PRELIMINARY PALEOMAGNETIC STUDY OF THE BARABOO QUARTZITE, WISCONSIN

by

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ABSTRACT

Preliminary paleomagnetic data for the Baraboo Quartzite of southern Wisconsin are presented in this report. Nineteen hand samples from areas on both sides of the Baraboo Syncline were analyzed using both alternating field (AF) demagnetization and thermal demagnetization techniques. AF demagnetization up to 100 millitesla had little effect on the magnetic directions or intensity. Thermal demagnetization indicated that the stable remanence is probably caused by hematite (curie temperature 650 to 700 °C). The statistics of the magnetic directions improve for the samples from the western end of the Baraboo Syncline when structural corrections are made. This indicates that the magnetization was set prior to folding. The virtual geomagnetic pole (VGP) is located at 19°S., 89°W., which is consistent with currently published pole positions for the time range of 1,800 Ma to 1,700 Ma for North America. The statistics for samples from the eastern end of the syncline do not improve when structural corrections are made. This suggests that the magnetism for these samples may be post folding. The VGP for these samples before structure corrections is 57°W., 44°N., which is similar to the VGP obtained for several of the associated rhyolite.

INTRODUCTION

The Precambrian geology of Wisconsin represents a complex succession of tectonic events. Of particular interest to this study is a suite of rocks in southern Wisconsin comprised of rhyolitic volcanic rock, associated granite, and overlying quartzite, which were originally deposited as sands sometime between 1,760 Ma to 1,450 Ma. The geologic history of this sequence and the tectonic causes are not fully understood, although there are several recent interpretations of it.

It is known that the rhyolite and granite intruded Penokean age rock (about 1,850 Ma old) about 1,760 Ma (Smith, 1978; 1983; Van Schmus and Bickford, 1981). This was followed by the extensive deposition of sand (now quartzite) in fluvial to shallow marine environments (Dalziel and Dott, 1970; Dott, 1983). Folding of the quartzite probably took place sometime between 1,630 and 1,500 Ma, the time of intrusion of the Wolf River batholith anorogenic granite complex.

Dott (1983) has suggested that the red sands which are now the Baraboo Quartzite formed on a passive continental margin between 1,700 to 1,600 Ma; deformation and metamorphism of the quartzite took place about 1,600 Ma by either an arc-continent or continent-continent collision from the south. Evidence for a tectonic event at about 1,630 Ma comes from Rb/Sr systems of the 1,760 Ma-old rhyolite which has been reset at 1,630 Ma (Van Schmus and others, 1975).

Greenberg and Brown (1984) present a different tectonic history for the area, one similar to the Basin and Range province of the western United States (Atwater, 1970). The deposition of the Baraboo Quartzite began on a subsiding continental crust during the late stages of anorogenic magmatism 1,760 Ma. The 1,630 Ma event is considered a time of epeirogenic uplift. This uplift brought about relatively mild deformation of the Baraboo rocks, with some metamorphism. Finally, the widespread intrusion of the 1,500 Ma-old Wolf River batholith further deformed the region and caused thermal metamorphism. No collision tectonics is considered in this model.

It is apparent from these two models that the time of the folding and metamorphism of the Baraboo Quartzite is still uncertain. There are certain specific questions which may be answerable from paleomagnetic studies. Two of great interest are the actual deposition age of the Baraboo Quartzite and the time of folding. Presently, the deposition and folding are bracketed between about 1,760 Ma and 1,500 Ma from the ages of igneous activity in the area. There is also uncertainty with the final age of intrusion and metamorphism in the Baraboo area. Dott (1983) suggests that the last thermal event was reheating at about 1,600 Ma. Greenberg and Brown (1984) place the final reheating activity closer to 1,500 Ma. The magnetic characteristics and paleomagnetic directions from the granite and rhyolite may help to determine the igneous history of the area.

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In this paper we present preliminary paleomagnetic results from the Baraboo Quartzite. Other studies are in progress on the associated rhyolite and granite near Baraboo, such as the Denzer rhyolite, Baxter Hollow granite, and the granitic and rhyolitic inliers of the Fox River Valley.

