STUDY OF THE

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ABSTRACT

AN INTEGRATED GEOLOGIC-GEOPHYSICS STUDY OF THE AUBURNDALE AREA, WOOD COUNTY, WISCONSIN

by Charles Howard Murrish

An area located in north-central Wisconsin, centered around Auburndale Township in Wood County, was selected for a gravity and magnetic survey. The purpose of the geophysical survey is to ascertain the value of a gravity and magnetic survey in mapping geology in an area of Precambrian bedrock where geologic control is limited. The Precambrian metamorphosed igneous and sedimentary rocks are masked by a mantle of Pleistocene glacial drift.

As a result of geologic field investigations and petrographic examination, the rock types present are identified as: gneissic quartz diorite, greenstone, hornblendite, feldspathic quartzite, magnetiferous "quartzite," metagraywacke, granite, and granite-doiorite contact rocks.

The geophysical survey consists of 215 gravity and 277 magnetic stations including those of detailed profiles. The residual gravity anomalies generally range from +2.5 to +5.0 and from -2.5 to -4.5 mgals. The vertical magnetic intensity anomalies range up to +5500 gammas, but most are less than +300 gammas, and relative negative anomalies average less

than -100 gammas. The gravity and magnetic anomalies trend westerly and northwesterly and are generally correlated with each other.

Densities and magnetic susceptibilities were measured for each rock type found in outcrop. These physical properties are used as the criteria for identification of rock types from the geophysical anomalies.

Analytical techniques were employed to determine a geologic cross section from the residual gravity anomalies. Gravity calculations were performed along a section where some geologic control is available to establish limits to the interpretation. This cross section, the geophysical anomaly maps, and the physical properties of the rock types, formed the basis for the construction of the geologic map of the area.

The value of a gravity and magnetic survey in mapping Precambrian bedrock geology in an area of limited geologic control is proven.

AN INTEGRATED GEOLOGIC-GEOPHYSICS STUDY OF THE AUBURNDALE AREA, WOOD COUNTY, WISCONSIN

By

Charles Howard Murrish

A THESIS

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INTRODUCTION

Purpose

The objective of this study is to ascertain the value of a gravity and magnetic survey in mapping Precambrian igneous and metamorphic geology in an area of limited geologic control. Relationships between known geology and the geophysical data should make possible the interpolation of rock types through areas where bedrock is hidden beneath glacial sediments. The geophysical-geological relationships can be determined from outcrop mapping and petrologic examination of the rock types combined with measurements of the density and magnetic susceptibility of the rocks. Utilizing empirical and analytical methods of examining the geophysical maps, the construction of an interpretative geologic map should be possible.

Geographic Setting

The area of study shown in Figure 1 is located in north-central Wisconsin and centers around the town of Auburndale in T. 25 N., R. 4 E. The total area of investigation is approximately 95 square miles. This includes a narrow strip of the southern edge of Marathon County, with the remainder lying in the north-central portion of Wood County.

