain. It is commonly thought to have occurred around 1630 Ma, a time of widespread disturbance of Rb-Sr ages in the region (Van Schmus and others, 1975). It is known that deformation occurred prior to regional 1500 Ma magmatism, based on the age of pegmatite dikes which cut folded quartzite at Waterloo, and the occurrence of deformed quartzite in the Wolf River batholith and related rocks (Brown, 1986).

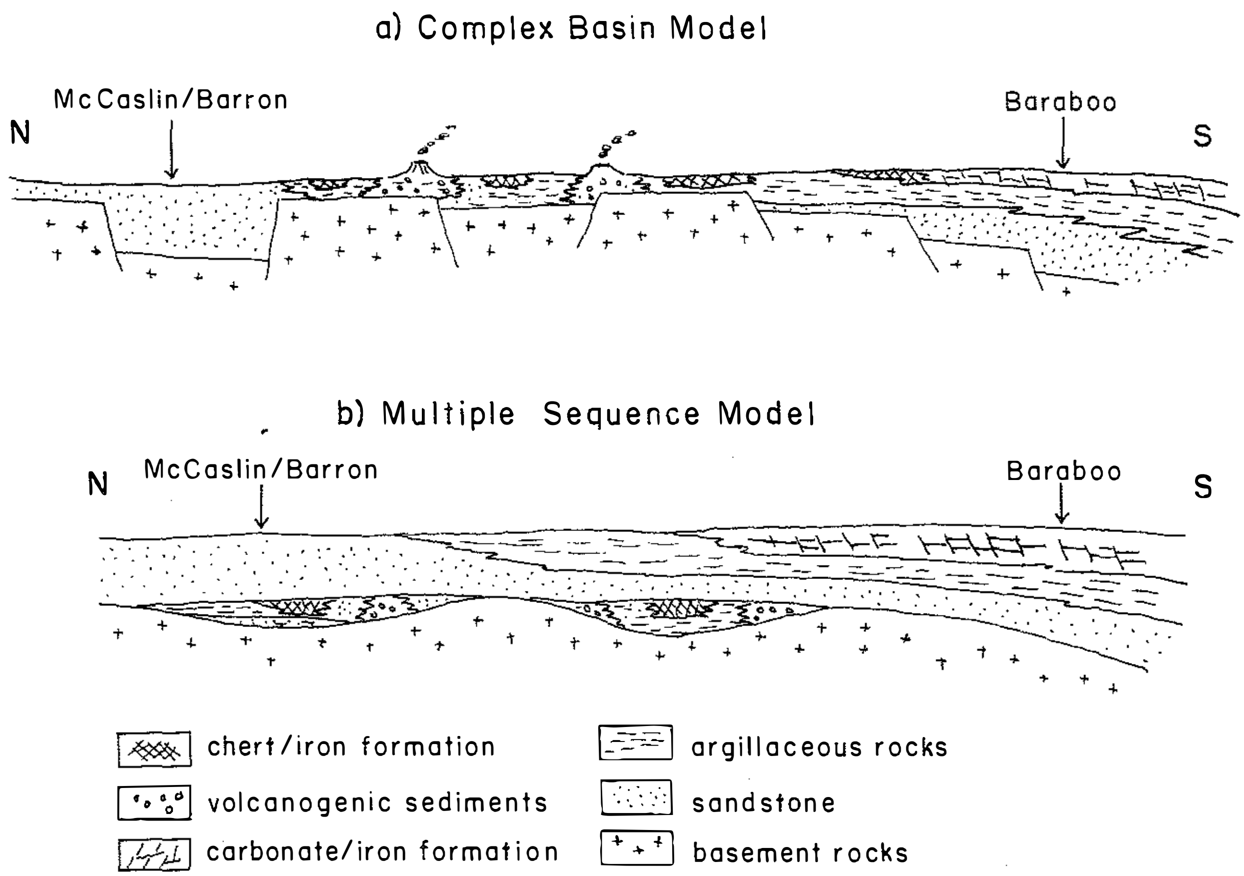


Figure 15. Models for deposition of Baraboo interval rocks.

Figure 16 is a summary of what is known from outcrop data and geophysics of regional structural trends in the Baraboo interval rocks of Wisconsin. Two striking features of this map are the increase in intensity of deformation from west to east, and the distribution of structures with respect to the area of central Wisconsin underlain by the 1500 Ma Wolf River batholith. This and other evidence suggests that deformation of the Baraboo interval rocks and the 1500 Ma magmatism may be related (Brown and Greenberg, 1981, 1982; Greenberg and Brown, 1984). The Baraboo rocks may have been folded by a thin-skin mechanism in which these rocks slid off of a major crustal uplift in central Wisconsin at 1630 Ma, which was a precursor to the 1500 Ma magmatism. This idea is consistent with the distribution of structures and the southward overturning of the Baraboo Syncline, and may be ultimately testable by deep drilling (Brown and others, 1984).

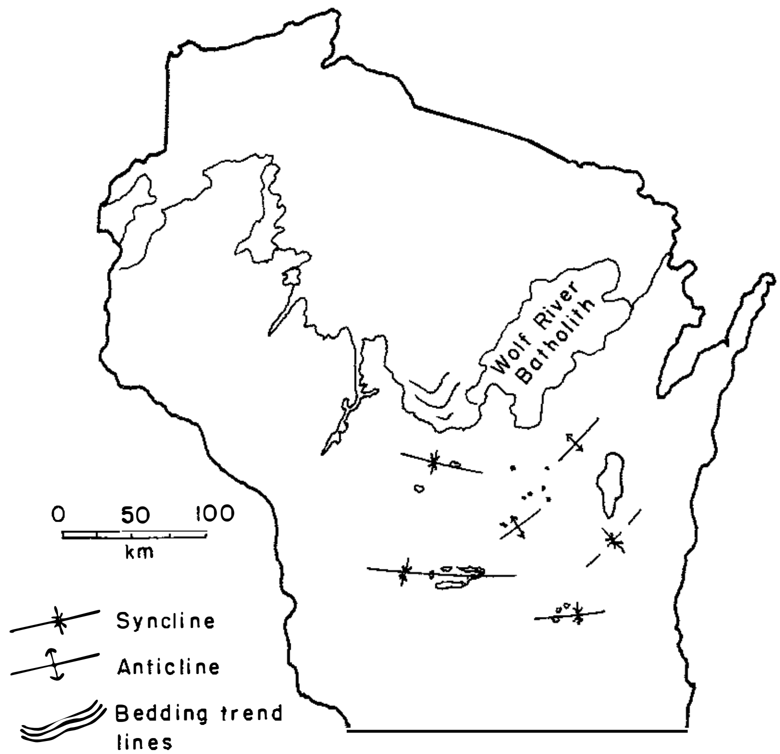


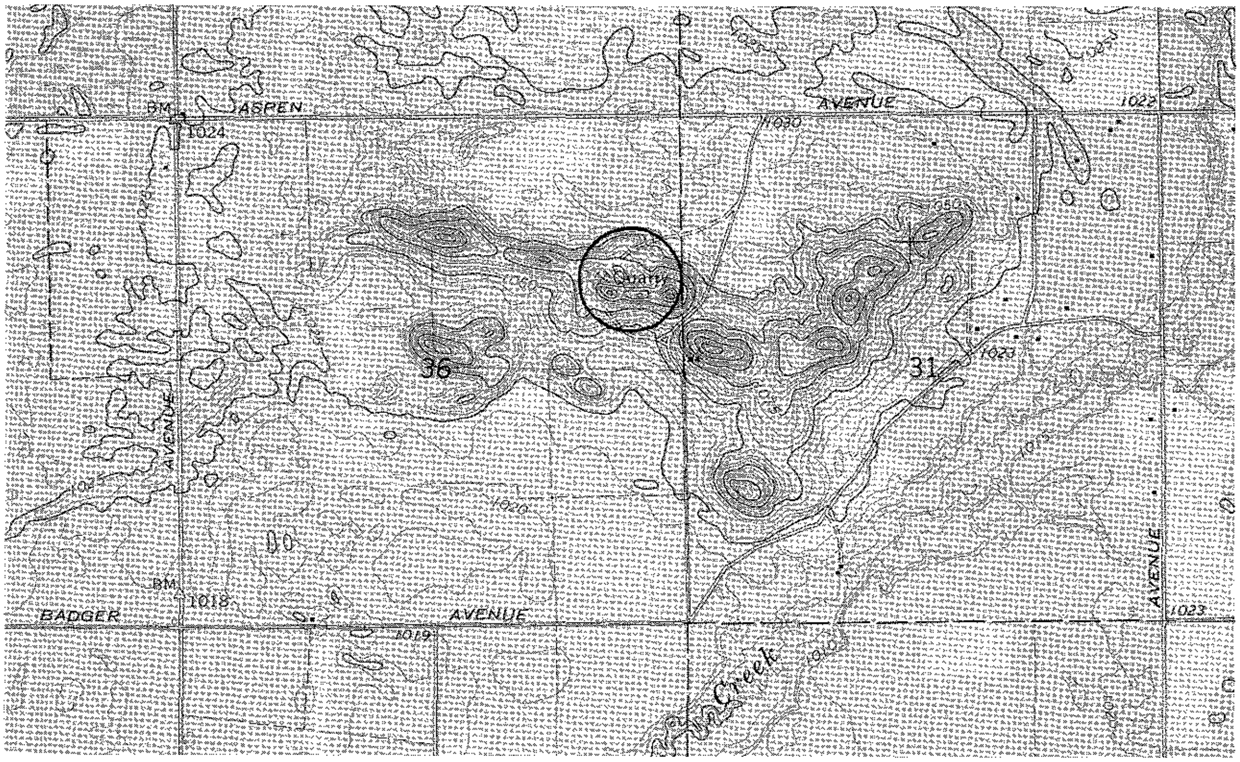
Figure 16. Major structures in the Baraboo interval rocks.