PREVIOUS PALEOMAGNETIC STUDIES

Runcorn (1964) undertook preliminary paleomagnetic studies of the Barron and Sioux Quartzites which are quite likely contemporaneous with the Baraboo. However, no cleaning methods were used, and the results show great scatter. No paleomagnetic studies have been reported for the Baraboo Quartzite. Irving (1979) and Roy (1983) have included in their reviews the paleomagnetic data for the geologic time of interest for the Baraboo, that is 1,800 Ma to 1,500 Ma, however, there is no data from locations in Wisconsin.

GEOLOGY

The Baraboo Quartzite crops out near the town of Baraboo in southern Wisconsin (fig. 1). It is a sequence of massive, vitreous rock, typically pink, maroon, or purple, and up to 1500 metres thick (Dalziel and Dott, 1970). It is composed of more than 80 percent quartz, which occurs as medium to coarse sand grains. Numerous layers or lenses of more argillaceous material occurs within the quartzite. Dott (1983) suggests that this unit is the result of braided-stream deposition. The quartzite is formed into a doubly plunging syncline with the major axis oriented east-northeast. The north limb of the major syncline is almost vertical. In some places it is overturned. The south limb has shallower dips on the order of 15° to 30° (fig. 2). The location of the associated rhyolite and granite is shown in figure 3 (Smith, 1978).

PALEOMAGNETISM: FIELD AND LABORATORY PROCEDURES

Three to eight, oriented, hand samples were collected from the 12 locations noted on figure 1. The sites were selected such that both limbs of the major syncline were sampled. The local strike and dip of the beds were also noted for each site. Each sample was cored in the laboratory to obtain three to eight core specimens of size 2.54 cm diameter by 2.54 cm long. However, all of these samples have not been measured as yet. The numbers of samples and specimens actually used in this report are listed in table 1.

An initial suite of 10 cores were chosen for demagnetization studies by both alternating field (AF) demagnetization and thermal demagnetization. This type of analysis is used to determine the magnetic stability of the rock samples. The natural remant magnetism (NRM) of all samples were initially determined using a two-axis cryogenic magnetometer. The samples were then subjected to either AF demagnetization or thermal demagnetization. The AF demagnetization was performed in a Schonstead single-axis AF demagnetization unit, stepwise from 0 to 100 millitesla. The remanent magnetic direction was measured after each demagnetization step. In general the Baraboo Quartzite does not respond to AF demagnetization; neither the directions nor the intensity of magnetization changes significantly (less than 5° and 5 percent) with peak fields to 100 millitesla. The remaining samples from this preliminary study were thermally demagnetized by stepwise heating and cooling cycles. The heating was performed in a noninductive, wound furnace set inside a three-axis set of helmholtz soils; the samples were then cooled in a three-stage, mu-metal shield. The helmholtz coils and mu-metal shield isolate the sample being measured from the ambient magnetic field of the earth. Thermal demagnetization (fig. 4) shows very little decrease in the magnetic intensity or changes in magnetic direction until the demagnetizing temperature reaches 600 °C or higher. These results indicate that the magnetic mineralogy is single phase and probably hematite (curie temperature 650 to 700 °C).

From this initial suite of samples the remaining samples were measured for NRM and also thermally demagnetized at values of 200, 400, 650, and 750 °C.

PALEOPOLE ANALYSIS

The mean inclination and declination were determined for each site from the averaged directions for each hand sample. This calculation was made before and after the removal of the known struc- ture for each site. This involves unfolding the beds and in some cases rotating them as well. We have chosen N. 90° E. as the direction of the main synclinal axis. Fisher statistics (Fisher, 1953) were determined after each set of corrections to determine what structural corrections, if any, should be made on the data. This represents the classic fold-test of Graham (1949). If the data has a tighter cluster or better statistics before the structure is removed, it generally in- dicates that the measured magnetism is post folding. However, if the data clusters better after the structural corrections are made, then the magnetic directions in the rocks are prefolding directions.