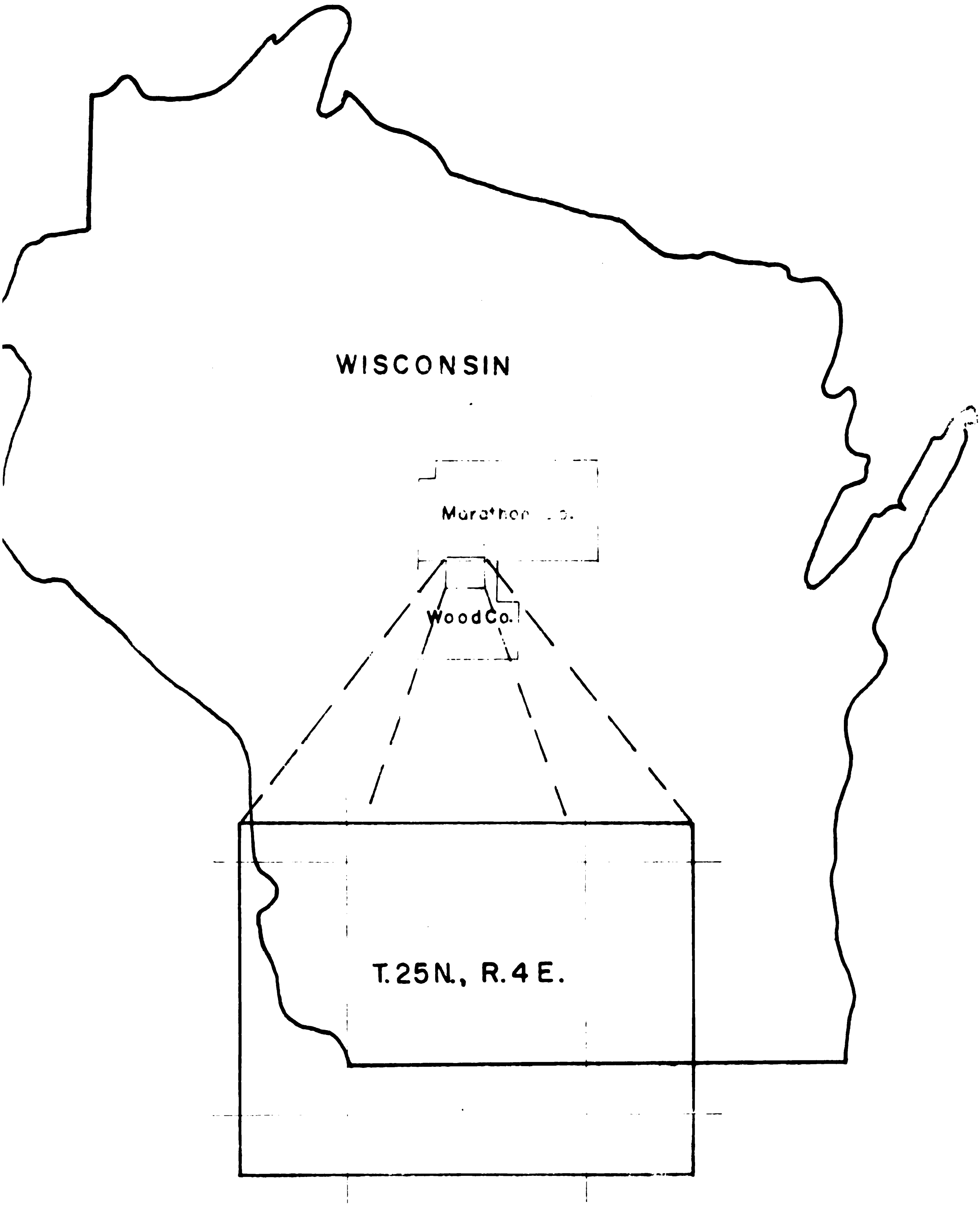

FIGURE I. AREA OF STUDY

The landscape is typified by gently rolling topography. The maximum elevation difference is of the order of 140 feet; this relief is expressed over a distance of nearly five miles. There are numerous small streams, but no great relief is associated with these features. The area is accessible by a network of roads which are, in most cases, the section lines. Only a minor portion of the area does not have roads defining the section boundaries.

General Geology

The bedrock is Precambrian in age and consists of igneous and metamorphic rocks. Rock types present include gneissic quartz diorite, greenstone, hornblendite, granite, granite-diorite contact rocks, quartzites, and metagraywackes.

Locally within the area, Upper Cambrian sandstone of St. Croixan age rests uncomformably on the Precambrian crystallines. The sandstone is found erratically throughout the area but seems to occur predominately near the western edge of the area of study.

Covering the basement rocks and sandstone is a thin veneer of glacial drift. The drift ranges in thickness from zero to at least 67 feet, concealing the majority of the underlying rocks.

Outcroppings are found where bedrock protrudes through the drift or where erosion has cut through the drift. Large angular boulders, possibly termed "rubble outcrops," also are prevalent. Often these are found near true outcrop. The geology previously has been mapped only in a general manner because of the masking effects of the glacial drift and lack of economic deposits.

The stratigraphic column of the north-central Wisconsin region is presented in Table 1. The rocks encountered in the area of study are correlated only roughly to those shown in the column. The gneissic quartz diorite and greenstone may be representatives of the Laurentian and Keewatin, the metasediments, most likely, are Huronian or Animikian as is the granite. The sandstone is, undoubtedly, Upper Cambrian, and the glacial drift is Pleistocene.

Previous Investigations

The first detailed account of the geology of this area is presented in a report of the Wisconsin Geological Survey found in Bulletin No. XVI, published in 1907; Samuel Weidman, the author, described the geology, including megascopic and microscopic descriptions of the main lithologies represented. Also described are the geomorphology and the natural resources of the north-central Wisconsin region.

In 1918 another study was conducted in this vicinity. This survey consisted of a geological investigation and was accompanied by a dip needle survey. Maps showing the locations of anomalous dip needle readings and locations and types of outrops and "rubble outcrops" were products of

Table 1.--Stratigraphic Column (Weidman, 1907).

Pleistocene		Wisconsin Drift Third Drift Second Drift First Drift Alluvial deposits contemporary with drift
	UNCONFORMITY	
Paleozoic . . .	Potsdam sandstone (Upper Cambrain)	
	UNCONFORMITY	
	Upper Sedimentary Series (Middle Huronian?)	North Mound conglomerate and quartzite Arpin conglomerate and quartzite Mosinee conglomerate Marshall Hill conglomerate Marathon conglomerate
	UNCONFORMITY	
Precambrian . . .	Igneous Intrusives	3. Granite, Nepheline Syenite Series 2. Gabbro Diorite Series 1. Rhyolite Series
	UNCONFORMITY	
	Lower Sedimentary Series (Lower Huronian?)	Rib Hill quartzite Powers Bluff quartzite Hamburg slate Wausau graywacke
	UNCONFORMITY	
	Basal Group (Laurentian or Keewatin?)	Gneisses and schists

this survey. Unedited reports on the area describe the geomorphology, geology, dip needle survey, and the economic resources.

GEOLOGICAL FIELD INVESTIGATIONS

Outcrops and "rubble outcrops" located by the 1918 survey of the Wisconsin Geological Survey were visited. In some areas the land had been cleared of all loose rock in order to render the soil tillable. In other locations, outcrops were not found where shown by the available maps. The maps, however, proved invaluable in the selection of areas of possible outcrops.

Due to the large area involved in this study, the majority of exposures which were sampled were proximal to roads. However, locations were visited in the interior of sections where the maps indicated much outcrop or along streams suspected of revealing bedrock. The outcrops were sampled taking care to avoid weathered specimens. In areas where no outcrops were found, stone piles were examined. These, in many cases, contained one dominate rock type. Obviously, this only could be used in providing a clue to the underlying rock type.

The rock types identified on the maps of the 1918 survey and those of the 1907 report presented a nomenclature problem. The rocks appear to have been given general names because of the reconnaissance nature of the 1918 survey. The problems occur in the identification of diorite and granite, both in the 1907 report and in the 1918 survey.

The diorite of the older surveys referred to greenstone; the diorite of this study refers to an intermediate basic, phaneritic rock. The diorite of this study is believed to be what was named in the older reports as gneissic granite. Also, some of the rock types shown on the maps of the 1918 survey were not encountered by the writer. For example, rhyolite which was reported to have been found in 20 of the 36 sections in Auburndale Township (Eidemiller, 1918), was not observed in the field. Possibly this rhyolite corresponds to the fine grained granite mapped in this study.

