MINERALOGY AND SEDIMENTOLOGY OF ROCK OVERLYING THE BARABOO QUARTZITE

by

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ABSTRACT

The thick Proterozoic Baraboo Quartzite of south-central Wisconsin is overlain by two sequences of metasedimentary rock. The first sequence consists of the Seely Slate and the Freedom Formation. The Seely Slate conformably overlies the Baraboo Quartzite and displays a low-grade mineral assemblage indicative of greenschist-facies metamorphism. The Freedom Formation consists of a lower, banded iron-formation with interbedded and overlying dolomite. Unconformably overlying the Freedom is the Dake Quartzite and Rowley Creek Slate. The Dake Quartzite appears to be a more immature lithology than the Baraboo Quartzite. It contains some detrital feldspar, although most has been replaced by kaolinite.

An environment of deposition on a continental margin or platform for the stratigraphically lowest three lithologies at Baraboo is consistent with the present data and the sedimentary model described by Dott (1983). The Dake may have micaceous quartzite analogues in central Wisconsin, but correlation of the Baraboo Quartzite and those in central Wisconsin is difficult to demonstrate and is open to considerable uncertainty at this time.

INTRODUCTION

The Proterozoic Baraboo Quartzite has been studied for over one hundred years, and thus one would expect that the tectonic setting and the related environment of deposition would be well understood. Unfortunately this is not the case, because diametrically opposite tectonic settings have been proposed recently to explain the metamorphic, structural, and sedimentologic features at Baraboo and possibly related central Wisconsin quartzite (Dott, 1983; Greenberg and Brown, 1984). As Dott has stressed, the absence of fossils in this rock makes the environment of deposition difficult to define. Therefore, sedimentologic criteria must be used. Much sedimentologic data are available for the Baraboo Quartzite. However, information is limited on the buried metasedimentary units overlying the quartzite. Much of the information that is available is old (Weidman, 1904) and not easily confirmed.

The purpose of this note is to further describe and document mineralogic and petrologic data for several lithologies that overlie the Baraboo Quartzite. Some of the sedimentologic features and stratigraphic relationships around the Baraboo area will be analyzed with this data. The information presented herein may help in the potential correlation of the Baraboo area and with central Wisconsin Proterozoic quartzite. It will also aid in the understanding of the sedimentary environment of deposition and thus the evolution of the Baraboo region as a whole.

GEOLOGIC HISTORY

Based upon structural studies, Irving (1872) was the first to demonstrate that the Baraboo Quartzite was older than the surrounding Paleozoic strata. He proposed, as Hall (1862) did earlier, that the Baraboo Quartzite was Huronian in age. Later, geologists working in the Baraboo area found and described several buried formations overlying the quartzite (Weidman, 1904; Leith, 1935). They formed the geological column of the Baraboo district as shown in table 1 and figure 1. Their work was initiated because of the discovery of iron ore in the western part of the syncline around 1900. Since most of these formations are not exposed, the descriptions of lithologies overlying the Baraboo Quartzite are known primarily from subsurface drill core and iron mining records. Leith (1935) proposed, however, that parts of the Dake Quartzite crop out. The metasedimentary rock around Baraboo overlies basement rhyolite and granite and have been described as an upper and lower series, with an unconformity separating the two (Leith, 1935). The Baxter Hollow granite on the southern part of the Baraboo Range is intrusive into the quartzite according to Gates (1941) and Schmidt (1951).

Early geologists correlated rock of the Baraboo district with the Menominee Group metasedimentary rocks and iron-formation in the Marquette area of Upper Michigan, because of the general stratigraphic similarities and the presence of iron-formation in the Freedom Formation. Both were considered Huronian in age. Today, the term Huronian is restricted only to metasedimentary and

