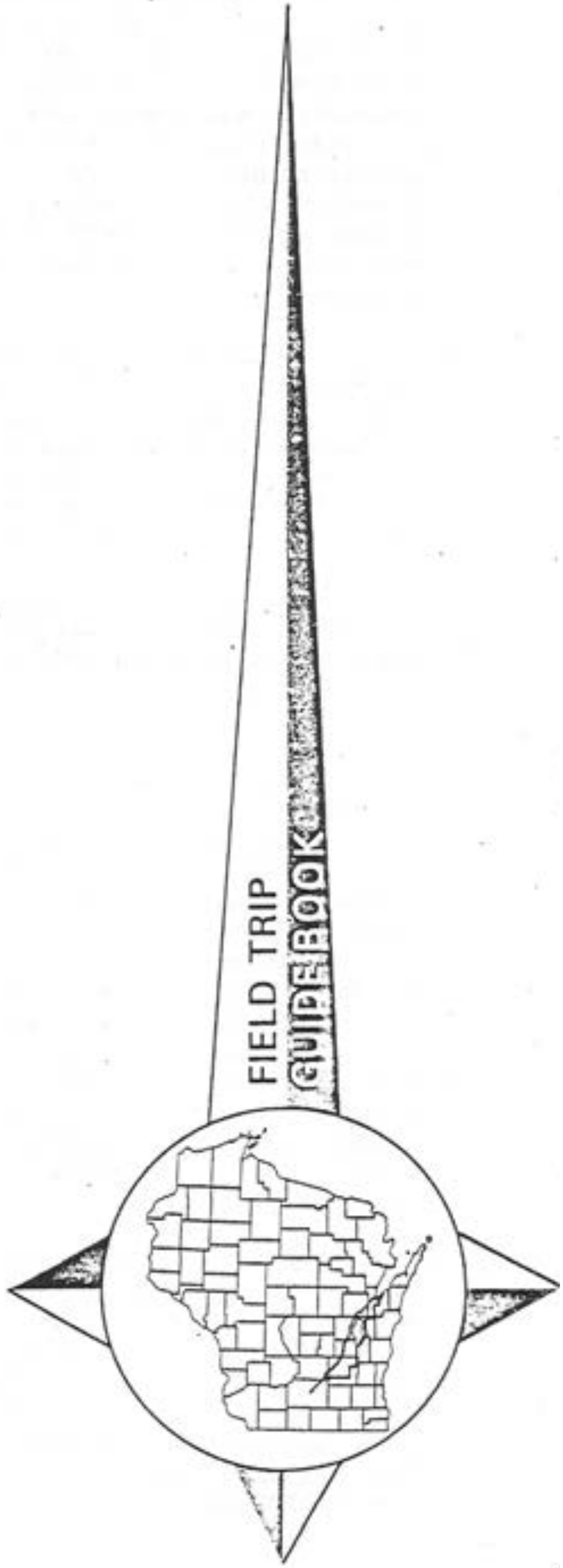
THE OOLITIC NEDA IRON ORE (UPPER ORDOVICIAN?) OF EASTERN WISCONSIN



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Introduction

The Neda Iron Ore, a red hematitic oolite, occurs at the Ordovician-Silurian boundary in Wisconsin and surrounding states. The oolite is composed of flattened ferruginous ooids whose shape prompted its early designation as "flax seed" or "seed" ore. Occurring in a few small localized deposits, the Neda exhibits a widespread patchy distribution throughout eastern Wisconsin (fig. 1). Because of its patchy distribution and its weak resistance to erosion, natural exposures of the Neda are extremely rare. The Neda overlies the Brainard Shale Member of the upper Ordovician Maquoketa Shale and underlies the lower Silurian Mayville Dolomite (fig. 2). The variable thickness of the Neda is due primarily to a significant unconformity at its upper surface. Its contact with the underlying Brainard has been interpreted as gradational by some authors and unconformable by others. Originally considered Silurian in age, the Neda is now thought to be late Ordovician although conclusive proof is lacking. Both the origin and depositional environment of the oolitic Neda are still under debate and a variety of theories concerning these aspects of the unit have been proposed.

The purpose of this fieldtrip is to examine the important Neda exposures in Wisconsin. In the guidebook we have included details for specific localities from older descriptions, many of which are from unpublished fieldnotes or theses or from obscure published sources. These descriptions provide information about outcrop features that are no longer visible, but critical to understanding the basis for previous interpretations of the Neda. A section on the history of the mining operations at Iron Ridge is also included.

We would like to dedicate this guidebook to the late Katherine G. Nelson and to Richard A. Paull, who introduced us to the mysteries of the Neda when we impressionable young undergraduates.

Age of the Neda

The age of the Neda is not known with certainty. Originally it was considered Silurian in age because of its lithologic similarity to the Clinton iron ore of New York. Referring to the ore at Iron Ridge, I. A. Lapham (letter to James Hall, Aug. 12, 1850) was the first to note this similarity, but he was unsure of the ore's "geologic place". Later (letter to Mrs. Lapham, Oct. 15, 1851) Lapham decided that "its geologic position is the same as the iron of the Clinton Group of New York and the Iron Ridge of Wisconsin is but a continuation of the Mountain ridge [Niagara Escarpment] of Western New York". Hall (1851) also believed that the Wisconsin ore was indistinguishable from that of the New York Clinton, and he placed the overlying limestone and uppermost beds of the underlying shale into the Clinton as well, even though neither could be seen in contact with the ore at Iron Ridge. Both Hall (1851) and Whittlesey (1852) recognized that most of the underlying shale belonged to the "Hudson River Group (now Maquoketa Shale), but Whittlesey (19852) and Hall (1862) continued to refer to the ore as Clinton in age.

Chamberlin (1877) called the ore at Iron Ridge the Clinton Iron Ore because of its lithologic similarity to the Clinton of New York and elsewhere. By this time the stratigraphic relationships of the Neda were well known and Chamberlin realized that assigning a Clinton age to the ore meant that a substantial portion of the underlying Silurian had to have been missing even though no evidence for such a marked unconformity existed. Chamberlin obtained some Cincinnatian age fossils from the ore at Iron Ridge, but he assumed they had come from underlying Cincinnatian shale that was mixed with and stained by the ore becuase of glacial disturbance of the beds.

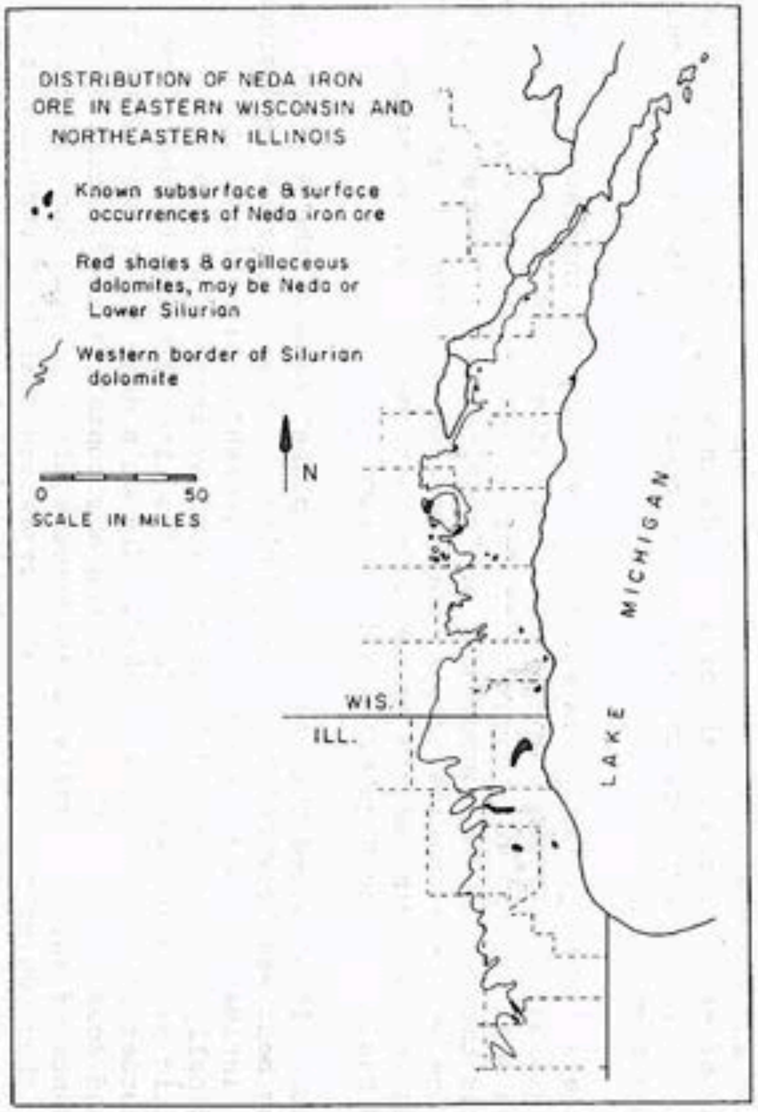


Fig. 1. Distribution of Neda in eastern Wisconsin and northeastern Illinois (modified from Mikulic, 1979).

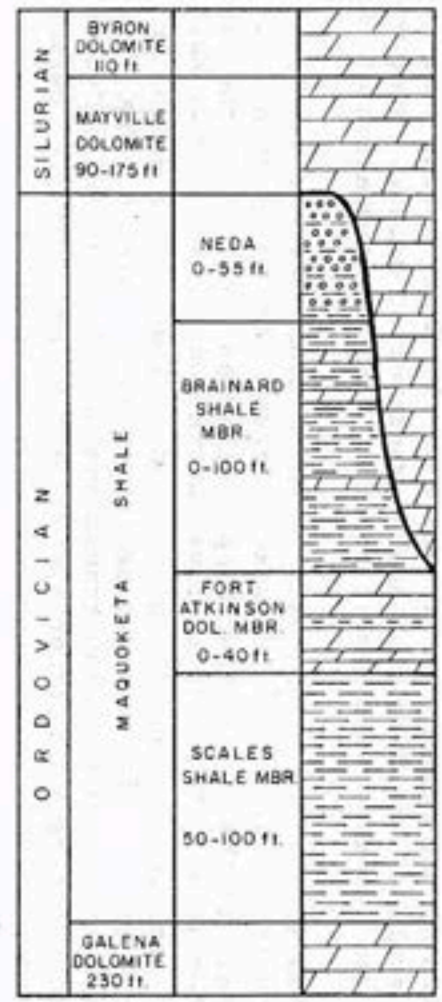


Fig. 2. Stratigraphic column of lower Silurian-upper Ordovician rock units discussed in text.

Savage (1916) demonstrated that the Mayville Dolomite was "Alexandrian" in age and thus much older that the Clinton Group of the Appalachians, implying that the Neda, which was overlain by the Mayville, could not be assigned a Clinton age.

Macrofossils were found in the lower portion of the Neda at Katell Falls by Savage and Ross (1916) who considered them to be Maquoketa in age. They also reported an unconformity at the base of the Neda, noting that it rests "on different levels of the Maquoketa Shale" wherever it occurs. They proposed the name Neda Iron Ore as a replacement for the Clinton designation of this unit.

Thwaites (1923) placed the Neda in the Medinan Series, and Ulrich (1924) put the Neda in the Ordovician Maquoketa Group. Twnehofel et al. (1954) designated the Neda Shale of the Upper Mississippi Valley as a member of the Ordovician Maquoketa Formation. The Neda in Iowa (Brown and Whitlow, 1960; Whitlow and Brown, 1963) and in Illinois (Templeton and Willman, 1963; Buschbach, 1964) has been assigned to the uppermost Maquoketa; however, Workman (1950) suggested that it was part of the Silurian transgression. In Wisconsin, Ostrom (1967) did not assign the Neda to either system because he considered definite proof of age lacking.

Mikulic (1979) noted that the presence of Ordovician fossils in the Neda is not conclusive proof of age since they could have been reworked from the underlying Brainard Shale. He found occurrences of Brainard-like sediments overlying the Neda in a few areas, however, suggesting that the Neda may be part of Maquoketa deposition. The presence of a pronounced unconformity between the Mayville and Neda was thought to demonstrate that the Neda was not part of the early Silurian transgressive sequence. Mikulic concluded that unless Silurian fossils are found in the Neda it should be considered Ordovician in age considering the presence of Ordovician fossils and the marked unconformity at its upper surface.

Depositional Environment

The major unresolved problem concerning the Neda involves its environment of deposition and diagenetic history. Several significantly different proposals have been offered for the origin of the Neda in Wisconsin and surrounding states; however, conclusive evidence for any one of these is lacking and no general consensus has been reached.

Daniels (1858a, b) made the earliest environmental interpretation of the Neda in Wisconsin, stating simply that it was of aqueous origin. He observed that the "flax seed" grains were concretions formed around siliceous nuclei, and attributed their flattened appearance to "gravitation". Chamberlin (1877) considered the oolite of marine origin, and the widely scattered nature of the Neda exposures in Wisconsin led him to conclude that the Neda was deposited in detached basins on the Maquoketa Shale surface.

Grabau (1913) noted that and "erosion plane" between the Maquoketa and overlying beds was "covered by shale pebbles which have a pronounced glossy surface, intimately suggestive of desert varnish". He believed that the oolite was originally calcareous and later replaced by iron. The form and structure of the oolitic ore bodies suggested "dunes of oolites similar to those now forming on the border of the Great Salt Lake". Grabau's dune theory was challenged by Savage and Ross (1916). They cited the horizontal stratification of the ore and presence of marine fossils as evidence against an arid dune formation; however, they concurred with Grabau's suggestion that iron replaced originally calcareous oolites. Savage and Ross believed that the Neda was deposited in "local but apparently connected basins (because of the marine fossils) during late Maquoketa (Richmond) time, and after the main portion of the normal main Maquoketa sea had withdrawn from the greater part of the region farther south in the Mississippi Valley".

In unpublished fieldnotes made in 1914, E.O. Ulrich noted that the Maquoekta and the Neda seemed conformable although he found shale pebbles mixed in the basal Neda. He proposed that elevation, possibly but not necessarily, accompanied by gentle downwarping drained the Maquoketa seas locally, and suggested that the Neda was deposited during shallow resubmergence of certain depressed areas in the Maquoketa Shale seas or in newer downwarps. Ulrich did not believe that the Neda was ever a widespread deposit, the bulk of which had been removed by pre-Mayville erosion even though evidence for considerable erosion existed at the top of the ore bed. Alden (1918), on the other hand, suggested that the Neda had had a more extensive distribution, but much of it was removed prior to Mayville deposition.

Rosenzweig (1951) mentioned cross-bedding, ripplemarks, fragmentary ooids, and shale clasts in the Neda as evidence of shallow water deposition. He proposed that compaction caused the flattening of the ooids and suggested that the hard ore layer at the top of the Neda may have been residual.

According to Paull's (1977) environmental interpretation, contemporaneous deposition of calcareous oolitic bars, similar to those now forming in the Bahamas, and "normal" Maquoketa occurred as the Maquoketa seas began to shoal. He concluded that replacement of these calcareous ooids by iron took place almost immediately after deposition, and suggested that the flattening of the ooids occurred while they were in a gel-like state during replacement, but he added that the ooids were firm enough to have been water-polished, resulting in their shiny varnished surfaces. He considered the presence of cross-bedding in the Neda and rip-up shale clasts at its base indicative of the high energy necessary for ooid genesis. Paull noted that subsequent erosion may have eliminated Neda oolite bars elesewhere in eastern Wisconsin although the bars at Iron Ridge persisted as topographic highs during early Silurian transgression. He considered the "dense ore" at the top of the Neda in places as representing a residual layer formed during the erosion interval.

Mikulic (1979) observed that calcareous oolites occur at the same stratigraphic horizon as the hematitic Neda (and its equivalents) in the upper Ordovician-lower Silurian of the central United States (fig. 3). He suggested that although these units may not be synchronous they may represent a similar depositional environment during periods of regression and transgression over a surface with major variation in topography. The absence of reworked Neda oolite in areas outside of the immediate vicinity of known ore bodies indicated to Mikulic that the Neda was not a remnant of a once more extensive sheet-like deposit. He believed that the Neda may have formed by shoaling on or around topographic highs on the Brainard surface. Based on its oolitic composition and cross-bedding and mounding in the ore, he invoked a high-energy depositional environment for the Neda. He added that this mounding could also have resulted from erosion, evidence for which is suggsted by thehard ore band at the top of the Neda. Mikulic further suggested that the complex environmental relationships between the Brainard, Neda, and overlying Silurian carbonate buildups, and "normal" Mayville may reflect a series of regressive-transgressive episodes associated with late Ordovician-early Silurian glacio-eustatic sealevel fluctuations described by Berry and Boucot (1973) and Sheehan (1973). Synowiec (1981) considered the hard ore layer at the top of the Neda to be a laterite formed during pre-Mayville regression and erosion.

Fig. 3. Distribution of calcareous and hematitic oolites at the Ordovician-Silurian boundary in the central United States. (from Mikulic, 1979)

Hawley and Beavan (1934) and Beavan and Hawley (1934) addressed the problem of a source for the iron. They found fragments of metamorphic rocks and intermediate or basic lava in the ore, suggesting to them that the iron was supplied by chemical weathering of a Precambrian terrain to the northwest. A primary origin for the ooids from a colloidal gel was suggested, and the hematite matrix was considered a prouduct of secondary reorganization of iron oxides. They and Johnson (1932) discussed ooid composition also.

In recent paleomagnetic studies Kean (1981) suggested that the ooids originated in a nearshore environment during shoaling of the Ordovician seas, and were incorporated into iron-rich muds either contemporaneously or shortly after their formation. Kean concluded that the source of these muds was possibly the Queenston delat to the east or weathered crystalline rocks of the western trans-continental arch, and he found a similar paleomagnetic pole position (S.45.4°, W.48°), considered of Permian age, for both the Neda and the Queenston. This disparity between the known time of Neda deposition and the time of magnetization was attributed to dehydration of goethite in the Neda during late Mississippian-early Permian tectonic uplift which produced the present hematitic matrix affecting the remanence.

In summary, the following questions concerning Neda origin and deposition remain to be answered.

1. Did the ooids originate as primary iron ooids, or were they originally carbonate ooids which were subsequently replaced by iron?

2. Did the oolite form in a high energy shoaling environment or did it originate from colloidal gel in quiet water, or by some other means?

3. What was the source of the iron and when was it emplaced?

4. Is the existing Neda only a remnant of a once more extensive deposit, or was it originally deposited in localized areas?

