INTRODUCTION

This map portrays the geology of part of the Midcontinent rift system along the southern limb of the Lake Superior syncline in northern Wisconsin and the upper peninsula of Michigan. The southeastern half of the map area is underlain by a great monoclinal succession of Middle Proterozoic rift-related rocks of the Keweenawan Supergroup. This steeply north-dipping structure, the Montreal River monocline, exposes 15 km of strata that record the opening of the Midcontinent rift, its subsequent transition to a thermal subsidence basin, and eventual inversion. About 3 km of underlying Early Proterozoic strata, including the Gogebic iron range, and about 10 km of Late Archean rocks, exposed in the southernmost part of the map area, are also part of the monocline.

The northwestern half of the map area, north of the Douglas fault, is underlain by nearly flat-lying continental red beds of the Bayfield Group, the youngest strata of the Keweenawan Supergroup. In spite of the simple surface geology in this area, geophysical data indicate a complex deeper rift structure, which is shown in the accompanying cross sections.

A wealth of geologic data exists for the area as a result of many individual studies over the last hundred years, but much has remained unpublished in theses, dissertations, and other reports of limited availability. This map has incorporated most of that data (see list of data sources) and includes results of our investigations conducted from 1991 to 1994. Our studies were designed to fill gaps in existing data and reconcile conflicting interpretations on some aspects of the geology of the region.

STRATIGRAPHY AND TECTONIC SETTING

Three principal stratigraphic sequences, separated by profound unconformities, are present in the map area. Each sequence was deposited in a distinctly different tectonic setting as the region evolved from a Late Archean primitive oceanic terrane to a Middle Proterozoic craton.

Late Archean

Metavolcanic and granitic rocks constitute a poorly exposed Late Archean terrane in the southern part of the map area. They are among the southernmost exposures of volcanic rocks in the Superior province and are typical of granite-greenstone terranes of that province. Volcanic rocks consist mostly of basalt and lesser andesite and rhyolite. Dacitic breccia is the dominant rock type immediately south of the Gogebic iron range between Hurley and Mellen, Wisc. Where best exposed, near Gile Flowage, the volcanic rocks are as much as 6 km thick and are overturned, so that they face northwest and dip steeply southeast (Greathead, 1975). The volcanic rocks were intruded by granitic rocks of the Puritan batholith at about 2750 Ma (Sims and others, 1977). Map unit Wp consists mostly of massive and pegmatoid granitic rocks of the Puritan Quartz Monzonite that form the Puritan Batholith. The unit also includes gneissic rocks probably derived from volcanic rocks during emplacement of the batholith.

Early Proterozoic

Early Proterozoic strata of the Marquette Range Supergroup comprise a 2- to 3-km-thick sedimentary sequence that records sedimentation successively on a stable craton, passive margin, and compressional foreland. The oldest strata are the Bad River Dolomite of the Chocolay Group, which was deposited unconformably on Archean rocks, apparently in a stable cratonic setting. The Bad River is a cherty dolomite, now commonly metamorphosed to tremolitic marble. It also includes a distinctive cherty breccia that constitutes most of the unit from near the Bad River eastward for about 10 km to near Ballou Creek. In part of that area the unit is too thin to show separately and is included within the Palms Formation (unit Xp). This breccia appears to be a variably reworked residuum of chert nodules and beds left by solution of the dolomite during the hiatus prior to deposition of the unconformably overlying Palms Formation.