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volcanic rock found on the north shore of Lake Huron (Card and others, 1972; Young, 1981). The early Proterozoic rock in Canada is now considered to be older than Proterozoic metasedimentary rock directly to the west, such as those found near Marquette and at Baraboo. Huronian sedimentary rock is considered to be about 2,500 to 2,100 Ma (Young, 1981). The metasedimentary rock and iron-formation in Michigan, which constitute the Marquette Range Supergroup (of which the Menominee Group is part, Cannon and Gair, 1970), are now thought to be Penokean, about 1,950 to 1,850 Ma in age (Van Schmus, 1982). Furthermore, Baraboo metasedimentary rock was interpreted by Dalziel and Dott (1970) and Dott and Dalziel (1972) as being distinctly younger than the somewhat lithologically similar Menominee Group Strata. The Baraboo Quartzite rests unconformably upon 1760 Ma rhyolites (Van Schmus, 1976). Therefore, Baraboo metasedimentary rock is also post-Penokean. Dott (1983) introduced the term Baraboo interval (1,760 to 1,500 Ma ago) for the time period in which sedimentation, deformation, and metamorphism formed the Baraboo and similar southern Lake Superior quartzite, such as at the Waterloo, Barron, and Sioux localities (fig. 2). Greenberg and Brown (1984) have recently described a number of quartzite, chert argillite conglomerate, and iron-formation localities in central Wisconsin (fig. 2), and have proposed that units were also deposited during the Baraboo interval.

PREVIOUS DESCRIPTIONS

Cambrian sandstone and conglomerate uncomformably overlie the Proterozoic metasedimentary rock around Baraboo. The oldest Cambrian sedimentary rock of the Mt. Simon and Eau Claire Formations is found in western Wisconsin, but are not exposed in the Baraboo region (Dalziel and Dott, 1970). They may, however, be present in the subsurface. The Galesville sandstone is the oldest Paleozoic unit exposed in the area. It is generally a white to gray rock, friable, unfossiliferous, and consists of well-rounded and well-sorted mediumto coarse-grained quartz sand, except around Baraboo where very coarse storm deposits have been noted (Dalziel and Dott, 1970).

The Precambrian sedimentary rock overlying the Baraboo Quartzite (table 1) has been described by Weidman (1904), Leith (1935), and Schmidt (1951). The Seely Slate is a soft gray and/or green chloritic slate. Weidman (1904) originally termed it a slate, although some parts might better be termed a phyllite or schist. Lenses of pure quartzite up to 8 m thick have been found in the Seely (Leith, 1935). Weidman described it to be uniform throughout the Baraboo region. The Seely displays a fine stratification and has a well-developed tectonic cleavage that cuts diagonally across bedding. Weidman listed chlorite, quartz, andalusite, and probably kaolinite as constituting the bulk of the rock. Brown mica, tourmaline, and apatite were also mentioned.

Table 1.--Precambrian Stratigraphy of the Baraboo District (modified slightly from Dalziel and Dott, 1970)

≥ 1,500 Ma	Rowley Creek Slate (maximum known thickness 45 m)
upper Baraboo series	Dake Quartzite (maxium known thickness 65 m)
	--- (Unconformity ?) ---
	Freedom Formation (dolomite, ferruginous slate, and iron-formation, minimum thickness 305 m)
lower Baraboo series	Seely Slate (maximum known thickness 110 m)
	Baraboo Quartzite (thickness over 1220 m)
	--- (Unconformity ?) ---
1,760 Ma	Rhyolitic basement (thickness unknown)

The Freedom Formation conformably overlies the Seely Slate. It is a thick (roughly 300 m) and lithologically diverse unit. Weidman proposed that the Freedom could be divided into two separate formations, although he did not do so. The upper member consists of a dolomite with or without chert. The lower member contains a thick banded-ferruginous chert, with thinner interbedded sideritic, calcitic, and dolomitic slate (Leith, 1935). Located in the lowermost Freedom is a ferruginous kaolinitic slate which is a transitional lithology between the underlying Seely and overlying ferruginous chert. The iron-formation of the lower member has a variable thickness ranging from roughly 60 to 160 m over relatively short lateral distances (Schmidt, 1951).