5. Was the Neda deposited in basins or on topographic highs on the Maquoketa surface?

6. Does the "hard ore" or any other portion of the Neda represent a laterite, soil, or other weathering product?

Stop 1. The Iron Ridge Area

The Iron Ridge in Dodge County contains the best and perhaps the most significant Neda exposures in the midwestern United States. The Iron Ridge (not to be confused with the present village of Iron Ridge, 1.5 miles south of Neda) refers to the southern half of a 3.5 mile westward-facing segment of the Niagara Escarpment running from near the northwest corner of section 36 (T.12N., R.16E.) south to the center of section 13 (T.11N., R.16E.)(fig. 4). This portion of the escarpment may be an outlier as is suggested by its abruptly terminatednorthern and southern ends. The northern half of the escarpment is about 100 feet high at its western edge and is the site of the Mayville White Lime Company quarry and the type section of the Mayville Dolomite. Neda exposures have never been reported here and it is known to thin or absent in the subsurface throughout this northern section. This portion of the escarpment is separated from the Iron Ridge by a largeeastward-trending gap in the vicinity of Wis. Hwy. 33.

Iron Ridge proper runs from the center of section 13 to just north of the center of section 12 in Hubbard Township. The ridge is about 60 feet high and an almost continuous exposure of 10-20 feet of Mayville Dolomite runs along its crest. Where the talus at the base of the ridge has been cleared by mining nearly 40 feet of Mayville is exposed. Several northeast-southwest trending deposits of Neda are present, reaching a maximum thickness of 37 feet, but averaging 10-15 feet in thickness (see Rosenzweig, 1951; Paull, 1977). The early descriptions of the ore by Hall (1851), Whittlesey (1852), and Percival (1855) suggest that the Neda did not originally outcrop along the ridge, but was observed first in talus along the base of the escarpment, in soil to the west, and in drift deposits. The Mayville Mine area contained the largest drift deposit, with the Neda covering the entire 60-foot escarpment. Drift ore was also found at an abnormally high elevation at the southern end of the escarpment. The loose drift ore at these locations was easily excavated and both drift bodies were mined before stripping or underground operation were commenced. Both Hall (1851) and Whittlesey (1852) recognized that these occurrences were not depositional but resulted from "diluvial forces" which concentrated the ore. Chamberlin (1877) correctly determined that the Mayville Mine drift deposit was due to Pleistocene glaciation. The anomalous exposure of Brainard in road ditches south of the ridge and the disturbed ore at the Paint Pit, to the northwest, are probably glacially controlled occurrences as well. The upper portion of the Neda and its contact with the overlying Mayville are well exposed at several areas in the mines along the ridge; however, the lower few feet of Neda and the contact with the underlying Brainard Shale are not visible except questionably at one exposure.

The Maquoketa Shale, excluding Neda, is about 220 feet thick in this area. The contact between the Maquoketa and underlying Galena Dolomite occurs at an

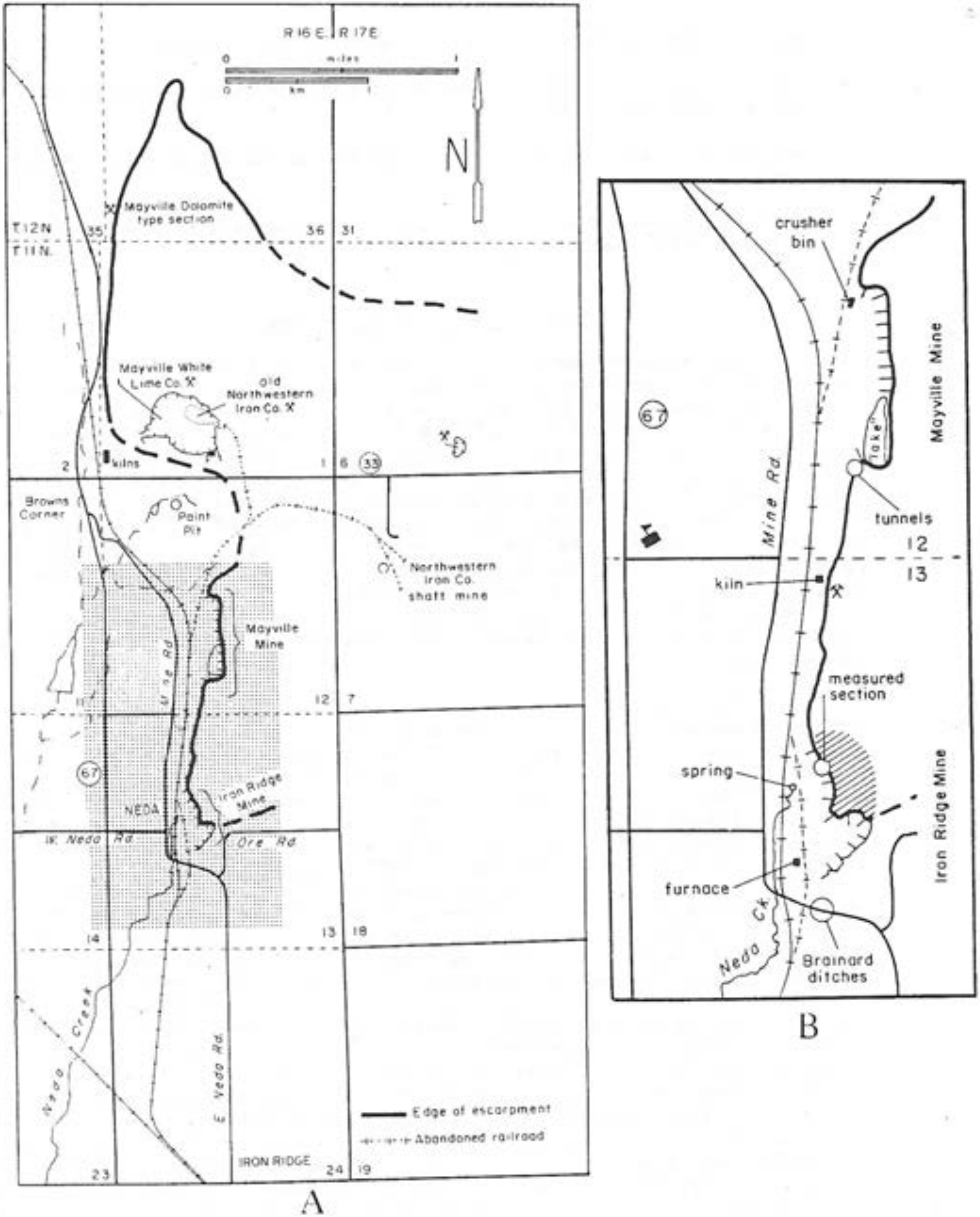


Fig. 4. A, Map of Iron Ridge area showing localities at Stop 1. B, Enlargment of the Iron Ridge portion of the escarpment (stippled area in A) showing location of features discussed in text. Diagonal line pattern indicates area of underground mining.

elevation of about 830 feet at the village of Iron Ridge (NE¼, NW¼, sec. 25) to the south and also at the Southview School (SW¼, SW¼, SW¼, sec. 12) about 2000 feet west of the Mayville Mine. The elevation of this contact drops to 735 feet at Mayville, four miles to the north.

Mining at Iron Ridge was for the mostpart confined to two locations, the Mayville Mine (commonly referred to as the Northwestern Iron Company open pit), which operated from 1849-1913, and the Iron Ridge Mine (often called the Oliver Mine) which ran from 1865-1914. Nearly all the exposures of Neda in the ridge are found at these two sites, although the outcrops are much reduced from what they were during active mining. The underground exposures at the Iron Ridge Mine are poor and very dangerous (Synowiec, 1981). Two other sites in the vicinity of the Iron Ridge, the Paint Pit and the Northwestern Iron Company shaft mine were short-lived operations that contributed little to the study of the Neda. The shaft mine is now flooded, and only a small, badly slumped exposure exists at the Paint Pit.

Descriptions of specific localities in the Iron Ridge area follow, and a detailed history of the iron mining operations is presented in a separate section of the guidebook.

Brainard exposures

NE cor., SW¼, NE¼, SW¼, sec. 13, T.11N., R16E., Hubbard Twp., Dodge Co., Wis. (Mayville South 7.5' quadrangle). Brainard Shale exposures in roadside ditches on E. Neda Rd., just west of the crest of the hill. Elevation at top of exposure is approximately 1030 feet.

Roadside ditches expose Brainard Shale consisting of weathered shale, siltstone, clay, and dolomite. Fossils, predominantly brachiopods and bryozoans, are common. A number of authors (Shrock, 1930, unpublished fieldnotes; Thwaites et al., 1937; 1947; Rosenzweig, 1951; Paull et al., 1977) have briefly described this exposure. These exposures do not appear to represent an in situ bedrock outcrop, but rather several factors suggest that this is glacially transported material. Most significantly, the top of this Brainard exposure is situated approximately 20 feet above the top of the Neda exposed in the escarpment a short distance to the north. Also, test pits described by Percival (1955) between this road and the south end of the escarpment, one eighth mile to the north, showed that the hill consisted of drift ore of varied thickness covered by dirt (see fig. 5). Percival did not think this ore was in place and suggested that it had been disintegrated and concentrated by water action like the original occurrence at the Mayville Mine. We do not believe that this is an in situ outcrop of Brainard Shale, but along with the drift ore to the north, is simply debris excavated by a southward-moving glacier and piled up in a low area south of the escarpment.

Iron Ridge Mine (Olive Mine)

Located primarily in S½, SE¼, SW¼, sec. 13, T.11N., R.16E., Hubbard Twp., Dodge Co., Wis. (Mayville South 7.5' quadrangle), just east of the village of Neda. Strip mine and underground workings in Iron Ridge. Elevation at highest point of escarpment is approximately 1070 feet.

This locality was originally referred to as Sterling because of the steam sawmill and spring owned by Theodore Sterling at this site. Based on an 1849 visit Whittlesey (1852) illustrated a section of the ore near the sawmill (fig. 6). In an excavation he found 15.5 feet of ore overlain by limestone rubble,

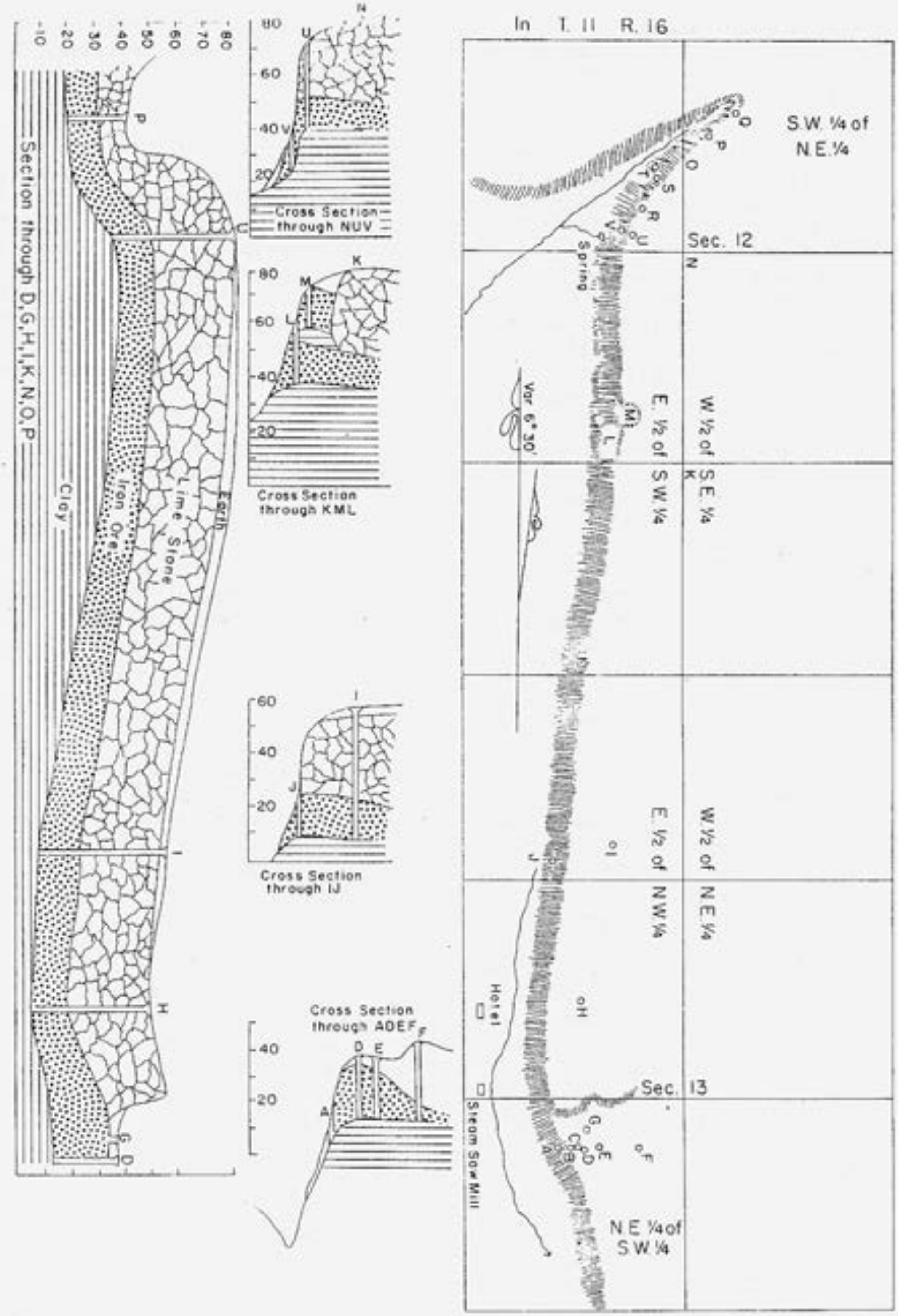


Fig. 5. Percival's (1855) diagram showing location of test pits (open circles) and Mayville Mine (L, M). Cross-sections show original occurrence of drift ore and in situ ore along the escarpment.

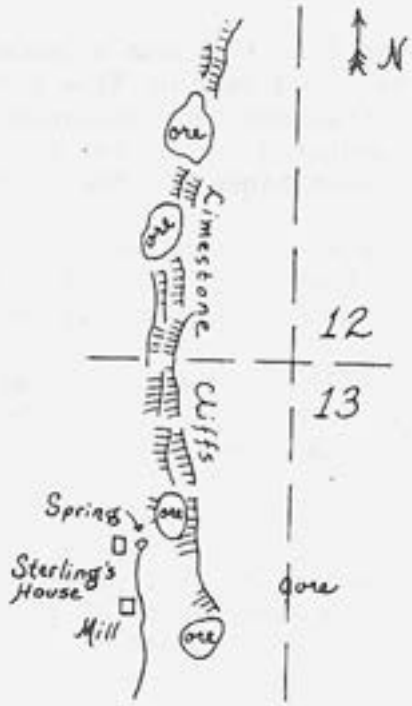


Fig. 6. Map made by C. Whittlesey in 1849 fieldnotes showing original ore concentrations along Iron Ridge.

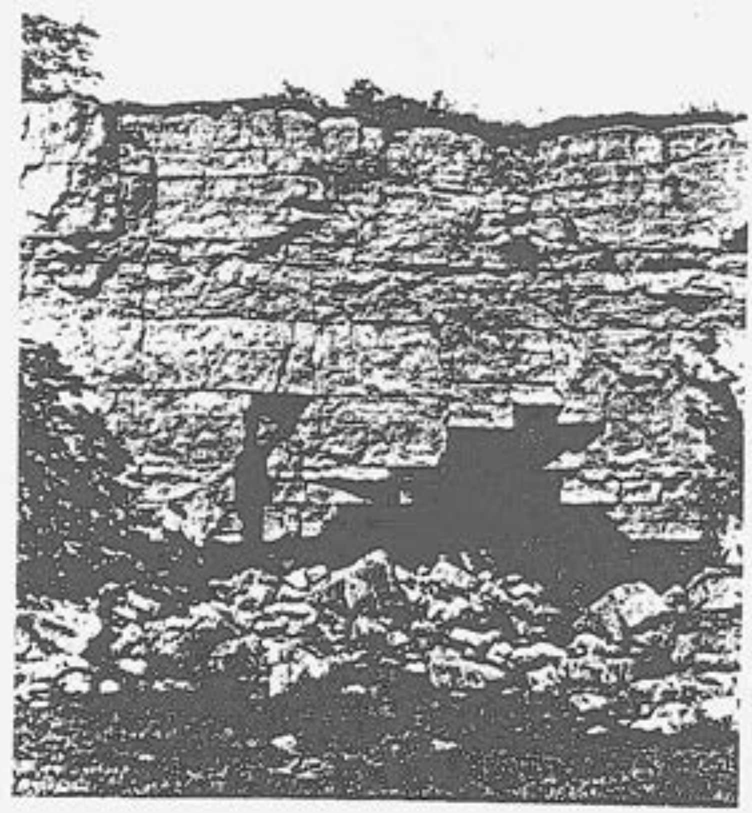


Fig. 7. Mine entrance to Iron Ridge Mine where measured section was made (see fig. 4B). Photo shows 30 feet of Mayville overlying 4 feet of Neda (contact at notebook) (Photo by R.R. Shrock, 1930, Milwaukee Public Museum No. 155526)

which would suggest that the exposure he examined was a body of loose weathered ore. He described the gray-yellow limestone exposed in the bluff as granular and unfossiliferous, making good lime.

Hall's (1851) description also suggests that this was a deposit of weathered ore and not in place as he had thought. He found four or five feet of ore "presenting the appearance of a regular, continuous bed, surrounded by a mass of pebbles and fragmentary rocks, accumulated during the drift epoch", and noted that the limestone outcropped 20 feet higher in the section.

Percival (1855) observed 15 feet of ore at the southern part of Iron Ridge at the village [Neda], where he noted that a furnace was to be erected. He also found a large deposit of loose ore on the south end of the ridge.

The ore was observed by Chamberline (1877) to be 15-25.5 feet thick and to occur in regular horizontal beds ranging from three to 14 inches in thickness and dipping slightly. He referred to this locality as the Iron Ridge mining property.

Alden (July 27, 1909 fieldnotes) visited this locality, which was then the property of the Oliver Mining Company, and found that paint was manufactured there. In an "old open cut mine" at this site Alden found 30 feet of rough textured, partly cherty limestone overlying about six feet of ore, harder in its upper 1-1.5 feet, and in an abandoned drift he found 9-10 feet of soft ore exposed.

Ulrich made a brief section in his 1914 fieldnotes which showed a "black leached ore reworked at the time of Mayville onlap" overlying partly decomposed, ocherous oolitic ore and unleached oolitic ore. The ore was overlain by 20 feet of Mayville Dolomite, cherty near its base.

Shrock made a section in his 1930 fieldnotes and found four feet of cross-bedded ore exposed with a 4-12 inch layer of hard ore, conglomeratic in places, at the top. The Neda was overlain by more than 30 feet of Mayville Dolomite.

