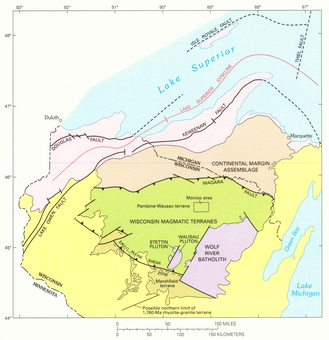
U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

GEOLOGIC INVESTIGATIONS SERIES
MAP I–2739
Explanatory pamphlet accompanies map



EXPLANATION

CONTINENTAL MARGIN ASSEMBLAGE

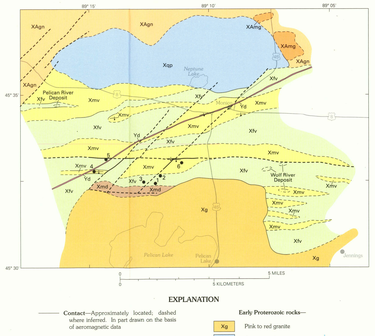
- Sedimentary rocks of Paleozoic age
- Middle Proterozoic (Keweenawan) mafic igneous and sedimentary rocks of Midcontinent rift system (~1,100 Ma)
- Anorogenic igneous rocks (1,470–1,520 Ma)
- Marquette Range Supergroup (1,820–2,100 Ma) and basement gneiss, granite, and greenstone (2,600–3,550 Ma)

WISCONSIN MAGMATIC TERRANES

- Island-arc metavolcanic and granitoid rocks in Pembine-Wausau terrane (1,835–1,880 Ma), includes post-tectonic granitic rocks (1,760 Ma)
- Island-arc metavolcanic and granitoid rocks (1,835–1,890 Ma) and basement gneiss (~2,800 Ma) in Marshfield terrane

- Contact
- High-angle fault
- Thrust fault—Possible suture
- Shear zone

Figure 1.—Regional geologic map showing location of the Monico area, northern Wisconsin. Modified from Sims (1992).



EXPLANATION

- Contact—Approximately located, dashed where inferred. In part drawn on the basis of aeromagnetic data
- Shear zone—Approximately located, dashed where inferred. In part drawn on the basis of aeromagnetic data. Mylonitic in places
- Strike of volcanic pillows—Steeply dipping to vertical; ball indicates stratigraphic top
- Location number for kinematic data—See figures 11 and 12

Middle Proterozoic rocks—

- Yd Diabase

Early Proterozoic rocks—

- Xg Pink to red granite
- Xap Quartz porphyry
- Xfv Felsic metavolcanics
- Xmd Metadiabase
- Xmv Mafic metavolcanics

Early Proterozoic or Late Archean rocks—

- XAmg Metagabbro
- XAgn Gneissic rocks

Figure 2.—Generalized bedrock geologic map of the Monico area. Locations of Pelican River and Wolf River (DeMatties, 1994) massive sulfide deposits are shown. Numbers 1–6 refer to outcrop locations at which kinematic determinations were made; see figures 11 and 12.

Figure 4.—Photograph of basaltic pillow-breccia debris flow from outcrop in the NW¼ sec. 1, T. 35 N., R.10 E., about 2.2 mi southwest of Monico. Clasts are amygdaloidal basalt in a fine-grained chloritic matrix. Area shown is about 2 m wide.

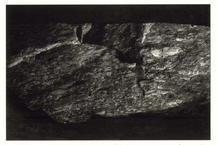


Figure 5.—Photograph of felsic lithic tuff from outcrop in the SW¼ sec. 2, T. 35 N., R.10 E., about 3.5 mi southwest of Monico. Clasts are mainly felsitic; however, several mafic clasts are also present. Matrix is somewhat chloritized. Area shown is about 24 cm wide.

