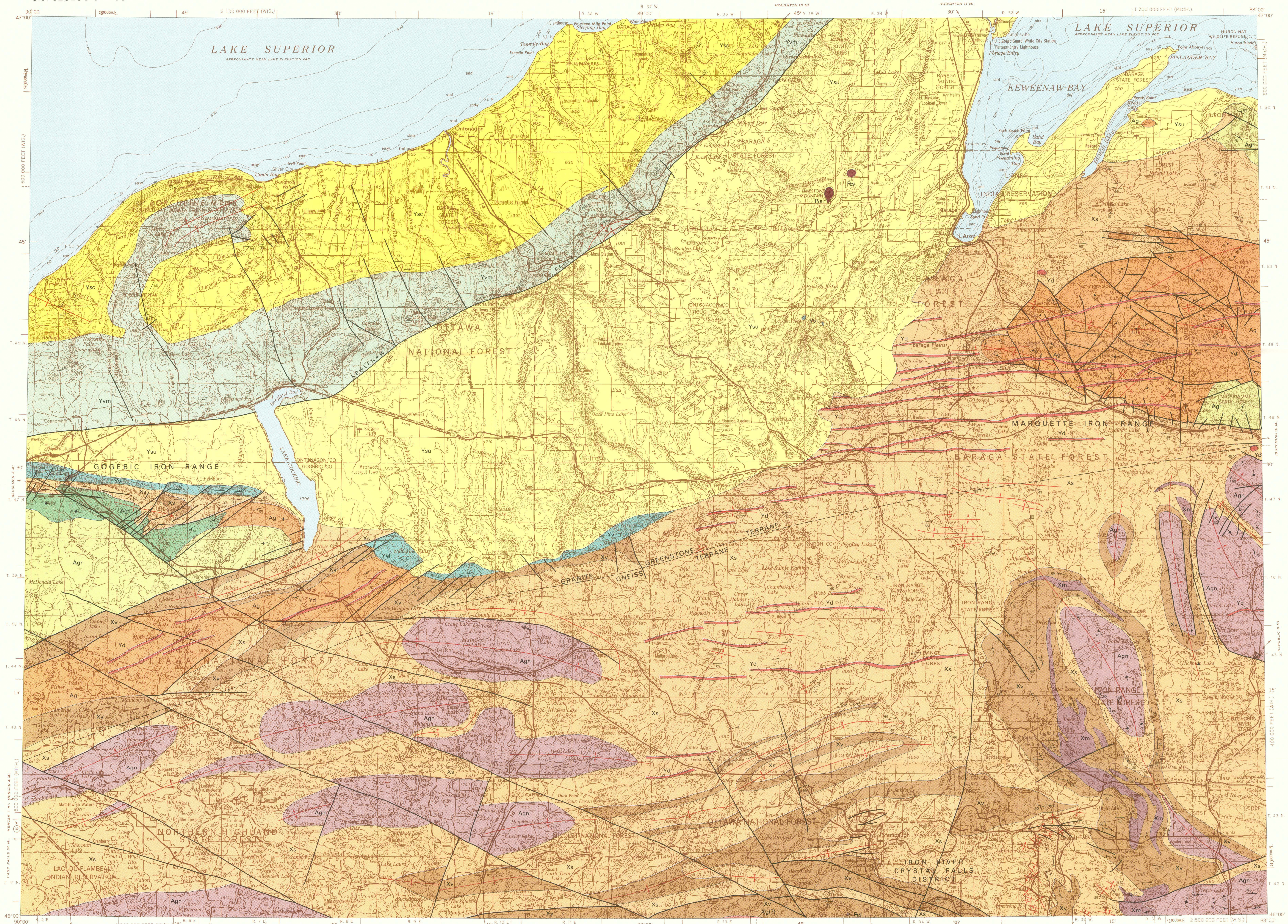
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
GEOLOGICAL SURVEY DIVISION OF THE
MICHIGAN DEPARTMENT OF NATURAL RESOURCES

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I–1360–D



Base from U.S. Geological Survey, 1958
Limited revision as of 1967
100,000-foot grids based on Michigan coordinate system, north zone and Wisconsin coordinate system, north zone
10,000-meter Universal Transverse Mercator grid ticks, zone 16