The Menominee Group was deposited on a south-facing passive margin. It is composed of argillite and quartzite of the Palms Formation that passes upward into banded iron-formation of the Ironwood Iron-Formation. The Palms grades from banded argillite near its base to thick-bedded quartzite near the top. It unconformably lies on the Bad River Dolomite or on Archean rocks where the Bad River is absent. At its upper contact the Palms grades upward over one or two meters into ferruginous beds of the Ironwood Iron-Formation. The Ironwood contains numerous lithologic types of iron-formation. East of Upson, Wis., it consists of five laterally continuous members that are alternating units of thin, even-bedded carbonate iron-formation and thick, wavy-bedded to lenticular hematitic iron-formation (Hotchkiss, 1919; Huber, 1959). West of Upson these lithologic types also are present, but laterally continuous members are more difficult to define, in part because of primary sedimentary changes, but also because of complications introduced by deformation and metamorphism. Within the map area, the Ironwood contains a thin (0-13 m) tuffaceous bed, at least locally (Schmidt, 1980), but it interfingers with more voluminous volcanic rocks both to the east and west. The metadiabase sills in the Ironwood Iron-Formation and Bad River Dolomite in the western part of the map area are believed to be coeval with volcanic rocks and thus were intruded shortly after sedimentation.

About 20 km south of Hurley, an iron-formation interbedded with mafic volcanic rocks is known from drilling and magnetic surveys. The sequence is tentatively correlated with the Ironwood Iron-Formation and may have been deposited on a more distal and volcanically active part of the continental margin.

The Baraga Group is represented by the Tyler Formation, a thick sequence of graywacke and slate believed to have been deposited in a foreland basin during accretion of island arc terranes to the south at about 1850 Ma. The contact with the underlying Ironwood Iron-Formation may be an unconformity, although its nature has been debated for many years (see summary by Schmidt, 1980). Evidence for an unconformity is a change in stratigraphic thickness of more than 100 m in the uppermost member of the Ironwood and a conglomerate at the base of the Tyler known from underground mine workings and drill core, but no longer accessible for observation. Schmidt (1980) concluded that the contact was most likely conformable. However, about 20 km to the east of the map area, the Copps Formation, equivalent to the Tyler, undoubtedly lies with angular unconformity on the Ironwood (Klasner and others, in press), so the Ironwood-Tyler contact corresponds to an interval of significant erosion nearby and, therefore, may be unconformable within the map area.

Early Proterozoic rocks are essentaially unmetamorphosed in the eastern part of the map area, but metamorphic grade increases toward the west. Near the western edge of the map, assemblages include orthopyroxene and garnet in iron-formation and large tremolite masses in carbonate rocks of the Bad River Dolomite. The metamorphism was static and related to Middle Proterozoic thermal events as discussed below in the section on metamorphism.

Middle Proterozoic

Middle Proterozoic rocks in the map area are composed of volcanic and sedimentary strata of the Keweenawan Supergroup and correlative intrusive rocks, all formed as part of the Midcontinent rift system. The Keweenawan Supergroup is as much as 15 km thick in the map area. With the exception of a thin basal quartzite (Bessemer Quartzite), the lower part of the sequence consists of volcanic rocks varying from basalt to rhyolite. The volcanic rocks were deposited during an approximately 15-m.y.-period of extension and rift subsidence. They filled a deep central depression and extended as thinner blankets over the rift flanks. The volcanic section was deposited both as flood basalts and as central volcanic complexes. The oldest volcanic rocks, the Siemens Creek Volcanics, are flood basalts. The sequence is subaerial except for the lowest one or two flows, which typically are pillow basalts or pillow breccias. The basal flow lies conformably on the Bessemer Quartzite, which appears to have been unconsolidated at the time of eruption. The Siemens Creek has not been dated but is generally considered to be correlative with the Osler Group on the north shore of Lake Superior, where eruption began at 1109 Ma (Davis and Sutcliffe, 1985).

The Kallander Creek Volcanics is, in part, a central volcanic complex that was deposited on the Siemens Creek and was probably erupted from vents near Mellen, Wis. (Cannon and others, 1993a). Units near the middle and at the top of the formation are dated respectively at 1106 Ma (Cannon, Nicholson, and others, 1993) and 1099 Ma (R.E. Zartman and others, 1994). Parts of the Mellen Intrusive Complex, including a granite body informally called the Mellen granite by numerous previous workers, and the Mineral Lake intrusion have been dated at 1102 Ma (Cannon and others, 1993a). The Mellen Intrusive Complex appears to be a near-surface intrusion emplaced into the active volcano and was probably a magma chamber from which part of the Kallander Creek Volcanics was erupted.