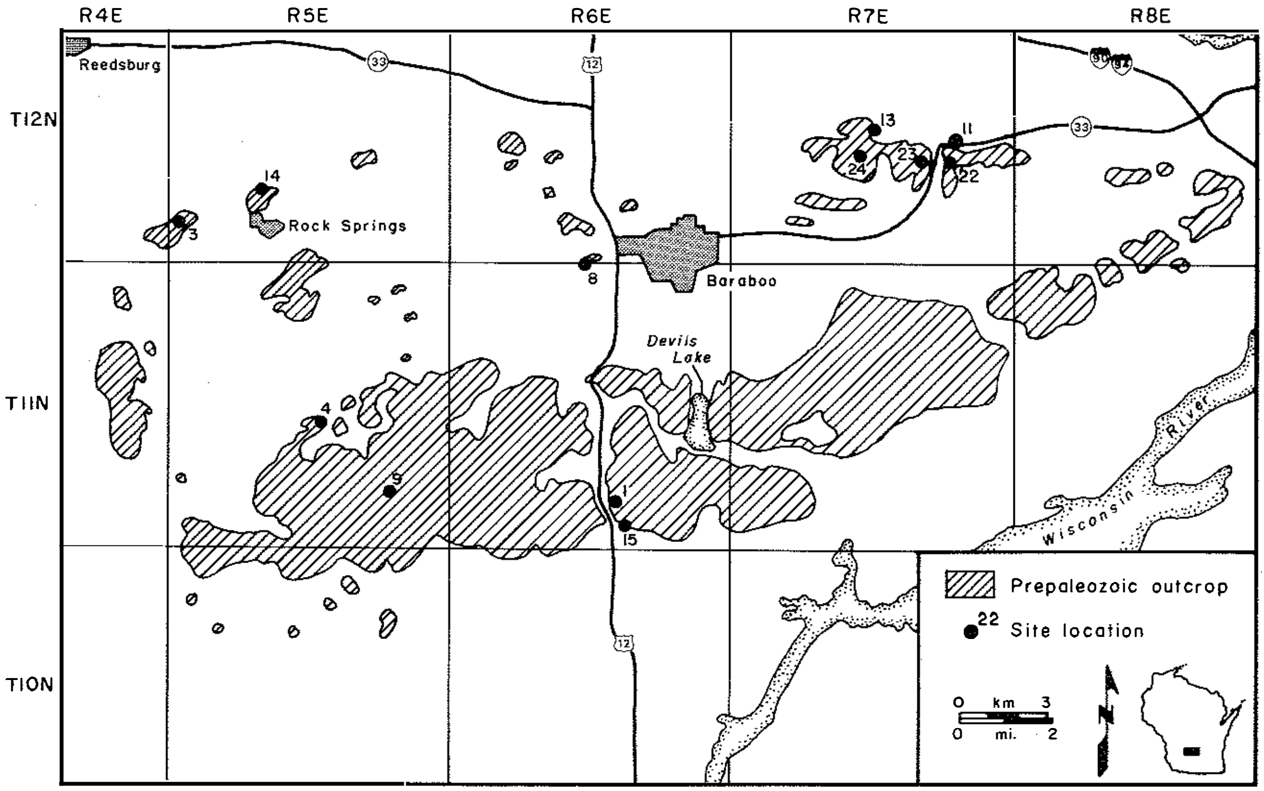

Figure 1.--Outcrop map of the Baraboo Quartzite modified from Dalziel and Dott (1970). Sample location numbers correspond to samples listed in table 1.

