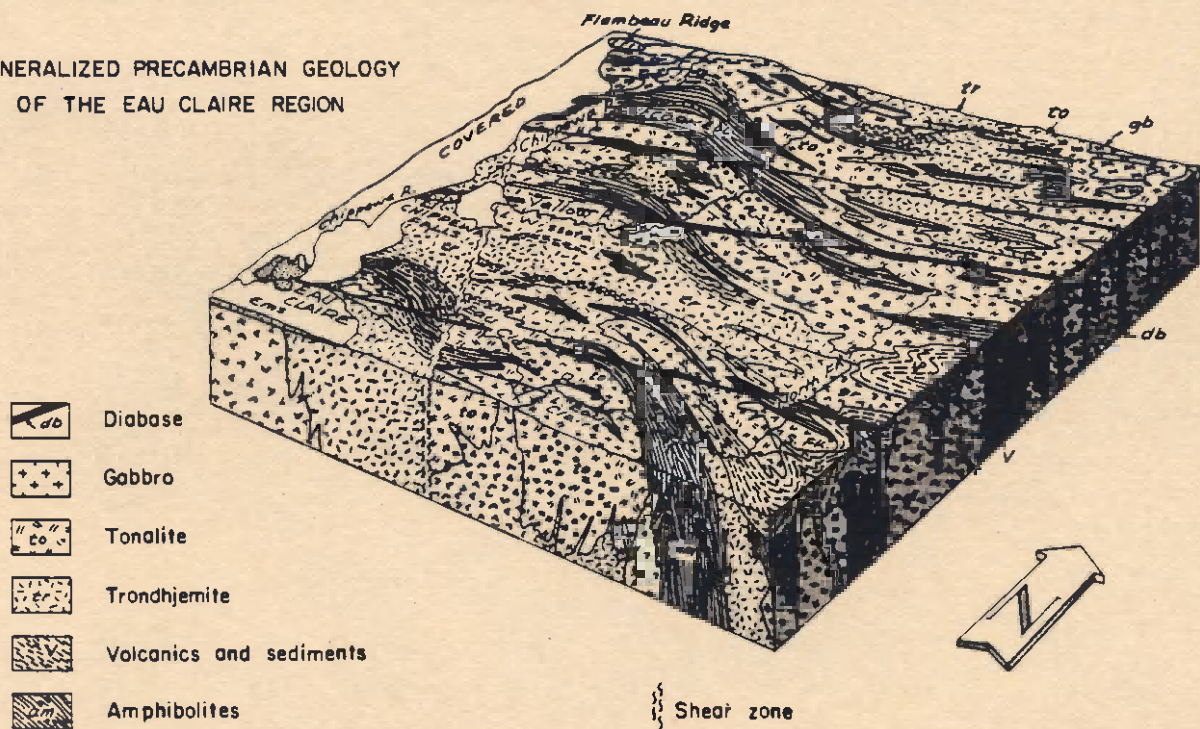




FIELD TRIP 1

Precambrian Geology of the Chippewa Valley, Wisconsin

GENERALIZED PRECAMBRIAN GEOLOGY
OF THE EAU CLAIRE REGION



May 6-7, 1980

University of Wisconsin-Eau Claire

PRECAMBRIAN GEOLOGY OF THE CHIPPEWA VALLEY

FIELD GUIDE

P. E. Myers, M. L. Cummings, and S. R. Wurdinger

Prepared for

Twenty-Sixth Annual Meeting
INSTITUTE ON LAKE SUPERIOR GEOLOGY

University of Wisconsin-Eau Claire
Eau Claire, Wisconsin

May 6-11, 1980

26th ANNUAL INSTITUTE ON LAKE SUPERIOR GEOLOGY

FIELD TRIP #1

May 6-7, 1980

<u>DAY</u>	<u>STOP #</u>	<u>LOCATION</u>	<u>LEADER</u>	<u>SUBJECTS</u>	<u>PAGE</u>
Tues. 5/6	1	Big Falls	Cummings	Geochemistry and Petrology of metamorphosed, layered gabbros deformational history	23
	2	Little Falls	Myers	Tonalitic intrusion breccia	35
	3	Confluence, N. Side	Myers	Amphibolite-volcanic contact	45
	4	Knight Pool	Myers	Metabasalts, pillow breccias(?)	55
	5	Rock Dam	Myers	Mylonitized rhyolite	59
	6	County Hwy M	Myers	Metasediments.	63
	7	Confluence, S. Side	Myers	Younger(?) sediments and volcanics	47
	8	"Big Bend" Yellow River	Myers	Cataclastic "dikes" in metadiorite	67
	9	Cadott Bridge	Myers	Cataclasis-intrusion-folding sequence; multiple deformations	71
RETURN TO EAU CLAIRE					
Wed. 5/7	10	Wissota Dam	Myers	Intrusion sequence: trondhjemitic-tonalite-pegmatite-diabase, etc.	75
	11	Jim Falls	Myers	Amphibolite-granite contacts, shearing, cataclasis, folding	81
	12	Cornell Dam	Myers	Relations between garnet amphibolite and flaser gneisses	89
	13	Fisher River	Myers	Tectonic or Intrusion(?) breccia	93
	14	Holcombe Dam	Wurdinger	Intrusion-deformation sequence	97
	15	Shoulder Creek	Cummings	Intermediate and felsic volcanics	113
	16	Jump River (N. Side)	Cummings	Intermediate fragmental volcanics	115
	17	Jump River: Hwy 73	Cummings	Contact metamorphism of felsite	117
	18	Sec. 22, T33N, R4W	Cummings	Intermediate crystal-lithic tuff	119

* Not all of the stops described in this guidebook will be visited. Their inclusion is to permit the use of this guidebook after the conference.

PRECAMBRIAN GEOLOGY OF THE CHIPPEWA VALLEY - AN INTRODUCTION.

P. E. Myers

Exposures of Precambrian rocks in west-central Wisconsin are confined mainly to the Chippewa Valley and its major tributaries, the Yellow, Jump, and Eau Claire rivers, which drain the southwestern edge of the Canadian Shield in Wisconsin. From the Eau Claire area, the Precambrian basement dips southwest at 10 feet per mile beneath a thickening cover of lower Paleozoic sandstones, shales, and carbonates. To the north and east, the Precambrian rocks are overlain by glacial deposits and occasional outliers of Cambrian sandstone. Owing to sparseness of outcrop and structural complexity of the rocks, traditional mapping methods have proven inadequate. However, a fair approximation of the regional geology has been gained through a combination of detailed studies of outcrops with petrographic and geochemical analyses, aeromagnetic and gravity mapping and radiometric dating.

Following initial reconnaissance of the region by Dutton, I began field work with the objective of defining the major problems and working out the geologic history of the region. Subsequent publication of Dutton and Bradley's geologic maps of northern Wisconsin (1970) provided a starting point. Additional, specialized studies by students (Cummings, 1974, 1975, 1978), Maercklein (1974), Piotruszewicz (1978), and Wurdinger (1979) have greatly accelerated the study of the region. This guidebook is a synthesis of available information on the Precambrian history of the Chippewa Valley. Relevant, supplementary information is drawn from important works by Anderson, Van Schmus, and Medaris (1975), LaBerge (1972, 1980), Maass, Medaris, and Van Schmus (1980), Maass and Van Schmus (1980), Sims (1976), Smith (1978), and Van Schmus (1974, 1976, 1980). Aeromagnetic maps by Karl and Friedel (1974-1976) and by United States Steel Corp. (1973) and Bouguer gravity maps by Ervin and Hammer (1974) have been most useful in interpolating contacts between widely separated outcrops.

The geologic map presented in Figure 1 is a "best approximation" of the Precambrian rock units in the Chippewa Valley. The rock units are typically heterogeneous, so that it was necessary to generalize units by selecting the predominant unit. Its purpose is to portray broad regional patterns of rock distribution. Quality of geologic information generally diminishes away from the rivers.

It is emphasized that the interpretations and conclusions in this guidebook are tentative. It is our hope that you will assist us in clarifying the history of these phenomenally complicated rocks. The geologic map (Figure 1) also shows stop locations. Those in parentheses are optional, but are included because of their relevance. You are encouraged to stay and continue your field trip after the conference or to return to Eau Claire soon with your own field trip. There remains a large number of thesis and dissertation topics. I may be able to assist you in the selection of one.

ACKNOWLEDGEMENTS

We are indebted to the University of Wisconsin - Eau Claire for general sponsorship of this conference. Under two research grants, the University also provided M. L. Cummings with summer field and lab assistants, and P.E. Myers chemical analyses and thin sections of 50 rocks. The Wisconsin Geological and Natural History Survey assisted us greatly, both through their provision of thin sections, probe analysis time, base maps as well as much encouragement throughout the term of the project. We thank Northern States Power Company for permission to study and visit their properties along the Chippewa River and for consenting to reduce, as possible, outflow from reservoirs during our visits at Lake Wissota, Jim Falls, and Holcombe. The University of Wisconsin-Oshkosh and the University of Wisconsin - Fox Valley, Menasha have generously allowed us the use of their vehicles for the trip.

We especially thank those of our colleagues and students who have offered their many helpful ideas and suggestions concerning our interpretations of the geology of this region. Eau Claire Students, as well as students from other universities have generously contributed time, talent, and ideas to our often frustrating work. Field trip drivers are Mike Mudrey, Len Weis, Gene LaBerge, and Al Sun. Nan Pickett, Penny Hoitomt, and Gail Wirz devoted long hours to the preparation of the guidebook, and Diane Carlson assisted in plotting geochemical data. Many students, past and present, have been involved with various aspects of field and lab preparations. We thank you all sincerely.

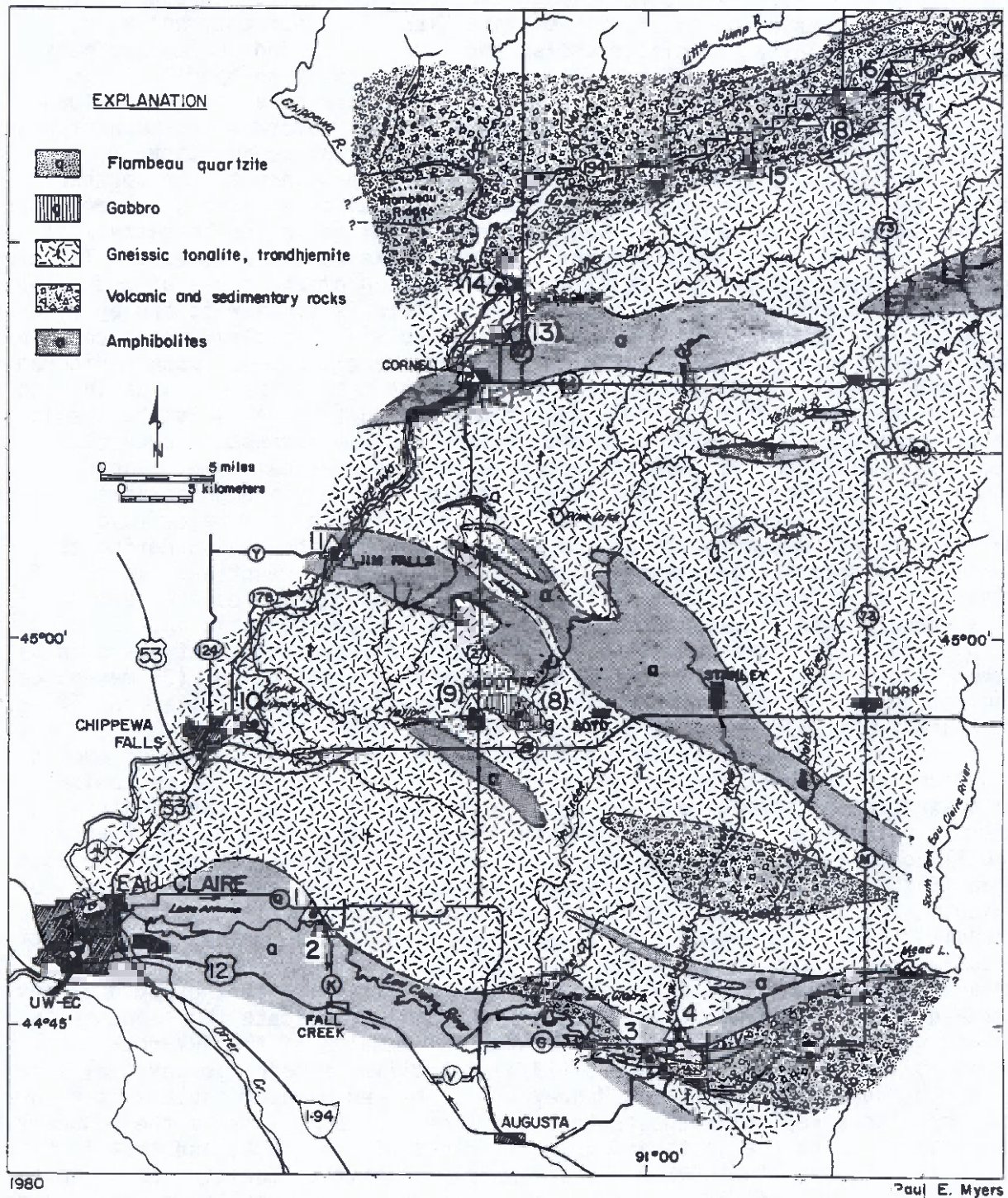
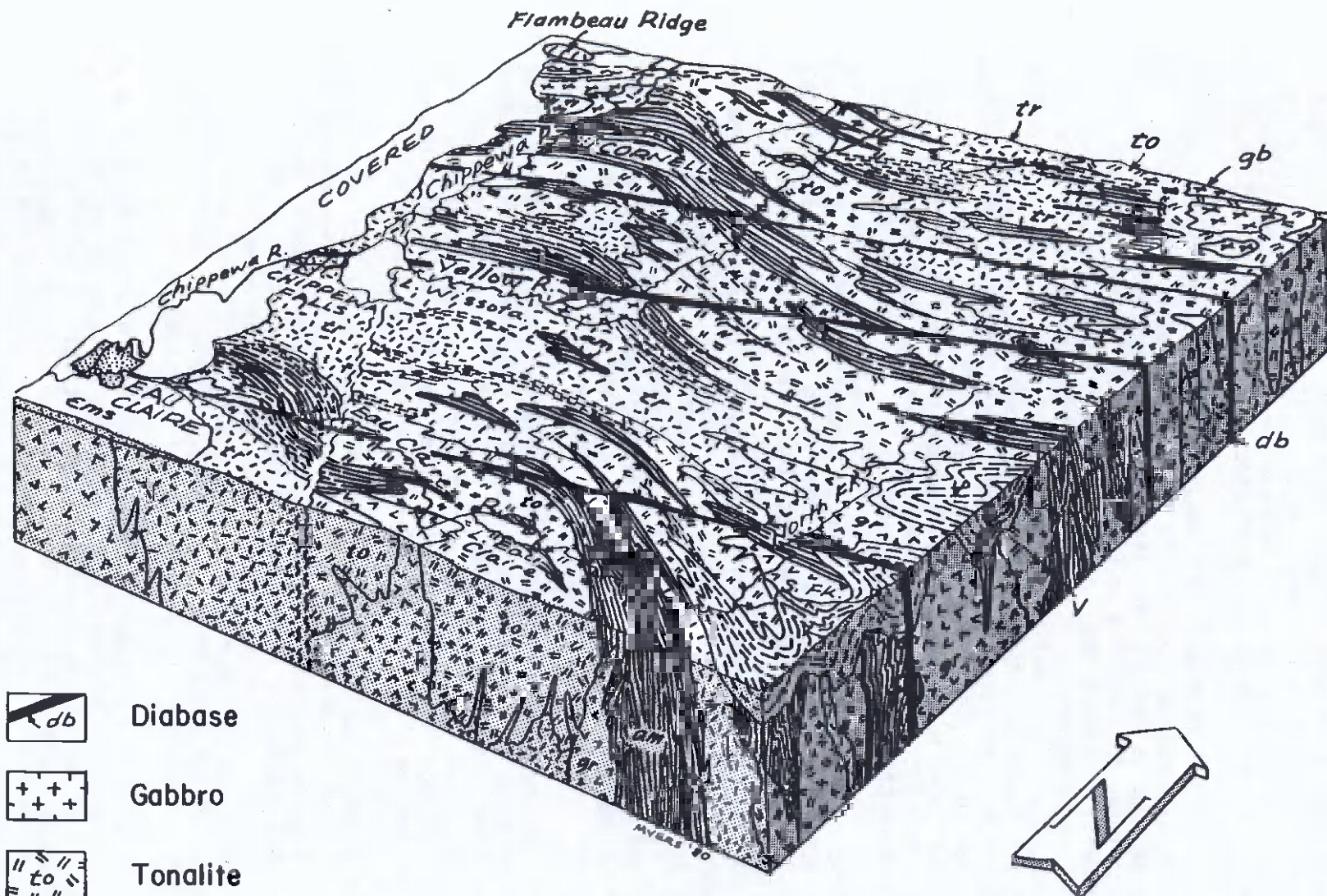


Figure 1 -- Distribution of major Precambrian rock units in the Chippewa, Yellow, Jump, and Eau Claire river valleys and their major tributaries as inferred from a study of sparse outcrops and from aeromagnetic mapping.

GENERAL GEOLOGY

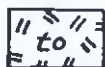
The Precambrian "Chippewa amphibolite complex" (Myers and others, 1974) is a megagneiss consisting of steeply-dipping, lensoidal screens, enclaves, and xenolith trains of amphibolitic gneiss and schist embedded subconcordantly in younger, synkinematic and late kinematic tonalite and trondhjemite (Figure 1). The Chippewa amphibolite complex (CAC) forms the core of an eastward-plunging Penokean orogen, which is overlain eastward by less deformed and metamorphosed volcanic and sedimentary rocks of the Flambeau volcanic-sedimentary province to the north and the Black River volcanic-sedimentary province to the southeast. Within the Chippewa region, these volcanic and sedimentary rocks are represented by the South Fork volcanic and sedimentary assemblage in the headwaters of the Eau Claire River and the Jump River volcanic rocks to the northeast. The block diagram (Figure 2) is a generalized representation of the types of rocks and structures occurring in this region. This pattern is similar to one by Glikson (1957, p. 21) for Archean tonalite-trondhjemite sialic nuclei, which contain attenuated relics of supracrustal enclaves and xenoliths. Glikson's diagram is included (Figure 3) for comparison. Probably the most conspicuous pattern to be seen on the generalized geologic map of the region (Figure 1) is the Z-shaped pattern produced by amphibolitic enclaves, which may represent large plunging fold remnants. Although the granitic rocks, as represented mainly by trondhjemite, tonalite, and subordinate adamellite, locally intrude the amphibolites, the contacts are most commonly sheared. Cataclasis has clearly played a major role in the deformation and metamorphism of the rocks throughout the region during at least three major deformational events, one of which was the Penokean. In the CAC, cataclasis is most conspicuously manifested by: (1) bending, crushing, and lenticulation of feldspars with simultaneous development of a characteristic interlensing foliation. (2) laminar transposition of originally discordant structures such as dikes, dikes, and xenoliths, into the plane of cataclastic foliation, (3) mechanical homogenization of contiguous rock units with or without recrystallization, (4) detachment and transposition of fold fragments as tectonic xenoliths. Since the proper interpretation of cataclastic features affects the interpretation of geologic sequence, and since there remains considerable debate as to the mechanisms, some good examples of them have been included in several of the stops (mainly #8-11). Whereas the volcanic rocks of the Jump River area (Cummings, p103) have at least locally been metamorphosed to the lower amphibolite grade, those of the South Fork area (SFVS) are of lower metamorphic grade as indicated by the prevalence of chlorite, epidote, and garnet. The Jump River volcanics (JRV) comprise mainly basaltic to andesitic flows and fragmental volcanics of andesitic to rhyolitic composition. One eruptive center was found in the area just east of the town of Jump River. The higher metamorphic grade of the JRV may be due to the proximity to the south of several large granitic plutons. Top indicators in the JRV indicate the sequence is overturned with beds facing (younging) southward. Examples of the JRV rocks will be seen at stops 15-18. Myers and others (1974) identified a major geophysical lineament along the Jump River. Sims and Mudrey (1978) placed a major fault in the same area. Cummings (this report) suggests that the lineament simply marks the boundary between volcanic rocks to the north and granitic rocks to the south, and that it is probably not a fault zone. The SFVS rocks are mainly andesitic, dacitic, and rhyolitic pyroclastics interstratified with tuffaceous conglomerates, phyllites, and micaceous quartzites. They have been regionally metamorphosed to upper greenschist facies and compressed into a series of open folds which plunge gently east-northeastward. Except where these rocks have been sheared, primary minerals and structures are well-preserved. These rocks will be seen at stops 3-7. Although bedding within the SFVS unit dips at moderate angles, its contact (at stop 3) with amphibolitic and plutonic rocks of the CAC is a high-angle shear zone. The best tentative hypothesis is that



Diabase



Gabbro



Tonalite



Trondhjemite



Volcanics and sediments



Amphibolites



Shear zone

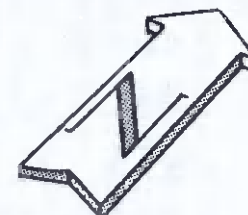


FIGURE 2--
GENERALIZED PRECAMBRIAN GEOLOGY
OF THE EAU CLAIRE REGION

the SFVS rocks rest on a folded, locally sheared and recrystallized angular unconformity. Considerably more detailed field mapping, petrographic and geochemical analyses are needed to work out the structural and genetic relationships of these rocks. However, it is clear that this area (stops 3 and 7) is one of considerable significance. Whereas the amphibolites were deformed and recrystallized at least twice before tonalite and trondhjemite intrusion 1842-1830 m.y. ago (Van Schmus, 1980)

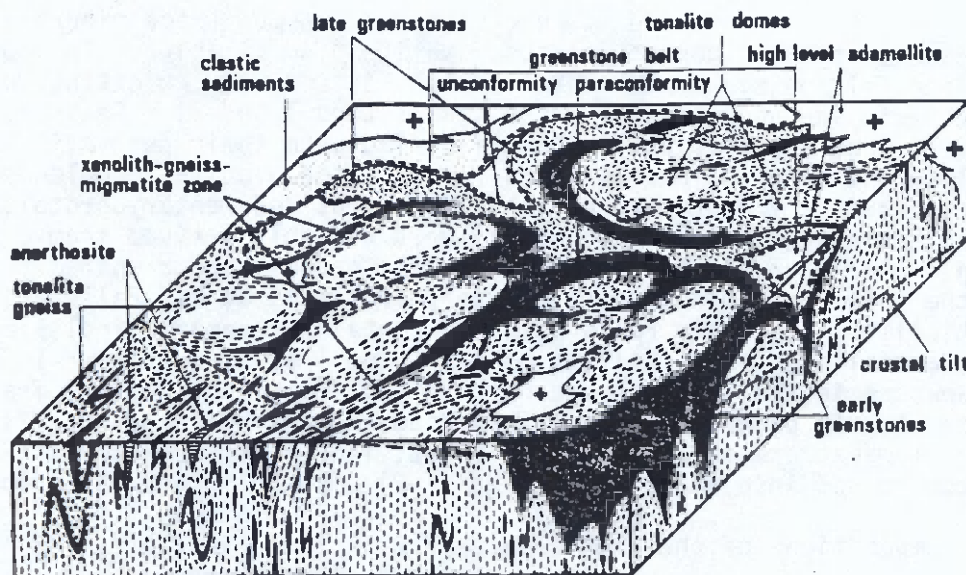
The amphibolites and volcanics were synkinematically and late kinematically intruded by trondhjemite, tonalite, gabbro, and adamellite (quartz monzonite). The most abundant rock type is faintly foliated leucotondhjemite. At Wissota Dam (Stop #10) Cadott (Stop #9), and Fisher River (Stop #13) the trondhjemite is intruded by hornblende-biotite tonalite. At other localities, however, the reverse relationship can be observed. The trondhjemites and tonalites are probably coeval and comagmatic. The tonalites display closer chemical and mineralogical similarities to the amphibolites from which they were probably derived. The gabbros form plug-like intrusions, and although they are younger than the tonalites, they have been involved in cataclastic deformation (Stop #8). The adamellite is complexly intergradational with the trondhjemite and in some localities (e.g. North Fork of Eau Claire River) intrudes the trondhjemite. Like the other granitic rocks, however, it has also been cataclastically deformed.

Almost regardless of older structures, granite pegmatite dikes, usually containing biotite and muscovite + garnet were intruded along a persistent east-north-east trend as exemplified at Little Falls, Wissota Dam, and Jim Falls as well as many other places. Many of the larger dikes are texturally and compositionally zoned with quartz cores. At Jim Falls (Stop 11-A) the pegmatite dike contains en echelon quartz veins as gash fracture fillings. Microcline crystals in these dikes have been severely bent, broken, and lenticulated. At several locations the dikes have been completely truncated by shearing. At Jim Falls at least three ages of pegmatite intrusion can be seen. The older dikes are boudinaged in the compositional layering of the banded amphibolite host rock. The pegmatite dikes have been offset by north-northwest-trending faults of Late Precambrian age.

Late Precambrian gabbro-diorite dikes cut all the other rocks with strong discordance. Their conspicuously chilled margins (Stop 10) indicate shallow intrusion after a prolonged erosional interval (1600-1100 m.y.). The dike at Wissota Dam contains large, partially resorbed fragments of labradorite and very coarse-grained norite. This dike is intruded by a thin leucotondhjemite dike, which displays an unusual type of crush texture where it is involved in a small fault zone.

The Precambrian basement was deeply saprolitized (Cummings and Scrivner, 1980) in Late Precambrian time with formation of kaolinite-rich soils. A distinctive illitic green clay developed on the hornblende-rich rocks (as seen at Little Falls). The clays form a conspicuous marker as the Eau Claire River repeatedly crosses the unconformity between Lak Eau Claire and Lake Altoona. Late Cambrian Mt. Simon Sandstone, which overlies the Precambrian rocks, occurs abundantly as ridge and knob-shaped outliers throughout the Chippewa Valley region. Clay and feldspar content decrease upward in the formation owing to reworking of the sands.

Glacial till and outwash of the Chippewa lobe of Wisconsin glaciers are exposed in the Chippewa Valley northeast of Eau Claire. At Little Falls (Stop #2) the tills are highly weathered and may represent an older glaciation. Silicified Cretaceous tree fragments found in outwash downstream from Eau Claire suggest that Cretaceous sedimentary rocks may locally underlie glacial deposits in the northern part of the State, or that Cretaceous fossil wood from Minnesota was carried into Wisconsin during an earlier glaciation and later redeposited in this region during Late Wisconsin time.



Block diagram illustrating the concept of coeval relations between Archaean granite-greenstone terrains and high-grade terrains. The diagram represents a tilted crustal segment allowing observation of a major greenstone synclinorium (about mid-way) and a high-grade terrain (front left part). Domal tonalites intrude relics of an ultramafic-mafic volcanic crust (early greenstones) (black). The tonalites become increasingly gneissose (dashed patterns) both toward their margins and with depth. Late greenstone depositories (hatched patterns) and sedimentary sequences (dotted) form unconformably and paraconformably above the tonalites and the early greenstones. Loci of maximum late supracrustal deposition coincide with interdomal synclinoria. Deep-seated gneiss root zones of batholiths are characterized by a linear structural grain, attenuated relics of supracrustal enclaves and xenoliths, mafic-ultramafic intrusions and anorthosites.

Figure 3 -- Block diagram from Glikson, 1957, p. 21

DESCRIPTIONS OF MAJOR ROCK UNITS

Introduction

Rocks of the Chippewa amphibolite complex (CAC) consist mainly of plagioclase (An_{20-55}), amphibole, quartz and biotite. Common accessory minerals are K-feldspar, epidote, chlorite and iron oxides. Granitoid components contain the same essential minerals as the amphibolites but in different proportions. The apparent mineralogical simplicity of CAC rocks suggests regional metamorphic equilibration, following the major plutonic phases of the Penokean orogeny (1840-1830 m.y.). By contrast, the Jump River (JRV) and South Fork (SFVS) rocks contain abundant chlorite, epidote, and garnet, and show significantly greater lithologic and chemical diversity. (See Figures 6 and 8).

Amphibolites

Mafic, intermediate, and feldspathic amphibolites of volcanic and plutonic derivation contain structures, fabrics, and minerals indicating at least three deformations and as many episodes of metamorphism (See Stop #1). In outcrop the amphibolites are medium to dark gray, commonly laminated and lineated, and cut by numerous granitoid veinlets, many of which have been strongly deformed. The dominant minerals are plagioclase (An_{25-55}) and hornblende. Subordinate quartz, biotite,

epidote, and c d 10 percent each. Common trace minerals are sphene, iron oxides, pyrite, garnet, zircon, apatite, and allanite. The coarse-grained mafic and feldspathic amphibolites possess structures indicating derivation from gabbroic and anorthositic protoliths (stops 1 and 2). Textures in fine-grained mafic and intermediate amphibolites indicate their derivation mainly from basalt flows and andesite pyroclastics. Associated biotite-hornblende-chlorite-epidote schists (Figure 8) probably represent sedimentary protoliths. The banded amphibolites at Big Falls (Stop 1) were probably derived from a layered gabbro (Cummings and Myers, 1979). Although relict garnets occur sparsely throughout the CAC, the large hornblendized garnet porphyroblasts at Big Falls are unique. Laminated amphibolites at Little Falls (Stop 2) contain ultramafic inclusions (autoliths?). Garnetiferous amphibolites of the Cornell area are richer in alumina than those elsewhere in the CAC. The garnets in these amphibolites are fresh, show no rotation, and engulf older laminations produced in part by shearing. Plagioclase + quartz laminae are axial-planar to tight, isoclinal shear folds (F-1), which were locally compressed into small open folds (F-2) with oblique axial trends.

Chemical compositions of the amphibolites are included in Tables 1-3, and in Figure 5.

Volcanic and Associated Sedimentary Rocks

Volcanics of the Jump River area (stops 15-18) comprise mafic and intermediate (basaltic and andesitic) flows and andesitic to rhyolitic pyroclastics. Relict sedimentary and porphyritic textures are well preserved despite local metamorphism to lower amphibolite grade. The JRV were intruded by Penokean(?) granitic plutons along the south side of the Jump River.

Basaltic(?) andesitic, and rhyolitic volcanic rocks interstratified with siliceous volcanoclastic sediments - phyllites, conglomerates, and micaceous quartzites - are exposed along the North Fork and South Fork of the Eau Claire River (Stops 3-7, Figure 21). Although bedding in the tuffaceous sandstone and conglomerate dips at moderate angles to the east and southeast, contacts with contiguous amphibolite and plutonic rocks are steeply dipping and strongly sheared. Numerous small exposures of andesitic to rhyolitic volcanic rocks crop out in the area between Eau Claire River and Jump River in the east side of the region. Thus it is inferred that the two terranes contain correlative rocks. The SFVS rocks show a "normal" calc-alkaline differentiation trend (Figure 6), and their compositions are close to those of nearby tonalite and trondhjemite. The possibility that the Penokean trondhjemitic and tonalitic plutons intruded their own volcanic piles should be examined, especially in light of the closeness in their ages (1860 m.y. for the SFVS and 1840 m.y. for the plutonic rocks according to Van Schmus, 1980.)

Plutonic Rocks

The tonalites of the Chippewa region are composed essentially of plagioclase (An₃₀₋₅₅), quartz, hornblende, or biotite, or both. Compositional variations are expressed megascopically as differences in the hornblende-biotite ratio and the abundance of quartz. Mafic tonalites, with total mafics in excess of 35 percent, tend to be hornblende-rich and are commonly associated with mafic amphibolites. Biotite, which is invariably younger than the hornblende, produces a well-defined foliation. Although foliation may not be conspicuous on weathered outcrops, it is invariably present. All tonalites seen in thin section show some effects of cataclasis, mostly as interlensing shear surfaces along which plagioclase and

quartz are mylonitized. Biotite flakes are crenulated by displacements along shear surfaces during cataclasis, a factor suggesting post-metamorphic cataclasis. Tonalite contacts are typically sheared with considerable mixing of contiguous rock units.

The trondhjemites are composed essentially of oligoclase, quartz, and biotite. Epidote, K-feldspar, muscovite, iron oxides, and sphene are ubiquitous accessory minerals. The trondhjemites tend to be leucocratic and only faintly foliated. They are continuously intergradational with adamellites by a slight increase in K-feldspar. The trondhjemites as seen in thin section contain large, subhedral grains of plagioclase with untwinned margins owing in part to structural disordering under conditions of cataclasis. Quartz grains show lamellar, undulatory extinction, are finer grained than the plagioclase, and commonly occur in clots or ribbons. In contact with K-feldspar grains, the plagioclase is myrmekitic. Biotite is commonly altered to green chlorite + muscovite. Muscovite is invariably a late mineral, probably formed during retrograde metamorphism of the region. The best exposure of trondhjemite is at Wissota Dam (Stop 10), where it is cut by dikes and irregular masses of gray tonalite containing amphibolite xenoliths.

The adamellites simply contain more K-feldspar (microcline) than the trondhjemites. Whereas most of the K-feldspar in the trondhjemites occurs as irregular inclusions in the plagioclase, it occurs more commonly as discrete grains in the adamellites. Early kinematic veins and dikes of adamellite showing folding and boudinage, indicate that the sequence of intrusion was complex and not confined to a single differentiation sequence (as at Jim Falls, Stop 11).

Several plug-like gabbro bodies were seen, but so poorly exposed as to render them unmappable. However, a gabbro body is well exposed along the Yellow River near Stop 8 about 2 miles east of Cadott. The gabbro has a brecciated margin against amphibolitic and volcanic(?) rocks in intermediate composition. Relict clinopyroxene grains are thickly mantled by hornblende, which is in turn rimmed with brown biotite. The gabbro on the Yellow River consists of plagioclase (An_{55}), hornblende, biotite and accessory quartz, pyrite, magnetite, sphene, zircon, apatite, and allanite(?) The rock is cut by numerous shear zones, and displays a subtle cataclastic foliation in thin section. The gabbro appears to be younger than the tonalite or trondhjemite - late kinematic.

Chemical analyses of the plutonic rocks are included in tables 5 and 6. An AFM diagram for the plutonic rocks is given in Figure 7. A variation diagram showing a well-defined interrelationship of the plutonic rocks is given in Figure 4. The significance of the double K_2O curve is not fully understood, except that it probably represents two distinctly unrelated series, which are otherwise indistinguishable. More chemical data are needed to verify this trend. It is suggested that future studies should concentrate on the alkali ratios in plutonic assemblages in the plutonic rocks of the Chippewa Valley.

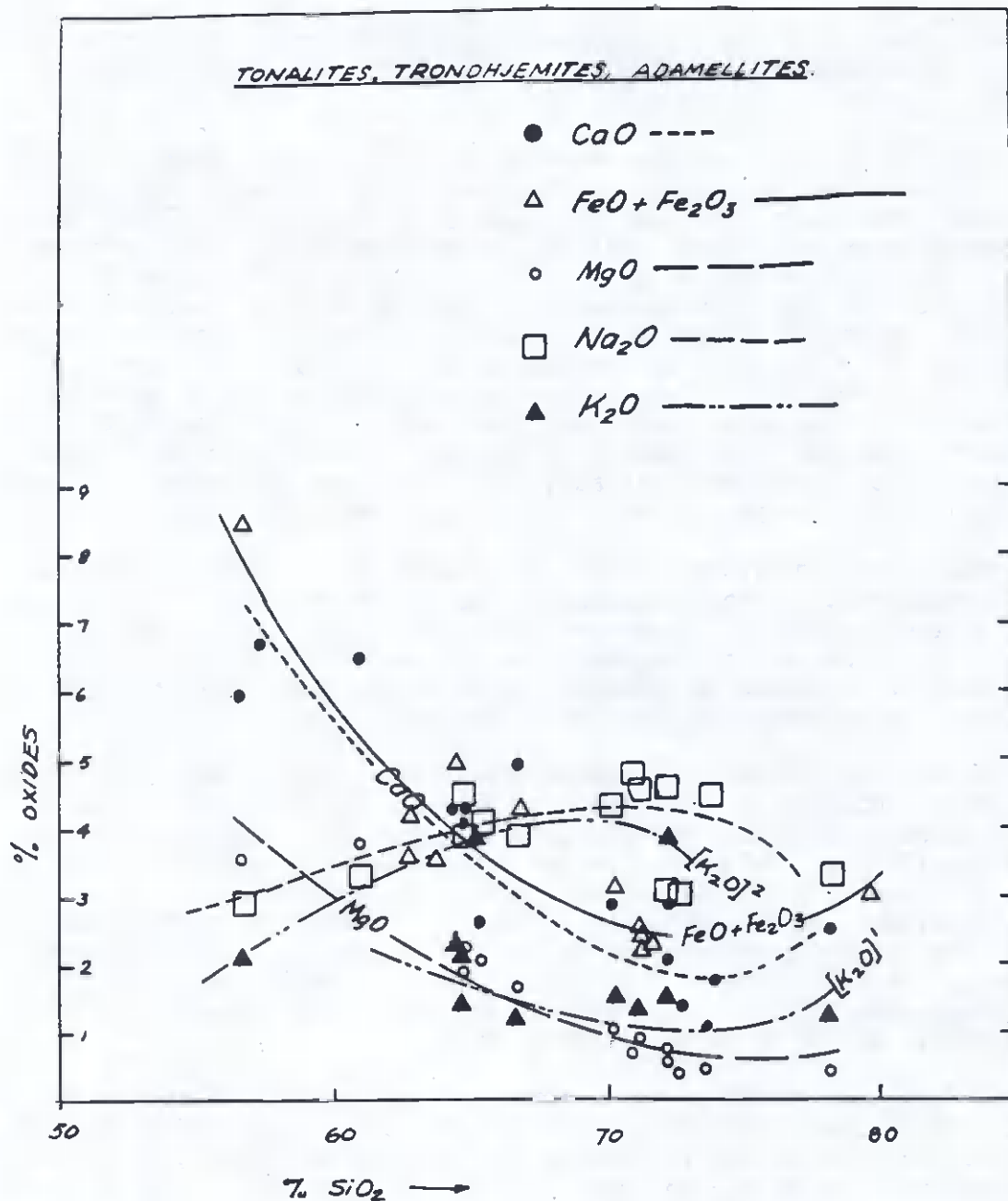


Figure 4 -- Variation diagram showing variation of various oxides in relation to weight percentage of silica for tonalites, adamellites, and trondhjemites in the Chippewa amphibolite complex. Bulk chemical analyses by Technical Service Laboratories, Mississauga, Ont.

AMPHIBOLITES

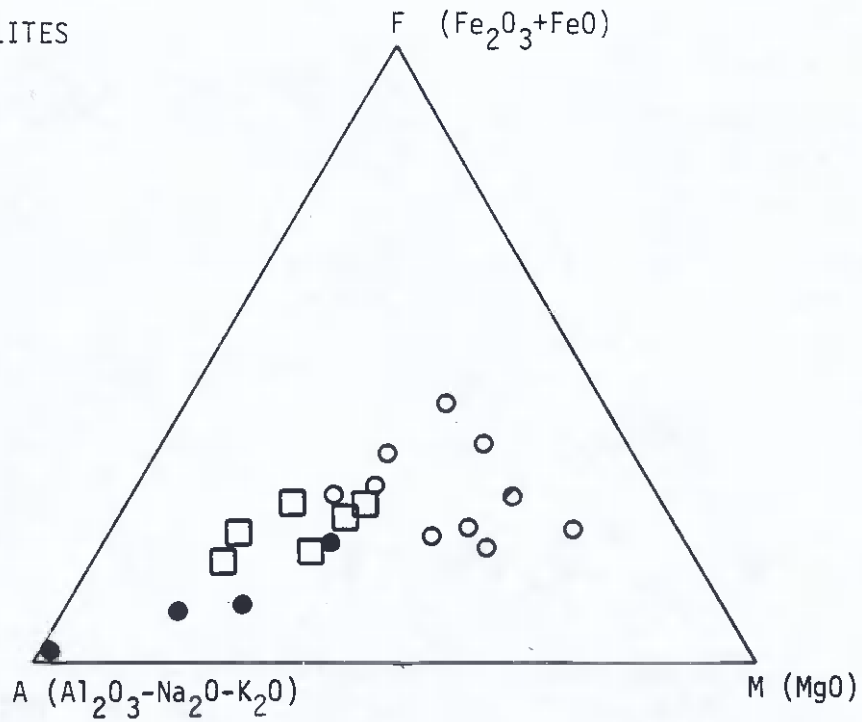


Figure 5 -- AFM diagram for amphibolites. $\circ$ mafic amphibolites, $\square$ intermediate amphibolites, and $\bullet$ feldspathic amphibolites. Plotted in molecular proportions. Total iron oxide expressed as Fe_2O_3

SOUTH FORK VOLCANIC AND METASEDIMENTARY ROCKS

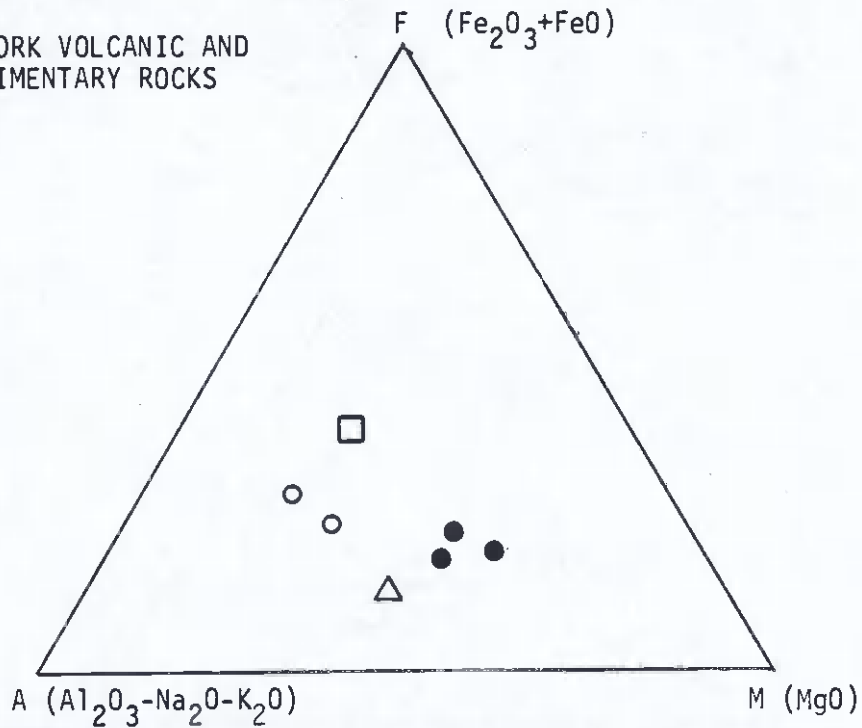


Figure 6 -- AFM diagram for metavolcanic and associated sedimentary rocks, $\bullet$ andesite tuffs, $\circ$ dacite(?), $\circ$ tuffaceous conglomerate, $\square$ rhyolite, $\triangle$ muscovite-biotite quartzite.

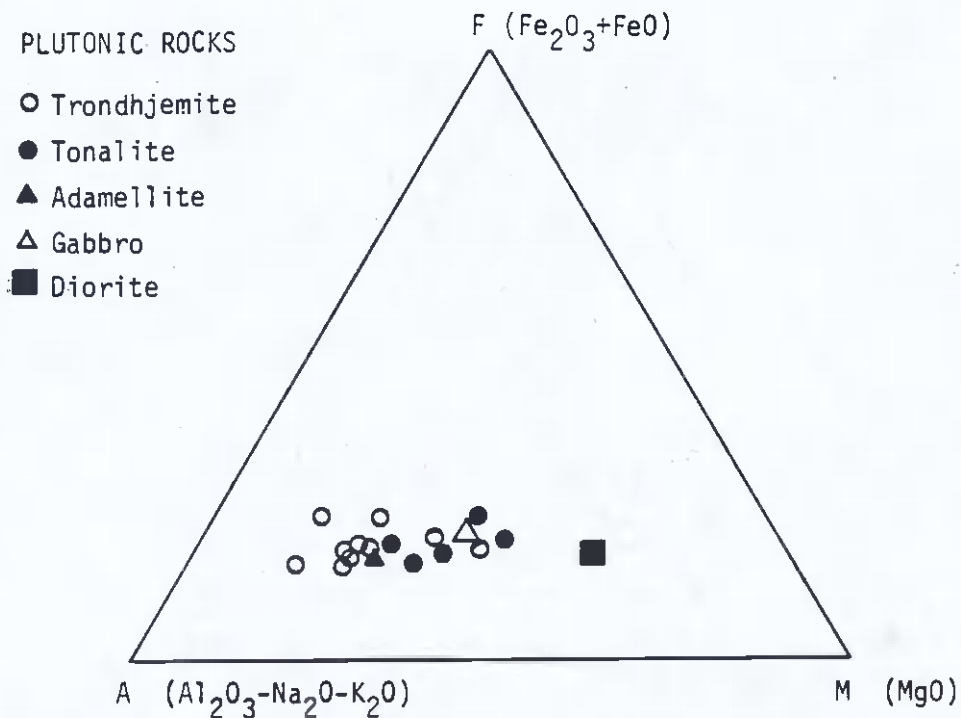


Figure 7 -- Composite AFM plot of plutonic rocks in the Chippewa amphibolite complex, plotted in molecular proportions. See tables 5 and 6 for descriptions of rocks.