The Portage Lake Volcanics was erupted as the rift reverted to flood basalt volcanism. The Portage Lake thins westward and pinches out about 10 km northeast of Mellen, suggesting that the Mellen area was a regional topographic high during eruption. Radiometric ages from east of the map area show that the Portage Lake was erupted rapidly between about 1096 and 1094 Ma (Davis and Paces, 1990).

The youngest volcanic rocks in the area are the Porcupine Volcanics, a second central volcanic complex, that was centered about 20 km east of the map area (Cannon and Nicholson, 1992). The youngest parts of the Porcupine Volcanics contain abundant interflow conglomerates marking the transition to dominantly sedimentary conditions and the end of extension and rifting.

As much as 7 km of continental clastic rocks, both fluvial and lacustrine, form the upper part of the Keweenawan Supergroup. These constitute the Oronto Group and the somewhat younger Bayfield Group and Jacobsville Sandstone. The oldest sediments, the Copper Harbor Conglomerate and perhaps the overlying lakebeds of the Nonesuch Formation, were deposited in a basin transitional between the earlier extensional rift basin and a successor thermal subsidence basin that was generally centered on the older rift basin but was much broader.

A regional paleotopographic high centered near Mellen affected the distribution and lithology of nearby sedimentary units. The Copper Harbor Conglomerate and Nonesuch Formation both pinch out against the high so that the Freda Sandstone locally lies unconformably on volcanic and intrusive rocks. The Freda Sandstone near Mellen is atypically conglomerate-rich, probably reflecting a nearby highland that provided coarse clastic material.

The Jacobsville Sandstone is also a conglomerate-rich unit in the map area in contrast to finer-grained facies farther east. The conglomeratic nature has been interpreted to have resulted from the onset of compressional tectonics and rift inversion during sedimentation (Hedgman, 1992; Hedgman and Cannon, in press).

Metamorphism of Middle Proterozoic rocks increases both with stratigraphic depth and from east to west. Sedimentary strata near the top of the section, as well as younger parts of the volcanic section show little to no metamorphic change. Burial metamorphism resulted in zeolite facies and prehnite-pumpellyite facies assemblages successively with increasing depth in the volcanic section. Some of the volcanic rocks in the western part of the map area are intensely recrystallized and metamorphosed to pyroxene hornfels as a result of a thermal node centered in that area as discussed in the section on metamorphism.

STRUCTURE

Midcontinent Rift System

The map area can be divided into two stuctural domains, each displaying contrasting structures developed mostly during and shortly after formation of the Midcontinent rift system. The southern half of the area is dominated by a great monoclinal sequence of strata of the Montreal River monocline (Cannon and others, 1993b). The monocline (see cross sections A-A' and B-B') exposes as much as 15 km of the Keweenawan Supergroup, 3 km of underlying Marquette Range Supergroup, and 10 km or more of Archean basement rocks. The combined thickness of 25 to 30 km of section contains no observed structural repetitions. Rather, it forms a moderately to steeply north-dipping and north-facing sequence that exposes a crustal-scale cross section of the Midcontinent rift and its basement. The age, kinematics, and dynamics of this large structure werer documented by Cannon and others (1993b), who proposed that uplift and northward tilting were caused by crustal-scale listric thrusting at about 1060 Ma. The thrusts include the Marenisco fault in the southeastern and southwestern parts of the map area. Within the monocline no penetrative structural fabric is developed in Middle Proterozoic rocks. Early Proterozoic strata also lack any fabric related to development of the monocline; all structures observed are attributable to Early Proterozoic deformation. Likewise, Archean rocks seem to be unaffected other than by northward tilting.