The Field Trip

The six planned stops will provide an overview of the Baraboo interval rocks of central Wisconsin. Stop 1, Hamilton Mound, illustrates typical Baraboo-type red orthoquartzite folded and intruded by a 1760 Ma granite. Stop 2, Necedah is another example of intruded quartzite, which provides a classic example of brecciation and the effects of contact metamorphism. Exposures in the Sandhill refuge (Stop 3), provide a look at quartzite in contact with 1760 Ma(?) rhyolite, and some excellent examples of rhyolite textures. Stop 4, the Veedum area, exposes what is thought to be locally derived basal Baraboo interval beds overlying 2800 Ma, Pittsville gneiss, one of the oldest rocks in the region. Stop 5 provides a rare opportunity to look at the argillaceous and cherty sediments of the Baraboo interval at Powers Bluff. Stop 6 is a probable basal contact of the quartzite overlying early Penokean granite in an abandoned quarry near Vesper.

Title: Hamilton Mound

Location: 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 SE¼, NE¼, Sec. 36, T. 20 N., R. 6 E. (Coloma NW, 7½-minute topographic quadrangle).



Authors: B. A. Brown and J. K. Greenberg (1986)

Description: Hamilton Mound is an inlier of folded Proterozoic quartzite similar to the Baraboo Syncline and the Waterloo area exposures. Quartzite is exposed on a series of low hills. Upper Cambrian sandstone of the Elk Mound Group overlaps the quartzite and is exposed on the slopes. A quarry developed in the Quartzite exposes a granite intrusive into the quartzite and an unusual zone of contact metasomatism and alteration within the quartzite.

Quartzite

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

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

Structural Features

The macroscopic structure of the Hamilton Mound exposures was mapped by Ostrander (1931) who identified four N 75° W trending major folds (fig. 17). The roughly east-west axial trend is similar to that of the Baraboo Syncline and the Waterloo area. Other structures, including distortion of bedding, several sets of fracture cleavage, foliation, shear zones, and zones of brecciation are well developed in the area of the granitic intrusion (fig. 18) and increase in intensity as the intrusive contact is approached. The intensity of deformation is evident in thin section (fig. 19) where quartz grains become highly strained.

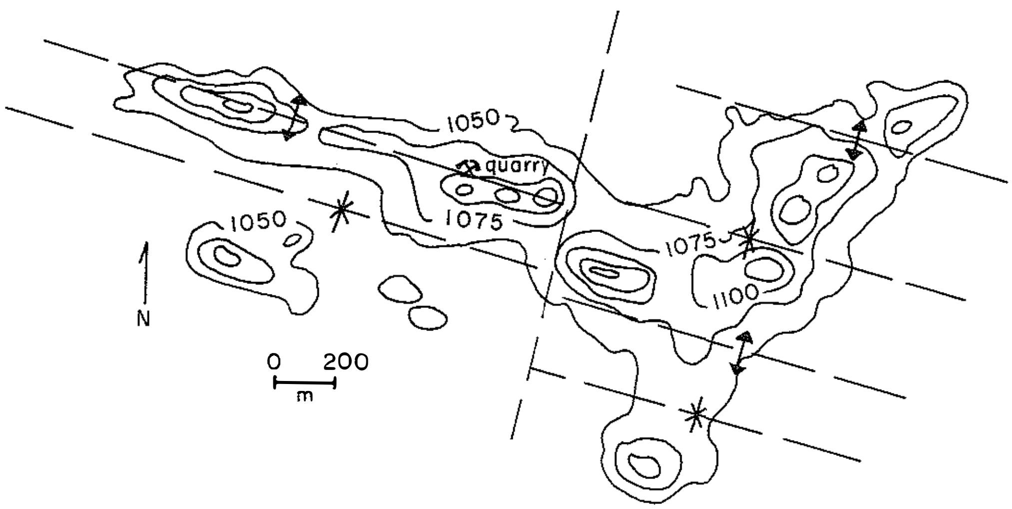


Figure 17. Major structures at Hamilton Mound (after Ostrander 1931).

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

The Intrusive Rocks

From the present extent of exposure, there is no certain way of knowing the original igneous character of the granitic intrusion at Hamilton Mound. Contaminated igneous material is of two types. The more original appearing rock is 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. 20). 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.

Figure 18. Excavation face at Hamilton Mound quarry showing steeply dipping beds in quartzite cut by nearly horizontal fracture cleavage.

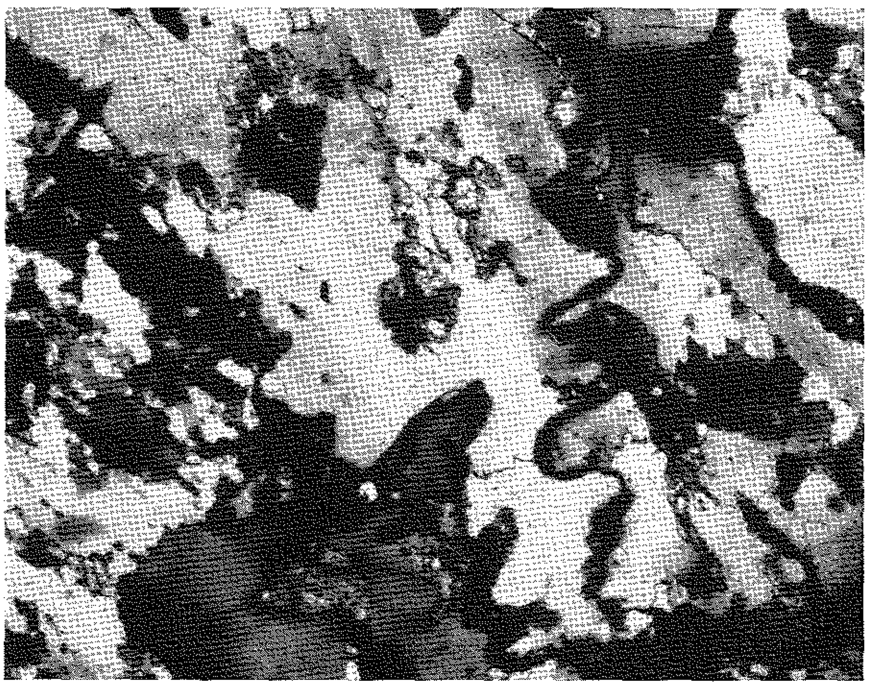


Figure 19. Micrograph of intensely deformed quartzite from near the intrusive contact. Note microstylolite developed between quartz grains. Long dimension is about 6 mm.

Chemical analyses of samples of the porphyritic granite are consistent with a granitic intrusion contaminated by mafic and aluminous material. (Taylor and Montgomery, 1986). Initial U-Pb zircon data from the porphyritic granitic rock suggest 1760 Ma (W. R. Van Schmus, unpub. data) as a possible age. Ths age would further establish a link between Baraboo-interval sedimentation and 1760 Ma magmatism. Rb-Sr analyses (Taylor and Montgomery, 1986) indicate that whatever the original age, the granite at Hamilton Mound was isotopically reset at 1585 ± 30 Ma, an age overlapping the uncertainties of both the 1630 Ma regional disturbance and the 1500 Ma (Wolf River) episode of anorogenic magmatism.

Figure 20. Micrograph of contaminated porphyritic granite. Note strained quartz and chlorite surrounding feldspar phenocrysts. Long dimension is about 8 mm.

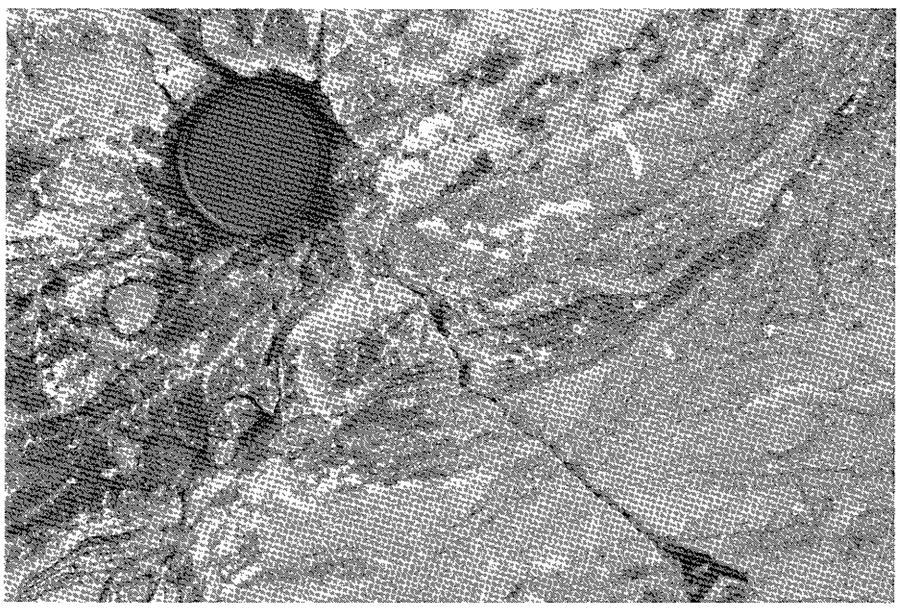


Figure 21. Distorted laminations and inclusions with reaction rims, from the quartzite-intrusion mixing zone at Hamilton Mound. Lens cap is 5 cm in diameter.