The Dake Quartzite was described by Leith (1935), and apparently was not recognized by Weidman (1904) in his study of the Baraboo region. The Dake unconformably overlies the Freedom, so that in places it rests on the lowermost part of the Formation. It also displays a flatter dip than the underlying Baraboo Quartzite (Leith 1935). These data were the basis for placing an unconformity between the upper and lower series (Leith 1935). The Dake is generally a coarse-grained quartzite containing a large amount of matrix sericite and chlorite, thus giving it a dirty appearance. Lower parts of the Dake are loosely cemented with iron oxide. Much of this formation is coarsely conglomeratic and has large angular pebbles. Most of the pebbles consist of quartz or quartzite. At Dake Ridge (fig. 3) where this formation is thought to crop out, red jasper pebbles, dark purplish quartzite and a few black or green pebbles also occur in conglomeratic beds (Leith, 1935). Greenberg and Brown (oral communication, 1983) have recently reexamined this outcrop and their observations agree with that given above. However, at least part of this outcrop consists of a cleaner well-sorted quartzite that is similar to the Baraboo Quartzite (Schmidt, 1951). The presence of jasper and dark purplish pebbles suggests local derivation from the lower Freedom and Baraboo Formations, respectively (Leith, 1935).

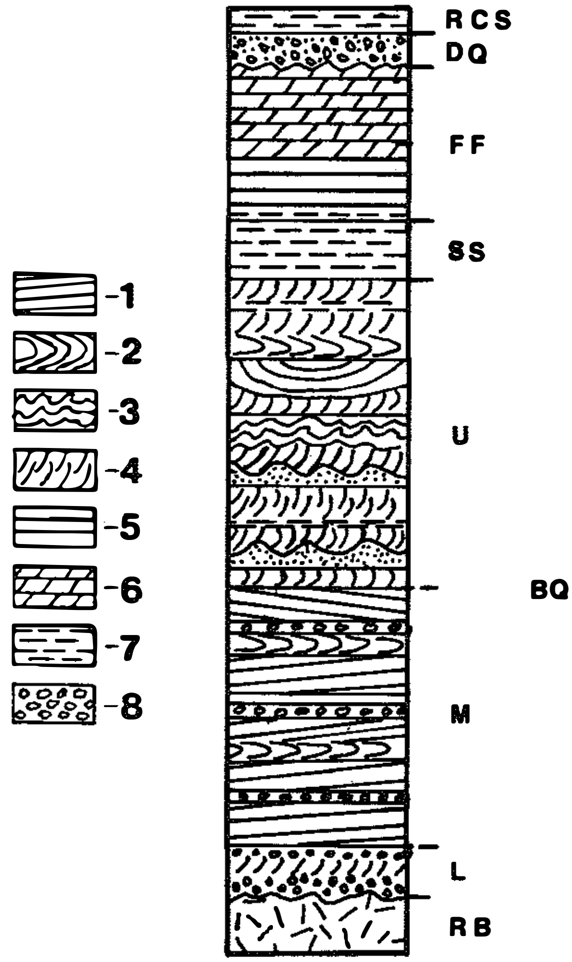

Figure 1.--Schematic geologic column of rock around Baraboo, Wisconsin, not to scale. Symbols and abbreviations: 8, conglomerate; 7, slate or argillite bed; 6, dolomite; 5, banded iron-formation; 4, high angle cross bedding; 3, ripple marks; 2, deformed cross bedding; 1, low-angle cross bedding; RB, rhyolitic basement; BQ, Baraboo Quartzite (L, lower; M, middle; U, upper); SS, Seely Slate; FF, Freedom Formation; DQ, Dake Quartzite; and RCS, Rowley Creek Slate (modified slightly from Dott, 1983).

The Rowley Creek Slate is the youngest Precambrian metasedimentary unit in the Baraboo area. It is only known in the eastern part of the district, as is the Dake (Leith, 1935). This may explain why it and the Dake were not described by Weidman (1904). Most of his work appears to have concentrated on the western part of the district in the vicinity of the Illinois mine (fig. 3). The Rowley Creek Slate is composed dominantly of sericite, with lesser amounts of chlorite and quartz. It is gray in color, but oxidizes red along bedding and cleavage planes. It has been folded and deformed and has not been found in outcrop.

METHODS

Several pieces of drill core taken from strata overlying the Baraboo Quartzite were made available by M.G. Mudrey, Jr. This core came from undescribed holes drilled many years ago (60-70?) at the Cahoon Mine. The Cahoon Mine is located about 1.5 km south of the town of Baraboo in the central part of the Baraboo Syncline (fig. 3). No information is available concerning the exact orientation or location of the drill core, except that it came from holes numbered 134 and

135 and depths between 410-509 ft. Most of the drill core from the turn-of-the-century iron mining period has since been destroyed or lost, and much of the information concerning the formations overlying the Baraboo Quartzite is based on an unpublished report (Dake, cited in Leith, 1935).