Three major Middle Proterozoic reverse faults project into the map area. All three appear to die out near the center of the area. The Keweenaw fault forms the southern boundary of the Portage Lake Volcanics to the east. It is known as far west as sec. 36, T. 47 N., R. 1 E., where several hundred feet of sheared basalt in contact with the Jacobsville Sandstone are known from a series of drillholes. West of the map area the Lake Owen fault forms the southern margin and the Douglas fault forms the northern margin of the St. Croix horst. Both are major reverse faults that thrust volcanic rocks over younger sedimentary rocks. Within the map area the Lake Owen fault passes upsection eastward until it dies out within the Freda Sandstone. Within the Freda its trace is poorly constrained but is interpreted to lie along the southern side of an elongate positive magnetic anomaly. The anomaly is believed to be caused by uplift of volcanic rocks at depth on the northern side of the fault. The trace of the Douglas fault can be located approximately by seismic reflection data (Allen, 1994). As with the Lake Owen fault, it passes higher in the stratigraphic section to the east and displacement diminishes and apparently dies out near the Lake Superior shoreline.

As these three major reverse faults died out within the same region, their combined displacements were apparently transferred to the Marenisco fault whose trace is now largely within Archean rocks. This fault was not recognized as a Middle Proterozoic structure until recent geochronologic and structural work (Cannon and others, 1993b) showed that rocks in its hanging wall were strongly uplifted and tilted northward during inversion of the Midcontinent rift at about 1060 Ma and that it is, therefore, one of a set of major reverse faults along the rift. Before our present mapping the Marenisco fault was located only by magnetic surveys in drift-covered areas. We have now located it in outcrop along the Marengo River, near the western edge of the map area. There, as much as several hundred feet of brittle mylonite, apparently mostly strongly crushed granitic rocks, are exposed. The fault has thrust basalts, originally deposited in the Midcontinent rift, southward over Archean and Early Proterozoic rocks of the rift flank.

In the northern half of the map area, the surface geology is simple and consists of very gently southeastward dipping sandstones of the Bayfield Group. A more complex deeper rift structure is revealed by geophysical data, however. A region of low density rocks, probably Archean basement, surrounded by rift basalts was inferred beneath the Bayfield Peninsula by White (1966) on the basis of analysis of gravity, magnetic, and geologic data. This structure has been confirmed and clarified by more recent analyses including seismic reflection data (Sexton and Henson, 1994; Allen, 1994) and named White's Ridge. The Keweenawan Supergroup volcanic strata progressively thin toward the ridge (see cross sections A-A' and B-B') and eventually pinch to a feather edge, which is approximately located on the map. Faults are not evident in any of the seismic lines around the ridge so it appears to have been a gentle topographic dome throughout rifting. The lowest units of the Oronto Group, including the Copper Harbor Conglomerate and perhaps the Nonesuch Formation, also pinch out against the ridge (Allen, 1994). The Freda Sandstone was the first unit to bury the ridge. The Freda and successive units of the Bayfield Group show no effects of the ridge in their stratigraphic thickness.

Penokean Orogeny

The Penokean orogeny resulted from collision of a series of island arcs with the southern edge of the Superior craton at about 1850 Ma (Sims and others, 1989). The map area lies north of the suture and contains Early Proterozoic rocks that were deposited on the craton margin and subsequently deformed in a foreland fold and thrust belt.

Along the Gogebic iron range Penokean deformation increases in intensity from east to west. East of Upson, Wis., deformation was mild to absent. Locally, a well-developed slaty cleavage is present in some beds of the Tyler Formation, but in general the Early Proterozoic strata remained essentially flat-lying and are structurally concordant with the base of the Keweenawan Supergroup. The steep northward dips on the iron range are a result of Middle Proterozoic tilting of the Montreal River monocline. West of Upson the degree of Penokean deformation becomes increasingly intense as expressed by both folds and faults. West of Ballou Creek the Marquette Range Supergroup is structurally detached from underlying Archean basement along a basal decollement. The decollement is especially well exposed in numerous outcrops in sec. 10 and 11, T. 44 N., R. 2. W. Numerous faults splay upward from the decollement and cut all Early Proterozoic strata. Folds from outcrop scale to about 1 km in wavelength are especially common west of the Bad River. On Mt. Whittlesey and near Mineral Lake the outcrop belt of the Ironwood Iron-Formation is widened by internal folding. At Mineral Lake the folds are nearly isoclinal and were originally upright. Because of northward tilting of the Montreal River monocline these folds are now recumbent so that the southern limbs of synclines are overturned.