PETROGRAPHIC STUDY

Method Employed

Several thin sections were prepared of each rock type that was collected in the field. The mineralogy was determined by petrographic study. Estimations were made of the relative percentages of the mineral constituents. The purpose of the petrographic study was mainly to ascertain a working nomenclature for the various rock types encountered. A map showing outcrop locations and thin section numbers of samples is found in Figure 2. The following are generalized descriptions and relationships which were observed megascopically and microscopically.

Descriptions of Rock Types

Gneissic Quartz Diorite

Megascopic.--The rock is distinctly foliated, the oriented constituents being mostly biotite. The strike of the foliation in outcrop ranges from N. 50° W. to N. 85° W. and the dip is nearly vertical. At the surface the rock is weathered to a light tan revealing considerable quartz. The felsic and mafic portions give a white and black effect. Other minerals identified are plagioclase, epidote, and in some samples hornblende.

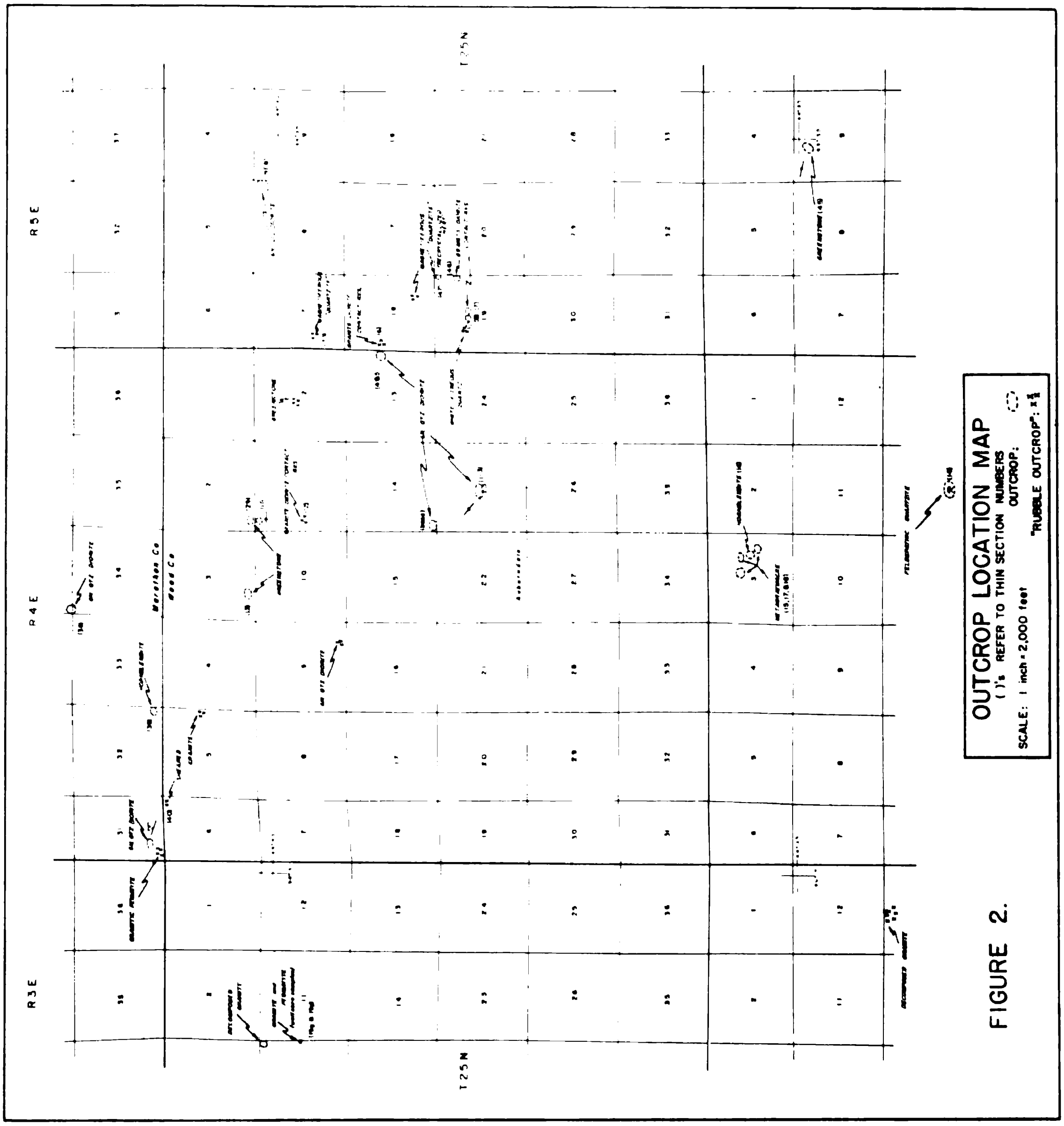
OUTCROP LOCATION MAP
( )'s REFER TO THIN SECTION NUMBERS
OUTCROP:
"RUBBLE OUTCROP":
SCALE: 1 inch = 2,000 feet
R3E
R4E
R5E
T25N

FIGURE 2.

A curious feature occurs in an outcrop in the northeast corner of section 8, T. 25 N., R. 5 E. Here exists a good exposure, and in the mafic "bands" occur large "augens" measuring almost a foot in cross section. Petrographic examination indicates these features are primarily biotite and epidote pods. The size of the pods gives them a xenolithic appearance, but the relationships in outcrop indicate that they were formed by metamorphic segregation.

Microscopic.--The major constituent in this gneissic rock is plagioclase which is found in the oligoclase-andesine range. The plagioclase is highly fractured and altered. In many instances the laths of plagioclase are fractured and offset, even rotated by shearing. In these zones recrystallization of the plagioclase and introduction of quartz have occurred. The quartz appears fresh and in every instance has sutured contacts.

The mafic fraction is mostly biotite. In the majority of the thin sections studied, the biotite did not show remanent forms of an amphibole or pyroxene. However, in a few slides, hornblende is found with the biotite; the hornblende is believed to be of metamorphic origin. The biotite is found predominately in sheared zones and in areas surrounding the plagioclase phenocrysts.