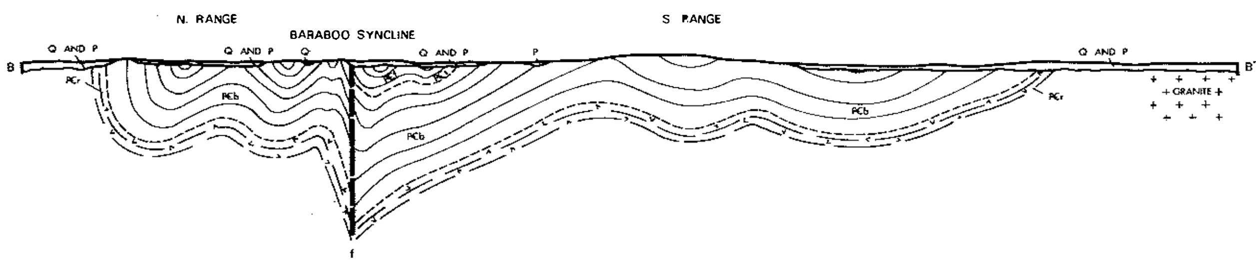

Figure 2.--Geologic cross section of the Baraboo Syncline (from Dalziel and Dott, 1970). The cross section is from the northwest to the southeast on the western end of the map, figure 1. PCr = rhyolite, PCb = Baraboo Quartzite, PCs = Seeley Slate, PCf = Freedom Formation, P = Paleozoic sedimentary rocks, Q = Quarternary deposits.

The results of the Fisher averages for all the sites are presented in table 1 and figure 5 and 6. The data is listed as original orientation, rotated, and rotated and unfolded. The original strike and dip of beds at the sampling locations are also given. This shows the changes in the mean declination, inclination, and data quality with progressive removal of the structure. The data is divided into two groups. The grouping was originally based on the similarity of the pole positions before structural corrections were made. The major difference between these two data sets is in the improved quality of the data in group I with the application of the structural corrections (table 2). For group I the precision parameter κ increases from 4.1 to 18.9 when the structure is removed. In group II the precision parameter κ improves only slightly (3.4-5.8). In addition, when the mean pole positions for group I and II are compared after the structure has been removed, they represent two distinct pole positions at the 95 percent confidence level.