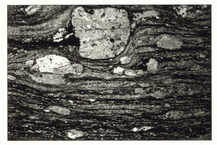


Figure 6.—Photomicrograph of flattened shards in a porphyritic welded tuff from outcrop in the NW¼ sec. 4, T. 35 N., R.10 E., about 4.8 mi west-southwest of Monico. Shards are "draped" over phenocrysts. Tectonic flattening has emphasized the original flattening. Large phenocryst at top center is about 1 mm wide.

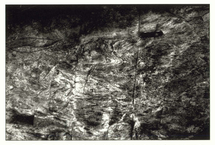


Figure 7.—Photograph of flow-banded felsic volcanic rock from outcrop in the SW¼ sec. 2, T. 35 N., R.10 E., about 3.5 mi southwest of Monico. Folding is mainly tectonic; however, randomly oriented folds are probably primary. Pocketknife is 8 cm long.

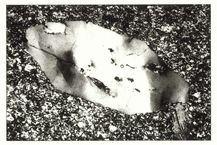
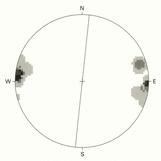
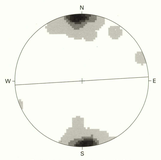


Figure 8.—Photomicrograph of the quartz porphyry from an outcrop at the northeastern edge of Neptune Lake, showing a 13-mm-long, slightly embayed, euhedral quartz phenocryst in a fine-grained quartz-feldspar matrix.

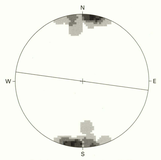
Figure 9.—Photograph of a dismembered diabase dike and intrusion breccia in the blue-quartz porphyry from the W½ SE¼ sec. 17, T. 36 N., R.10 E. Field of view is approximately 2 m wide.



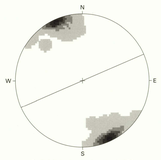
A. SA_1 foliation in gneiss. N=15.



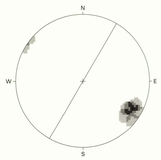
B. S_1 foliation in volcanic rocks. N=244.



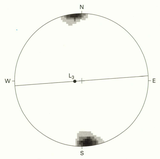
C. S_1 foliation in quartz porphyry. N=23.



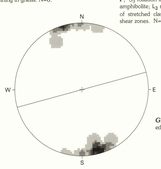
D. S_2 foliation in volcanic rocks. N=156.



E. S_2 foliation and veining in gneiss. N=6.



F. S_2 foliation in volcanic rocks and amphibolite. L_2 represents long axes of stretched clasts in D_2 mylonitic shear zones. N=30.

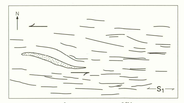


G. S_2 foliation along southern edge of gneiss. N=17.

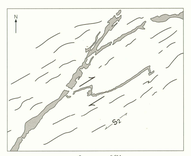
Figure 10.—Lower hemisphere stereoplots of poles to foliation. Variable percentages, from lowest to highest, are represented by five degrees of shading, from lightest to darkest.

A. Minor folds in flow-banded rhyolite suggesting left-lateral shear (shown by paired arrows) for D_2. Note that S_2 is axial planar to F_1 folds. Weak-S_2 fracture fabric strikes northeast and crosscuts S_2. Map view. Location 1.

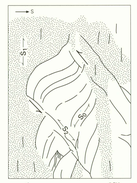
B. Minor folds in rhyolite flow bands (S_0) suggesting right-lateral sense of movement (shown by paired arrows) for D_2. Note that this does not agree with sense of movement for D_2 from sketch *A*. Map view. Location 1.



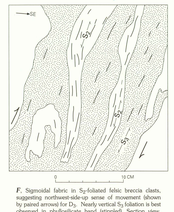
C. Phyllosilicate pod (stippled) in S_1-foliated rhyolite has a sigmoidal S-C fabric and indicates left-lateral movement (shown by paired arrows), the same as in sketch *A*. Map view. Location 1.