Epidote occurs associated with plagioclase, biotite, and hornblende. Epidote is identified in all the slides of this rock type as a minor constituent. Another alteration product is calcite. The calcite probably was formed as a result of recrystallization of the plagioclase. Paragonite is observed as a plagioclase alteration product.

Accessory minerals are apatite, sphene, chlorite, pyrite, ilmenite, leucoxene, and magnetite. The relative mineral percentages and the slides studies are shown in Table 2.

Table 2.--Estimations of relative mineral percentages of the gneissic quartz diorite.

Slide No.'s . . .	base	1	4	5	NE8	38	aver. %
Minerals:			Percentages:				
Andesine-Olig.	50	35	45	35	30	30	39%
Quartz	15	25	20	15	10	13	16%
Biotite	20	24	20	25	20	20	22%
Calcite	5	5	-	5	15	-	5%
Epidote	5	tr	5	10	10	10	7%
Paragonite	4	10	9	9	4	2	6%
Others:	1	1	1	1	1	25	5%
Apatite							
Magnetite							
Ilmenite							
Leucoxene							
Sphene						5	
Chlorite							
Hornblende						20	
Pyrite							

On the basis of the amount of fracturing and recrystallization of the plagioclase and other constituents, the rock is believed to have been originally more basic, possibly a gabbro. The majority of the quartz is thought to have been introduced.

Greenstone

Megascopic.--The rock is very dense and fine grained. On the fresh surface the rock is a very dark green-black; the weathered surface is slightly lighter in color. In some locations a distinct foliation can be seen but, elsewhere, is not as apparent. Strike and dip of the foliation is almost the same as that of the gneissic quartz diorite.

The mineral composition cannot be determined in hand specimen because of the fine texture. Some iron-staining is observed, and a pencil magnet is strongly drawn to these areas of staining. This would indicate the presence of magnetite. Small quartz veins are observed cutting the rock.

Microscopic.--In thin section the rock is seen to consist mostly of a very fine hornblende. Interstitially plagioclase and minor quartz occur. The plagioclase was not seen in a good section and identification could not be made. The plagioclase and quartz never exceed 30-40%. Other minerals present are sphene, calcite, epidote, and magnetic. The magnetite is found disseminated throughout the rock and ranges in percentages from less than one per cent to four to six per cent. The majority of the magnetite is believed to have formed from the alteration of the original mafic constituents. The position of the magnetite seems to have controlled to a degree by the shearing. In Table 3 the relative mineral percentages are shown.

Table 3.--Estimations of the relative mineral percentages of the greenstone.

Slide No.'s . . .	11	13	29	45	aver. %
Minerals:		Percentages:			
Hornblende	80	85	60	70	74%
Quartz and plagioclase	15	13	32	20	20%
Magnetite	≈4	2	3	1	2%
Others:	1		5	9	4%
Epidote			5		
Calcite				9	
Sphene					
Hematite					

The original rock is thought to have been a fine grained basic extrusive, very possibly a basaltic flow.

Hornblendite

Megascopic.--The rock is fine to medium grained and is very dark, almost black in color. The majority of the rock appears to be composed of hornblende. Slight foliation can be seen in the rock. Felsic grains are interstitial to the amphibole. In sample no. 39 a zone of epidote is concentrated at one end of the specimen. In the epidote zone are found much pyrite and magnetite. The thin section was cut from the amphibole area.

Microscopic.--In sample no. 39, plagioclase identified as oligoclase slightly exceeds the amount of hornblende. The oligoclase is highly altered, fractured, and granulated. It appears to have been recrystallized forming a mosaic of oligoclase grains displaying sutured grain contacts. The hornblende seems to have formed in the mosaic of plagioclase and is slightly oriented. There also is some minor paragonite which has altered from the plagioclase.

The thin section of sample no. 16 shows the amount of hornblende exceeding the plagioclase by a ratio of 2:1. The hornblende, again, has a preferred orientation. The interstices between the hornblende crystals are filled mostly with a mosaic of twinned and untwinned andesine grains. Also present in minor amounts are stringers of sphene which transect the rock intermittently.

The rock is believed to have formed as a result of thermal metamorphism of greenstone. The hornblendite is considered to be a hornfels facies product. In Table 4 the relative mineral percentages are shown.

Table 4.--Estimations of relative mineral percentages of the hornblendite.

Slide No.'s . . .	16	39	aver. %
Minerals:	Percentages:		
Hornblende	65	43	54%
Andesine-Olig.	30	55	42%
Epidote and paragonite	2	2	2%
Magnetite	<1	<<1	<1%
Sphene	3		2%

Metagraywacke

Megascopic.--The hand specimens reveal a fine grained and coarsely foliated rock. There are mafic bands, dark gray to black, which measure nearly 3/4 of an inch in width and consist mostly of biotite. The remainder of the rock is light tan to light gray in color and has a texture looking much like a quartzite. One sample displays bands which have been highly contorted. Also present are feldspar "augens" whose dimensions range up to 8 x 12 mm. These seem to be prevalent only in one zone of the hand specimens. The groundmass seems to be fine quartz, either quartz grains or granulated quartz. Pyrite and chalcopyrite are observed in minor amounts along fracture surfaces.

Microscopic.--Thin sections show this rock to be in a highly altered state. The majority of the feldspars have been altered to paragonite and/or sericite. The major constituents are quartz, plagioclase, orthoclase, antiperthite, biotite, and paragonite and/or sericite. The quartz is found in mosaic bands, and the grain contacts are highly sutured. The texture closely resembles that of a quartzite. No original grain boundaries could be distinguished. In the banded samples, shear zones are composed of biotite. These bands or zones are in some areas highly contorted. Found with the biotite are epidote, chlorite, apatite, magnetite, and minor hematite. Calcite also is present in minor amounts in the interstices between the quartz and feldspar. The relative mineral percentages are shown in Table 5.