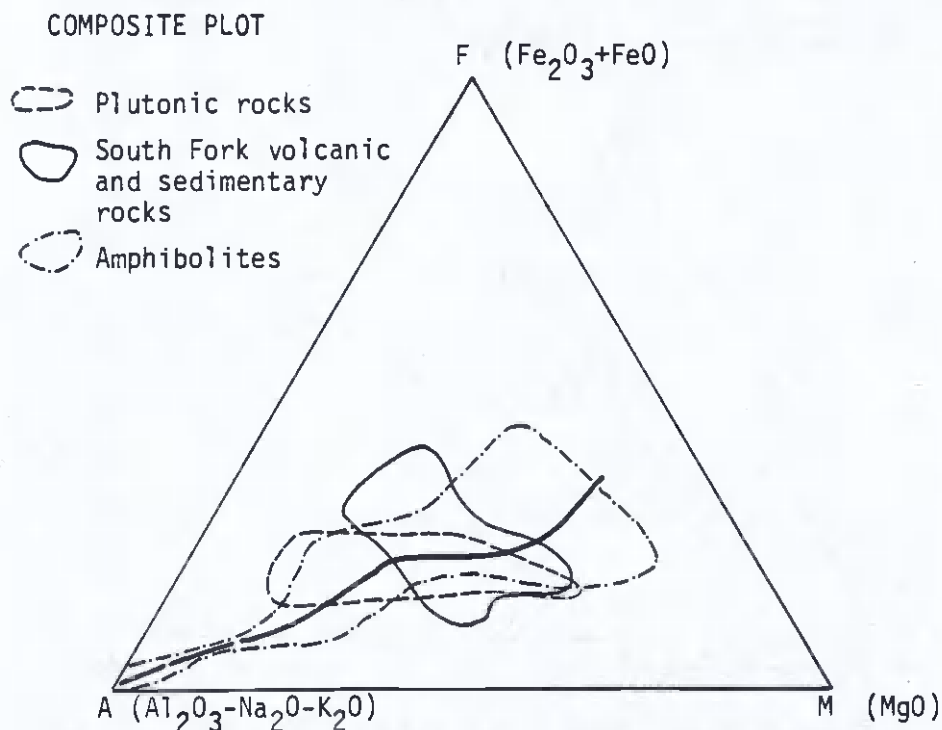


Figure 8 -- Composite AFM plot showing compositional limits of plutonic rocks, South Fork volcanic and sedimentary rocks, and amphibolites. Average trend shown with a heavy black line.

TABLE 1 - BULK CHEMICAL COMPOSITIONS OF MAFIC AMPHIBOLITES*

	7336 A	7425 B	77132	77138 A	77155 B	7902 A	7908 A	7927 N-1	7941 A	7950 A
SiO ₂	49.06	51.41	55.48	50.98	51.52	47.28	44.30	45.98	49.66	48.09
Al ₂ O ₃	15.61	17.12	14.88	13.16	13.30	13.51	19.95	11.06	14.66	13.86
Fe ₂ O ₃ + FeO	12.40	11.16	11.12	14.46	13.51	11.59	13.24	11.62	11.09	11.93
CaO	10.04	9.65	10.90	9.02	9.69	11.87	11.47	12.34	12.10	14.75
MgO	6.60	6.21	3.19	5.57	7.31	10.85	5.52	15.28	8.11	7.66
Na ₂ O	3.08	2.32	0.85	2.32	2.93	1.32	2.57	1.18	2.23	1.64
K ₂ O	0.77	0.68	1.04	0.68	0.31	0.78	0.90	0.70	0.58	0.71
TiO ₂	0.77	0.61	0.56	1.01	1.13	0.34	0.96	0.19	1.00	0.60
MnO	0.19	0.18	0.14	0.21	0.18	0.21	0.21	0.20	0.19	0.21
P ₂ O ₅	0.14	0.12	0.19	0.29	0.17	0.00	0.27	0.09	0.08	0.15
LOI	0.64	0.75	1.99	0.60	0.26	0.56	0.66	0.71	0.37	0.42
TOTAL	99.28	100.2	100.3	98.28	100.31	98.31	100.0	99.35	100.1	100.0

Spec. No.	Location	Description **
7336-A	Eau Claire R. SE $\frac{1}{2}$ SW $\frac{1}{4}$ Sec.18; T26N, R5W	H-P-B-E-C schist with contorted granitic veinlets in isoclinal folds; banding cut discordantly by granitic veinlets, dikes
7425-B	Cornell Dam SW $\frac{1}{2}$ SE $\frac{1}{4}$ Sec.18; T31N, R6W	H-G schist; strongly lineated; isoclinal folds of P
77132	Eau Claire R. SW $\frac{1}{2}$ SW $\frac{1}{4}$ Sec. 20; T27N, R7W	fine-grained H-P schist; strongly lineated
77138-A	Eau Claire R. NE $\frac{1}{2}$ SE $\frac{1}{4}$ Sec.29; T27N, R7W	H-P schist, lineated; associated with banded P-H gneiss.
77155-B	Knight Pool; North Fork, Eau Claire R. NW $\frac{1}{2}$ SE $\frac{1}{4}$ Sec.10; T26N, R7W	Fine-grained H-P schist (H=60%); thinly banded with lensoidal masses of feldspar very tight isoclinal folds of P locally Q-B bearing
7902-A	Little Falls, Eau Claire R. SW $\frac{1}{2}$ NW $\frac{1}{4}$ Sec.19; T27N, R7W	H-rich inclusion of lineated hornblendite gneissic H tonalite intrusion breccia; H has a pronounced green color in specimen and in thin section.
7908-A	Fisher R. Bridge SW $\frac{1}{2}$ SW $\frac{1}{4}$ Sec. 4; T31N, R6W	H-P schist-looks like gneissic H gabbro; cut by pegmatite veinlets and mylonite "veinlets" with right-lateral displacement
7927-N-1	Little Falls, Eau Claire R. SW $\frac{1}{2}$ NW $\frac{1}{4}$ Sec. 19; T27N, R7W	Lineated hornblendite xenolith in H-tonalite intrusion breccia
7941-A	Knight Pool; S. Fk. NW $\frac{1}{2}$ SE $\frac{1}{4}$ Sec.10; T26N, R7W	Medium fine-grained H-P schist
7950-A	Jim Falls, Chippewa R. SW $\frac{1}{2}$ NE $\frac{1}{4}$ Sec.30; T30N, R8W	Medium-grained H-P schist with P in tight isoclinal shear folds, whose limbs impart a pronounced layering in the rock

* Chemical analyses by Technical Service Laboratory, Mississauga, Ontario, Canada

** Mineral Abbreviations: P = plagioclase; H = hornblende; Q = quartz;
B = biotite; K = K-feldspar; M = muscovite; E = epidote; C = chlorite;
S = sericite; G = garnet

TABLE 2 - BULK CHEMICAL COMPOSITIONS OF INTERMEDIATE AMPHIBOLITES*

	7830 A	7830 B	7830 G	7830 H	7830 I	7904 C
SiO ₂	57.08	57.24	57.58	63.03	68.42	63.39
Al ₂ O ₃	15.87	14.89	17.74	14.35	14.37	17.22
Fe ₂ O ₃ + FeO	8.68	9.75	5.80	6.64	3.77	5.28
CaO	6.10	5.42	6.13	6.13	4.94	5.18
MgO	4.51	4.55	3.47	3.31	1.74	2.20
Na ₂ O	3.66	3.16	3.96	2.69	3.02	4.17
K ₂ O	0.72	1.36	1.89	1.18	0.99	1.00
TiO ₂	0.46	0.61	0.34	0.27	0.22	0.70
MnO	0.14	0.14	0.08	0.11	0.06	0.06
P ₂ O ₅	0.02	0.13	0.23	0.03	0.00	0.25
LOI	1.17	1.61	1.53	1.19	0.71	0.80
TOTAL	98.41	98.85	98.73	98.94	98.22	100.2

Spec. No.	Location	Description**
7830-A	Confluence of N & S Forks of the Eau Claire R. SE 1/4 NE 1/4 Sec. 16; T26N, R5W NE end of outcrop	Lineated P-H gneiss with lensoidal P clots. Interlensing shear surfaces with E-C laminae; Segmented, lenticulated P & H.
7830-B	2 meters west of 7830-A	Feldspathic H-P gneiss, with subhedral P & H lineation; Large Q-P bands form banding; E (10%) along and across H-P layering.
7830-C	3 meters west of 7830-B	P-H gneiss composed of bent and crushed lensoidal P & H; both show undulatory extinction and fragmented crystal boundaries; cross-cutting shear planes are E-rich.
7830-G	15 meters west of 7830-F	Medium-coarse-grained feldspathic P-H gneiss with lenticular H, P, and subordinate fine grained Q. P nearly all altered to S; H mostly converted to green C. H grains segmented, broken into sigmoidal lenses which wrap around coarser P lensoids. Cataclastic lamination N40°W, vertical.
7830-H	5 meters west of 7830-G	Banded P-H gneiss; contains abundant pyrite. Broken and bent P porphyroclasts and lenticulated, bent, segmented H in a matrix of Q, E, and P. P altered to S; H partly altered to C+E. Tension fractures across cataclastic lamination are filled with C+E.
7830-I	Same location as 7830-G	Felsic layer in 7830-G; more Q, less H than 7830-G; much mylonitization.
7904-C	Yellow River, east of Cadott	Volcanic (?) Now a fine-grained H-B tonalite or trondhjemite. H layering parallel to B foliation. No evidence of volcanic origin.

* Chemical analysis by Technical Services Laboratories, Mississauga, Ontario, Canada

** Mineral Abbreviations: P = plagioclase; H = hornblende; Q = quartz
B = biotite; K = K-feldspar; M = muscovite; E = epidote; C = chlorite;
S = sericite; G = garnet

TABLE 3 - BULK CHEMICAL COMPOSITIONS OF FELDSPATHIC AMPHIBOLITES*

	7711	77105 A	77119 C	77128
SiO ₂	48.36	50.51	49.69	57.54
Al ₂ O ₃	28.48	26.71	24.89	18.80
Fe ₂ O ₃ ⁺ FeO	3.05	3.48	4.18	7.15
CaO	12.99	14.46	13.31	6.72
MgO	1.92	0.68	2.94	2.87
Na ₂ O	3.11	1.67	2.91	4.34
K ₂ O	0.28	0.26	0.44	0.26
TiO ₂	0.18	0.25	0.31	0.49
MnO	0.04	0.05	0.06	0.08
P ₂ O ₅	0.02	0.02	0.09	0.12
LOI	0.52	0.40	0.60	0.60
TOTAL	98.96	98.48	99.43	98.96

Spec. No.	Location	Description
7711	Cornell Dam NW $\frac{1}{2}$ NE $\frac{1}{4}$ Sec. 19; T31N, R6W	Strongly lineated P-H-G schist; ragged G in layers.
77105-A	Eau Claire R. at Nine-mile Cr. NE $\frac{1}{4}$ SW $\frac{1}{4}$ Sec. 15; T27N, R8W	Strongly lineated P-H gneiss with folded lineation
77119-C	Big Falls, Eau Claire R. NW $\frac{1}{4}$ SE $\frac{1}{4}$ Sec. 13; T27N, R8W	Lineated P-H gneiss similar to 77105-A
77128	Eau Claire R. NW $\frac{1}{4}$ NE $\frac{1}{4}$ Sec. 19; T27N, R7W	Intermediate P-H gneiss; tight isoclinal folds of P bands

* Chemical analysis by Technical Services Laboratory, Mississauga, Ontario, Canada

** Mineral Abbreviations:

P = plagioclase; H = hornblende; Q = quartz; B = biotite; K = K-feldspar;
M = muscovite; E = epidote; C = chlorite; S = sericite; G = garnet

TABLE 4 - BULK CHEMICAL COMPOSITIONS OF METAVOLCANIC AND METASEDIMENTARY ROCKS FROM SOUTH FORK OF THE EAU CLAIRE RIVER*

	7829 A	7829 B	7829 C	7830 E	7830 F	7831 B	7832
SiO ₂	56.84	59.48	48.19	61.76	61.60	75.89	82.64
Al ₂ O ₃	19.46	20.41	20.54	17.56	17.18	10.33	8.51
Fe ₂ O ₃ + FeO	6.03	4.08	10.40	7.14	6.80	1.22	2.60
CaO	1.33	0.76	0.60	3.65	4.06	0.06	0.00
MgO	3.43	3.10	8.10	2.03	2.25	0.22	2.23
Na ₂ O	7.44	7.77	4.68	3.29	3.38	0.16	0.08
K ₂ O	0.71	1.26	1.51	2.02	2.11	8.45	2.03
TiO ₂	0.51	0.49	0.65	0.56	0.51	0.24	0.10
MnO	0.05	0.04	0.09	0.07	0.08	0.00	0.01
P ₂ O ₅	0.21	0.10	0.27	0.21	0.25	0.00	0.00
LOI	2.11	1.89	4.47	1.80	1.52	0.20	1.51
TOTAL	98.11	99.39	99.50	100.1	99.74	96.77	99.72

Spec. No.	Location	Description**
(7329)	Confluence of N. & S. Forks of Eau Claire River SE 1/4 Sec. 16; T26N, R5W	Chloritized, sericitized vitric andesite tuff with lensoidal P and clasts in fine-grained tuffaceous matrix; thinly laminated, bedded. (Thin section only)
7829-A	Same as 7329 above	Feldspathic andesite(?) tuff
7829-B	Same as 7329 above	Coarse feldspathic tuff
7829-C	Same as 7329 above	Coarsest, H-bearing, feldspathic andesite tuff; Clastic P is broken and bent; rocks have been strongly sheared, locally cataclasis produced interlensing shear surfaces along which C formed. Fragmented H.
7830-E	Eau Claire River: NE 1/4 SW 1/4 Sec. 16; T26N, R5W; 4 meters west of 7830-F	Gray meta-agglomerate (?) similar to C. Rounded, ovoid clasts of strained Q, P, C (pennine); devitrified glass(?) Matrix is a laminated meshwork of fine-grained Q+P+E-C.
7830-F	5 meters west of 7830-E	Coarse, sheared dacite(?) with bent, broken P and Q in E-C matrix of interlensing folia, very fine-grained crush debris. Some angular fragments of strongly zoned P. Van Schmus sample for zircon - U-Pb dating (1859±20 m.y.) sample 74-VS-10. Metatuff?
7831-B	Hay Creek below Rock Dam SW 1/4 NE 1/4 Sec. 15; T26N, R4W	Sheared rhyolite (?) contains polygranular lenses of Q in a laminated matrix of Q+K+M
7832	County Hwy. M at Eau Claire River NE 1/4 NE 1/4 Sec. 1; T26N, R4W	M-C quartzite and phyllite with kink folds on the limbs of a small anticline which plunges ENE at about 40°

* Chemical Analysis by Technical Services Laboratory, Mississauga, Ontario, Canada

** Mineral Abbreviations: P = plagioclase; H = hornblende; Q = quartz;
B = biotite; K = K-feldspar; M = muscovite; E = epidote; C = chlorite;
S = sericite; G = garnet

TABLE 5 - BULK CHEMICAL COMPOSITIONS OF TONALITES*

	7906 A	7922	7923 A	7927 D-2	7927 N-2	7952 B
SiO ₂	64.52	64.71	56.79	61.05	66.81	64.79
Al ₂ O ₃	16.39	16.56	16.73	16.00	16.18	16.69
Fe ₂ O ₃ + FeO	4.98	4.12	8.40	7.18	4.24	3.45
CaO	4.28	4.28	5.93	6.48	4.91	4.05
MgO	2.24	2.27	3.43	3.81	1.74	1.82
Na ₂ O	3.79	3.89	2.93	3.34	3.98	4.52
K ₂ O	2.29	2.11	2.10	1.37	1.23	1.41
TiO ₂	0.62	0.43	0.67	0.68	0.53	0.36
MnO	0.06	0.06	0.14	0.11	0.05	0.04
P ₂ O ₅	0.20	0.25	0.18	0.11	0.17	0.19
LOI	0.89	0.46	0.92	0.35	0.37	0.75
TOTAL	100.3	99.14	98.23	100.5	100.2	98.07

Spec. No.	Location	Description **
7906-A	Wissota Dam, Chippewa R. NE $\frac{1}{4}$ NW $\frac{1}{4}$ Sec. 3; T28N R8W	B-H tonalite with slight flow lineation; not sheared
7922	Fisher River SW $\frac{1}{4}$ SW $\frac{1}{4}$ Sec. 4; T31N, R6W	Gneissic B tonalite protomylonite with Q blebs (20%); contains occasional xenoliths of feldspathic rock (adamellite?)
7923-A	Fisher River SW $\frac{1}{4}$ SW $\frac{1}{4}$ Sec. 4; T31N, R6W	Banded, gneissic H-B tonalite; xenolith in adamellite or granodiorite (?) B = 10%; H = 30%; P = 35%; Q = 15%; E = 2%
7927-D-2	Little Falls, Eau Claire River SW $\frac{1}{4}$ NW $\frac{1}{4}$ Sec. 19; T27N, R7W	Gneissic P-H-B tonalite matrix for intrusion breccia containing abundant, elongated H- rich xenoliths
7927-N-2	Little Falls, Eau Claire River SW $\frac{1}{4}$, NW $\frac{1}{4}$, Sec. 19, T27N, R7W	Massive H tonalite or trondhjemite (?) P (63%) not twinned; Q = 21%; H = 13%; matrix for H-rich xenoliths
7952-B	Jim Falls; Chippewa River NE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 30; T30N, R8W	Sheared gneissic H-B tonalite; locally con- tains lenses and bands of H-schist and dike- pegmatite masses

• Chemical analyses by Technical Service Laboratory, Mississauga, Ontario, Canada

** Mineral Abbreviations: P = plagioclase; H = hornblende; Q = quartz;
B = biotite; K = K-feldspar; M = muscovite; E = epidote; C = chlorite;
S = sericite; G = garnet

TABLE 6 - BULK CHEMICAL ANALYSES OF TRONDHJEMITES, ADAMELLITES, GABBRO, AND DIORITE*

	TRONDHJEMITES									ADAMELLITE	GABBRO & DIORITE	
	7335	7337	77131	77136	7830 D	7905 C	7906 D	7907	7942 A	7425 A	7904 A	7945 A
SiO ₂	70.22	73.85	70.97	72.63	70.62	72.36	71.18	78.27	65.66	72.20	49.45	52.33
Al ₂ O ₃	15.50	14.10	15.13	13.75	15.52	14.59	15.64	12.00	16.69	14.02	16.30	20.27
Fe ₂ O ₃ +FeO	3.12	2.09	2.97	2.17	2.49	2.54	2.11	1.68	3.53	2.04	9.11	6.75
CaO	2.95	1.12	2.71	1.44	2.61	2.90	2.56	2.56	2.65	2.04	9.53	9.86
MgO	1.03	0.56	0.96	0.42	0.97	0.81	0.71	0.44	2.14	0.68	8.45	5.13
Na ₂ O	4.39	4.57	4.59	3.05	4.45	4.62	4.84	3.33	4.06	3.07	2.88	3.59
K ₂ O	1.51	3.11	1.34	4.33	1.43	1.45	2.39	1.22	4.05	3.96	0.86	0.96
TiO ₂	0.26	0.15	0.29	0.17	0.28	0.26	0.27	0.12	0.38	0.18	0.88	0.43
MnO	0.05	0.03	0.04	0.04	0.03	0.03	0.02	0.01	0.05	0.03	0.16	0.10
P ₂ O ₅	0.06	0.01	0.04	0.02	0.05	0.09	0.09	0.00	0.25	0.05	0.25	0.24
LOI	0.48	0.64	0.40	0.52	0.84	0.34	0.21	0.36	0.76	0.74	0.88	0.59
TOTAL	99.57	100.2	99.44	98.54	99.30	100.0	100.0	99.99	100.2	99.01	98.75	100.2

Spec. No.	Location	Description**
TRONDHJEMITES		
7335	Eau Claire River near mouth of Whippoorwill Creek SW $\frac{1}{4}$ SE $\frac{1}{4}$ Sec.18; T26N, R5W	Gneissic Leucotonalite; gneissosity produced by elongation of Ab-rimmed P
7337	Eau Claire River at mouth of Whippoorwill Creek SW $\frac{1}{4}$ NW $\frac{1}{4}$ Sec.18; T26N, R5W	Highly sheared, chloritized, gneissic trondhjemite; banded, mylonitized, mechanically intermixed with H-P schists.
77131	Eau Claire River SE $\frac{1}{4}$ SW $\frac{1}{4}$ Sec.20; T27N, R7W	Foliated, fine-grained, aplitic B trondhjemite.
77136	Eau Claire River NE $\frac{1}{4}$ SW $\frac{1}{4}$ Sec.20; T27N, R7W	Foliated, H-B trondhjemite
7830-D	Eau Claire River 0.5 meters of 7830-C NE $\frac{1}{4}$ SW $\frac{1}{4}$ Sec.16 west T26N, R5W	Coarse, feldspathic trondhjemites (Oligoclase porphyroclasts in fine-grained matrix of strained Q; laminated) Feldspars bent, broken, and intruded by Q-rich mylonite.
7905-C	Cadott Bridge, Yellow Riv. SW $\frac{1}{4}$ NE $\frac{1}{4}$ Sec.31; T29N R6W	Trondhjemite protomylonite gneiss with ovoid P and H altered to E+H+B.
7906-D	Wissota Dam, Chippewa Riv. NE $\frac{1}{4}$ NW $\frac{1}{4}$ Sec.3; T28N, R8W	Gneissic B-M trondhjemite: major rock type below Wissota Dam.
7907	Fisher River NW $\frac{1}{4}$ NW $\frac{1}{4}$ Sec. 9; T31N, R6W	Gneissic M-leucotondhjemite. Accessory B and E form throughgoing foliation; contains round zircons.
7942-A	Knight Pool, North Fork of Eau Claire River SE $\frac{1}{4}$ NE $\frac{1}{4}$ Sec.10; T26N, R5W	B-trondhjemite or granodiorite gneiss.
ADAMELLITE		
7425-A	Cornell Dam, Chippewa Riv. SE $\frac{1}{4}$ NE $\frac{1}{4}$ Sec.18; T31N, R6W	B-M adamellite flaser gneiss or mylonite gneiss with lensoids of P and K in Q-rich mylonitic matrix; interlensed with H-P-G gneiss and schist
GABBRO AND DIORITE		
7904-A	Big Bend, Yellow River NE $\frac{1}{4}$ SE $\frac{1}{4}$ Sec.33; T29N, R6W	Sheared, foliated, cataclastic H-diorite with B foliation cut by cataclastic tonalite "dikes".
7945-A	Little Falls, Eau Claire River SW $\frac{1}{4}$ NW $\frac{1}{4}$ Sec. 19; T27N, R7W	B-H quartz gabbro; probably a contaminated form of H-tonalite.

* Chemical analyses by Technical Services Laboratories, Mississauga, Ontario, Canada

** Mineral Abbreviations: P = plagioclase; H = hornblende; Q = quartz;
B = biotite; K = K-feldspar; M = muscovite; E = epidote; C = chlorite
S = sericite; G = garnet

GEOPHYSICS

Aeromagnetic quadrangle maps by Karl and Friedel (1974-1976) have not been published in final form. However, the preliminary maps show important trends, and the patterns help to identify and correlate aeromagnetic signatures with mapping on the ground. Steep-sided ridges and troughs elongate parallel to structural grain characterizes areas underlain by screens and enclaves of amphibolite. The amphibolite terranes are in sharp contrast with the splotchy contour patterns and low relief of areas underlain by granitic rocks. These maps were of considerable help in compiling the generalized geologic map in Figure 1.

A portion of the Bouguer gravity anomaly map of Wisconsin by Ervin and Hammer (1974) has been included (Figure 9) for reference. Note the pronounced gravity slope along the Jump River. Extended along its trend southwestward, the "lineament" follows the north shore of Lake Holcombe and along the south side of Flambeau Ridge, where Barron-type quartzite conglomerates are thrown into large open folds which plunge northwest at about 55°. The Barron quartzites northwest of Flambeau Ridge are typically undeformed.

A strong aeromagnetic lineament trending northwesterly across the mouth of the Yellow River on the east end of Lake Wissota is matched by a major shear zone of similar trend in the rocks there. Sims (1976) shows several major north-west-trending faults of similar trend. The Bouguer gravity anomaly map shows a large "positive" anomaly just east of Lake Wissota. This anomaly may be fault-bounded on the west.

GEOCHRONOLOGY

Major events in the geologic history of the Chippewa Valley region have been compiled in the chronology presented in Table 7. It is emphasized that this is a tentative chronology. Only those age relationships for which there is field evidence have been included. Zircon U/Pb dates have been published (Van Schmus, 1980 and Maass and Van Schmus, 1980) for four rocks in the Chippewa Valley: (1) sheared dacite(?) from the South Fork volcanic and sedimentary rocks at location 7830-F (See Table 4 for description). Age = 1860 ± 20 m.y.; (2) banded amphibolite from Big Falls, Stop 1. Age = 1850 ± 20 m.y.; (3) foliated hornblende tonalite from Little Falls, Stop 2. Age = 1842 ± 10 m.y.; and (4) trondhjemite at Chippewa Falls Dam. Age = 1830 ± 15 m.y.

If the banded amphibolite (unit #1 of Cummings) is only 1850 m.y. old, it will be very difficult to explain when two episodes of metamorphism and deformation preceding intrusion of the Little Falls Tonalite took place. Van Schmus (1980, p. 3) states that, "In the case of the Big Falls zircon the possibility still exists that they are metamorphic, formed during the Penokean Orogeny about 1850 m.y. ago (Van Schmus, 1980) and that the gneiss is Archean, but for the present a Penokean primary age is preferred." We are inclined from abundant field evidence at many other places to support the contention that the age of the amphibolites at Big Falls - and elsewhere throughout the CAC - is Archean.

BIG FALLS - LITTLE FALLS AREA - INTRODUCTION

A generalized geologic map of the Big Falls-Little Falls area (Figure 10) shows that the rock units occur in bands trending west-northwest. It is suggested that if the mafic hornblende schist underlies the feldspathic hornblende gneiss (layered gabbro), the symmetry of the units indicates an overturned anticline cored in part by the hornblende tonalite intrusion breccia. Later faulting has modified this structure. The biotite-hornblende-epidote-chlorite schists may be the substrate for the layered gabbro.

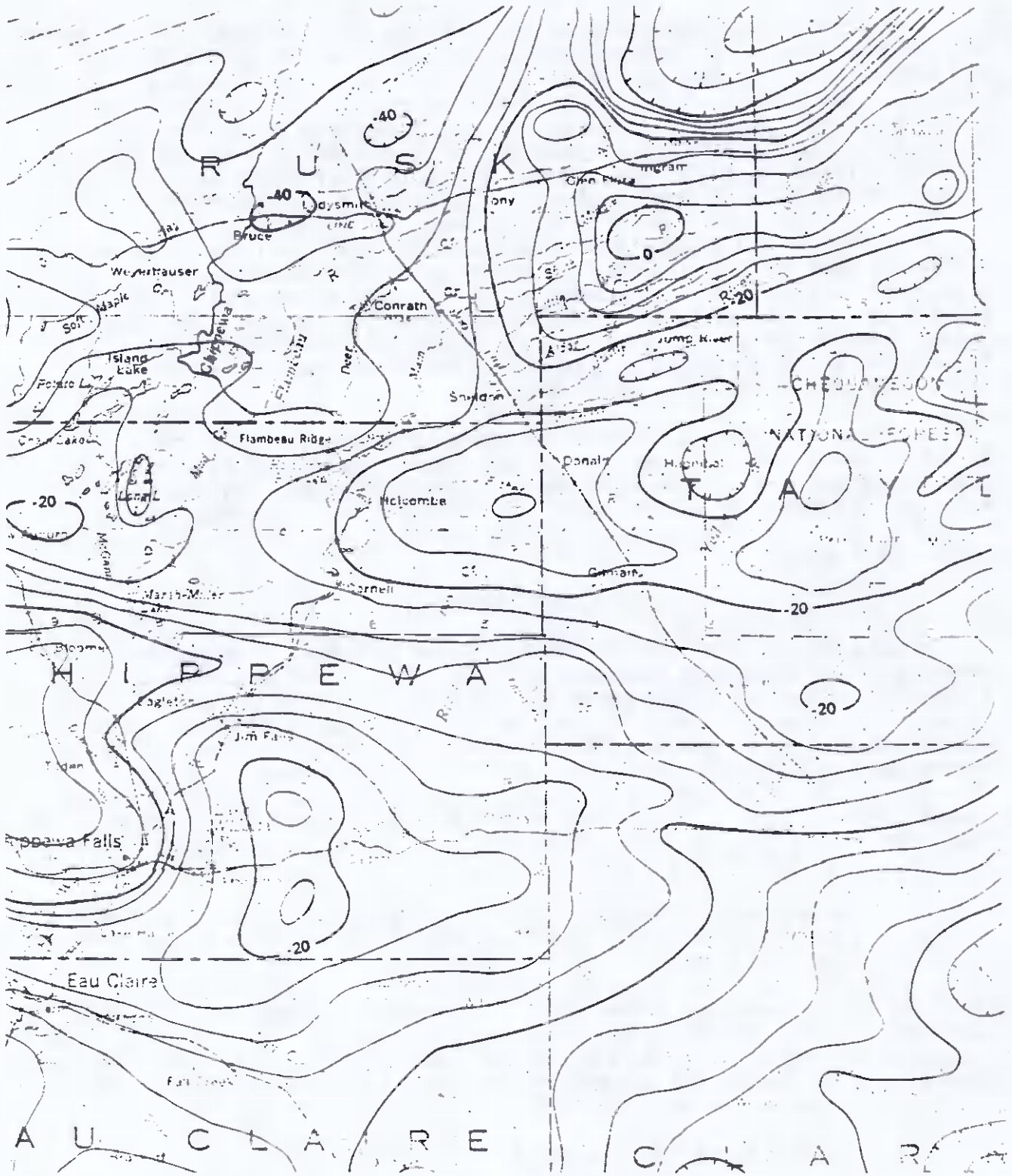


Figure 9 -- Bouguer anomaly gravity map of the Chippewa Valley region from Ervin and Hammer, 1974.

TABLE 7

TENTATIVE CHRONOLOGY FOR THE CHIPPEWA VALLEY REGION

LATE PRECAMBRIAN	UNCONFORMITY	Erosion, jointing, regional uplift
		<u>Fourth Deformation</u> , Block faulting along northwest-trending faults. Holcombe Dam, Lake Wissota.
		Intrusion of leucotronchjemite veins, Lake Wissota
	1100 m.y. (?)	Intrusion of gabbro-diabase dikes throughout region; ENE trends
	UNCONFORMITY	Erosion - removal of several kilometers of rock
MIDDLE PRECAMBRIAN		<u>Third Deformation, Cataclasis, and Greenschist Facies Metamorphism</u>
	?	Large scale open folding and local drag folding associated with strike-slip faulting and widespread mylonitization; formation of garnet, chlorite, and epidote in amphibolites and South Fork, Jump River volcanic and sedimentary series.
		Aplite and pegmatite dike intrusion (Little Falls, Jim Falls)
	1824 ± 25 m.y.*	Intrusion of "Lineated tonalite", Jim Falls, Wissota Dam (dikes) Late Kinematic intrusion of gabbro, Yellow River (Stop 8)
	1830 ± 15 m.y.*	Intrusion of trondhjemite, granodiorite, adamellite, Lake Wissota, Chippewa Falls, Fisher River (leucotronchjemite) Main pulse of plutonic activity. Intrusion of composite batholiths along the axis of the Penocean orogen.
EARLY PRECAMBRIAN	1842 ± 20 m.y.*	Intrusion of "Foliated Tonalite" Breccia, Little Falls, Cadott. Synkinematic intrusion under high compression and in the presence of a steep geothermal gradient. Formation of Little Falls and Fisher River breccias, and possibly the breccia at Cadott.
	1860 ± 20 m.y.*	Volcanism and Sedimentation: deposition of South Fork and Jump River volcanic and sedimentary rocks as part of the Flambeau and Black River volcanic provinces.
	UNCONFORMITY	
		<u>Second Deformation, Cataclasis, and Regional Metamorphism</u>
		Strike-slip faulting, localized cataclasis, formation of tight, open (F-2) open folds, development of tectonic breccias by differential movement along shear planes; intrafolial folds. Subsequent erosion.
		Intrusion of trondhjemite (Cadott, Jim Falls) and Granite (Little Falls)
		<u>First Deformation and Metamorphism</u>
		Isoclinal folding (F-1) with axial plane shearing, displacement; formation of garnet porphyroblasts (Big Falls).
		Intrusion and gravity differentiation of Big Falls gabbro For details, see Table 8.
		Basaltic Volcanism and Sedimentation

* Van Schmus, 1980

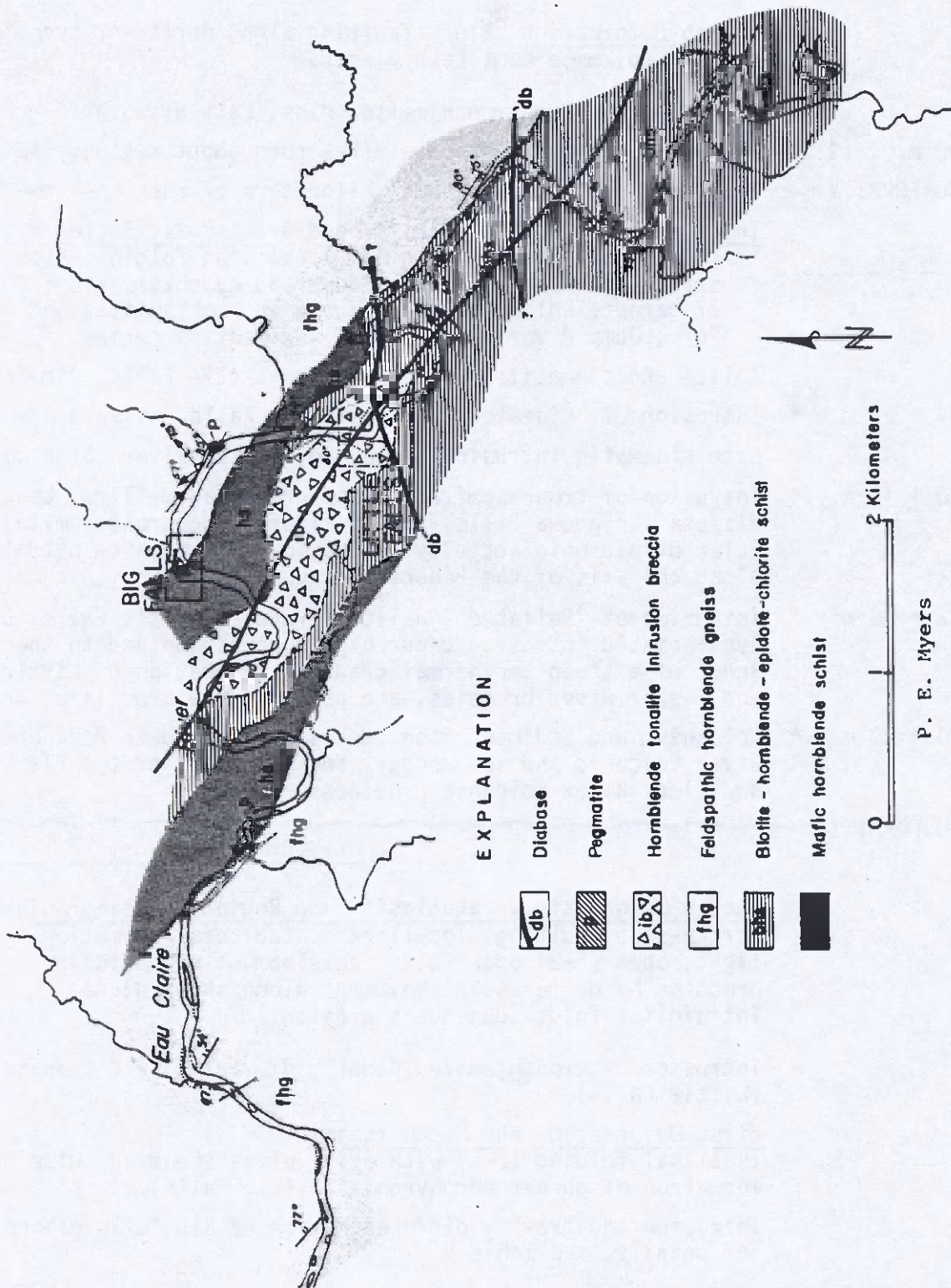
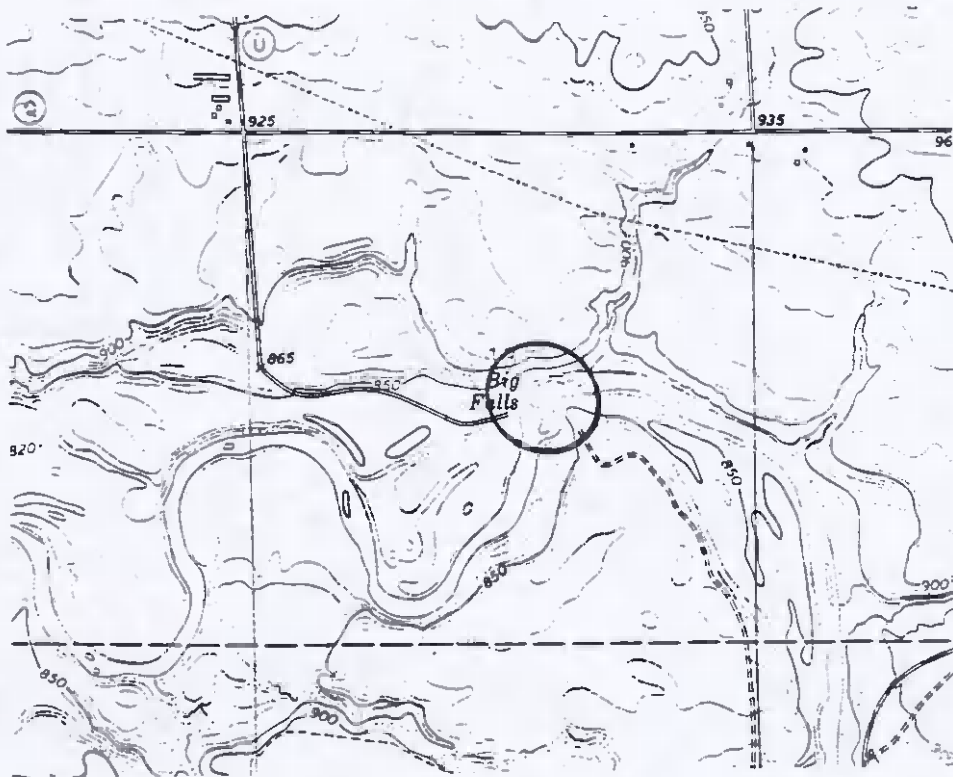


Figure 10-- Geologic map of the Eau Claire River including the Big Falls and Little Falls areas.

STOP #1

TITLE: GEOLOGY OF BIG FALLS COUNTY PARK, EAU CLAIRE COUNTY, WISCONSIN

LOCATION: Eau Claire River, NW $\frac{1}{4}$, SE $\frac{1}{4}$, SEC. 13, T. 27N., R. 8W, Eau Claire County



AUTHOR: M.L. Cummings

DATE: March, 1980

SUMMARY OF FEATURES:

The rocks at Big Falls County Park are part of a differentiated mafic intrusive of Early Precambrian age. Primary igneous compositional banding is present in all units. Rocks in the area have been deformed and metamorphosed three times producing complex relations between primary igneous structures and structures formed by tectonic processes.

INTRODUCTION:

The outcroppings of Precambrian rocks at Big Falls County Park in north-central Eau Claire County, Wisconsin, record a complex geologic history for the west-central Wisconsin area. Although on first inspection, the geology seems relatively straightforward, a closer examination reveals evidence for possibly three periods of deformation and metamorphism and three late stage fault sets. The apparent long geologic history recorded in the rocks suggests that the Big Falls area and at least parts of the west-central Wisconsin area are underlain by rocks of Archean age, possibly early Archean age.

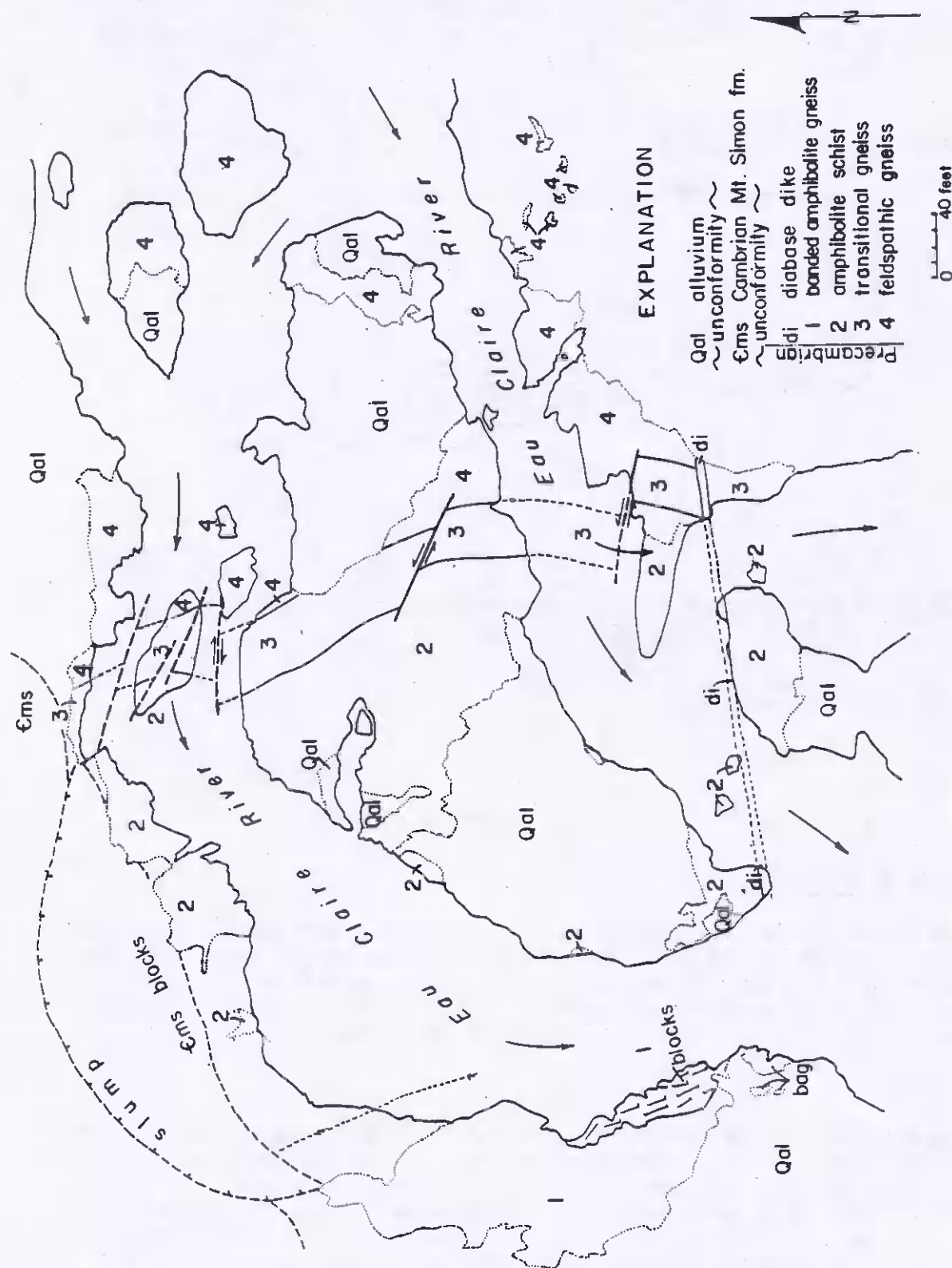


Figure 11 -- Outcrop geologic map of the Big Falls area, Eau Claire County, Wisconsin

The outcrops at Big Falls are the most extensive and best exposed outcrops of a differentiated mafic intrusive of unknown size. Outcrops of the intrusive are found for approximately 3.5 km up river from Big Falls to approximately 4 km down river (Cummings and Myers, 1978). The intrusive contains anorthosites, gabbroic anorthosites, gabbros and mafic cumulates. Mostly anorthositic rocks crop out down river from Big Falls; gabbroic to mafic cumulates crop out upstream. Besides representing the best exposures of the intrusive, the Big Falls outcrops include examples of the major rock units of the intrusive.

PREVIOUS WORK:

Big Falls was one of the first areas studied in west-central Wisconsin (Cummings, 1971). The area was mapped in detail and preliminary chemical data was presented by Cummings and Myers (1974) and Cummings (1975). An expanded study along the Eau Claire River Valley in which the extent of exposure of the differentiated intrusive was mapped, was reported by Cummings and Myers (1978). This paper has drawn from these earlier works but also presents new interpretations and reexamines earlier conclusions.

ROCK UNITS:

The differentiated intrusive is represented by four lithologies at Big Falls (Figure 11). The units are recognized by the percentage of hornblende and plagioclase, and the prominence of compositional banding.

Unit 1 is distinctly banded with hornblende-rich bands alternating with plagioclase-rich bands. The unit has been called a banded amphibolite gneiss (Cummings, 1975, Cummings and Myers, 1974) but it must be emphasized that the banding is inherited from the protolith and is not due to metamorphic differentiation. Unit one is found only at Big Falls and from local relationships appears to be in fault contact with the other three units at Big Falls. Coarse garnet porphyroblasts are prominent in the unit occurring both in hornblende-rich and plagioclase-rich compositional bands.

Units 2, 3, and 4 are stratigraphically continuous and are representative of apparent mesoscopic and megascopic compositional banding in the intrusive.

Unit 2 is dark green to black, finely-banded amphibolite schist of unit 2 to an anorthositic unit in unit 4. The third unit is 2.3 m thick and has sharp contacts against units 2 and 4. The unit is best exposed on the island where its width is uniform along strike, however it is absent or greatly disrupted on the north and south banks of the river because of faulting.

The third unit is transitional from the amphibolite schist of unit 2 to an anorthositic unit in unit 4. The third unit is 2.3 m thick and has sharp contacts against units 2 and 4. The unit is best exposed on the island where its width is uniform along strike, however it is absent or greatly disrupted on the north and south banks of the river because of faulting.

The fourth unit, previously referred to as a feldspathic gneiss, is an anorthositic unit that displays diffuse composition banding. The unit ranges from a gabbroic anorthosite to an anorthosite.

One of the major difficulties in interpreting the geology of Big Falls is deciding which structures and textures are metamorphic and which are primary igneous features formed during crystallization and differentiation of the intrusive.

PRIMARY IGNEOUS FEATURES:

The most prominent igneous feature is compositional banding. All rock units display such banding and each of the rock units is, in itself, a compositional layer of the larger intrusive.