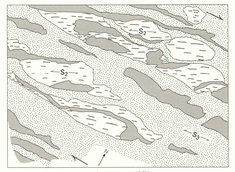
D. Folded quartz vein (shaded) indicating right-lateral sense of movement (shown by paired arrows) for D_2. Quartz veins are in basalt that has S_2 foliation. Map view. Location 4.



E. Vertical S_1 foliation in phyllosilicate-rich zones (stippled), with isolated sigmoidal fabric in flow-bands (S_0) in rhyolite indicating south-side-up sense of movement for D_2. The south-dipping (S_2) shear bands have a north-verging sense of movement, shown by arrows. Section view, looking east. Location 3.



F. Sigmoidal fabric in S_2-foliated felsic breccia clasts, suggesting northeast-side-up sense of movement (shown by paired arrows) for D_2. Nearly vertical-S_2 foliation is best observed in phyllosilicate band (stippled). Section view, looking northeast. Location 5.



G. Northeast-trending S_2 fabric and long axes of felsic clasts (shown by long dashes) are overprinted and truncated by east-trending S_3 phyllosilicate shear fabric (stippled). D_3 has right-lateral sense of movement. Felsic clasts appear stacked by right-lateral sense of movement, shown by paired arrows. Map view. Location 5.

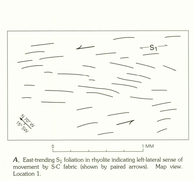
Figure 11.—Sketches from field photographs of outcrops showing macroscopic kinematic indicators. Kinematic observations were made near locations 1, 3, 4, and 5, shown in figure 2. Some of these locations are also referred to in figure 12.

Summary of kinematic data from field observations:

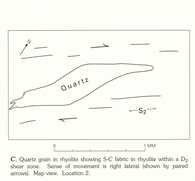
D_1—Produced east-trending, vertical S_1 foliation. Data indicate north side is up, with conflicting sense of horizontal movement. See text for further explanation.

D_2—Produced northeast-trending, steeply dipping S_2 foliation. Sense of movement is right lateral, south side up.

D_3—Produced east-trending, vertical S_3 foliation. Sense of movement is right lateral, north side up.



A. East-trending S_1 foliation in rhyolite indicating left-lateral sense of movement by S-C fabric (shown by paired arrows). Map view. Location 1.



C. Quartz grain in rhyolite showing S-C fabric in rhyolite within a D_2 shear zone. Sense of movement is right lateral (shown by paired arrows). Map view. Location 2.

E. Asymmetric quartz grain in rhyolite with pressure shadows (shaded) and S-C fabric indicating north-side-up D_2 movement (shown by paired arrows). Dark area is opaque mineral. Section view. Looking southwest. Location 5.

B. Amphibole fish with S-C fabric indicating north-side-up D_2 movement (shown by paired arrows). Section view. Looking northwest. Location 1.

D. Quartz grain in rhyolite with pressure shadows (shaded). S-C fabric indicates south-side-up D_2 movement (shown by paired arrows). Section view. Looking southwest. Location 2.

F. Stretched asymmetric volcanic clast in breccia elongated parallel to S_2. Note tension veins (wavy lines) indicating clast was stretched along S_2 (shown by paired arrows). Map view. Location 6.