SCALE 1:250 000

5 0 5 10 15 20 25 MILES

5 0 5 10 15 20 25 30 35 KILOMETERS

CONTOUR INTERVAL 50 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES AND SOUNDINGS IN FEET

CORRELATION OF MAP UNITS

- k, Pzs — Devonian or younger — PALEOZOIC
- Unconformity
- Yau — MIDDLE PROTEROZOIC(?)
- Unconformity
- Ysc, Yvm
- Unconformity
- Yvl, Yd — MIDDLE PROTEROZOIC
- Unconformity
- Xg(?), Xm, Xs Xv — EARLY PROTEROZOIC
- Unconformity
- Agr, Ag, Ags, Agn — ARCHEAN

DESCRIPTION OF MAP UNITS

k Kimberlite pipe incorporating Paleozoic sedimentary rocks (about 15 km northeast of Crystal Falls, Mich.)

Pzs Outliers of Paleozoic sedimentary rocks of the Midcontinent platform, weakly to moderately deformed. May be cryptovolcanic structures

ROCKS OF THE MIDCONTINENT RIFT

Yau Fluvial sedimentary rocks unconformably on lower Keweenawan volcanic rocks and, in part, overlapping onto older rocks

Ysc Fluvial and lacustrine sedimentary rocks conformably on and locally interbedded with middle Keweenawan volcanic rocks

Yvm Middle Keweenawan basalt and andesite flows and interflow conglomerates of the Keweenaw Point-Isle Royale lava plateau

Yvl Lower Keweenawan basalt and andesite flows including a thin basal unit of the Siemens Creek lava plateau and a thicker upper unit of the Ironwood-Grand Portage-Nopeming plateau

Yd Lower Keweenawan diabase dikes and plugs. Probably feeders to flows of the Ironwood-Grand Portage-Nopeming lava plateau

ROCKS OF THE PENOKEAN FOLD BELT

Xg(?) Granitic intrusive rocks inferred from geophysical data and sparse outcrops south of quadrangle

Xm Mafic intrusive rocks

Xs Xv Stratified rocks unconformably on Archean crystalline rocks. Xs—Sedimentary rocks, dominantly deep-water deposits but near base are shallower-water shelf, and miogeosynclinal rocks. Xv—Tholeiitic submarine volcanic rocks

ROCKS OF THE ARCHEAN GRANITE-GREENSTONE TERRANE

Agr Granitic rocks, in part foliated, intruded into Ags and Ag about 2.65 b.y. ago

Ag Paragneiss and schist derived from Ags

Ags Metavolcanic and metasedimentary rocks about 2.65 b.y. old. Deformed and metamorphosed shortly after deposition.

ROCKS OF THE ARCHEAN GNEISS TERRANE

Agn A variety of rocks including gneisses 3.4 b.y. old, younger metavolcanic rocks and gneisses and schist derived from them, and intrusive granitic rocks about 2.6 b.y. old.

EXPLANATION OF MAP SYMBOLS

- Contact
- Fault
- Anticline—Showing direction of plunge
- Overturned anticline
- Syncline
- Strike and dip of bedding
  - Inclined
  - Vertical
  - Overturned
- Strike and dip of foliation
  - Inclined
  - Vertical
- Strike and dip of cleavage
  - Inclined
  - Vertical
- Bearing and plunge of minor fold axis

INTRODUCTION

This tectonic and structural map presents information on the geologic evolution of the area within the Iron River 1° x 2° quadrangle, Michigan and Wisconsin. Rocks of this area contain fragmentary evidence of geologic events from at least 3.4 billion years (b.y.) ago to early Paleozoic time. This map is a companion to the bedrock geologic map of the Iron River quadrangle (Cannon, 1986 and other maps in the Iron River folio prepared as a project of the Conterminous United States Mineral Assessment Program (CUSMAP).

This map is part of a folio of 1:250,000-scale maps of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, prepared as a project of the Conterminous United States Mineral Assessment Program. A list of maps (U.S. Geological Survey Miscellaneous Investigations Series Maps I–1360–A–N) for the complete folio follows.