Compositional bands are best displayed in unit 1. Individual hornblende-rich bands range from 0.6 cm to nearly 20 cm thick and alternate with plagioclase-rich bands 0.6 cm to 30 cms thick. Bands are generally uniform in thickness along strike but individual bands cannot be traced the length of the outcrop because of late faults. A crude mesoscopic banding is also present; feldspar-rich bands are prominent near the river, but the number and thickness of hornblende-rich bands increases away from the river.

Compositional banding in unit 2 is not as obvious as in unit 1, but is nonetheless present. Fine-scale banding (<.5 cm) may be metamorphically produced, however bands greater than 15 cm thick are believed primary. The more mafic layers, possibly representing clinopyroxene - olivine cumulates, contain 60 to 90 percent hornblende. Cumingtonite-garnet-hornblende layers may represent olivine, orthopyroxene cumulates. The mesoscopic compositional bands can be easily traced through the park. Some of the mesoscopic bands are characterized by fine-scale bands of plagioclase alternating with hornblende. Such fine-scale bands are difficult to trace because of deformation.

The fourth unit is weakly banded. The percentage of hornblende varies from band to band, generally composing less than 15 percent of a given band.

The contact zone between unit 2 and unit 3 is remarkable for a number of apparently primary features. During crystallization of the intrusive blocks of already crystallized material apparently dropped to the floor of the intrusive and were buried by the crystals accumulating there. Three examples of blocks have been found. Figure 12 is a feldspar-rich clast that displays internal compositional banding. The internal banding is truncated by banding in the more mafic enclosing rock, folds in the clast may have been produced by later deformation. Two examples of hornblende-rich clasts have been discovered. In each case the clast is clearly more mafic than the enclosing rock. Internal banding is not present in either sample. Although the clasts have been flattened in the plane of schistosity they can be recognized as clasts formed during magmatic crystallization. Blocks of earlier crystallized materials from different stratigraphic units of differentiated mafic intrusives have been noted in major complexes, including the Bushveld Complex (Willemse, 1969) and the Stillwater Complex (Hess, 1960).

Another feature near the contact between unit 2 and unit 3 is illustrated in figure 3. A strongly contorted band approximately 0.3 m wide can be traced across the island. The width and the relative stratigraphic level of the band are approximately uniform. The axes of folds in the band are apparently random, and limbs are commonly truncated against limbs of other folds. The fold axes do not coincide with any deformation features observed in the enclosing rocks. Apparently the material represents soft sediment deformation of the crystals that accumulated on the floor of the magma chamber during crystallization. Slumpage of early formed crystals on the chamber floor may have been triggered by convection in the cooling magma or earthquakes during crystallization of the intrusive.

The abundance of apparently primary clasts and slump features in the contact zone between unit 2 and unit 3 and the apparent lack of such features in the rest of the outcrop area suggests either a slow rate of accumulation of crystals on the chamber floor allowing such features to appear concentrated over a thin stratigraphic zone, or might indicate a period of tectonic instability during which blocks of crystalline material dropped to the floor of the chamber and slumpage of unconsolidated crystals occurred.

TECTONIC FEATURES:

Polymetamorphism and polydeformation make interpretation of the geologic evolution of Big Falls difficult. The response of the rocks to deformation and metamorphism under varying conditions has produced a wide variety of structural and mineralogical features. One of the important features of the rock is that the intensity of dislocative deformation is not constant throughout the area. Intensely deformed rocks are adjacent to rocks containing primary igneous features. The deformational and metamorphic history of the area has been reconstructed from thin section analysis coupled with interpretation of structures observed in outcrop.

The oldest apparent metamorphic features are the coarse garnet porphyroblasts which occur in unit 2 and prominently in unit 1. The garnets are believed to be oldest because they appear to have been present while younger structures and mineral textures were developing in the rocks. Highly elongated isoclinal folds in unit 1 may have formed at the same time. The axial planes of such folds are typically sheared (Figure 14.) Some of the well-developed fold structures found in unit 2, particularly on the island, may be of the same age. Folding preceded faulting. The faults cross the compositional banding at a low angle (probably emphasized by later flattening) producing a pattern that resembles cross-stratification (Figure 15). The above features appear to be the remnants of the earliest deformation and metamorphism of the area. Deformation, although intense and pervasive, did not destroy primary features in the rock. The main deformational features are found in rocks with a relatively high percentage of plagioclase. Metamorphic grade apparently was in the garnet amphibolite facies. Faulting late in the deformational period suggests a more brittle behavior in the rock after having behaved in a ductile manner during the peak of metamorphism.

The second metamorphism-deformation did not develop as extensive a suite of deformational features. The main structures appear to be associated with flattening as indicated by compositional banding and early fault planes wrapped around garnet porphyroblasts. Major zones of dislocation are a minor feature of the deformation; one occurs in unit 2 where a shear zone cuts the schist. The zone presents an excellent example of transposition of foliation, where pre-existing compositionally banded rocks occur as tectonic inclusions or rootless intrafolial folds in a strongly deformed matrix. The deformational zone is approximately 2 meters wide. Locally some open folds may have developed in units 1 and 2 and foliation developed particularly in unit 2. The rock was metamorphosed under amphibolite facies conditions. The metamorphism produced a coarse grained plagioclase-hornblende assemblage and recrystallization of the fault planes of early-formed faults. In unit 1 coarse garnet porphyroblasts apparently became

unstable in the presence of plagioclase under the new metamorphic conditions and reaction rims of a highly aluminous hornblende developed between the two phases. Similar alteration of garnet to hornblende also occurs in unit 2 but is not as readily observed in outcrop because of the high percentage of amphibole in the rock.

The third deformational-metamorphic sequence is associated with development of intense zones of deformation that occur on the south bank and island and the development of a weak schistosity oriented N 55 W. The main deformation appears to have been before recrystallization since shear zones that developed on the island and south bank are thoroughly recrystallized and fine pervasive shear zones in unit 1 are not only recrystallized but served as the locus for crystallization of fine-grained garnet. Although deformation features are not prominent, recrystallization textures are extensive. The main new mineral to appear was euhedral epidote. The coarse grained plagioclase that had formed during the second metamorphism recrystallized to form clusters of fine polygonal grains that preserve the outline and twinning of the original plagioclase grains. The recrystallized plagioclase is variable in composition ranging as much as 10 percent anorthite content within a single relict plagioclase grain. In unit 2 the development of prismatic hornblende and locally euhedral epidote was accompanied by crystallization of fine-grains of ilmenite in relict coarse hornblende crystals. Such ilmenite inclusions are highly concentrated in the old grains but a narrow inclusion-free band surrounds each grain. Apparently the third metamorphism occurred under epidote amphibolite facies conditions that produced extensive recrystallization but did not completely destroy the coarse grained textures produced during the second metamorphism.

All younger structural features in the rocks are associated with late faults. In each case the fault planes are not recrystallized and are the sites of alteration of the rock.

A summary of deformation and metamorphism for the Big Falls outcrops is presented in Table 1. The grouping of deformational features is different than the interpretations presented by Cummings (1975) in that growth of garnet porphyroblasts and folding of the rock into tight isoclinal folds are included in the first deformation. Also the second deformation is interpreted more as a flattening event than an intense folding event as previously. In any case, the interpretation of three major deformational and metamorphic events has not changed.

Relating the deformational and metamorphic events recorded at Big Falls to the broader framework of regional tectonic activity is not an easy task. The third deformation is apparently younger than the Penokean Orogeny. Cataclastic zones and recrystallization found at Big Falls are also present at Little Falls (stop 2), one mile east, where a 1842 ± 10 m.y. (Van Schmus, 1980) tonalite intrusive has experienced the same deformation and recrystallization. Possibly the third event coincide with widespread low-grade metamorphism at 1650-1700 m.y. (Van Schmus, 1976, Sims, 1976) reported in the Lake Superior Region. The structures developed at that time, as seen at Big Falls, may not be prominent and shear zones, although preserving cataclastic textures in hand sample are thoroughly recrystallized. Structures produced at Big Falls during the third deformation could be easily overlooked without great attention to

TABLE 1: Chronology for Big Falls County Park

Intrusion and differentiation of a mafic intrusive.

Slump structures develop on the floor of the magma chamber and autoliths are produced by tectonic activity.

First deformation and metamorphism

Crystallization of coarse garnet porphyroblasts in units 1 and 2.

Isoclinal folding and shearing of axial planes of the developing folds.

Faulting.

Second deformation and metamorphism

Flattening and development of local intensely sheared zones. Minor open folds produced.

Crystallization of coarse grained hornblende and plagioclase.

Alteration of garnet to an aluminous hornblende because of incompatibility between plagioclase and earlier formed garnet.

Third deformation and metamorphism

Local intense cataclasis and deformation, crystallization of N55W schistosity.

Growth of euhedral epidote, recrystallization of the rock but textures produced during the 2nd metamorphism are not destroyed.

Late faulting

Development of lens shaped, fault-bounded structures in unit 1 as unit 1 is faulted into place against unit 2.

Right-lateral faults

Left-lateral faults

the fine details in the rock. The second deformation and metamorphism at Big Falls coincides with regional plutonism and metamorphism associated with the Penokean Orogeny. Intense folding does not appear to have occurred at Big Falls at this time. Instead a pronounced flattening and the development of local shear zones are recorded. The first deformation produced the pervasive isoclinal folding at Big Falls and appears to represent late Archean deformation. Thus the intrusion and differentiation of the mafic intrusive appears to have been an earlier Archean event.

SUMMARY:

The outcrops at Big Falls are part of a differentiated mafic intrusive that crops out along the Eau Claire River. The intrusive was emplaced during the Archean. Differentiation produced compositional layering and possible tectonic activity during crystallization produced slump structures and autoliths. Three deformational and metamorphic periods resulted in folding, faulting and recrystallization of the rocks. The first deformation appears to have been Archean in age and produced isoclinal fold structures in all rock units. The second deformation occurred during the Penokean Orogeny and is primarily associated with flattening of the area. The third deformation is possibly associated with widespread regional low-grade metamorphism in the Lake Superior Region.

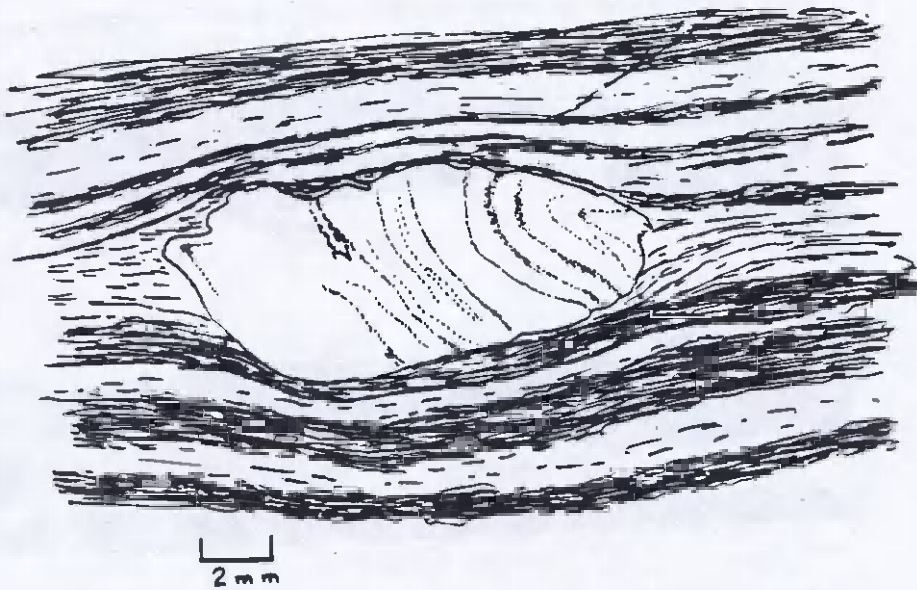


Figure 12 -- Anorthositic clast enclosed in amphibolite schist. Contact zone between unit 2 and unit 3 is exposed on the island.

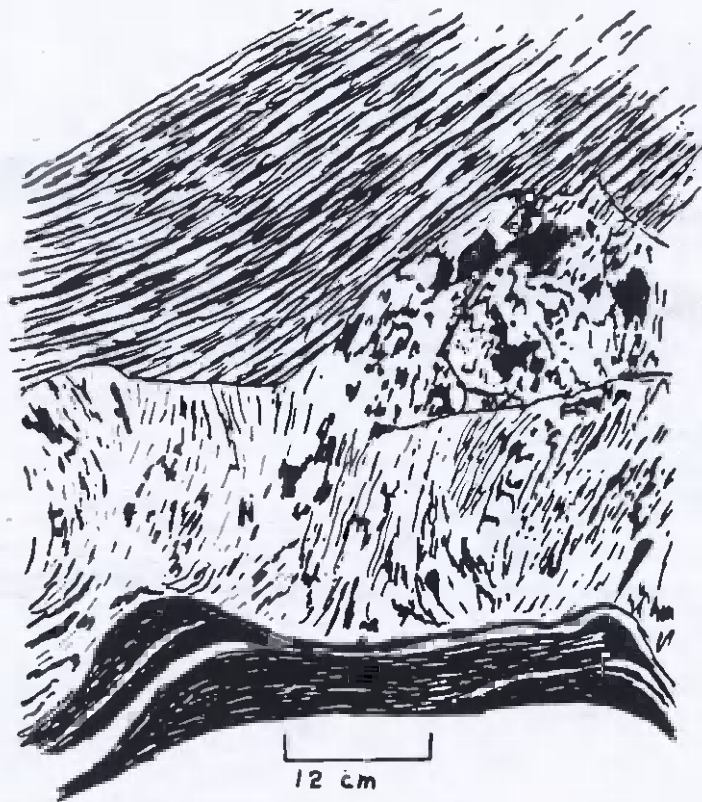


Figure 13 -- Possible slump structure in amphibolite schist in the contact zone between unit 3 and unit 4 as exposed on the island.

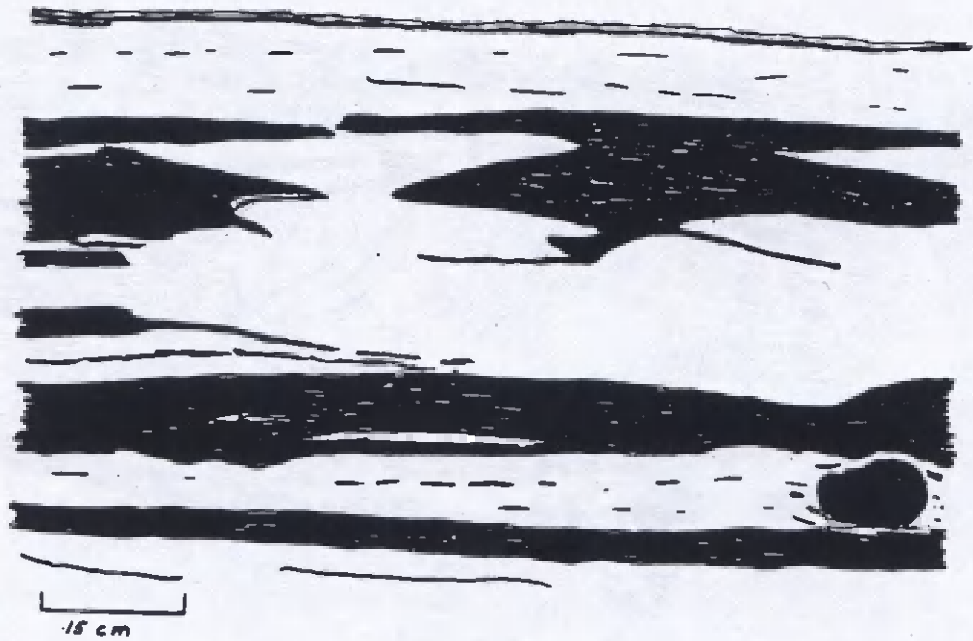


Figure 14 -- Sheared fold structure from unit 1. Black areas are hornblende-rich bands and round object in lower right corner is a garnet porphyroblast

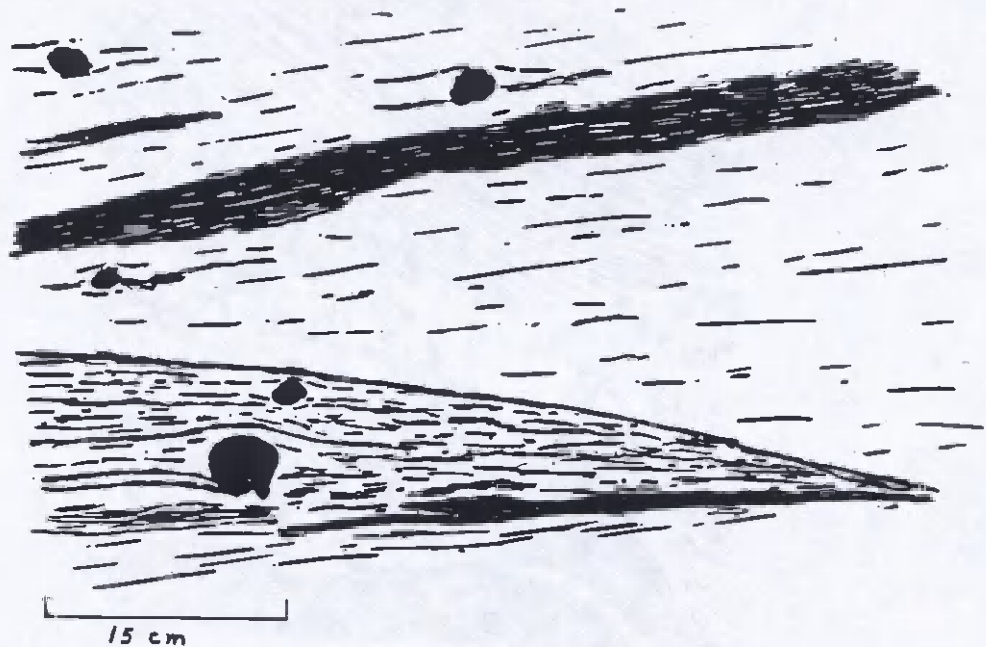


Figure 15 -- Early formed fault in unit 1. Note the similarity to cross-stratification found in sediments. The fault plane has been wrapped around garnet porphyroblasts shown as black roughly circular features.

ACKNOWLEDGEMENTS:

The present interpretation of the geology of Big Falls is the result of years of work and discussions with many people. Discussion with P. Myers, R. Maass, J. Grant, D. Davidson and participants on several field trips have influenced my thinking.

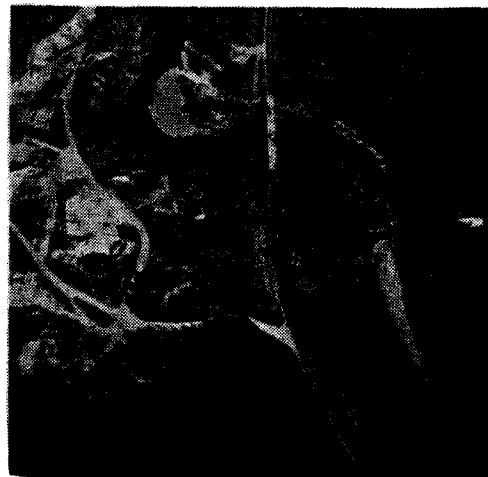
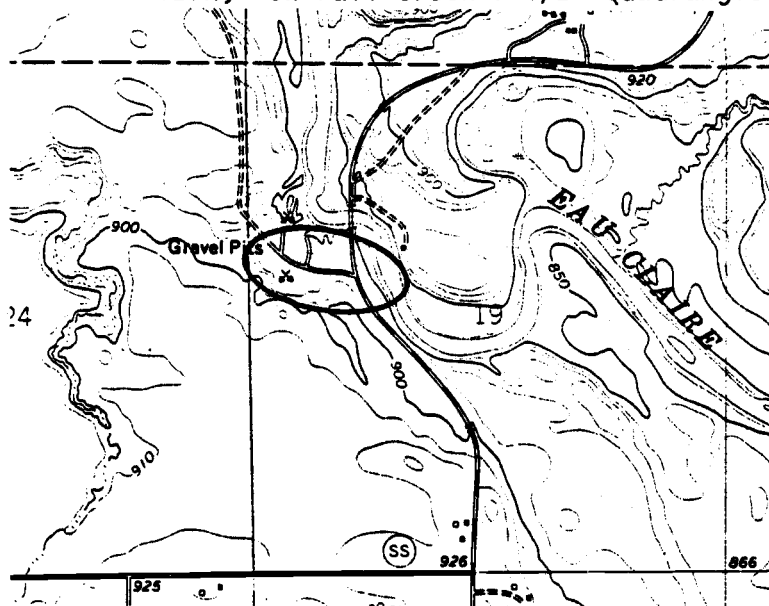
REFERENCES CITED

- Cummings, M.L., 1971, Geology of Big Falls, Wisconsin: Guidebook, 3rd Annual Wisconsin State University Geology Field Conference, p. 13-20.
- Cummings, M.L., Myers, P.E., 1974, Geology of the Big Falls Area: Guidebook, 38th Annual Tri-State Geological Field Conference.
- Cummings, M.L., 1975, Petrology and structure of Precambrian gneisses at Big Falls, Eau Claire County, Wisconsin: M.S. thesis, University of Minnesota, Duluth.
- Cummings, M.L., Myers, P.E., 1978, Petrology and geochemistry of Amphibolites, Eau Claire River, Eau Claire County, Wisconsin: (abs) 24th Annual Institute on Lake Superior Geology.
- Hess, H.H., 1960, Stillwater Igneous Complex: Geological Society of America, Memoir 80, p. 225.
- Sims, P.K., 1976, Precambrian Tectonic and Mineral Deposits, Lake Superior Region: Economic Geology, V. 71, p. 1092-1118.
- Van Schmus, 1976, Early and Middle Proterozoic history of the Great Lakes Area, North America: Phil. Trans. R. Soc. Long. A. 280, p. 605-628.
- Van Schmus, 1980, Geol. Soc. Amer. Spec. Paper, #180, Goldich Volume.
- Willemse, J., 1969, The geology of the Bushveld Igneous Complex, the largest repository of magmatic ore deposits in the world: in Magmatic ore deposits: Economic Geology Publishing Co. p. 1-22.

STOP #2

TITLE: LITTLE FALLS BRECCIA

LOCATION: County Highway K at Eau Claire River; SW 1/4, NW 1/4, Sec. 19,
T27N, R8W Fall Creek 7 1/2' Quadrangle



AUTHOR: Paul E. Myers

DATE: February, 1980

SUMMARY OF FEATURES:

Archean (?) basalt, volcanogenic sediments, and granite, after being deformed and recrystallized at least twice, were synkinematically intruded by hornblende tonalite to form the Little Falls breccia about 1842 $\pm$ 10 m.y. ago (Van Schmus, in press). After intrusion of granite pegmatites, the rocks were again deformed by shearing, with widespread development of cataclastic rocks and narrow, interlensing, ENE to WNW-trending faults. Most of these faults at Little Falls are right-lateral. Shallow intrusion of diabase about 1100 m.y. ago followed prolonged uplift and the erosion of several kilometers of rocks. Pockets of green clay remaining in low places on the amphibolitic terrane were buried during marine deposition of the Mt. Simon Sandstone in Late Cambrian time. Deeply weathered till and outwash southwest of the bridge at Little Falls may represent a pre-Wisconsin glaciation of this region.

DESCRIPTION:

The complex structures and textures in the Little Falls breccia are mainly a manifestation of a variation in the proportions of plagioclase, quartz, and hornblende. Biotite, epidote, and chlorite are sparse accessories.

Banded amphibolite, composed of 45-70% hornblende and 20-40% plagioclase make up about 90% of the xenoliths in the breccia. Many of the banded amphibolite xenoliths contain folds which were detached during tonalite intrusion. However, most of the xenoliths are elongated parallel to their lamination. It is noteworthy that the amphibolite xenoliths at Little Falls do not contain garnets, although garnetiferous amphibolite is exposed 1/4 mile downstream. Biotite is rare in the xenoliths (<5%) as it is in the enveloping tonalite.

Ultramafic xenoliths, which are composed of over 90% greenish gray Mg-rich hornblende with accessory epidote-clinozoisite, and plagioclase, make up less than 5% of the xenoliths in the breccia. Their angular shape and occurrence in clusters indicate fragmentation and partial dispersal of larger blocks during tonalite intrusion. This feature of fragmentation is well-displayed at Location 7927-D (Figure 16). Some of the ultramafic xenoliths show relict gabbroic textures with primary pyroxene apparently replaced by metamorphic hornblende. (Table 1, 7927-N-1)

A tabular xenolith (?) of fine-grained, foliated hornblende tonalite occurs at the location just east of the bridge. (Table 5, 7927-N-2).

A large fragment of foliated, porphyroblastic biotite granite is exposed at Location 7927-V. The fragment was mapped in detail (Figure 4). The granite contains 1-3 cm porphyroblasts of K-feldspar in a foliated granoblastic matrix of microcline, quartz, and brown biotite. Sodic plagioclase is accessory. Lenticular form of the K-feldspar porphyroblasts indicates recrystallization before and/or during cataclasis. The gradational contact between the fragment and enclosing breccia is marked by an inward substitution of K-feldspar for plagioclase and biotite for hornblende and by an increase in abundance of quartz. The gradational contact along at least the west side of the fragment indicates that it is a xenolith and not a fault slice, although its shape and position were probably modified by post-intrusive shearing.

The tonalite is composed of 35-40% plagioclase (An_{50-55}), about 30% bluish green hornblende, 25-30% quartz, 5-10% biotite, and accessory epidote, is flow-laminated, and commonly displays an indistinct lineation produced mainly by hornblende alignment. Large variation in plagioclase/hornblende ratio indicates considerable contamination by amphibolite. The plagioclase commonly displays bent albite twin lamellae, while associated, polygonal quartz grains are unstrained. Biotite commonly produces a crude, transgressive foliation. The biotite may have formed from hornblende during a later deformation.

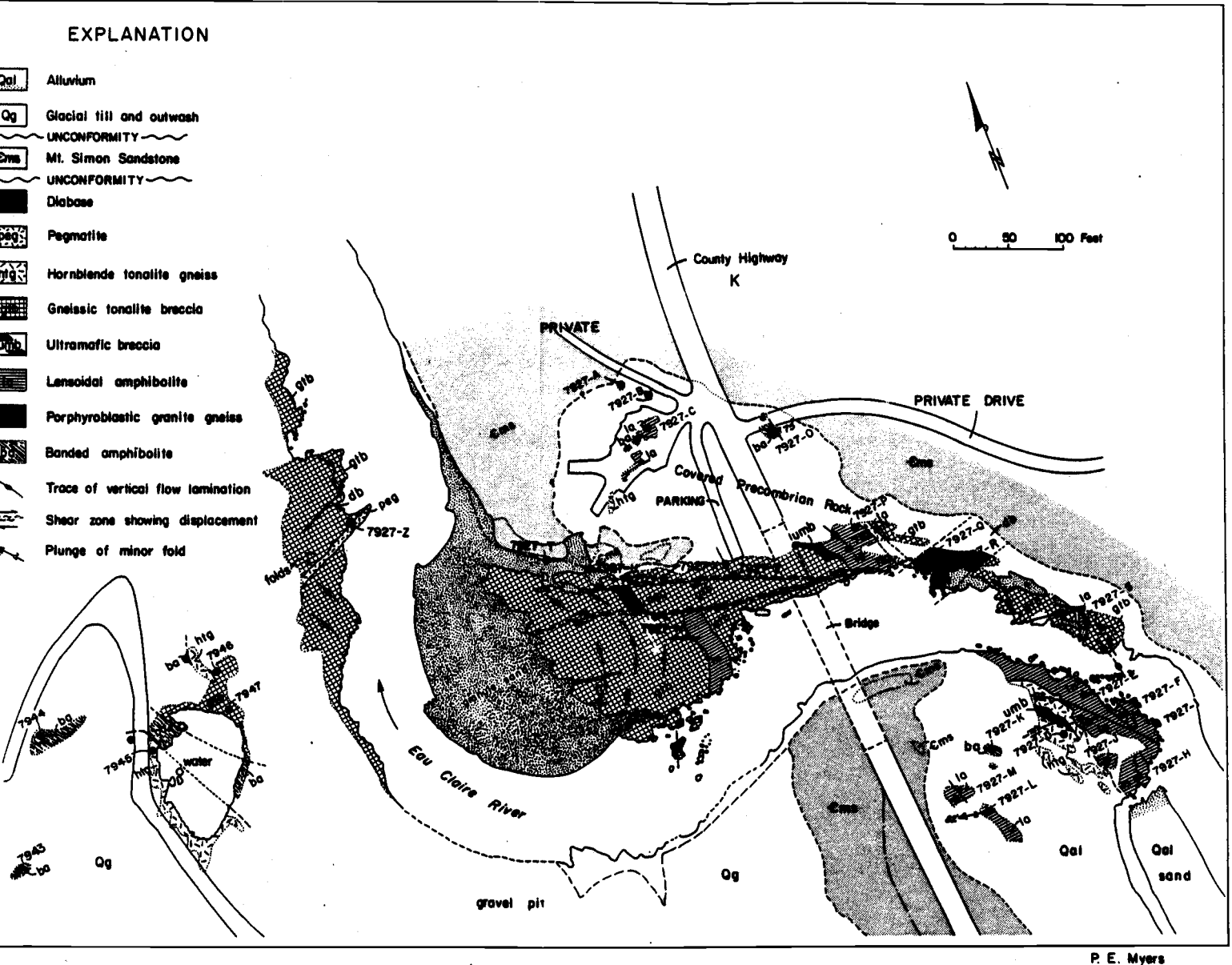


Figure 16-- Geologic map of the Little Falls area showing points of interest

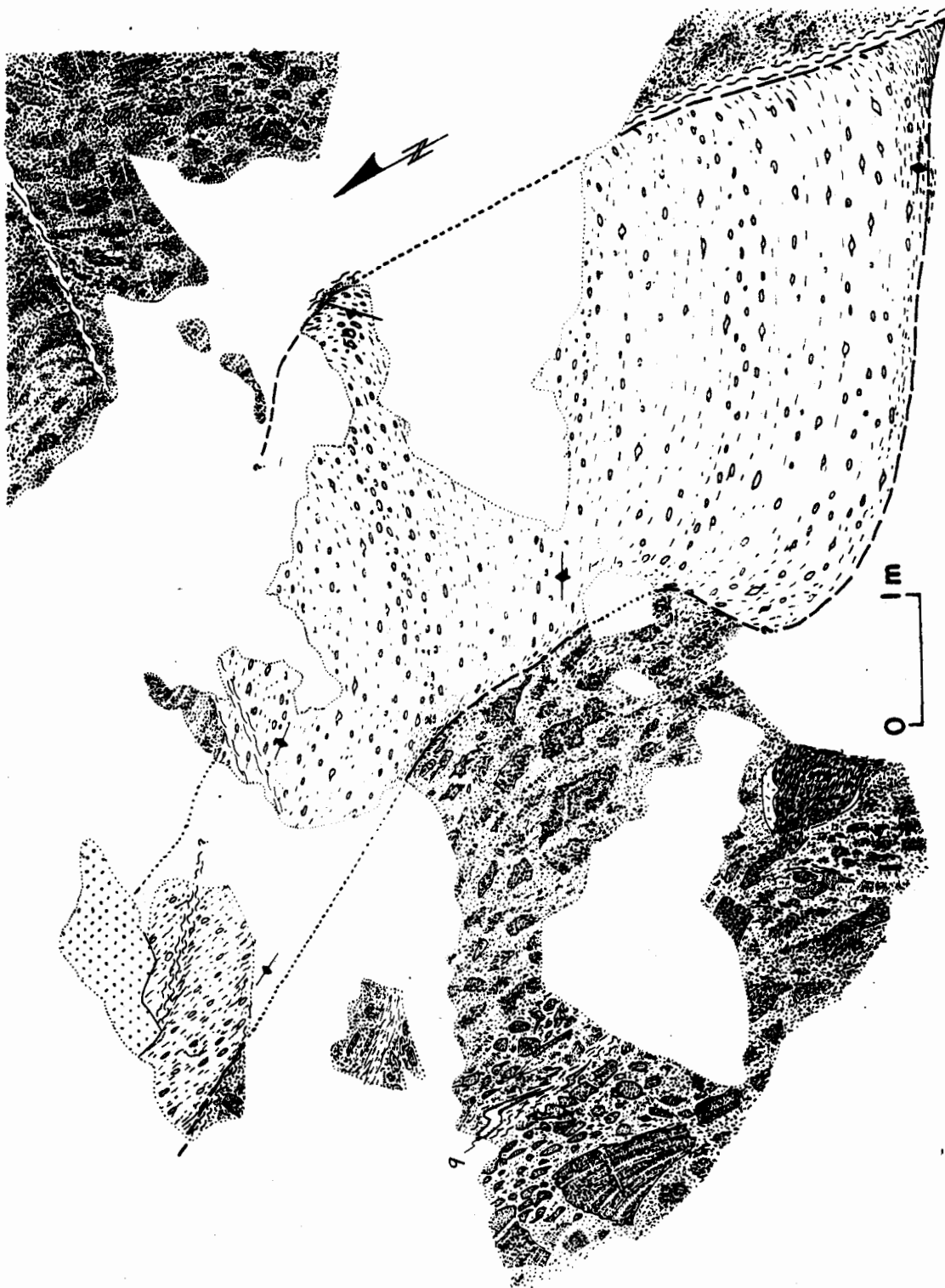


Figure 17 -- Deformed xenolith of porphyroblastic biotite granite gneiss in hornblende tonalite intrusion breccia (Location 7927-W on Figure 16). Foliation in the xenolith shows drag along both edges; indicates north-northeast flowage of tonalite magma relative to the xenolith. Porphyroblasts are microcline.

STAGES IN BRECCIA FORMATION:

A study of outcrops like that at Location 7927-C shows that intrusion of tonalite took place under stress and may have involved anatexis in the amphibolite with formation of a mobile phase of tonalite composition. The following sequence is suggested:

- 1) Formation of veined amphibolitic gneiss by segregation (?) of feldspathic laminae subparallel to original banding in the amphibolite (Location 7927-C) with local accumulation of tonalitic clots and dike-like masses, blocks of amphibolite became detached.
- 2) Partial fusion of quartz-feldspar fraction to form a tonalitic crystal mush which intruded across original layering to form breccia dikes (Location 7927-C, Figure 18-A).
- 3) Detachment, rotation, and mixing of blocks; through-going flowage, lenticulation, and partial assimilation of xenoliths (Figure 18 C and D). Fluidization of the xenoliths-rich mixture under stress resulted in development of steeply plunging flow folds.

AGE OF THE BRECCIA

A relatively xenolith-free sample of hornblende tonalite from Location 7947 was recently dated using U-Pb methods by Van Schmus (1980) at 1842 ± 10 m.y. If the porphyroblastic gneiss is truly a xenolith in the breccia, and episode of granite emplacement and subsequent(?) metamorphism must have preceded this date. The granite may therefore represent a fragment of Archean crust carried up from a granitic basement in the tonalite magma. This could indicate that granitic rocks may underlie the amphibolites at Little Falls.

PEGMATITE DIKES

Biotite-muscovite granite pegmatite with K-feldspar crystals up to 30 cm in maximum dimension cut at nearly right angles across flow lamination in enclosing breccia. Orientation of the dikes suggests that they were intruded during stress release and/or thermal contraction of the intrusion breccia. Quartz veins and lenses of similar orientation and origin are exposed at the east end of the outcrop here at Little Falls. The best pegmatite exposure is at Location 7927-Z, where the one to three-meter dike contains very large, bent and marginally crushed K-feldspars. Although not visibly offset by shear zones at Little Falls, the internal deformation in the dike indicates it was intruded prior to major shearing in the Middle Precambrian.

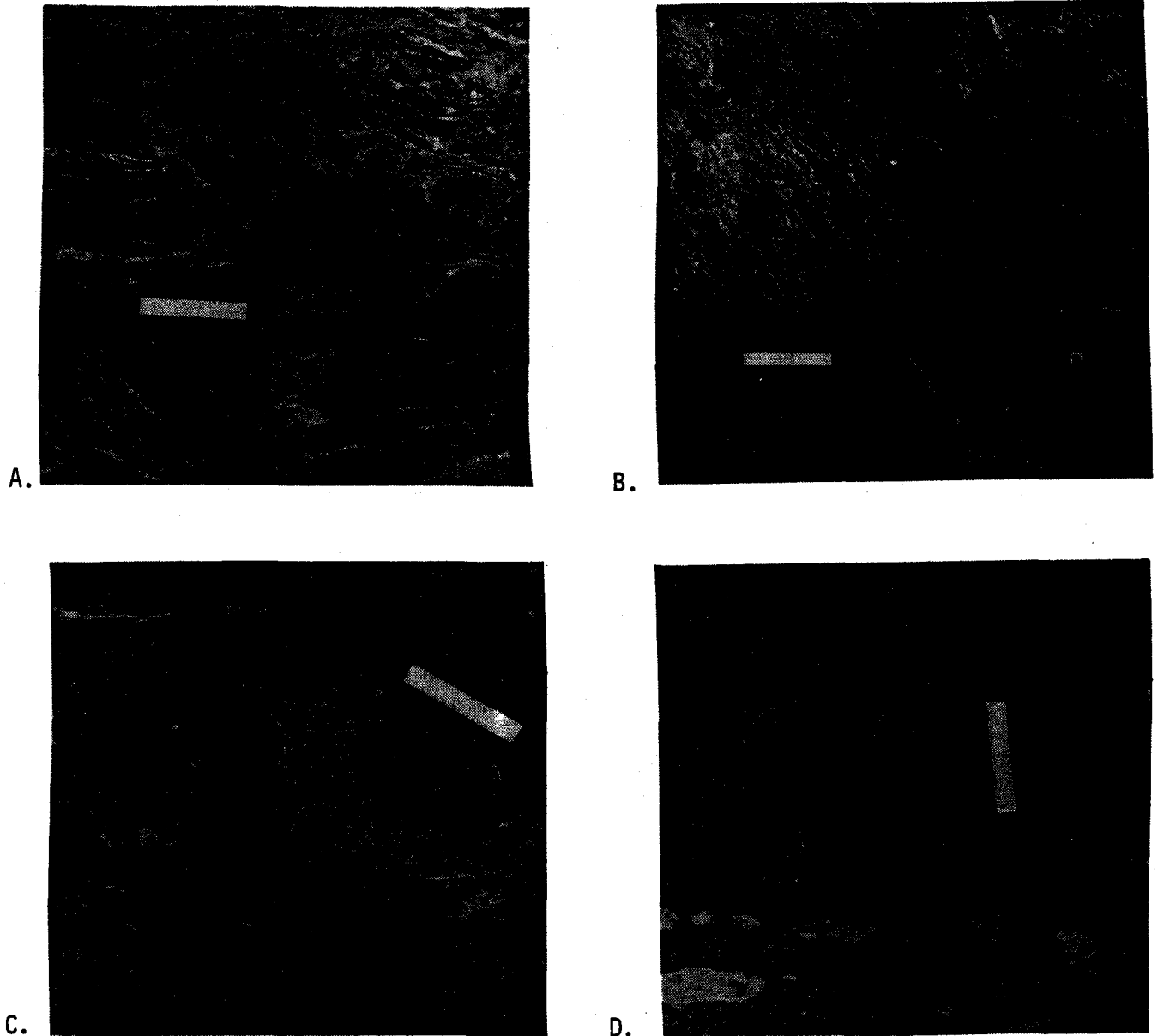


Figure 18 -- Outcrop photographs showing textures and structures in the Little Falls breccia. (A) Tonalite breccia dike cutting lamination in amphibolite at Location 7927-C. For detail, see detailed geologic map in Figure 19. (B) Sheared and segmented mafic xenolith cut by minor fault along which quartz later crystallized. View east at Location 7927-W. (C) Mafic amphibolite xenoliths in flow-laminated hornblende tonalite 20 feet northeast of Location 7927-W. Xenoliths with a higher feldspar content commonly show more plastic deformation and veining. The larger xenolith appears to have been folded prior to its engulfment in the tonalite magma. Well developed flow lamination suggests differential movement between magma and xenoliths before and after detachment. (D) Mafic and ultramafic xenoliths show relatively little assimilation in the tonalite. Mixing of diverse xenolith lithologies suggests considerable turbulence and vertical flow within the tonalite magma, which probably contained a high proportion of xenocrystic hornblende as well as xenoliths. Location 7927-X.

SHEAR ZONES

Interlensing, west-northwest-trending shear zones involving modest, right-lateral displacement and conspicuous drag folding (Locations 7927-X and Y, Figure 2- have segmented and transposed primary flow lamination in the intrusion breccia. Where small shear zones converge, the breccia is converted to a zoned, laminated dike-like body with walls of hornblende schist and a core of quartz-epidote mylonite up to 1.5 meters wide. If this small scale transposition of primary lamination is expanded to map scale, one can readily see how primary layering may be totally obliterated and replaced by a secondary lamination parallel to shear dislocation in the rock. Many of the interlensing structures of the Precambrian terrane of west-central Wisconsin may represent large-scale tectonic transposition by shearing.

The fault seen at Locations 7927-X and Y probably offsets pegmatites but not the diabase dikes. Its age is therefore probably Late Middle Precambrian (Penocean?)

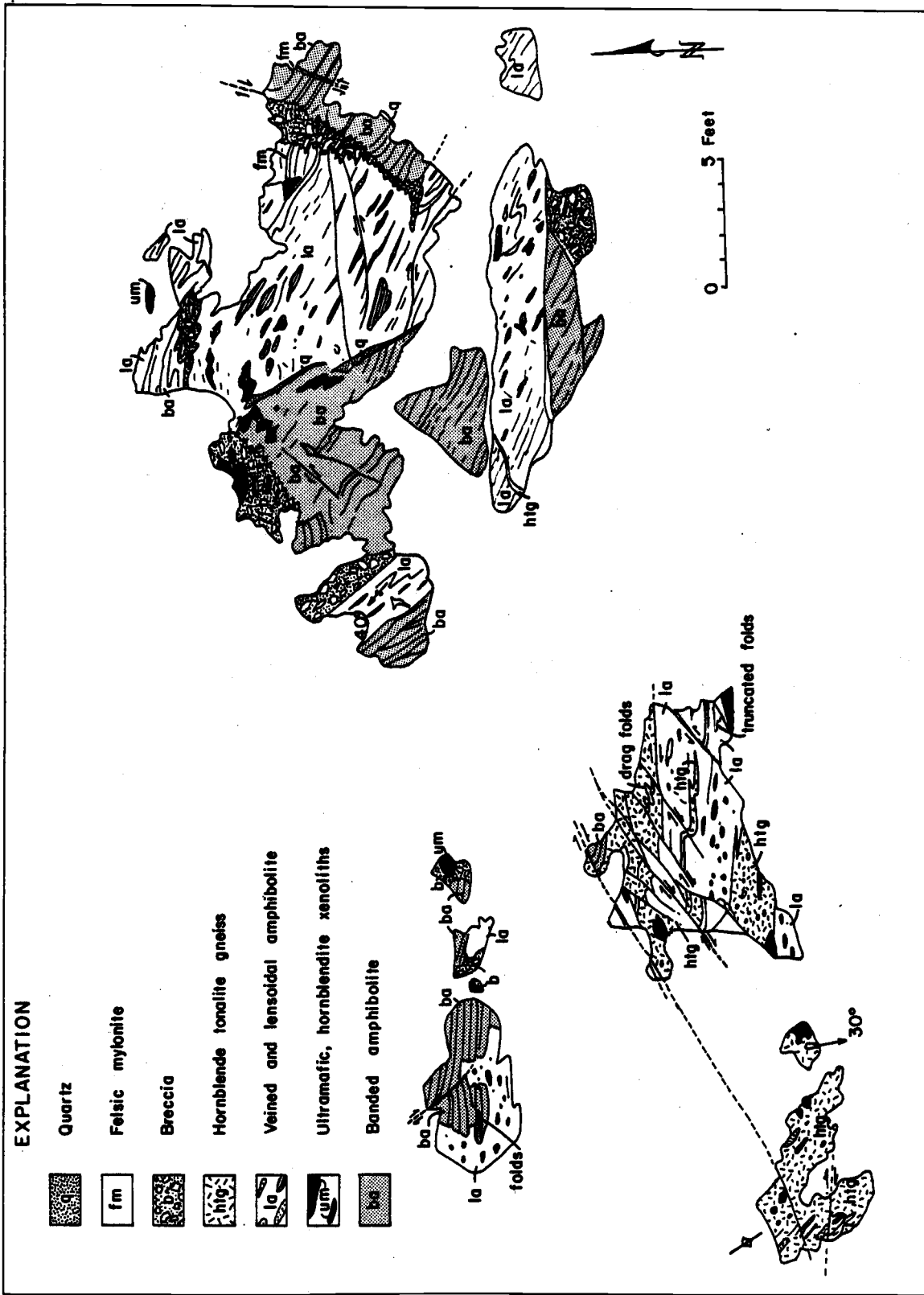
A much earlier deformation produced isoclinal folds and banding in the amphibolites before intrusion of the tonalite 1842 ± 10 m.y. ago.

DIABASE DIKES

East-northeast-trending, Late Precambrian (Keweenaw?) basalt-diabase dikes cut the breccia near locations, 7927-Z and Q. Their chilled margins indicate shallow intrusion after considerable erosion.

THE PRECAMBRIAN-CAMBRIAN UNCONFORMITY

A surface of deep weathering and erosion with about 20 meters of relief dips gently west-southwest beneath Late Cambrian Mt. Simon Sandstone throughout the region. The Eau Claire River flows approximately down the dip of this major unconformity. Chemical weathering of underlying amphibolitic rocks engendered a highly impermeable green, illitic clay. Some of this weathering may have occurred after deposition of the sandstone by reaction of circulating groundwater with ferromagnesian minerals in the amphibolites. Groundwater circulating downward through the Mt. Simon Sandstone flows laterally along the clay layer until it comes out at the surface as a spring. Since the Precambrian-Cambrian unconformity is generally just above or below the level of the Eau Claire River, the river's major discharge is major from groundwater systems. Its discharge varies only slightly, even during prolonged periods of drought.