Archean Structures

Folds of mappable scale have not been delineated within Archean rocks, probably because of very sparse exposure. Archean volcanic rocks are highly deformed internally. Finer-grained pyroclastic and sedimentary rocks are generally schistose and generally have steep to moderate southward dips. Coarser pyroclastic rocks typically have clasts strongly stretched along moderately southward plunging axes. Near Gile Flowage, where Archean volcanic rocks are best exposed, they form a southeast-dipping but northwest-facing sequence (Greathead, 1975). This overturning resulted from Middle Proterozoic tilting of an originally north-dipping upright section.

Gneissic rocks that mostly form border zones between the volcanic rocks and the Puritan batholith, are intensely folded and migmatized. They are poorly exposed, and a coherent regional structure has not been delineated.

METAMORPHISM

Metamorphism during Archean time converted volcanic rocks to greenschist facies assemblages. Near contacts with the Puritan batholith the volcanic rocks were more intensely metamorphosed to hornblende and biotite gneisses.

Early Proterozoic metamorphism was produced during the Penokean orogeny. In the eastern part of the map area an orderly increase in metamorphic grade toward the south was mapped by Schmidt (1976) by using assemblages in Early Proterozoic mafic dikes emplaced into Archean rocks. Schmidt showed that the Early Proterozoic strata of the Gogebic iron range and immediately underlying Archean rocks were not detectably metamorphosed during the Penokean orogeny. Metamorphic grade increases rather abruptly to the south and the greenschist-amphibolite facies boundary lies only about 10 km south of the iron range. In the remainder of the map area studies have been inadequate to distinguish Early Proterozoic from Archean metamorphism in rocks of the Archean terrane.

The most intense metamorphism in the map area is of Middle Proterozoic age. It increases in intensity from east to west. In the east, the metamorphism is related to deep burial during development of the Midcontinent rift. Metamorphism of the Middle Proterozoic volcanic rocks is limited to the development of chlorite in the basaltic matrix and combinations of quartz, calcite, chlorite, and rarely epidote in amygdules. A Middle Proterozoic isotherm of roughly 250 oC, the Rb-Sr blocking temperature of biotite, was mapped by Cannon and others (1993b). At the eastern edge of the map area it lies about 10 km south of the Gogebic iron range, within Archean rocks. This suggests that the geothermal gradient in Middle Proterozoic time was only about 10o/km and that burial temperatures within Middle Proterozoic and Early Proterozoic rocks were no higher than about 150 oC.

West of Upson, Wis. the intensity of Middle Proterozoic metamorphism increases. It is expressed especially strongly in the Ironwood Iron-Formation. Successive changes are breakdown of iron carbonate minerals and development of iron-silicate minerals, mostly grunerite. Near the western end of the iron range, near Mineral Lake, grunerite is converted to iron-rich orthopyroxene. Magnetite becomes more abundant as metamorphic grade increases. The Bad River Dolomite is metamorphosed to dolomitic marble that contains coarse rosettes of tremolite in originally siliceous layers. The Tyler Formation shows less obvious changes. The common occurrence of biotite instead of chlorite, and incipient porphyroblasts of andalusite at a few localities are the principal indications of metamorphism.

Middle Proterozoic rocks are also strongly metamorphosed in the western part of the area. The Bessemer Quartzite contains small porphyroblasts of garnet in argillaceous units from near Upson westward. Basalts are altered to amphibole-bearing assemblages, and near the western edge of the area are, in part, thoroughly recrystallized to pyroxene hornfels that contain stringers of granophyric granite interpreted to have originated by partial melting of the basalt.