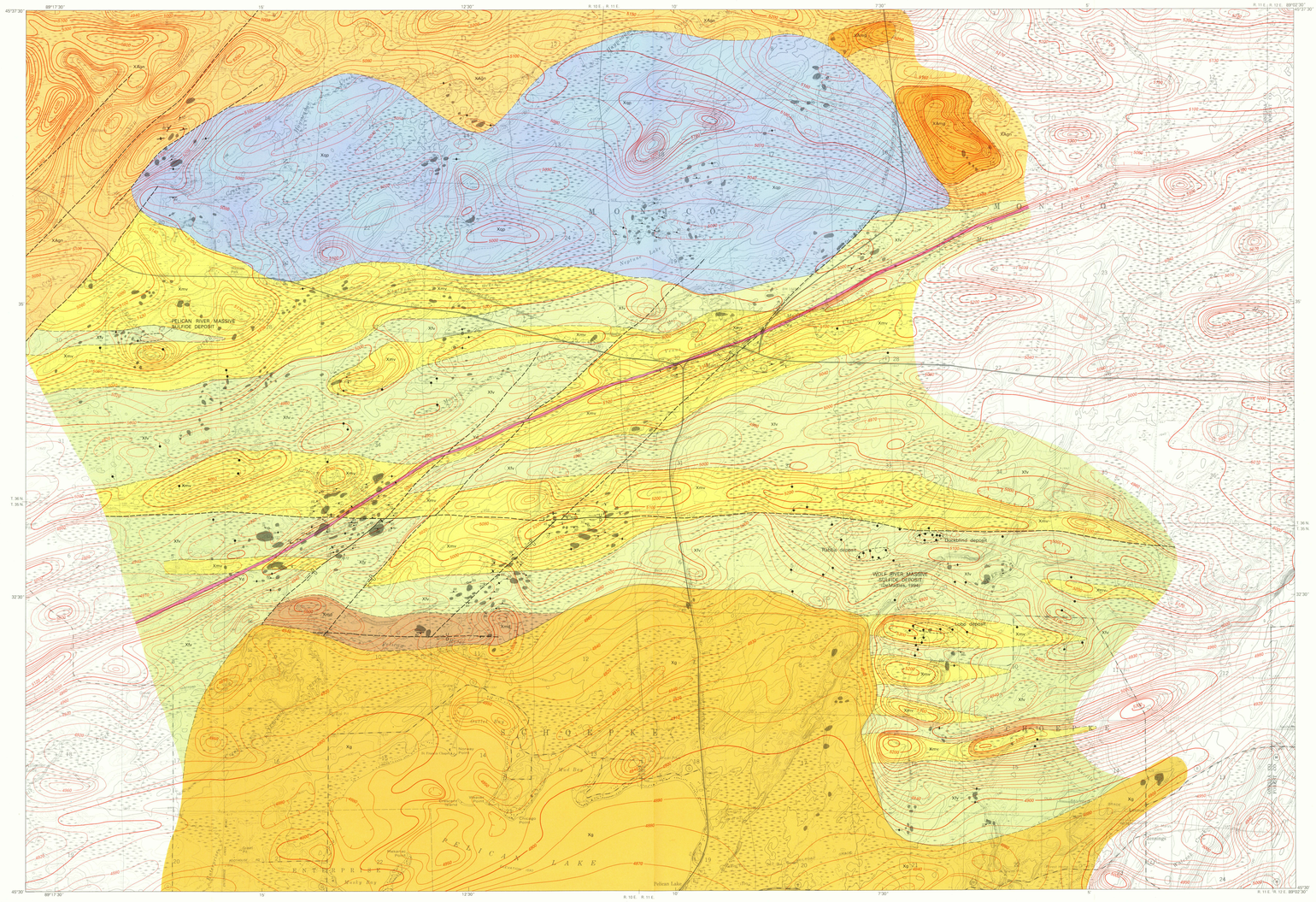
Figure 12.—Sketches from petrographic thin sections. All sections except that in sketch *F* are 2 mm long. Numbers 1, 2, 5, and 6, shown in figure 2, designate the locations of the source outcrops. Locations 3 and 4 were not used for this figure.

Summary of kinematic data from petrographic thin sections:

D_1—Involved both left- and right-lateral, north-side-up movement to form S_1 foliation.

D_2—Right-lateral, south-side-up movement.

D_3—Involved right-lateral, north-side-up movement.