P. E. Myers

Figure 19 -- GEOLOGIC MAP OF LOCATION 7927-C, LITTLE FALLS

CHRONOLOGY FOR LITTLE FALLS AREA

1. Basaltic volcanism and sedimentation
2. Intrusion of Big Falls gabbro; differentiation with deposition of ultramafic autoliths. Mineralogical and chemical similarity of amphibolites at Big Falls (Unit 2) and those at Little Falls suggest their close relationship.
3. Isoclinal folding and shearing
4. Intrusion of (porphyritic?) granite (Location 7927W)
5. Catalasis and regional metamorphism, folding.
6. Intrusion of hornblende tonalite (1842 ± 20 m.y. according to Van Schmus, 1980)
7. Intrusion of granite pegmatite (Location 7927Z)
8. Strike-slip faulting (WNW trend) and localized cataclasis
9. Prolonged erosion with formation of a surface of low topographic relief and a soil rich in green clay on the mafic amphibolites
10. Intrusion of diabase dikes (Location 7927R) (1100 m.y. ?)
11. Erosion
12. Marine deposition of Mt. Simon Sandstone - Late Cambrian

THE SOUTH FORK AREA -- INTRODUCTION

Figure 21 is a geologic strip map of the South Fork area in eastern Eau Claire and western Clark counties (Stops 3-7). An examination of the map should reveal one reason for difficulties in interpolating bedrock units between exposures in this region. If the exposed contact between cataclastic feldspathic gneiss and metatuff at Stop 3 is representative of concealed contacts in the area, it can be inferred that contacts are typically sheared and nearly vertical and that they enclose lensoidal fault slices which have been juxtaposed mainly by strike-slip displacement (Figure 20). Although the metavolcanic and metasedimentary rocks of the South Fork area (SFVS) are commonly foliated (as at Rock Dam and Mead Dam) they all show excellent preservation of primary minerals and sedimentary textures. Garnet, chlorite, epidote, and muscovite indicate attainment of upper greenschist facies metamorphism under conditions of moderate stress. SFVS rocks are interlayered at Stop 3 with sheared mafic and feldspathic plagioclase-hornblende gneisses of the Chippewa amphibolite complex (CAC). The contacts are nearly vertical, northwest-trending. In contrast with the CAC rocks which were deformed and metamorphosed at least three times, the SFVS rocks at Stop 7 display relict upright bedding which dips at moderate angles. It is believed that the SFVS rocks were deposited unconformably upon eroded, twice-deformed and metamorphosed Archaean amphibolites about 1860 m.y. ago. Andesite metatuff from the confluence area (Stop 3, Station 7830-F), as dated by Van Schmus (1980), is $1860 \pm$ m.y. After greenschist grade metamorphism and some folding, these rocks were imbricated by strike-slip displacement along nearly vertical, interlensing faults. The imbrication also involves tonalitic and trondhjemitic intrusive rocks about 1840 m.y. old but not

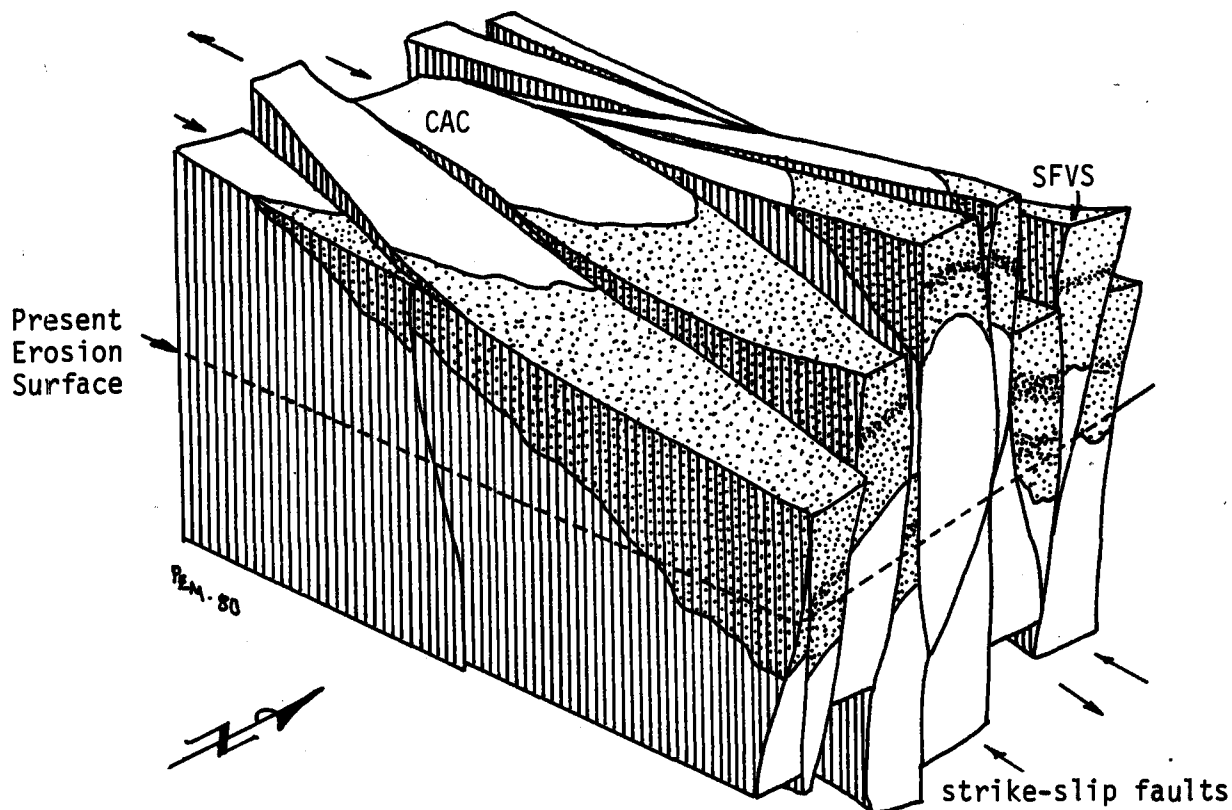


Figure 20 - Block diagram showing hypothetical displacement mechanism which best explains the distribution and spatial relations of SFVS and CAC rocks in the South Fork area.

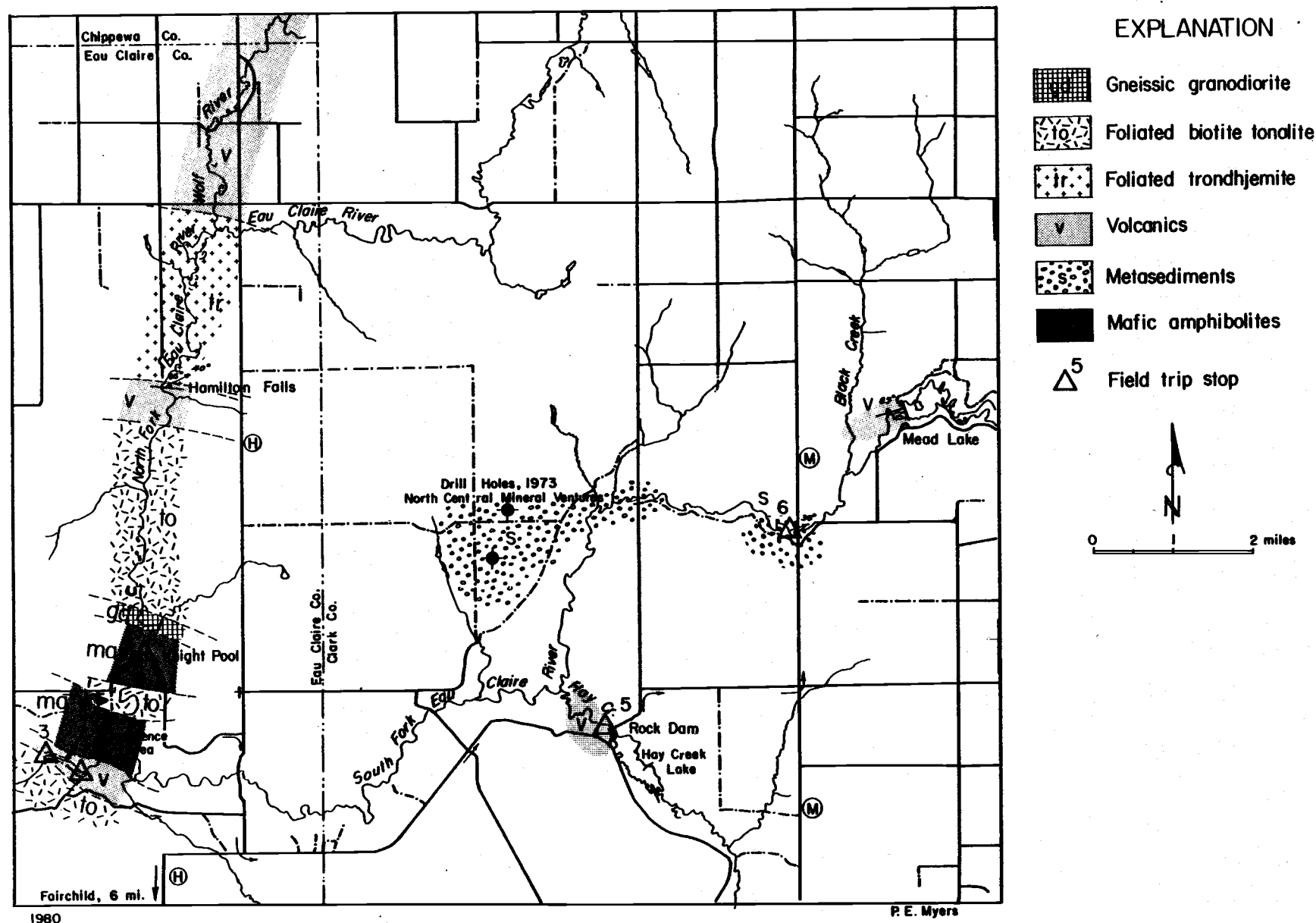
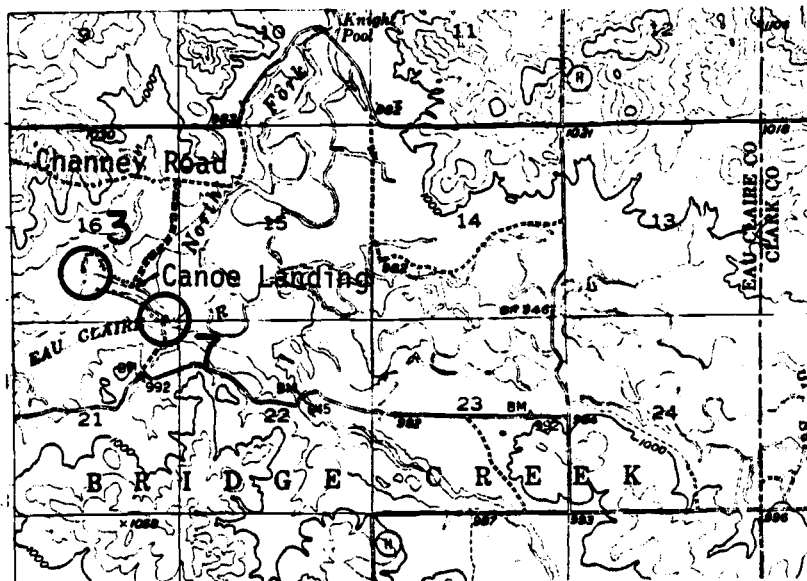


Figure 21 -- Geologic strip map of the North Fork and South Fork of the Eau Claire River in eastern Eau Claire and western Clark counties.

STOPS #3 and #7

TITLE: CONTACT BETWEEN CHIPPEWA AMPHIBOLITES AND SOUTH FORK VOLCANIC ROCKS

LOCATIONS: Stop #3, SE 1/4, SE 1/4, Sec. 16, T26N, R5W: Field Loc. 7830
Stop #7, NE 1/4, SW 1/4, Sec. 16, T26N, R5W: Field Loc. 7329



AUTHOR: P. E. Myers

DATE: March, 1980

SUMMARY OF FEATURES:

The lithology and contact relations of sheared metatuffs, tuffaceous sedimentary rocks and plagioclase-hornblende gneiss are well-exposed, but difficult to interpret at Stop 3. Tuffaceous conglomerate, sandstone, and siltstone with well-preserved primary depositional features dip 45-60° SSW at Stop 7.

DESCRIPTION:

Stop 3: Four nearly vertical rock units here (Figure 22) are listed from northeast to southwest : (1) banded, mafic, hornblende-plagioclase gneiss and Table 8 (#7830-A and B), (2) andesite tuff and quartzo-feldspathic volcaniclastic sedimentary rocks (#7830-D, E, and F), (3) mafic hornblende tonalite (no analyses), and (4) feldspathic tonalite gneiss. Discordant leucotronohjemite dikes with concordant cataclastic foliation cut all units. Sericitization of plagioclase was followed by small scale faulting and chlorite vein emplacement with conversion of hornblende adjacent to the veins to chlorite and epidote. Garnets and mafic clasts in the metatuff were almost completely chloritized at this time. Two basic questions arise here: (1) which of the units is of volcanic origin, and (2) to what extent and in what sequence were primary minerals and textures modified by metamorphism and cataclasis in each unit?

TABLE 8
MODAL AND CHEMICAL ANALYSES OF ROCKS FROM THE CONFLUENCE AREA

Modal Analyses											
MIN*	7829 A	7829 B	7929 C	7830 A	7830 B	7830 D	7830 E	7830 F	7830 G	7830 H	7830 I
Plag	65		78	58	29	69	61	71	78	68	53
Hb				30	63				8	11	6
Qtz	6?		4?	7	6	24	5	9	6	14	32
Chl.	28		16	1	Tr	Tr	16?	13	4	3	5
Ep.				2	1	Tr	17?	6	3	1	3
Op.			<1			2					

* Minerals: Plagioclase, Hornblende, Quartz, Chlorite, Epidote, Muscovite
Modal analyses using 1000-point counts. Identification uncertain for very fine-grained varieties

Chemical Analyses											
SiO ₂	56.84	59.48	48.19	57.08	57.24	70.62	61.76	61.60	57.58	63.03	68.42
Al ₂ O ₃	19.46	20.41	20.54	15.87	14.89	15.52	17.56	17.18	17.74	14.35	14.37
Fe ₂ O ₃ *	6.03	4.08	10.40	8.68	9.75	2.49	7.14	6.80	5.80	6.64	3.77
CaO	1.33	0.76	0.60	6.10	5.42	2.61	3.65	4.06	6.13	6.13	4.94
MgO	3.43	3.10	8.10	4.51	4.55	0.97	2.03	2.25	3.47	3.31	1.74
Na ₂ O	7.44	7.77	4.68	3.66	3.16	4.45	3.29	3.38	3.96	2.69	3.02
K ₂ O	0.71	1.26	1.51	0.72	1.36	1.43	2.02	2.11	1.89	1.18	0.99
TiO ₂	0.51	0.49	0.65	0.46	0.61	0.28	0.56	0.51	0.34	0.27	0.22
MnO	0.05	0.04	0.09	0.14	0.14	0.03	0.07	0.08	0.08	0.11	0.06
P ₂ O ₅	0.21	0.10	0.27	0.02	0.13	0.05	0.21	0.25	0.23	0.03	0.00
LOI	2.11	1.89	4.47	1.17	1.61	0.84	1.80	1.52	1.53	1.19	0.71
TOTAL	98.11	99.39	99.50	98.41	98.85	99.30	100.1	99.74	98.73	98.94	98.22

* Includes FeO.

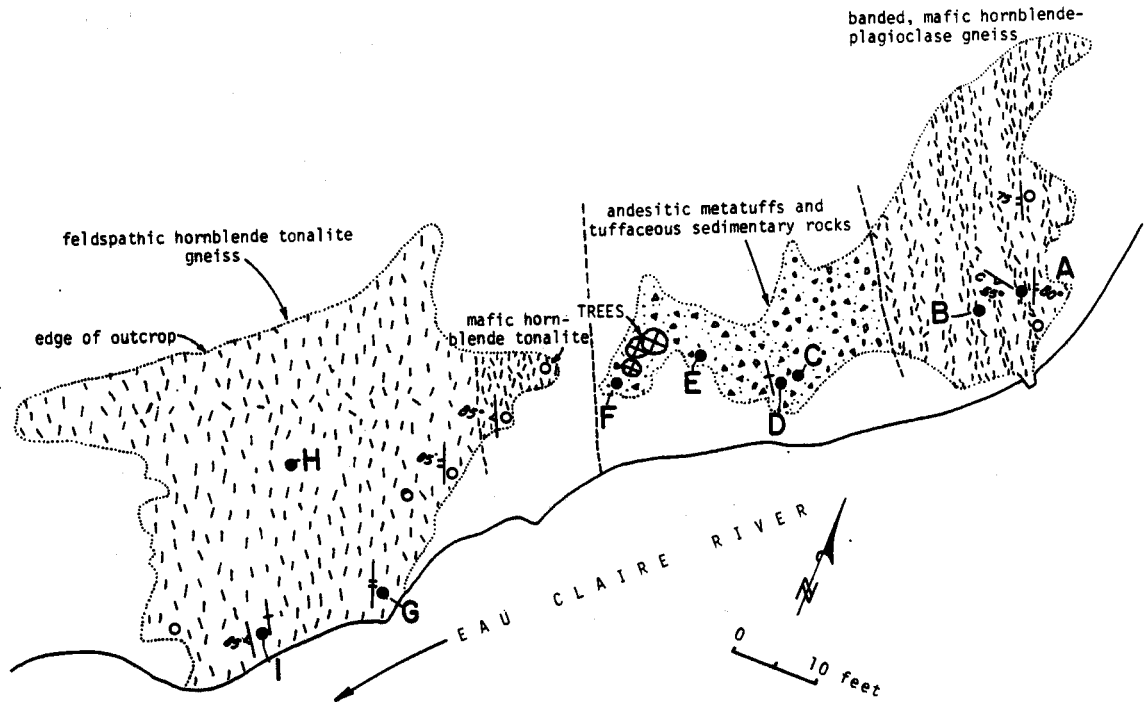


Figure 22-- Outcrop map showing geology and sample locations (Field No. 7830). Chemical analyses for these rocks are tabulated in Tables 2 and 4.

Unit #1 consists of aligned, dark green (Y), subhedral hornblende and lenticular plagioclase laths or its mylonitized equivalent - a crush debris of anhedral, bent, and broken plagioclase fragments. Although the existence of large, ovoid plagioclase grains and shadowy darker patches (best seen on weathered surfaces) suggests a volcanoclastic protolith for this rock, thin section study shows that at least some of the lamination is of cataclastic origin. Thin seams of chlorite, some of them along small faults, cut all other structures in all four rock units. Epidote and chlorite become much more abundant in hornblende near these chlorite veinlets. The chloritization and epidotization of these rocks was, therefore, post-kinematic. (Figure 23.)

Unit #2 is composed of about 30 to 60 percent ellipsoidal plagioclase clasts in a foliated, fine-grained matrix of plagioclase, epidote, and chlorite (Figure 24). Chlorite-mantled garnets make up about 0.5% of specimen 7830-E (Figure 25). Cataclastic foliation is manifested locally by interlensing chlorite folia. The plagioclase clasts are well-rounded and thinly coated with chlorite or very fine-grained quartz and contains zoned inclusions of brown biotite and pyrite. Lithic fragments and/or glass shards were apparently replaced by chlorite. This unit was U-Pb dated by Van Schmus (1980) at 1860 m.y.

Unit #3 is a hornblende-rich tonalite with conspicuous lamination but less obvious lineation. Its composition is similar to, but more mafic than, 7830-A.

Unit #4 is light greenish gray feldspathic tonalite gneiss which closely resembles the feldspathic amphibolites of the Big Falls area. However, its cataclastic fabric and the deep green color of the hornblende give this rock quite a different appearance in thin section. Lensoidal plagioclase porphyroclasts are surrounded by fine grained quartz which may have been post-kinematically introduced.

All units display a pronounced cataclastic fabric characterized by bent, broken, and lenticulated plagioclase and interlensing foliation accentuated by accumulations of chlorite and quartz-feldspar crush debris. Late kinematic leucotrandhjemite dikes cut the layering and cataclastic foliation but themselves possess a weak foliation parallel to that in the enclosing rocks. The fine-grained matrix of the metatuff allowed for concentration of cataclasis with little abrasion and fragmentation of the insulated feldspar clasts. This may explain the unusually good preservation of primary textures in these rocks.

A profile of minor element variation across this outcrop is shown in Figure 26. Rock 7830D, a rock composed of coarse, lenticulated plagioclase clasts in a fine-grained quartz matrix, has an anomalously low V, Cr, and Zn content. The rock has the composition but not the texture of a trondhjemite. The protolith of this rock is unknown. Its relatively coarse grain size suggest an intrusive origin.

Stop 7: Three small outcrops on the south side of the Eau Claire River about 1/2 mile east of Stop 3 expose a 100-foot sequence of well-stratified, but poorly sorted volcanic conglomerate and siltstone (Figure 8). The 1-7 mm plagioclase and blue quartz clasts are well rounded, and quite evenly distributed in a well-stratified, fine-grained plagioclase-chlorite matrix. These rocks show only localized effects of cataclasis, and most closely resemble specimen 7830-F at Stop 3. On the basis of lithologic similarity, the volcanic rocks at Stop 7 are correlated with those of Unit #2 at Stop 3.

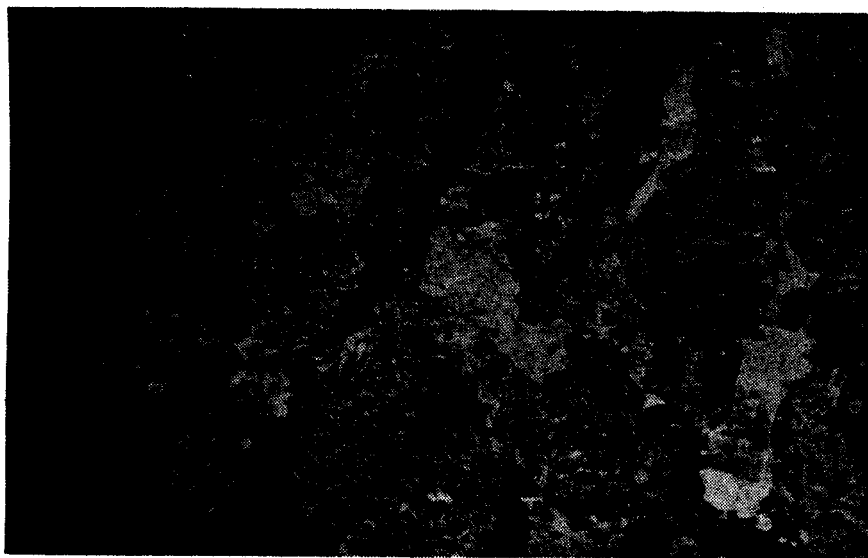


Figure 23 -- Chlorite-epidote veinlet (upper left to lower right) cutting epidotized plagioclase-hornblende gneiss. Location G. Crossed polars. Width of photo = 4.2 mm. Note occurrence of epidote in veinlet where it crosses hornblende crystals.

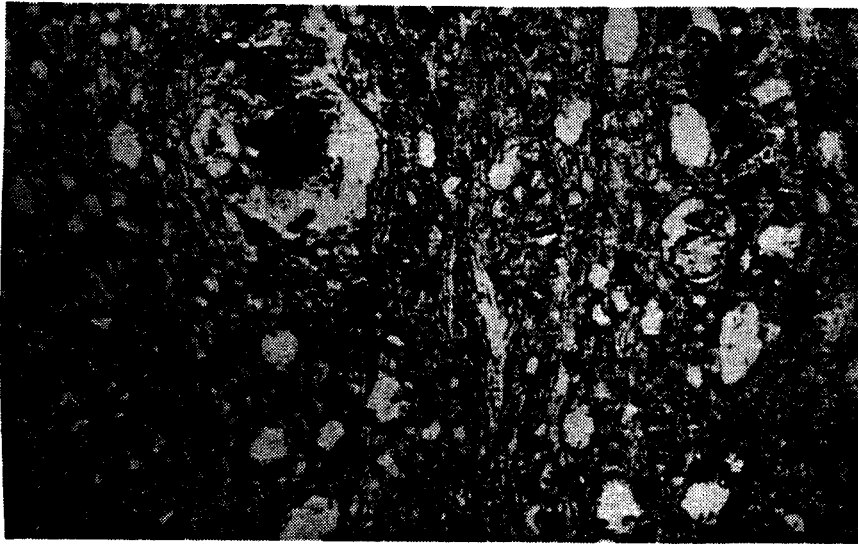


Figure 24 -- Rounded plagioclase clasts in a foliated matrix of fine-grained plagioclase, chlorite, and epidote. Location E. Small chloritized garnet right-center and lithic fragment (dark) on left. Photo width is 4.2 millimeters. Textural lamination (relict bedding) occurs in other specimens from this same location.



Figure 25 -- Chloritized garnet in sheared and metamorphosed andesite tuff or tuffaceous sediment from Location E. Note rounded outline of pseudomorph. Relict garnet (g) remains in core. Ordinary illumination. Photo width is 4.2 millimeters.

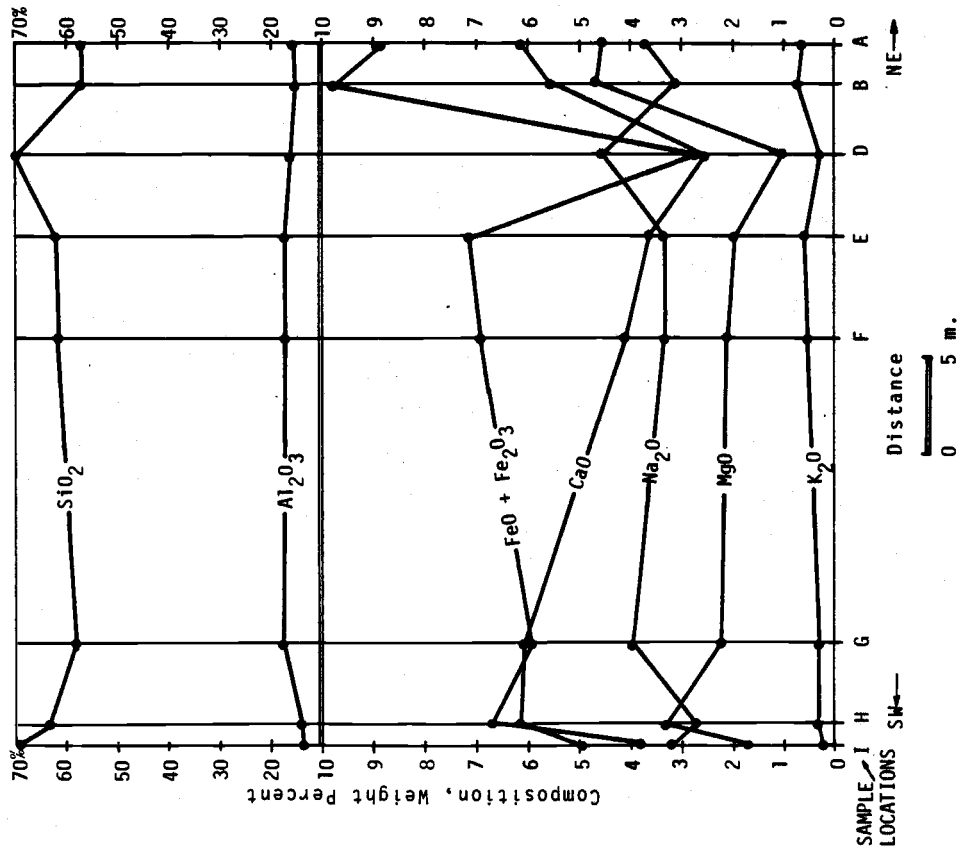
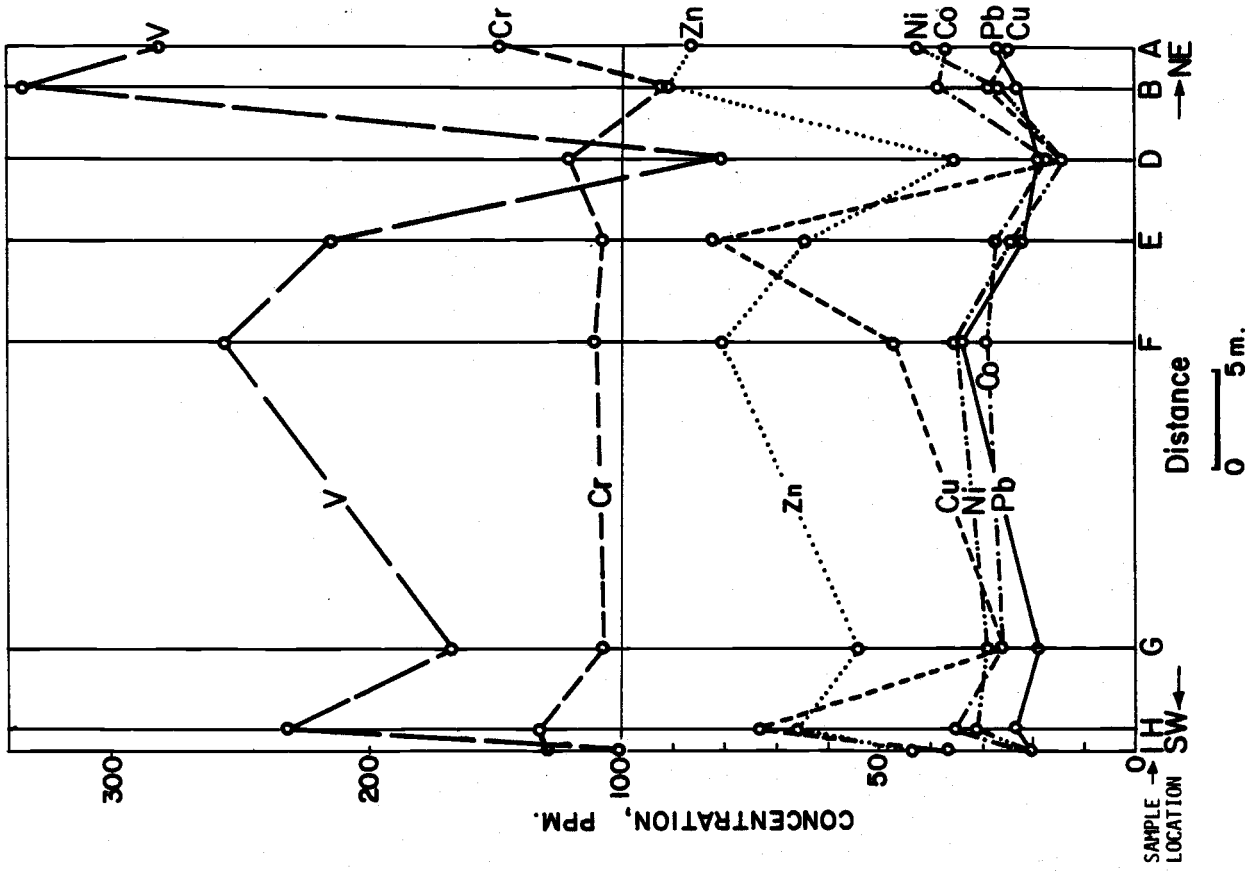


Figure 26 -- Major and minor element variations across outcrop at Stop #3. Sample numbers along base of each diagram are shown to scale. (Figure 22.)

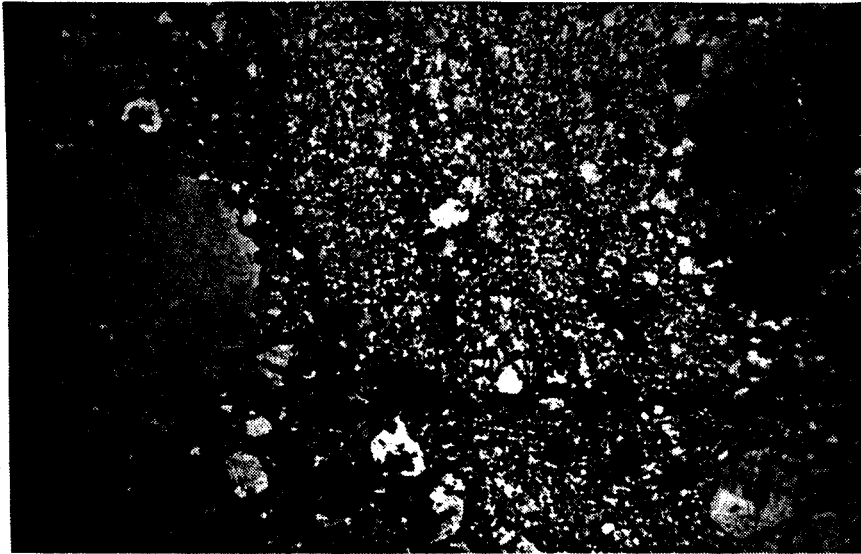


Figure 27 -- Relict bedding in andesite metatuff from Location 7829-C (Stop #7) showing poor sorting. Plagioclase clasts show considerable bending and marginal fragmentation. Crossed polars. Photo width is 4.2 mm.

DISCUSSION:

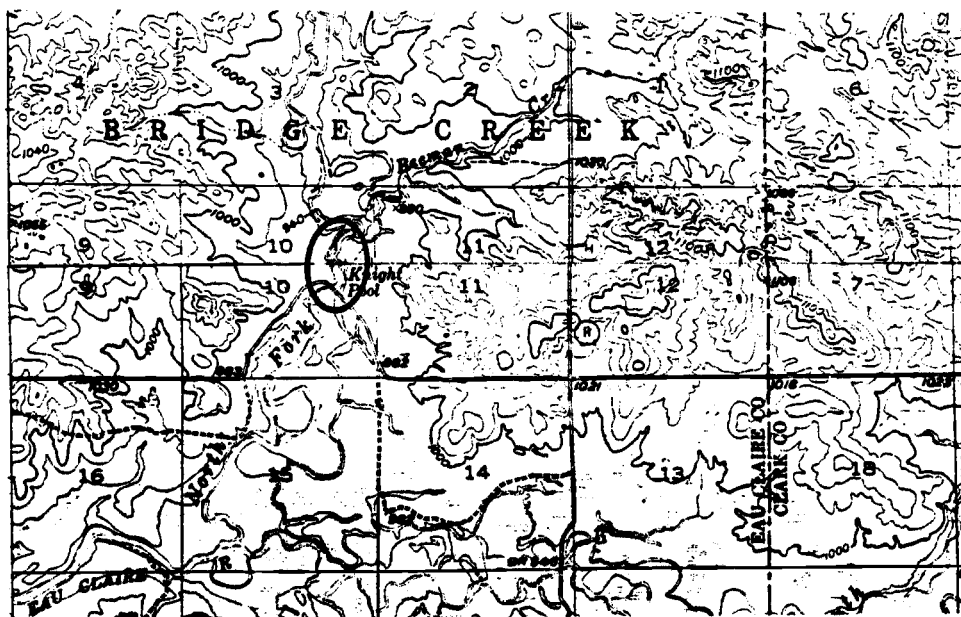
The protolith for the hornblende-bearing gneisses which enclose the volcanic rocks at Stop 3 has not been established. The hornblende-bearing rocks at this location are intermediate between the mafic and feldspathic amphibolites of the CAC terrane. The hornblende is a deep green (γ) to moderate yellow-green (α). Since the chemical analyses in Figure 26 do not distinguish between Fe^{2+} and Fe^{3+} , it is impossible to speculate on the partitioning of iron in the hornblende, chlorite and epidote. The anomalous extinction colors of chlorite minerals commonly reflect differences in composition: yellow-gray is commonly aluminian prochlorite; chocolate brown-purple is commonly ferroane prochlorite; deep (Prussian) blue is pennine. In the rocks at Stop 3, pennine is confined to hornblende alteration, whereas aluminian prochlorite is found in the mafic-poor volcanic rocks, although pennine also occurs in these rocks as a replacement of garnets. Thus two chlorite minerals coexist in the volcanic rocks, apparently as a function of the chemical composition of the host mineral.

Structural and age relationships of volcanic and amphibolitic rocks at these locations cannot be confidently extrapolated regionally. The eastward increase in the proportion of volcanogenic rocks, and the virtual disappearance of amphibolitic rocks suggests a major transition, which might be a sheared and folded angular unconformity as suggested here, or possibly a northwest-trending fault. It should be noted that the foliation at Stop #3 bends abruptly north-northwesterly, while elsewhere in this area, foliation trends west-northwesterly. The relative freshness of cataclastic features might support the cross-fault hypothesis. More detailed field work, particularly with small-scale structures and petrofabrics will be necessary to resolve the problem.

STOP #4

TITLE: KNIGHT POOL META-BASALT

LOCATION: Knight Pool, Channey Road, North Fork of Eau Claire River, SE¼, NE¼ Sec. 10, T26N, R5W, Fairchild 15' Quadrangle.



AUTHOR: Paul E. Myers

DATE: March, 1980

SUMMARY OF FEATURES:

Fine-grained, lineated amphibolite containing relict pillow structures(?) and amygdulites is cut discordantly by aplite veinlets which show different types and ages of deformation. These rocks, because of evidence of several ages of deformation, including an early phase of isoclinal folding, are tentatively assigned to the Chippewa amphibolites and not to the younger(?) volcanics to the east.

DESCRIPTION:

Fine-grained, mafic, epidote amphibolites with relict pillow structures were first isoclinally folded (Figure 28C), intruded by aplite veinlets (Figure 28A) and then by a body of biotite granodiorite. Shearing in and along the contact of the granodiorite converted the massive intrusive rock to a mylonite gneiss. This late episode of shearing and cataclasis folded the aplite veinlets in the mafic amphibolite (Figure 28B). A veinlet of laminated mylonite gneiss lies in the plane of foliation of the amphibolite (Figure 28B). This gneiss consists of eye-shaped porphyroclasts of plagioclase enveloped in mantles of biotite and siliceous mylonite. The plagioclase is strongly sericitized. Quartz-epidote-filled gash fractures developed perpendicular to foliation during stress release.

The lineated mafic amphibolite here displays a pronounced sheeting and biotite foliation accentuated by plagioclase laminations which form the limbs of high-amplitude isoclinal folds. Hornblende lineation and small fold axes plunge east at 50-75° near the bridge and 80° northeast at location 7941 (Figure 29.) The lineations are offset by east-west vertical faults, north sides down.



Figure 28-- Near-vertical face of an outcrop of fine-grained amphibolite (dark) cut by veinlets of aplite veinlets, one of which shows a cataclastic foliation parallel to its walls (A). The aplite veinlets cut older isoclinal folds shown at C. A cataclastic veinlet at B closely resembles the granodiorite which crops out just north of here. This outcrop is at location 7941 (Figure 29).

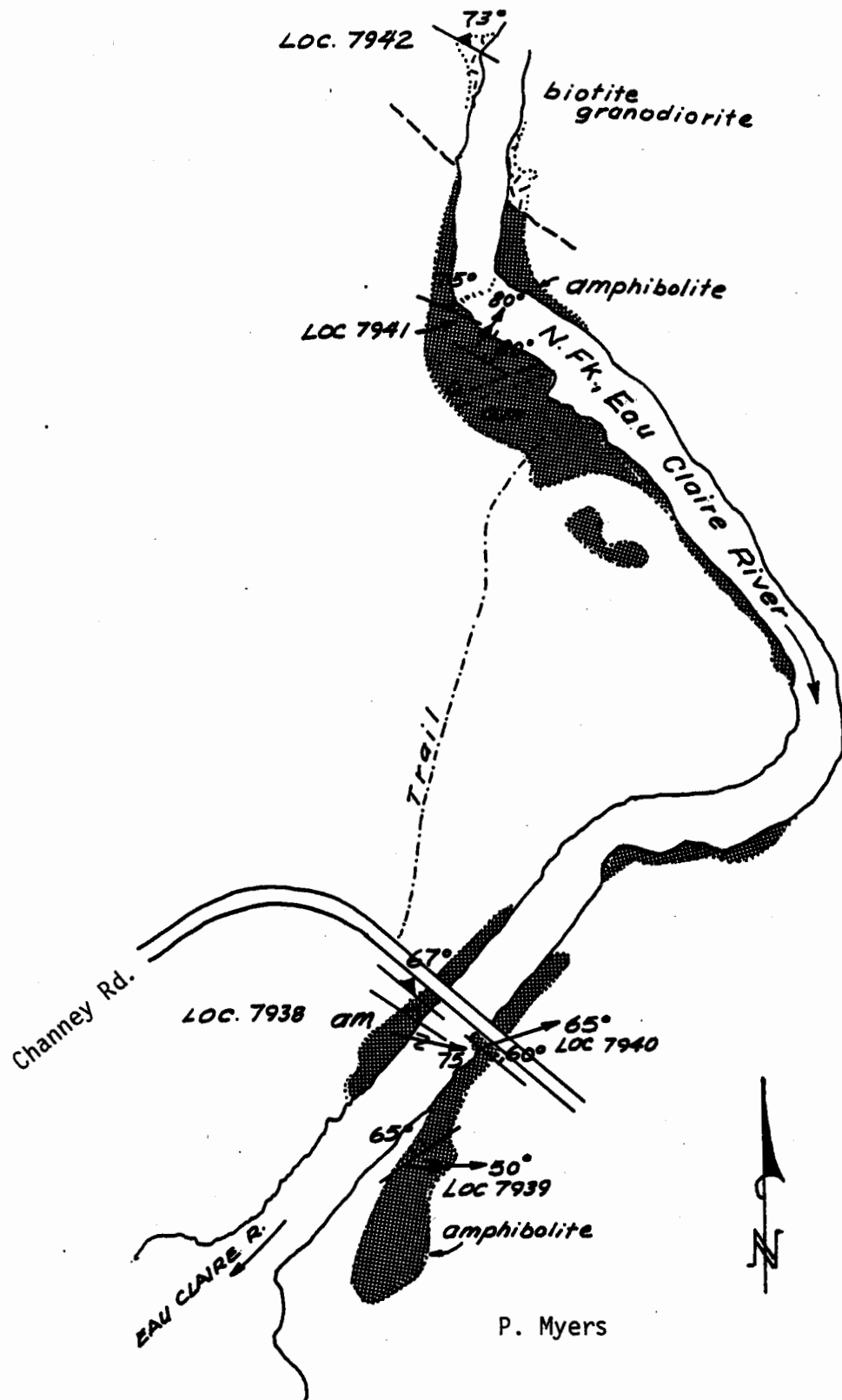
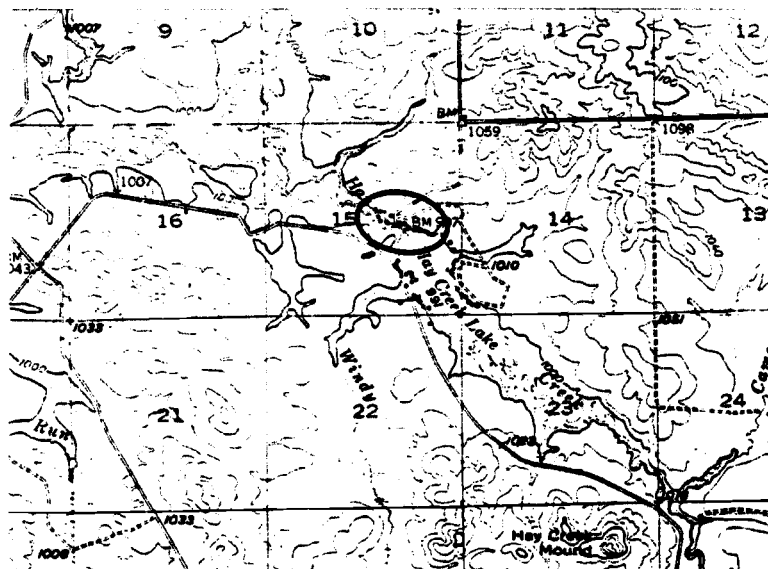


Figure 29 -- Geologic map of the Knight Pool Area. Note steep eastward to east-northeastward plunge of small folds and lineation.

STOP #5

TITLE: ROCK DAM META-RHYOLITE

LOCATION: Hay Creek 0.15 mile downstream from Rock Dam, SE 1/4, NW 1/4 Sec. 15, T26N, R4W; Fairchild 15' Quadrangle



AUTHOR: Paul E. Myers

DATE: February, 1980

SUMMARY OF FEATURES:

Debate continues on the significance of criteria used to distinguish "metamorphosed" rhyolitic volcanics from "mylonitized" leucogranites. If this stop does not solve the "rhyolite-granite problem," it may at least add more fuel to the fire.

A foliated, muscovite-bearing felsic mylonite containing eyes of strained quartz in a very fine-grained matrix of K-feldspar, quartz, and muscovite crops out below Rock Dam, where it unconformably underlies conglomeratic Mt. Simon Sandstone (Figure 31). Foliation in the felsic mylonite is N87°W, 85°N. Complimentary joint sets at N18°W, 73°E and N77°E, 8°S account for the blocky appearance of the outcrop here. The exposed angular unconformity has a local relief of about 5 meters.

DESCRIPTION:

The mylonite is pale pink and contains conspicuous eyes of strained quartz 1.0 - 2.5 mm long. The rock clearly resembles a porphyritic rhyolite with quartz phenocrysts or clasts. In thin section, the quartz eyes are sub-rectangular to lenticular in outline. (Figure 30). They commonly possess crush trails: that is, the coarse-grained cores display an outward decrease in grain size into the fine-grained matrix. The quartz eyes commonly contain coarse, pale green muscovite with anomalously high birefringence. Strain is indicated by the conspicuous lamellar, wavy extinction. The matrix is composed of very fine-grained K-feldspar (microcline), quartz, muscovite, biotite, and magnetite. The magnetite occurs as streaks along foliation and in muscovite grains, where

it appears to have formed with muscovite at the expense of primary biotite. Estimated mineral composition is: K-feldspar, 57%; quartz, 35%; muscovite, 3%; magnetite, 2%; and biotite, 1%. In addition to the quartz eyes, this rock contains occasional lenticular clusters of relatively coarse-grained muscovite, quartz, and biotite (Figure 30).