Table 5.--Estimations of the relative mineral percentages of the metagraywacke.

Slide No.'s . . .	15	17	18	aver. %
Minerals:		Percentages:		
Quartz	25	40	35	33%
Feldspars	22	35	34	30%
Sericite and/or paragonite	50	-	31	27%
Biotite	2	15	-	6%
Epidote and calcite	1	9	-	3%
Others:				1%
Chlorite				
Apatite				
Magnetite				
Hematite				
Pyrite				
Chalcopyrite				

The original rock may have been a graywacke. However, no rock fragments are identified in the thin section study of this rock type. A statement concerning the original identity of the rock is difficult because of the altered state in which the rock is found.

Feldspathic Quartzite

Megascopic.--The rock is very fine grained and reddish-pink on the fresh surface. The weathered surface is a pale yellowish-tan and is soft enough to be scratched with a knife. The weathering would indicate the presence of feldspar(s). The majority of the weathered surface, however, is not feldspar, but fine quartz. On close inspection of the fresh surface, the rock resembles a quartzite. Occasionally observed are "metaclasts" of plagioclase whose dimensions range up to approximately 1 x 1.5 mm. No bedding features could be distinguished.

Microscopic.--The thin section shows the rock to be composed mostly of quartz grains ranging from cherty appearing to 0.5 x 0.4 mm, the majority being less than 0.1 x 0.1 mm. About 20% of the rock is composed of albite and microcline. The albite attains the largest dimensions seen in thin section, namely 0.9 x 0.4 mm. The grain contacts are all sutured, and the grain boundaries are not rounded, but irregular. The irregularity is mainly due to recrystallization. The relative mineral percentages are shown in Table 6.

Table 6.--Estimations of relative mineral percentages of the feldspathic quartzite.

Slide No. . .14 Minerals:	Percentages:
Quartz	75%
Albite	15%
Microcline and orthoclase	5%
Muscovite	5%
Others: (minor)	
Magnetite	
Hematite	
Pyrite	

The original rock could have been an argillaceous sandstone or a siltstone which underwent recrystallization.

Magnetiferous "Quartzite"

Megascopic.--These rocks are gray to dark gray in color and are very fine grained. On the weathered surface are found irregular, elongated, grayish-black areas which are set in a dark tan background. The dark areas appear to represent areas where magnetite has been concentrated (a pencil magnet is drawn strongly to these areas). The dark tan areas apparently are produced as a result of the weathering of the iron. The quartz in some samples has the appearance of vein quartz; this could be the result of recrystallization. A parallelism of the dark constituents can be distinguished. The dark constituents form band-like features which are less than 1 mm apart.

Microscopic.--In thin section the rock is seen to consist primarily of quartz and with a varying minor amount of magnetite. The magnetite content ranges from zero to almost ten per cent. The grain sizes of the quartz are approximately 0.1 x 0.2 mm. The grain contacts are highly sutured and a definite orientation of the quartz grains exists. Much recrystallization must have occurred. The quartz in some areas ofthe slide appears chert-like. The magnetite seems to favor zones parallel to the direction of elongation of the quartz grains. However, the magnetite appears, both as irregular blobs, and as parallel bands consisting of elongated masses of magnetite. Some of the magnetite is euhedral. Relative mineral percentages are shown in Table 7.

Table 7.--Estimations of relative mineral percentages of the magnetiferous "quartzite."

Slide No.'s . . .	33	37	47	aver. %
Minerals:		Percentages:		
Quartz	92	99	90	94%
Magnetite	8	1	10	6%
Hematite	<1	<1	<1	<1%

Because of the lack of original grain boundaries, the rock is believed to have undergone much recrystallization. Initially the rock may have been a chert and was later granulated and recrystallized to the present quartzite appearance. The magnetite may have been introduced via hydrothermal media. Or, the rock may have been a highly siliceous iron formation, the quartz being recrystallized chert and the magnetite being originally present.

Granite and Pegmatite

Megascopic.--The granite is medium grained and pink in color. Potash feldspar phenocrysts range in size to nearly 2 x 4 mm. An occasional twinned plagioclase also can be seen. Much quartz appears throughout the rock and appears to be interstitial to the feldspar. Small booklets of muscovite and biotite also are present.

The pegmatite is reddish-pink and is very coarse grained; phenocrysts of feldspar are over 5 cm in length, the majority being about 6 x 10 mm. Quartz occurs in crystals whose dimensions are 10 x 13 mm, but most are of the size 4 x 6 mm. Finely twinned plagioclase is very abundant and is frequently cut by quartz or other plagioclase crystals. Muscovite plates are observed and range up to 2 mm in diameter and are usually enclosed within a feldspar phenocryst. Much limonite staining is seen on most of the surfaces of the larger feldspar phenocrysts.

Microscopic.--The granite in thin section is observed to be composed of quartz, microcline, albite, and much antiperthite. The crystal boundaries of the quartz and the feldspars are sutured. There appears to be at least two compositions of feldspar; one is highly altered to mica and epidote, and the other, for the most part, is fresh appearing. The latter is mostly microcline and antiperthite. There are many instances where quartz has intergrown with the feldspar and where feldspar has grown into feldspar (micropegmatitc texture). Also present are biotite, chlorite, and hematite as minor constituents. Pleochroic halos are numerous in the biotite, possibly around zircon.

The pegmatite in thin section is found to consist mostly of antiperthite, plagioclase (albite to oligoclase in composition), quartz, and microcline. The quartz in some areas is in optical continuity and also is seen as intergrowths into feldspars. Again, there has been much recrystallization evidenced by sutured contacts of the minerals present. The antiperthites illustrate that there must have been a varying composition of the feldspars. Muscovite, chlorite, and biotite are primarily found in areas of shears and adjacent to crystal edges. Epidote and hematite are present in minor amounts. Mineral percentages are presented in Table 8.