Base from U.S. Geological Survey
George Lake, 1982; Monico and Nashville, 1965
Polyconic projection. 1927 North American datum
10,000-foot grid based on Wisconsin coordinate system, north zone

APPROXIMATE MEAN DECLINATION, 2001

SCALE 1:24 000
1 MILE
1 KILOMETER
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

MAP LOCATION

Geology mapped by LaBerge and John Franklin, 1990, and by LaBerge and Klasner, 1991

Aeromagnetic data prepared in 1976 by Geoterrex, Ltd., for Noranda Exploration, Inc., Rhinelander, Wis., and provided by U.S. Geological Survey. Flight-line spacing approximately 1,000 ft (300 m); terrain clearance 400 ft (120 m). Horizontal control based on photomosaics

Figure 3.—Aeromagnetic and bedrock geologic map of the Monico area.

CORRELATION OF MAP UNITS
(Figure 3)

- Yd — MIDDLE PROTEROZOIC
- Intrusive contact
- Xg
- Intrusive contact
- Xfv, Xap — EARLY PROTEROZOIC
- Intrusive contact
- Xmv, Xmd
- Unconformity?
- XAgn, XAmg — EARLY PROTEROZOIC OR LATE ARCHEAN

DESCRIPTION OF MAP UNITS
(Figure 3)

Diabase (Middle Proterozoic)—Unmetamorphosed diabase having subhedral plagioclase laths as large as 5 mm in a matrix composed mainly of pyroxenoids. Exposures are limited to a few localities along a major diabase dike that transects the map area in a northeasterly direction

Granite (Early Proterozoic)—Mainly medium-grained quartz, microcline, and plagioclase; pink to red. Plutons largely are undeformed, post-tectonic intrusives into highly deformed metavolcanic rocks and gneisses. Locally porphyritic

Quartz porphyry (Early Proterozoic)—Massive gray rock with aphanitic matrix containing abundant euhedral to subhedral, somewhat embayed, quartz and plagioclase phenocrysts. Quartz phenocrysts tend to have a distinctive blue color. East of Neptune Lake the body appears to be mainly extrusive. West of Neptune Lake the porphyry appears to be intrusive, with abundant xenoliths of mafic volcanic rocks and gneiss

Felsic metavolcanic rocks (Early Proterozoic)—Tuff breccias, tuffs, welded tuffs, debris flows, massive and flow-banded lava flows, and probable subvolcanic plutons composed of dacite to rhyolite. Lava flows are typically porphyritic with quartz and plagioclase phenocrysts. Lithic tuff breccias and lithic and vitric tuffs are common, with welded tuffs present locally. Recrystallization and deformation have produced a granoblastic texture, obscuring most primary features

Metadiabase (Early Proterozoic)—Generally medium-grained dikes and sills within the volcanic sequence. Pyroxenes are converted to amphiboles and diabasic texture is variably obscured by recrystallization

Mafic metavolcanic rocks (Early Proterozoic)—Massive and pillowed lava flows, pillow breccia, and debris flows composed of high-alumina basalt to low-silica andesite. Pillowed basalts are generally highly amygdaloidal. Pillow breccias contain monolithologic, angular to subrounded mafic clasts in a fine chlorite-rich matrix. Massive basalts located generally along U.S. Route 8 are extensively epidotized and contain abundant quartz and quartz-feldspar veins

Metagabbro (Early Proterozoic or Late Archean)—Medium- to coarse-grained metagabbro with hornblende crystals as large as 1 cm. Extensively cut by granitoid veins. Present within the gneissic rocks in the northern part of the map area. Appears to be an older generation of mafic rocks than the metadiabases within the volcanic succession

Gneissic rocks (Early Proterozoic or Late Archean)—Compositionally banded gneisses. Granitoid gneisses contain quartz, feldspar, and biotite. Mafic phases are amphibolites cut by granitoid veins. Xenoliths of gneiss are common in the quartz porphyry north and west of Neptune Lake. Age is uncertain

EXPLANATION OF MAP SYMBOLS
(Figure 3)