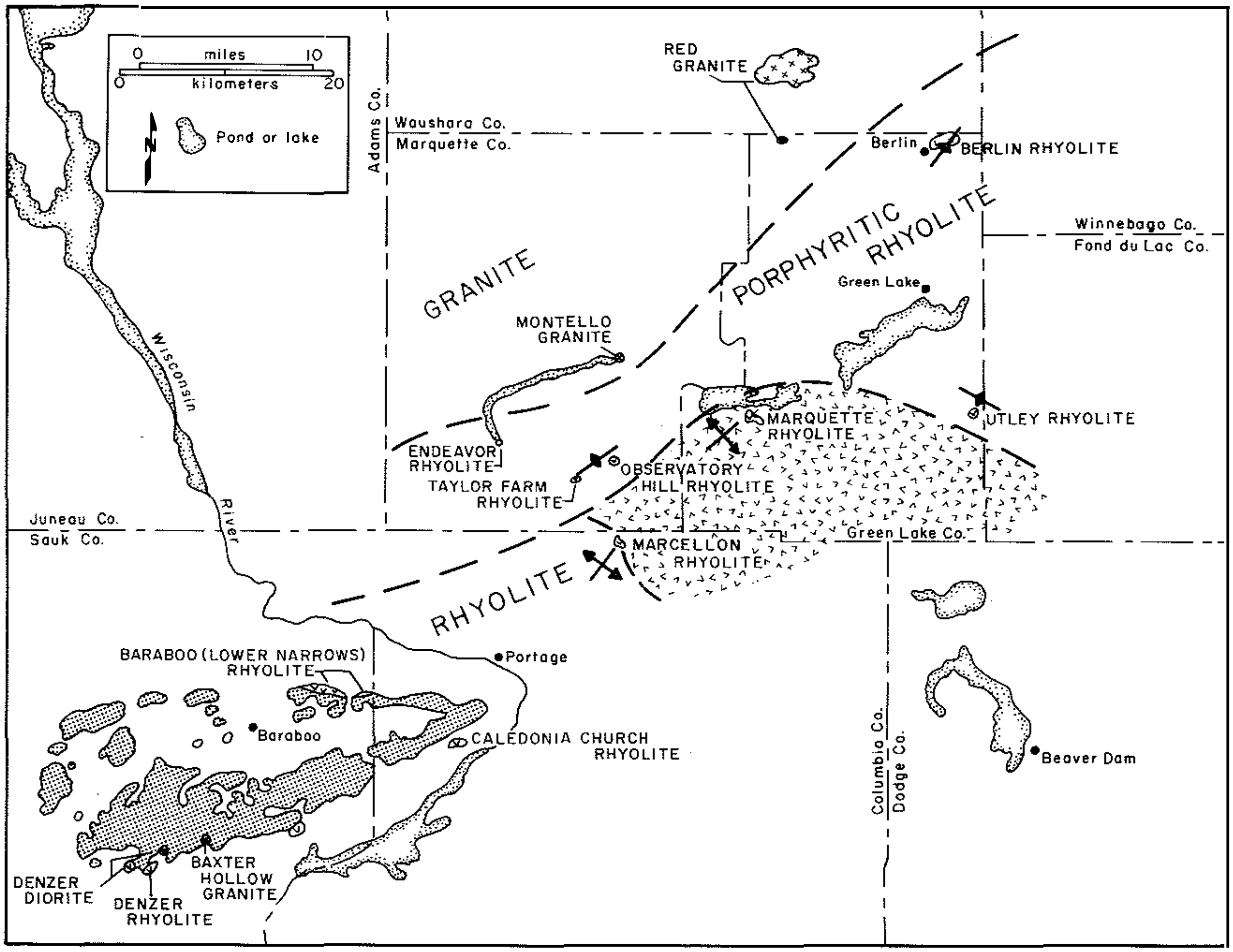

Figure 3.--Associated granite and rhyolite outcrop in the vicinity of Baraboo, Wisconsin (from Smith, 1978).

Data for group I come from the western end of the syncline and consist only of quartzite samples. Data for group II are from the eastern end of the syncline, where the quartzites are more deformed, and adjacent to outcrops of rhyolite. Group II also includes some phyllites, which are magnetically softer (Kean and others, 1983).

INTERPRETATION

The overall data quality improves as the structural corrections are made on the group I data. This provides a positive fold test (Graham 1949), which implies that the magnetization was set in previous to the major folding of the quartzite. This in itself is a significant finding. The thermal demagnetization results indicate that the only magnetic carrier of the magnetism in the quartzite is hematite. The only likely time of acquisition is during the original formation of the hematite, by oxidation processes during or soon after the deposition of the sand. The possibility of a major heating event after the deposition and before folding cannot be ruled out. However, it would require temperatures on the order of 600 °C to cause a post-deposition remagnetization of the hematite. There is no indication from any geologic studies that this area was ever heated above 250 °C after 1,760 Ma (Smith, 1978).

The data from group II are more problematic. The removal of the structure in this area does not statistically improve the quality of the data, and it does not move the magnetic directions closer to that of group I data.

Table 1.--Statistical data for the samples from all the sites indicated on Figure 1. **Asterisk** indicates overturned beds.

Sample Location	Strike & Dip	No. of Samples	No. of Specimens	Before Structural Correction			After Structural Correction		
				Dec.	Inc.	Kappa	Dec.	Inc.	Kappa
1	N.90°E., 14°N.	2	4	194	45	82.9	199.9	58.7	27.5
3	N.67°E., 83°NW.a	3	8	276	61	7.0	197	17.1	8.0
4	N.80°E., 15°NW.	2	7	145	55	48	139.9	67	49.6
8	N.66°E., 45°SE.	1	3	168	75	1500	183	30	8552
9	N.15°E., 21°NW.	1	3	88	39	178	157	59	134
14	N.68°E., 86°NW.a	2	6	346	57	15	176	30	15
15	N.8°W., 3°SW.	1	3	258	53.4	60.2	176.9	50.6	64.7
11	N.62°E., 84°NW.a	2	4	63	68	13	165	-2.9	12
13	N.73°E., 83°NW.a	2	3	30	63	16	160	11	16
22	N.83°E., 65°NW.a	1	3	352	70	345	182	-5	282
23	N.91°E., 75°NE.a	1	3	166	65	44	181	-39	46
24	N.98°E., 78°NE.a	1	3	127	63	14	171	-34	14