The general plan of the underground mine workings was described by Rosenzweig (1951). He noted that 20 feet of ore was present underground while four feet of soft ore was exposed at the surface. The lower shaley portion of the Neda was not visible there. He found angular clayey and calcareous fragments and hematite pebbles in the hard ore layer and noted a suggestion of cross-bedding in the soft ore. The contact with the overlying Mayville was observed to be sharp and undulating, exhibiting up to two feet of relief.

Paull (1977) figured an exposure at this mine, and Elger (1979) presented a composite section of the Mayville Dolomite from this locality and the Mayville Mine. Synowiec (1981) provided petrographic data for the Neda from this area.

The Neda is well exposed at only one tunnel entrance at the Iron Ridge Mine (fig. 7) and the following section was measured there.

Mayville

Unit 1. 10.5 ft. (3.15 m) Vuggy, fine crystalline, grayish orange dolomite, weathering with granular texture.

Unit 2. 6 ft. (1.8 m) Thin-bedded, rubbly-textured, fine crystalline, grayish orange dolomite with thin clay layers, patches of white chert at top.

Unit 3. 15.5 ft. (4.7 m) Very dense, fine crystalline, grayish orange dolomite with reworked ferruginous ooids and much iron staining at the base, fossiliferous. Very irregular lower contact.

Neda

Unit 4. 3 in. (7.62 cm) "Blue band". Very dense, nonporous, blackish red, compact hematite with a few scattered ferruginous ooids and patches of specular hematite. Very irregular lower contact which cuts down well into Unit 5.

Unit 5. 3-8.5 in. (7.6-21.6 cm) Dark reddish brown hematitic oolite. Upper portion is conglomeratic looking with clasts of hematite, oolite and phosphatic nodules. Lower portion is oolitic hematite with some shale, horizontally bedded. Undulating lower contact.

Unit 6. 1 ft. 8.5 in. (5.2 m) Moderate brown hematitic oolite, well indurated, bedded, very little shale present. Base covered. Upper surface forms depression in which Unit 5 is deposited.

Mayville Mine (Northwestern Iron Company Open Pit)

E½, SW¼, sec. 12, T.11N., R.16E., Hubbard Twp., Dodge Co., Wis. (Mayville South 7.5' quadrangle). Abandoned strip mine and water-filled pit ("lake"), three-fourths mile north of Neda and four miles south of Mayville. Elevation at highest point of escarpment is approximately 1110 feet.

This abandoned open pit mine of the Northwestern Iron Company, historically referred to as the Mayville Mine, was originally dug into a natural gap in the western face of the escarpment. This segment of the escarpment is about 60 feet high and currently exposes approximately 40 feet of Neda and Mayville Dolomite. The base of the Neda and part of the underlying Brainard Shale were once well exposed during mining, but both are now obscured. The first ore was extracted from this mine in 1846 or 1847 (Bartsch, 1947; 1972), and mining continued here until 1913 when a new shaft mine was opened one mile to the east.

Many prominent geologists have visited this exposure, and it has greatly influenced ideas about the depositional environment of the Neda and Mayville. Hall (1851) was the first to mention the ore at this locality in the geologic literature, noting that "the superincumbent limestone recedes to the eastward, and in a bend thus formed, an extensive ore-bed has been opened,by simply removing the soil. It is in a loose and incoherent condition, like some of the beds in this association in Oneida County, New York. I was unable to detect any rock in connection with the ore, the under surface of the bed not being visible".

Whittlesey (1852) made similar observations based on an 1849 visit of the early-exposed features of this outcrop, stating that where "the Wisconsin Iron Company take out their ore, the hill appears to be all ore for 60 feet in height. The surface ore is here mined almost as readily as sand or loose earth, only stripping the soil and taking out the roots that are intermingled with it." Whittlesey also observed that "the upper and external part of the bed have evidently undergone movements, apparently some great diluvial force, from the westward, pushing the outcropping mass up the hill, wherever its face was not too bold." As evidence, he described "lines of deposition" in the ore which were "inclined and curved following the form of the hill up and down its western slope." He found that the ore itself was loose and weathered, mixed with some lumps of clay and marl which he thought resembled the marls in the "Cincinnati blue limestone." Whittlesey believed that as the excavation was deepened the loose ore would "doubtless change to a more compact and stratified mass lower down the hill, like that seen at Sterling's Spring" [Iron Ridge Mine].

Percival (1855) noted that "at Iron Ridge, the ore bed underlies a line of bluff of the overlying limestone, about 30 feet high...interrupted for about a quarter of a mile at the Mayville ore bed..." He also observed that "at the Mayville bed in the cove between the two sections of the limestone bluff...the ore occurs loose and incoherent, but composed of small flattened grains...The ore here is arranged in layers, but less regularly than [at Iron Ridge Mine] with more clay intermixed, both in horizontal and vertical seams, and with interposed irregular beds and pockets of bluish joint clay and a yellow brown loamy drift with boulders of limestone; the whole presenting the appearance of a drift accumulation. The limestone and underlying ore may be supposed to have originally extended farther west, and to have been removed by the action of water, and the rock ore to have been disintegrated and then accumulated by eddies in the cove at the Mayville bed." He included a map (fig. 5) of Iron Ridge indicating the position of the Mayville Mine excavations (points L and M) and a cross section demonstrating the relationship of the "loose ore" to the bedrock in the escarpment. Cassels (1858) provided a chemical analysis of samples from the Mayville Mine.

At the time of Chamberlin's (1877) visit this pit was known as the Mayville Mine and was being worked in what was called the Mayville ore bed. He observed the Mayville Dolomite overlying undisturbed ore and separated from it by a layer of hard blue ore which he referred to as the "blue band." Chamberlin's diagram (fig. 8) of the pit shows that some of the Neda had been pushed to the southeast over undisturbed ore beds (which were first being uncovered at the time on his visit), accounting for the unusual thickness of the ore that Whittlesey (1852) observed. Chamberlin attributed this to Pleistocene glacial activity, supporting Whittlesey's (1852) earlier observations, if only in a mechanical sense. Chamberlin's diagram also shows the underlying "Cincinnatian"Shale rising to the north with Neda overlying it uniformly. Irving (1880) repeated some of Chamberlin's observations.

Alden (1918) described the pit as it appeared during a 1909 visit. He found that the Maquoketa Shale formed the floor of the pit and noted that "the lower face of the uppermost shale layer is covered with a very remarkable network of varied and curious forms, which may be of either organic or concretionary origin." Alden may have been referring to trace fossils which are

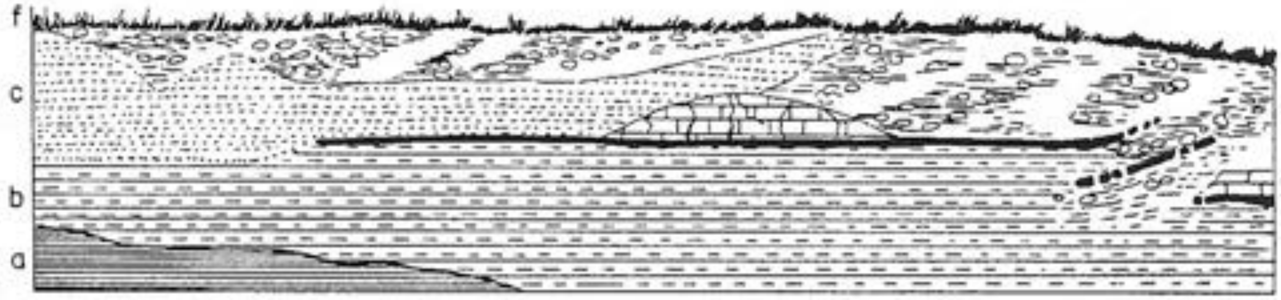


Fig. 8. Diagram of the Mayville Mine showing effects of glaciation on the drift ore (c), drift (f) and Mayville Dolomite (d) and their relationships to undisturbed ore (b) and Brainard Shale (a) (from Chamberlin, 1877).

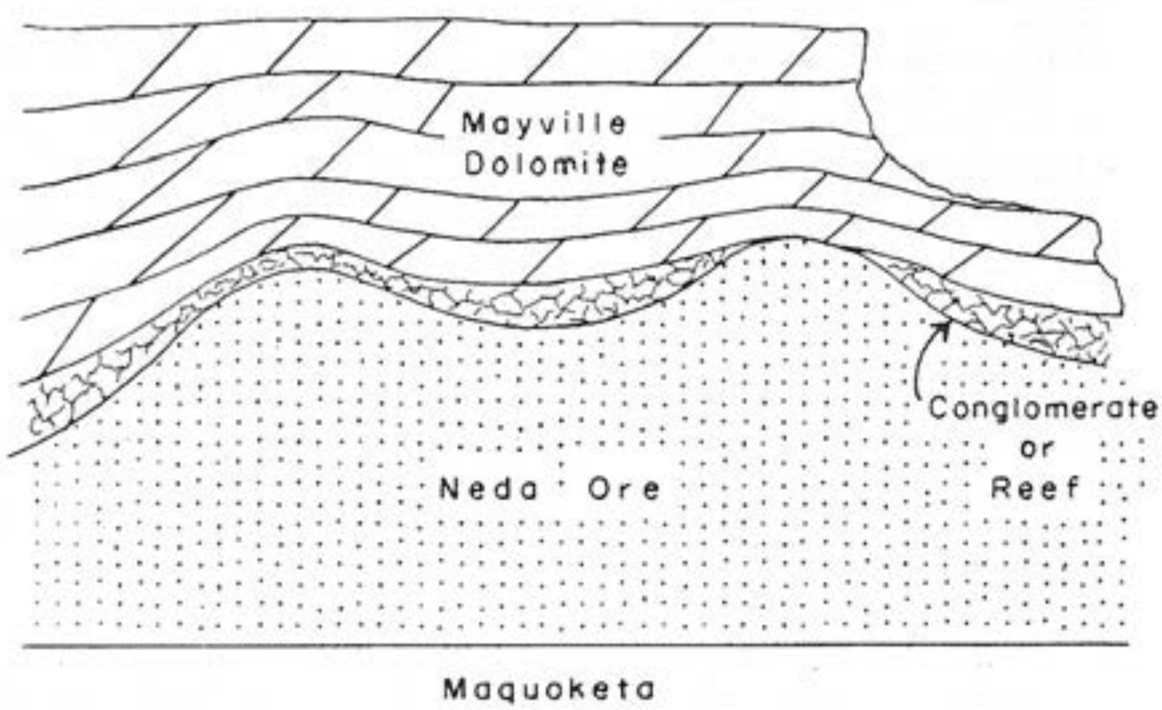


Fig. 9. Diagram showing relationships between the Neda and overlying Mayville Dolomite in south wall of Mayville Mine "lake" area (after E.O. Ulrich, 1914, unpublished fieldnotes).

present at that horizon at other localities. He also stated that "at the bottom of the ore bed and the top of the shale there is a hard purplish layer, partly indurated shale and partly ore. Reference is made above to the remarkable organic or concretionary structures on the lower side of this layer. Just above this the ore appears to be conglomeratic, containing pebble-like nodules of soft ocherous rock." He found the ore to be 15 to 25 feet thick underlying 10 to 25 feet of Mayville Dolomite. Alden also described and illustrated (1918, Pl XI, a, p. 81) an unconformity between the Neda and overlying Silurian just south of the open pit at the old tunnel entrances. He concluded that the limited distribution of the ore was due in part to pre-Silurian erosion.

Ulrich (1914, unpublished field notes) referred to the mine as the old Northwestern pit, and photos indicate that the pit was abandoned when he visited. He noted that the Neda was between 12 and 25 feet thick, and found that the Brainard-Neda contact seemed conformable except for small shale pebbles mixed into the basal inch or two of ore. His diagrams indicated that the upper surface of the Brainard was relatively flat and provided no evidence for a relationship between Brainard topography and the mounds of Neda he observed in the south wall of the pit. He was the first to recognize these mounds or hills of Neda over which the Mayville thins (fig. 9, 10). Ulrich noted that overlying the Neda mounds was 4 to 5 feet of conglomeratic dolomite with a ground-up ore matrix and pebbles of ore and well-rounded Mayville Dolmite pebbles up to 3 inches in diameter. Ulrich believed this to be an intraformational conglomerate "formed by the breaking up of partly consolidated inclined sediments near shore by waves." In the lower 6 to 8 feet of Mayville he found two horizons with lenses a few inches thick containing oolitic dark red ferruginous clay intermixed with iron-poor gray clay, which chemical analysis suggested to him was "bauxite possibly mixed with kaolin." On the westernmost Neda mound in the south wall Ulrich found a "conglomerate" or "coral reef" containing the tabulate corals Halysites and Amplexus; this is the first reference to the possible association of carbonate buildups with the Neda mounds. Ulrich also discovered a highly diverse fauna of small silicified brachiopods and bryozoans in rotten chert at the base of the Mayville in the southwest corner of the pit.

Savage and Ross (1916) described a section at the old ore pit near Neda (Mayville Mine) and illustrated the northern part of the east wall of the "lake" (fig. 11). They noted a "break in sedimentation" between the iron ore and the Maquoketa and a "break in deposition" between the ore and the Mayville. Ross (1915) presented a section similar to theirs and Savage (1916) published an abbreviated version, but called both unconformities breaks in sedimentation. Savage noted the presence of zaphrentid and favositid corals in the lower Mayville at the mine, and he also provided a somewhat expanded view of the area photographed by Savage and Ross (1916).

Shrock visited this open ore pit several times from 1930-34 and found the pit flooded to approximately the present water level, obscuring the Brainard-Neda contact. Shrock (1930-34, unpublished fieldnotes; 1938, manuscript) observed that the Neda formed several mounds or hills in the east and south walls of the pit (figs. 12, 13). He noted a nodular, reefy, or conglomeratic dolomite overlying these mounds containing tabulate corals, stromatoporoids, gastropods, and pelmatozoans. This nodular dolomite, ranging from 0-22 feet in thickness, is thickest over these mounds and thins rapidly away from them. In a 1934 visit Shrock and W. H. Twenhofel noted that the bedded Mayville, ranging from 0-44 feet in thickness, thins, drapes over and dips away from the top of the nodular dolomite and Neda mounds filling in low areas between the mounds and wedging out against the nodular beds.

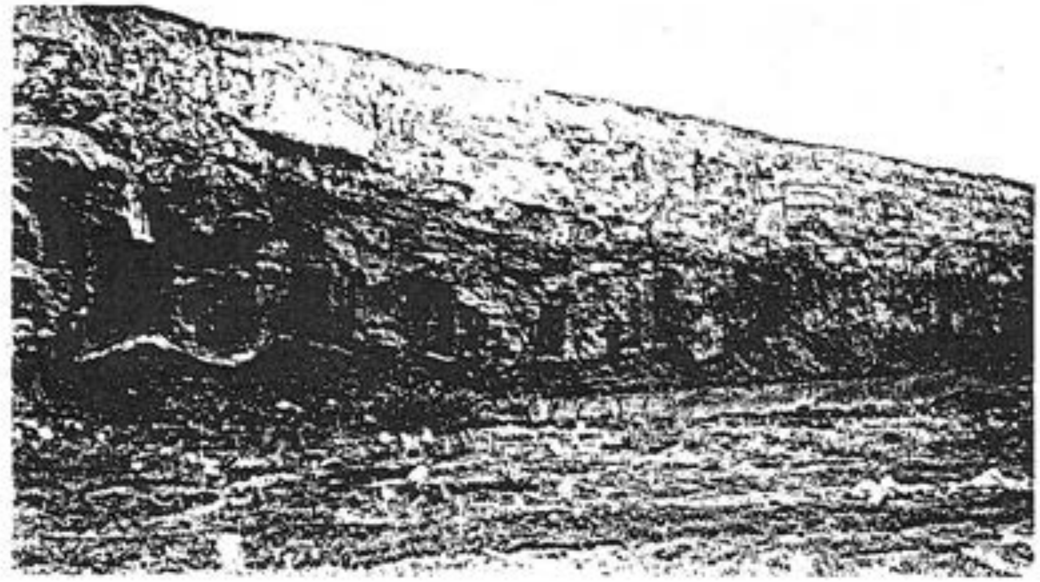


Fig. 10. Photo of north one-third of east wall at Mayville Mine "lake" showing carbonate buildup overlying mound of horizontally-bedded Neda at left. Bedded Mayville Dolomite can be seen thinning over buldup and wedging out against the Neda and the buildup. (Photo by W. Hotchkiss, 1914, Wis. Geol. Surv. No. 775)

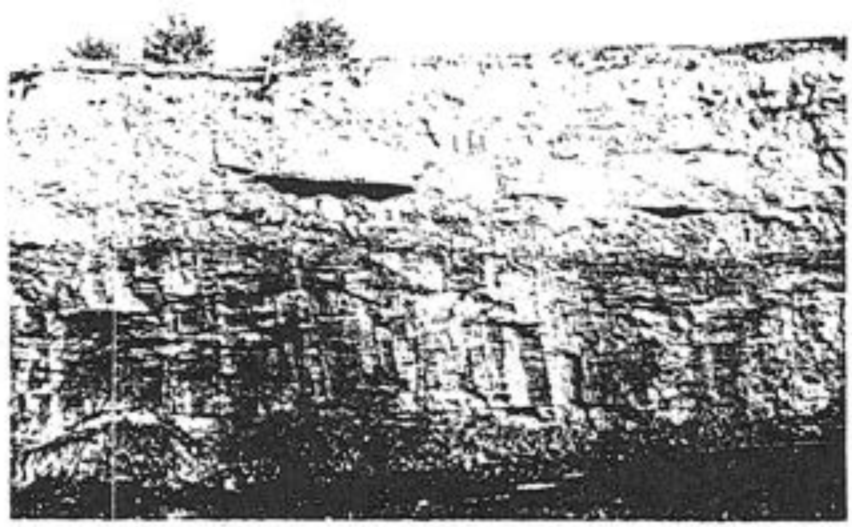


Fig. 11. Enlarged view of relationships seen in fig. 10. (Photo from Ross, 1915; Hsü, 1915; Savage, 1916; Savage and Ross, 1916)