At the west end of the quarry, quartzite and magma appear to be very complexly mixed. The gray foliated rock which is exposed here ranges from a highly deformed micaceous quartzite into a very quartz-rich banded rock containing large amounts of fresh fine-grained feldspar (microcline and plagioclase), biotite, and less common hornblende near the granite. In this zone of transition or mixing, fine banding with the appearance of sedimentary laminations, becomes contorted and indistinguishable from tectonic foliation (fig. 21). 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 Ma 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, 1986; Greenberg, 1986). These observations, along with the extensive brecciation, suggest both a forceful intrusion and a substantial chemical interaction between magma and overlying quartzite.

A definite influence of granitic intrusion on the quartzite is color alteration. Although Hamilton Mound quartzite away from the intrusion is characteristically pink-red (as seen on the ridge southeast 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 in the contact zone of the Baxter Hollow granite at Baraboo (Greenberg, 1986).

Sandstone

A thin cap of sandstone sits atop poorly exposed quartzite along one wall of the quarry (fig. 22). This sandstone, like most other exposures in the area, is correlated with the Upper Cambrian Elk Mound Group. The sands are interpreted as having been deposited on a topographic high of the eroded Precambrian rocks.

Just above the quartzite, the sandstone is very poorly sorted with alternating beds of rubbly conglomerate and finer sand beds (fig. 22). 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 described in the Baraboo area by Dalziel and Dott (1970). The Hamilton Mound inlier probably stood above sea level as small islands or stacks during deposition of the flanking sandstone.

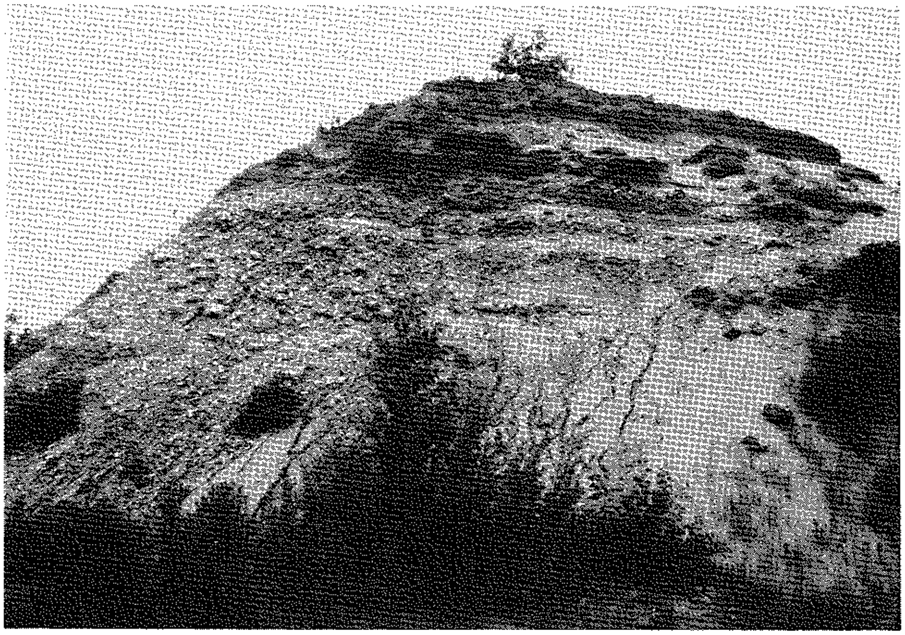
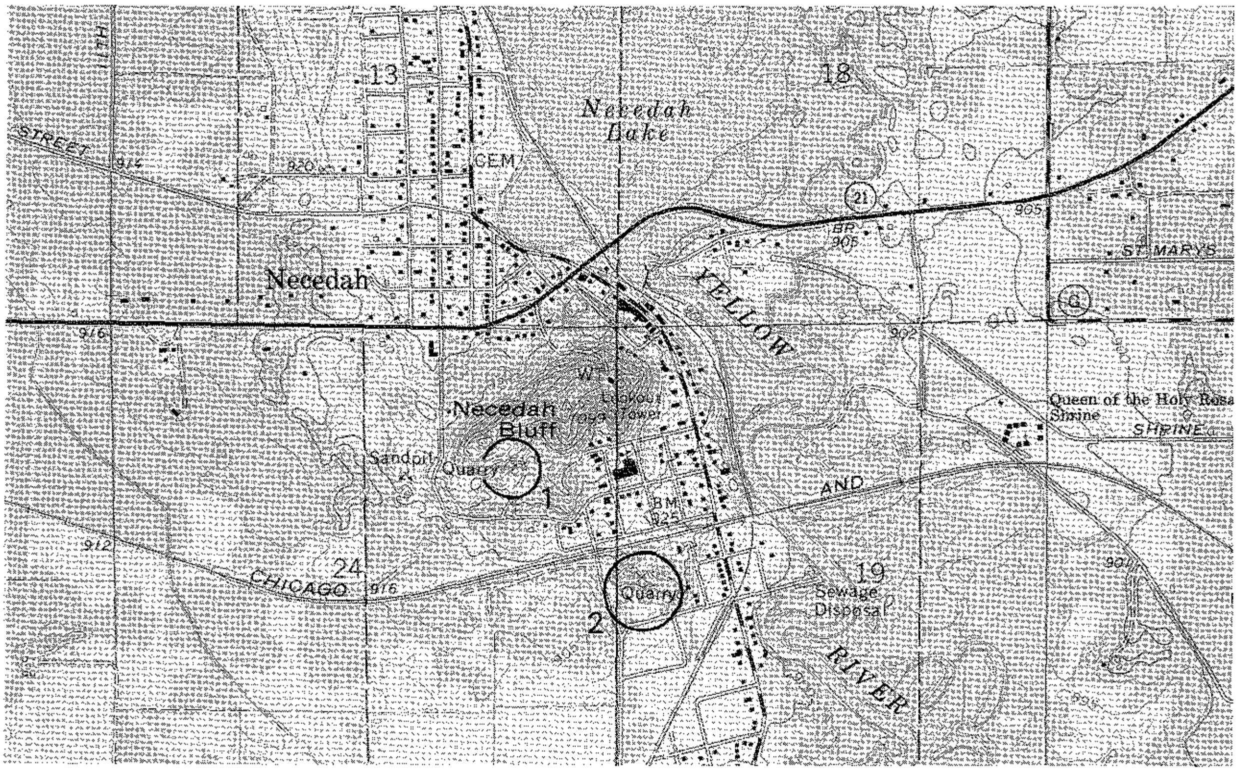


Figure 22. Excavation face at Hamilton Mound quarry showing quartzite blocks in Cambrian sandstone overlying quartzite. Sandstone beds become more regular and flaggy to the right of the photo, quartzite bluff is to left. Horizontal dimension is about 10 m.

Title: Necedah quartzite

Location: NE¼, Sec. 24, T. 18 N., R. 3 E., and NW¼, Sec. 19, T. 24 N., R. 4 E. (Necedah 7½-minute topographic quadrangle).



Author: B. A. Brown (1986)

Description: Necedah Bluff is a hill of quartzite which rises 60 m above the surrounding sand plain, formerly the bed of glacial Lake Wisconsin. Quartzite is exposed on the flanks of Necedah bluff, and in a large quarry on the southwest end of the bluff (locality 1). Quartzite is also exposed in an abandoned quarry on a small hill south of the Chicago & Northwestern railway tracks (locality 2), 0.5 km south of the bluff, and in a series of small knobs between Highway 80 and the Yellow River (locality 3).

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 coloration. The gray to green and black colors are caused by a reduction of iron by an intrusive granite, as at Hamilton Mound. Bedding is largely obscured in the bluff exposure due to intense brecciation, but at localities 2 and 3 it strikes east-west and dips steeply (80°) to the north. The only primary sedimentary structure identified at Necedah is cross bedding (fig. 23), the most common primary structure of the Baraboo interval quartzites in Wisconsin. In thin section the quartzite appears to have originally been a medium- to fine-grained sandstone which has been completely recrystallized. Most grains show sutured boundaries and varying degrees of strain. Muscovite and sericite are commonly present between grains. Veins of secondary quartz, some containing euhedral feldspars, commonly cut the quartzite.

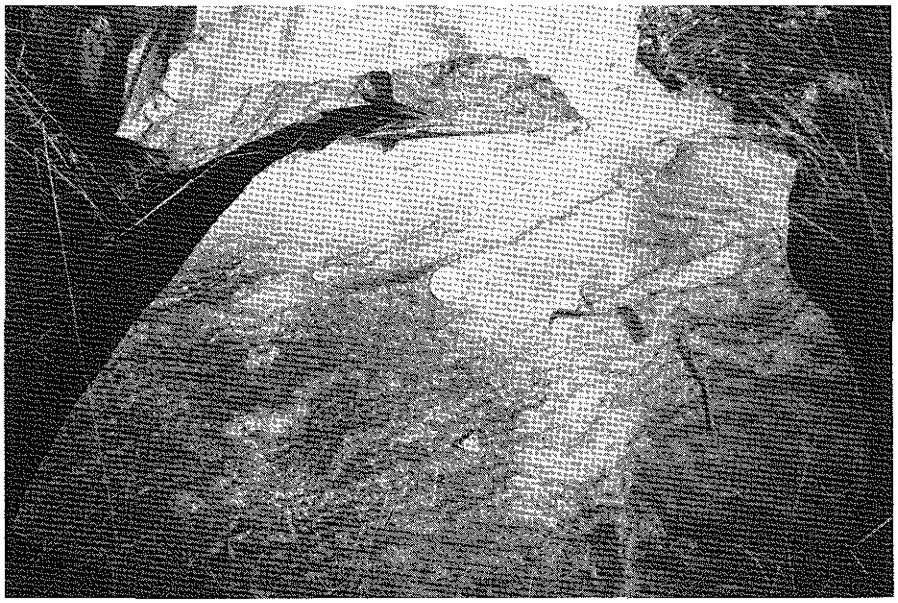


Figure 23. Distorted cross-bedding in quartzite (locality 2). Quarter for scale.