a - overturned bed

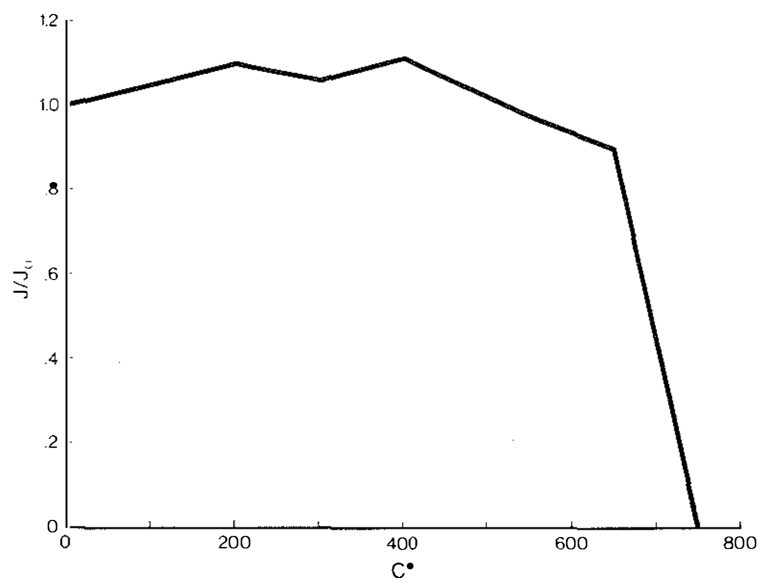

Figure 4.--Thermal demagnetization of Baraboo Quartzite, J/Jo is magnetic intensity normalized to the initial intensity.

When the pole positions from group I and group II samples are compared to published paleomagnetic poles for the time interval 1,800 Ma to 1,400 Ma, certain conclusions can be made. The pole position for group I data after the structural corrections are made (that is, 19° S, 89° W) is located in the general vicinity of most North American paleopole positions for the time range of 1,800 Ma to 1,700 Ma as seen in figure 7. The polar-wander path on figure 7 (from Irving, 1979) was chosen for comparisons. However, as was pointed out by Roy (1983), the limited amount of data for this time interval warrants considerable caution in assigning a definitive date to a new pole position based on currently drawn polarwander paths. The pole position for Group II data is much more enigmatic. At present, it does not fit well with any presently proposed polarwander curve.

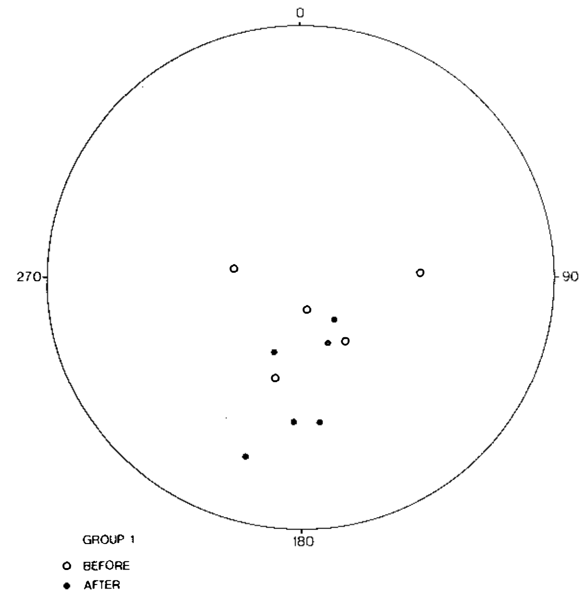

Figure 5.--Stereographic plot of declination and inclination for group I data, before and after structural corrections.

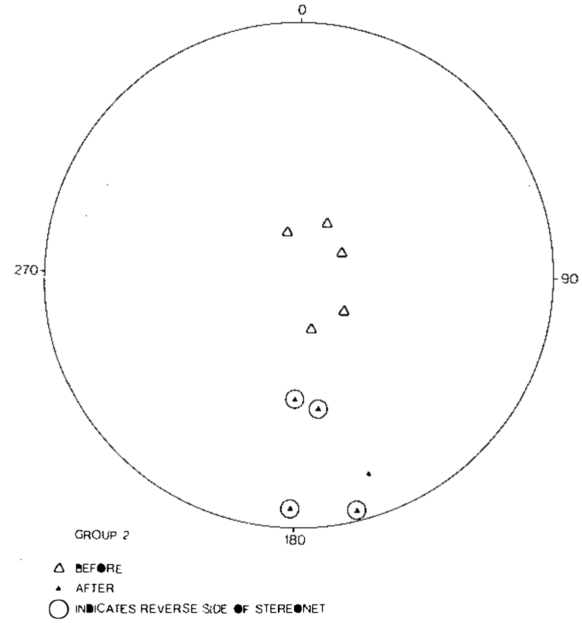

Figure 6.--Stereographic plot of declination and inclination for group II data, before and after structural corrections.