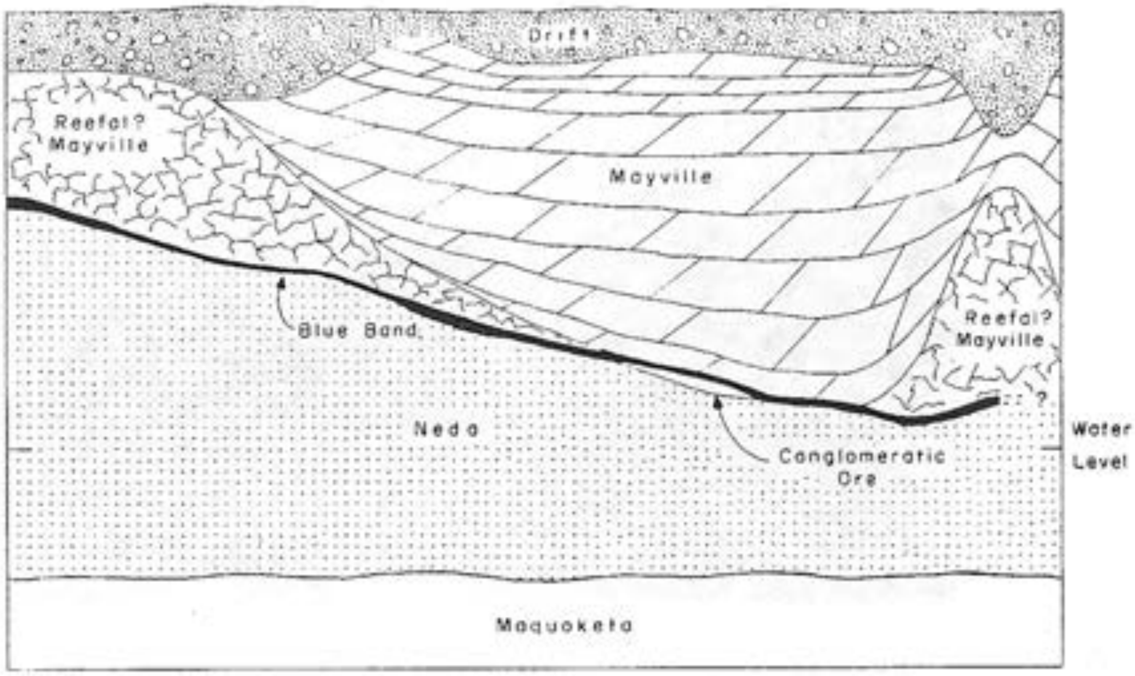


Fig. 12. Diagram of entire east wall of Mayville Mine "lake" showing relationships between Neda and overlying units. (after R.R. Shrock, 1930, unpublished fieldnotes; portion below waterlevel after E.O. Ulrich, 1914, unpublished fieldnotes)

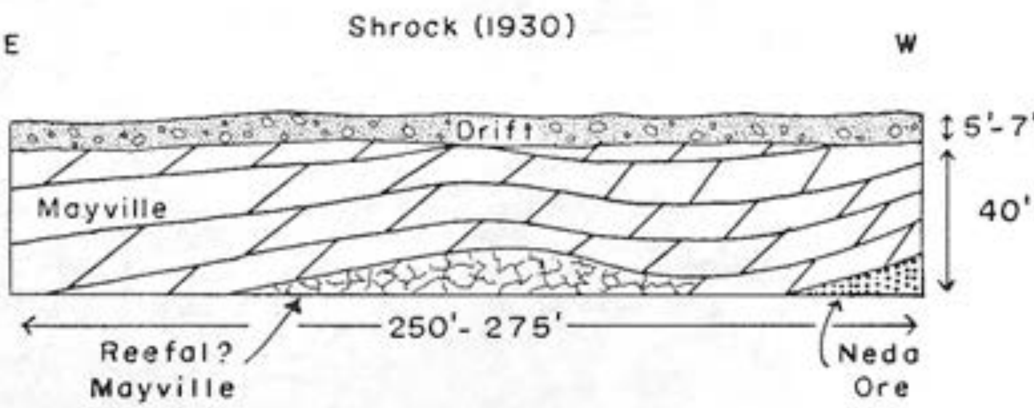


Fig. 13. Diagram of south wall of Mayville Mine "lake" showing Neda mounding and carbonate buildups as they appeared after flooding of the "lake"; see fig. 9 for view of area before flooding. (after R. R. Shrock, 1930, unpublished fieldnotes)

and the ore. They noted that the thickness of the normal Mayville is inversely proportional to the combined thickness of the underlying nodular dolomite and Neda. A 2 to 4 inch green, maroon, or chocolate-colored shale separated the bedded Mayville and nodular dolomite, and both lithologies were found to bevel against irregularities in the Neda surface. This bevelling and the presence of a thin conglomeratic dolomite layer containing reworked ooids between the Neda and Mayville suggested a significant unconformity. He noted that the Neda ranged from 1-25 feet in thickness, was frequently cross-bedded, and appeared laminated because of the alignment of the ooids.

At the northwest corner of the "lake" Shrock found 7.5 feet of Brainard Shale overlain by 1.5 feet of Neda, which he originally interpreted as the eastward dipping contact betwen the two units. Shrock and Twenhofel later determined that this exposure was not in situ. Recent bulldozing at the site has again uncovered several feet of Brainard overlain by Neda, but it is clearly disturbed material. Paull (1982, pers. comm.), however, recently found what appears to be the Neda-Brainard contact only a few inches above water level at the edge of the "lake" near Shrock's locality. The basal Neda and Brainard here are very similar to the lithologies at the contact where it is exposed elsewhere, but since this site is located near dump piles, a boring should be made to determine if the contact is in situ. If this is the true contact it suggests the top of the Brainard is higher here than is the east wall of the pit.

Thwaites, et al. (1937; 1947) and Prouty (1960) described this locality briefly in fieldtrip guidebooks. Rosenzweig (1951) described exposures at the Mayville Mine which he called the crusher pit of the Northwestern Milling Company. He had access to both Shrock's and Ulrich's fieldnotes and his description of the exposure at the pit are similar to theirs. Rosenzweig provided an isopach map of the subsurface ore bodies based on borings, and this map shows there is a very large lens of ore in the center of the Mayville Mine area, accounting for the northward thickening along the east wall in the vicinity of the "lake" in the southern one-third of the pit. Rosenzweig's cross-sections revealed the Neda to be thickest surrounding "hills" in the underlying Maquoketa. He noted that the contact between the hard ore and the soft oolitic ore was undulating and marked by a leached oolitic zone in places; and the hard ore apparently truncated bedding in the soft ore. He also observed that the hard ore had a "fragmental aspect" in places, with pieces of hard ore present in a softer matrix.

Paull (1977) and Paull and Paull (1977) observed that the Neda formed topographic highs on which the Mayville was deposited during early Silurian transgression, and noted that the Mayville beds along the east wall of the "lake" thin and disappear as they approach the thickest portions of Neda. Elger (1979) examined the lower Silurian at this locality and found that the contact between the Mayville and the Neda was extremely irregular, with up to 1.5 feet of relief. The base of the Mayville was very fossiliferous and reworked oolitic hematite occurred in the basal 3 feet. The petrography of the ore and individual ooid morphology were described by Synowiec (1981). Most recently, Emerick (1983) attributed the topography of the Neda to post-depositional deformation. He considered the hard ore to have been unlithified at the time of Mayville deposition and suggested that no unconformity existed between the Neda and Mayville.

Based on these past descriptions and our observations we believe that the following features may be seen at the Mayville Mine in the "lake" area. Although the lower portion of the Neda is no longer well exposed, it is presumably present in dump piles at the northwestern corner of the pit. The lower Neda contains more shale and fewer ooids than the upper part of the Neda and phosphatic and ferruginous nodules abound. Lithologically, the lower Neda here is very similar to the Neda exposed at Katell Falls and other exposures in the Midwest, which all display thinner sections of Neda than at Iron Ridge. Most of the overlying Neda consists of a relatively pure oolite containing no ferruginous or phosphatic nodules, and it horizontally-bedded for the mostpart although cross-bedding has been reported. Apparently two subdivisions of the Neda exist, a lower shaley oolite containing abundant ferruginous and phosphatic nodules and an upper pure oolite commonly capped by a dense hematite layer. This upper portion is seldom seen in outcrop outside the Iron Ridge area.

The presence of several mounds in the Neda account for its variation in thickness from 12-25 feet, about half of which is underwater. The largest mound is located in the northeast corner of the pit, a smaller mound occurs near the south end of the east wall, and two small mounds are present in the south wall. Based on old descriptions most of these mounds appear to be independent of Brainard surface irregularities, but it is uncertain whether these mounds are erosional or depositional in origin.

A distinctive 1-12 inch layer of hard ore ("blue band") marks the top of the Neda and in places is bounded both above and below by thin conglomeratic beds. This blue band has been interpreted as a leached zone indicative of weathering and erosion prior to Mayville deposition, and it has even been considered lateritic.

Overlying the Neda mounds unconformably is a distinctive dolomite which has been termed nodular, conglomeratic, and reefal in the past. It thickens over the top of the Neda mounds and thins and disappears away from them. This unit ranges from 0-22 feet in thickness and consists of hard, porous, crystalline, massive dolomite, containing a diverse fauna dominated by tabulate corals (Favosites, Halysites, "Amplexus") and stromatoporoids. Rugose corals, gastropods, trilobites, possible bryozoans, and pelmatozoan debris also occur. The tabulate coral colonies range from several inches to over a foot in diameter and are lenticular or domal. Some colonies are fragmented, while others appear to be in growth position. The trilobite Stenopareia occurs in localized accumulations of disarticulated cranidia and pygidia oriented convex-side down. In the northeast corner of the pit this dolomite is overlain by a prominent reddish brown clay layer from 0-4 inches thick which is absent elsewhere.

Well-bedded Mayville Dolomite 0-40 feet thick overlies this clay or rests directly on the ore where the clay is absent. The thickness of the Mayville is inversely proportional to the combined thickness of the "nodular" dolomite and the Neda. The Mayville is dense, fine crystalline to granular dolomite, cherty in part, containing tabulate corals in its basal two feet. The lower contact is sharp, distinct and irregular. The bedded Mayville thins, drapes over, and dips away from the "nodular" dolomite at the top of the Neda mounds and fills low areas between the mounds where it wedges out against both the ore and "nodular" dolomite. Although these beds exhibit a typical Mayville lithology it is uncertain how they correlate with the Mayville, either exposed or subsurface, at the Mayville White Lime Company quarry.

We believe the "nodular" dolomite represents carbonate buildups which developed on topographic highs on the Neda surface for the following reasons. This lithology is found only on the mounds of horizontally-bedded Neda. This "nodular" unit is thickest where the Neda is thickest and it thins laterally as the mounds level out. Both lithologically and faunally this unit is very similar to many Silurian carbonate buildups, and in particular, the localized accumulation of Stenopareia compares to trilobite accumulations typical of Paleozoic carbonate buildups (Mikulic, 1980). The bedded Mayville thins and drapes over the top of the "nodular" unit and wedges out against the sides, suggesting that the "nodular" unit had relief during Mayville deposition. The age of these buildups is uncertain; however, they unconformably overlie the Neda and are separated from the bedded Mayville by a thin prominent clay layer; the bedded Mayville was certainly deposited after the buildups developed.

High in the escarpment, north of the "lake" 1-5 feet of Neda is overlain by about 15 feet of Mayville. A possible Neda mound occurs and Shrock reported "conglomeratic" dolomite overlying this feature. Since exposures between here and the "lake" are poor it is not known how these outcrops relate to each other. South of the "lake" the old tunnel entrances which Alden (1918) figured and described are still visible.

The most important exposure of the Neda in the Midwest occurs in the "lake" area at the Mayville Mine, and we strongly recommend that this land be acquired as a park or scientific reserve to ensure its preservation and guarantee future access for research. The exposures at the Iron Ridge Mine on University of Wisconsin property to the south exhibit none of the complex stratigraphic relations present here, and even though those exposures should be improved, the Mayville Mine area would retain its significance.

Paint Pit

At a large gap in the escarpment between sections 1 and 12 a small pit was located near Brown's Corner (NW¼, NE¼, NW¼, sec. 12, T.11N., R.16E. [fig. 4] elevation 1050 feet) which, according to R. R. Shrock's fieldnotes, was still producing ore in 1930. Shrock reported that the ore from this pit was hauled to Neda where it was ground for use as pigment and because of this the site was called the "Paint Pit." He described a 27-foot section of ore, most of which was soft and weathered (fig. 14). A slumped section of Mayville Dolomite was present along the east wall of the pit, and blocks of Mayville were scattered over the top and sides of the hill. Considering its low elevation, location, weathered condition, and the slumped Mayville it is likely that this exposure represents a deposit of drift ore; however, transportation and weathering may have been minimal.

The mining history of this operation is poorly known, but it is probable that when the Northwestern Iron Company shaft mine closed in 1928 this pit was opened to supply ore to the paint manufacturer at Neda. A 1937 airphoto shows the pit to be abandoned, but a 1940 airphoto shows recent excavations. The pit is now badly slumped and Neda can be seen only in animal burrows below the slump blocks along the east wall.

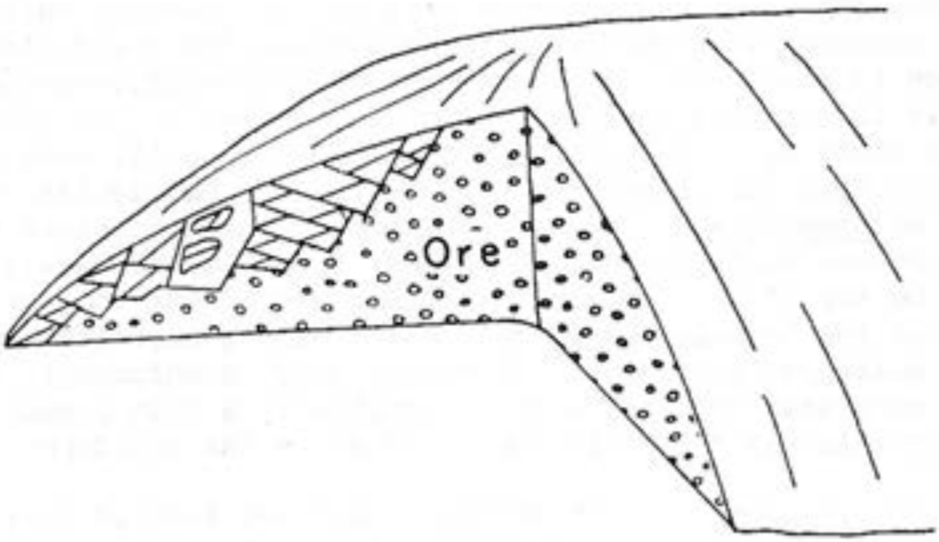


Fig. 14. Diagram of Paint Pit showing hill of ore and slumped blocks of Mayville Dolomite. (after R.R. Shrock, 1930, unpublished fieldnotes)

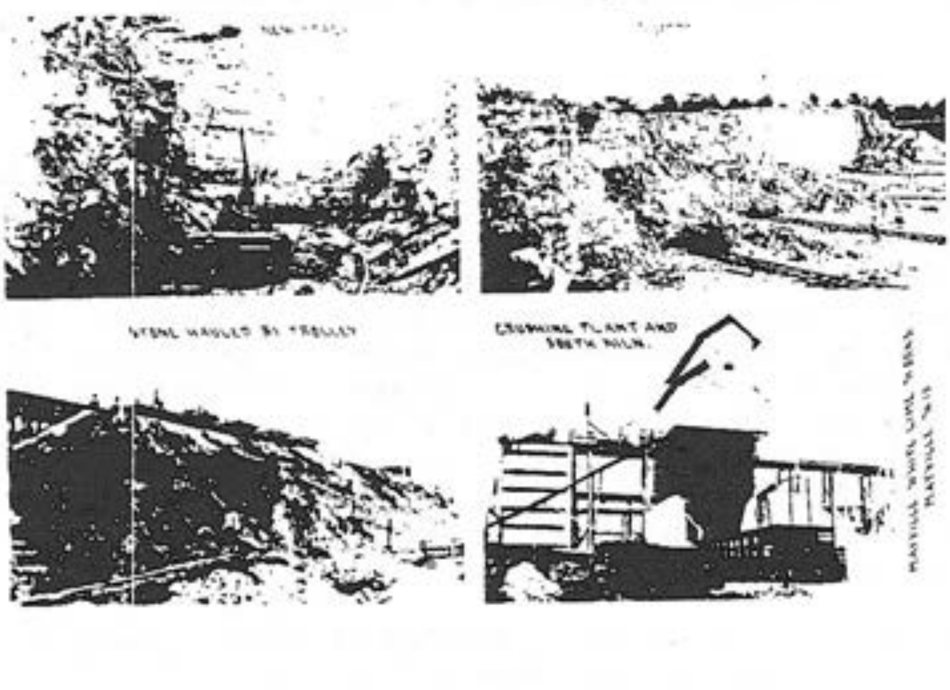


Fig. 15. Postcard showing operations of the Mayville White Lime Company quarry in the early 1900s. (Photo courtesy of E. Boeck, Mayville Historical Society)

Northwestern Iron Company Shaft Mine

Around 1913 the Northwestern Iron Company opened a shaft mine about one mile east of the Mayville Mine (NW¼, SE¼, NW¼, sec. 7, T.11N., R.17E.). The ore body mined here was located by borings in an area where no outcrops were present. Two 140-foot shafts were constructed and mining was carried out from 1914 until 1928. Rosenzweig (1951) illustrated the general layout of this mine and made several cross-sections of this ore body based on company boring records. The mine is now flooded.

Mayville White Lime Company Quarry

SW¼, sec. 1, T.11N., R.16E., Hubbard Twp., Dodge Co., Wis. (Mayville South 7.5' quadrangle) (fig. 4). Elevation of Mayville-Byron contact on east side of quarry is approximately 1116 feet.

The Mayville and Byron Dolomites are well exposed just north of Iron Ridge at the Mayville White Lime quarry and vicinity (fig. 15). Exposures in this area are known for the abundance of the brachiopod Virgiana mayvillensis at the top of the Mayville.

The type section of the Mayville Dolomite, originally described by Chamberlin (1877) is located in an old quarry in the escarpment (SW¼, sec. 36, T.12N., R.16E.) less than a mile north of the main quarry. The Byron Dolomite overlies about 80 feet of Mayville here, but the contact with the underlying Neda or Brainard is not exposed, however, it may be close to the base of the outcrop. This part of the escarpment is owned by the Nature Conservancy.

Although expanding laterally, the Mayville White Lime Quarry has not been deepened much since Shrock's work in the 1930s. Approximately 65 feet of Mayville is exposed here. The Mayville was once overlain by a 30-foot high hill of Bryon Dolomite near the center of the quarry, but it has been completely removed, and only 15 feet of Byron remains in other parts of the quarry. The Mayville-Byron contact is best exposed at the entrance ramp to the old Northwestern Iron Company quarry (NE cor., NE¼, SE¼, SW¼, sec. 1, T.11N., R.16E.), at the east side of the main quarry, and in a small inactive quarry one mile east (W½, SW¼, SE¼, sec. 6, T.11N., R.17E.) on the north side of Wis. Hwy. 33. R. R. Shrock (1930, unpublished fieldnotes) placed the Mayville-Byron contact at a prominent stylolite just above the Virgiana bed. He observed small mounds of porous, granular Mayville projecting up into the dense Byron. Shrock (1939) described these mounds as being two to three feet high, reaching a diameter of up to 20 feet, and containing leperditiid ostracodes and spiriferid brachiopods, but no Virgiana. Brooks (1978) found favositid corals in these mounds also. The overlying Byron was seen to ride up over the tops of these mounds, but the mounds graded into the underlying Mayville and laterally into the Byron.