MAP

- I–1360–A Mineral resources of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. Cannon.
- I–1360–B Bedrock geologic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. F. Cannon.
- I–1360–C Surficial geologic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. L. Peterson.
- I–1360–D Structural and tectonic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by W. F. Cannon.
- I–1360–E Bouguer gravity anomaly map and geologic interpretation of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by J. S. Klasner and W. J. Jones.
- I–1360–F Aeromagnetic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by E. R. King.
- I–1360–G Metamorphic map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by Karen Wier.
- I–1360–H Copper distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by H. V. Alminas, J. D. Hoffman, and R. T. Hopkins.
- I–1360–I Chromium distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by H. V. Alminas, J. D. Hoffman, and R. T. Hopkins.
- I–1360–J Cobalt distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by J. D. Hoffman, H. V. Alminas, and R. T. Hopkins.
- I–1360–K Nickel distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by J. D. Hoffman, H. V. Alminas, and R. T. Hopkins.
- I–1360–L Silver distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by R. T. Hopkins, H. V. Alminas, and J. D. Hoffman.
- I–1360–M Molybdenum distribution in B-horizon soils in the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by R. T. Hopkins, H. V. Alminas, and J. D. Hoffman.
- I–1360–N Interpretive geochemical map of the Iron River 1° x 2° quadrangle, Michigan and Wisconsin, by H. V. Alminas, J. D. Hoffman, R. T. Hopkins.

ARCHEAN HISTORY

The Archean rocks of the quadrangle are divided into two terranes first identified by Morey and Sims (1976) and further described by Sims (1980). A granite-greenstone terrane underlies much of the northern part of the quadrangle whereas an older gneiss terrane underlies the southern part of the quadrangle. The boundary between the two terranes is covered everywhere by Proterozoic rocks. Near the east edge of the quadrangle and in the southwest ¼ of the quadrangle, the boundary is mapped accurately where the outcrop belts of the two terranes are close together.

GNEISS TERRANE

Rocks of the gneiss terrane are predominantly granitic gneisses (Agn) of high metamorphic grade, mostly upper amphibolite facies. Locally, near Watersmeet, Mich. gneisses have a minimum age of 3.4 b.y. and possibly are considerably older (Sims and Peterman, 1976; Peterman and others, 1980). Elsewhere in the terrane, similar gneisses yield younger, possibly reset, ages in the range of 2.6 to 2.8 b.y. Archean volcanic rocks and granitic plutons are scarce. The gneisses are complexly folded, most likely resulting from two or more folding events, but the folding history is poorly understood because of the paucity of outcrops. The gneisses were reactivated as domes and horsts during Proterozoic deformation and are now exposed only in the cores of these Proterozoic uplifts.

GRANITE–GREENSTONE TERRANE

Rocks of the granite-greenstone terrane are typical of greenstone belts of the Superior Province in Canada and are considered an extension into the United States of the Shebandowan greenstone belt. The rocks include submarine metavolcanic rocks (Ags) 2.6–2.7 b.y. old, schists and gneisses (Ag) derived from them, and essentially synchronous granitic plutons (Agr) that intrude the metavolcanic rocks. The only extensive metavolcanic rocks of this terrane in the quadrangle are south of the Gogebic Range and are tightly folded on east-west axes. Gneisses and schists near Marenisco, Mich., and north of the Marquette Range are also tightly folded. Outcrops are sufficient to map structures only north of the Marquette Range, where reconnaissance mapping shows many antiformal and synformal folds of diverse trends.

The greenstone-granite terrane is believed to have been welded onto the gneiss terrane about 2.6 b.y. ago during the final stage of evolution of the Archean crust in the Lake Superior region (Morey and Sims, 1976; Sims, 1980).

EARLY PROTEROZOIC HISTORY

Rocks of Early Proterozoic age record a sequence of sedimentation and volcanism in a progressively less stable environment and later metamorphism and deformation. Rocks of the Marquette Range Supergroup (Xs and Xv) are not accurately dated but are constrained by the 2.6 b.y. age of the Archean basement and the approximately 1.8 b.y. old metamorphism that recrystallized them. A volcanic unit in the supergroup has been dated at 1.9 b.y. (Banks and Van Schmus, 1972).