A muscovite-rich phyllite crops out near the base of Rock Dam. The rock is composed of K-feldspar, quartz, and muscovite (approximately 20%). The quartz eyes and biotite are absent, factors suggesting a different protolith for this rock. Since the abundance of K-feldspar could not be determined petrographically, comparison with the previous rock is based mainly on hand specimen descriptions.

Cataclastic degradation of granite to mylonite produces similar, but hopefully not identical, features. The chief differences are: (1) mylonitization of quartzofeldspathic rocks typically mylonitizes the quartz first; feldspars thus become porphyroclasts; (2) sheared granites are characterized by inter-lensing slip planes coated with phyllosilicates such as mica or chlorite and mylonite; (3) transitions between relatively unsheared granite and the felsic mylonite can be seen in the field. The quartz eyes in the absence of feldspar porphyroclasts strongly suggests a primary origin for the quartz - either as phenocrysts or as clasts in a tuff. No other primary volcanic textures were observed here.

The chemical composition of this rock (7931-B) as presented in Table 1 on page 13 shows this rock to contain anomalously high K_2O and anomalously low Al_2O_3 . The K_2O is consumed by the microcline and muscovite.

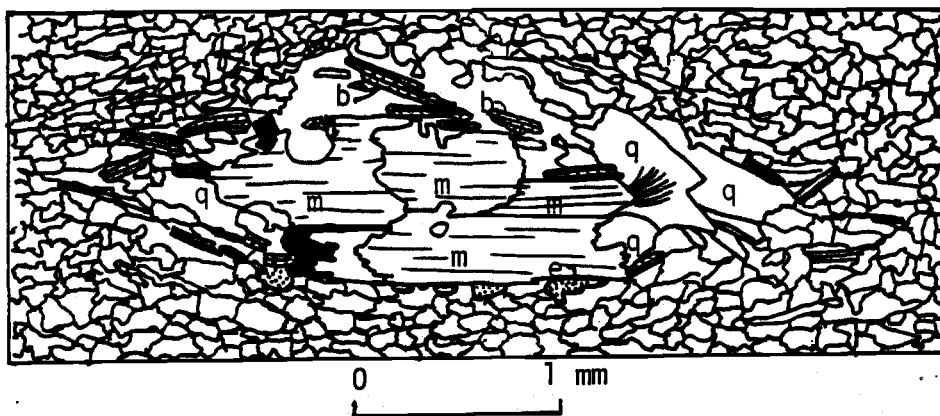


Figure 30 -- Micrograph showing lenticular cluster of strained quartz (q), muscovite (m), biotite (b), magnetite (black), and epidote (e) in texturally laminated, fine-grained quartz and microcline.



Figure 31 -- Foliated metarhyolite composed of quartz, K-feldspar, muscovite, biotite, epidote, and magnetite. Steeply dipping schistosity strikes N87°W here. The metarhyolite is unconformably overlain by conglomeratic Mt. Simon Sandstone. Photo by Gene LaBerge, UW - Oshkosh.

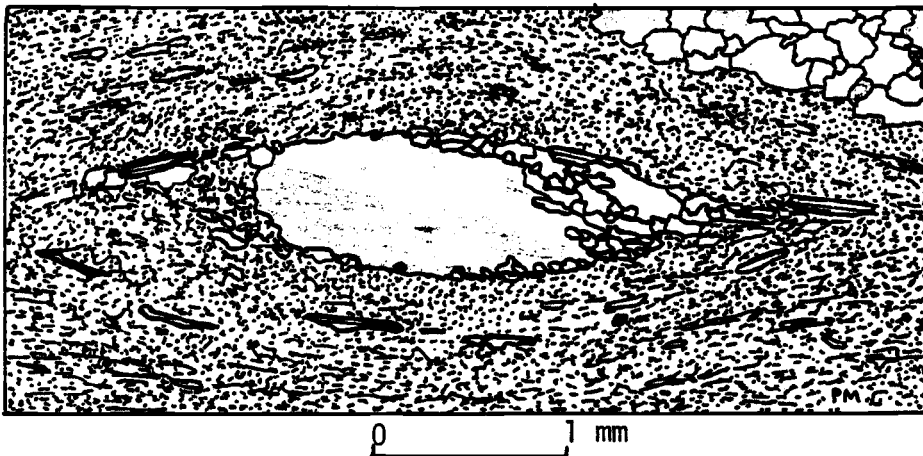
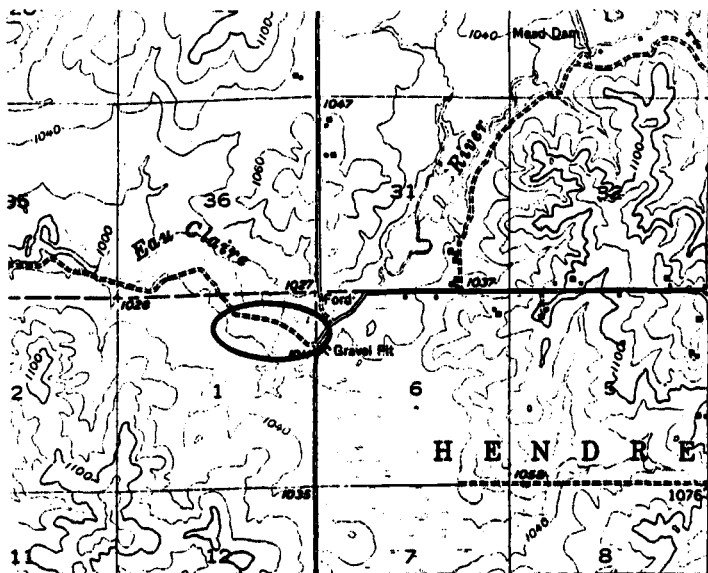


Figure 32 -- Micrograph showing lensoid cored by in a fine-grained, laminated, foliated matrix of strained quartz, K-feldspar, muscovite, and nearly colorless chlorite.

TITLE: METASEDIMENTARY ROCKS OF THE SOUTH FORK AREA

LOCATION: Clark County Highway M; NE 1/4, Sec. 1, T26N, R4W: Stanley 15' quadrangle, Field Location 7832



AUTHOR: Paul E. Myers

DATE: February, 1980

SUMMARY OF FEATURES:

Mica-chlorite schist and quartzite at this quarry exemplify the metasediments of the South Fork area. Features of multiple deformation, and high-grade metamorphic minerals, which typify the Chippewa amphibolite terrane to the west are absent in these rocks, a factor suggesting a greater age and/or more complex history for the amphibolites.

DESCRIPTION:

Metasediments exposed here (Figure 33) include: (1) coarse to medium-grained, foliated, muscovite-biotite quartzite with indistinct relict cross-bedding, (2) quartz-chlorite-biotite schist showing spectacular kink-banding, and (3) lenticulated quartz-muscovite schist with subordinate biotite and chlorite.

On the basis of a strong geophysical anomaly, North Central Mineral Ventures (1973) drilled two cores at a site 3.7 miles west of here. These cores were later studied petrographically and geochemically by M.A. Piotruszewicz (1978) as part of a Masters thesis at the University of Wisconsin-Milwaukee. The first hole penetrated fine-grained graphitic schists; the second hole from the base of the Mt. Simon Sandstone at 180 feet, to a depth of 1075 feet cut through quartz-muscovite-chlorite-garnet schist with accessory biotite, actinolitic hornblende, pyrite, and calcite.

Small outcrops of fine-grained quartz-muscovite schist along South Fork 2 miles west of here and at Mead Dam 2 miles to the northeast suggest widespread distribution of the metasediments in this area.

The quartzite is composed of quartz (84%), muscovite (12%), biotite (2%) and accessory plagioclase, pyrite, and chlorite. The quartz is equigranular and forms polygranular pods enclosed in muscovite. The pods may be relict detrital grains. The rock lacks banding and is quite homogeneous. Sparse shreds of fine-grained brown biotite are interspersed with the muscovite.

The kink-banded quartz-chlorite-biotite is a spectacular rock when seen in thin section. (Figure 35) Brown biotite flakes have been kink-folded, locally rotated with cleavage perpendicular to foliation, and partially replaced by the chlorite. Kink folds have an amplitude of approximately 1.0 mm. The composition of this rock is: chlorite (57%), quartz (38%), opaque (3%), and biotite (1%). The chlorite has unusually high relief, is pale green, non-pleochroic, and shows anomalous yellow-gray extinction colors. Quartz grains are interleaved with the folded chlorite.

The lenticulated, fine-grained quartz-muscovite schist has essentially the same mineralogy as the quartz, but with higher ratio of muscovite to quartz.

A chemical analysis of the micaceous quartzite was obtained from a specimen taken at Location A. (See Table 4; 7832)

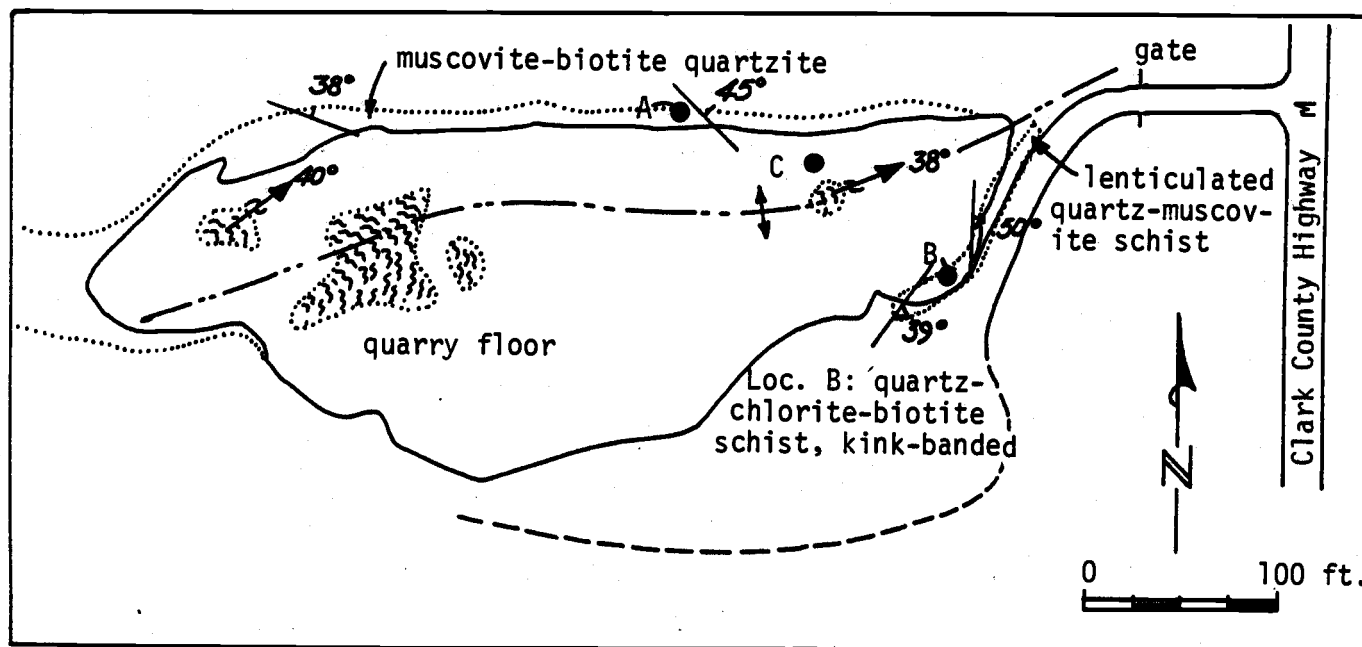


Figure 33 -- Geologic map of county quarry, Eau Claire River at Highway M.

REFERENCE: Piotruszewicz, M.A., An analysis of a drill core from western Clark County, Wisconsin. Unpub. M.S. thesis, University of Wisconsin, Milwaukee, 1978.

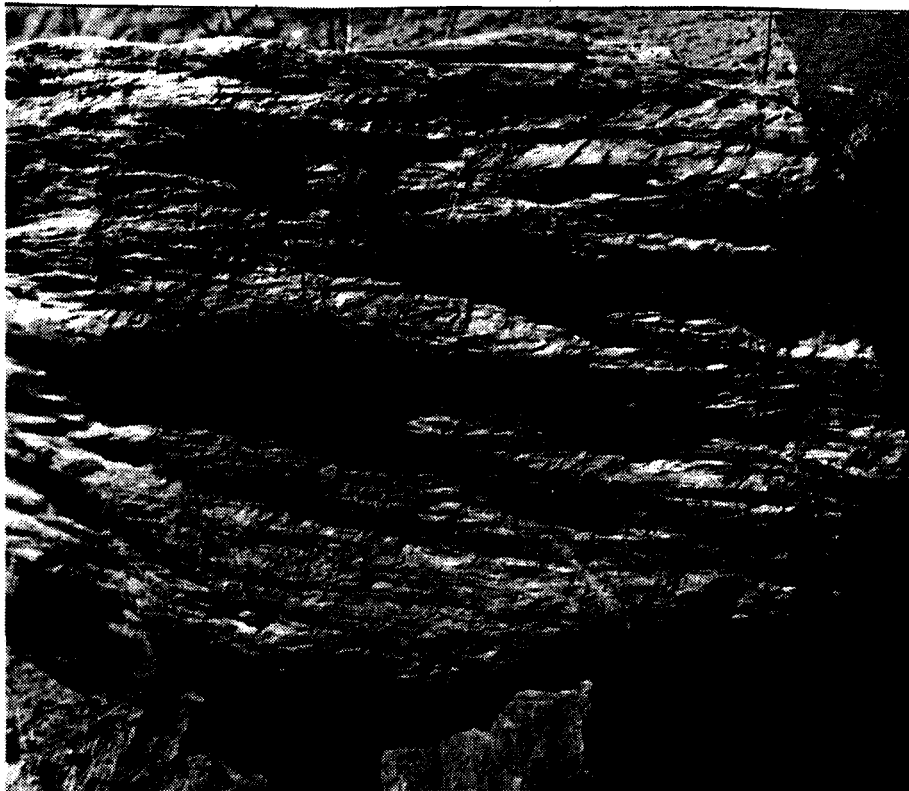


Figure 34 -- Kink folds in quartz-chlorite-biotite schist from quarry floor, Location C. Photo by Gene LaBerge.

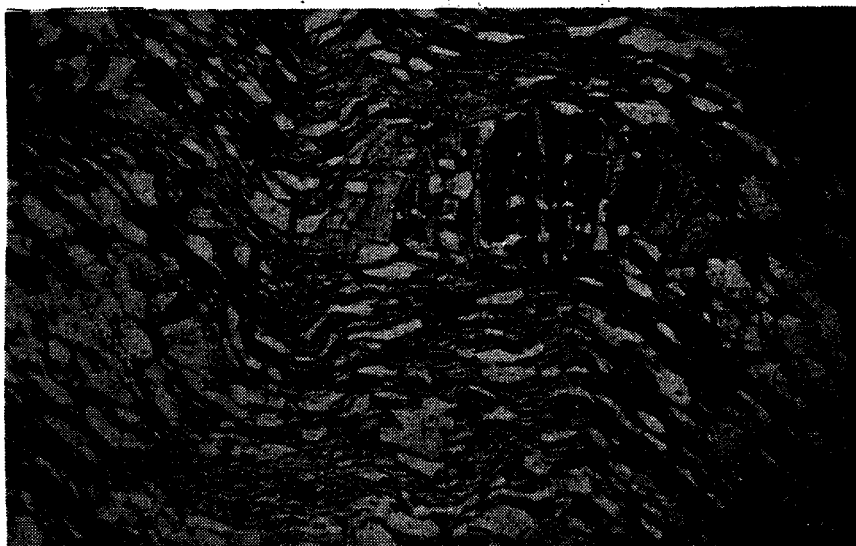
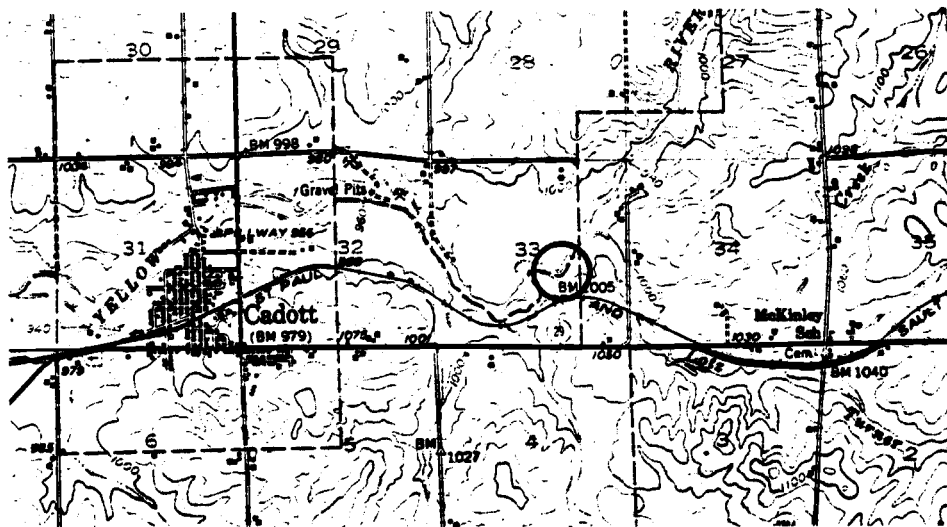


Figure 35 -- Photomicrograph showing kink folds in chlorite-quartz-biotite schist, Location B. Biotite, now partly altered to chlorite, has been folded also.

STOP #8

TITLE: CATACLASTIC VEINLETS IN HORNBLENDE-BIOTITE METADIORITE

LOCATION: Yellow River 2 miles E of Cadott; NW 1/4, SE 1/4, Sec. 33, T29N, R6W
Cadott 15' quadrangle



AUTHOR: Paul E. Myers

DATE: March, 1980

SUMMARY OF FEATURES:

This enigmatic contact between faintly foliated hornblende-biotite diorite and strongly deformed, foliated metadacite(?) (Figure 36) exemplifies the many problems of working out sequence in rocks affected by recurrent cataclasis, intrusion, folding, and metamorphism. Field and petrographic evidence here, and at most places throughout this region, strongly support the hypothesis that cataclastic veinlets and dikes are synkinematically intruded into more brittle rocks at sub-anatectic temperatures. The basic question here is, "Under what conditions, and at what time were the cataclastic biotite tonalite veinlets (7904-B) emplaced?"

DESCRIPTION:

A chronology field station, based on field relations and features seen in three thin sections (Myers 7904-A-C) is proposed below. Three pre-cataclastic protoliths exist: (1) Hornblende-biotite dacite or tonalite, (2) pegmatite, and (3) hornblende-biotite metadiorite.

The foliated metadacite(?) or metatonalite(?) is composed of approximately 50% plagioclase (An_{42}), 10% fragmented and altered hornblende, 25% fine-grained, polygonized, strained quartz, and 5% biotite. Plagioclase, hornblende, and biotite are partially altered to epidote, prochlorite, calcite, and magnetite(?). The metadacite or metatonalite(?) has a conspicuous cataclastic foliation; bent and fragmented plagioclase porphyroclasts have ovoid outlines and fragmented hornblende crystal remnants have been dispersed along interlensing shear surfaces. The coarse, polygonal form of the quartz and the replacement of hornblende by biotite suggest metamorphism after cataclasis. This rock contains several detached isoclinal fold hinges (Figure 36-E).

The pegmatite (not studied in thin section) is probably a granite in composition: it is leucocratic, and composed of pink feldspar and quartz. Feldspar cleavage planes are conspicuously bent, and the quartz locally has been lenticulated by cataclasis.

The sheared hornblende-biotite meta-diorite is composed of reverse-zoned, strained, marginally crushed plagioclase (An_{54}) (39%), fragmented, subhedral green hornblende (54%), pale yellow-brown biotite in random orientation and distribution (3%). Epidote and prochlorite, formed by alteration of hornblende make up approximately 3% of the rock. Accessories include coarse apatite, sphene, and magnetite (?).

Figure 36 shows the relations of these three rocks. The following sequences are possible: (1) Intrusion of tonalite into diorite and subsequent deformation with most intense cataclasis and development of foliation in the metadacites; (2) intrusion of diorite into dacite and subsequent deformation with localization of isoclinal folding and cataclasis in the dacite, possible injection of felsic "cataclastic dikes" into the broken blocks of more brittle diorite. Note that these alternatives reverse the relative ages of the diorite and the dacite. The curvature of the cataclastic foliation near the "veins" cutting the diorite (B) suggests that the diorite was broken and pulled apart to allow intrusion of the more felsic rock. It is clear, however, that cataclasis affected both the diorite and the dacite with its pegmatite dikes. Note that the folds are detached, rootless, a factor suggesting considerably chaotic internal displacement during or after folding.

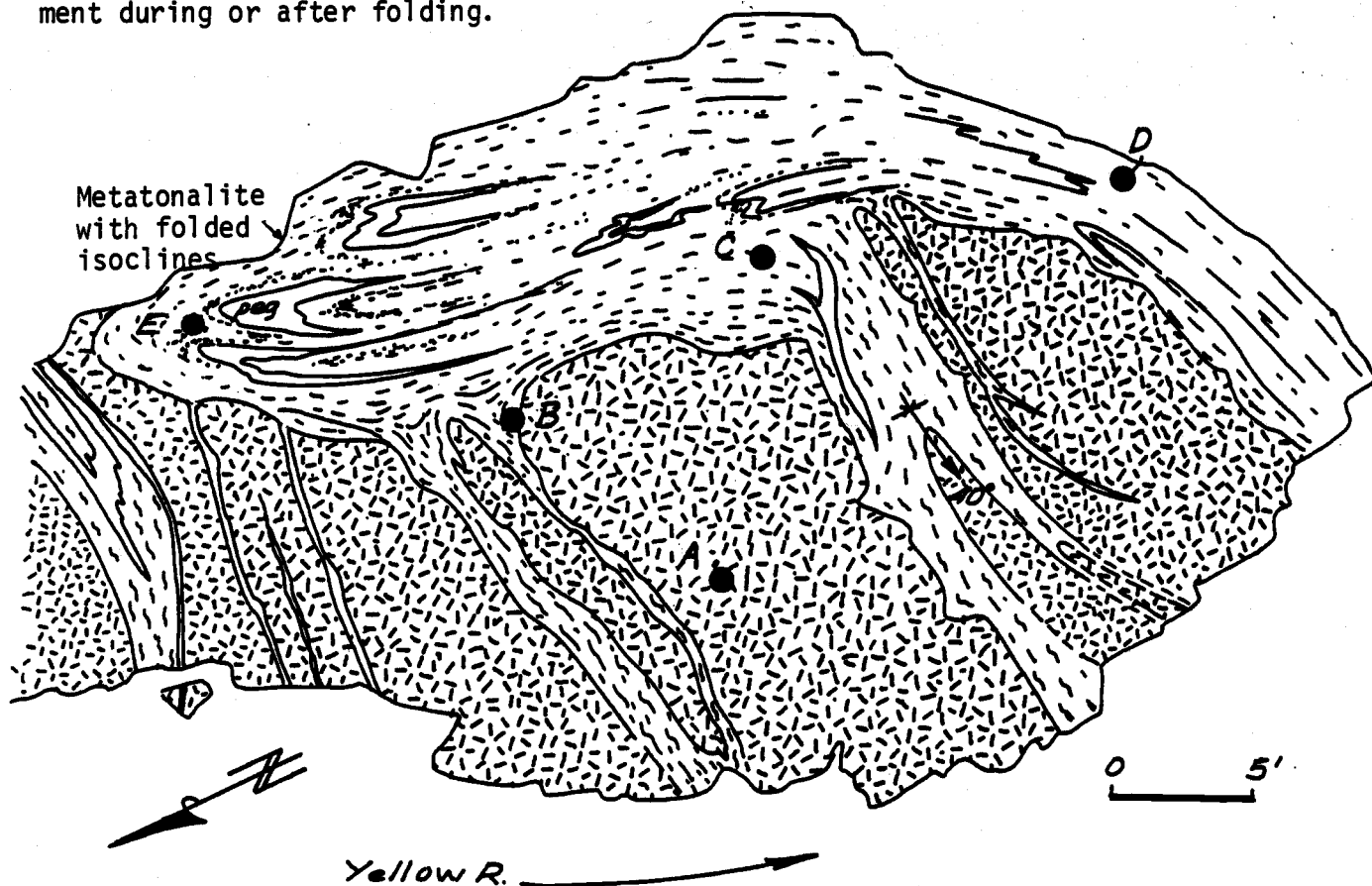


Figure 36 -- Biotite tonalite flaser gneiss veinlets (B) cutting metadiorite (A) Antiformal hinges in metadacite(?) or metadiorite(?) plunge steeply northeast. Foliation in metadacite(?) bends into cataclastic veinlets (B). Outcrop slopes gently toward the bottom of the profile.

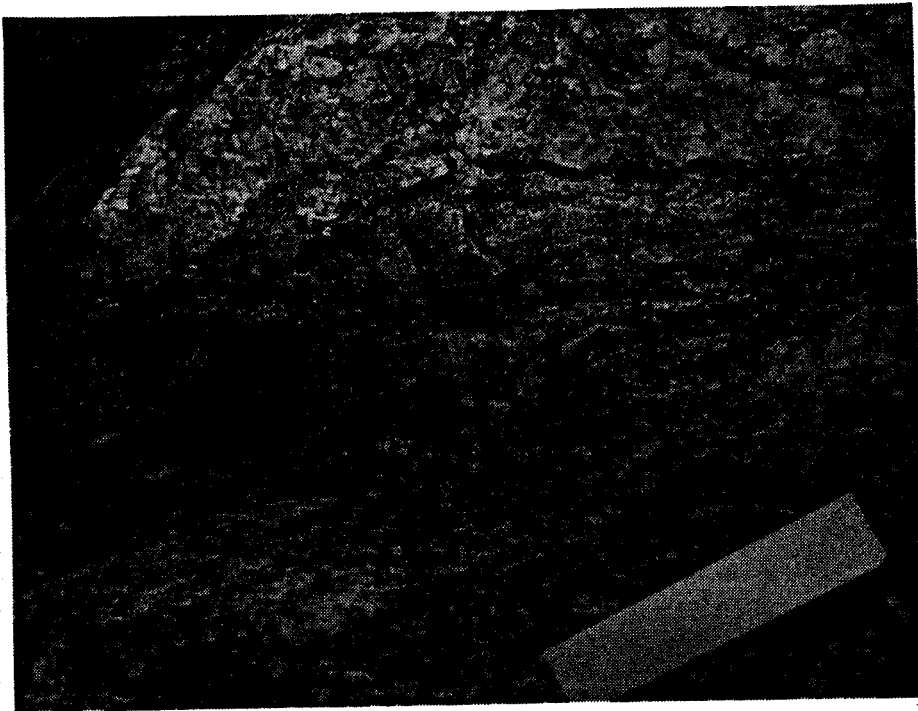
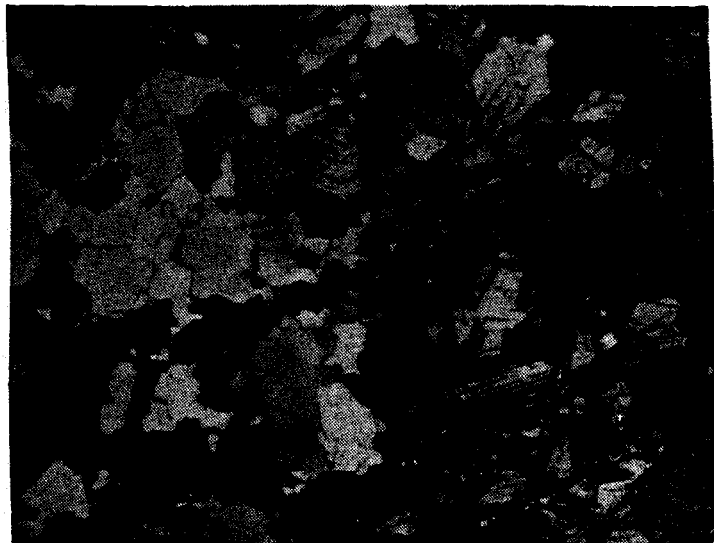
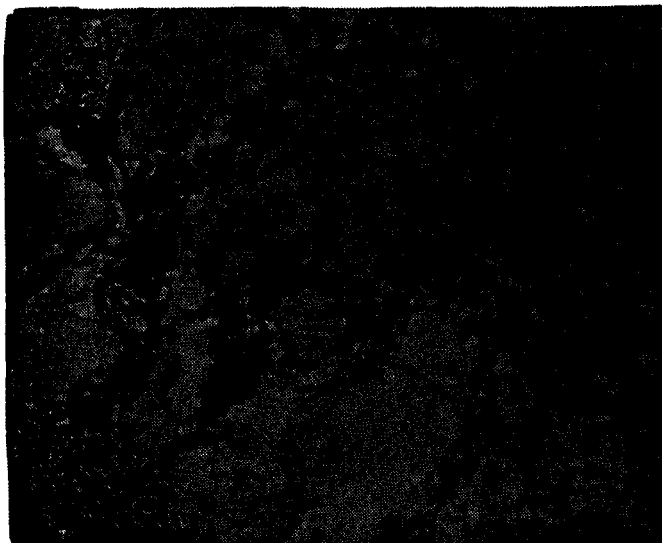


Figure 37 -- Axial portion of hinge of detached isoclinal fold segment, Location E. Scale is 6 inches long.



Figure 38 -- Nearly vertical cataclastic veinlets cutting faintly foliated hornblende metadiorite near location A. Note zoning of veinlet with concentration of coarse lenticular feldspar porphyroclasts near the center; quartzofeldspathic layers along outside edges. Line on photo is analogous in location to veinlet margin described in Figure 39.



Biotite tonalite flaser gneiss
Lenticular plagioclase in biotite folia with quartz.

Banded leucotrochilite
Very coarse plagioclase with bent twin lamellae surrounded by finer-grained quartz

Hornblende diorite
with shears and drag folds.

Plagioclase	65%
Quartz	20
Biotite	15
Hornblende	0
Chlorite	Tr
Epidote	Tr

40%
55
5
0
Tr
Tr

45%
5?
5
40
5
Tr

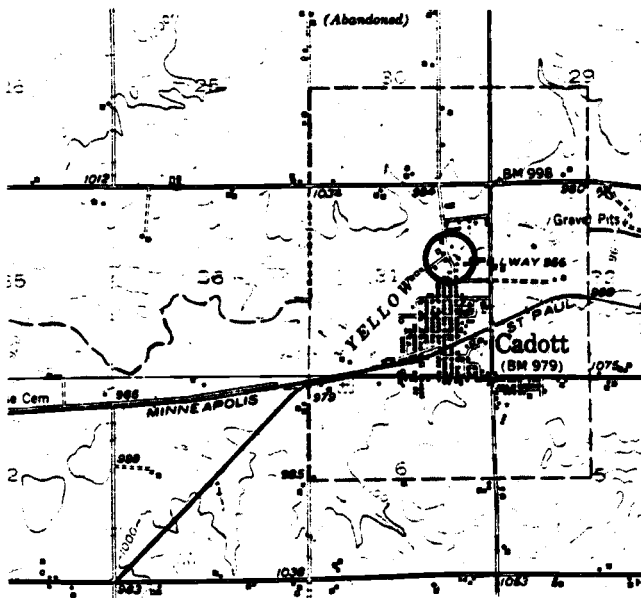
calcite



Figure 39 -- Cross section of zoned cataclastic veinlet (Location B). Width of section from hornblende diorite (right) to center of veinlet (left) is 7.0 cm.

TITLE: CADOTT INTRUSION BRECCIA AND CATACLASTIC ROCKS

LOCATION: SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 31, T29N, R6W: Cadott 15' quadrangle; Field Location 7905



AUTHOR: P. E. Myers

DATE: February, 1980

SUMMARY OF FEATURES:

Mafic amphibolites and foliated hornblende tonalite containing isoclinally folded quartz, aplite, and pegmatite veinlets exist as angular xenoliths in a lighter biotite tonalite. Folds in the xenoliths and lineations in the enclosing tonalite plunge southeast (Figure 40). The biotite tonalite contains a pervasive cataclastic foliation which was locally buckled into chevron folds, which plunge steeply north-west. The first cataclastic foliation is truncated by a second one (Location A in Figure 40). The later cataclastic event produced discordant veinlets of leucotondhemite flaser gneiss with a strong cataclastic foliation parallel to their walls (Figure 42). The second cataclastic event included significant amounts of strike-slip displacement along west-northwest trending faults.

DESCRIPTION

The predominant rock type here is foliated tonalite composed of plagioclase (An₂₅₋₃₅, 30-55%), quartz (10-40%), hornblende (0-25%) and biotite (0-15%). These minerals are partly replaced by chlorite (of several varieties), epidote, and sericite. Magnetite (1-5%) is a by-product in the chloritization of hornblende. The tonalites have been mylonitized and locally recrystallized (Location A).

At locations A-D (Figure 40) biotite tonalite with an older cataclastic foliation (N10-20°W) contains lenticular xenoliths of chlorite and epidote-rich meta-volcanic(?) rock. The older cataclastic foliation is axial-planar to isoclinally folded pegmatite, aplite, and quartz layers (Location A). These rocks are cut by a pervasive N65-75°W trending foliation and mylonitic shear zones.

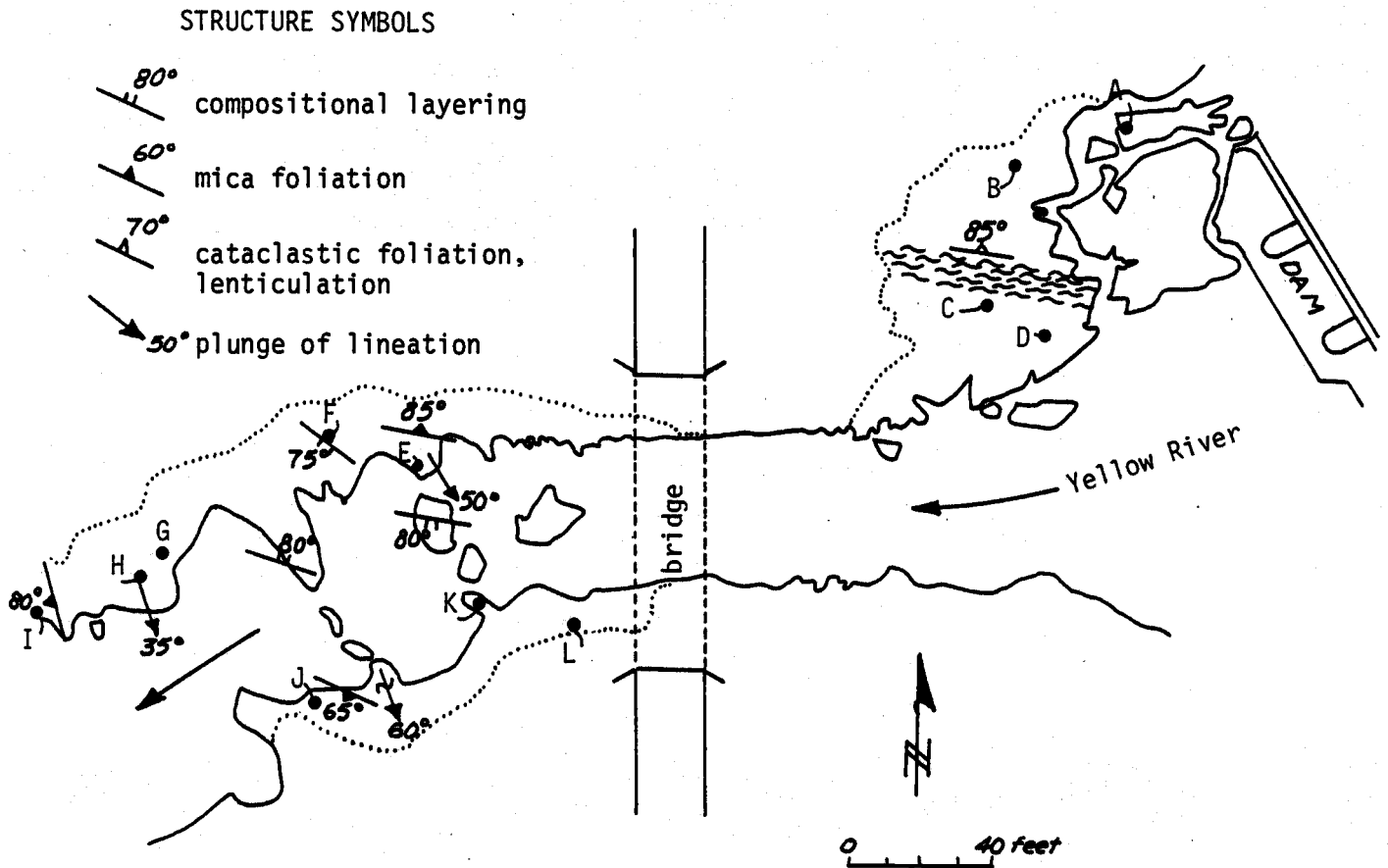


Figure 40 -- Outcrop structure map of the Yellow River bridge area, Cadott



Figure 41 -- Folded isoclinal folds in mafic amphibolite xenolith in foliated biotite tonalite. Lineation on left side of the xenolith plunges 55° southeast. Location E



Figure 42 -- Folds in banded mafic tonalite cut by aplite veins (left and right) and by coarser tonalite vein with cataclastic foliation parallel to its walls (center) Location G.

West of the Yellow River bridge, foliated biotite tonalite encloses angular xenoliths of more mafic hornblende tonalite or amphibolite containing strongly deformed aplite and pegmatite stringers (Figure 41 and 43). Xenolith orientation here (as at Little Falls) is about N10°W. Small folds within the xenoliths plunge southeast at 10-60° (See Figure 40).

CHRONOLOGY

The following sequence is based solely on the cross-cutting relationships of features at this location, but they correlate well with sequences worked out for other areas.

1. (Oldest) Metamorphism of mafic protolith to coarse, tonalitic amphibolite accompanied by segregation(?) of felsic stringers, quartz veins.
2. Shear folding with formation of isoclinal folds.
3. Intrusion of light-colored biotite tonalite ("foliated tonalite") with formation of an intrusion breccia (Figure 41).
4. Cataclasis, formation of more isoclinal folds (Location D). Cataclasis may have accompanied intrusion. (Figure 45).
5. Local chevron folding of cataclastic foliation (Location E, Figure 44).
6. Intrusion of darker tonalite (Location D) with formation of intrusion breccia containing xenoliths of cataclastically deformed lighter tonalite.
7. Intrusion of aplite and pegmatite.
8. Formation or intrusion(?) of cataclastic veinlets (Locations G and H, Figures 42 and 45). Strike-slip displacement along west-northwest-trending faults.

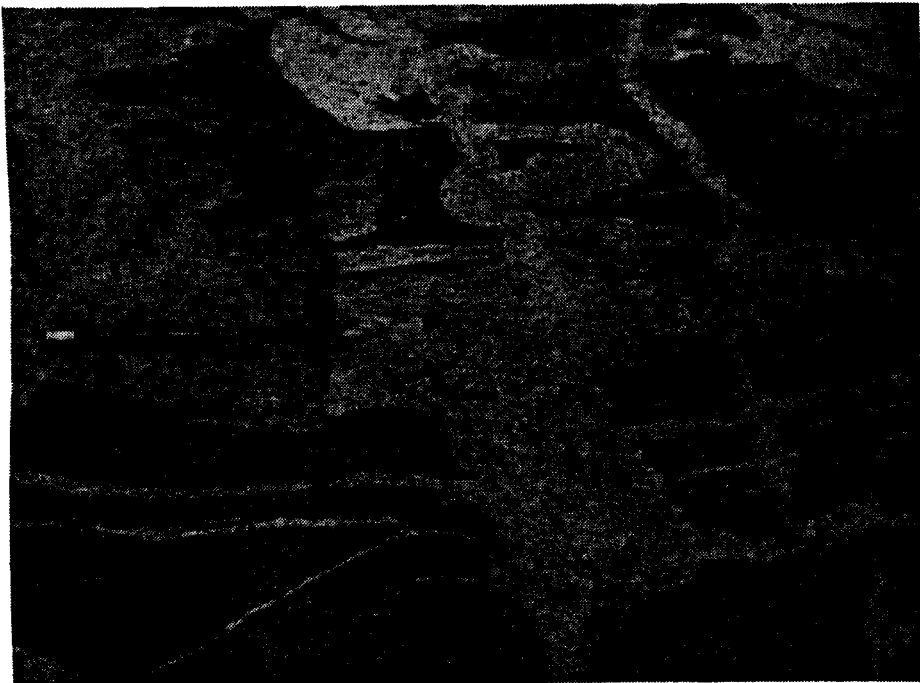


Figure 43 -- Intrusion breccia of banded amphibolite in bio-foliated biotite tonalite at Location H.

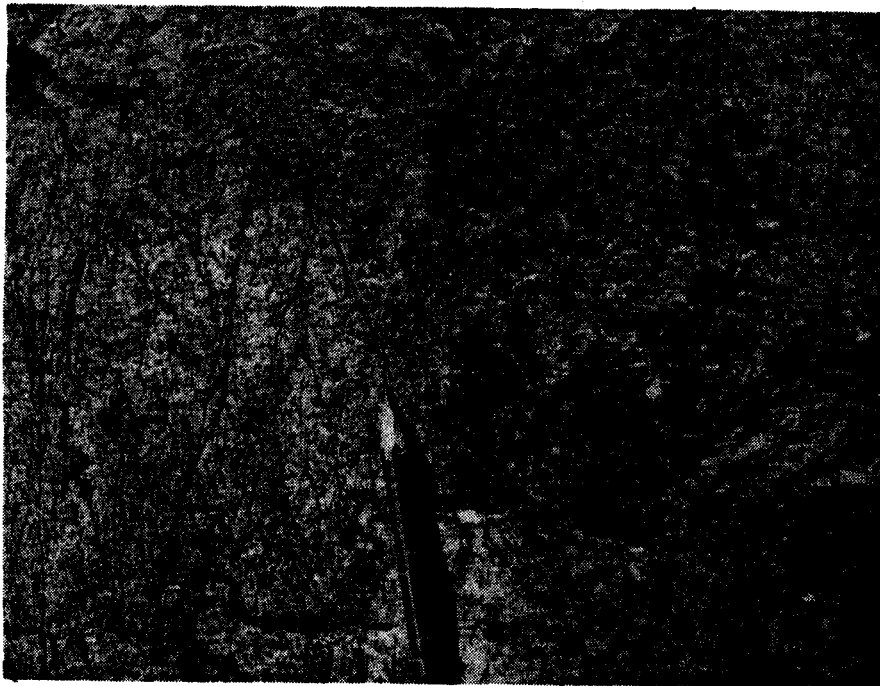


Figure 44 -- Chevron-folded foliation in biotite tonalite which contains the mafic amphibolite xenoliths at Location E. Folds here plunge steeply north(?) Horizontal outcrop.

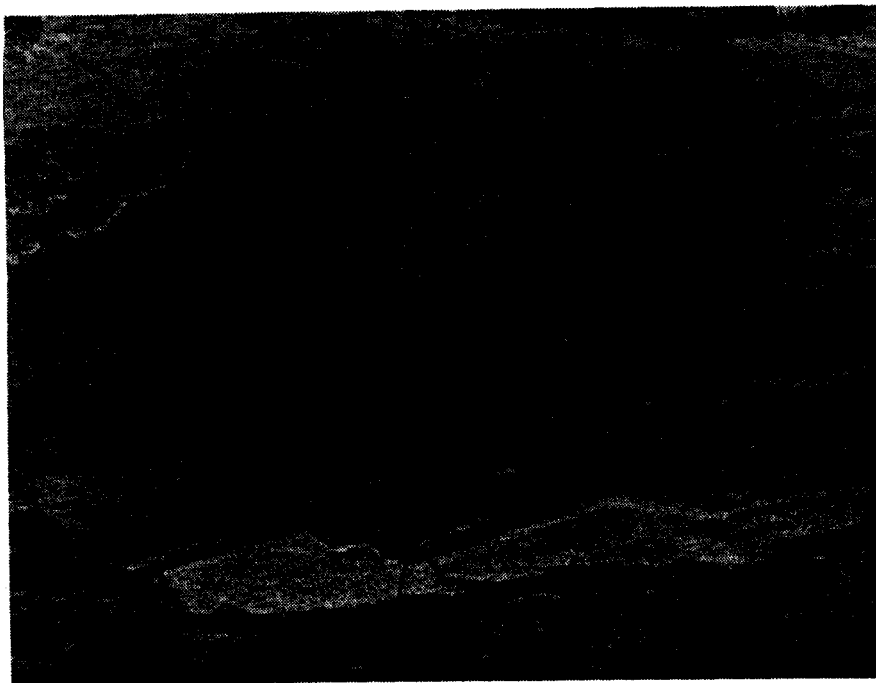
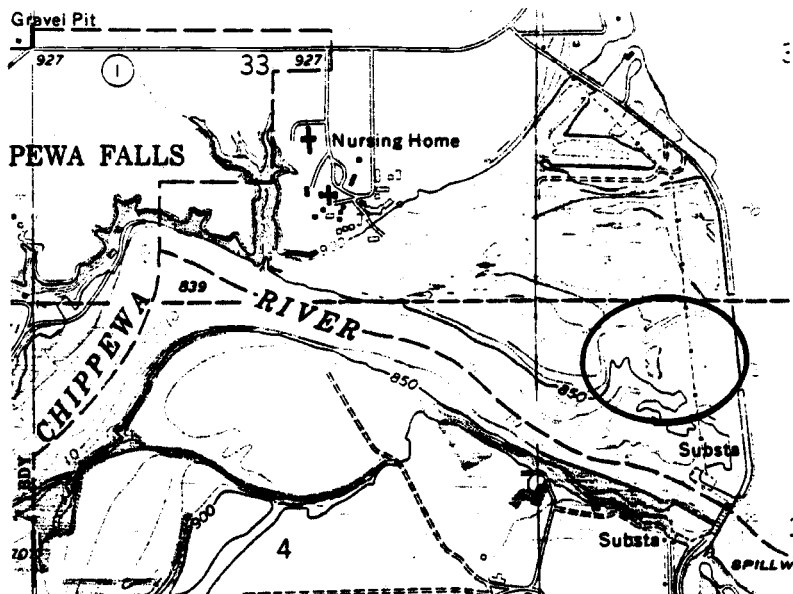


Figure 45 -- Isoclinally shear folded biotite tonalite stringers in darker tonalite. Location D. Cataclastic foliation here is N80°E, 75°N. View north-northeast.