The Virgiana in the Mayville are of particular interest from an environmental standpoint. Virgiana are scattered throughout the upper 20 feet of the Mayville, but are concentrated in a 3-foot bed at the top (Elger, 1979). The Virgiana are disarticulated, randomly oriented, and unsorted. Virgiana dominates the fauna which also includes rugosid and favositid corals and leperditiid ostracodes (Brooks, 1978); pelmatozoan debris is absent. Fürsich and Hurst (1980) described a very similar occurrence of Virgiana from the lower Silurian of North Greenland, and suggested that this deposit represented a generally quiet water, relatively hypersaline, marginally-marine environment. The lower portions of the Mayville show evidence of alternating normal marine and hypersaline conditions in a subtidal environment (Elger, 1979), and the Byron Dolomite, which conformably overlies the Virgiana bed, is thought to represent a regressive environment trending toward hypersaline conditions (Brooks, 1978). The Byron at the contact contains a sparse fauna of leperditiid ostracodes and gastropods, often indicative of a restricted environment, and consists of mat-laminated mudstones, packstones and wackestones with some oolites (Brooks, 1978). The environmental characteristics of the Virgiana bed, suggest a subtidal, slightly hypersaline depositional environment becoming more hypersaline in the Byron.

The Mayville White Lime Company has been one of the more successful quarrying operations in the state. Several lime and stone operations were scattered along the escarpment from Neda north to the Mayville type section during the 1800s, and it is unknown when this site was first quarried. In 1847-48 Henry Mace purchased two parcels of land comprising the S½, SW¼, sec. 1, and operated a quarry and lime kiln here prior to 1873. In 1876 he sold his property to his son, Garwin, and Charles Ruedebusch, who jointly established the Mayville White Lime Works. Around 1890 Garwin Mace sold his interest in the business to Ruedebusch, but he stayed in the lime business, operating plants in Ozaukee, Washington, and Waukesha Counties. The Ruedebusch family has operated the quarry, which produces mainly lime and crushed stone, ever since.

Stop 2. High Cliff State Park

W½, SE¼; E½, SW¼; and S½, NE¼, sec. 36, T.20N., R.18E., Harrison Twp., Co., Wisconsin (Sherwood 7.5' quadrangle). Abandoned stone quarries and natural exposures in Niagara Escarpment. Elevation at top of escarpment is approximately 960 feet.

The Niagara Escarpment is well exposed at the northeast corner of Lake Winnebago in High Cliff State Park (fig. 16) where it rises more than 210 feet above lake level, forming a continuous bluff which extends for approximately five miles from the town of Sherwood south to Calument County Park. The escarpment is capped by about 40 feet of Mayville Dolomite which is well exposed in natural outcrops and old quarries in the park. Although the lower 170 feet of the escarpment is covered by talus it apparently consists of Maquoketa Shale. Most of the escarpment is in a relatively natural state here, but before establishment of the park the Mayville Dolomite was quarried extensively for lime and crushed stone, and some old lime kilns may be seen halfway down the escarpment. The Maquoketa Shale was used in brick-making at High Cliff and at the site of Calumet County Park. Lake Winnebago, just west of the escarpment is a broad shallow depression less than 25 feet deep carved partially into the Galena Dolomite by the southward-moving Wisconsinan Green Bay glacial lobe. Near the concession building huge blocks of Mayville Dolomite have separated from the escarpment, forming large crevices along its crest. Just south of the quarries a fine group of Indian effigy mounds may be seen (Read, 1947)

The best exposures of Mayville Dolomite are in the "new" quarry of the Western Lime and Cement Company. The contact between the Mayville and the

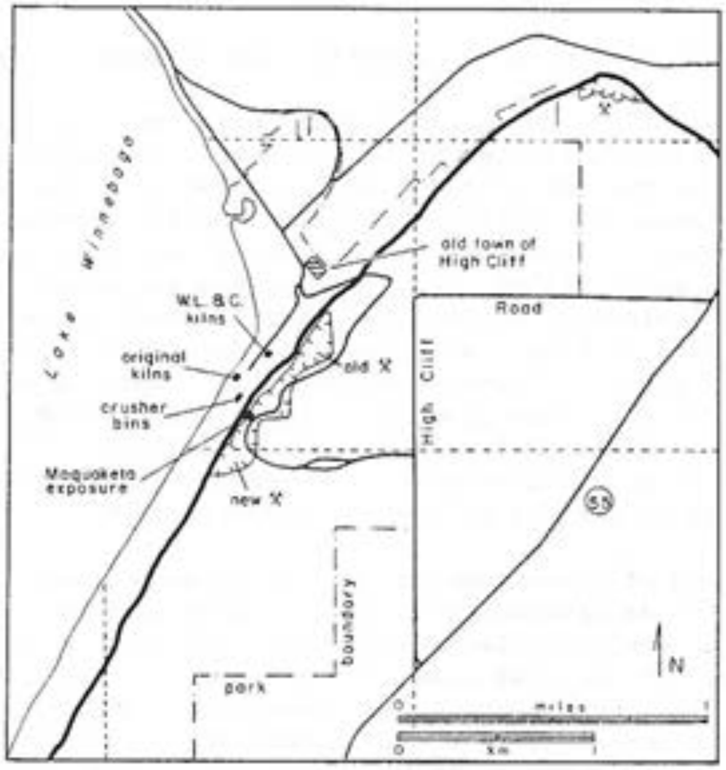


Fig. 16. Map of High Cliff State Park area (Stop 2) showing location of various features discussed in text.

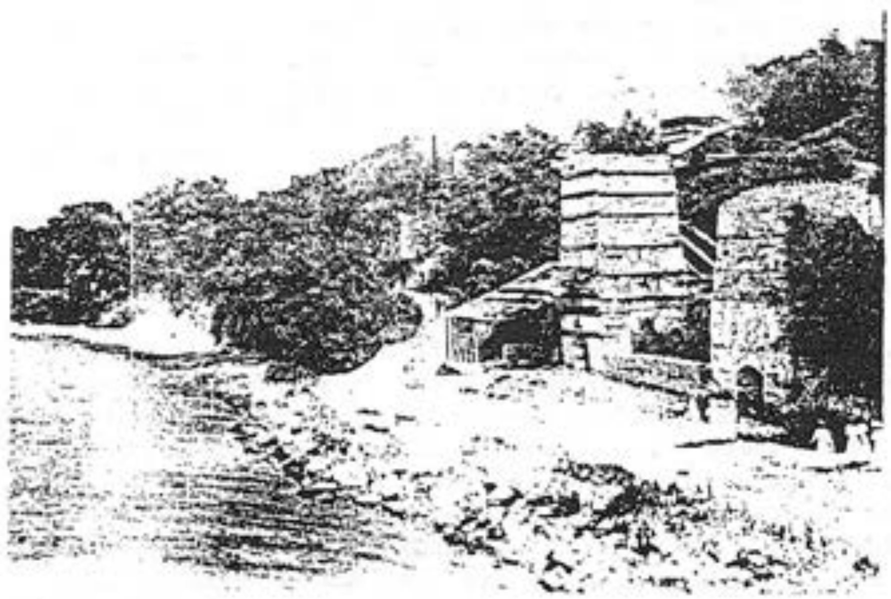


Fig. 17. Photo of original lime kilns along lake shore in High Cliff State Park (ca. 1900). Western Lime and Cement Co. kilns may be seen in background, higher up the escarpment. (Photo courtesy of Mr. and Mrs. R. Funk)

Maquoketa is not exposed in the quarries and no Neda has been reported here.

The following is a generalized section at the "new" quarry based in part on unpublished 1930 fieldnotes by R. R. Shrock and in part on a section by Elger (1979). At the top of the Mayville there is 8 feet of well-bedded, fine crystalline dolomite containing silicified corals, stromatoporoids, and pelmatozoan debris. This is underlain by 20 feet of cherty dolomite in the lower 8 feet of which Elger (1979) reported possible anhydrite crystal molds. Twelve feet of thinly laminated, bluish gray, argillaceous dolomite underlies this and overlies 6-10 feet of highly argillaceous, dark gray dolomite which breaks into thin platy pieces. Shrock considered this unit Maquoketa, but its lithology is typical of the lower Silurian elsewhere and we believe it is Silurian in age. Slabs of typical, highly fossiliferous Brainard Shale are present at the base of a 10-foot high concrete wall which covers the Ordovician-Silurian contact at the cut to the old crusher bins.

The location of these quarries on the shore of Lake Winnebago provided cheap and easy transportation of lime and stone by boat in summer and sleigh in winter to the newly-settled communities, such as Neenah, Menasha, Oshkosh, and Fond du Lac, on the west side of the lake. The development of the lime industry (fig. 17), brick-making and lumbering, prompted the establishment of Clifton, a small community on the lakeshore which existed primarily as a home for the local quarry workers and brick makers. Later the town's name was changed to High Clifton, and finally to High Cliff.

As early as 1860 the Federal Census Schedule 5 reported that a J. Plummer, near Clifton, employed 5 men and burned 2000 barrels of lime per year valued at $800. J. A. Day burned lime in a pot kiln from 1864 until he sold his land to Ossian Cook in 1868. Cook, along with R. C. Brown and F. E. Waite, organized Cook, Brown and Company in 1874 to supply brick and lime to the city of Oshkosh, and in 1878 the company was incorporated as Cook and Brown Lime Company. The brickworks at High Cliff was short-lived; however, the company continued to operate its extensive brickworks at the site of Calumet County Park until 1915. Although a railroad spur was built to the lime kilns in the early 1890s, lime continued to be shipped by lake as well. In 1902 the lime plant and quarry was sold to Nast Brothers and became part of Western Lime and Cement Company in 1921. Details of the quarry and kiln operations may be found in High Cliff State Park Visitor. The plant operated until 1956 when the site was sold to the state for parkland. We would like to thank Mr. and Mrs. Roman Funk and Henry Cook for supplying much of this historical information.

Between Iron Ridge and High Cliff no Neda is known except for an exposure at Stockbridge, Calumet County reported by Chamberlin (1877) and a subsurface occurrence at Campbellsport, Fond du Lac County (Cohee, 1948; Rosenzweig, 1951; Newport, 1962) where 20 feet of ore is present beneath 310 feet of Silurian dolomite. Although not found at High Cliff, the Neda has been discovered in subsurface borings five miles to the east near the town of St. John (Woodville Twp., Calumet Co., Hilbert 7.5' quadrangle). Rosenzweig (1951) reported six feet of "red and yellow oolitic ore with shale pebbles and red calcareous shale layers" beneath 11 feet of dolomite in the NE¼, NW¼, sec. 35, T.20N., R.19E. Three more recent borings made in the SE¼, SE¼, sec. 26, T.20N., R.19E., have penetrated Neda. One of these borings (B-27) showed greenish gray dolomite and claystone with common phosphatic ooids and pebbles overlying grayish red oolitic Neda and underlying cherty dolomite.

Stop 3A. Katell Falls

SE¼, SE¼, NW¼, sec. 32, T.23N., R.21E., DePere Twp., Brown Co., Wis. (Bellevue 7.5' quadrangle). Cascade in a small northward-flowing stream just north of Co. Hwy. G, approximately 4 miles east of DePere and 0.4 mile west of the town of Kolb (fig. 18). Elevation at top of outcrop is approximately 800 feet.

Katell Falls (fig. 19) is a small picturesque cascade which flows over the Mayville Dolomite at the top of the Niagara Escarpment. The falls has cut into the Brainard Shale and exposes about five feet of Neda.

Throughout its history this falls has been known by many names, but is now commonly known as Katell Falls. Daniels (1858a, b), the first to report iron ore here, compared this cascade to the "famed Falls of Minnehaha" and noted a 6.5 foot lenticular bed of ore between the overlying "Niagaran limestones" and underlying "Hudson Shales." He considered this ore "identical in age, composition, and structure with the Iron Ridge and Hartford ores," although it was more shaley. He observed that the ore bed could be traced along the base of the escarpment for about 200 rods but was then covered.

Hall (1862) found three feet of oolitic ore "east of the town of Green Bay," and although it is uncertain exactly where this outcrop was located, the section he described is very similar to that exposed at Katell Falls.

Sweet (1876) listed iron ore and other rock specimens (probably collected by I. A. Lapham) from "Monoseesee Falls" in Wisconsin, which may have been an early name for Katell Falls.

Referring to this locality as "Cascade Falls," Chamberlin (1877) found the ore here very similar to that at Iron Ridge, although somewhat more argillaceous and with larger ooids, and thought that the pyritiferous layer was equivalent to the "blue band" at Iron Ridge. Chamberlin observed that the ore varied between 4 feet 6.5 inches and 5 feet, and where it was thickest he noted that "there are slight indications of 'taking on' layers."

Thwaites (1914) briefly mentioned the ore here, indicating that it was a lower grade than at Iron Ridge due to the many shale interbeds. In 1913-14 fieldnotes he further described this locality, then known as Katells Falls. He noted that the contact between the ore and the underlying shale was nearly horizontal and very even. He also observed a decomposed ferruginous layer (1/4 -3 inches thick) between the Mayville and the ore, cross-bedding in the ore, and reworked ooids at the base of the Mayville.

In 1914 fieldnotes E. O. Ulrich suggested that erosion of the ore bed occurred prior to Mayville "submergence", but he found little indication of erosion or solution at the contact between the ore and the underlying shale. Ulrich made the following section at the falls.

Unit 1. Mayville Dolomite. Hard, gray, 2-12 inch layers, very cherty.

Unit 2. Dark gray, very pyritiferous dolomite with undulating base correspondingly cutting off beds of underlying ore. Just above contact with ore is a decomposed zone 1/4-3 inches thick of very ferruginous clay (6-14 inches).

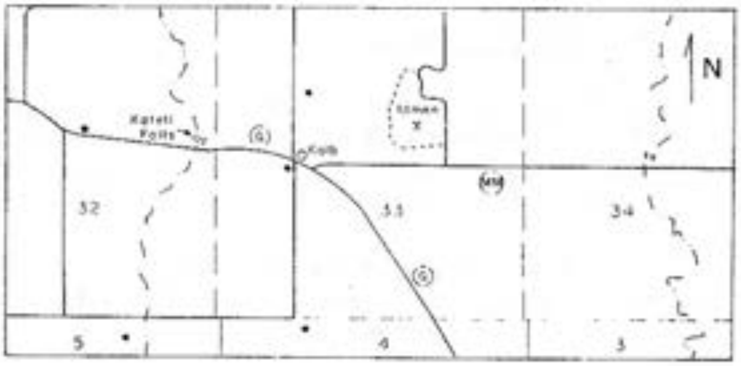


Fig. 18. Map of Katell Falls area (Stop 3A,B). Closed circles are location of wells and Xs indicate exposures in which Rosenzweig (1951) reported Neda absent.

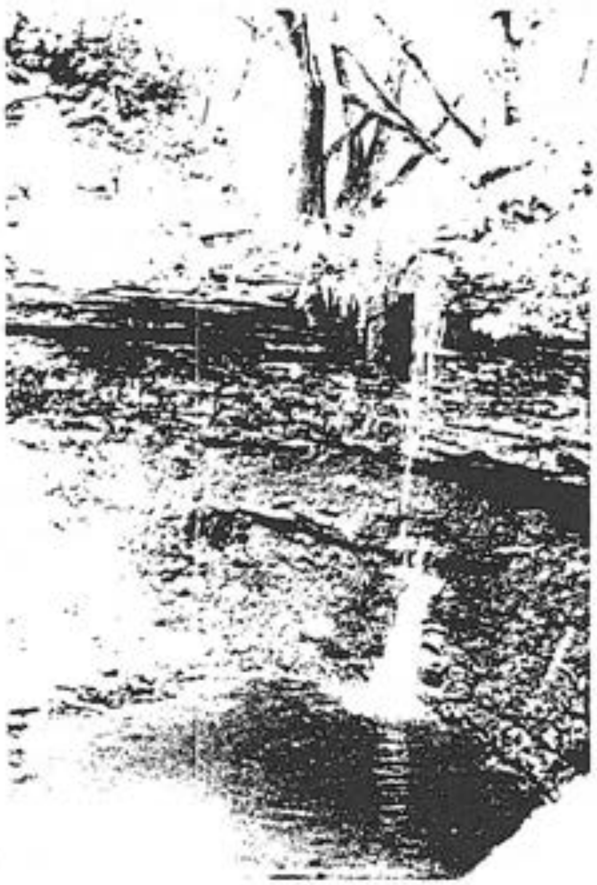


Fig. 19. Photo of Katell Falls showing Neda overlain by Mayville and underlain by Brainard.

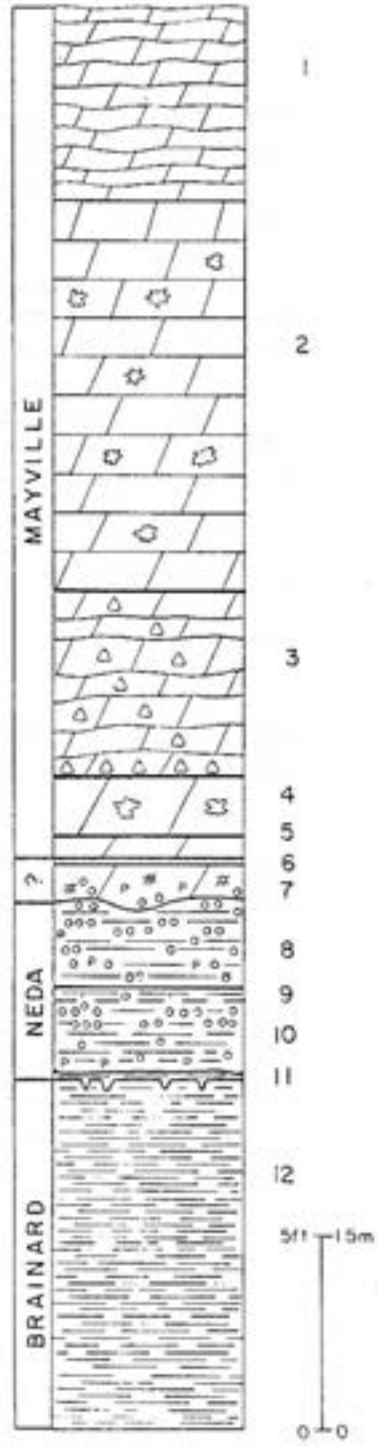


Fig. 20. Stratigraphic section at Katell Falls.

Unit 3. Ferruginous clay-residual weathering product (0-2 inches).