The core was studied using thin section and X-ray diffraction techniques. Most of the samples examined are relatively fine-grained and identification of some minerals was only possible in X-ray scans. X-ray scans often indicated the presence of 3 or 4 minerals, with quartz predominant. Due to diffraction-peak overlapping, a few minerals were tentatively identified using one or two peaks. Whenever possible, mineral separates were made by crushing and hand picking. All major phases were identified, but minerals in small modal amounts may not have been detected. Because of the fine-grain size, visual modal estimation of the various minerals was not attempted.

DISCUSSION

Four distinct lithologies are evident in the five pieces of core studied. The first lithology examined was a fine-grained green chloritic phyllite. X-ray scans showed chlorite, muscovite, quartz, and possibly albitic feldspar. Tourmaline and apatite were observed in thin section. Red hematite-rich bands or segregations are also evident in certain samples. Alternating arenaceous and argillaceous layers are visible in some thin section samples, thus producing a fine stratification (fig. 4). These bands probably represent original depositional layering. The most prominent tectonic foliation, S_1, strikes at a low-angle to this bedding. A second, weaker crenulation cleavage, S_2, is observable in some sections (fig. 5). The S_1 cleavage either partly accompanied or occurred after the development of small porphyroblasts or cross micas of chlorite which display cleavages at a high angle to S_1 (fig. 6). These observations fit the description of the Seely Slate as given by Weidman (1904). However, Weidman reported the presence of kaolinite and andalusite. The latter is very likely a misidentification (for albite?), as no andalusite was observed in several different samples. Furthermore, based upon a simple petrographic examination, this rock appears to have a metamorphic grade too low for the development of andalusite. Kaolinite may be present in small amounts, but it was not positively identified.

The second lithology can be best described as a red, iron-rich, cherty marble or carbonate. White or gray chert layers or semi-irregular patches constitute a major fraction of the core. A typical macroscopic chert layer is on the order of 1 to 4 mm thick. Some samples in thin section display alternating chert or carbonate or both with hematite layers about 0.1 to 1 mm thick. This

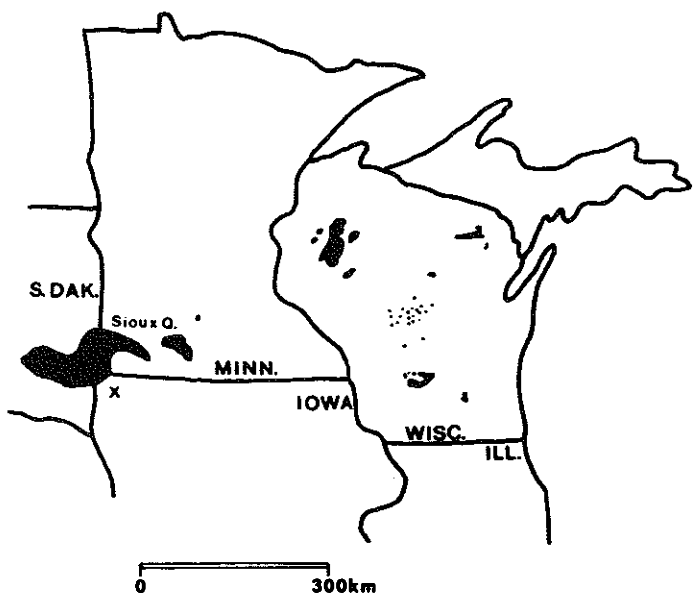

Figure 2.--Distribution of Baraboo interval exposures in the upper midwestern US shown in black. Veedum and Vesper are located in one of the small central Wisconsin outcrops Figure 2, p. 160 reproduced with permission of The Journal of Geology, by permission of the University Press, from J.K. Greenberg and B.A. Brown, 1984, Cratonic sedimentation during the Proterozoic: An anorogenic connection in Wisconsin and the upper midwest: v. 92, p. 159-171.

banding is distinct and usually additional to the large macroscopic banding. X-ray scans show the presence of calcite, quartz, hematitie, and goethite in the core sample. Other core samples that were only examined in thin section contain small amounts of white mica. One of these thin sections contains a small band of quartz and white mica, which appears to be detrital in origin. The presence of goethite is typical of many soft iron ores, and suggests in this case that significant