Table 8.--Estimations of relative mineral percentages of granite and pegmatite.

Slide No.'s . . .	19g	19p	40	aver.%
Minerals:		Percentages:		
Quartz	30	25	15	23%
Albite-Olig.	10	20	40	23%
Microcline	20	15	10	15%
Antiperthite	20	25	10	18%
Muscovite	10	10	23	14%
Others:	9	4	2	5%
Calcite and epidote	4			
Biotite			2	
Chlorite	4	4		
Hematite				
Apatite				

Granite-diorite Contact Rocks

Megascopic.--The rock types found occurring where the granite intrudes the gneissic quartz diorite range in color from a light tan to a dark grayish-tan. The phenocryst sizes are primarily 1 x 1 mm, however, some the feldspar laths attain a size of 2 x 3 mm. The rock varies from non-foliated to foliated. The tan variety appears to be a fine grained granite which has undergone alteration and possible granulation. There is an abundance of feldspar and quartz and a development of fine muscovite along shears which appear infrequently. The mafics are minor constituents. One sample, no. 3, is noticeably foliated, the aligned mineral being biotite. There also is a subparallelism of the plagioclase laths. The major constituents in this sample are feldspar, quartz, and biotite. Sample no. 46 is thought to be more closely related to the gneissic quartz diorite than to the granite, although there is not gross orientation of the mafics as seen in the diorite.

Microscopic.--The thin section observations support the idea that sample no. 46 is more closely related to the diorite than to the granite. Oligoclase-andesine, the major constituent, is highly fractured and has been altered extensively to paragonite. The interstices have been filled with quartz, calcite, and biotite. Areas of calcite exceed 1 x 2 mm. The opaque minerals are commonly associated with biotite.

Sample no.'s three and eight represent rocks which were apparently closer to the granite. The major constituent is oligoclase. Again, the plagioclase laths are highly fractured and recrystallized, possibly downgrading the plagioclase. Quartz appears to have been a late addition. Biotite and calcite seem to have been formed in zones of weakness and are adjacent to the plagioclase laths. Paragonite is another common alteration product as is epidote. Sample no. 12 is believed to represent rocks located very close to the granite-diorite contact. The potassic feldspars greatly exceed the plagioclase in abundance. Quartz appears, in part, as intergrowths into the feldspars.

Sample no. 12 has been sheared creating an alignment of the muscovite. Also present is much antiperthite. The relative percentages of the minerals identified are shown in Table 9.

Table 9.--Estimations of relative mineral percentages of the granite-diorite contact rocks.

Slide No.'s . . .	3	6	7	12	8W	46	aver. %
Minerals:	Percentages:						
Oligoclase-andesine	40	37	30	20	35	40	34%
Biotite	10	13	20	-	1	5	8%
Quartz	38	10	20	25	28	10	22%
Epidote	8	15	5	-	-	-	4%
Calcite	2	20	20	-	10	25	13%
Sericite and/or paragonite	2	3	4	10	25	15	10%
Microcline, orthoclase, and antiperthites				44		4	8%
Others:							1%
Pyrite							
Ilmenite							
Luecoxene							
Hematite							
Magnetite							
Apatite							

The abundance of the quartz occurring in the contact zone, as well as in the gneissic quartz diorite, is believed to have been added from the intruding granite. These silicifying solutions would have, most likely, been potassic-sodic.

GEOPHYSICAL FIELD INVESTIGATIONS

Gravity Survey

A total of 215 gravity stations were occupied, including those along two detailed profiles, with Worden Gravimeters no. 99 and no. 262. Over most of the area, stations were spaced at one mile intervals. In areas where detail was desired on the basis of known geology or where steep gradients occurred, the spacing was tightened to one-half mile intervals. The locations of the stations were determined by automobile odometer and with the aid of topographic and planimetric maps. The base station was centrally located within the area of study, 500 feet north of the south-west corner of section 14, T. 25 N., R. 4 E. adjacent to a bench mark. The base was tied gravimetrically to a station located on a bench mark at the railroad station in Babcock, Wisconsin. The station in Babcock was established by the United States Steel Corporation through a tie to an absolute gravity station in Winona, Wisconsin.

Elevations of road intersections are given on U.S.G.S. topographic quandrangles for two-thirds of the area. Planimetric maps are available for the remainder of the area. The elevations of stations along detailed profiles were obtained by leveling and tying to a point of known elevation.

The elevations of stations located between road intersections or in the area of planimetric map coverage were determined through the use of barometric altimeters. Two altimeters were used: a Wallace and Tiernan instrument and a Surveying Micro-altimeter made by American Paulin Systems. The American Paulin Systems' instrument and Micro-surveying Barograph, Model MB5, were used for the majority of these elevations. The Micro-survey Barograph was centrally located in the area. This instrument continuously records the change of barometric pressure. The change of pressure effects the readings of the altimeter producing error in the measured elevations. The barograph allowed the application of a barometric correction to the altimeter readings increasing the accuracy of elevations. The Wallace and Tiernan altimeter was used without the aid of a continuous recording barograph. To decrease error, barometric pressure changes were determined by periodic occupation of stations of known elevations at intervals not exceeding 20 minutes. This procedure resulted in correction curves such as shown in Figure 3. The curves reflect the barometric pressure changes as a function of time. The correction for each station was taken from this type of curve.