The Marquette Range Supergroup lies with sharp angular unconformity on Archean rocks. The unconformity represents a hiatus of at least 500 m.y. Judging by the great lateral continuity of some basal units, the top of the Archean was a peneplain when sedimentation began. The oldest rocks of the Marquette Range Supergroup are a shelf-like sequence of sedimentary rocks including orthoquartzite, dolomite, and shale. Basal beds locally are thick conglomerate which may be tillite.

These shelf rocks are preserved sparsely; in many areas younger rocks of the Marquette Range Supergroup lie directly on Archean basement. If the shelf sequence was deposited in those areas, it was eroded soon after deposition.

In the Gogebic and Marquette Ranges, the shelf sequence is overlain unconformably by a complex rock assemblage consisting of quartzite, slate, and iron-formations. To the south, volcanic rocks become dominant and iron-formations are thinner. The rocks were deposited in a tectonically unstable environment, apparently less stable in the south than the north. Unconformably above that sequence is a thick eugeosynclinal assemblage consisting mostly of graywacke and shale turbidite rock in the north and containing progressively more submarine volcanic rocks with tholeiitic differentiation trends and iron-formation toward the south. Large bodies of mafic intrusive rocks (Xm) were probably emplaced during volcanism. Apparently, the major volcanic belt of the eugeosyncline was south of the quadrangle where rocks of equivalent age are mostly volcanic.

The Marquette Range Supergroup and underlying Archean rocks were deformed and metamorphosed during the Penokean orogeny about 1.8 b.y. ago. The nature of the orogeny varied over the two contrasting Archean terranes (Sims, 1976; Sims and others, 1980). In the north, in the granite-greenstone terrane, deformation consisted of reactivation of basement rocks, largely along shear zones and by penetrative cataclasis, in places producing well-formed cleavage in metavolcanic and metasedimentary rocks. The overlying Marquette Range Supergroup was folded in varying intensity; near the boundary between granite-greenstone and gneiss terranes the folds are nearly isoclinal and overturned toward the north, but farther north folding diminishes. The western part of the Gogebic Range, for instance, was unaffected by Penokean folding. This distinctive tectonism occurs in a belt from 25 to 50 km wide that is immediately north of the boundary. This belt was named the Great Lakes tectonic zone by Sims and others (1980).

South of the boundary, where the Marquette Range Supergroup lies on the gneiss terrane, basement was reactivated by a combination of cataclasis, recrystallization, and partial melting into broad domes and depressions. Structural trends are mostly east-west in the western part of the quadrangle and north to northwest in the eastern part. Locally, in the eastern part of the quadrangle, Penokean deformation of the Archean was not penetrative, and uplift to form domes was by movement of fault blocks (Cannon, 1973). The Marquette Range Supergroup was strongly folded, generally along east-west axes. In general, the intensity of folding, and consequent north-south shortening increases in higher parts of the section. Lower parts of the section are generally simple, homoclinal sequences dipping outward from domes, whereas higher stratigraphic units are more tightly and complexly folded. The most intense folding is in the stratigraphically youngest rocks in the vicinity of Iron River and Crystal Falls. This relationship suggests that the sedimentary rocks were at least partly decoupled from basement during folding so that upper units underwent more shortening than did basal units or basement rocks (Cannon, 1973).

Metamorphism was of low grade over the granite-greenstone terrane, mostly lower greenschist facies. Over the gneiss terrane, several nodes of higher metamorphic intensity formed (James, 1955). Metamorphism was approximately synchronous with folding.

Numerous faults cut Penokean folds. Most are probably caused by late Penokean brittle deformation, but some faults could have been formed or reactivated during development of the younger Midcontinent rift.

MIDDLE PROTEROZOIC HISTORY

Rocks of Middle Proterozoic age, consisting of the Keweenawan Supergroup, were deposited in, and marginal to, the Midcontinent rift during the rifting about 1.2 b.y. ago.

Middle Proterozoic rocks include flood basalts, dominantly olivine tholeiite flows (White, 1960, 1966), and a great volume of clastic sedimentary rocks. The flows through the Lake Superior region form seven partly overlapping lava plateaus (Green, 1977), three of which are partly in the Iron River quadrangle. The oldest flows, about 120 m thick, are preserved along the southernmost outcrop belt of flows (southern margin of Yvl). They form the Siemens Creek plateau, which is volumetrically small and aerially restricted. They have mostly normal magnetic polarity but record a magnetic reversal near their top.