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 breccia consisting of angular quartzite blocks up to 30 cm across, floating in a matrix of white vein quartz (fig. 24). Vugs in the breccia are filled with white clay and euhedral quartz crystals. Similar breccias, considered by Greenberg (1986) to be hydrothermal phenomena associated with granitic intrusions, are observed at Baraboo, Hamilton Mound, Waterloo, and at several minor exposures in Wood and Clark Counties.

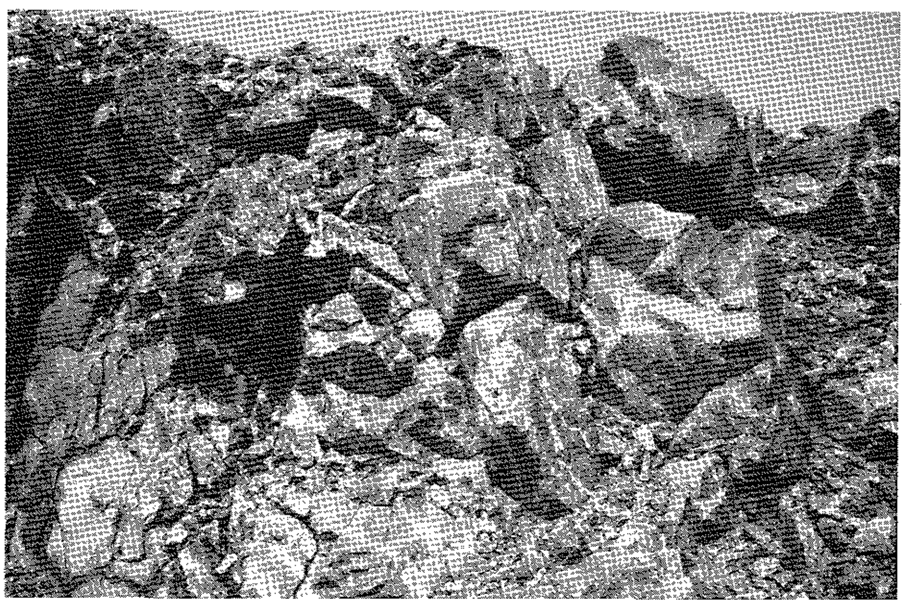


Figure 24. Quartzite breccia in bluff quarry (locality 1). Note abundant white vein quartz which forms matrix.

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 is exposed at Necedah, several large blocks in the Bluff quarry (locality 1) consist of an intrusion breccia of quartzite clasts in a pink granitic matrix (fig. 25). These blocks were probably removed from the quarry floor from the last area of active quarrying, now unfortunately covered by stockpile. 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 intrusion breccia indicate the presence of an intrusion into the quartzite much like the situation at Hamilton Mound (Stop 7). Efforts are currently (1986) being made to date the granitic phase of the intrusion breccia.

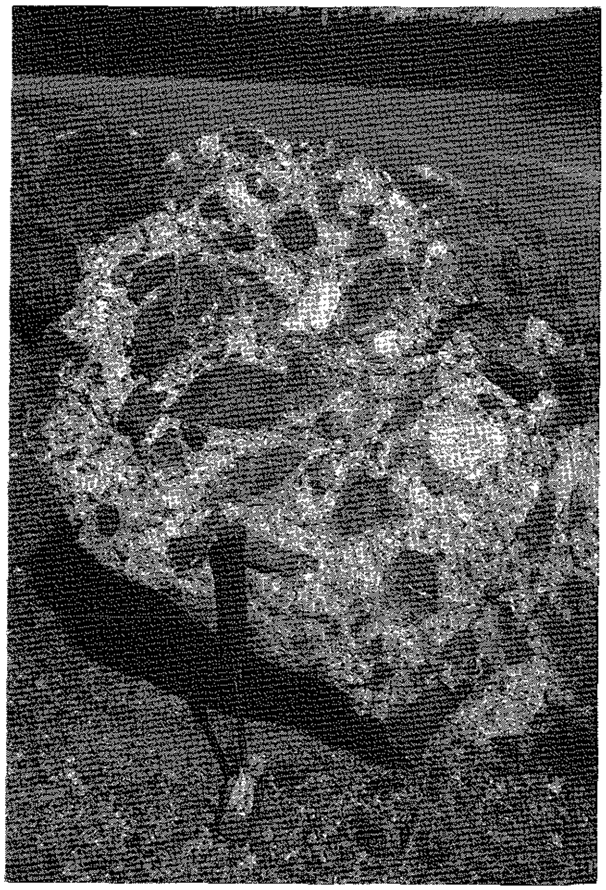
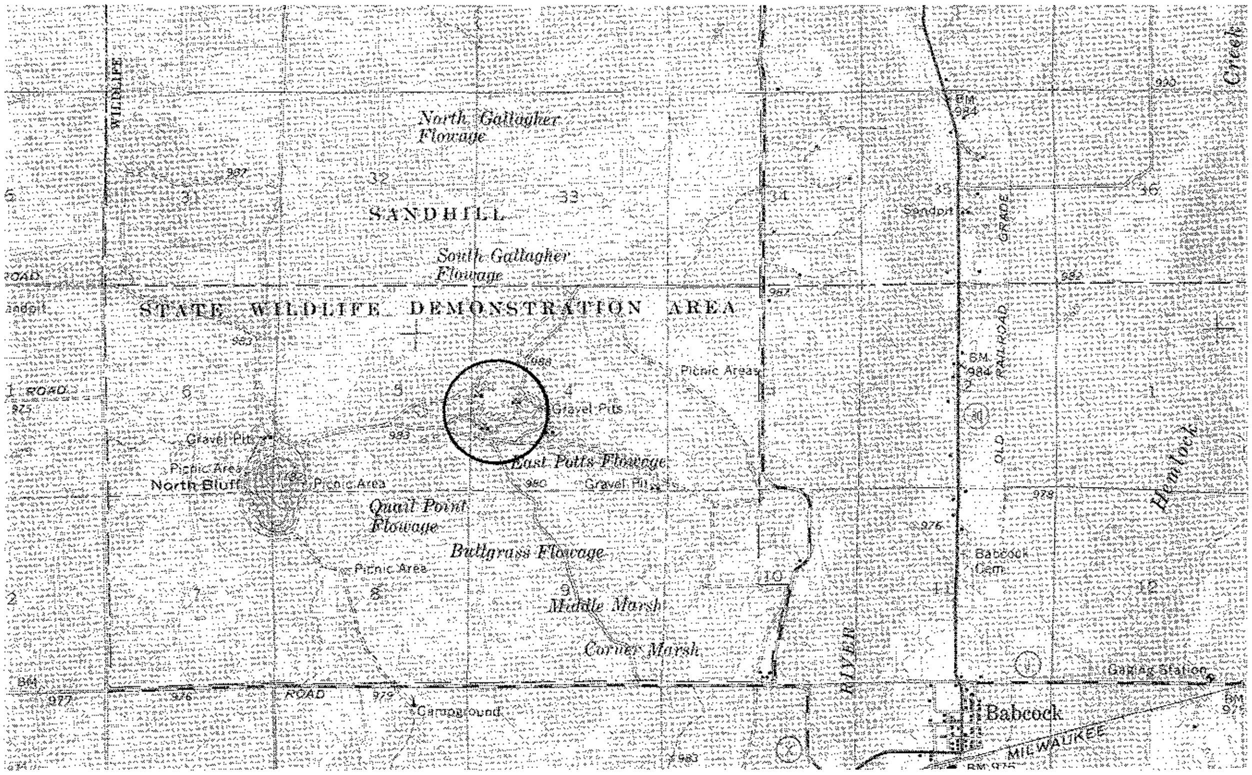


Figure 25. Intrusion breccia of dark quartzite fragments in pink granitic matrix.

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 1) and Sandhill (Stop 3).

Title: Sandhill Wildlife Refuge

Location: Sand pit about 4 km northwest of visitor entrance, NW¼, SW¼, Sec. 4, T. 21 N., R. 3 E. (Quail Point Flowage 7½-minute topographic quadrangle).



Authors: J. K. Greenberg and B. A. Brown (1986)

Description: 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 this exposure is the direct contact of subaerial rhyolite and Baraboo interval quartzose metasedimentary rocks. At Baraboo the two units are typically separated by a covered zone of several metres. There is also an excellent example of Cambrian sandstone lapping upon the Precambrian rocks in the Sandhill pit (Fig. 26).