The stations were determined from topographic and planimetric maps and, also, from mileage obtained from automobile odometers. The stations were then located on maps scaled at 1:24,000. An east-west line was extended

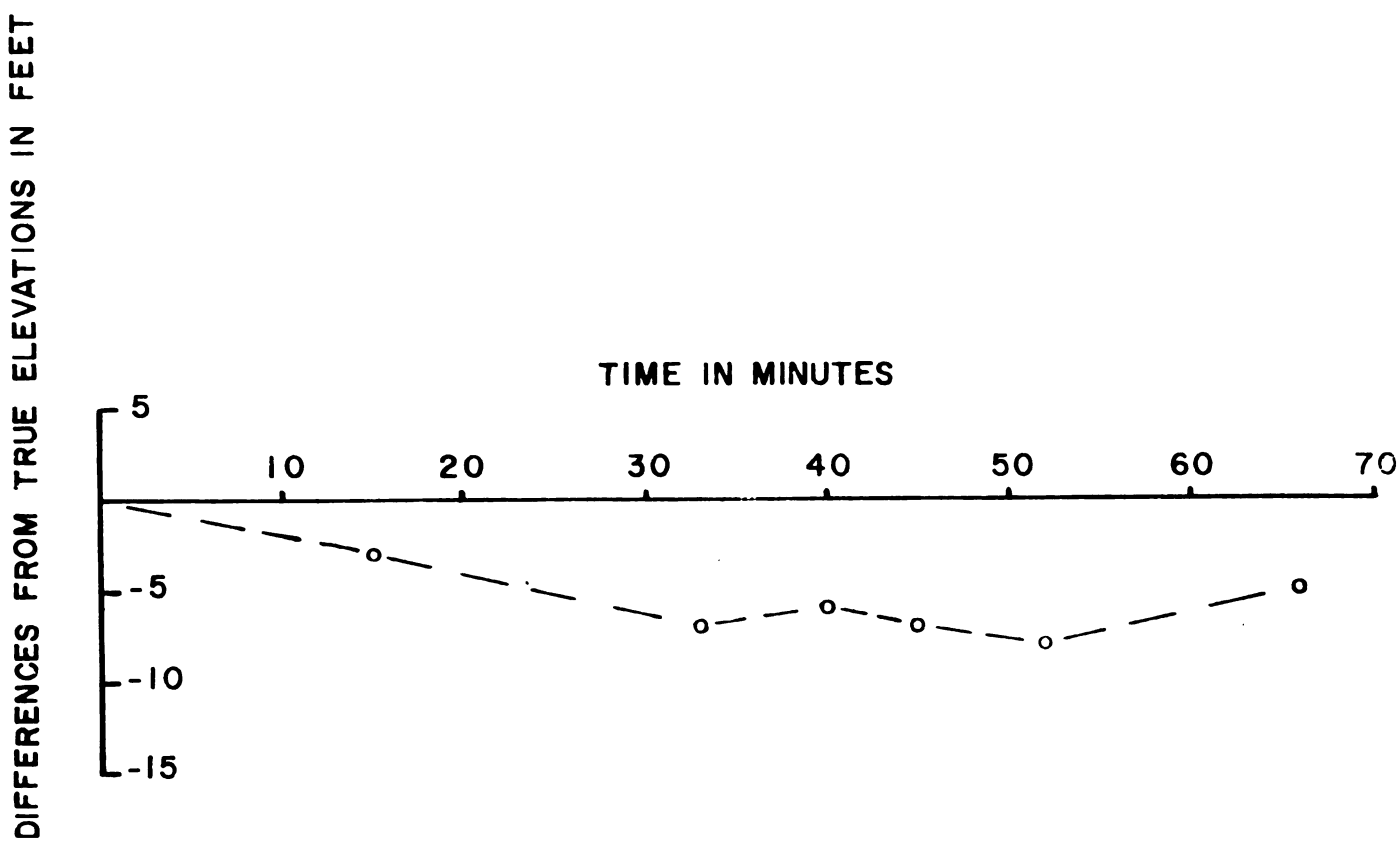

FIGURE 3. BAROMETRIC PRESSURE CHANGE CURVE AS EXPRESSED IN CHANGES OF ALTIMETER READINGS FOR KNOWN ELEVATIONS.

through the gravity base and was established as the latitude datum. Measurements of each station's variation from the datum were taken from these maps.

Magnetic Survey

The magnetic observations were made with Askania Torison-type magnetometers which measure variations in the vertical component of the magnetic field. A total of 277 stations were occupied including those of detailed profiles. The stations were spaced at one mile and one-half mile intervals except where highly anomalous observations necessitated closer intervals to define the areal extent of the anomalies. The base for the magnetic survey was not coincident with the gravity base because of the presence of metallic fencing. The magnetic base was located approximately 600 feet west of the southeast corner of section 15, T. 25 N., R. 4 E.

The magnetic stations were located in the same manner as the gravity stations.

REDUCTION OF DATA

Gravity

Many corrections must be applied to the observed readings before the data can be considered meaningful. Gravimeter drift is the first correction which was applied to the readings; this drift is the change of meter readings for a station as a function of time. This factor incorporates the effects of variation in the elastic components of the gravimeter as well as environmental and tidal effects. Drift corrections were obtained by periodically reoccupying the gravity base. The difference in meter readings between two successive base checks was distributed as a function of time among the stations observed between the base checks.

The readings in scale divisions were multiplied by the constant of the meter. This converted the readings into milligals. The resulting values in milligals, because of their relativity to the base, can be properly termed relative observed gravity.

A latitudinal variation of the acceleration of gravity between the equator and the poles exists because of the polar flattening of the earth and the centrifugal force due to the earth's rotation. A latitude correction of 1.307 mgals/mile was applied according to each station's variation in the north-south direction from the datum. All the stations were related to the arbitrary east-west datum extending through the base.

The free-air correction also was applied. The free-air correction takes into account the vertical gradient of gravity and corrects for varying station elevations with respect to the horizontal datum. Sea level was used as the datum in this survey.

Consideration also must be made for the mass between a station and the horizontal datum, namely sea level. For the purpose of calculations,the earth's surface was assumed to approximate an infinite horizontal slab. A density of 2.67 gm/cc was selected for the rock material of the infinite horizontal slab. The density of 2.67 gm/cc is the commonest value assumed for the mass or Bouguer correction in gravity surveys in Precambrian terranes.