Unit 4. Main part of ore bed. Reddish oolites with pebbles of shale or clay up to 2 inches though commonly smaller. Bedding averages 2 inches (2 feet 6 inches).

Unit 5. Blue black limy clay shale, pinching out to west (0-4 inches).

Unit 6. Much more impure dark brownish red oolitic ore with abundant ferruginous shale pebbles and admixture of clay. Seams of clay also occur frequently. Oolites often very large, up to 1/8 inch or so, causing them to be confused at times with small pebbles, which indeed some of them may be. Pebbles in ore are rounded and suggest derivation from adjacent areas rather than from material just beneath (2 feet).

Unit 7. Richmond Shale. Blue gray, limy, thinly laminated with few fossils (chiefly Hebertella) (5 feet).

Unit 8. Shale rock similar to above but more heavily bedded and solid. Weathers shale-like (2 feet 6 inches).

Both Hsü (1915) and Ross (1915) briefly described the stratigraphy at this locality, which they called Cascade Falls. Ross (1915) observed a very distinct unconformity between the Mayville and the ore and a minor one between the ore and the underlying shale.

Savage (1916) mentioned the presence of Ordovician fossils in the ore at Cascade Falls, and Savage and Ross (1916) published a list of the fossils, which were collected from an "undisturbed zone" approximately 1-1.5 feet above the base of the ore. This fauna included the following: cf. Stenaster sp., cf. Eurydictya montifera, Lingula cf. coburgensis, Strophonema wisconsinensis, Dalmanella tersa, Byssonychia intermedia, B. cf. radiata, Pterinea cf. demissa, Liospira sp. Since all of these fossils were Maquoketa in age and none appeared to have been abraded or reworked Savage and Ross placed the ore in the Maquoketa and named it the Neda Iron Ore, with its type section at Neda, Wisconsin. They discerned a break in sedimentation between the Neda and the underlying shale, noting that the ore rested on different levels of the shale wherever the unit was exposed. They believed that the uneven contact and residual character of the pyritiferous layer suggested an unconformity between the Neda and the Mayville.

This locality was referred to as Lambert's Falls by R. R. Shrock and W. H. Twenhofel in 1934 fieldnotes. They observed a sharp distinct break between the ore and the underlying shale and a thin basal conglomerate between the Mayville and the ore. They made the following section at the falls.

Mayville

Unit 8. (9 ft.) Dolomite much like unit 5 with much chert. Exposed in gorge between brink of falls and bridge on road.

Unit 7. (2 ft.) Fairly thick, well-bedded, gray, somewhat cavernous dolomite with little or no chert.

Unit 6. (5 ft. 3 in.) Irregularly-bedded, cavernous, gray dolomite. chert nodules along separation planes.

Unit 5. (4 ft.) Cherty, thin and irregularly bedded, dense, gray dolomite. Chert along separation planes and in beds averaging 4-6 in. thick.

Unit 4. (3 ft. 4 in.) Heavy-bedded dolomite with chert only along separation planes.

Unit 3. (9 in.) Pyritized basal conglomerate.

Neda

Unit 2. (5 ft.-4 ft. 8 in.) Oolitic hematite which weathers in a shaley or splintery way rather than into thin laminations as the underlying rock does.

Richmond

Unit 1. (9 ft.) Thinly laminated, blue Richmond shale, breaking down into very thin filmy laminations, but does not go into shale or mud easily.

Rosenzweig (1951) presented a section and indicated that the ore body was of limited extent since water wells surrounding the exposure failed to show any ore.

Ostrom (1978) described this locality (Kittell Falls) briefly and gave a section. In addition to a stratigraphic section, Synowiec (1981) provided petrographic data, and considered the Neda-Brainard contact gradational. J. Emerick (1983, pers. comm.) found a variety of fossils at about the same horizon as Savage and Ross (1916), including brachiopods, bivalves, conularids and trilobites.

The outcrop at Katell Falls is difficult to study because of its vertical caliche-covered face. The following section was measured on the east side of the falls (see fig. 20).

Mayville

Unit 1. 5 ft. (1.5 m) Irregularly-bedded, very rubbly, gray dolomite.

Unit 2. 10 ft. (3.0 m) Fine-medium crystalline, well-bedded, medium-bedded yellow gray to light olive gray dolomite, vuggy in places.

Unit 3. 4 ft. 9 in. (1.4 m) Coarse crystalline, somewhat porous, thin-medium bedded, very cherty, yellowish gray dolomite. Chert occurs as white nodules.

Unit 4. 1 ft. 7 in. (0.5 m) Fine crystalline, nonporous, massive, dense yellowish gray dolomite with lenticular vugs. Upper contact marked by conspicuous chert layer.

Unit 5. 7 in. (0.2 m) Very fine crystalline, nonporous, dense, light olive gray to medium gray dolomite, breaks into angular blocks.

Unit 6. 1 in. (0.03 m) Moderate yellow brown, ferruginous clay, plastic when wet. This unit forms a conspicuous reentrant along entire outcrop.

Unit 7. 12-15 in (.3-.4 m) Dense, very fine crystalline, nonporous heavily pyritized, greenish gray dolomite, with scattered small black phosphatic nodules. Two thin (1/8-1/4 in.) layers at top of unit. Patches and stringers of flattened, black-brown phosphatic and pyritic ooids common at bottom appear to project up from unit below; scattered black phosphatic nodules. Undulating lower contact. Units 6 and 7 are questionably Silurian.

Neda

Unit 8. 2 ft. 5 in. (0.7 m) Shaley, blackish red oolitic hematite. Ooids are ferruginous, flattened, and aligned horizontally. Common phosphatic nodules.

Unit 9. 2.5 in. (0.06 m) Platy to fissile, indurated, slightly calcareous, very dusky red hematitic shale with scattered patches of ferruginous ooids at base. Sharp upper contact, gradational lower contact.

Unit 10. 1 ft. 10 in. (0.6 m) Shaley, blackish red oolitic hematite. Shale patches more common than in Unit 8. Ferruginous and some pyritic ooids abundant, phosphatic nodules scattered throughout but concentrated and larger in a layer 1-2 inches above the base. A possible bivalve fragment found 3 inches above the base in shale.

Unit 11. 1 in. (0.03 m) Indurated, shale mottled dark grayish red and dark yellow brown. Occasional patches of ferruginous ooids and small phosphatic nodules. Ooids and shale fill burrows and trails on Brainard surface. Sharp, irregular upper contact. Trace fossils and finely-ribbed brachiopods are common in this unit.

Brainard

Unit 12. 9 ft. (2.7 m) Well indurated, fissile to platy, dark greenish gray shale, slightly silty, plastic when wet.

Stop 3B. Ulmen Construction Company Quarry

E½, SW¼, NE¼, sec. 33, T.23N., R.21E., DePere Twp., Brown Co., Wis. (Bellevue 7.5' quadrangle). Stone quarry about 0.1 mile north of Co. Hwy. MM, 0.6 mile east of Kolb and 1.0 mile east of Katell Falls (see fig. 18). Elevation at top of quarry is approximately 845 feet.

Approximately one foot of Neda is visible in a 14 foot deep water-filled sump in the southeast corner of this quarry. Dump piles adjacent to the sump contain excavated blocks of pyritiferous dolomite, oolitic Neda, and possible Brainard. The lithologies of the Neda and the pyritiferous dolomite are identical to that at Katell Falls. The top of the pyritiferous unit is a thin crust-like layer with abundant phosphatic and pyritic nodules; a coarsely-ribbed brachiopod was collected from this layer. The pyritiferous layer and possibly Neda may be exposed in the quarry floor to the south of the sump. The overlying Mayville in this quarry is approximately 40 feet thick and its basal portion is similar to that exposed at Katell Falls.

Stop 4. Wequiock Falls

NW¼, sec. 7, T.24N., R.22E., Scott Twp., Brown Co., Wis. (Green Bay East 7.5' quadrangle). Cascades and streamcut along Wequiock Creek at Wequiock Wayside Park on the west side of Wis. Hwy. 57 (fig. 21). Elevation at top of main cascade is approximately 700 feet.

In the composite section along Wequiock Creek over 100 feet of Maquoketa Shale strata are exposed, extending from the Brainard Shale Member down into the Scales Shale Member, making this one of the best Upper Ordovician sections in eastern Wisconsin. The Maquoketa is overlain by 15 feet of Mayville Dolomite (see fig. 22), and the main cascade falls nearly 30 feet where the creek flows over the Mayville at the edge of the Niagara Escarpment. Further downstream a step-like series of much smaller cascades is developed on carbonate beds in the Fort Atkinson Dolomite Member of the Maquoketa.

The section at Wequiock Falls was briefly described by Stieglitz, et al. (1980a). Sivon (1979, 1980) presented a comprehensive discussion of the Ordovician stratigraphy and paleontoloty here, and Allen (1980) conducted a detailed paleoecologic investigation in the Fort Atkinson.

At Wequiock Falls the Mayville Dolomite occurs only at the main cascade and the following section was measured there (see fig. 23).

Mayville

Unit 1. 10 ft. (3.0 m) Thin bedded-flaggy, very fine crystalline, nonporous, grayish brown dolomite, with little chert at bottom and scattered vugs.

Unit 2. 1 ft. 8 in. (0.5 m) Top 1-1.5 in. is thin platy dolomite interbedded with clay. Rest of unit is thick-bedded, fine grained, greenish gray, argillaceous dolomite which breaks into thin flaggy beds. Large chert nodules present.

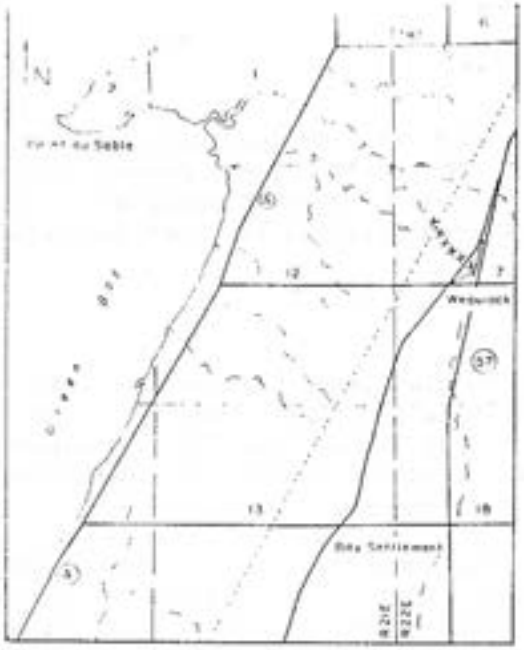


Fig. 21. Map of Wequiock Falls area (Stop 4). Extent of exposure along Wequiock Creek indicated by Xs.

Fig. 22. Photo along Wequiock Creek showing massive Mayville overlying thin-bedded Brainard.

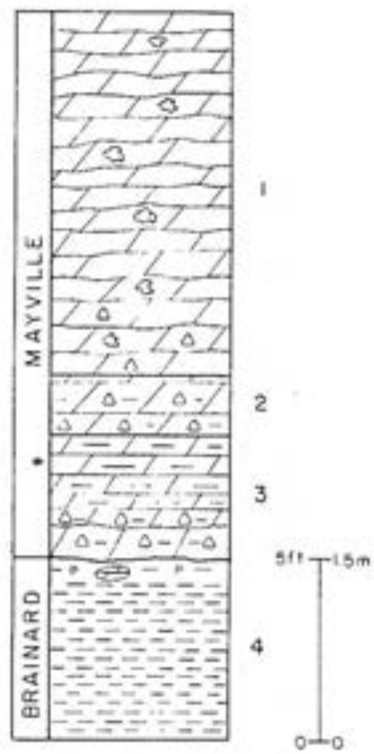


Fig. 23. Stratigraphic section at Wequiock Falls showing Mayville and upper few feet of Brainard.

Unit 3. 3 ft. 4 in. (1.0 m) Thin-bedded, fine grained, argillaceous grayish green dolomite which breaks into blocky pieces. Becomes very cherty towards bottom. Lower contact is sharp and slightly irregular. Small patches of iron-staining in upper few inches.

Brainard

Unit 4. Light greenish gray calcareous claystone, plastic when wet. At the top of the Brainard are small phosphatic nodules and pebbles of crumbly red shale. Large flat rounded nodules of laminated, fine crystalline, argillaceous, greenish gray dolomite coated with ferruginous crust also occur at the top.

Further downstream 13 feet of Fort Atkinson strata, consisting predominately of carbonates, forms three small cascades. The contact between the Brainard and Fort Atkinson is conformable and the contact between the Fort Atkinson and Scales is covered (Sivon, 1980). At the west end of the exposure 24 feet of unfossiliferous Scales claystone is present although mostly concealed.

Percival (1856) reported that at the Bay Settlement the rock of the "Mound Limestone" [Mayville] formed a low bluff about a mile back from the shore where it is crossed by a small stream forming a cascade. This cascade exposed the underlying "Blue Shale" and between it and the Mayville, Percival observed traces of iron ore in the same position as the ore at Iron Ridge. Several streams cross the escarpment in this area and it is not known to which one Percival referred. He may have been referring to Wequiock Falls, which is not far from Bay Settlement, and the ore which he observed may now be obscured.

Stop 5. Bayshore County Park

SW¼, NW¼, SW¼, sec. 14, T.25N., R.22E., Green Bay Twp., Brown Co., Wis. (Dycksville 7.5' quadrangle). Roadcut in Bayshore County Park (fig. 24). Elevation at top of escarpment is approximately 690 feet.

An access road to a boat launching ramp on the shore of Green Bay has been cut into the Niagara Escarpment in the park, exposing a section primarily in the Mayville Dolomite. A large amount of talus, including huge blocks of dolomite, occurs at the base of the escarpment obscuring most of the underlying Maquoketa strata. This talus slope apparently formed by ice-wedging along joints in the dolomite which probably took place during the last Wisconsinan glacial recession (Stieglitz, et al., 1980b). Movement of the talus was aided by the soft nature of the underlying shale which has, in turn, been deformed somewhat in response to the downslope movement of the dolomite blocks.

Stieglitz and Allen (1980) and Stieglitz et al. (1980a) briefly described the section here. Stieglitz et al. (1980a) stated that the escarpment along the east shore of Green Bay is incorrectly designated as the "Niagaran Escarpment" because the rocks there are "Alexandrian" (Lower Silurian) and not "Niagaran" in age. This statement is incorrect for the following reasons. The term "Niagaran" was found to have little time significance and consequently little use in correlation, therefore, Berry and Boucot (1970) recommended that its use be discontinued and replaced by European terminology. However, rocks once considered "Niagaran" in age do make up part of the escarpment throughout much of Door County. Most importantly, it should be pointed out that the escarpment in Wisconsin

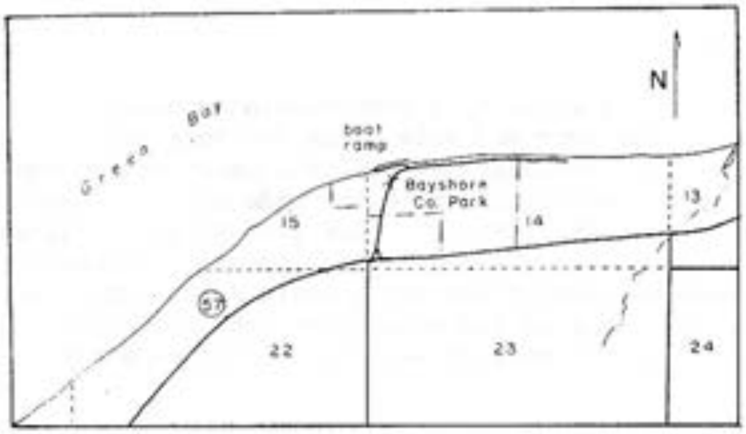


Fig. 24. Map of Bayshore County Park (Stop 5).

Fig. 26. Photo of contact between questionable Neda with overlying Mayville and underlying Brainard. Hammer handle rests on Unit 6 in the Brainard.

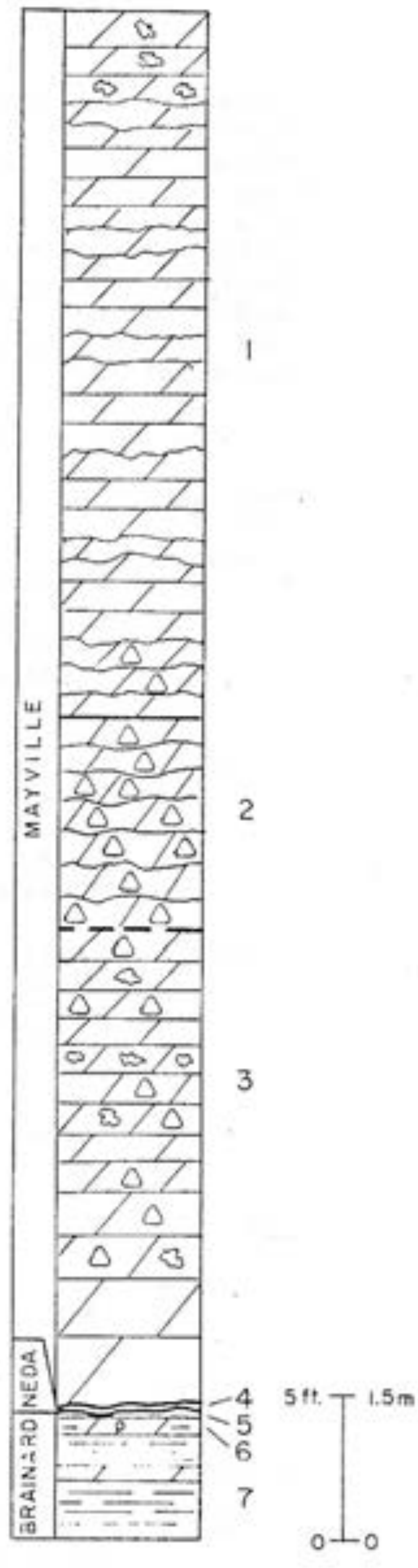


Fig. 25. Stratigraphic section measured along roadcut at Bayshore County Park showing Mayville, ?Neda, and upper few feet of Brainard.

represents a portion of the Niagara Escarpment, a geomorphologic bedrock feature which extends almost continuously for over 900 miles from New York State through the Great Lakes region. The continuity of the escarpment was recognized some time ago as demonstrated in the following statement made by I. A. Lapham in a letter to his wife dated October 15, 1851: "...the Iron Ridge of Wisconsin is but a continuation of the Mountain Ridge [Niagara Escarpment] of western New York. This remarkable limestone ledge forms the Niagara Falls, then sweeping through Canada and upper Michigan, turns to the south along the east side of Green Bay and Lake Winnebago and is lost only at Ashippun in Dodge County, Wisconsin!"