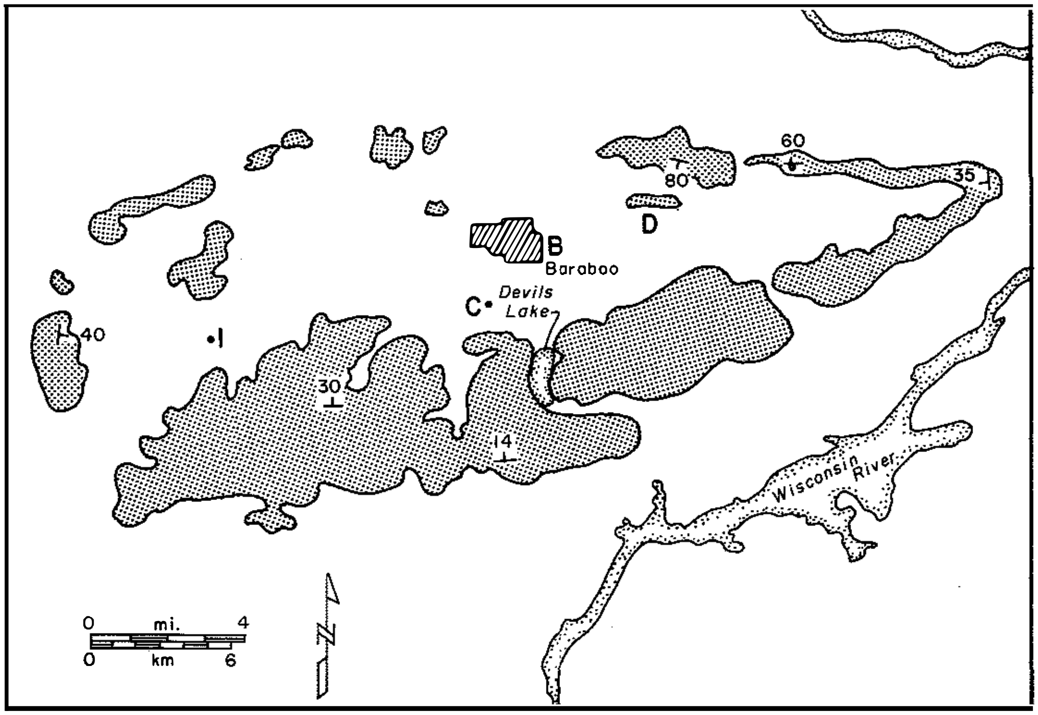

Figure 3.--Generalized geologic map of the area around Baraboo, Wisconsin, showing outcrop locations of the Baraboo Quartzite. Abbreviations: B, Baraboo; C, Cahoon Mine; D, Dake Ridge; and I, Illinois Mine.

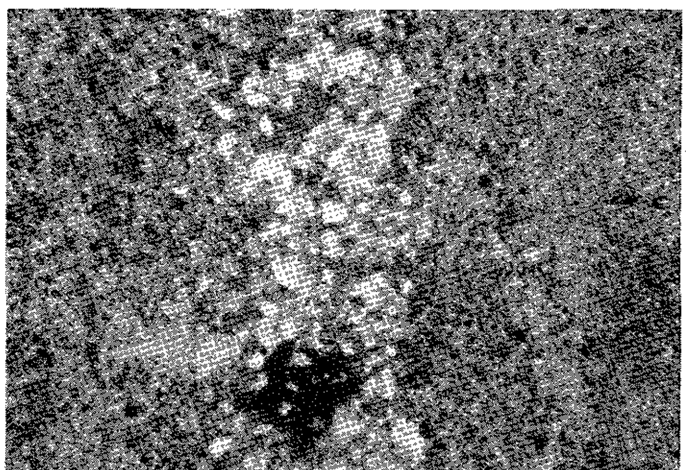

Figure 4.--Photomicrograph of the Seely Slate showing a thin arenaceous layer composed dominately of quartz. The large opaque grain is hematitie. Long direction is about 2.5 mm; crossed nicols.

alternation of a primary chert-carbonate-magnetite or hematite lithology occurred. The core and the thin sections match the description of the Freedom Formation, as given by Weidman (1904) and Schmidt (1951).