The Rhyolite

The volcanic rocks at Sandhill are rhyolite with abundant preserved volcanic textures and quartz-sericite mineralogy. A general correlation can be made between this rock and 1760 Ma rhyolites exposed to the south and east in central Wisconsin (Smith, 1978). The rhyolite occurs both as a massive flow-banded rock and breccia. Lithologic variation, banding, and a weakly developed foliation are nearly parallel, strike N 80° E and are vertical to dipping 75° NW. The foliation is defined by the orientation of sericite and fine muscovite grains. Quartz veins commonly transect the banding.

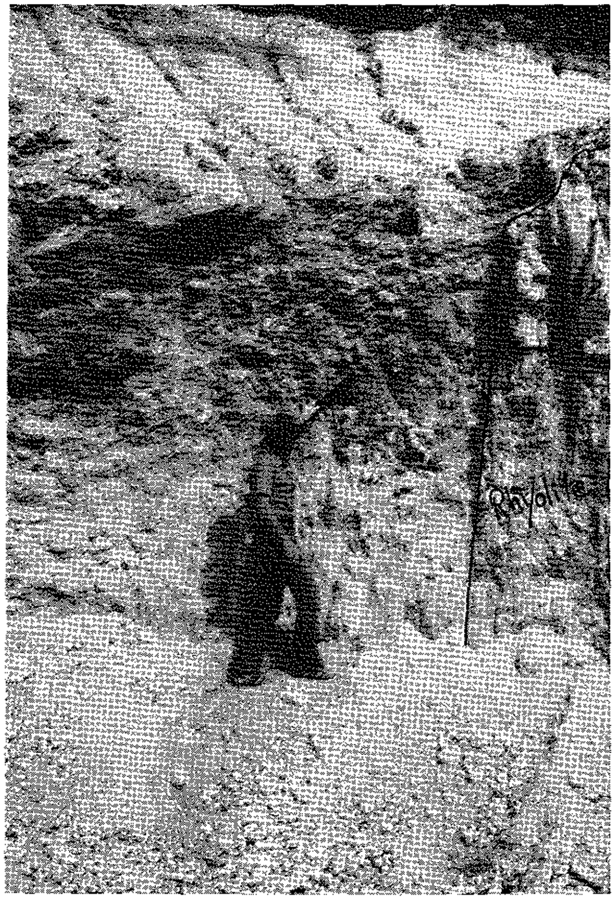


Figure 26. Pit face at Sandhill showing unconformable contact between steeply dipping rhyolite breccia and overlying Cambrian sandstone.

Sandhill rhyolite is distinctly weathered and colorful with rose pink flow-banded rocks and light to dark gray matrix in breccias. Exposed surfaces commonly 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. Montogomery, 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. 27), may have significance in this regard. These might be late magmatic features related to gaseous fluid activity and brecciation.

A weak 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. 28). Quartz veins are abundant and do not appear to be recrystallized. Fine-grained sericite 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. Chemically, this rhyolite is silicic (74.8% SiO_2), very potassic (8.2% K_2O), and Rb-rich (376 ppm). It contains relatively low abundances of Al_2O_3 (11.0 %) and CaO (.10%) and is extremely depleted in Na_2O (.21%) and Sr (4 ppm). The latter two values may reflect selective alkali mobility.

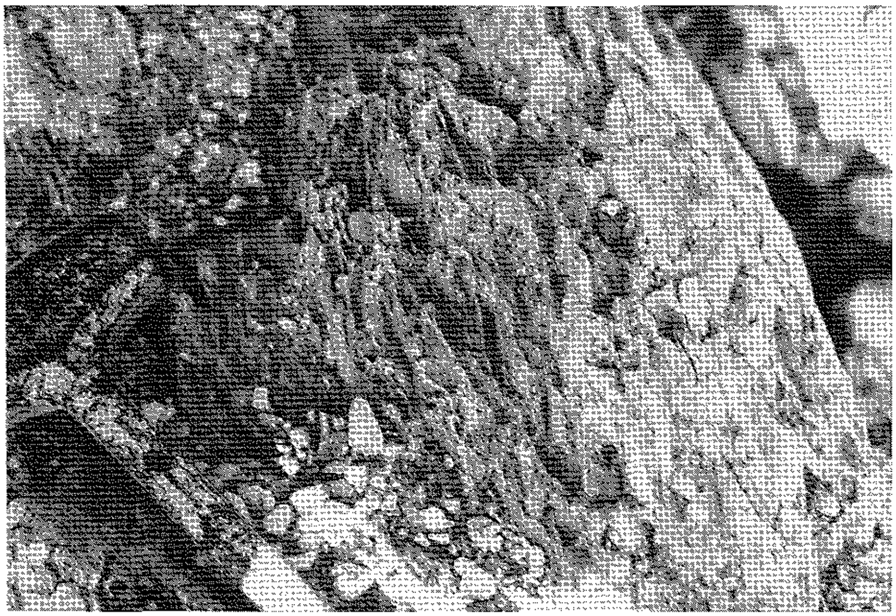


Figure 27. Tube-like voids in Sandhill rhyolite.

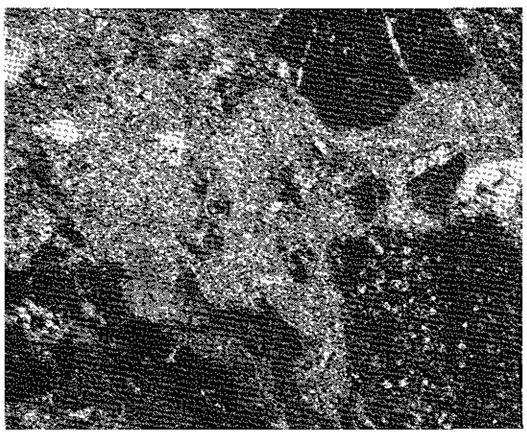


Figure 28. Micrograph of rhyolite breccia, volcanic fragments in quartz-rich matrix. Long dimension is about 8 mm.

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 6; Veedum, stop 4; Baxter Hollow, Baraboo; Dake Quartzite, Baraboo). Bedding can be distinguished on the basis of variation in grain-size and color. Thin pebbly beds are often interlayered with finer-grained beds. Quartzite at the contact with rhyolite is generally more micaceous. There is no reason to suspect that the contact represents an unconformity 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 show evidence of metamorphism beyond the lower greenschist facies. Evidence from this exposure implies that rhyolite volcanism was soon followed by deposition of quartzose sediments in this area during the Baraboo interval and that both units were probably deformed together.

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

As at Hamilton Mound, 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 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 spherulitic rhyolite and distinct purple-pink blocks of chert--another common Baraboo interval rock in this region. There are also rounded clasts of rhyolite, quartzite, and vein quartz of various sizes, all floating in poorly sorted sand and clay.

Away from the unconformity, certain beds in the sandstone are fairly well sorted. These include beds 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 contrast with the nature of the Cambrian sandstone. Contrasting maturity may support the concept that the weathering was different in the Early to Middle Proterozoic than it was in the Paleozoic, but not necessarily. An immature, rhyolite-bearing conglomerate (fig. 29) assigned to the Baraboo interval occurs in northwestern Wood County (Sec. 23, T. 24 N., R. 4 E.). This rock is very comparable to the Cambrian conglomerate at Sandhill.

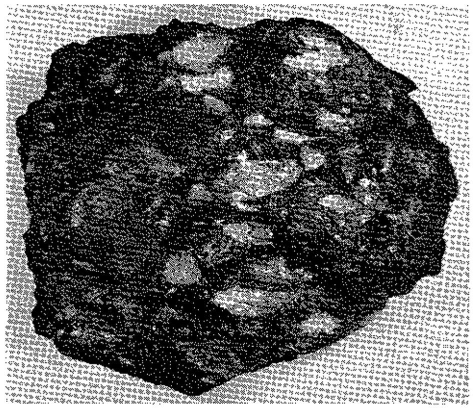
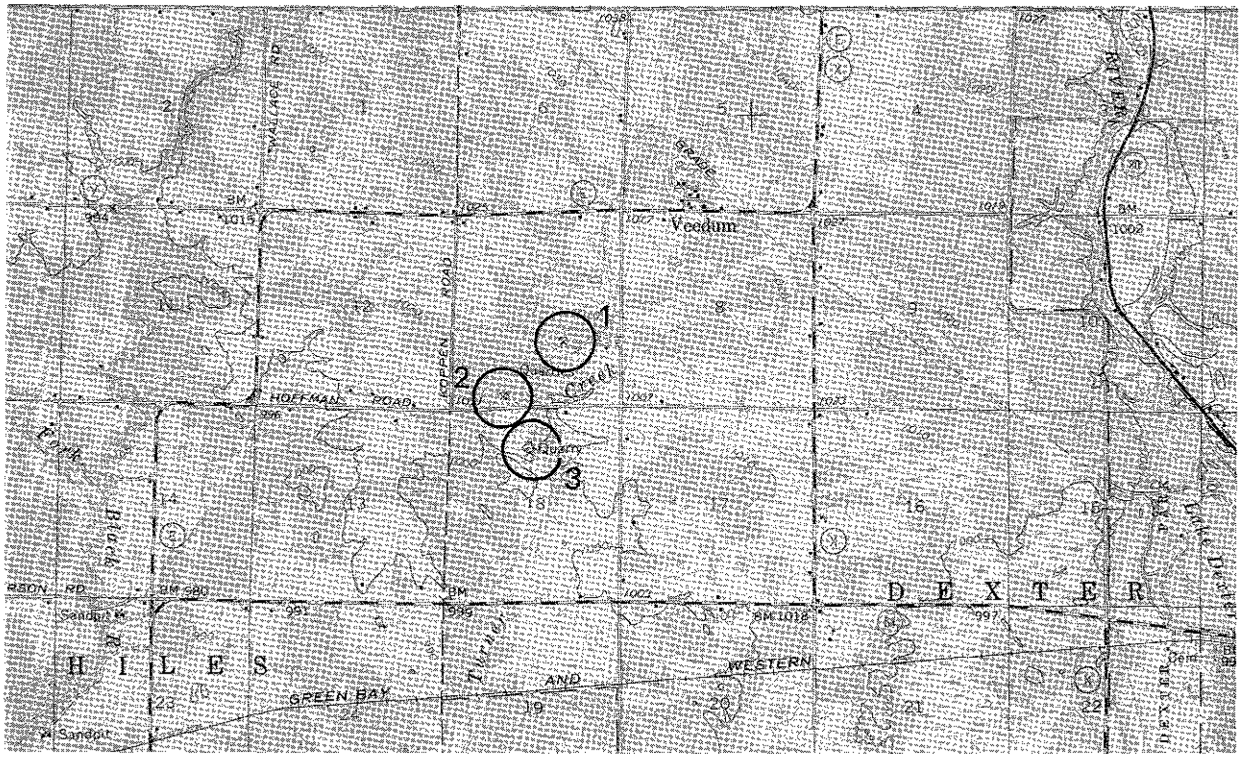