The following section was measured along the road (see fig. 25):

Mayville

Unit 1. 24 ft. 3 in. (7.3 m) Light gray, fine crystalline, dense, well-bedded dolomite in beds 1 to 7 inches (2.5-17.8 cm) thick alternating with rubbly-textured, thin-bedded gray dolomite with numerous black argillaceous partings. Near the base of the unit silicified tabulate corals and a chert layer occur in the rubbly lithology. A dense layer about 2 ft. (.6 m) above the base contains numerous trace fossils.

Unit 2. 7 ft. 4 in. (2.2 m) Fine crystalline, dense, nonporous, grayish brown dolomite possessing a very rubbly texture which obscures bedding. Abundant rubbly white chert in irregular nodules or discontinuous layers. This unit is somewhat less resistant than the rest of the Mayville and is indented across the face of the exposure.

Unit 3. 16 ft. (4.8 m) Fine crystalline, dense, cherty gray dolomite. Chert is not fractured as in Unit 2 and decreases in abundance downwards until it disappears about 4 ft. (1.2 m) above the base. A conspicuous bed of yellowish brown, vuggy dolomite occurs 2.4 ft. (.7 m) below the top of the unit. Bedding ranges from 4 in. (10.2 cm) at the top to nearly 3 ft. (.9 m) at the base, where the rock also appears darker in color.

Neda?

Unit 4. 1 in. (2.5 cm) Earthy, ferruginous reddish brown clay, forming a small reentrant across the face of the outcrop. Unit 4 is tentatively assigned to the Neda although apparently no ooids are present (see fig. 26).

Brainard

Unit 5. 1 in. (2.5 cm) Grayish green clay containing small phosphatic and ferruginous nodules.

Unit 6. 5.5 in. (13.9 cm) Very thin-bedded, irregular-textured, crumbly, gray, argillaceous dolomite containing very common phosphatic and ferruginous pebbles. Unit 6 is not very resistant and breaks down into rough, irregular-shaped fragments.

Unit 7. 2 ft. (0.6 m) Interbedded greenish gray, platy calcareous dolomite and fissile, greenish gray shale. Small phosphatic and ferruginous nodules cover the surface of the uppermost dolomite layers, and large branching burrow systems on the underside of the layer appear to have connections with the upper surface. Although no ooids are evident in Unit 4, some of the ferruginous nodules in Units 5-7 contain what may be very badly degraded ooids, but which cannot be definitely identified. The Maquoketa Shale presumably continues for about 60 feet to the level of the bay, but is covered by talus at the base of the escarpment.

Other Neda Outcrops in Vicinity of Green Bay

The presence of oolitic Neda or red clay presumed to represent Neda in the vicinity of Green Bay has been known for some time. As early as 1856 Percival reported a trace of ore at the Bay Settlement, and soon afterwards Daniels (1858a, b) noted traces of iron ore in the bluffs along the shores of Green Bay. Thwaites (1914) indicated "red beds" along the east shore of Green Bay on his map, and Savage and Ross (1916) noted an iron deposit at a few points southwest of the town of Sturgeon Bay.

Many early reports refer to exposures in the vicinity of Little Sturgeon Bay (fig. 27). Hall (1862) found "indications" of ore between Sturgeon and Little Sturgeon Bay. Chamberlin (1877) reported a fairly continuous bed of ocherous iron ore several inches thick along the shore of the bay south of Little Sturgeon Bay. He considered the bed equivalent to the ore at Iron Ridge, although rarely oolitic, based on its stratigraphic position.

E. O. Ulrich (1914, unpublished fieldnotes) made the following section based on exposures in sec. 18, and the SE corner of sec. 7, T.27N., R.24E., Door County.

Mayville

Unit 5. 4 ft. Heavy layers of gray dolomite.

Locally wedging in between Units 5 and 4 are five or six feet of hard, gray, coarse and fine "sandv" very fossiliferous dolomite, containing corals, overlain by a residual oolitic iron ore (fig. 28).

Unit 4. 25 ft. Like Unit 3 but thinner beds and with much shale and several chert layers. Beds of peculiar chert 5-6 ft. above base contain ostracodes and clay pebbles.

Unit 3. 12 ft. Heavy beds of magnesian argillaceous rock, layers to 5 ft. Chert layers (3 or 4) in lower half. Some layers at base stained with iron.

Unit 2. 10 ft. Bluish to purplish and gray limy shale. Beds very thin to 4-5 in.

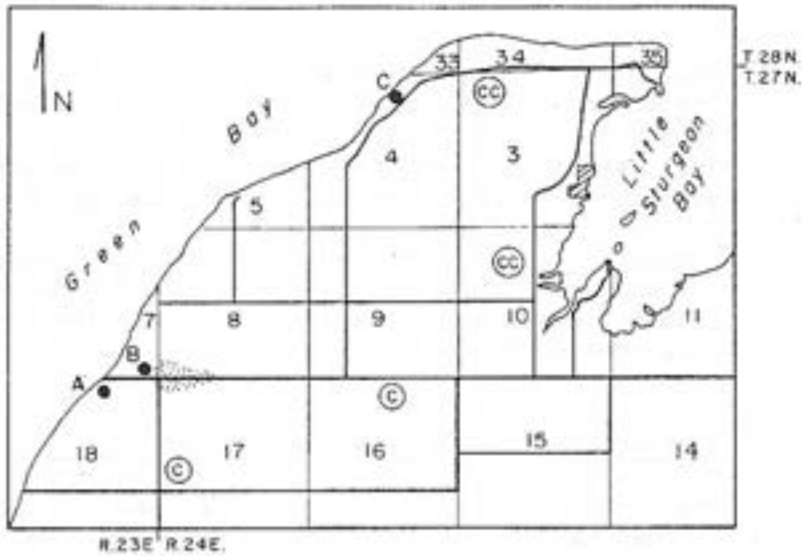


Fig. 27. Map of Little Sturgeon Bay area. A. locality diagrammed by Ulrich (see fig. 28); B. location of other oolitic Neda reported by Ulrich (1914, unpublished fieldnotes); C. locality described by Shrock and Twenhofel (1934, unpublished fieldnotes) and Havard (1935). Stippled area indicates area in which Rosenzweig (1951) reported loose fragments oolitic ore.

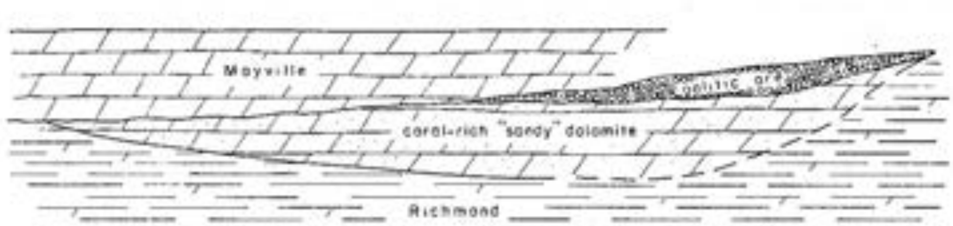


Fig. 28. Diagram of unusual stratigraphic relationships associated with a Neda occurrence near Little Sturgeon Bay (fig. 27, loc. A). (after E.O. Ulrich, 1914, unpublished fieldnotes)

Unit 1. 25 ft. Unexposed at bottom, presumably shale.

The following section was made by R. R. Shrock and W. H. Twenhofel (1934, unpublished fieldnotes) for a Neda exposure on the William Bosman property (sec. 4, T.27N., R.24E., Door Co.).

Mayville. 20± ft. Typical dolomite. Heavy beds (1+ ft.) of gray, semi-saccharoidal dolomite in lower part, grading upward into cherty beds in the upper 5 ft. Once burned for lime apparently. No fossils seen.

Neda. 1-3 in. A mere trace of red ore. Dust.

Richmond. 25± ft. Upper 12-15 ft. composed of thin-bedded argillaceous blue dolomite. Very much mudcracked and somewhat ripple marked. Ostracods in some beds. Lower 10 ft. more typical shaley though, containing much argillaceous material.

Havard (1935) visited this same locality and described the Neda as a "wet, bright brick red, earthy substance" which provided a footing for vegetation and an outlet for groundwater seepage.

One-half mile east of the bay shore and three miles west of Little Sturgeon Bay (sec. 7, 8, 17 and 18, T.27N., R.24E., Door Co.) Rosenzweig (1951) found rounded fragments of oolitic ore up to 20 cm in diameter near an outcrop, but no ore was seen in place. The fragments contained flattened ferruginous ooids mixed with clayey and calcareous material. The outcrop exposed five feet of heavy-bedded Mayville Dolomite underlain by 47 feet of thin-bedded to platy dolomite interbedded with bluish purple shale and chert.

It is evident from these reports that Neda is present in the escarpment in the area of Little Sturgeon Bay, and it is likely that traces of this unit exist in even more places but are obscured by slumping of the Mayville Dolomite. Because of this, Neda exposures are generally seen where waterfalls scour the face of the escarpment or where new cuts are made.

Other Neda Localities

The Neda has been reported from several other localities in Wisconsin, mostly in the subsurface. The only other Wisconsin outcrops of Neda have been observed at Ashippun, Dodge County (Rosenzweig, 1951)and on the south bank of the Rubicon River at Hartford, Washington County (Percival, 1855). The iron deposit at Hartford was reported to be up to 12 feet thick, covered by only a few feet of Mayville, and there was some interest in mining the area, but these plans never materialized and the outcrop is no longer visible.

Neda is known from the subsurface in Kenosha, Manitowoc, Milwaukee, Racine, Washington, and Waukesha Counties. The Neda is generally argillaceous, and in thin, localized deposits in these occurrences, but at Manitowoc 55 feet of ore was reported (Fuller and Sanford, 1906; Thwaites, 1914).

The following is a description of the core interval containing Neda lithology from the Vulcan Materials Company quarry at Ives (SE, sec. 29, T.4N., R.23E.) Racine County, Wisconsin (see Mikulic, 1977).

The Neda here is overlain by approximately 290 feet of Silurian.

Mayville

Unit 1. The basal Mayville is fine crystalline, porous, cherty, yellow gray dolomite with common pyrite and some glauconite near base. Sharp lower contact.

Neda

Unit 2. 10.2 in. (.26 m) Greenish gray silty shale containing light olive gray dolomite lenses. The lower 6 inches is darker and contains patches of flattened phosphatic ooids, some filling ?burrows. Lower contact somewhat gradational.

Unit 3. 12.5 in. (.3 m) Grayish red, silty, hematitic claystone, semi-plastic when wet. Contains scattered phosphatic and more common ferruginous ooids and small phosphatic nodules.

Unit 4. 1 ft. (.3 m) Mottled grayish red and yellow gray dolomitic siltstone. Trace fossils common. Occasional argillaceous partings. Sharp irregular contact with Unit 3.

Brainard

Unit 5. Greenish gray slightly silty shale.

History of Mining at Iron Ridge

The iron mines at the Iron Ridge in Dodge County were the most important source of iron in Wisconsin during the latter half of the eighteenth century. They were the first iron mines to operate in the state and the smelting furnace at Mayville, which processed this ore, was the first built in Wisconsin. Although these mines played an important role in the industrial development of southeastern Wisconsin, surprisingly little has been written about their history. Unfortunately, some significant errors have been published about the history of the mine operations, particularly in Lake Superior Iron Ores (Lake Superior Iron Ore Assoc., 1938), and these errors have been perpetuated in more recent work. The following is a comprehensive history of the mining operations, in which we have attempted to correct these previous errors, and which will clarify locality information in early reports.

Iron was mined at three locations in the Iron Ridge district. The Mayville Mine was the first to open and also the longest operating; later the Iron Ridge Mine and finally the Northwestern shaft mine were opened. The first two mines were very economical to operate and their proximity to major markets in Milwaukee and Illinois made them very profitable operations for many years.

The ore deposits at Iron Ridge were not discovered by geologists or explorers as were many of the iron deposits in the Lake Superior area. During the 1840s fumors maintained that iron deposits were present near the east branch of the Rock River (Helmbrecht, 1972). In 1845 Chester May and his son, Eli, along with Alvin and William Foster explored the eastern portion of Dodge County looking for a site with potential waterpower on which to erect a sawmill (Bartsch, 1947, 1972). They decided on the present site of Mayville, and soon afterwards Chester May reportedly discovered red dirt about four miles to the south. A friend of May's, Edward Cowen, identified the dirt as iron ore (Bartsch, 1947, 1972) and in 1846 May purchased 80 acres of ore-rich land at the site later to be known as the Mayville open pit mine. Although ore was present along the entire length of Iron Ridge, the ore deposit on May's property was the richest and most extensive because it had been concentrated by glaciation. May dug out three tons of ore and shipped it to the nearest furnace (Mishawaka Iron Works at Mishawaka, Indiana) for testing. The ore was found to make high quality iron, and one of the first objects cast from this ore shipment was an ornamental stove, now in the Wisconsin State Historical Society collection (Bartsch, 1947, 1972).

James Warren (in: Western Historical Co., 1880) claimed that Reuben Allen originally purchased the best ore land at Iron Ridge and made no mention of May's property. Allen's property, however, was located to the southwest of the Iron Ridge (W½, SW¼, sec. 13) and contained no ore deposits and was never mined.

In 1848 John H. Orr and John Niles of the Mishawaka Iron Company purchased May's property at Iron Ridge and began construction of a furnace at Mayville. The furnace was not built at the mine because the site lacked waterpower to operate the bellows (Bartsch, 1947, 1972). Niles and Orr organized the Wisconsin Iron Company in 1848, and in 1849 the first iron was produced at their furnace. Because of its disaggregate nature and its concentration along the bluff face, the "flax seed" ore could be dug out easily with pick and shovel; no drilling, blasting, or underground mining was necessary. The ore was loaded into carts and wagons and hauled over plank road the five miles to the furnace. Charcoal to fuel the furnace was cheap and abundant because dense hardwood forests surrounded the site, and very little flux was needed, making for a low-priced product. Pig iron and iron castings were produced at the furnace and shipped via wagon to Oconomowoc, the nearest railroad station. Apparently much of the iron was then sent to Milwaukee for use or for shipment on Lake Michigan to other areas. The furnace capacity was about eight tons, and in 1849 three tons of iron was produced per week (Milwaukee Sentinel, July 26, 1849). The 1850 Federal Industrial Census Schedule 5 provided the following data on this company: Capital invested $18,000; Number of employees, 60; average monthly cost of labor, $1800; quantity of annual production, 1000 tons of pig iron valued at $17,000.

In 1853 the Wisconsin Iron Company was purchased by Jacob L. Bean, J. Burchard, James Ludington, and Fred Wilkes (Milwaukee Sentinel, Oct. 15, 1853; Feb. 21, 1854). They formed a new company, the Northwestern Iron Company, to operate the mine and furnace, and served on its board of directors. Improvements were made at the furnace to enable production of railroad rails to be used in construction of the LaCrosse-Milwaukee Railroad, which was to pass a couple miles south of Iron Ridge (Milwaukee Sentinel, July 16, 1853). At this time, Byron Kilbourn, one of the railroad backers began purchasing all of the ore land around Iron Ridge, except for Northwestern's Mayville Mine, and undoubtedly intended to set up a major mining operation close to the new railroad.

Kilbourn had purchased two parcels of land that would become the Iron Ridge Mine. One parcel (E½, SW¼, sec. 13) was originally bought by Eli May from the U.S. government in 1847 and later sold to Northwestern. This area, just south of the south end of Iron Ridge, contained a deposit of glacially-concentrated, easily mined ore, but it was smaller than the deposit at the Mayville Mine and thinned rapidly in all directions. The other important parcel (SE¼, NW¼, sec. 13) purchased by Kilbourn was just east of the spring and Sterling's steam sawmill, the site of the original village of Iron Ridge, now Neda. This land was first purchased by Charles Woalston in 1847 and sold to Kilbourn in 1854. Weathered and eroded ore occurred in the talus below the Mayville Dolomite along the entire ridge, but the ore bed itself was not well exposed and could be mined only by stripping off the overlying dolomite or tunneling into the ore. Kilbourn wanted to encourage other investors to help finance his planned operations and in order to publicize the ore deposits he paid to have Percival's (1855) report and Cowle's (1863) pamphlet published, both of which are informative, but now very rare publications.

Kilbourn along with E. Hunter, S. L. Ross, J. D. Reyment, and Charles Jenkins incorporated the Swede's Iron Company in 1854, with a capital stock of $600,000. The LaCrosse-Milwaukee Railroad was completed past Iron Ridge in 1855 and the company planned to have a spur built north to their property where by 1857 they intended to erect a furnace. Due to poor economic conditions, however, the spur was not finished until 1864 and the furnace not until 1865. In the fall of 1864 the company began shipping ore to Milwaukee by rail, and 2592 tons arrived during the remainder of the year. L. J. Higby and son had built an elevator to load the ore (like grain) into lake vessels, and in 1864, 2370 tons were shipped to Cleveland and elsewhere (Milwaukee Chamber of Commerce, 1865).

The Swede's Iron Company was apparently not very successful, and it along with 1000 acres of land were jointly purchased by the Milwaukee Iron Company, the North Chicago Rolling Mill Company, and the Wyandoff Rolling Mill Company in 1870 (Milwaukee Sentinel, May 12, 1870). The new operations were named the Wisconsin Iron Company, which should not be confused with the company of that same name that operated the Mayville Mine at an earlier date.

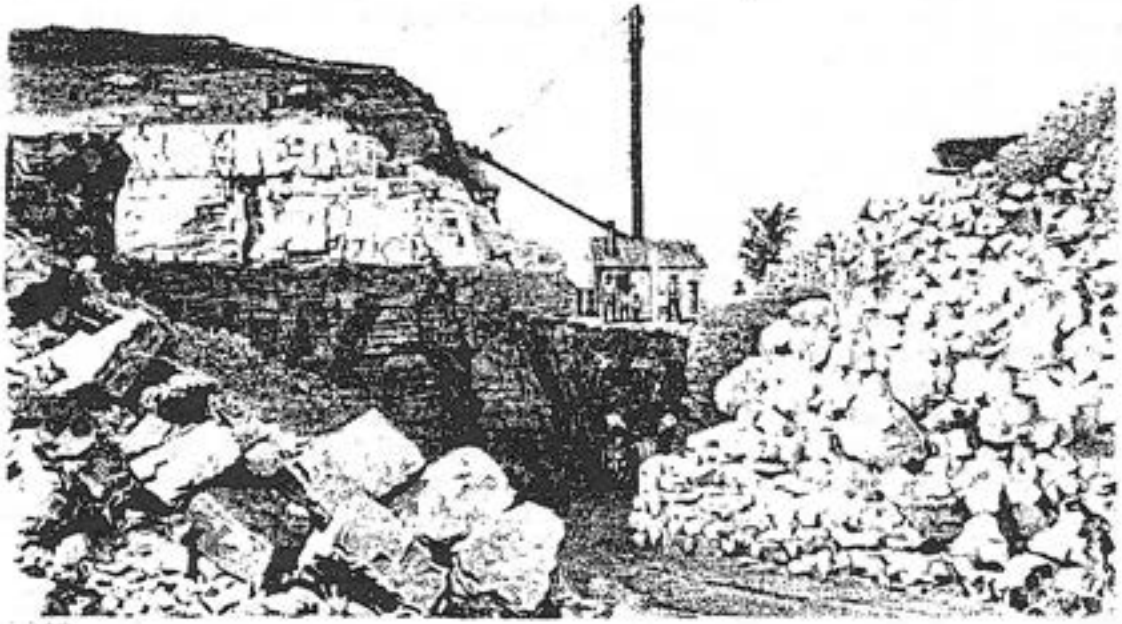
Iron mining at Iron Ridge increased dramatically during the early 1870s because of two new blast furnaces constructed at the Bay View works of the Milwaukee Iron Company (Whitbeck, 1921). The Bay View works produced railroad rails and pig iron mainly, and by 1873 was the second largest iron works in the country, employing over 1000 men. For the early history of the company see Milwaukee Chamber of Commerce (1870) and Hoyt (1870). The company owned a locomotive and 140 cars for hauling the ore to Milwaukee, and a dock was set up in Milwaukee for shipping ore by boat.