The third rock type is a medium-grained quartzite or subarkose. This rock is composed of quartz (95-90%), kaolinite, white mica, and trace feldspar. On a weathered surface this rock has a red iron-stained color, but freshly broken surfaces disclose a relatively clear quartzite. Some of the quartz grains are cloudy or milky colored. In thin section the quartz grains show a slight dimensional preferred elongation. These grains range up to 3 to 4 mm in diameter, but average about 0.5 mm. The kaolinite is concentrated in pockets that are up to 4 to 5 mm in size (fig. 7). X-ray scans of separates taken from these pockets give major kaolinite and small feldspar peaks. Matrix sericite or clay is sparse and is broadly disseminated between the larger quartz grains. The kaolinitic pockets probably formed from the breakdown of detrital feldspar. Thus, this rock is petrographically similar to some Baraboo interval rocks at Veedum and Vesper in central Wisconsin (fig. 2 in Greenberg and Brown, 1984).

Lithology type four can be best described as a fine-grained arkose. X-ray scans show mainly quartz, with substantial albitic feldspar, and probably microcline. Thin sections show also about 5 percent of muscovite, carbonate, chlorite, and heavy accessory minerals such as zircon. Feldspar is often sericitized and sometimes displays albite twinning. In addition the rock is colored red due to the presence of interspersed hematite. Grain sizes are fairly uniform averaging around 0.05 mm. Sorting is good and the majority of grains are subangular in shape. The core displays a distinctive intersecting cross-stratification in hand sample. This rock shows no evidence of pervasive metamorphism or recrystallization as in the other rocks mentioned above.

CONCLUSIONS

Dott (1983) proposed that the lower beds of the Baraboo Quartzite could be interpreted as fluvial clastic sands that were deposited on a continental margin. These sands grade upwards into a series of transgressive marine sediments called the Seely Slate and Freedom Formation (Dott, 1983). The iron-formation in the lower part of the Freedom contains a significant amount of ferruginous chert (Weidman, 1904) or what might better be called banded iron-formation. This lithology probably constituted a major fraction of the lower Freedom prior to the alteration which produced the soft iron ore. Weidman described the ferruginous chert as "layers of red and grayish chert alternating with layers of nearly pure hematite, and with layers of chert mixed with hematite. These alternating layers generally vary from one-fourth of an inch in thickness." This general description would also apply to much of the approximately 1,900 Ma-old oxide facies banded iron-formation located throughout the Lake Superior region (James, 1954). But it is now known, however, that the sedimentary rock at Baraboo was deposited 150-250 m.y. after the Lake Superior-type iron-formation.

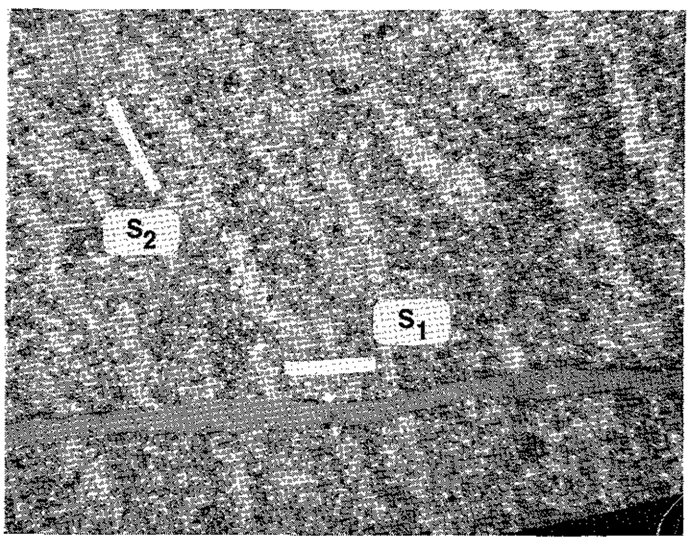

Figure 5.--Photomicrograph of the Seely Slate showing S_2 crenulation (light streaks) superimposed at a high-angle to S_1 which is parallel to the parting or crack in this slide. The major minerals are quartz, white mica (muscovite), and chlorite. Long direction is about 2.5 mm; crossed nicols.