Figure 29. Hand specimen of rhyolite-bearing quartzite conglomerate from Wood County. The foliation plane is near horizontal. Long dimension about 18 cm.

Title: Veedum - abandoned sandstone quarries

Location: Three small quarries are located in the S ½ of Sec. 7 and N ½ of Sec. 18, T. 22 N., R. 3 E., 1.5 to 2 km southwest of Veedum in Wood County (Pittsville 7½-minute topographic quadrangle).



Author: B. A. Brown (1986)

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 m. thick and the floors of the pits consist of Precambrian rocks, both Baraboo interval micaceous quartzites and Archean (2800 Ma) Pittsville Gneiss.

In the quarry at locality 1, a 10 to 20 cm thick bed of Cambrian conglomerate overlies red, sericite-rich quartzite (fig. 30). 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. 31 and 32) contains bands rich in fine grained micas, partly altered to clay, which may have been derived from the breakdown of feldspar in an originally arkosic sediment.

The quarry at locality 2 exposes flat-lying Cambrian 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 muscovite (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.

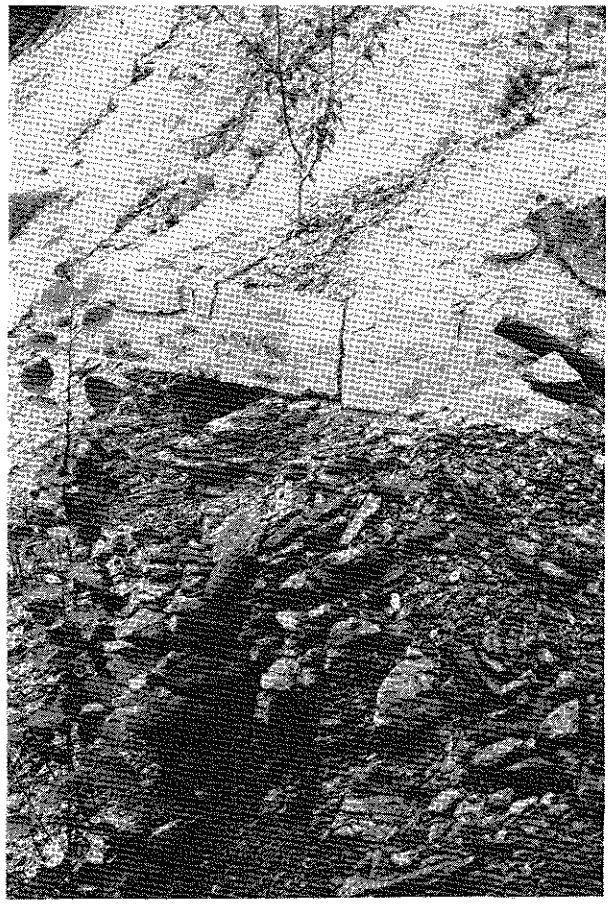


Figure 30. Contact of Cambrian conglomerate overlying micaceous quartzite at Veedum, locality 1.

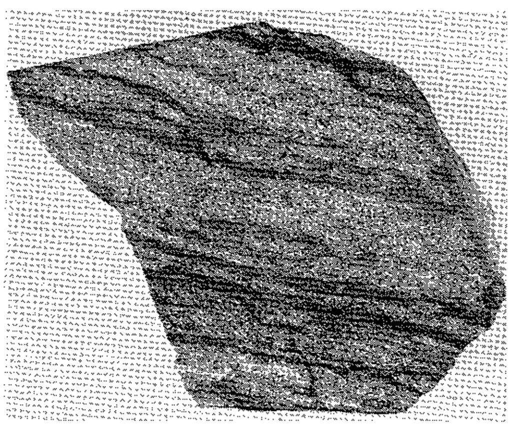


Figure 31. Hand specimen of micaceous, clay-rich quartzite from Veedum, locality 1. Dark beds are quartz-rich, lighter beds are rich in sericite partially altered to clay.

The 2800 Ma (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 m 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. 32). 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 is infolded with the gneiss.

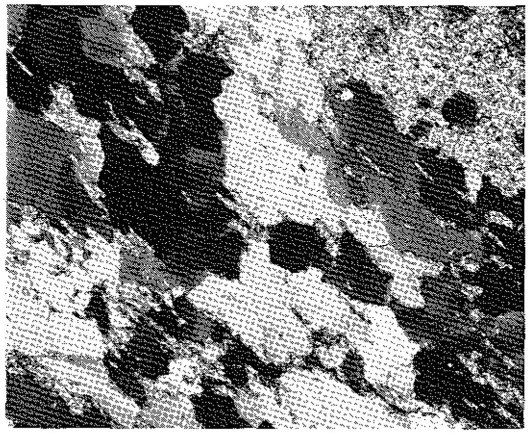
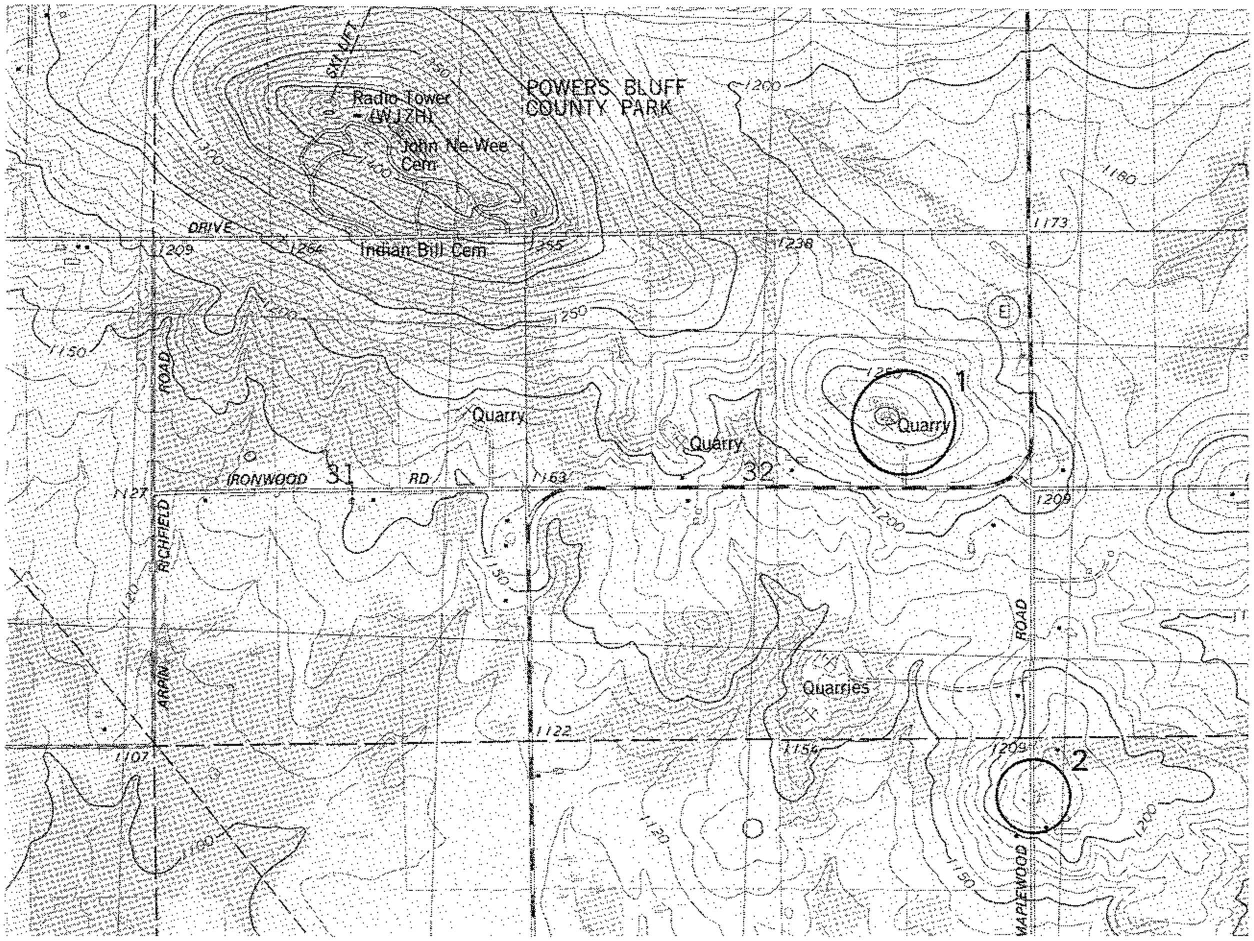


Figure 32. Photomicrograph of sample shown in Figure 31. Note foliation defined by micas parallel to long dimension of strained quartz grains. Field of view is 2.5 mm in long dimension.