Nearly all previous workers believed that the metamorphism in the western part of the area was caused by emplacement of the Mellen Intrusive Complex. We question whether these intrusive rocks are an adequate source of heat. Although a general correspondence exists between the area of most intense metamorphism and the Mellen Intrusive Complex, the correspondence is not strong in detail. A metamorphic aureole less than one kilometer wide been mapped around the Potato River intrusion (Cooper, 1973). We have observed similar relations around the Mineral Lake intrusion. Metamorphism of the Tyler Formation detectable in field observations is limited to a narrow zone no more that a few hundred meters wide beyond which metamorphic grade quickly diminishes. Similar relations also are seen in some areas where basalts seem to show only low-grade burial metamorphic assemblages only a short distance from their contact with the intrusion. In contrast, strongly metamorphosed iron-formation occurs as much as 5 km away from the Mellen Intrusive Complex, and the most intensely metamorphosed Middle Proterozoic volcanic rocks extend even farther from the complex. The 250 oC isotherm mapped by Cannon and others (1993b) can be projected westward so that it passes stratigraphically upward into Early Proterozoic rocks near Upson. It appears that this hotter-to-the-south gradient is responsible for the metamorphism of Early Proterozoic rocks in contrast to a hotter-to-the-north gradient as would have been the case if metamorphism were a result of emplacement of the Potato River intrusion. Considering all of these features, we suggest that the metamorphism in the western part of the map area is a result mostly of a high heat flow from some unknown source south of, or originally below, the presently exposed rocks. The Mellen Intrusive Complex was of secondary importance and produced metamorphism only in a narrow contact aureole.

MINERAL RESOURCES

Iron

The map area contains part of the Gogebic iron range, one of the Lake Superior region's major iron-producing districts. Between the 1880's and the 1960's, more than 300 million tons of ore were produced from the range, of which roughly 200 million tons were produced from the map area. Major mines extended westward to Montreal, Wis., and lesser production came from as far west as Iron Belt, Wis. Ore consisted of secondary concentrations of iron oxide and hydroxide minerals within the Ironwood Iron-Formation and was formed where deeply circulating meteoric waters leached silica from the iron-formation. Leached and oxidized rocks extend for more than 2 km below the present surface. Production ceased in the early 1960's as deposits became depleted, as mining of progressively deeper ores became uneconomic, and as pelletized iron concentrates became favored by iron and steel manufacturers. Although some ore remains in the ground, foreseeable production is unlikely.

The map area contains large resources of concentrating grade iron deposits. Part of the Gogebic iron range from Upson, Wis., westward to near Mineral Lake consists largely of magnetic iron-formation part of which is amenable to beneficiation. An analysis of available mapping, drilling, and beneficiation tests indicates that a resource of 3.7 billion tons of ore on the basis of economic and technologic parameters of the mid-1970's (Marsden, 1978). This material was believed to be economically extractable by open-pit mining and amenable to magnetic concentration with recoveries of 30 to 35 percent Fe304. A larger tonnage of similar material exists downdip but would require underground mining.

Near Pine Lake, about 20 km south of Hurley, Wis., a minable deposit consisting of 200 million tons of iron-formation was estimated (Marsden, 1978) with magnetic recovery of 25 to 30 percent Fe304.

Sediment-Hosted Copper

Basal beds of the Nonesuch Formation host major copper deposits (chalcocite and native copper) in Michigan, mostly east of the map area. The principal deposit is at the White Pine mine, about 30 km to the east (see summary by Cannon and others (1995)). An additional important, but as yet unmined, deposit is in the Presque Isle syncline, also mostly east of the map area, but projecting into it in secs. 1 and 2, T. 49 N., R. 45 W. We have observed mineralization in the basal Nonesuch Formation as far west as sec. 8, T. 48 N., R. 48 W., where individual hand specimens contain as much as 6 percent copper. From the Montreal River westward no significant mineralization is known.