Age differences aside, the environment of deposition could well be similar for both groups of iron-formation. Many workers believe that the banded iron-formation in the Lake Superior region was deposited in shallow water on a continental shelf or platform environment (James, 1954; Gross, 1983; Lougheed, 1983; however see Larue, 1981). The banded chert-hematite iron-formation and associated carbonate in the Freedom may have formed under similar conditions. This sedimentary environment for the Baraboo region agrees with the sedimentary model proposed by Dott (1983), which was based upon studies conducted primarily on the lower Baraboo Quartzite.

James (1954) described four distinct iron-formation facies that could be recognized in the Lake Superior region. The oxide facies which is characterized mainly by chert-magnetite-hematite, is conjectured to have formed in shallow water adjacent to the slightly deeper water carbonate facies iron-formation. At Baraboo not only does a thick unit of dolomite overlie banded chert-hematite iron-hematite iron-formation, but lesser amounts are also interbedded with it. These two facies, carbonate and oxide, also grade laterally into one another over relatively short distances (Schmidt, 1951). These observations suggest that deposition in the lower part of the Freedom occurred in a transitional facies, and that the upper Freedom represents a transgression to deeper water levels. Moreover, the presence of dessication cracks and carbonaceous matter in the lower Freedom (Weidman, 1904) are not definitive criteria for, but are consistent with, an intertidal environment of deposition. More petrographic work on the iron-formation in the Freedom could disclose the type of textures observed by Lougheed (1983) in early Proterzoic Lake Superior type iron-formation, and would enable correction or refinement to be made regarding the enviroment of deposition of the Freedom at Baraboo.

The Dake Quartzite unconformably overlies the Freedom (Leith, 1935). The kaolinitic quartzite or former subarkose sample described above could be from the Dake. This rock has pockets of kaolinite which still contain a little detrital feldspar. Therefore, it is unlike anything described from the lower Baraboo Quartzite, because most of the Baraboo is devoid of feldspar (Dott, 1983). Thin, widely spaced argillite beds are found in the Baraboo, but these are composed of the highly aluminous mineral pyrophylite. Such aluminous-rich bulk compositions usually occur in areas of intense chemical weathering (for example, tropical areas). For these reasons Dott (1983) argued that intense chemical weathering occurred at the source region for the Baraboo. The Dake as described by Leith (1935) is a less mature lithology. If the above hypothe- sis is correct, the presence of detrital feldspar indicates that the sedimentary environment or provenence changed between deposition of the Baraboo and the Dake. Hence, the unconformity be- tween the upper and lower series is a real possibility.

The composition of the Seely Slate, which comformably overlies the Baraboo Quartzite, may also indicate less maturity than the highly aluminous interbeds in the Baraboo. The Seely is richer in iron, magnesium, and the alakali elements because of the presence of abundant muscovite and chlorite. Its source region may not have been as deeply weathered, as that which provided the material for the pyrophyllite beds in the Baraboo. According to Dott (1983) the Seely Slate marks the transition between a fluvial (Baraboo) and a truly marine environment (Seely).

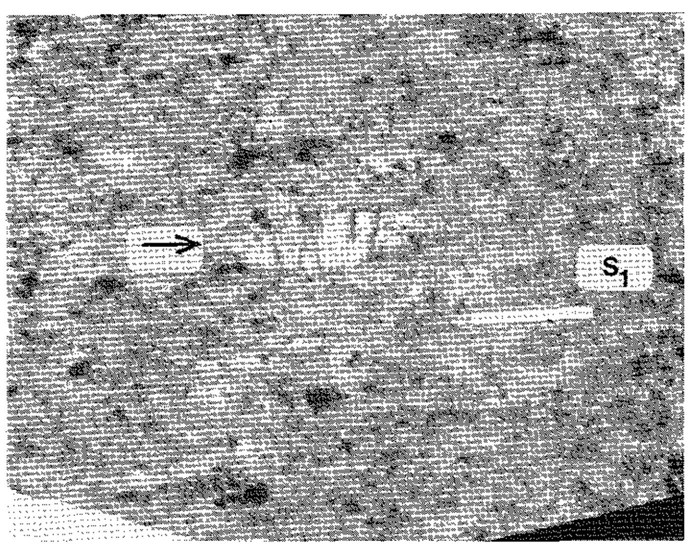

Figure 6. Photomicrograph of the Seely Slate displaying porphyroblast or "cross mica" of chlorite with growth cleavages roughly perpendicular to S_1 Long direction is about 1.0 mm; crossed nicols.