- Magnetic contours—Showing total-intensity magnetic field of the earth in gammas relative to an arbitrary datum. Contour interval 10 and 20 gammas; 100 gammas in far northwestern part of map area
- Contact—Approximately located, dashed where inferred. In part drawn on the basis of aeromagnetic data
- Shear zone—Approximately located, dashed where inferred. In part drawn on the basis of aeromagnetic data. Mylonitic in places. Paired arrows indicate relative movement. U, upthrown side; D, downthrown side
- Outcrop area
- Strike of volcanic pillows—Steeply dipping to vertical; ball indicates stratigraphic top

Strike and dip of penetrative foliation

- Inclined
- Vertical

Strike and dip of shear zone foliation—Generally occurs in bands or zones. Mylonitic shear zone indicated by M

- Inclined
- Vertical
- Bearing and plunge of mineral lineation
- Bearing and plunge of minor fold axis
- Bearing and plunge of long axis of stretched volcanic clast, vesicle, or amygdule

Drill hole

- Vertical
- Inclined—Stem shows direction of inclination
- Massive sulfide deposit—Approximate location of mineralized area

Conversion Factors

Multiply	By	To obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
kilometers (km)	0.6214	miles
feet (ft)	0.3048	meters
square kilometers (km²)	0.3861	square miles

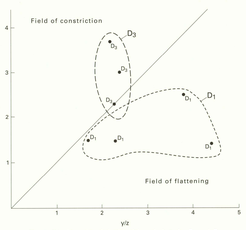


Figure 13.—Flinn plot of ductilely deformed clasts for D_1 and D_2 deformational events. Long, intermediate, and short dimensions of clasts are represented by x, y, and z, respectively.

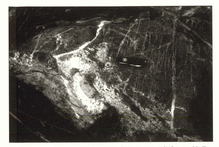


Figure 14.—Photograph of altered basalt from outcrop in SW¼ sec. 29, T. 36 N., R.10 E., just west of the Pelican River massive sulfide deposit. The basalt is highly epidotized and contains numerous quartz and quartz-feldspar veins. Pocketknife is 8 cm long.

Figure 15.—Photograph of felsic dikes cutting altered basalt near the Pelican River massive sulfide deposit. Field of view is approximately 2 m wide.

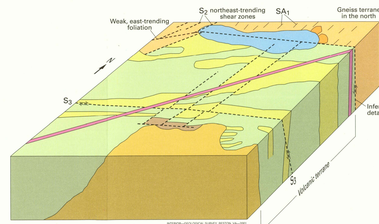


Figure 16.—Interpretive block diagram sketch showing major lithologic and structural features in the Monico area. See "Interpretation" section of pamphlet for discussion. Regional east-trending S_1 foliation is not shown.

EXPLANATION

- Contact—Approximately located or inferred
- Shear zone—Approximately located or inferred. Arrows show relative movement

Middle Proterozoic rocks—

- Diabase

Early Proterozoic rocks—

- Granite
- Quartz porphyry
- Felsic metavolcanics
- Metadiabase
- Mafic metavolcanics

Early Proterozoic or Archean rocks—

- Metagabbro
- Gneissic rocks

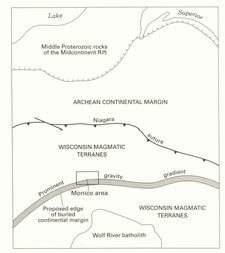


Figure 17.—Geologic sketch map of northern Michigan and Wisconsin showing location of the Monico area relative to the inferred continental margin, which lies along a prominent, south-sloping gravity gradient (from Attoh and Klasner, 1989).

GEOLOGY AND TECTONIC SIGNIFICANCE OF EARLY PROTEROZOIC ROCKS IN THE MONICO AREA, NORTHERN WISCONSIN

By

Gene L. LaBerge[1] and John S. Klasner[2]

2001

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ISSN 0-607-98330-2

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