The low cost of mining and shipping the ore was the main reason for its widespread use. Chamberlin (1877), in his description of the geology and operation of the Iron Ridge Mine as it existed in 1873 (fig. 29), emphasized how cheaply the ore could be mined and shipped: "The position of the ore, outcropping along the face of a terrace, at a convenient elevation, rendering drainage, 'stripping', loading into cars, or the furnace, convenient, the soft character of the ore, its horizontal bedding of medium thickness, the ease with which it may be bored or blasted, its situation in a rich agricultural and heavily timbered region, and its railway connections, combine to render this locality unsurpassed in the advantages it presents for mining, reducing and shipping the ore...The cost of mining the ore is from 50 to 75 cents per ton. The value of the ore, delivered on the cars, is from $1.50 to $2.00 per ton". Chamberlin also reported that although both open pit and underground mining had been done, open pit mining was the most economical. The furnace had a capacity of about 3500 tons per year using no flux. Stripping of the Mayville Dolomite at the Mayville Mine had also started (fig. 30) around the time of Chamberlin's visit in 1873, but the ore was still being taken from the drift deposit which covered most of the escarpment. From 1873 to 1879 little mining took place at the Iron Ridge Mine due to a major economic recession (Western Historical Co., 1880). In 1877 a railroad line from Fond du Lac south through Mayville connected with a spur at Iron Ridge, which allowed iron from the Northwestern Iron Company to be shipped by rail for the first time. Little information is available about the operations of either mine during the 1880s.

During the late 1870s the Milwaukee Iron Works went bankrupt and was taken over by the North Chicago Rolling Mill Company (Whitbeck, 1921). By 1883 steel was replacing iron for railroad rails, but while other plants converted to steel production, the Bay View works did not. In 1889 the North Chicago Rolling Mill Company, including the Bay View works, was incorporated into the Illinois Steel Company. The Bay View works was still using Iron Ridge ore in 1890, but the Iron Ridge Mine was reportedly inactive from 1892 until 1902 (Lake Superior Iron Ore Assoc., 1938).

From 1902 to 1914 the Iron Ridge Mine was apparently operated by the Oliver Mining Company (fig. 31). After 1914 ore production ceased except for 1919-20 when less than 2000 tons were mined for paint pigment. The furnace at Iron Ridge was dismantled as part of a questionable W.P.A. project in 1937 (Bartsch, 1947; 1972), and the property at the mine site was given to the University of Wisconsin in the 1960s by U. S. Steel.

During the 1890s the Mayville Mine produced a large amount of ore, and in 1907 the mine and Mayville furnace were sold to Milwaukee financier Ferdinand Schlesinger, who continued to operate the company under the name Northwestern Iron Company. The Mayville furnace and plant were greatly expanded by Schlesinger (fig. 32)(see Bartsch, 1947; 1972, for a detailed history of this plant). By 1913 the original Mayville Mine property had been completely mined out, mostly by stripping but also limited tunneling. Test drilling on company land one mile to the east revealed a thick ore bed, and a shaft was constructed at the site (fig. 33). A railroad spur was built to the shaft, and by 1914 all operations had switched to the shaft mine and the original Mayville Mine was abandoned. In 1919 the Northwestern Iron Company became part of the Steel and Tube Company of America, but was still owned by Schlesinger. Both the furnace and mine were sold to the Youngstown Sheet and Tube Company in 1923 and were operated as a subsidiary called the Mayville Iron Company. Production was high at the new shaft mine, reaching a peak of 131,950 tons of ore in 1926. Some of the iron was sold to the nearby Kohler Company for use in bathroom fixtures, and a small



IRON RIDGE MINE.

Fig. 29. Chromo-lithograph of stripping and mining operations at the Iron Ridge Mine (ca. 1873). (from Chamberlin, 1877, Pl. III)

Fig. 30. Photo of the Mayville Mine showing 15-20 feet of Mayville Dolomite being stripped from 12 feet of ore. (Photo by W.C. Alden, 1909; courtesy of U.S. Geological Survey, No. Alden 417)

Fig. 31. View of Iron Ridge Mine (Oliver Mining Company) taken between 1890-1910 by Frank Fell. [Courtesy of E. Boeck, Mayville Historical Society; State Historical Society of Wisconsin neg. no. (F422)56]

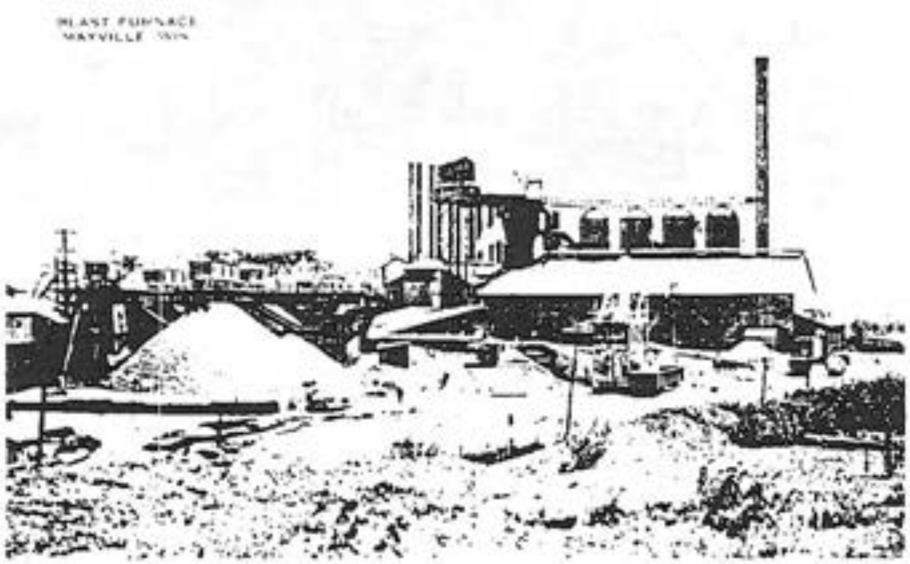


Fig. 32. Postcard view of Northwestern Iron Company furnace at Mayville (ca. 1916).

amount was sold for paint. The company also operated a stone quarry for flux adjacent to the Mayville White Lime quarry. Although apparently successful, the mine and furnace were closed early in 1928. According to local residents, the Kohler Company was interested in purchasing the operations, but the owner refused to sell. The Mayville plant was dismantled by 1933 (Bartsch, 1947; 1972) and the population of Mayville shrunk considerably. Some mining was still going on in 1930 at a small pit of drift ore (Paint Pit, NW¼, sec. 12). This ore was hauled to Neda where it was ground for paint pigment (Shrock, 1930 fieldnotes). The two companies that owned the iron deposits recently sold the surface land to farmers, but have apparently retained the mineral rights.

The Iron Ridge mining district was an important iron producer for almost 80 years. The high phosphorus content of the ore, making it unsuitable for modern steel making, was the main reason mining operations closed down. The reserves of the district are certainly small compared to other operating mines in the Lake Superior area, but a fair amount of ore remains to be mined.

Fig. 33. Photo of tipple at the Northwestern Iron Company shaft mine, looking west (ca. 1913). (Courtesy of E. Boeck, Mayville Historical Society)

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Road Log

Mileage in the first column is cumulative; mileage in brackets is distance between mileage points.

Mileage		
0.0		Intersection of I-94 and U.S. 151 on the northeast side of Madison, proceed north on U.S. 151.
17.5	(17.5)	Junction U.S. 151 Business, proceed northeast (straight ahead) on U.S.151 Business into Columbus.
19.7	(2.2)	Junction Wis. 60, turn right (east) onto Wis. 60.
42.1	(22.4)	Junction Wis. 109, turn left (north) onto Wis. 109 into Hustisford.
47.9	(5.8)	Junction Wis. 67, turn left (north) onto Wis. 67.
49.4	(1.5)	Community of Iron Ridge. This community was originally named Iron Ridge Station because it was located at the head of the railroad spur leading to the iron mines at the original village of Iron Ridge (now Neda).
51.8	(2.4)	Junction with W. Neda Rd., turn right (east) onto W. Neda Rd. into the village of Neda. Straight ahead is the southern end of the Iron Ridge and the site of the Iron Ridge Mine. The village of Neda has been known by several different names in the past. Originally called Sterling, it was the site of Theodore Sterling's spring and steam sawmill in the 1850s. By 1869 it was known as Iron Ridge, the original community with that name. Around the turn of the century the name was changed several times, first to Iron Mountain, later to Nye, and finally to Neda.
52.1	(0.3)	Junction with E. Neda Rd., turn right (south) onto E. Neda Rd.
52.2	(0.1)	Stop 1. Iron Ridge exposures. Park at the gate and proceed up the hill to the east to examine exposures of the Brainard Shale in roadside ditches. Return to gate and follow path north to the Iron Ridge Mine (Oliver mine) area, which is a scientific reserve owned by the University of Wisconsin. Most of the entrances to the extensive underground mine system have been sealed, and the Neda is exposed only at two tunnel entrances. Follow the escarpment north. Along the way one can see several old exploration drifts, mostly from the mid-1800s, that were dug through the talus to the base of the Mayville Dolomite in search of ore. Approximately 1500 feet north of the Iron Ridge Mine a dilapidated eighteenth century lime kiln can be seen at the base of the escarpment. At the top of the escarpment here is a shallow old quarry which furnished rock for the kiln. The scientific reserve property ends a short

distance to the north, and on the private property ahead is the old Mayville Mine (Northwestern Iron Company mine). Much of the escarpment between the property line and the "lake" is covered by excavated material dumped during mining activity. The area surrounding the "lake" at the Mayville Mine offers the best and most unique exposure of the Neda. Walk a short distance west to Mine Rd. to board the bus, proceed north on Mine Rd. to Wis. 67 and turn right (north).

54.4	(2.2)	Junction Wis. 33 and 67, proceed north on Wis. 67.
54.5	(0.1)	Mayville White Lime Company quarry and kilns to right (east). (For description of geology of the quarry see Burpee, 1932; Brooks, 1978; Shrock, 1939; Elger, 1979; Soderman, 1962).
55.3	(0.8)	Old quarry in escarpment to the east is approximate location of Chamberlin's type section for the Mayville Dolomite. Proceed on Wis. 67 through Mayville.
58.9	(3.6)	Historical marker on right. Site of Wisconsin's first iron smelter, which operated from 1849 to 1928 and used iron ore predominantly from the Mayville Mine.
64.0	(5.1)	Junction Wis. 175 in Theresa, turn left (north) onto Wis. 175.
72.2	(8.2)	Old quarry on left (west) just south of Fond du Lac County line.
76.4	(4.2)	Fond du Lac Stone Company quarry on left (west). This quarry is in a large bedrock hill, apparently controlled by one or more unexposed carbonate buildups in the Mayville Dolomite. The upper Mayville which is exposed does not contain the <u>Virgiana</u> beds that are present at the Mayville White Lime Company quarry. Approximately 40 feet of Byron Dolomite are exposed and are seen to dip away from the center of the hill, apparently draping over the Mayville buildup(s). See Shrock (1939), Froemke (1976), LaBerge (1978a), Brooks (1978) and Elger (1979) for detailed information.
76.9	(0.5)	Bueckel Stone Company quarry on right (east). On the left are old abandoned lime kilns along the northwest edge of the hill. Continue north on Wis. 175 into Fond du Lac.
81.7	(4.8)	Junction U.S. 151, turn right (east) onto U.S. 151.
85.7	(4.0)	The south end of Lake Winnebago may be seen to the left (north) and the Niagara Escarpment, running north-south, may be seen ahead.
101.1	(15.4)	Junction Wis. 55, proceed straight ahead (north) on Wis. 55.
108.3	(7.2)	Road to Calumet County Park on left (west).
111.6	(3.3)	Junction High Cliff Rd., turn left (north) onto High Cliff Rd.

112.3	(0.7)	Turn left (west) into High Cliff State Park. <u>Stop 2</u>. High Cliff State Park. Lunch stop. Exposures of Mayville Dolomite in abandoned stone quarries along top of Niagara Escarpment. Proceed through park.
115.4	(3.1)	Turn right (north) onto State Park Rd.
115.6	(0.2)	Turn right (east) onto Springhill Drive.
117.2	(1.6)	Junction Wis. 55, turn left (north) onto Wis. 55, proceed on Wis. 55.
118.7	(1.5)	Junction U.S. 10, turn right (east) onto U.S. 10.
124.9	(6.2)	Junction Wis. 57, turn left (north) onto Wis. 57.
132.5	(7.6)	Large quarry in the Mayville Dolomite in escarpment to the east of Greenleaf. Proceed on Wis. 57 into DePere.
142.3	(9.8)	Turn right (east) onto County G, proceed on County G.
147.3	(5.0)	<u>Stop 3A</u>. Below the level of the road, just west of the barn on the left (north) side of County G is Katell Falls. Proceed on County G.
147.7	(0.4)	Junction County MM, turn left (east) onto County MM.
148.0	(0.3)	<u>Stop 3B</u>. Ulmen Construction Company quarry.
150.7	(2.7)	Junction I-43, turn left (north) onto I-43.
157.8	(7.1)	Junction Wis. 57, turn right (east) onto Wis. 57.
164.4	(6.6)	<u>Stop 4</u>. Wequiock Cascades Wayside Park. Exposures in Silurian Mayville Dolomite and Ordovician Maquoketa Shale. Proceed north on Wis. 57.
170.3	(5.9)	<u>Stop 5</u>. Bayshore County Park. Last stop of the trip; follow Wis. 57 back to I-43.
182.8	(12.5)	Junction I-43, turn right (west) onto I-43N and proceed to end of I-43.
188.8	(6.0)	Junction U.S. 41, turn south onto U.S. 41S (Exit 119B) and return to Madison via routes U.S. 41, Wis. 26, and U.S. 151.
318.8	(130.0)	Madison

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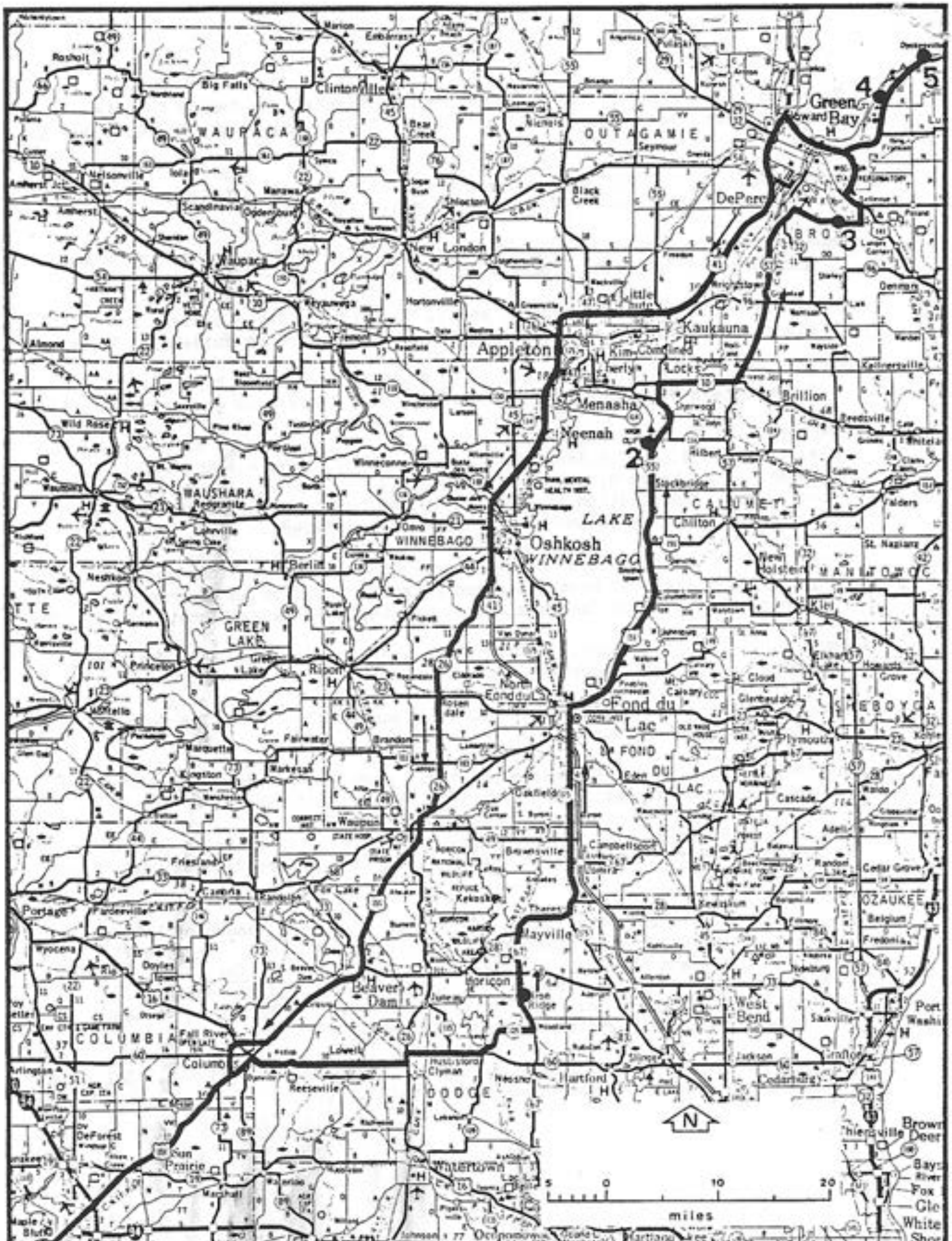
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