STOP #10

TITLE: DIKES AT WISSOTA DAM

LOCATION: NW 1/4, Sec. 3, T28N, R8W, Lake Wissota 7 1/2' Quadrangle
Field location, 7835 + 7906



AUTHOR: Paul E. Myers

DATE: December, 1977, and March, 1980

SUMMARY OF FEATURES:

A complex intrusion sequence exposed in a large outcrop (Figure 47) below Wissota Dam 4.0 km (2.5 mi.) northeast of Chippewa Falls is: (1) protoclastic biotite trondhjemite, (2) biotite tonalite, (3) pegmatite and quartz veins, (4) gabbro-diabase, and (5) trondhjemite veinlets. A cataclastic zone cuts units 1 through 3 and shows left-lateral displacement. The 40-50 meter gabbro-diabase dike grades inward from aphanitic basalt along its walls to coarse pyroxene gabbro in its core. Inclusions of very coarse norite and plagioclase crystal fragments occur along the north wall of the dike. The gabbro-diabase dike is intruded by coarse, pink trondhjemite (quartz + oligoclase) which is offset by numerous small faults. These middle to late Precambrian rocks are overlain here by thin outwash gravels and silts of Pleistocene age.

DESCRIPTION:

Trondhjemite and Tonalite:

The oldest rock at Wissota Dam is faintly gneissic biotite trondhjemite composed of oligoclase (50%), quartz (35%), microcline (5%), biotite (5%), muscovite (5%), and abnormally abundant sphene. Weak foliation strikes N15°W and dips steeply east. The gneissic adamellite is cut (N20-50°W) by dikes (Loc. G,D) and irregular masses (Loc. I and J) of medium-grained, darker gray biotite tonalite (Loc. D), which locally (Loc. G) contains lenticular xenoliths of

banded amphibolite similar to that seen at Big Falls. The tonalite intrusions show no grain size diminution along contacts, and the amphibolite xenoliths are relatively unaltered. Some of the tonalite masses are of such irregular shape that doubt exists as to whether they are intrusions or segregations in the trondhjemite. Euhedral sphene, so characteristic of the trondhjemite is absent in tonalite sections examined. The tonalite is composed of plagioclase (An-38), biaxial quartz, biotite, and epidote. All minerals in these rocks show internal fracturing and dislocation, although the mortar textures characteristic of mylonitized plutonic rocks are absent.

The trondhjemite and tonalite are cut by east-northeast-trending pegmatite, quartz and epidote veinlets. The pegmatites show crystal orientation perpendicular to their walls--a factor indicating emplacement under conditions of tension or thermal contraction. Although no isotopic dates have been obtained from these rocks, it is probable that by correlation with similar rocks elsewhere, their age is between 1820 and 1845 million years.

A thin, branching discordant sheet of foliated biotite trondhjemite (Loc. D)-- here cuts and offsets the older rocks by left-lateral displacement (Figure 46) The foliated, mylonitized trondhjemite layer is 1-3 meters wide and trends N55°W. Drag folded foliation in the enclosing rocks indicates left-lateral displacement. Slickensided fault surfaces elsewhere in this outcrop have similar strike and dip and slickensides plunging 5°NW, a factor indicating nearly horizontal, left-lateral strike-slip displacement.

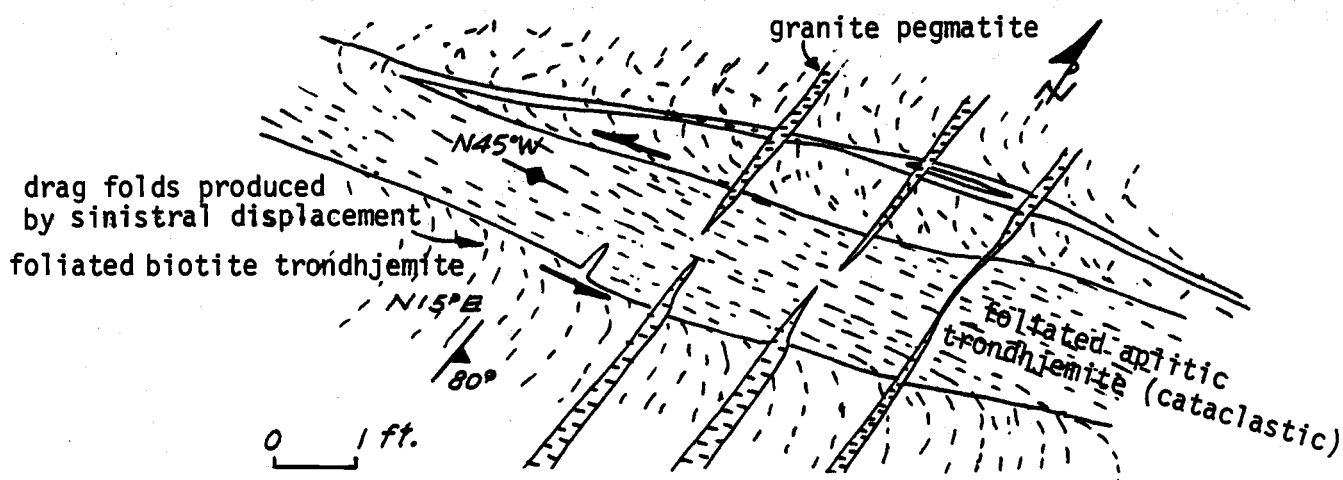


Figure 46 -- Field sketch of mylonitic veinlet in foliated trondhjemite Location F

Diabase Dike:

The rocks described above were intruded at shallow depth in Late Precambrian time (~1100 m.y. B.P.) by numerous gabbro-diabase dikes, one of which is superbly exposed in this outcrop. The vertical dike strikes N20-60°E and has chilled margins of aphanitic basalt. Numerous apophyses extend along joints in the enclosing granitic rocks (Loc. A, Figure 47). A narrow zone of plagioclase and hypersthene gabbro xenoliths occurs about one meter inside the north wall of the dike at Location B. The labradorite (An₆₀) fragments are up to 20 centimeters long and are oriented with long

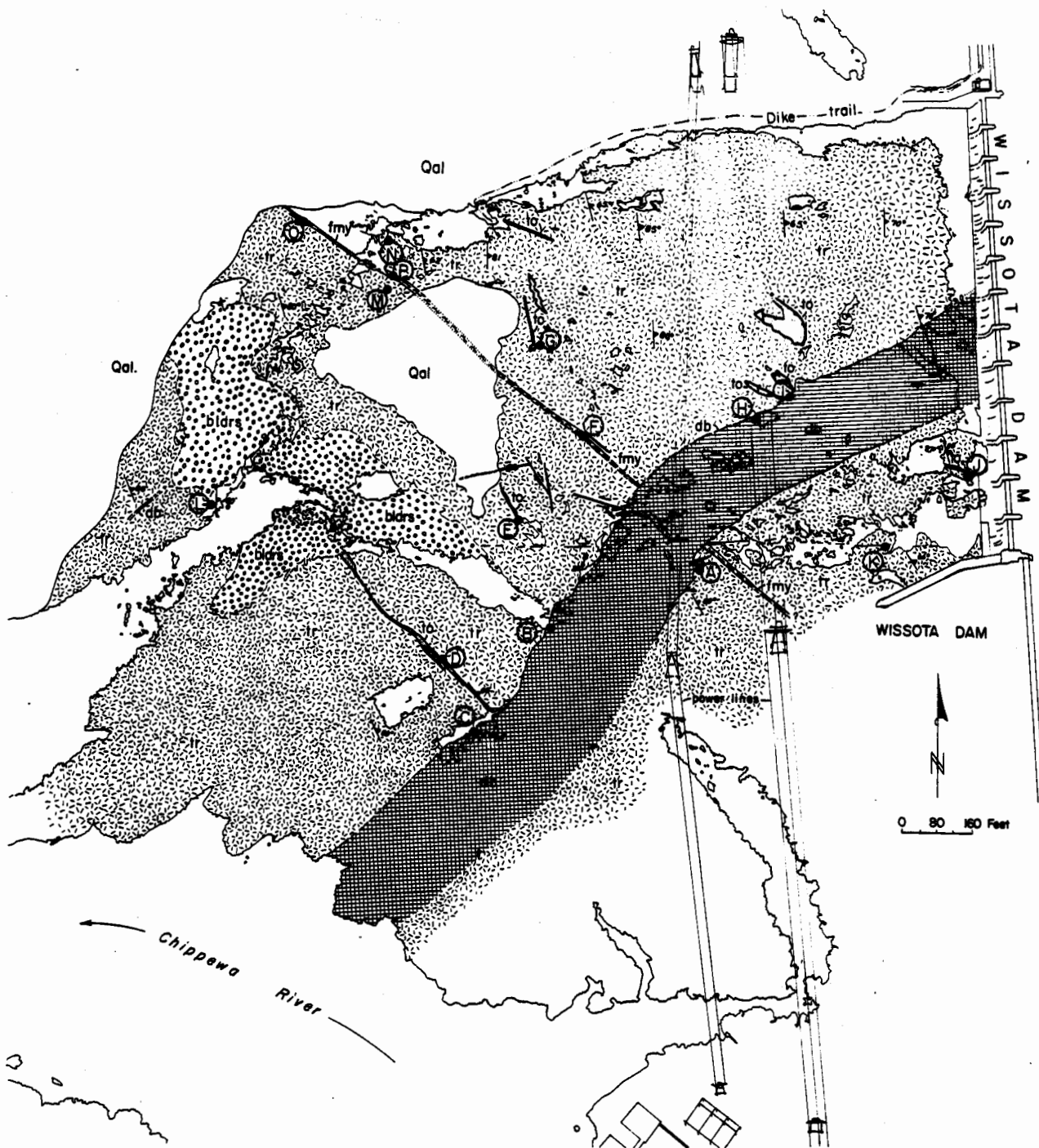


Figure 47 -- Geologic map of Wissota Dam area.

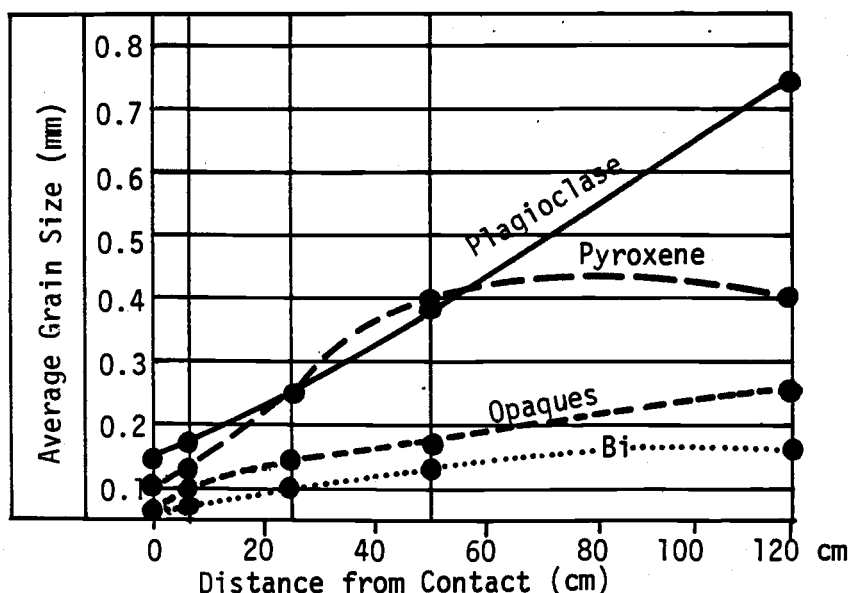
directions parallel to the dike wall. The fragments were first rounded by corrosion (?) and later broken in transit upwards during dike intrusion. Closely associated angular hypersthene (?) gabbro or norite xenoliths up to 40 centimeters long consist of very coarse, dark brown to dark olive gray hypersthene, now mostly altered to talc, iddingsite, and chlorite, which is intimately intergrown with very coarse plagioclase laths up to 15 centimeters in maximum dimension. Where and how did these xenoliths crystallize? (They closely resemble gabbros found near the base of layered intrusions like those along the north shore of Lake Superior.) Why are the xenoliths concentrated only along one wall of the intrusion? How did the dike form?

The diabase dike was sampled at location B at its contact with gneissic trondhjemite, and at distances of 6, 25, 50, and 120 cm from the contact. The rock is composed almost entirely of plagioclase (An₇₀₋₅₅) enstatite, and pegeonite. Opaques (mostly magnetite, pyrite, and hematite) decrease in abundance inward (See Table 9). Plagioclase occurs as anhedral to subhedral

TABLE 9 -- COMPOSITION OF DIKE BORDER PHASES

MINERALS	Contact	6 cm	25 cm	50 cm	120 cm
Plag	68%	63%	48%	53%	52%
	7+	12+	28	27	28
Biotite	--	--	3	4	6
Opaques	15	16	14	10	9
Olivine	--	--	--	1	2
Chlorite	9	8	4	3	1
Accessories	1	1	1	2	2

TABLE 10 -- SIZE VARIATION INWARD IN DIKE



laths with size ranging from 0.13 mm at the contact to 0.75 mm at a distance of 120 mm. An content in the plagioclase increases inward. Enstatite forms blocky wedge-shaped, interstitial grains, has a 2V of 50-60°, and a size from 0.10 mm at the contact to 0.50 mm at a distance of 120 mm. (Table 10.) Finer grained pigeonite forms pale greenish brown to pink, weakly pleochroic fibers. Biotite increases in abundance to about 6 percent at a distance of 120 mm from the contact.

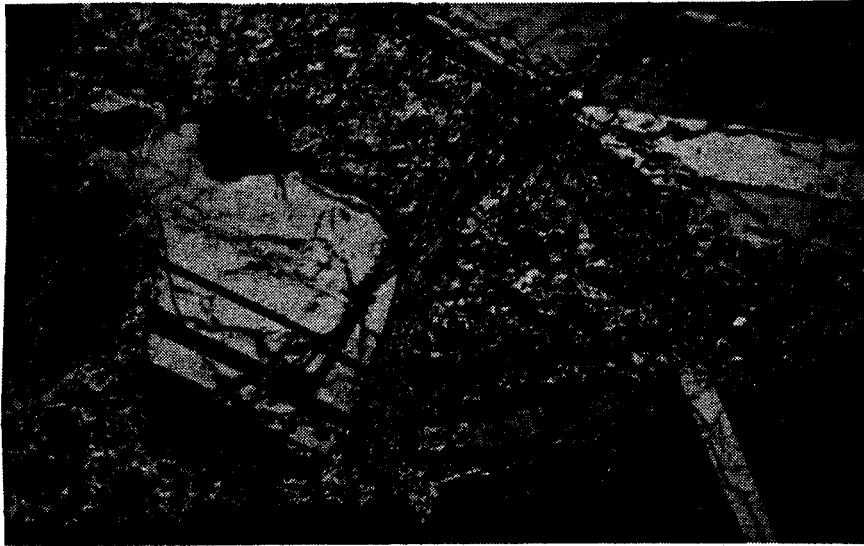


Figure 48 -- Intrusive contact between chilled basalt (center) and anorthositic gabbro inclusion at Location C. Note late, fault-related fracturing. Photo width is 4.2 millimeters.

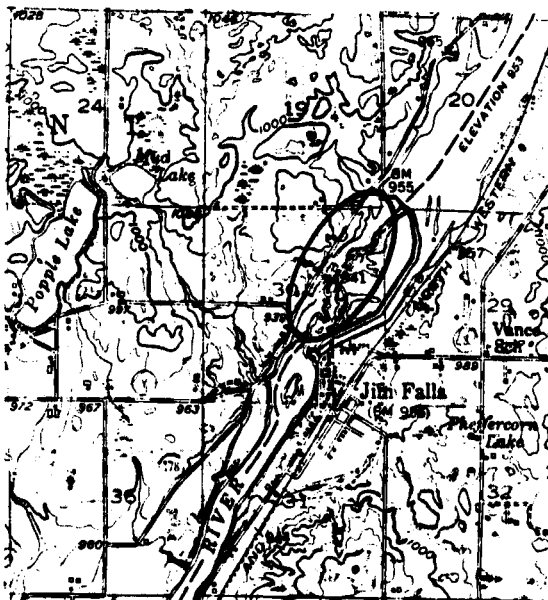
At location B, the diabase dike is cut by a 3-5 centimeter vein of coarse-grained trondhjemite (oligoclase + quartz). The rock is unusual because of the pervasive orange-red color of the plagioclase (dispersed iron oxides) and the degree of strain exhibited in thin section by the quartz, which shows an unusual feathery, lamellar undulatory extinction. The plagioclase is locally bent and crushed. Since the vein occurs in a north-northwest fault zone which cuts the diabase dike, it is not surprising to see strain features, but it is unusual to see it so strongly developed in Late Precambrian rocks. Since the mineral composition of this rock is so simple, it would not be difficult to calculate an approximate norm. The quartz-plagioclase ratio is about 0.8. The trondhjemite dike is offset by small faults which were subsequently filled with fibrous calcite, an indication of considerable post-diabase activity in this area.

CHRONOLOGY - WISSOTA DAM AREA

1. Metamorphism and formation of amphibolite (xenoliths in tonalite)
2. Synkinematic emplacement of foliated biotite trondhjemite with development of foliation N10-15°W.
3. Intrusion (?) of biotite tonalite roughly parallel to foliation in the trondhjemite (Location G, D)
4. Left-lateral strike-slip faulting and development of cataclastic veinlets N45-55°W. (Locations F, P, and O)
5. Intrusion of pegmatite dikes associated with thermal contraction and/or crustal tension. (Location E.)
6. Jointing, deposition of epidote, and small-scale faulting. (Location E)
7. Intrusion of diabase with magma derived from a differentiating sill(?) at depth. (Locations A, B, C, H)
8. Intrusion of leucotondhjemite dike (Location B)
9. Faulting and development of strain features in leucotondhjemite
10. Precipitation of calcite veinlets in the fault zone. (Location B)
11. Erosion.

TITLE: AMPHIBOLITES AND GRANITES OF JIM FALLS

LOCATION: E 1/2 Sec. 30, T 30 N, R 7 W, Jim Falls, Bloomer 15' Quadrangle



AUTHORS: Paul E. Myers and Douglas R. Maercklein

DATE: February, 1980

SUMMARY OF FEATURES:

Banded amphibolites, probably derived from mafic volcanics and associated sediments, were intruded by granites of diverse composition and their cogenetic pegmatites at several times in Middle Precambrian time. Cataclasis, folding and metamorphism produced a highly deformed system of tectonically interlensing rock units showing only partial preservation of older structures. Prevailing regional structural grain is ENE. Late Precambrian diabase dike intrusion (1100 - 900 m.y.?) followed prolonged erosion.

DESCRIPTION:

Garnetiferous hornblende gneiss and schist with folded, high-amplitude isoclinal, (Figure 49) persistent ENE strike and steep dip are cut subconcordantly by granitic rocks ranging in composition from leuco-tonalite to granite. Pegmatite dike intrusion occurred at several stages of "granite" intrusion. The older granitic rocks are foliated and locally mylonitized. Shearing and boudinage of pegmatite stringers transposed them into oblique concordance with lamination in the enclosing rocks (Figure 51). A rough correlation can be made between relative age and concordance of veinlets.

At location A, thinly laminated amphibolite was intruded by granite so that lenticular slices of the amphibolite were dragged en echelon away from the wall (Figure 54). The coarse granite pegmatite intruded under stress

contains en echelon fractures filled with very coarse quartz. The amphibolite-granite (trondhjemite) contact is sheared, cataclastically blended, and recrystallized - "granitized". Since the granite intrusion was apparently guided by lamination in the amphibolite, the effects of cataclasis in modifying the contact could be easily overlooked.

Small (F-2) folds at Location C plunge gently east-northeast. These are folded F-1 isoclinal folds, and a few hinges can be found in the outcrop. The geometry of the isoclinal folds, not modified by F-2 folding is best displayed at Location B. The unusual nature of the F-2 folds is shown in Figure 50. Since aplite and pegmatite veins were clearly involved in the F-1 event, and since these veins also cut the granitic intrusives here, it appears that the F-2 folding was quite late. The deformational sequence is summarized on page 83. Xenoliths of isoclinally folded amphibolite occur in the granite (Figure 52).

The aeromagnetic map (Figure 55) shows a pronounced V-shaped westward convergence at Jim Falls. The low magnetic relief of the bedrock between these two magnetic (amphibolite) ridges is probably an eastward extension of the granitic rocks exposed in the Chippewa River channel between Location A and the dam. A well-defined, discordant ridge arcs southwestward across the map and crosses the "amphibolite ridge" about 2 miles east of the bridge at Jim Falls. The feature is probably a diabase dike of considerable size, possibly the dike that is exposed at Wissota Dam.

Petrography and Geochemistry

In contrast to the alumina-rich, garnetiferous amphibolites of the Cornell area, the amphibolites at Jim Falls are chemically indistinguishable from those of the Eau Claire River area, and are composed of hornblende (45-65%), plagioclase (25-50%), epidote (5-15%) and ubiquitous accessory quartz, magnetite, pyrite, sphene, and chlorite. Epidote is the alteration product of hornblende, which is pale green (α) to moderate bluish green (γ), and shows a pronounced alignment in the plane of compositional lamination. The lamination results mainly from changes in proportion of hornblende and plagioclase. The plagioclase occurs as "windows" between the well-oriented hornblende laths. Its average size is less than the hornblende, and it is typically anhedral. More than 95% of the plagioclase shows no twinning. Relict twinning in a few grains permits measurement of extinction angles. By this method the approximate An content was found to be between An₃₅ and An₅₅. With a CaO:Na₂O:K₂O ratio of 86:10:4 (Table 1) such a composition should be anticipated.

As is the case at Cadott and Wissota Dam, the oldest recognizable intrusive rock here is a foliated, light gray biotite trondhjemite. It is intruded by darker biotite-hornblende tonalite and a later trondhjemite with pegmatite segregations. K-feldspar is a very rare commodity in these rocks. Even the pegmatites are adamellites, and contain approximately equal parts K-feldspar and sodic plagioclase. The lack of K₂O in the Chippewa amphibolites suggests first-cycle reworking of primitive basaltic basement rocks.

No rock seen at Jim Falls (with the exception of the diabase dikes) is devoid of cataclastic fabrics. Most of the contacts are either totally or partially modified by shearing and mechanical intermixing of contiguous rock units.

Chronology

Based on cross-cutting and structural relationships, the following chronology has been worked out for the Jim Falls area: (1) Archean (?) basaltic volcanism and associated sedimentation, (2) regional metamorphism converting the volcanics to amphibolites and isoclinal folding, (3) cataclasis forming ultramylonite zones, (4) faulting and brittle deformation, (5) successive intrusion of at least four granitic magmas with intervening episodes of cataclasis as evidenced by the occurrence of folded mylonite xenoliths in some of the younger intrusives (Figure 52), (6) prolonged erosion, and (7) Late Precambrian diabase dike intrusion. This sequence is modified from Maercklein, 1974, p. 16-20. At least three deformational episodes can be distinguished here as they can elsewhere in the Chippewa amphibolite complex.

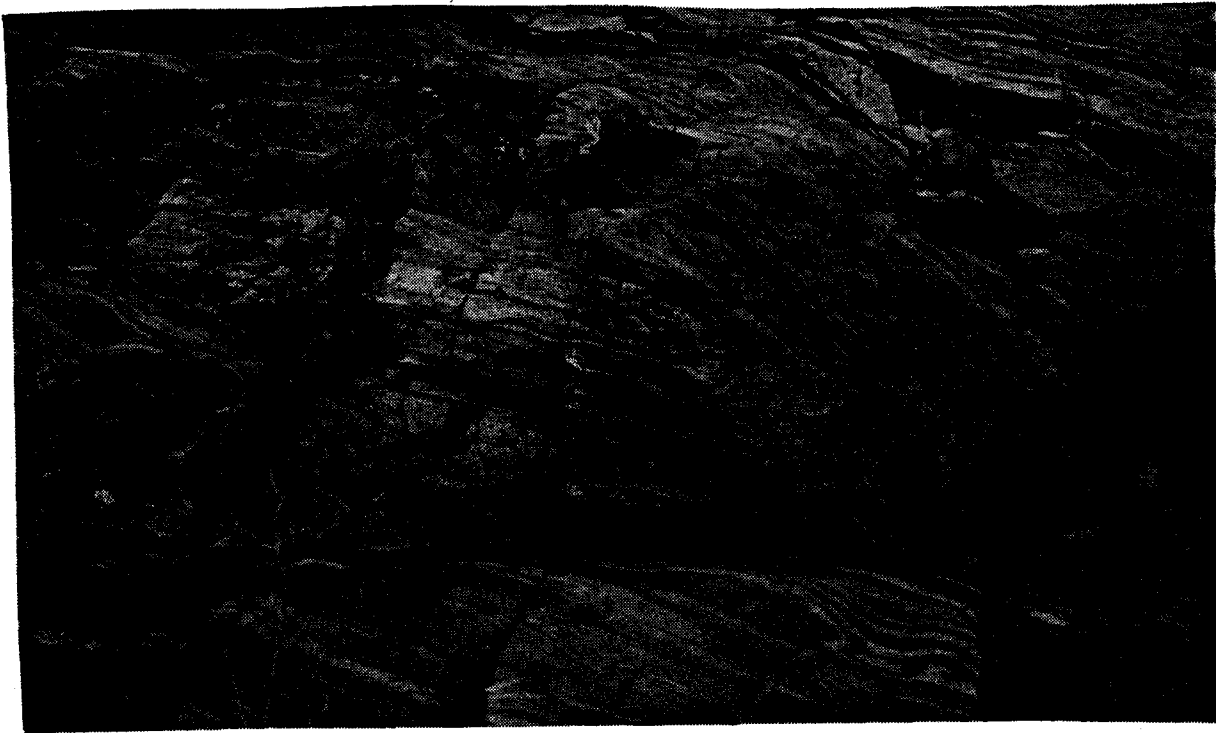
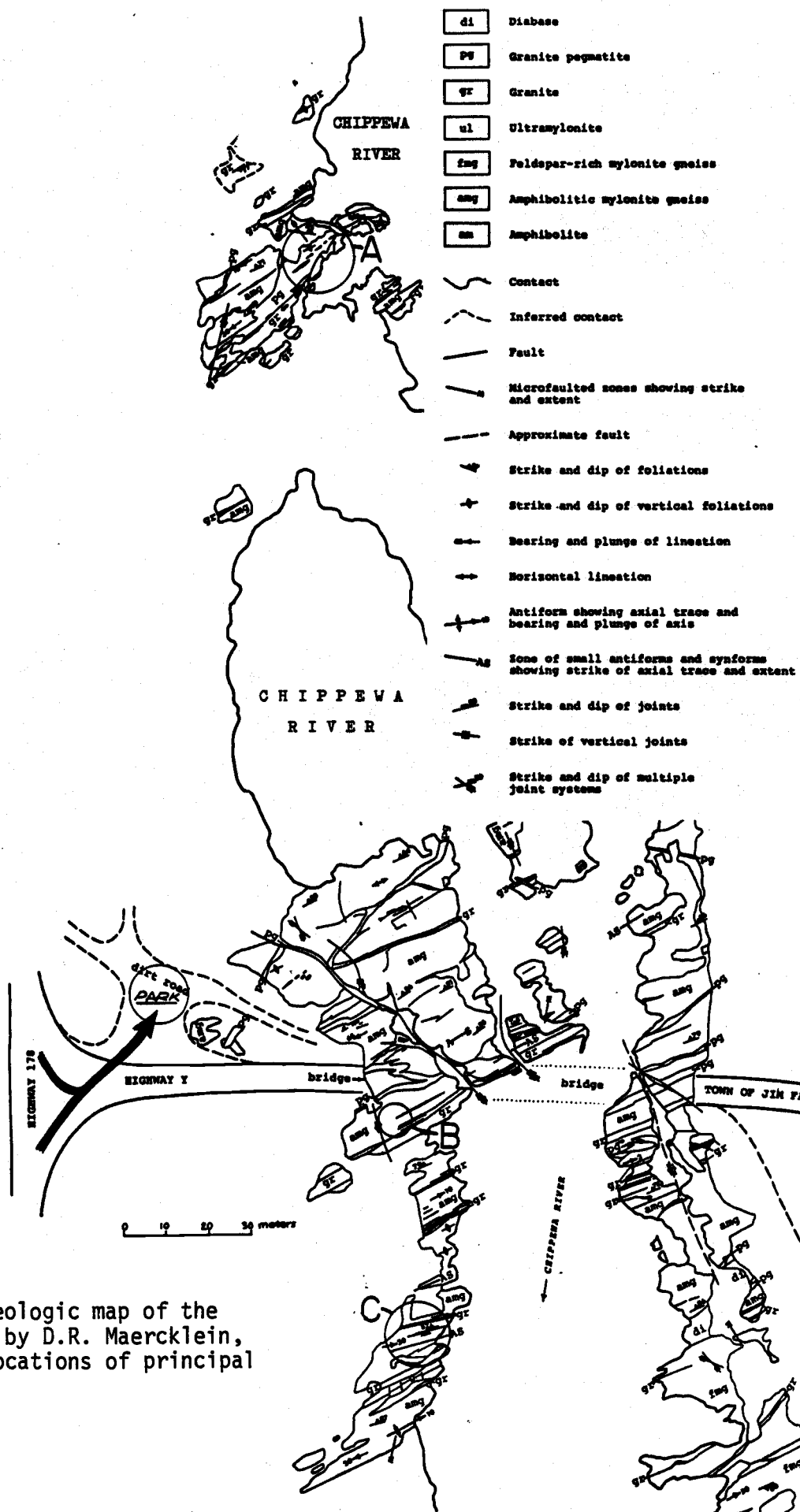


Figure 49 -- F-2 folds here plunge about 15-20° east-northeast. The hinges of isoclinal F-1 folds can be found in this outcrop. Throughgoing cataclasis and associated faulting have locally broken these structural blocks into lensoidal blocks. Drag folding and and brecciation can be seen in the limbs of some of the F-2 folds.

REFERENCES:

- Maercklein, Douglas R., 1974, Analysis of deformation at Jim Falls, Wisconsin, unpublished M.S. thesis, University of Wisconsin - Milwaukee.
- Myers, Paul E., and Maercklein, Douglas R., 1974, 38th Annual Tri-State Geological Field Conference Guide Book, p. 35-42.

EXPLANATION



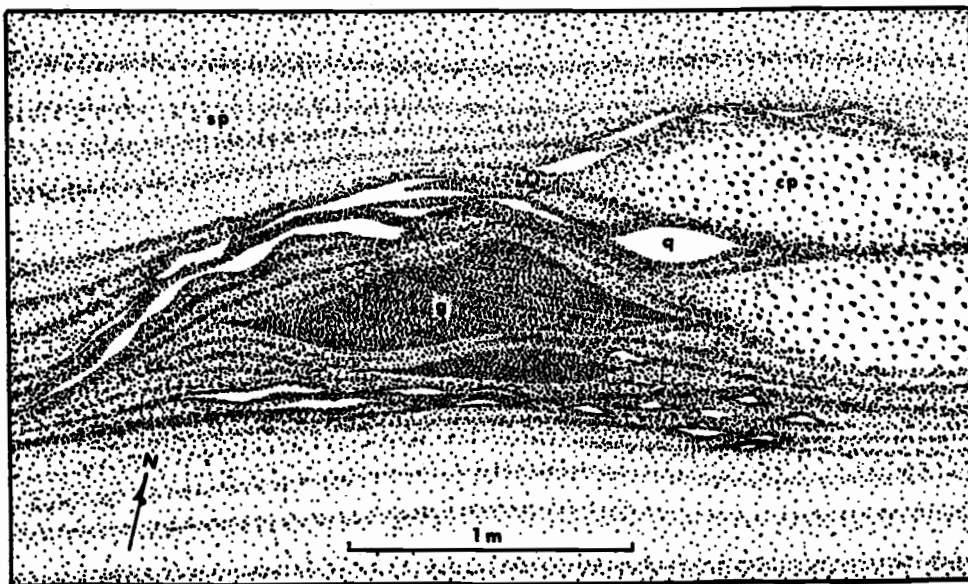


Figure 51-- Interlensing shear cutting granite pegmatite at Location A. Lenticular white areas are quartz, which tends to be localized along surfaces of major slippage. Sketch by Maercklein (1974, p. 61)

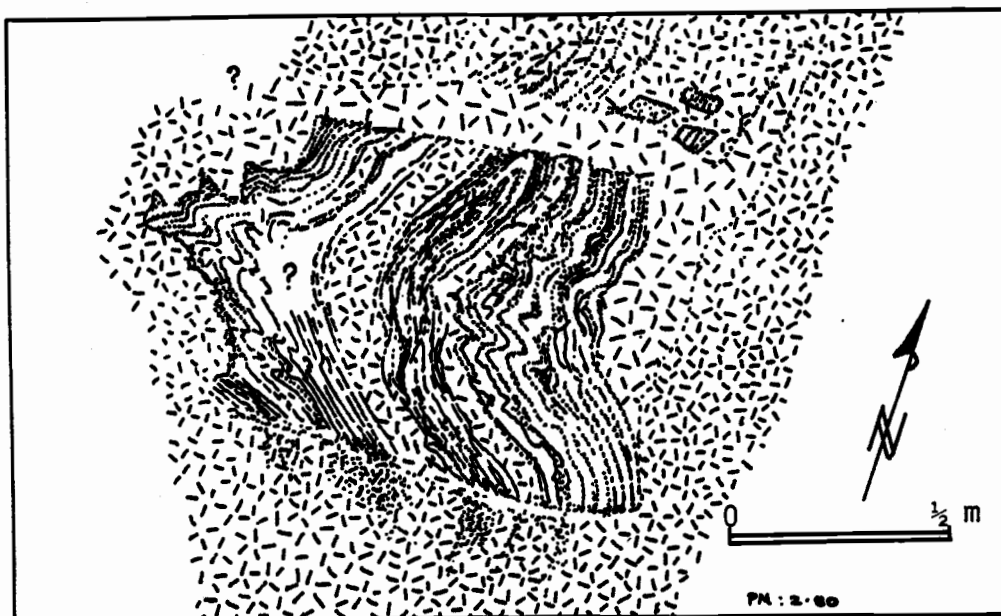


Figure 52-- Partially assimilated and granitized amphibolite xenoliths in biotite adamellite(?). Contact is locally discordant. Biotite-rich bands extend into the adamellite(?) from the large xenolith. Location: halfway between the dam and bridge on west side of the Chippewa River.

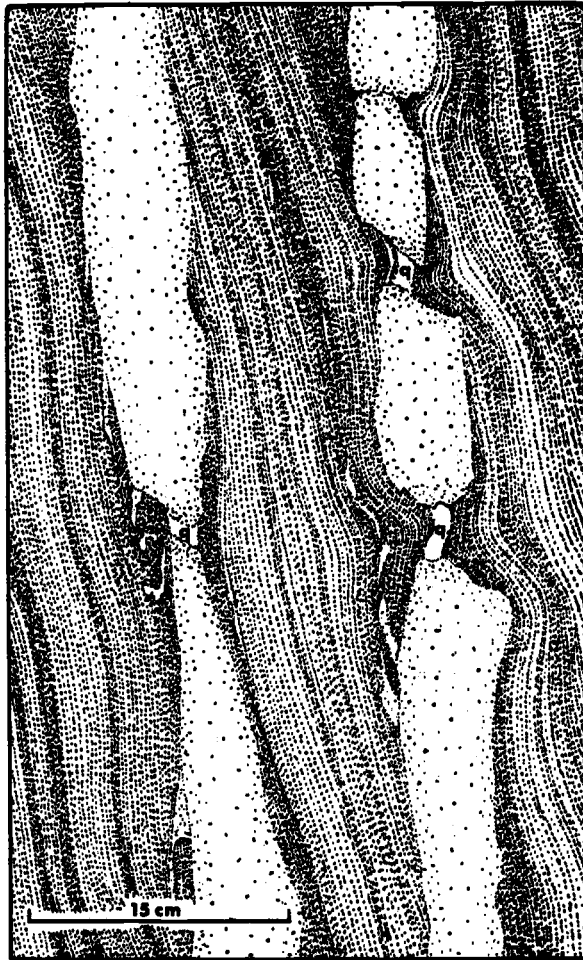


Figure 53-- Boudinage structures in pegmatite dikes cutting thinly laminated amphibolite just north of the bridge. Note accumulation of quartz at points of pegmatite separation. Sketch by Maercklein (1974, p. 65)

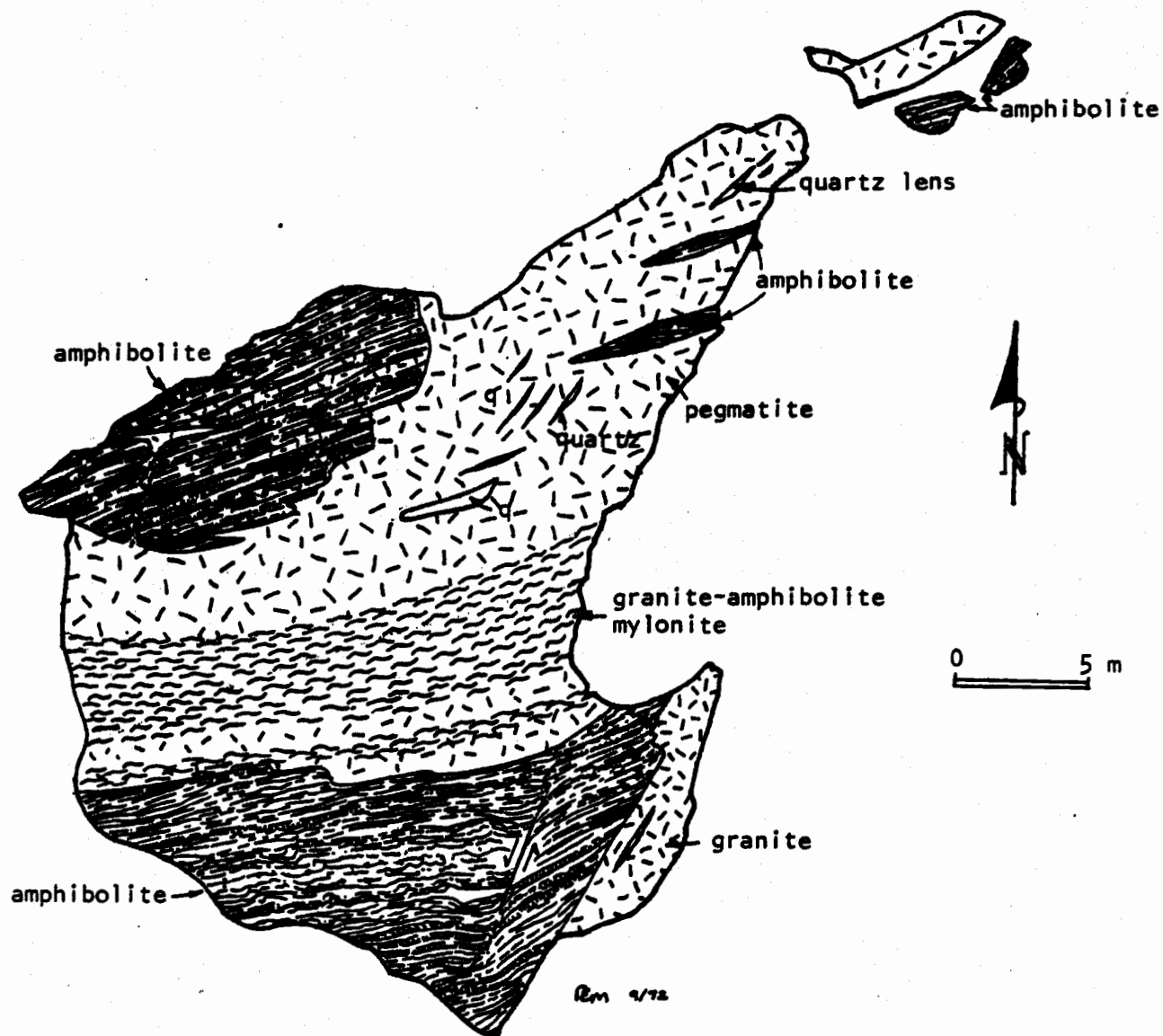


Figure 54-- Detailed geologic map showing sheared intrusive contact of "granite" in thinly banded amphibolite. Lenses of amphibolite were carried away from the wall by the granite. En echelon fractures were filled by quartz during contraction of the pegmatite. Location A

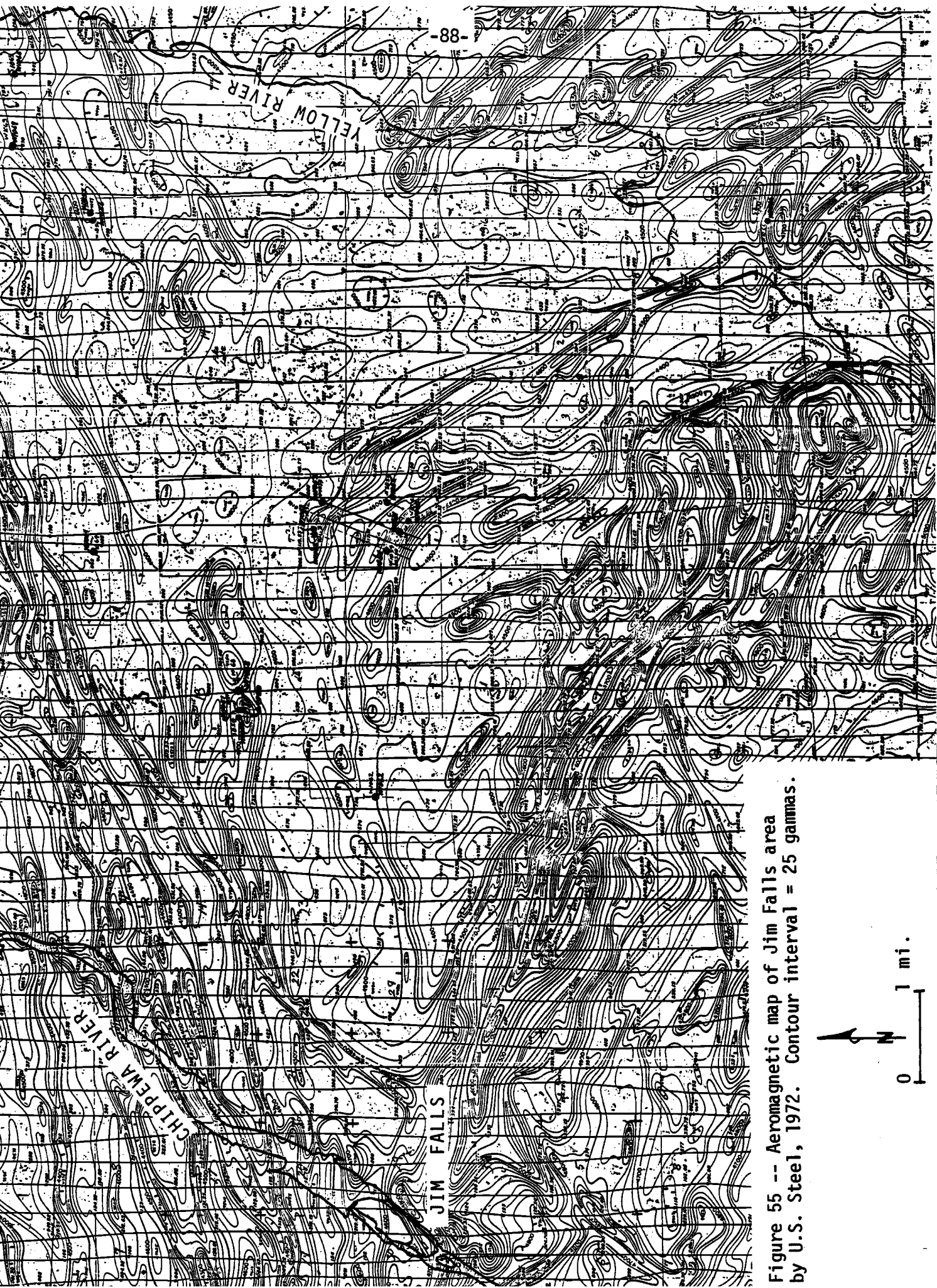
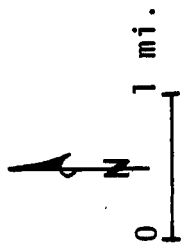


Figure 55 -- Aeromagnetic map of Jim Falls area
by U.S. Steel, 1972. Contour interval = 25 gammas.



STOP #12

TITLE: CORNELL FLASER GNEISS AND AMPHIBOLITE

LOCATION: A SE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 18, T31N, R6W: West side of Hwy. 64 Bridge, Cornell
B SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 18, T31N, R6W: East side of Hwy. 64 Bridge, Cornell,
Cornell 15' quadrangle.

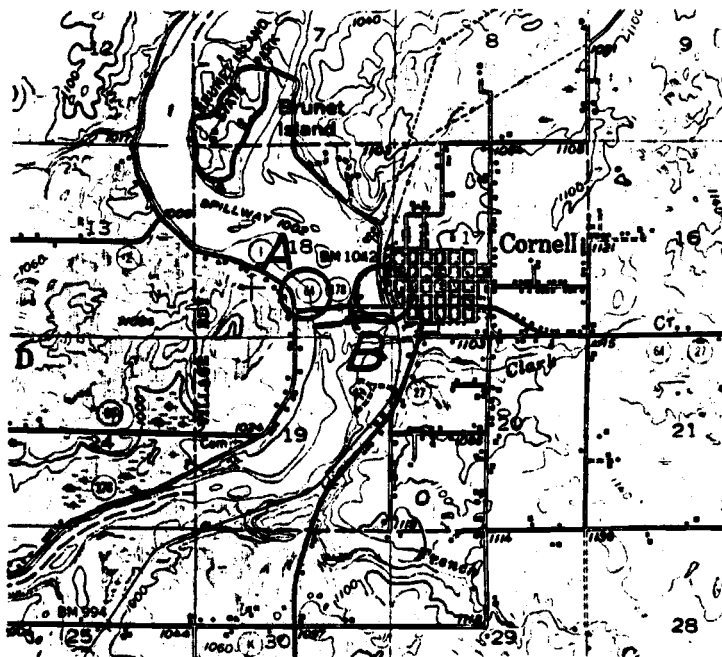


Photo taken 9/17/74 during dam repairs.