Greenberg and Brown (1984) have recently documented Proterozoic quartzite in central Wisconsin that is intimately associated with micaceous conglomerate, argillite, bedded chert, and iron-formation (fig 2.). The Dake could be correlative with these micaceous quartzites in central Wisconsin or they could be transgressive equivalents of the Baraboo Quartzite (Greenberg and Brown, 1984). The central Wisconsin quartzite is not always similar to the Baraboo interval quartzite described by Dott (for example, the Baraboo, Waterloo, Barron, and Sioux), although a few are. Furthermore, they generally do not appear to show the kind of thicknesses between 300 and 1000 m as indicated by the isopach map of Baraboo interval sandstone presented by Dott (1983). The Proterozoic metasedimentary rock and stratigraphic relationships in central Wisconsin are not well exposed or well understood. Hence, obvious or strict correlations between the Baraboo area and central Wisconsin are difficult, and at this time are open to considerable interpretation. The Dake may have analogues in central Wisconsin, but further work is needed to test this hyothesis.

It is not possible from this study alone to choose between the orogenic model of Dott (1983) and the anorogenic model of Greenberg and Brown (1984) for the tectonic setting of the Baraboo interval. More metamorphic and geochronologic studies (Geiger and Guidotti, in preparation), in combination with structural studies of all the quartzite are needed to resolve this problem. The data herein are consistent with the sedimentologic scenario for the lower series as presented by Dott (1983). Dott did not consider in detail the upper series, and no sedimentologic model has been advanced for these younger and poorest known lithologies at Baraboo. Unfortunately, at this time it is not wise to formulate any model based upon the limited data in this paper and in Leith (1935). However, in the future the presence of the upper series should be considered when constructing geologic models of the Baraboo region.

The fine-grained arkose described above may be a basal Cambrian lithology. This was suggested by J.K. Greenberg (oral communication, 1983), as he has observed similar lithologies from other drill core taken in the Baraboo region. The lack of any evidence for significant metamorphism in this rock is consistent with this proposal, with which I agree. Yet, this arkose is unlike many of the mature quartz arenites found among the Wisconsin Paleozoic sandstone. This rock may reflect local changes in Cambrian facies in the Baraboo region (for instance, a storm related deposit--Dalziel and Dott, 1970) as compared to elsewhere in Wisconsin.

Based upon the reconnaissance work presented in this paper, it appears that the sedimentological history of the Baraboo district remains a complex problem. Obiously much more work needs to be done, primarily sedimentologic in nature, on the buried and unexposed rock overlying the Baraboo Quartzite to gain a better understanding of the depositional history there.

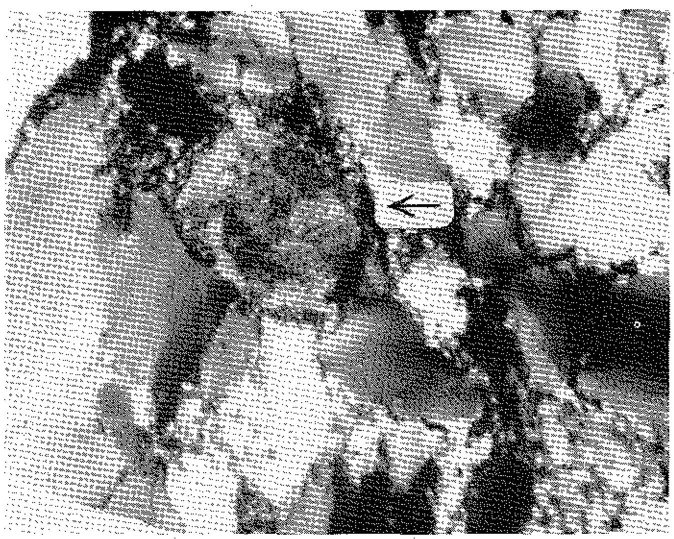

Figure 7. Photomicrograph of the Dake Quartzite showing a kaolinite pocket in left-center of this slide. Long direction is about 1.25 mm; crossed nicols.

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