The Veedum quarries illustrate a type of exposure commonly encountered in central Wisconsin. The bedrock over wide areas of Wood County is Cambrian sandstone, often only 2 to 5 m thick. Local road districts and private individuals have opened many small pits in search of slaty sandstone for fill and road surfacing. These pits are often not used on a regular basis, become overgrown, and are difficult to find. They are invaluable to the geologist however, because they provide layers of "windows" to the underlying Precambrian rocks which otherwise would not be exposed.

Title: Powers Bluff - quartzite quarry and county park

Location: NE¼ of Sec. 32, T. 24 N., R. 4 E. (Arpin 7½-minute topographic quadrangle).



Author: B. A. Brown (1986)

Description: The small quarry (locality 1) and another .75 km to the south provide the best known exposures of argillite of the Baraboo interval sedimentary sequence. At locality 1, approximately 50 m. of argillite are exposed in the pit. The argillite is bounded on the north and south by bedded chert units. 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 interbedded 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.

Bedded chert is the dominant lithology at Powers Bluff (fig. 33). 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. 34), the chert is aphanitic, consisting of an aggregate of very fine-grained quartz occasionally cut by quartz veins.

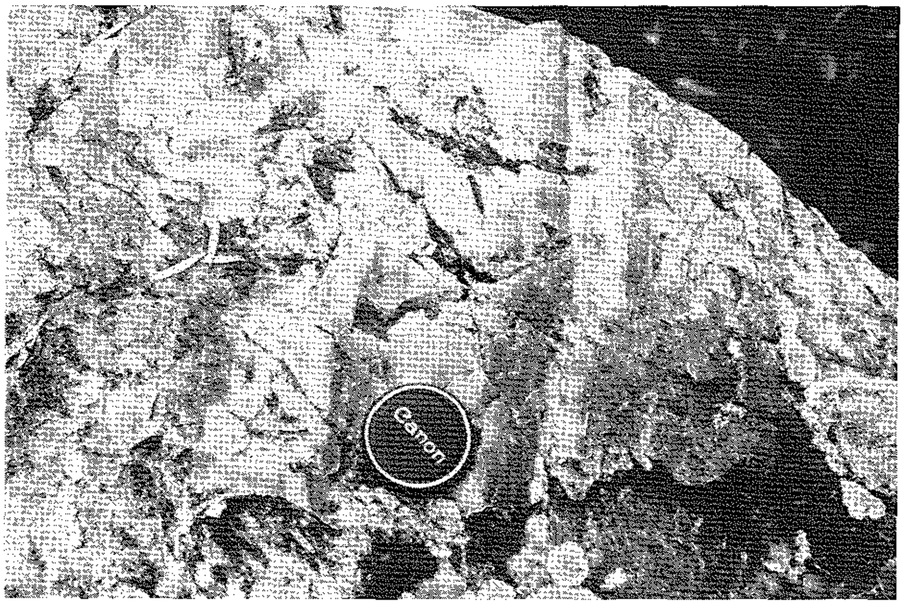


Figure 33. Bedding in chert at Powers Bluff County Park. Lens cap is 5 cm in diameter.

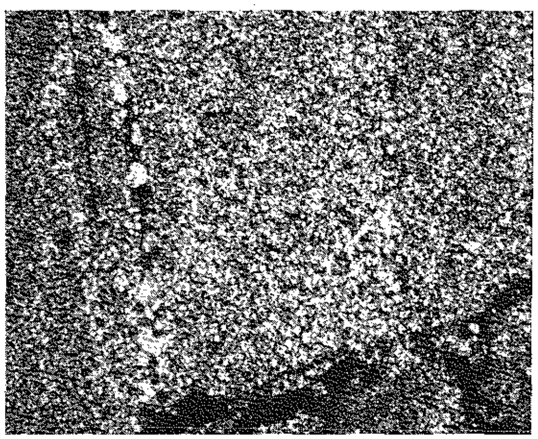


Figure 34. Photomicrograph of chert. Rock consists almost entirely of very fine quartz grains. Long dimension of field of view is 8 mm.

The argillite (fig. 35) 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. 36), and the mineralogy is quartz and kaolinite with varying amounts of iron oxide. Chert occurs as scattered modules and as discontinuous beds within the argillite.

Coarser clastic rocks occur at locality 2, where pebble conglomerate (clasts up to 5 mm) is interbedded with chert, 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. The dip of the bedding is steep and rarely varies more than ten degrees from vertical. Local variation in strike, particularly in the quarry (locality 1), suggests folding about steep northeast trending axial surfaces. A slaty cleavage is locally developed in the argillite, trending N 20° E and near vertical.

Mapping by Brown and Greenberg (1986) has shown that the Baraboo interval rocks of the Powers Bluff area are underlain by gneiss similar to the Archean Pittsville gneiss to the west of the park, and by mafic volcanic rocks of unknown age to the north. Areas of Baraboo interval sediments ranging from several square metres to several square kilometres are scattered throughout Wood and Portage Counties, overlying basement ranging in age from Archean to Penokean (Greenberg and Brown, 1986b; Brown and Greenberg, 1986).

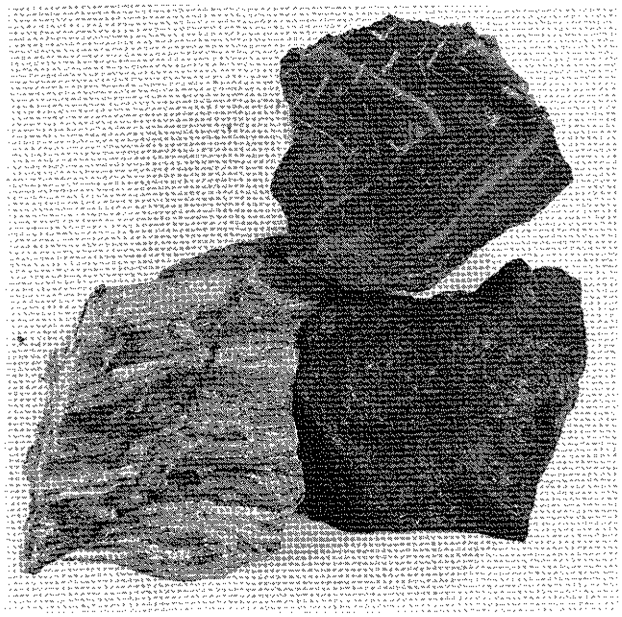


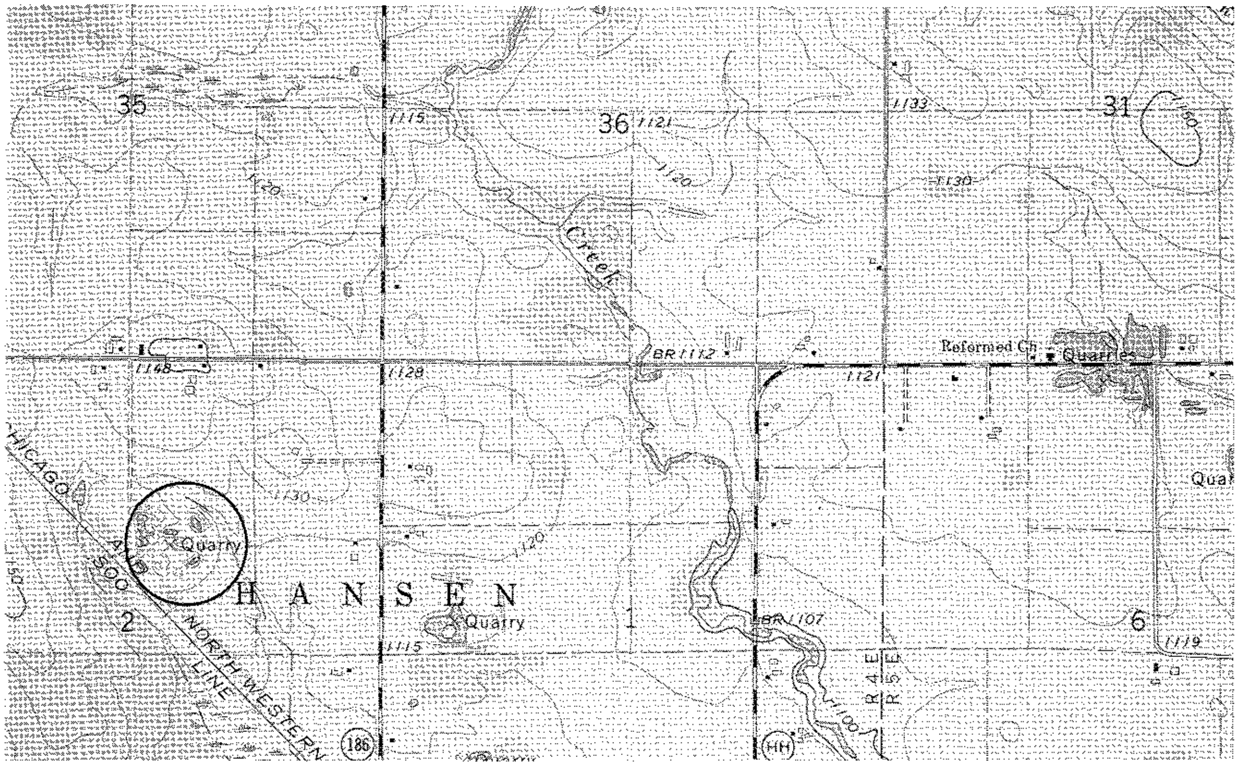
Figure 35. Hand specimens of argillite from Powers Bluff quarry. Clockwise from top: folded ferruginous argillite, carbonaceous argillite, banded kaolin-rich argillite.