AUTHOR: P.E. Myers

DATE: September, 1974, March, 1980

SUMMARY OF FEATURES:

Flaser gneiss composed of mica, quartz, feldspar and sparse garnets is tectonically interlensed with thinly laminated fine-grained banded garnet amphibolite. Although granite, which became the flaser gneiss, was probably intruded into the amphibolite, its contact today is a shear zone. Rocks at this locality show an intermediate stage in the tectonic interlensing shear and cataclasis of rocks of disparate lithology followed by metamorphism to garnet grade.

LOCATION A -- GARNETIFEROUS ADAMELLITE FLASER GNEISS

Garnetiferous, biotite flaser gneiss (Figure 56) near water level at the northwest corner of the Cornell bridge is composed of coarse lenses and zoned feldspar in a micaceous mylonitic matrix. Polygranular lensoids and layers of untwinned plagioclase (41%) intergrown and mantled by anhedral microcline (18%) are encased in a laminated, micaceous crush debris. Polygranular, strained quartz (32%) with sutured boundaries forms long, thin laminae and lenses which impart the conspicuous lamination seen in outcrop. Very dark olive green to pale yellowish green biotite (5%) with coarse muscovite (3%) and occasional

grains of epidote and garnet are confined to the foliated crush debris. This rock contains more biotite and less garnet than flaser gneiss at Locality B. Interlensing shear dislocation and cataclasis normally involve several stages of differential grain fracture, displacement, and ablation accompanied by laminar flow of crush debris with lateral displacement, ablation and mixing of rocks. The rock from which this gneiss formed was probably a coarse-textured biotite quartz monzonite. Each component mineral in a granitic rock behaves differently under shearing stress.

Stage 1 -- Protomylonite

Early strain is expressed as progressive microscopic crushing of minerals, first at corners, then on edges, and last on faces. The lens is an equilibrium form at all scales. Quartz is easily fractured and accumulates with fragmented feldspar as an insulating film of crushed rock or "mylonite" encasing relict feldspar lenses or "porphyroclasts". Such a rock is characterized by a faint foliation and ovoid shape of feldspars. Primary textures are still conspicuous.

Stage 2 -- Flaser Gneiss

With continued deformation, relict feldspar lenses become decidedly lenticular (Figure 56). Primary mica is reoriented along interlensing slip planes, and the rock becomes conspicuously foliated. New mica may begin to crystallize at this stage. The proportion of mylonite to surviving grains increases while relict feldspar lenses become thinned by ablation. Crenulation or microfolding or residual rock lenses is common at this stage. "tectonic xenoliths" or lenticular fragments of non-mylonitized rock are carried along in the flowing granular mass. Drag folds and pygmy folds show differential movement and turbulence. Most of the displacement becomes localized along thin, interlensing zones of slippage (Figure 59).

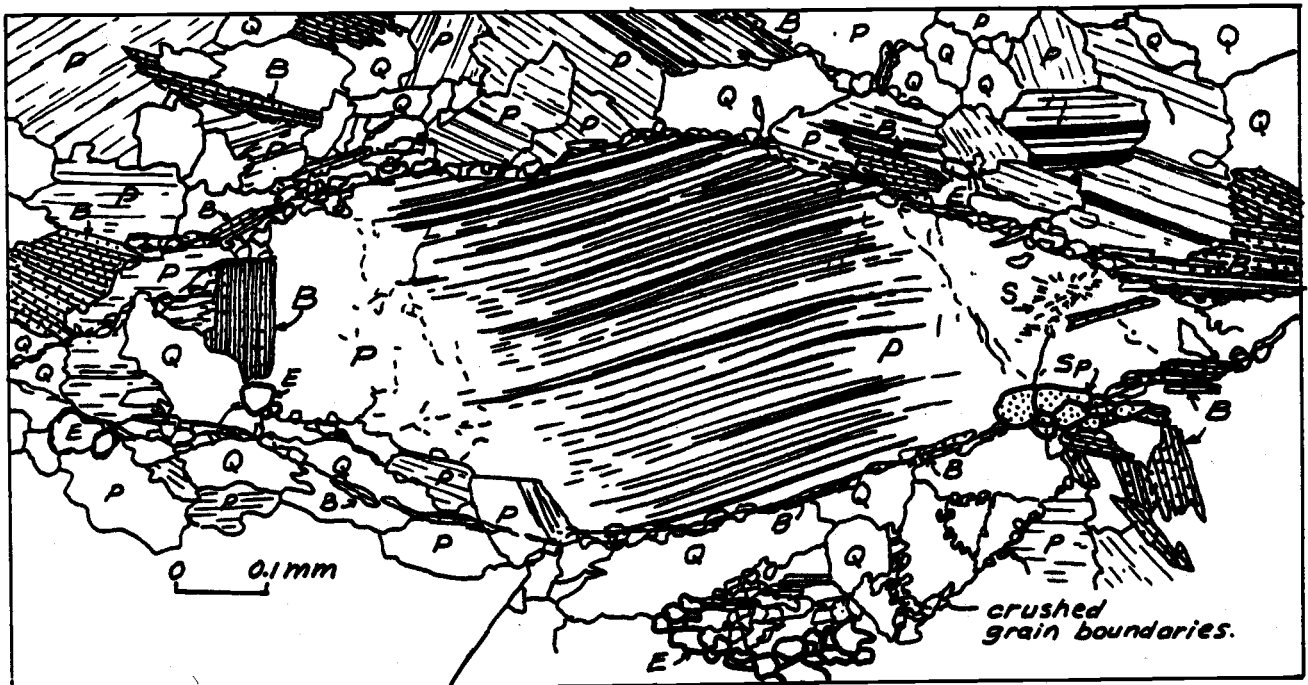


Figure 56 -- Biotite tonalite protomylonite from Hamilton Falls, Eau Claire Co. Ends of lenticulated plagioclase porphyroclast show no twinning. Note crushed grain boundaries. P=plagioclase, B=biotite, Q=quartz, E=epidote, Sp=sphene.

Stage 3 -- Ultramylonite

Reduction of relict rock and mineral lenses by ablation may ultimately result in a thinly laminated, flinty ultramylonite, or in crystallization of new feldspar. Relict feldspar lenses become mantled by new feldspar. Reversed zoning is common. The rock at this stage becomes a blastomylonite. The point at which feldspar regrowth begins varies even from one part of an outcrop to another.

Reaction rates accelerate with: (1) increased surface area in accumulating mylonite. (2) frictional heat and (3) pressure of mobilized water.

Anhedral form of the garnets and absence of deformation around them indicate their late-kinematic age. Fresh garnet is a relatively rare mineral in rocks of the Eau Claire region. Large, relict garnets at Big Falls are altered to hornblende. With rocks that have been deformed and metamorphosed at least three times, it becomes difficult to discriminate between surviving "relict" minerals and those produced during later metamorphism.

Foliation and compositional layering in rocks at Cornell strike N80°E to N80°W. These same structural elements at Fisher River 4 km northeast of here trend N40°-50°E, a factor taken to indicate a major flexure in the rocks north of Cornell.

LOCATION B -- GARNET AMPHIBOLITE AND SHEARED PEGMATITE

Laminated garnet amphibolite at Location B is representative of the "Cornell amphibolite" which crops out almost continuously for 4 km down the Chippewa River. The amphibolite could also be classed as a gneissic, mafic hornblende tonalite or hornblende gneiss. It is composed of subhedral to anhedral, lensoidal hornblende clusters (54%) with coarse, lensoidal porphyroclasts of twinned plagioclase (28%) and fine-grained quartz. The hornblende is strongly pleochroic (α = pale yellowish green; γ = dark bluish green). Banding in the amphibolite is cut by lenticular segments of granite and quartz veinlets. The nearly vertical banding is thinly interlensing in 3 dimensions, and strikes N80°E to N80°W. Small, isoclinal folds plunge at low angles in the plane of compositional banding. Garnets in the amphibolite tend to be randomly clustered and have ragged borders. No evidence of garnet porphyroblast rotation was seen. The distribution of garnet clusters shows little relation to banding or fold morphology. The garnets appear to have formed after most of the particulate flowage of the rocks, as evidenced by the good preservation of garnet crystal apophyses in the amphibolite.

Coarse, garnetiferous felsic flaser gneiss and sheared pegmatite are in contact with amphibolite in this outcrop. Granite commonly intrudes amphibolite at other locations (Jim Falls). Intrusive relations of most granite bodies in the area are obliterated by shear displacement and partial recrystallization. The occurrence of garnet in the flaser gneiss indicates that both rocks were metamorphosed after tectonic imbrication. An excellent example of sheared pegmatite and other coarse-grained granitic rocks can be seen just north of the east end of the Hwy. 64 bridge at Location B (Figure 58). Coarse, bent, lenticulated and fractured feldspar porphyroclasts are enclosed in a fine-grained matrix of quartz-feldspar-muscovite crush debris. Some flow folds can be seen in the mylonite in some of these rocks.

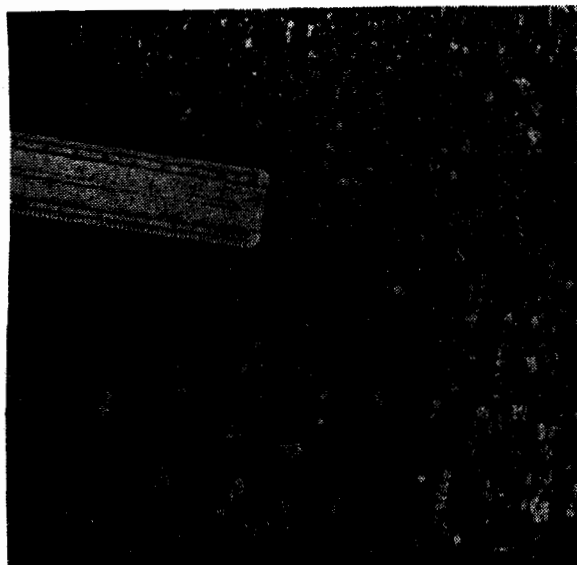


Figure 57 -- Garnetiferous biotite adamellite flaser gneiss (Location A)
Lensoidal feldspars are enclosed in a recrystallized, foliated matrix.

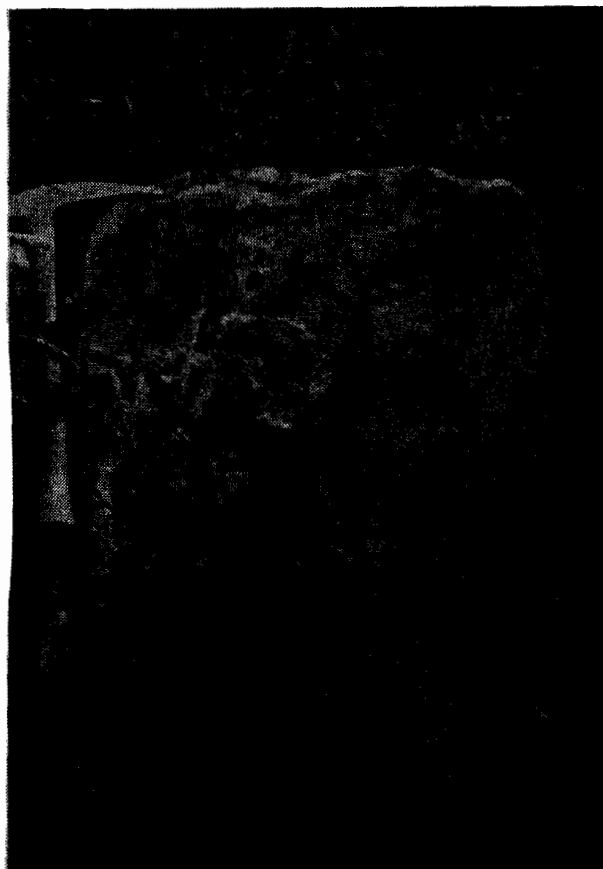
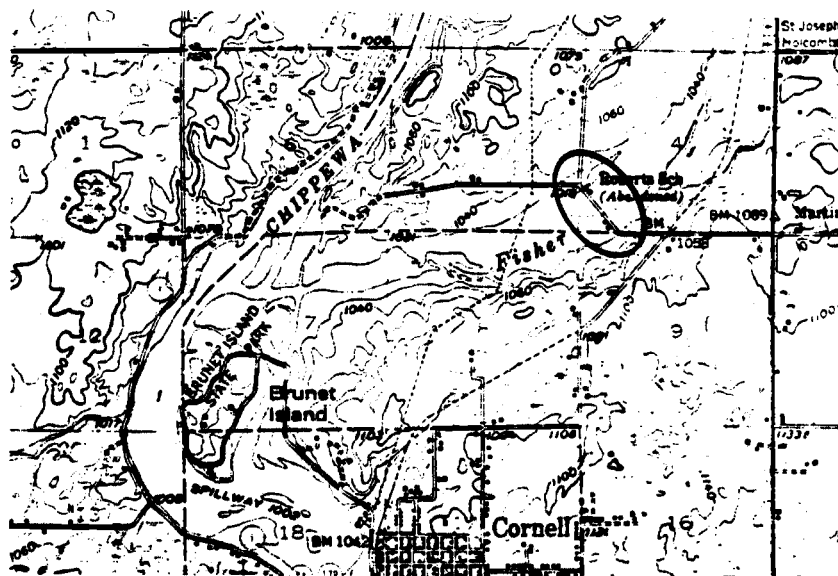


Figure 58 -- Sheared pegmatite (Location B near eastern bridge abutment)
Lensoids of coarse K-feldspar in matrix of crush debris.

STOP #13

TITLE: FISHER RIVER BRECCIA

LOCATION: NW¼. SW¼, Sec. 4, T31N, R6W, Chippewa County, Cornell 15' quadrangle



AUTHOR: P.E. Myers

DATE: February, 1980

SUMMARY OF FEATURES:

This unusual, heterolithic breccia contains clasts of rock types not seen elsewhere in the region, such as porphyritic gabbro, greenstone, metapyroxenite(?), andesitic tuff, and cataclastically laminated granitic rocks. The breccia is enclosed on the north and south sides by foliated trondhjemite and on the west by gneissic biotite-hornblende tonalite. The gneissic trondhjemite elsewhere in the area (Fisher River Bridge) contains abundant metadiorite and tonalite xenoliths which are elongated in the plane of foliation. It is tentatively proposed that the breccia unit, like the other xenoliths, is an inclusion in the gneissic trondhjemite, and that it was originally formed by faulting.

DESCRIPTION:

Reconnaissance along the scoured glacial meltwater channel of Fisher River (Figure 59) indicates that the area is underlain by gneissic tonalite and trondhjemite containing abundant xenolithic masses of metadiorite and tonalite. The breccia unit, which is apparently enclosed by foliated trondhjemite and tonalite, contains angular to subrounded, non-sorted clasts of ultramafic rock (metapyroxenite?), massive and porphyritic hornblende gabbros, hornblende biotite tonalite, greenstone, andesite tuff, and massive and cataclastically laminated granitic rocks - probably trondhjemite and adamellite (quartz monzonite).

The dominant mineralogy of these rocks, including those in the breccia, is plagioclase (An₂₀₋₅₅), quartz, hornblende, biotite, and K-feldspar. Accessory epidote, chlorite, magnetite and/or pyrite are ubiquitous.

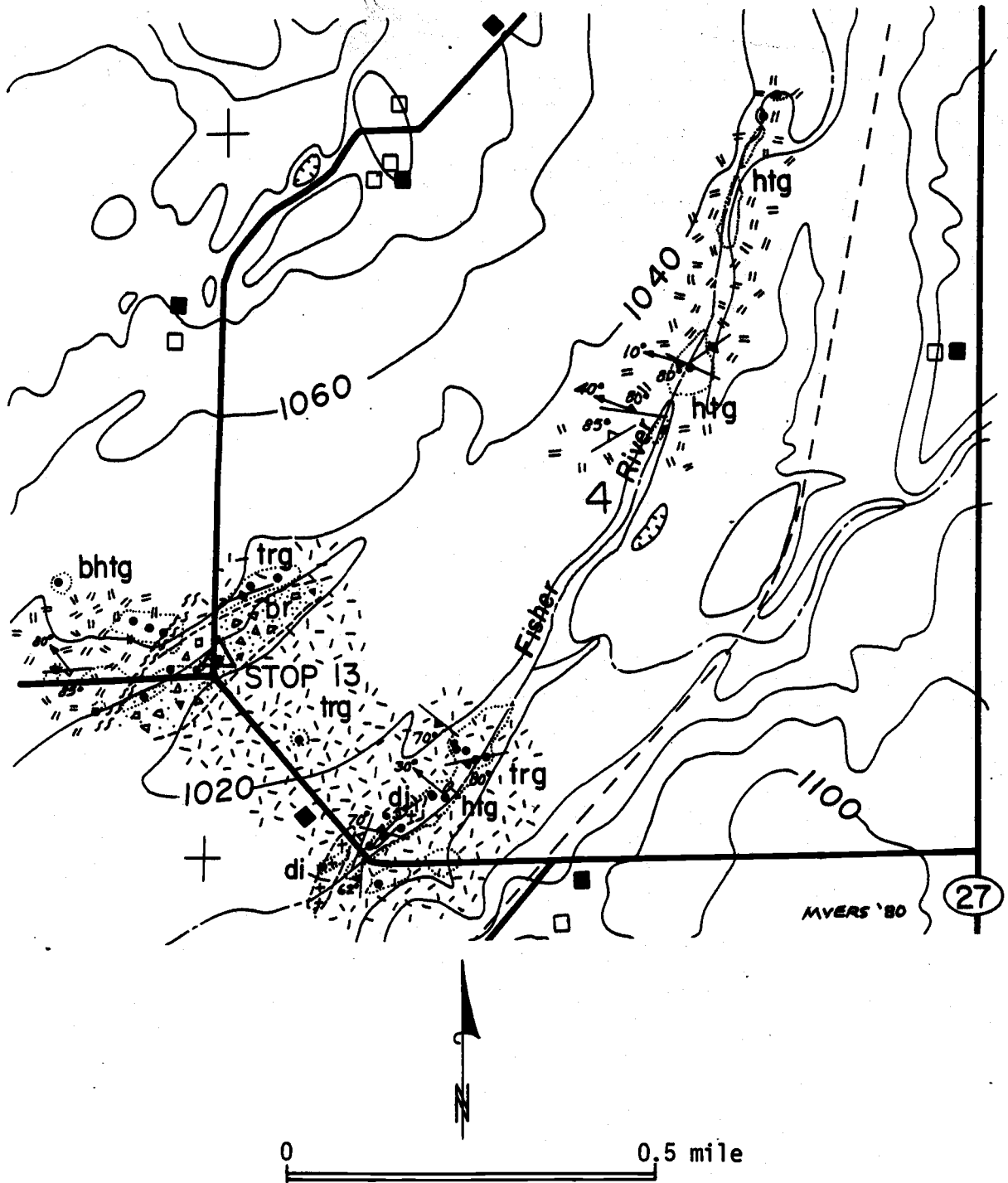


Figure 59 -- Geologic map of the Fisher River area. htg = hornblende tonalite gneiss; bhtg = biotite-hornblende tonalite gneiss; trg = trondhjemite gneiss; di = diorite; br = breccia. Note fairly gentle northwest plunge of lineation in the tonalite gneiss.

Characteristics of the Breccia:

The breccia is composed of angular to subrounded, non-sorted clasts of chloritized ultramafic rocks, massive and laminated gabbros, tonalites, and granitic rocks, greenstones, and crystal tuffs. The fine to medium grained matrix is composed essentially of plagioclase, quartz, and biotite. Chlorite seams cut through the breccia fragments and matrix at high angles. Epidote occurs as joint coatings and as a partial replacement of mafic minerals in the breccia. Clast size ranges from 1 - 20 cm with an average of about 4 cm. The fragments show a subtle preferred orientation (Figure 60), which here is about N50°E, vertical. The clasts show no post-depositional rounding or fragmentation, as would be expected in a fault breccia. Chalcopyrite occurs in the matrix.

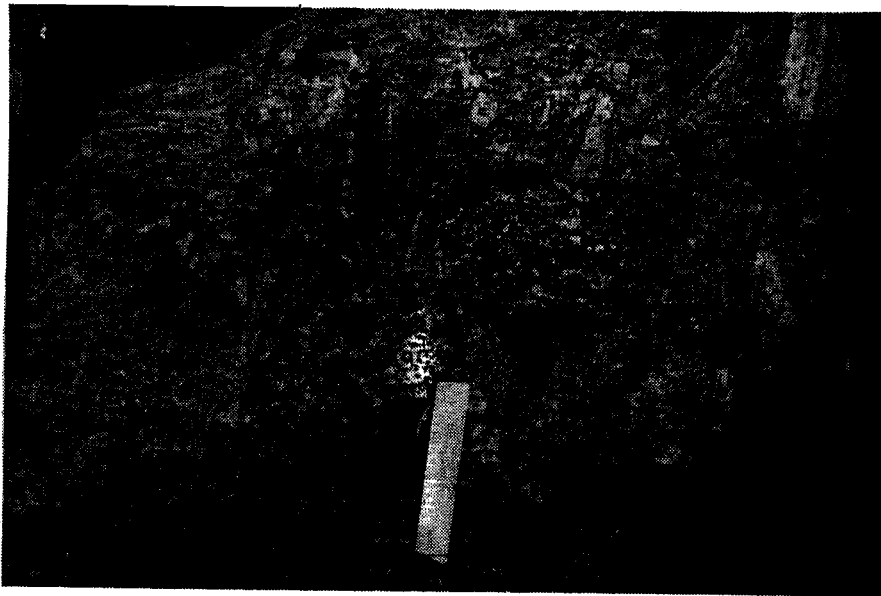


Figure 60-- Photograph of the Fisher River breccia at this location. Note wide variety of clast lithology the relatively high clast/matrix ratio, and the crude near-vertical orientation of clasts.

Chronology of the Fisher River Area:

A chronology can be synthesized from field observations in the Fisher River area. Compare with Table 7.

- *1. Intrusion of mafic hornblende gabbro and diorite
 - *2. Intrusion of adamellite and trondhjemitic
 3. Shearing and cataclasis, probably accompanied by regional metamorphism
 - *4. Extrusion of basalt and andesite(?) tuff
 5. Intrusion of mafic hornblende-biotite tonalite
 6. Faulting and brecciation - formation of the Fisher River breccia
 7. Intrusion of leucotondhjemitic
 8. Cataclasis, metamorphism, lenticulation of pegmatites, mylonite "veinlets" with right-lateral displacement
 9. Intrusion of tonalite and diabase dikes (Late Precambrian)
- *Position in sequence not known. Inferred on the basis of breccia clast lithology and structures.

Although no trondhjemite dikes were seen to cut the breccia, the trondhjemite is in contact with the breccia along its north and south sides. The trend of the breccia unit is N55°E; its dip is unknown. At several locations along the Fisher River (south of here), the gneissic leucotondhjemite contains abundant schistose mafic inclusions and large xenoliths of metadiorite. The xenoliths are elongated in the plane of foliation. It is therefore tentatively concluded that the breccia unit itself is a large lensoidal xenolith in the gneissic leucotondhjemite.

The leucotondhjemite here closely resembles that at Wissota Dam. As at that locality, the trondhjemite is cut by gray tonalite dikes.

Mode of Formation of the Fisher River Breccia - Possibilities, Evaluations:

1. Pyroclastic Breccia: Fisher River breccia (FRB) contains mainly metamorphic and plutonic clasts. The matrix, now recrystallized, might be a metatuff.
2. Intrusion Breccia: Matrix is not discernably a plutonic igneous rock; matrix lacks flow fabric around clasts;
3. Tillite: Clasts in FRB are too angular; do not show evidence of transport.
4. Fault Breccia: Recrystallized matrix does not contain relict fault gouge texture. The absence of post-depositional fragmentation makes the fault breccia hypothesis a bit shaky.
5. Talus Breccia: The lithologic heterogeneity, angularity of clasts, favor this interpretation. The likelihood for preservation of a Precambrian surficial feature is not great, however.

What are some other possibilities? How could the mystery be solved?

TITLE: STRUCTURES IN QUARTZ DIORITE, GRANITIC INTRUSIVES AND META-ANDESITE AT HOLCOMBE DAM.

LOCATION: Holcombe Dam, SW 1/4 Sec. 28, T32N, R6W, Chippewa County, Cornell 15" quadrangle.

AUTHOR: Stephanie R. Wurdinger, University of Minnesota, Duluth

DATE: February, 1980

SUMMARY OF FEATURES:

Synkinematic quartz diorite was metamorphosed to the lower amphibolite facies during F_1 folding. Granitic intrusives and dikes, and a hypabyssal andesite were intruded during F_2 folding of the quartz diorite. These rocks were later converted to schist along a shear zone exposed along the Chippewa River. A system of N50W faults with a dominantly right lateral strike offset later segmented all rock units. The major fold deformations, and thus the rock units at Holcombe Dam, are believed to be Penokean in age.

DESCRIPTION:

In order of decreasing age, the rock units of the Holcombe area are: banded gneiss at the Fisher River, quartz diorite at Holcombe Dam, and amphibolite schist along the Chippewa River (Figure 61).

Gneissic quartz diorite and associated meta-igneous rocks crop out below Holcombe Dam. In order of decreasing age, the latter are: Ultramafic and spotted mafic xenoliths in the quartz diorite, quartz diorite gneiss, granite and associated granite dikes, and meta-andesite (Figure 62). These units were converted to schist along shear zones which cross the outcrop.

The quartz diorite contains two types of inclusions: hornblende rich ultramafic inclusions, and spotted mafic inclusions. Ultramafic inclusions occur along the northwest portion of the exposed quartz diorite. These are generally less than 0.5 meters in length, although one is at least 2 meters long. Ultramafic inclusions are composed of 75-85% hornblende and 11-13% biotite with a small amount of plagioclase. Chlorite occurs as an alteration product of biotite and less commonly of hornblende, and can compose more than 20% of the rock.

Spotted mafic inclusions occur along the southeast section of the exposed quartz diorite. They range from a few centimeters to more than 6 meters in length. The same rock type occurs as dikes in the banded gneiss at the Fisher River. Spotted mafic xenoliths are composed of hornblende clots to 3 mm in size in a fine-grained matrix of plagioclase and hornblende. A few hornblende clots are pseudomorphs after pyroxene. The spotted inclusions are commonly surrounded by white rinds of plagioclase and quartz, probably due to the preferential nucleation of plagioclase on the inclusions during intrusion of the quartz diorite.

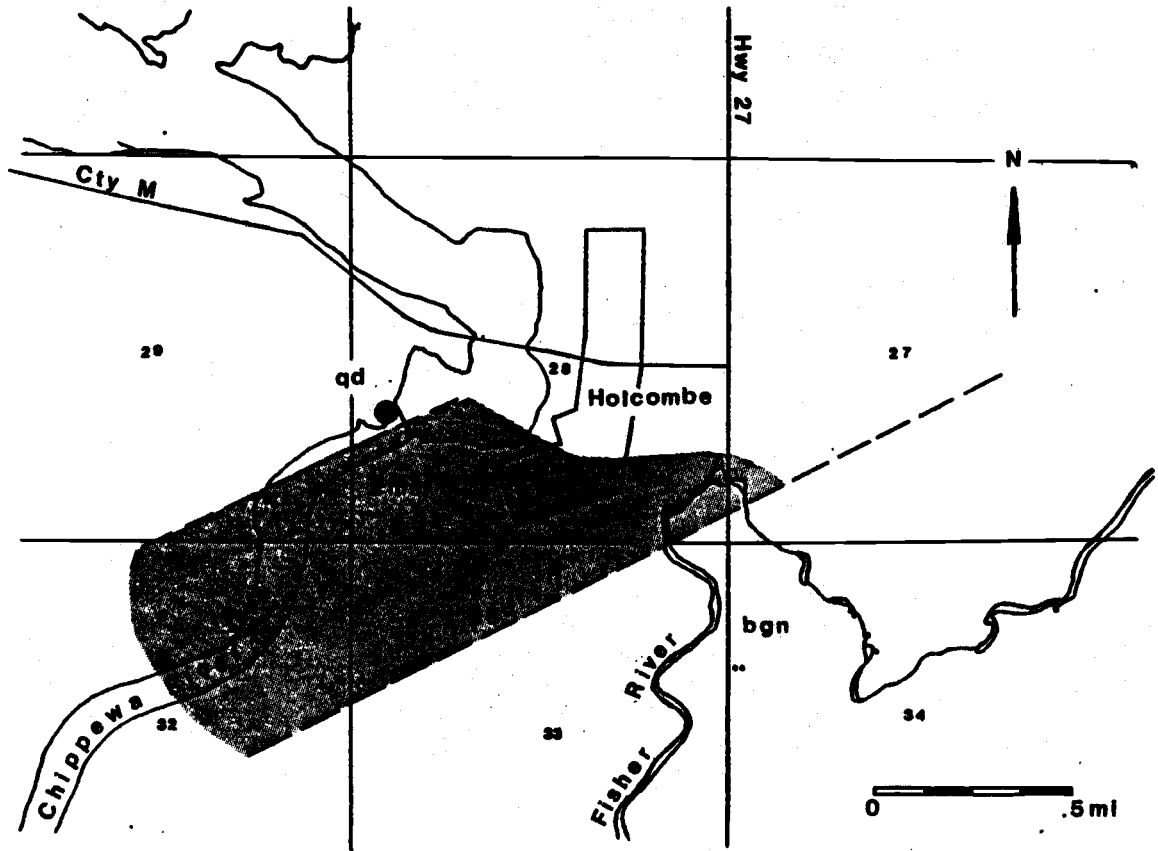


Figure 61-- Geologic map of Holcombe area. bgn = banded gneiss, qd = quartz diorite, ams = amphibolite schist.

The quartz diorite is a medium-grained, dark to medium grey rock with rusty weathering surfaces. It is faintly foliated and has white discontinuous bands and lenticles which are more quartz rich than the rest of the rock. Quartz diorite is composed of plagioclase (32-51%), quartz (11-31%) and mafic minerals (12-33%). Mafic minerals range from entirely hornblende to entirely biotite.

The quartz diorite is cut by medium-grained granite pods with migmatitic contacts and by finer-grained dikes with sharp contacts. The granite is a pink, faintly foliated rock which locally contains porphyritic microcline grains reaching 1 cm in size. Granitic rocks consist of plagioclase, microcline and quartz, with minor amounts of biotite, muscovite and epidote.

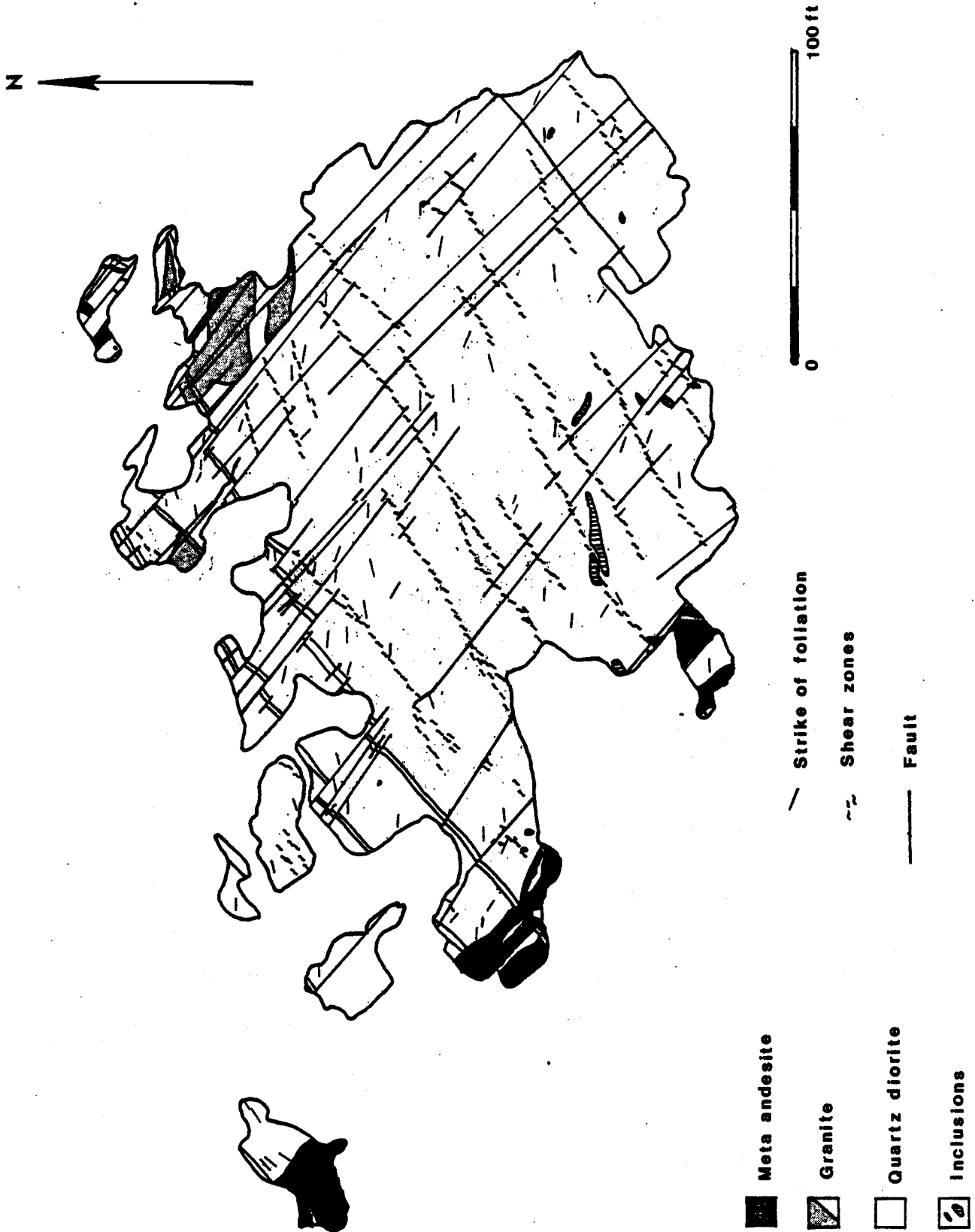


Figure 62 -- Outcrop map of quartz diorite gneiss at Holcombe Dam. Granite dikes are unpatterned, and trend northeast across the top of the outcrop in this figure.

The youngest intrusive unit at Holcombe Dam, a hypabyssal andesite, intrudes the quartz diorite and granite dikes with sharp, steeply dipping contacts. It consists of about 10% lineated hornblende grains in a fine-grained pale gray matrix. Where the andesite cuts the granite dikes, it contains numerous pale green veins of epidote.

Shear zones which cut the quartz diorite gneiss are long, narrow, sinuous zones of schist, containing pods of quartz and pyrite or of quartz and feldspar. The shear zones are a few millimeters to 1.5 meters wide and a few centimeters to 60 meters long. They cut both the quartz diorite gneiss and the andesite. Schistose rocks in the shear zones are thoroughly recrystallized and display no cataclastic textures. A shear zone at the northwest corner of the outcrop is cataclastic and may have formed during the late stages of shear deformation. Large, unsheared lenses in the shear zone give the appearance of having undergone spheroidal weathering.

The three intrusive rock units at Holcombe Dam all contain relict igneous subhedral and euhedral feldspars, and all have metamorphically induced fabrics, imparted dominantly by the mafic minerals. All of the above mentioned rock units have partially to thoroughly recrystallized in the lower amphibolite facies.

Late hydrothermal alteration occurred along fracture systems to a width of a few centimeters. In altered zones, plagioclase is altered to sericite or saussurite, and biotite is converted to chlorite. Quartz is partially replaced by albite and/or calcite, and hornblende has overgrowths of pale actinolite. This type of hydrothermal alteration could be produced by hydrogen metasomatism along with the introduction of Na_2O and CO_2 .

STRUCTURAL GEOLOGY:

A summary of deformations which affected rocks in the Holcombe area is presented in Table 11. The only rock showing all the fold deformations is the banded gneiss at the Fisher River.

F_1 folding produced a dominantly east-west foliation, S_1 . The quartz diorite at Holcombe Dam shows an east-west foliation, but there are no F_1 folds. This suggests intrusion of the quartz diorite during the F_1 event.

S_1 foliation in the quartz diorite gneiss was folded during F_2 folding. F_2 folds are tight to isoclinal folds in foliation, compositional layering and in felsic veins. F_2 folding occurred at a low, oblique angle to F_1 fold trends and produced moderate to steep ($60-80^\circ$) westerly plunging lineations. Granite intrusives and the hypabyssal andesite display east-northeast foliations and steep to moderate lineations, suggesting that they were intruded during the F_2 event.

During F_3 folding, foliation and fold axial planes in the gneissic rocks at Holcombe were broadly warped along a steeply dipping north-south axis. At Holcombe Dam, the axial planes of F_2 folds, and metasomatic bands of granite were affected by the F_3 event.

TABLE 11

		Banded Gneiss-Fisher River	Quartz Diorite Gneiss-Holcombe Dam	Amphibolite Schist-Chippewa River
D ₁	F ₁	Isoclinal folds		
	S ₁	Penetrative foliation and lithologic layering trending E-W	Penetrative foliation trending E-W	
	L ₁	Penetrative fold axis and mineral lineations		
D ₂	F ₂	Tight to isoclinal folds, folding F ₁ , S ₁ , and L ₁	Tight to isoclinal folds folding S ₁	
	L ₂		Penetrative lineations in granite and andesite	
D ₃	F ₃	Broad warping along N-S trend	Broad warping along N-S trend	
D ₄	F ₄			Folding of S ₄ and shearing form rootless folds
	S ₄		Shear zones cross-cut all rock units at N70E. Late cataclastic shearing.	Schistosity and Compositional layering, N70E
	L ₄		Penetrative lineation at about 40° SW	Penetrative lineation at about 40° SW
		Faulting along discrete planes at N50W and N20W	Faulting along discrete planes at N50W and N20W	Faulting along discrete planes at N50W and N20W
				Late faulting along S ₄ planes at N70E

An extensive period of shearing affected the quartz diorite gneiss and intrusives. A series of small shear zones formed in the gneiss, coincident with the formation of the amphibolite schist along the Chippewa River. The amphibolite schist displays all the same structural characteristics as the smaller shear zones in the quartz diorite gneiss. For this reason, the amphibolite schist is interpreted to represent a major shear zone which crosscuts the area. Shear zones in the area trend N70E and have lineations which average 40° SW. A linear negative aeromagnetic anomaly which trends N70E across the area is probably a result of this major shear zone.

The final phases of deformation produced brittle faulting throughout the area. Faults trending N50W offsets all other structural features in the area (Figure 63). These faults display both right and left lateral strike separation, although right lateral offset is dominant.

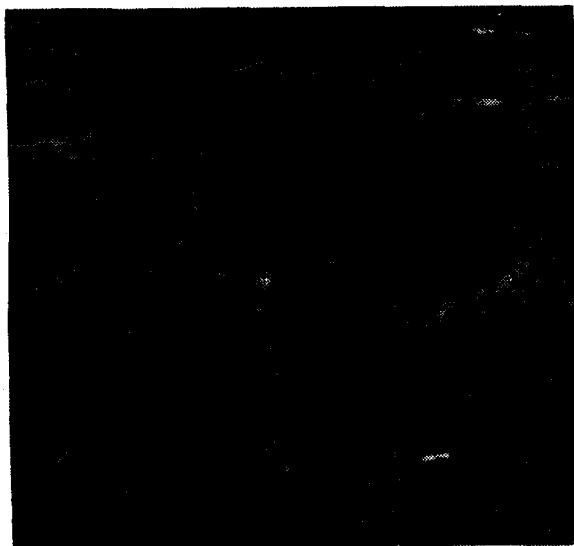
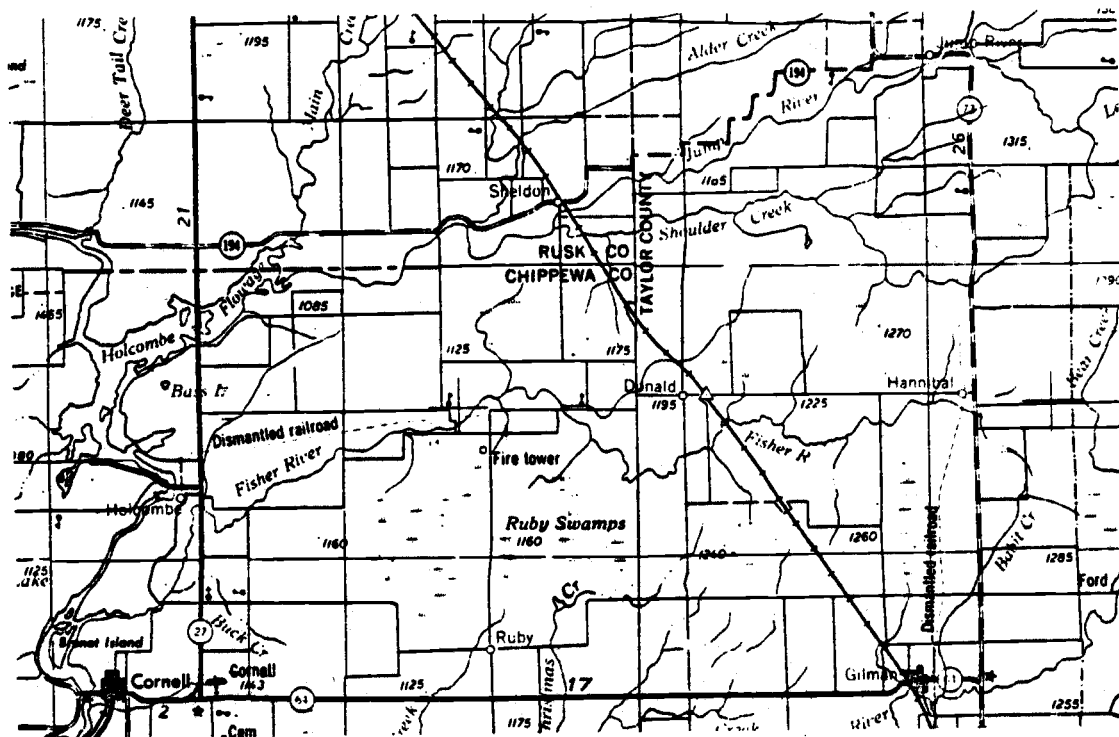


Figure 63 -- NW-trending fault offsets of granitic dikes. Dike in foreground is about 2 feet wide.

TITLE: PRELIMINARY REPORT ON THE GEOLOGY OF THE JUMP RIVER VALLEY

LOCATION: Jump River valley from Big Falls County Park in Price County to the east end of Holcombe Flowage in northeastern Chippewa County.



AUTHOR: M.L. Cummings

DATE: March, 1980

SUMMARY OF FEATURES:

Intermediate to basic flows and fragmental volcanic rocks crop out along the Jump River and its tributary valleys. Coarse volcanic blocks and a plagioclase porphyritic felsite flow are associated with a volcanic center east of the village of Jump River. Several granitic plutons appear to form an intrusive belt immediately south of the Jump River. One of the plutons is tonalitic in composition and was emplaced before deformation but the granitic plutons are late or post kinematic.

INTRODUCTION:

Geologic mapping along the Jump River and tributary streams in southwest Price, southeast Rusk and northeast Chippewa Counties was completed in the summer of 1979. The mapped area extends from 3 miles east of Big Falls County Park in Price County, west, to Holcombe Flowage in northeastern Chippewa County. Searches for outcrops were carried out on the North and South Forks of the Jump River, Levitt Creek, Shoulder Creek and Main Creek; all tributaries of the Jump River. Localized searches for outcrops were carried out on the Little Jump River and the upper reaches of the North Fork of the Jump River and Main

Creek. The search for outcrops centered on streams that have head-waters north of Highway 8 since these streams served as major channels for melt-water during deglaciation of the area (personal communication, Adam Cahow, 1979) and thus were more probably scoured to bedrock than other streams in the area.

This report is based primarily on field relations and hand sample descriptions. Thin section studies have been completed on some samples but are not available for all samples. Further thin section study, chemical analyses and structural analysis are presently underway.

PREVIOUS WORK:

The geology of the Jump River valley has been reported only briefly in the literature. The area northwest of the study area was included in a map for a discussion of the Flambeau Copper Deposit at Ladysmith (May, 1977) but the discussion of the rock units was limited to the regional geology section of the paper. A field trip stop description was included in the guidebook for the 1979 meeting of the Institute on Lake Superior Geology by LaBerge (1979) for Big Falls County Park at the eastern end of the present study area. Wurdinger (1979, 1980) and Myers, (1974, 1980) have mapped southwest of the study area along the Chippewa River Valley.

ROCK UNITS:

The volcanic rocks along the Jump River have been tentatively divided into 1) mafic to intermediate flows and 2) basic to intermediate fragmental volcanics (Figure 64).

Two areas of mafic and intermediate flows have been identified. The first underlies the area of the Jump River Valley west of the confluence of the North and South Forks of the Jump River to $4\frac{1}{2}$ miles east of the village of Jump River. The second area lies southeast of the village of Sheldon along Shoulder Creek and west along the Jump River for 2 miles.

The fragmental volcanic rocks crop out along the South Fork of the Jump River near Big Falls County Park in Price County and from $4\frac{1}{2}$ miles east of the village of Jump River to approximately 3 miles east of the village of Sheldon. A coarse fragmental unit occurs immediately east of the village of Jump River and appears to represent an explosive volcanic center.

Since the Jump River flows approximately parallel to the strike of lithologic units, the stratigraphic thickness exposed along the river is not great. It would appear that for the area east of Sheldon the fragmental volcanic units are underlain by basic flows. The fragmental volcanic units may extend west of Sheldon as fine-grained crystal tuffs that are overlain by intermediate flows however a possible fault east of Sheldon provides some ambiguity to this interpretation. In general, it appears that basaltic flows are overlain by intermediate to mafic fragmental volcanic rocks that were deposited from a volcanic center in the area east of the village of Jump River and this in turn was buried by intermediate flows. Top indicators in the fragmental units indicate that the stratigraphic section is overturned with tops facing south. Thus the proposed stratigraphic sequence is southward younging sequence.