Flows of the Ironwood-Grand Portage-Nopeming plateau immediately overlie the Siemens Creek. The flows have reversed magnetic polarity. According to Green (1977), these flows formed an extensive plateau in the western part of the Lake Superior basin and to the southwest. A thickness of at least 1.5 km of these flows is exposed in the Iron River quadrangle. A swarm of west-trending diabase dikes (Yd), also having reversed magnetic polarity, occurs throughout a large area south and east of the outcrop belt of the flows. These dikes were probably feeders to the flows and indicate that the plateau originally extended well south of its outcrop belt.

The youngest plateau, the Keweenaw Point-Isle Royale plateau, is preserved as an extensive belt of volcanic rocks (Yvm) immediately north of the Keweenaw fault. It consists of about 6 km of flows and interflow sedimentary rocks. The volcanic rocks are mostly tholeiitic basalt, but near the Porcupine Mountains andesite and felsite are dominant in the upper part of the sequence. The flows have normal magnetic polarity. The stratigraphic relationship of these flows to the older flows to the south is not known because the two flow sequences are everywhere separated by the Keweenaw fault.

Sedimentary rocks of fluvial and lacustrine origin (Ysc and Yau) (Hamblin, 1958, 1961) overlie the volcanic rocks and apparently represent the final filling of the rift after volcanism waned.

North of the Keweenaw fault, the sedimentary rocks (Ysc) are conformably and locally interbedded with the volcanic rocks. South of the Keweenaw fault, the sedimentary rocks (Yau) unconformably overlie the volcanic rocks. There, the volcanic rocks were tilted to the north and eroded before sedimentation. The original thickness of Yau and Ysc rocks cannot be determined but at least several thousand meters are preserved.

The Middle Proterozoic rocks are deformed in relatively simple structures. The rocks generally dip northward in shallow to moderately dipping homoclinal sequences. Only rarely do complications, such as those in the Porcupine Mountains and near the mouth of the Presque Isle River, reverse the northward-facing section of rocks. Much of the northward dip is probably caused by tilting during opening of the rift. Stratigraphically lower flows generally dip more steeply than younger flows indicating that the area was being tilted throughout the time of volcanism. Later, apparently during partial closing of the rift, compressional features such as the Keweenaw fault, a major reverse fault, and folds in the Porcupine Mountains were formed.

PHANEROZOIC HISTORY

Traces of Phanerozoic rocks (Pzs) in the quadrangle are scarce. No geologic events are recorded from the close of the Midcontinent rifting event until sedimentation during the Cambrian. The area appears to have remained stable for this eon of approximately 600 m.y., during most of which erosion probably took place.

Small outliers of Cambrian and Ordovician sedimentary rocks, mostly too smaoo to show at 1:250,000 scale, are common in the southeast corner of the map near the area where continuous Paleozoic cover is still preserved east and southeast of the quadrangle. Two other outliers of Paleozoic sedimentary rocks of Ordovician and Silurian age are near Pelkie, Mich., about 15 km west of Keweenaw Bay, where talus blocks of Devonian rocks also have been found (Case and Robinson, 1914). These outliers strongly suggest that the entire quadrangle was once covered by Paleozoic shelf strata now mostly eroded.

Most outliers of Paleozoic rocks are flat lying, but a few, including those near Pelkie and one shown along the Brule River south of Iron River, Mich. are deformed, dipping locally as steeply as 60° and have been dropped below their expected altitude. Regional Phanerozoic deformation is not known, and it is postulated that these outliers may be cryptovolcanic structures. A kimberlite pipe (k) containing inclusions of downdropped Paleozoic carbonate rocks is about 15 km northeast of Crystal Falls, Mich. (Cannon and Mudrey, 1981). The outliers of deformed and downdropped Paleozoic rocks may be caused by buried kimberlite pipes.

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STRUCTURAL AND TECTONIC MAP OF THE IRON RIVER 1° X 2° QUADRANGLE, MICHIGAN AND WISCONSIN

By
W. F. Cannon

1986

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