Figure 36. 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.

The argillaceous and cherty rocks of Powers Bluff and the surrounding area are of particular significance to Baraboo interval sedimentation in that they are in all aspects very much like cherty and argillaceous rocks of the Freedom Formation which overlies the Baraboo Quartzite. This lithologic similarity and the direct association of chert and argillite with quartzite at locality 2 are critical factors in establishing the correlation of these rocks into the Baraboo interval.

Title: Vesper - abandoned granite quarry

Location: This small granite-quartzite quarry is located about 0.7 km west of Hwy 186 in Wood County in the SW¼, NE¼, Sec. 2, T. 23 N., R. 4 E. (Sherry 7½-minute topographic quadrangle).



Authors: J. K. Greenberg and B. A. Brown (1986)

Description: Quartzite (fig. 37) and red granite have been quarried from this exposure. The red granite is similar in appearance to that quarried for dimension stone north of Wausau. This was a small-scale operation which probably produced road material.

This granite is associated with an overlying (?) quartzite, correlated with other quartzites of the Baraboo interval. The exact contact in this quarry lies within a covered zone (a metre or two wide) between the granite and the quartzite. The inferred contact strikes northeast, the same orientation as the regional structural grain, as seen in foliation and aeromagnetic trends.

Quartzite

Quartzite exposed northwest of the granite quarry and nearest the access road is light-colored, buff, gray, or pinkish in color. In hand specimen it appears to have been a clean, well-sorted orthoquartzite. Microscopic examination shows that mica is abundant in almost all samples as a supporting matrix for rounded quartz grains (fig. 38). The 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 foliation are difficult to recognize.

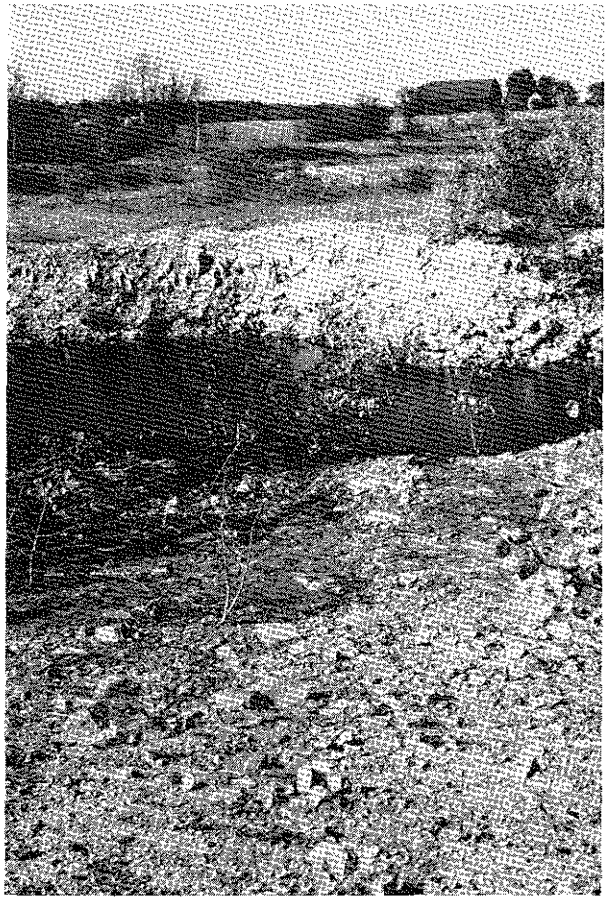


Figure 37. View of quartzite pit perpendicular to bedding, looking north from hematitic, micaceous conglomerate toward finer-grained quartzite.

Figure 38. Micrograph of matrix-supported conglomerate. Long dimension about 8 mm.

Southeast of the light-colored quartzite and closer to the granite, there is a zone several metres wide of dark red micaceous conglomerate and quartzite. The red color is caused by large quantities of disseminated hematite. This rock is a pebble conglomerate with 20 percent matrix composed of sericite, hematite, muscovite, and silt-sized quartz. 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 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 there is no evidence of the quartzite having been derived locally from eroded granite. The high concentration of sericitic matrix in the basal quartzite does suggest derivation from weathering granite.

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, with a minor fault being located somewhere in the covered interval.

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.

The red granite is not compositionally distinctive. SiO_2 (73.3%), Al_2O_3 (11.8%), Na_2O (3.69%), K_2O (4.66%), Fe_2O_3* (2.30%), MgO (.21%), and TiO_2 (.12%) are all consistent with normal calc-alkaline granite chemistry. Low mafic content, a very high Rb/Sr ratio (44.3) and a significant Eu anomaly indicate that this rock is highly differentiated.

Rb-Sr data including mineral separates on the coarse-grained and aplitic rocks indicate that the isotopes were reset with a high initial ratio (.734) at 1479 ± 32 Ma (C. Montgomery, unpub. data). This date in Wisconsin coincides with the widespread intrusion of anorogenic 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 intruded at about 1900 Ma (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 Ma episode of deformation and metamorphism in northern Wisconsin.

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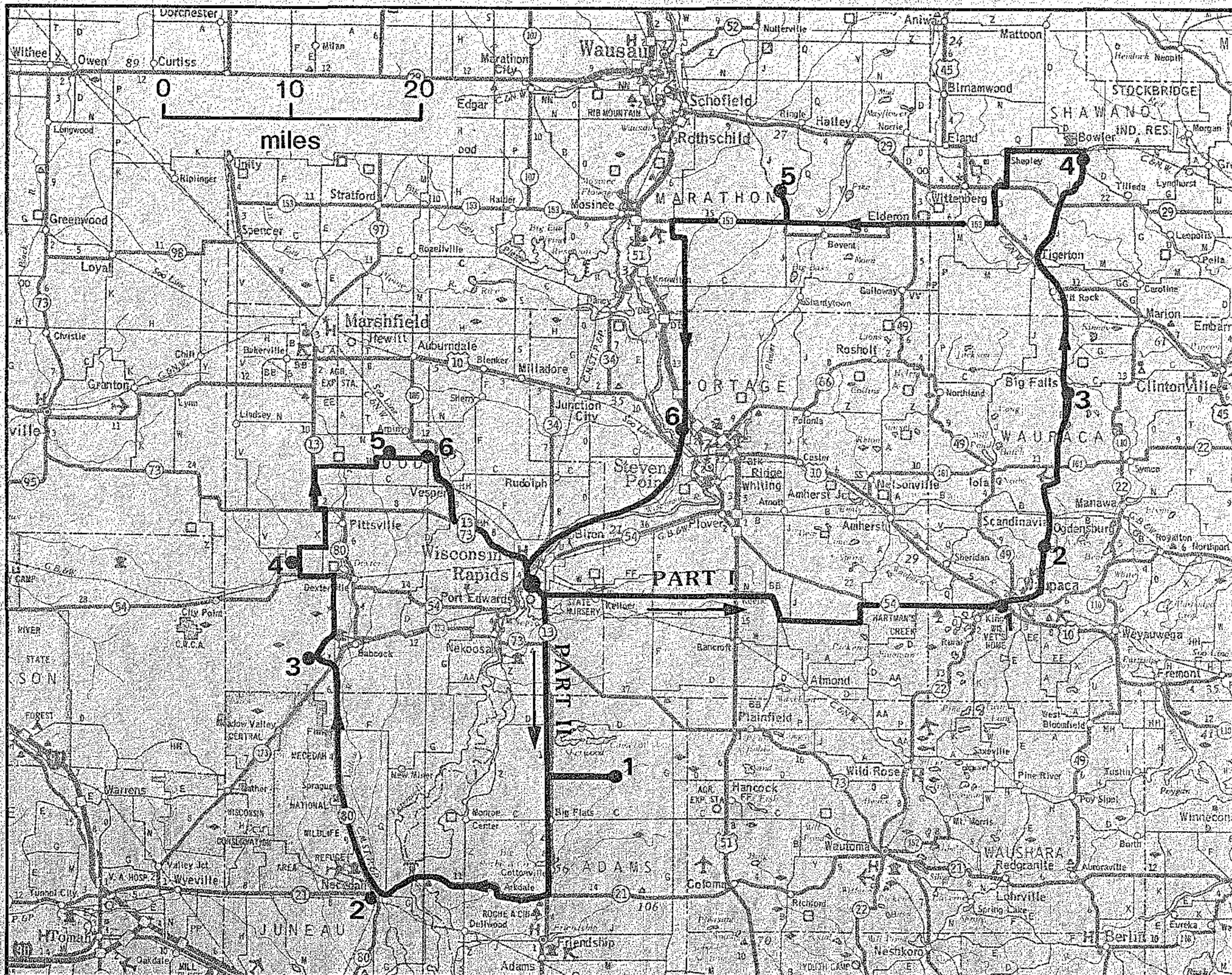

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Stratford
Spencer
Greenwood
Loyal
Granton
Owen
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