Magmatic Copper-Nickel

Copper and nickel sulfides, mostly chalcopyrite and pentlandite, are concentrated in places in the Mineral Lake intrusion and were the target of mineral exploration in the late 1950's. In secs. 12 and 13, T. 44 N., R. 4 W., a zone of mineralization can be traced by drill core and surface exposures for about 1.5 km. It varies from 100 to 200 m thick and is variably mineralized with maximum grades of about 0.8 percent copper and 0.2 percent nickel (Bakheit, 1981). The host rock is olivine-bearing gabbro that forms the basal zone of the Mineral Lake intrusion. The deposit is similar to the much larger deposits in the Duluth Complex in Minnesota (Weiblin, 1982).

Native Copper

Middle Proterozoic volcanic and sedimentary rocks are possible hosts for native copper, and the map area was considered to have strong potential for undiscovered deposits by White (1978),although few direct indications of mineralization are known. The Middle Proterozoic rocks in the map area are correlative with rocks that host the major native copper deposits of Michigan's Keweenaw Peninsula. The nearest significant mine in Michigan is about 50 km east of the map area in rocks of the Portage Lake Volcanics (Cannon and others, 1995). Less important mineralization, which supported some small mining operations, extends to about 10 km east of the map area. Native copper mineralization also is known west of the map area, in the Chengwatana Volcanics, where numerous uneconomic native copper concentrations have been discovered, mostly in the late 1800's (Grant, 1901).

Within the map area few indications of native copper mineralization are known. Some very old prospecting and attempts at small-scale mining are known in felsite of the Porcupine Volcanics at Copper Peak in sec. 32, T. 49 N., R. 46 W., and we have observed minor malachite staining on joint surfaces in basalt in a nearby quarry.

In exposures of the Copper Harbor Conglomerate along the gorge of the Montreal River, there are areas as much as about 10 m in diameter in which the generally reddish conglomerate is bleached to tan or white. Within the bleached areas malachite staining is rather common, mostly on the outer surfaces of pebbles, but we have not identified a primary copper mineral. A short adit has been driven into the western wall of the gorge in that same area but we found no mineralized rocks there.

Along the Potato River, a short adit penetrates the uppermost basalt of the Portage Lake Volcanics and at Copper Falls on the Bad River an adit intersects basalt near the top of the Kallander Creek Volcanics. Significant copper mineralization is not evident at either of these locations.

Although the scarcity of outcrops in most of the area of volcanic rocks precludes a definite conclusion, we believe that the probability of significant native copper mineralization in the map area is low.

Stone

Gabbro, granite, sandstone, and marble have been produced from quarries within the map area.

Gabbro- Gabbro and gabbroic anorthosite, so-called black granite, were quarried to produce construction and decorative stone near Mellen, Wis. until the 1960's. Quarries are inactive, but large amounts of similar rock remain if new markets develop.

Sandstone- Ferruginous sandstone in the Bayfield Group was quarried at numerous localities on the Bayfield Peninsula and Apostle Islands in the late 1800's and early 1900's during the era of brownstone construction in the Eastern U.S. There has been no production since about 1910.

Granite- Several small and long inactive quarries are in granite and granophyre in the Mellen Intrusive Complex.

Marble-Marble for dimension stone was produced in the 1930's from several quarries in the Bad River Dolomite along the Marengo River near the western edge of the area. The siliceous and tremolitic nature of the rock may be deleterious for some industrial uses.

ACKNOWLEDGMENTS

Walter S. White, in the 1970's, late in his USGS career, had gathered and partly compiled regional data on Middle Proterozoic rocks of northern Wisconsin. That unpublished work is incorporated here and forms a foundation for our current investigations.

Michael G. Mudrey, Jr. and Bruce A. Brown of the Wisconsin Geological and Natural History Survey provided access to a wealth of unpublished data on file at that organization's office in Madison, Wis. and to drill core at their core repository in Milwaukee, Wis.

Various aspects of field work were conducted by Gene L. Laberge, John S. Klasner, Martha Daines, and Klaus J. Schulz, in addition to the authors.

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