The basic volcanics at the proposed lowest stratigraphic level of the exposed volcanic pile are massive with locally developed amygdaloidal zones. The flows

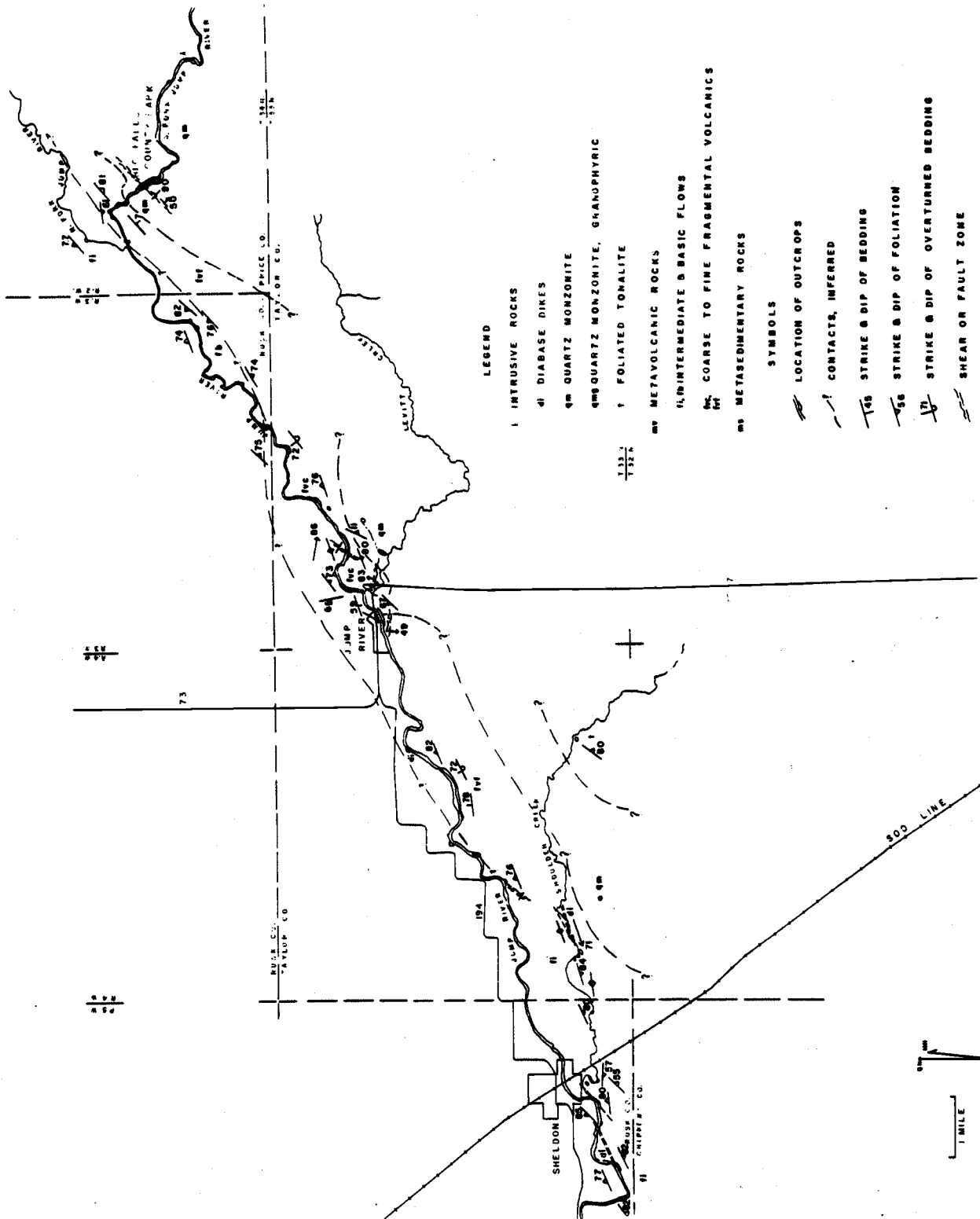


Figure 64 -- Geologic Map of the Jump River area.

are fine-grained and weakly schistose but locally a well developed schistosity is found to coincide with late shear zones. The mineralogy of the units includes actinolitic-hornblende, plagioclase, epidote and locally chlorite.

Overlying the basaltic flows are fragmental intermediate to basic volcanics. The units include crystal and crystal-lithic tuffs and lapilli-sized to block-sized fragmental units. The coarsest fragment sizes occur from immediately east of the village of Jump River (Stop 16) to 2 miles up river. Apparently this area is near an irruptive center since lithic blocks to 1 foot in diameter are found locally. The size of lithic fragments decreases and the ratio of crystal fragments to lithic fragments increases away from the volcanic center. Fine-grained bedded tuffs and ash beds occur interbedded with coarse fragmental beds in the area of the volcanic center. Coarse clasts of volcanic debris apparently fell into the accumulating fine grained materials allowing determination of the stratigraphic top for the volcanic pile. Such top indicators have been found in the area of the coarsest fragmental rocks and in crystal-lithic tuffs away from the volcanic center. In each case the top of the volcanic pile is south facing and is overturned. Sulfide mineralization up to 10 volume percent (estimated in hand sample) is particularly common in the fragmental units, locally defining sulfide-rich beds. A porphyritic felsic flow also occurs in the area of the volcanic center along with intermediate flows. The felsic flow contains plagioclase phenocrysts in a fine-grained matrix and may be flow banded (Stop 17). The felsic flow is the only felsic unit found in the study area.

The volcanic center may represent a collapsed submarine caldera complex in which the coarse fragmental units represent part of the rims of the caldera. The center of the caldera was filled by intermediate flows and intermediate to felsic fragmental rocks. The felsic rocks in the area may represent a rhyolitic dome developed during caldera resurgence producing the dome and supplying felsic pyroclastic material to the caldera complex.

The area south of Sheldon on Shoulder Creek is underlain by an intermediate prominently porphyritic flow unit that apparently overlies the fragmental unit. West of Sheldon and apparently stratigraphically underlying the flow unit are fine grained intermediate crystal tuffs that may be the westward extension of the crystal and crystal-lithic tuffs found to the east. A fault occurs east of Sheldon and may have displaced units in the area but the nature and extent of movement on the fault is not known. Locally along Shoulder Creek intermediate to felsic tuffs appear to be interlayered with the intermediate flows (Stop 15) suggesting coeval eruption of flows and pyroclastics.

Throughout the volcanic sequence of strike of bedding in fragmental units and contacts between units ranges from N50E to N75E. The strike of units in the area of the volcanic center are more irregular.

INTRUSIVE UNITS:

The intrusives (Figure 64) in the Jump River Valley are poorly exposed and are represented by small outcrops, in cases only one outcrop is known for a pluton. The most extensively exposed intrusive crops out at, and to the east of, Big Falls County Park in Price County. A second occurs southeast of the village of Jump River and is best exposed on a tributary of Levitt Creek. The

same pluton intrudes volcanic units at the wayside park in Jump River. A third intrusive is known by only 2 or 3 small outcrops in a wooded area about $\frac{1}{2}$ mile south of Shoulder Creek along County highway H. A fourth intrusive crops out along Main Creek north of the Jump River. The intrusives are granitic and have variable mineralogies and textures. A fifth pluton is exposed in low outcrops south of the Jump River on Shoulder Creek. The intrusive is tonalitic. Unmetamorphosed basalt dikes crop out in the area and generally strike N70E.

The pluton at Big Falls County Park is a massive pink quartz monzonite cut by minor aplitic and pegmatitic dikes. The intrusive has also been described by LaBerge (1979). The pluton contains subhedral grains of plagioclase, anhedral orthoclase, quartz and biotite. The plagioclase grains contain subhedral epidote; chlorite is interlayered with biotite suggesting that the pluton has been metamorphosed. Locally the rock has a weak foliation but in general metamorphic fabric is weakly developed. A well developed shear zone cuts the intrusive in the park area (will be discussed below). One mile west of the park the quartz monzonite is in intrusive contact with the volcanic rocks and contact metamorphic effects are observed in the volcanics.

The pluton exposed along Levitt Creek appears to be more granitic in composition. Thin sections of the unit indicate k-feldspar greater than plagioclase. The plagioclase occurs as small grains in the k-feldspar. Muscovite occurs interstitially to feldspars and quartz and appears to be of igneous origin. Fine sericite replaces k-feldspar near sericitic microshears. Chloritized biotite is prominent in the microshears and to a lesser extent in the fresh rock. Hand samples of the intrusive in areas that indicate little deformation contain more biotite.

The pluton south of Shoulder Creek has not been studied in thin section at this time. The granitic intrusive contains small xenoliths of volcanic rocks. A fabric due to metamorphism is not present or is weakly developed. Outcrops are small and difficult to find.

The pluton exposed along Main Creek is a quartz monzonite characterized by granophyric intergrowths developed on subhedral plagioclase grains. The feldspars are red colored due to fine hematite inclusions and alteration of the pluton is locally intense. Epidote is a common alteration mineral. Outcrops of volcanic rocks are known within a mile both southeast and northwest of the intrusive outcrops on Main Creek.

The tonalitic intrusive is not only unique in its composition but also in its strong foliated fabric. Outcrops are low, flat and smooth and have been found in only one area along Shoulder Creek. Hand samples indicate biotite and plagioclase are the main minerals while quartz is apparently minor. Thin section study has not been initiated. The intrusive is clearly pre-kinematic. Contacts with other intrusive rocks have not been found and so the relation of the tonalite and quartz monzonite intrusives in the area is not known but textural relations and the differences in foliation suggests that the tonalite intrusive is earlier than the quartz monzonite intrusives.

STRUCTURAL FEATURES:

The structural elements of the area are both continuous and discontinuous. The main continuous structural element is schistosity. Commonly schistosity is found to be parallel to compositional banding, contacts and bedding in the volcanics. The schistosity in the tonalitic intrusive discussed above is sub-parallel to the schistosity in the volcanics. Schistosity is locally influenced by faults and younger shear zones and also appears to be warped by large open folds.

The schistosity associated with discontinuous structural elements cross-cuts earlier schistosity and is often related to local shear zones and/or faults. Important fault zones have been identified in 3 areas, 1) Big Falls County Park, 2) east of the village of Jump River, and 3) east of Sheldon. In each case the fault zone is associated with strong disruption of earlier formed textures and fabrics.

At Big Falls the fault has produced a significant zone of mylonite which has subsequently been recrystallized. The best exposed development of the mylonite is on the south side of the river in a nearly continuous group of outcrops. In the outcrops the progressive development from unsheared quartz monzonite to mylonite to unsheared quartz monzonite occurs in a distance of about 500 feet. The quartz monzonite on either side of the fault appears to be the same rock unit.

The fault east of the village of Jump River is spectacularly exposed in the south bank of the river. The volcanics are intensely folded locally and a possible large drag fold occurs in the volcanic tuffs at the site. The fault area is also the site of an old copper mine. The geology of the fault zone is not clearly understood and will be investigated in thin sections and by analysis of structural data from the site.

The fault that occurs south of Sheldon is poorly exposed in the bed of the Jump River. Small outcrops in the middle of the river are strongly deformed and considerable alteration occurs in the volcanic along the shore but the fault itself is not exposed above water even during periods of low stream flow.

The sense of displacement or magnitude of displacement for the three major north to northeast trending fault structures are not known. However, in all cases the faults do not form boundaries between different lithologic units or are characterized by a change in metamorphic grade across the fault zone.

DISCUSSION:

The following discussion is based on field work and limited thin section and chemical study and is therefore preliminary in nature and subject to revision. The intent is to stimulate discussion on the problems raised so as to improve interpretation of the geology of the Jump River Valley.

The geologic evolution of the Jump River valley must be viewed in terms of the location and nature of the boundary between the Chippewa amphibolite

complex to the south and the Flambeau volcani-sedimentary province to the north of the Jump River. The boundary was originally placed at the Jump River by Myers (1974) based on the location of gravity and aeromagnetic anomalies in the area, however the nature of the boundary was not defined. Part of the intent of the present study was to investigate the field evidence that might shed light on the nature of the Jump River lineament (Myers, 1974) and to attempt to define the nature of the boundary between the two major geologic provinces in the west-central part of Wisconsin.

LaBerge (1979) pointed out that the lineament is expressed topographically, in Bouguer anomaly patterns (Ervin and Hammer, 1974) and on aeromagnetic maps (Zietz, Karl, and Ostrom, 1978). The lineament has commonly been assumed to be produced by a major fault zone (Cummings, 1975) and recently the Jump River Fault has appeared in reports (Sims, Cannon, Mudrey, 1978).

From field relations the Jump River lineament may be shown to result from contrasting geophysical characteristics of lithologies and the glacial history of the area. The topographic expression of the lineament is evident in stream patterns in the area and by the valley of the Jump River. In the field the course of the Jump River can be shown to be controlled by bedding in the volcanic rocks along the river banks. The strong alignment of stream valleys in a northeast-southwest direction is closely related to the glacial history of the area (Cahow, personal communication, 1979). The Jump River and local streams served as major flood channels for melt water during deglaciation of the area in the process carving large valleys and scouring to bedrock in many places. The valley of the Jump River is clearly larger than the river that flows in the valley. Thus it would appear that the topographic expression of the lineament may not be controlled by a major tectonic boundary but by the influences exerted by glacial run-off and bedding structures in the volcanic rocks of the present valley. The Bouguer anomaly map for the area shows a distinct change in the gravity of the area across the Jump River Valley. The gravity change may be due to the contrasting densities of volcanic rocks north of the river and the belt of granitic plutons south of the river. It must be emphasized that the granitic rocks can be shown to be intrusive into the volcanic rocks and are not in fault contact with the volcanics. The aeromagnetic anomaly for the area can also be explained by contrasts between sulfide-bearing tuffs and sulfide-free granitic rocks. The northeast strike of volcanic units and the northeast trends of basalt dikes in the volcanic rocks would expectedly produce some type of magnetic contrast to granitic rocks south of the river. The Jump River lineament can thusly be explained by the geologic features in the rocks and does not necessarily require a major tectonic boundary along the Jump River to explain the observed geophysical and topographic features of the lineament.

The Jump River Fault Zone (Sims, Cannon and Mudrey, 1978) has also been placed in the general study area, however the presence of a major fault zone of significant displacement does not appear to be supported by field evidence. It may be argued that the plutonic rocks south of the Jump River were intruded along such a fault zone, this would require the fault to be Middle Precambrian in age since the plutons along the Jump River are probably related to the plutonic phase of the Penokean Orogeny. The development of a fault after emplacement of the plutons is questionable since the plutons can clearly be shown intrusive into the volcanics suggesting little post intrusive displacement along the zone.

An alternate hypothesis to explain the geologic history of the area is that the Jump River Valley does not represent a major tectonic boundary but represents normal plutonic activity during deformation of the volcanic rocks in the Penokean Orogeny. The plutonic rocks may be interpreted as forming a roughly linear belt of intrusives that is sub-parallel to the bedding and possible fold structures in the volcanic rocks. The development of schistosity parallel to bedding in the volcanics can be interpreted as suggesting north-easterly trending major fold structures in the area if the schistosity is axial planar to the folds. Thus the emplacement of plutons may have been guided by the fold crests and troughs that had already developed in the volcanics. Tonalitic intrusives were emplaced prior to deformation and the same orientation of schistosity was imposed on the tonalite as on the volcanics.

In an attempt to further resolve the disputes over the significance of the geology of the Jump River Valley a reconnaissance survey was undertaken in the Gilman area along the Yellow River (Figure 64). The area contains metavolcanic rocks that were metamorphosed under amphibolite facies conditions but some primary volcanic structures are preserved. The local metamorphic grade may have been influenced by intrusion of intermediate and gabbroic intrusives that have well developed schistosity. Basalt dikes are unmetamorphosed and trend northeasterly. Since the volcanic rocks still preserve primary textures they are more similar to the volcanic rocks along the Jump River than the amphibolites exposed along the Chippewa River at Jim Falls or the gneisses at Holcombe Dam or Cornell. The similarity of the volcanic rocks to those exposed in the Jump River Valley would argue against a major fault zone or tectonic boundary existing between the Yellow River and the Jump River. The greater incidence of plutonic rocks along the Yellow River may reflect proximity to the core of the Penokean Orogenic belt rather than a different geologic province. Some of the questions about the relation of the volcanic rocks in the Yellow and Jump River Valleys will hopefully be resolved by major and minor element chemistry presently being prepared. The possibility of finding outcrop areas between the two river valleys is dampened by the expanse of swamps and apparently thick glacial drift that lies between.

SUMMARY:

In summary, several difficult and perplexing questions have been raised about the nature of the boundary between the Chippewa Amphibolite complex and the Flabeau volcani-sedimentary province by field studies in the Jump River Valley. At present the available mapping, chemical and petrologic data are not able to provide definitive answers. As further study of materials collected from the area continues, new light may be shed on the issues. However, on the basis of present information, a Jump River lineament may be reasonably accepted as marking the differences in geophysical properties of volcanic and plutonic rocks but not as a major tectonic break. The evidence in the field does not appear to support a major Jump River Fault in the area.

ACKNOWLEDGEMENTS:

This study was funded by research grant number 102-155 from the University of Wisconsin - Eau Claire. V. Lueth, R. Weegman, and C. Lutzewitz assisted in field mapping and L. Prueher, and J. Lauer prepared thin sections for this study. All were students in the Department of Geology, University of Wisconsin-Eau Claire. Discussion in the field with R. Maass were helpful and appreciated.

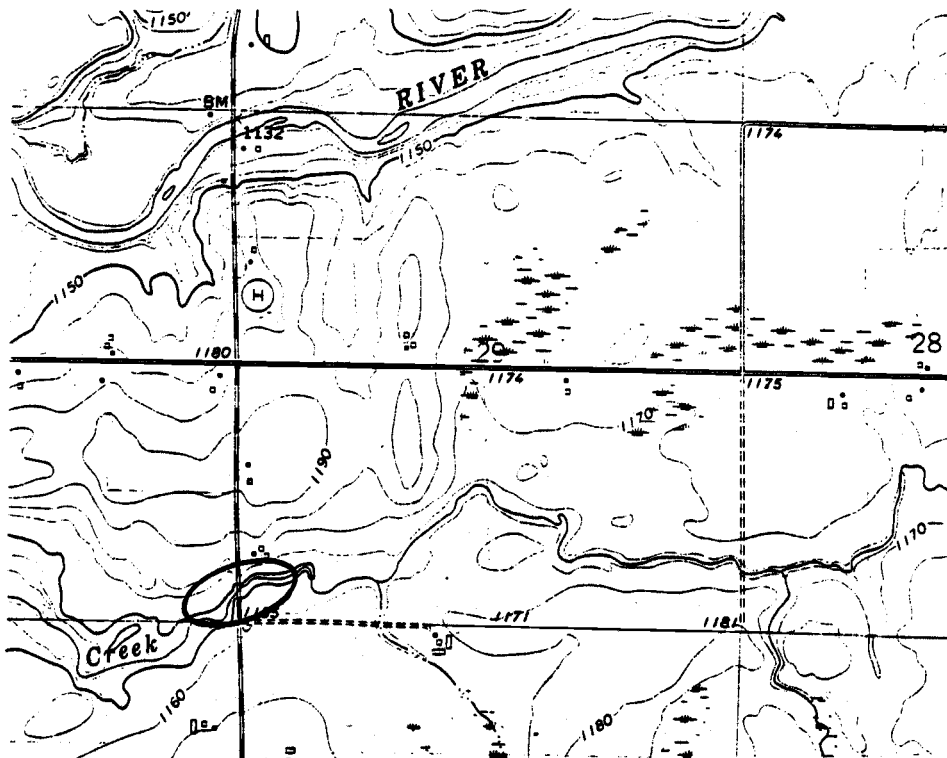
REFERENCES CITED

- Cummings, M.L., 1975, Petrology and structure of Precambrian gneisses at Big Falls, Eau Claire County, Wisconsin: M.S. Thesis, University of Minnesota, Duluth
- Ervin, C.P., Hammer, S., 1974, Bouguer anomaly gravity map of Wisconsin: Wisconsin Geological and Natural History Survey, Scale 1:500,000
- LaBerge, G.L., 1979, Jump River at Big Falls County Park: Field Trip Guidebook No. 4, University of Wisconsin - Extension, Geological and Natural History Survey, p. 40-42
- May, E.R., 1977, Flambeau - A Precambrian Supergene enriched massive sulfide deposit: Geoscience Wisconsin, V. 1, p. 1-26
- Myers, P.E., 1974, Precambrian geology and field trip stop descriptions in the Guidebook, 38th Annual Tri-State Geological Field Conference
- Myers, P.E., 1980, Fieldtrip stops and general geology section in the Guidebook, 26th Annual Institute on Lake Superior Geology
- Sims, P.K., Cannon, W.F., Mudrey, M.G. Jr., 1978, Preliminary geologic map of Precambrian rocks in part of northern Wisconsin: U.S. Geological Survey Open-file Report 78-318, Scale 1:250,000
- Wurdinger, S.R., 1979, Structural geology of amphibolitic gneisses, Northeast Chippewa County, Wisconsin: (abs) 25th Annual Institute on Lake Superior Geology, p.42
- Wurdinger, S.R., 1980, Structures in quartz diorite, granitic intrusives and meta andesites at Holcombe Dam: Guidebook, 26th Annual Institute on Lake Superior Geology
- Zietz, I., Karl, J.H., Ostrom, M.E., 1978, Preliminary aeromagnetic map covering most of the exposed Precambrian Terrane in Wisconsin: U.S. Geological Survey Miscellaneous Field Study MF-888, Scale 1:250,000

STOP #15

TITLE: INTERMEDIATE PORPHYRITIC FLOWS AND TUFFS

LOCATION: Shoulder Creek at Rusk County Highway H bridge. SW $\frac{1}{4}$, SW $\frac{1}{4}$, Sec. 29, T. 33N., R. 4W, Sheldon 7 $\frac{1}{2}$ minute quadrangle



AUTHOR: M.L. Cummings

DATE: March, 1980

SUMMARY OF FEATURES:

Intermediate porphyritic flows are interlayered with possible intermediate fine-grained tuff. Local stretched phenocrysts and development of schistosity appears to reflect late shearing. The rocks are cut by a northeast trending basalt dike.

DESCRIPTION:

The valley of Shoulder Creek is subparallel to the valley of the Jump River which is one mile north. Study of topographic maps suggests that Shoulder Creek may have been a melt-water channel during deglaciation of the area and may have formed a parallel channel to the Jump River. Shoulder Creek provides several key exposures in the volcanic stratigraphy and intrusive history of the Jump River Valley.

Several lithologic units crop out along a $\frac{1}{2}$ mile length of Shoulder Creek. The most prominent rock type is an intermediate porphyritic flow. Phenocrysts

of plagioclase feldspar occur in a strongly recrystallized matrix. The recrystallization may be due to a basalt dike that intrudes the outcrop. The flow unit is exposed at the bridge on county highway H.

Intermediate non-porphyritic units are interlayered with the flow unit and appear to be fine-grained tuffs. Although a contact between the two rock types is not exposed it appears that the contact has a strike of N 60 E. A weakly porphyritic, pinkish-gray felsite crops out in the pasture area west of the highway and appears to be either a flow unit or a fine-grained tuff.

An unmetamorphosed basalt dike crops out east of highway H, however the contacts of the dike and country rock are not exposed. The prominent jointing in the dike that strikes approximately N75E is believed to be the strike of the dike.

A granitic intrusive crops out in a wooded area approximately $\frac{1}{2}$ mile to the southeast (SW $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 32, T. 33 N., R. 4 W). The granite contains small xenoliths of volcanic rock suggesting that the granite is intrusive into the volcanics but the contact of the intrusive and volcanics is not exposed.

A narrow shear zone is exposed approximately $\frac{3}{8}$ mile west of highway H at a sharp northward bend in the creek. The zone has a strike of N 65 E and is vertical. Alteration along the zone is prominent. The schistosity in the enclosing volcanic rocks has a strike of N 70 E and is vertical and may be related to the shear zone. Often the foliation in the intermediate flow units is associated with stretched feldspar phenocrysts.

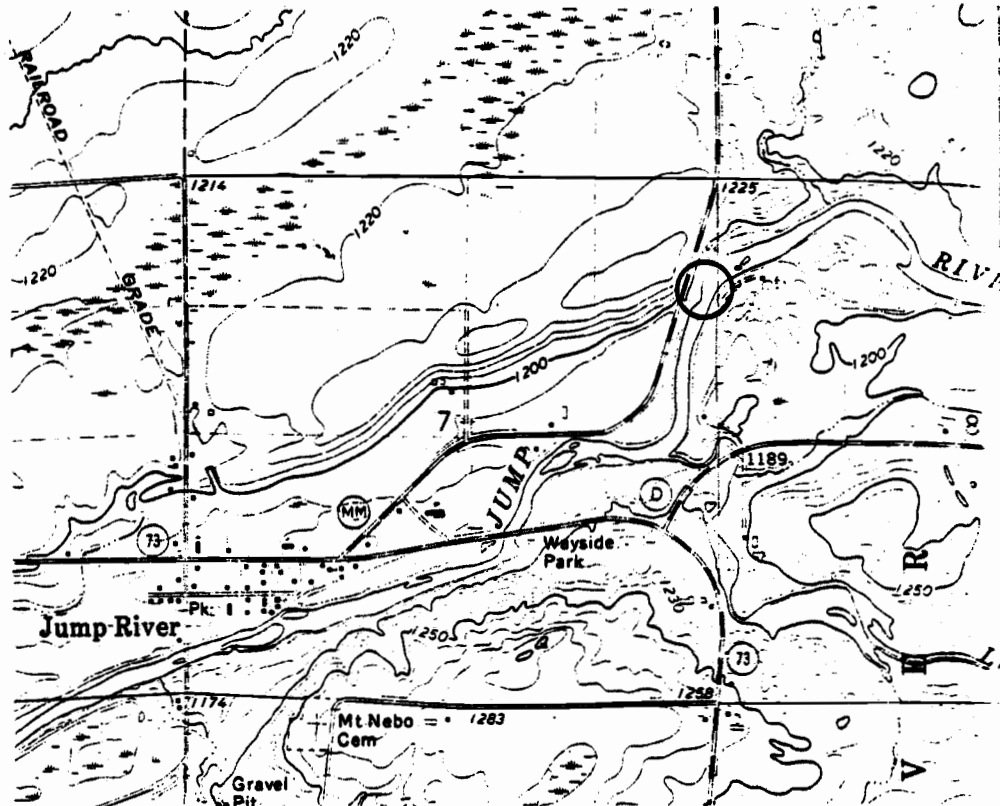
DISCUSSION:

The interbedded tuffs and intermediate flows exposed along Shoulder Creek and the Jump River in the vicinity of Sheldon appear to either stratigraphically overlie or are interbedded with the fragmental crystal and crystal-lithic tuffs that crop out to the east. Eruption of intermediate flows in this area may have been roughly concurrent with continued eruptions at the volcanic center which is exposed 7 miles to the east. These eruptions may have produced the fine-grained tuffs that are interbedded with the flows.

STOP #16

TITLE: COARSE FRAGMENTAL INTERMEDIATE VOLCANIC ROCKS

LOCATION: One mile east of the village of Jump River on County Highway MM. Site of old highway 73 bridge. G. Smith property. NE $\frac{1}{4}$, NE $\frac{1}{4}$, Sec. 7, R. 3 W., T. 33N. Jump River 7 $\frac{1}{2}$ minute quadrangle, 1971



AUTHOR: M.L. Cummings

DATE: March, 1980

SUMMARY OF FEATURES:

Coarse volcanic blocks form massive units that are interlayered with finely bedded tuffs. The intermediate fragmental volcanics are associated with porphyritic intermediate flows immediately to the east of the main outcrop area.

DESCRIPTION:

The most distinct rock unit in the area is composed of volcanic blocks up to 1 foot in diameter. Fragment size is variable but most fragments are larger than 1 inch in diameter. The volcanic rock fragments are typically touching and matrix between clasts is sparse. The lithic fragments range from basaltic to fragments of exceptionally high plagioclase content. Clasts of differing composition appear to form crude localized concentrations. Vesicles are prominent in many fragments and the vesicles are now filled by chlorite

and epidote. Porphyritic clasts contain plagioclase phenocrysts. Although the clasts vary in textures and mineralogy they all are intermediate in composition.

The coarse fragmental units are interbedded with fine-grained tuffaceous materials that are commonly distinctly bedded. The tuffaceous rocks are rich in epidote and feldspar and tend to be extremely fine-grained. The fine-grained beds strike N 10 W which is anomalous in the Jump River area.

The volcanoclastic units are spatially associated with weakly porphyritic flows which crop out as low outcrops immediately up stream from this locality. Possible fragmental units are interlayered with the flows but textures are poorly developed.

Prominent veins cross-cut the coarse fragmental units and are to varying degrees deformed. The thickest veins are usually undeformed. Thin sections of the veins indicate euhedral epidote developed in from the walls of the vein and quartz filling the remaining space.

DISCUSSION:

The coarseness of volcanic blocks at this location suggest that the outcrops are near a significant explosive volcanic center. Similar coarse fragmental rocks interbedded with fine-grained tuffs occur approximately 2 miles east of this site. The area between appears to be underlain by massive intermediate flows and intermediate to felsic, often pyritic, tuffs and possibly lapilli-sized tuffs. Less than $\frac{1}{2}$ mile south (Stop 17) are outcrops of a massive, weakly porphyritic felsite flow or possibly a felsite dome. A possible interpretation of the volcanic rocks in the immediate area is a submarine collapsed caldera complex in which the coarse fragmental rocks are part of the rim of the complex and the interior of the collapsed structure filled with flows and intermediate to felsic pyroclastic materials. The massive felsite may represent a felsite dome formed during a caldera resurgence stage after the main collapse had occurred. Such resurgent caldera complexes are possibly important in development of economic mineralization. Such an environment has been suggested for Kuroko deposits (Kouda, Korde, 1978) and possibly the massive sulfide mineralization in the Noranda district (Spence, deRosen-Spence, 1975).

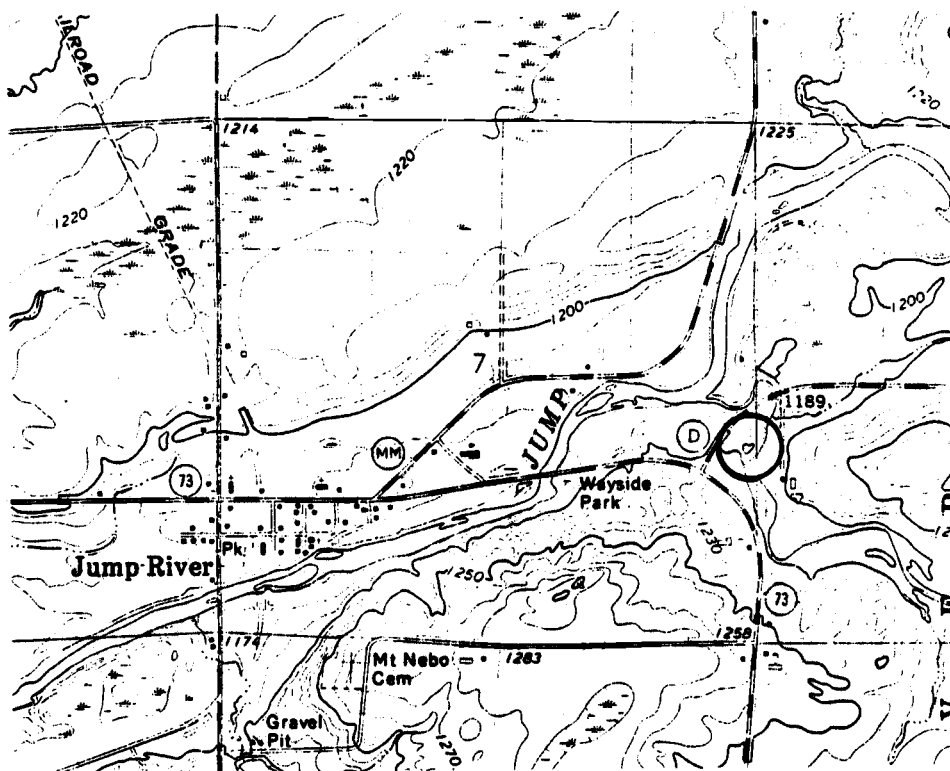
REFERENCES CITED

- Kouda, R., Korde, H., 1978, Ring structures, resurgent cauldron, and ore deposits in the Hokuoku volcanic field, northern Akita, Japan: *Mining Geology*, V. 28, p. 233-244
- Spence, D.D., deRosen-Spence, A.F., 1975, The place of sulfide mineralization in the volcanic sequence at Noranda, Quebec: *Economic Geology*, V. 70, p. 90-101

STOP #17

TITLE: PORPHYRITIC FELSITE FLOW

LOCATION: Along Levitt Creek south of County Highway D on the James Miller Farm. NE $\frac{1}{4}$, SE $\frac{1}{4}$, Sec. 7, R. 3 W., T. 33 N. Jump River 7 $\frac{1}{2}$ minute quadrangle, 1971



AUTHOR: M.L. Cummings

DATE: March, 1980

SUMMARY OF FEATURES:

A fine-grained, weakly porphyritic felsite flow forms massive outcrops along Levitt Creek. The felsite contains a possible metamorphic fabric or relict primary flow structure and is cut by a local E-W shear zone which locally produces a lineation in the rock.

DESCRIPTION:

Two outcrops of a felsite occur west of the farm buildings on the James Miller farm in the bed of Levitt Creek. The felsite is pink and massive. Small subhedral to anhedral plagioclase phenocrysts occur in a fine-grained matrix dominated apparently by quartz and feldspar but sericite bands with minor chlorite define a fabric in the rock.

The felsite is cut by a shear zone containing irregular clots of white quartz in an outcrop immediately west of the barn. The shear zone superimposes

a secondary schistosity on the earlier fabric and locally produces a lineated fabric in the felsite.

DISCUSSION:

A massive felsite crops out west of the wayside park along highway 73, but the unit is coarser grained than the felsites at this location, possibly because of contact metamorphic effects from granitic intrusive material.

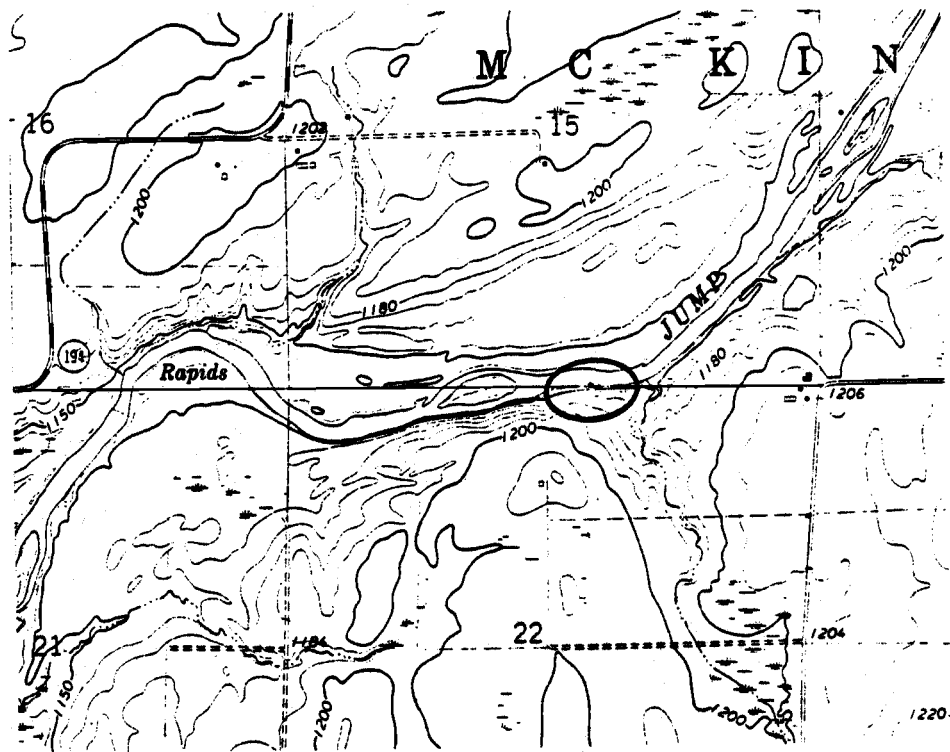
The banding in the massive felsite may be a metamorphically induced fabric or may represent primary flow banding. The felsites are apparently closely related to coarse intermediate fragmental volcanic rocks which crop out along the Jump River approximately $\frac{1}{2}$ mile north (Stop 16). Possibly the felsites form a late rhyolitic dome formed during caldera resurgence in a large collapsed caldera complex. Stratigraphic top indicators would suggest that the felsites stratigraphically overlie the coarse fragmental rocks exposed to the north.

The felsites have apparently been intruded by granitic rocks which are exposed at the wayside park along highway 73 to the west and along an intermittent tributary stream which flows into Levitt Creek less than $\frac{1}{4}$ mile south of the present site. The development of the shear zone cutting the felsite appears to be later than the intrusion of the granites since similarly oriented shear zones cut the granite exposed in the wayside park to the west.

STOP #18

TITLE: CRYSTAL AND CRYSTAL-LITHIC TUFFS

LOCATION: Section line between sections 15 and 22, T. 33N., R. 4 W. along the Jump River behind the farm of Edwin and Gerald Ahlers. Jump River 7½ minute quadrangle, 1971



AUTHOR: M.L. Cummings

DATE: March, 1980

SUMMARY OF FEATURES:

Well-bedded crystal and crystal-lithic tuffs are beautifully exposed along the south bank of the Jump River. Impact structures produced by larger clasts falling into finer grained bedded materials indicate that the stratigraphic tops of the volcanic pile are to the south and that the units are overturned.

DESCRIPTION:

Well-exposed, stream polished outcrops of tuffaceous of various rocks characteristics crop out for approximately 0.75 miles along the Jump River west of the Edwin and Gerald Ahlers property. Since the river flows approximately parallel to the bedding in the volcanics the exposures do not provide a thick stratigraphic section and may represent nearly one stratigraphic level.

The lowest stratigraphic unit is farthest north and is fine-grained, massive, light green, intermediate crystal tuff. Bedding is massive and can be identified by faint bands that have a higher percentage of slightly coarser phenocrysts than the surrounding rock.

The main rock type is an intermediate crystal-lithic tuff. The rock is prominently bedded with the strike of bedding N 60E and dipping 72° N. A coarse, approximately 4 inches long, volcanic clasts has been found that apparently fell into the accumulating finer-grained tuffs and produced an impact feature from which a stratigraphic top determination can be made. The top of the volcanic unit appears to be to the south indicating that the bedding is overturned.

Beds of crystal tuff are interbedded with crystal-lithic tuff along the outcrop area. Typically lithic fragments are less than ½ inch in diameter and are of intermediate composition. The tuffs contain plagioclase crystals and possible pyroxene crystals that are pseudomorphically replaced by amphibole. The plagioclase crystals contain subhedral to anhedral epidote. Epidote also forms part of the matrix between crystal and lithic clasts in some samples. Hornblende porphyroblasts are prominent in most beds, and sulfide minerals are found locally in concentrations of 2 percent.

DISCUSSION:

The tuffs exposed at this stop are believed to be related to a caldera complex exposed east of the village of Jump River (3 miles to the east, Stop 16). The tuffs in this area are possibly stratigraphic equivalents of the coarse fragmental units at Stop 16. The grain size of fragments decreases and the proportion of crystal fragments to lithic fragments increases away from the volcanic center. To the west of this site the tuffs are fine-grained and lithic fragments have not been observed. The rocks have been metamorphosed under epidote-amphibolite facies conditions but a schistosity is not strongly developed.

BIBLIOGRAPHY

- Anderson, Van Schmus, and Medaris, 1975, "Proterozoic Granitic Plutonism in the Lake Superior Region and its Tectonic Implications," (abs). EOS Trans. Am. Geophys. Union, V. 56, p. 603.
- Cummings, M.L., 1971, "Geology of Big Falls, Wisconsin," Guidebook, 3rd Annual Wisconsin State University Geology Field Conference, p. 13-20.
- Cummings, M.L., Myers, P.E., 1974, "Geology of the Big Falls Area," Guidebook, 3rd Annual Tri-State Geological Field Conference.
- Cummings, M.L., 1975, "Petrology and Structure of Precambrian Gneisses at Big Falls, Eau Claire County, Wisconsin," M.S. thesis, University of Minnesota Duluth.
- Cummings, M.L., Myers, P.E., 1978, "Petrology and Geochemistry of Amphibolites, Eau Claire River, Eau Claire County, Wisconsin," (abs). 24th Annual Institute on Lake Superior Geology.
- Cummings, M.L., Scrivner, J.V., 1980, "The saprolite at the Precambrian-Cambrian Contact, Irvine Park, Chippewa Falls, Wisconsin." Transactions, Wisconsin Academy of Arts, Sciences and Letters. In press.
- Dutton, C.E., and Bradley, R.E., 1970, Lithologic, Geophysical, and Mineral Commodity Maps of Precambrian Rocks in Wisconsin. U.S. Geol. Survey. Misc. Inv. Map 1-631, scale 1:500,000.
- Ervin, C.P., Hammer, S., 1974, Bouguer Anomaly Gravity Map of Wisconsin, Wisconsin Geological and Natural History Survey, Scale 1:500,000.
- Glikson, A.Y., 1979, "Early Precambrian Tonalite-Trondhjemite Sialic Nuclei," Earth Science Reviews, 15, 1-73.
- Hess, H.H., 1960, "Stillwater Igneous Complex," Geological Society of America, Memoir 80, p. 225.
- Karl and Friedel, 1974-76, Aeromagnetic map series, Wisconsin Geological and Natural History Survey, Scale 1:62500.
- Kouda, R., Korde, H., 1978, "Ring structures, Resurgent Cauldron, and Ore Deposits in the Hokuroku Volcanic Field, Northern Akita, Japan." Mining Geology, v. 28.
- LaBerge, G.L., 1972, "Lineaments and Mylonite Zones in the Precambrian of Northern Wisconsin," 18th Annual Institute on Lake Superior Geology, Abs., paper #27.
- LaBerge, G.L., 1979, "Jump River at Big Falls County Park." Field Trip Guidebook No. 4, University of Wisconsin-Extension, Geological and Natural History Survey.
- LaBerge, G.L., and Palmer, E., 1980, "Middle Precambrian History of Marathon County, Wisconsin," 26th Annual Institute on Lake Superior Geology, Field Trip Guidebook #2.

- Maass, R.S., and Van Schmus, W.R., 1980, "Precambrian Tectonic History of the Black River Valley," 26th Annual Institute on Lake Superior Geology, Field Trip #2 Guidebook.
- Maass, R.S., Medaris, Jr, L.G., and Van Schmus, W.R., 1980, "Archean and Early Proterozoic Tectonic History of North-Central Wisconsin," 26th Annual Institute on Lake Superior Geology, Eau Claire, WI., Abs.
- Maercklein, Douglas, R., 1974, "Analysis of Deformation at Jim Falls, Wisconsin," unpublished M.S. Thesis, University of Wisconsin-Milwaukee.
- May, E.R., 1977, "Flambeau--A Precambrian Supergene Enriched Massive Sulfide Deposit," *Geoscience Wisconsin*, v. 1, p. 1-26.
- Myers, P.E., 1974, Precambrian geology and field trip descriptions in the guidebook, 38th Annual Tri-State Geological Field Conference.
- Myers, P.E., 1980, General introduction and field trip descriptions in Field Trip Guide Book for 26th Annual Institute on Lake Superior Geology Field Trip #1.
- Myers, P.E., Cummings, M.L., May, E.R., Kopp, R.A., Willis, R.P., Bergstrom, J. R., 1974, 38th Annual Tri-State Geological Field Conference Guidebook, 125 p.
- Piotruszewicz, M.A., 1978, "An Analysis of a Drill Core from Western Clark County, Wisconsin," unpub. M.S. thesis, University of Wisconsin, Milwaukee.
- Sims, P.K., 1976, "Precambrian Tectonic and Mineral Deposits, Lake Superior Region," *Economic Geology*, v. 71, p. 1092-1118.
- Sims, P.K., Cannon, W.F., Mudrey, M.G., Jr., 1978, "Preliminary Geologic Map of Precambrian Rocks in Part of Northern Wisconsin," U.S. Geological Survey Open-file Report 78-318, Scale 1:250,000.
- Smith, E.I., 1978, "Precambrian Rhyolites and Granites in South-Central Wisconsin," *Geol. Soc. America Bull.*, v. 89, p. 875-890.
- Spence, D.D., deRosen-Spence, A.F., 1975, "The place of sulfide mineralization in the volcanic sequence at Noranda, Quebec," *Economic Geology*, v. 70.
- United States Steel Corporation, 1973, unpubl. aeromagnetic maps of the Jim Falls area, Wisconsin.
- Van Schmus, W.R., 1974, "Chronology of Precambrian Events in Wisconsin" (abs). *EOS. Trans. Amer. Geophys. Union*, v. 55, p. 465.
- Van Schmus, R., 1976, "Early and Middle Proterozoic History of the Great Lakes Area, North America", *Phil. Trans. R. Soc. Lond. A*. 280, p. 605-628.
- Van Schmus, R., 1980, "Chronology of Igneous Rocks Associated with the Penokean Orogeny in Wisconsin", *Geol. Society Amer. Special Paper*, #180, Goldich Volume.

Willemse, J., 1969, "The Geology of the Bushveld Igneous Complex, the Largest Repository of Magmatic Ore Deposits in the World" in Magmatic Ore Deposits, Economic Geology Publishing Co., p. 1-22.

Wurdinger, S.R., 1979, "Structural Geology of Amphibolitic Gneisses, Northeast Chippewa County, Wisconsin", (abs) 25th Annual Institute on Lake Superior Geology, p. 42.

Zietz, I., Karl, J.H., Ostrom, M.E., 1978, "Preliminary Aeromagnetic Map Covering Most of the Exposed Precambrian Terrane in Wisconsin," U.S. Geological Survey, Miscellaneous Field Study MF-888, 1:250,000.