Table 2.--Statistical data for group I and group II data, before and after structural corrections were made.

	Mean Dec.	Mean Inc.	Kappa	α	VGP	dp	dm
Group I							
Before	193.5	80.3	4.7	31	25°N., 94.3°W.	57	10.3
After rotation	182	70	5.8	27	8°N., 90.7°W.	41.0	15.9
After unfolding	179	46	12.9	17.4	19.1°S., 89°W.	14.3	15.5
12 samples 34 specimens							
Group II							
Before	77	78	11	23	44°N., 57°W.	41.5	41.4
After rotation	89.3	75	13.9	21.2	37°N., 58°W.	35	38
After unfolding	165	-12.6	13.5	22	50°S., 66°W.	11	22
7 samples 16 specimens							

It may be a problem of improper removal of the structure or the results of a heating event. We expect a more definitive answer to this when additional samples are measured and when our study of the associated rhyolite and granite is completed. Initial results from some of the rhyolite give pole positions near to those of Group II (Kean and others, 1983).

CONCLUSIONS

A preliminary paleomagnetic study of the Baraboo Quartzite has produced the following results: (1) the magnetism of the Baraboo Quartzite is due primarily to hematite which formed prior to the major folding in the area; (2) two dominant pole positions are found, one definitely predates the folding based on a positive fold test. The pole position is consistent with published Precambrian poles for North America in the time range of 1,850 to 1,700 Ma (Irving, 1979). A second pole position is also noted but not understood. This second pole position is similar to some pole positions obtained for a few of the associated granite and rhyolite in the area. However, additional work is needed to confirm this; and (3) this initial study suggests that paleomagnetic studies will be useful in deciphering the geologic history of the Baraboo interval rock of southern Wisconsin.

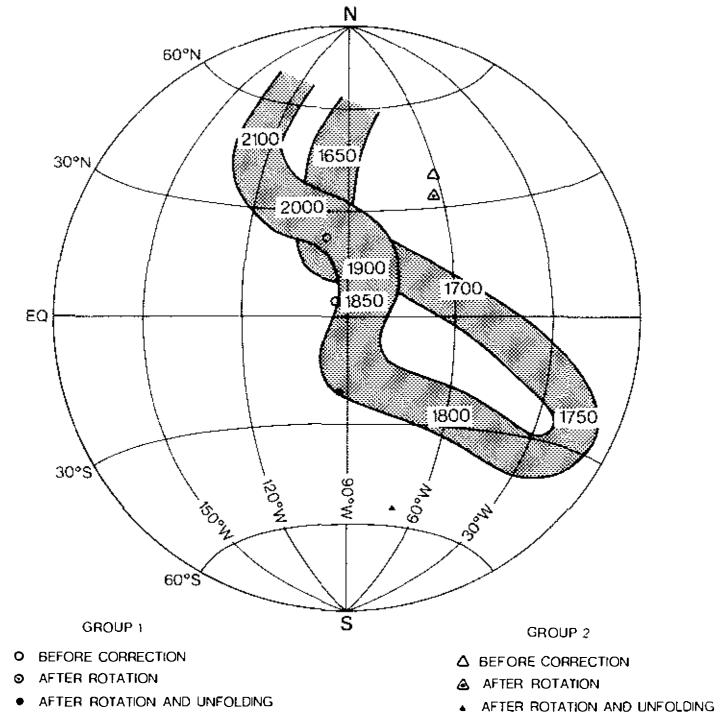

Figure 7.--Paleopole positions for group I and group II data in relation to Irving's (1979) polar-wander path.

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