A terrain correction takes into account the gravitational effect due to variations from the infinite horizontal slab which is assumed in the Bouguer correction. In the area of study the topography is very gentle, hence, the terrain correction was not applied to any station occupied in this survey.

The Bouguer gravity anomaly is employed to study the geological effects causing the gravitational variations. This anomaly is defined as the difference between the observed gravity and the calculated theoretical gravity based on the preceding corrections. Utilizing the

International Gravity Formula and applying the elevation and mass corrections, a theoretical gravity value was obtained for the base. The base's Bouguer gravity anomaly value was found to be -63.5 mgals. Because the gravity values of all the stations were related to the base, a simple constant was applied to the relative observed gravity to obtain an absolute observed gravity value. The Bouger Gravity Anomaly Map is shown in Figure 4.

Magnetics

The reduction of the magnetic data was much simpler than the reduction of the gravity data. Time variations or drift also is a factor in magnetics and is caused by the diurnal variation of the earth's magnetic field. The magnetic drift was removed from the meter readings by the same method employed in the gravity reductions. The magnetometer readings in scale divisions then were multiplied by the constant of the meter. This converted the scale divisions to observed magnetic values in gammas. The value for the magnetic base was arbitrarily given the value in gammas of that obtained in the first observation at the base.

The size of the area of study is sufficiently small so that a correction was unnecessary for the regional change in the earth's magnetic field. The variation of the earth's

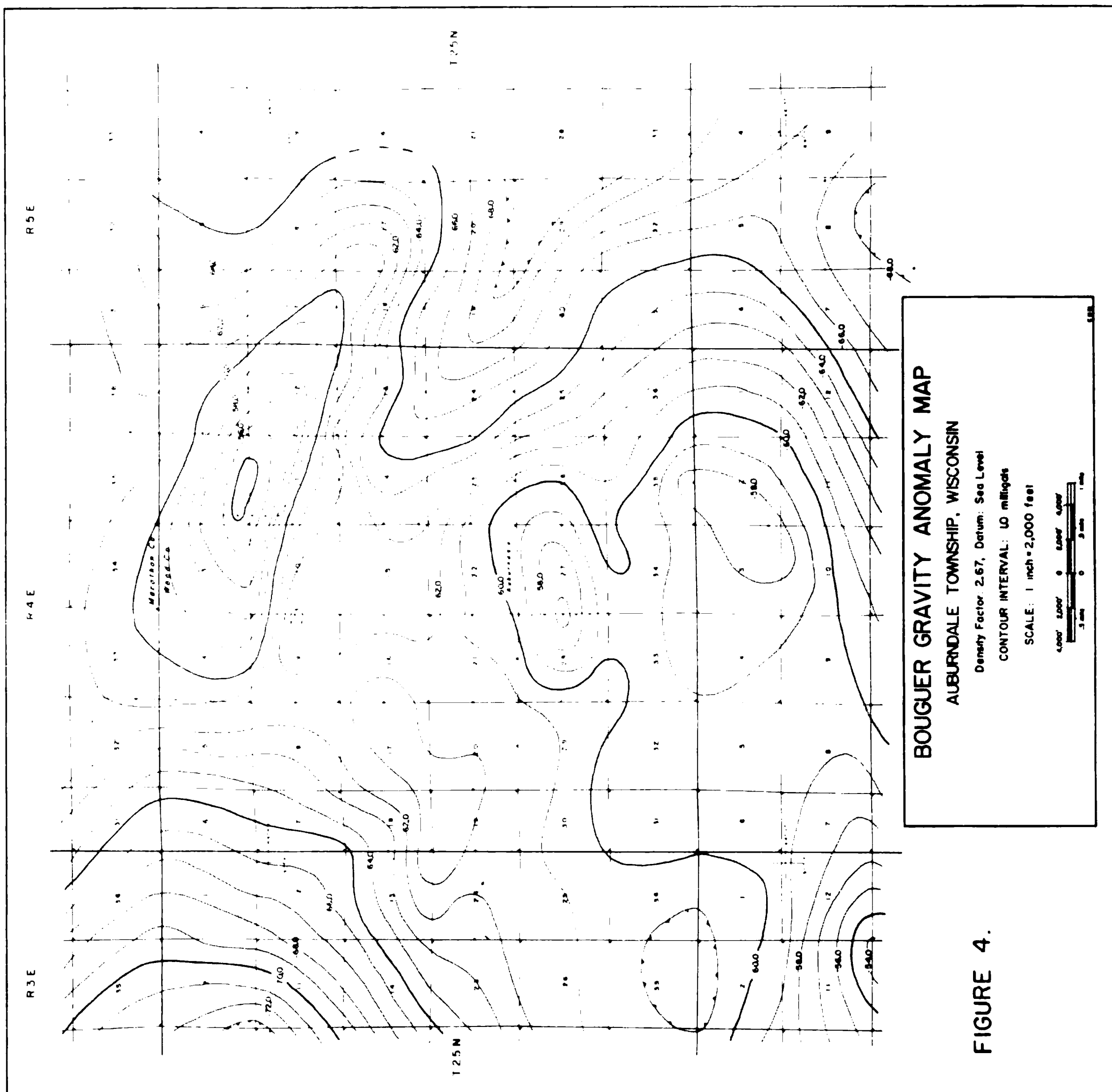
BOUGUER GRAVITY ANOMALY MAP
AUBURNDALE TOWNSHIP, WISCONSIN
Density Factor 2.67, Datum: Sea Level
CONTOUR INTERVAL: 1.0 milligals
SCALE: 1 inch = 2,000 feet
R3E
R4E
R5E
T25N

FIGURE 4.

magnetic field was found to of the order of three to five gammas from the northern to the southern extremities of the area.

The Relative Vertical Magnetic Intensity Map is shown in Figure 5.

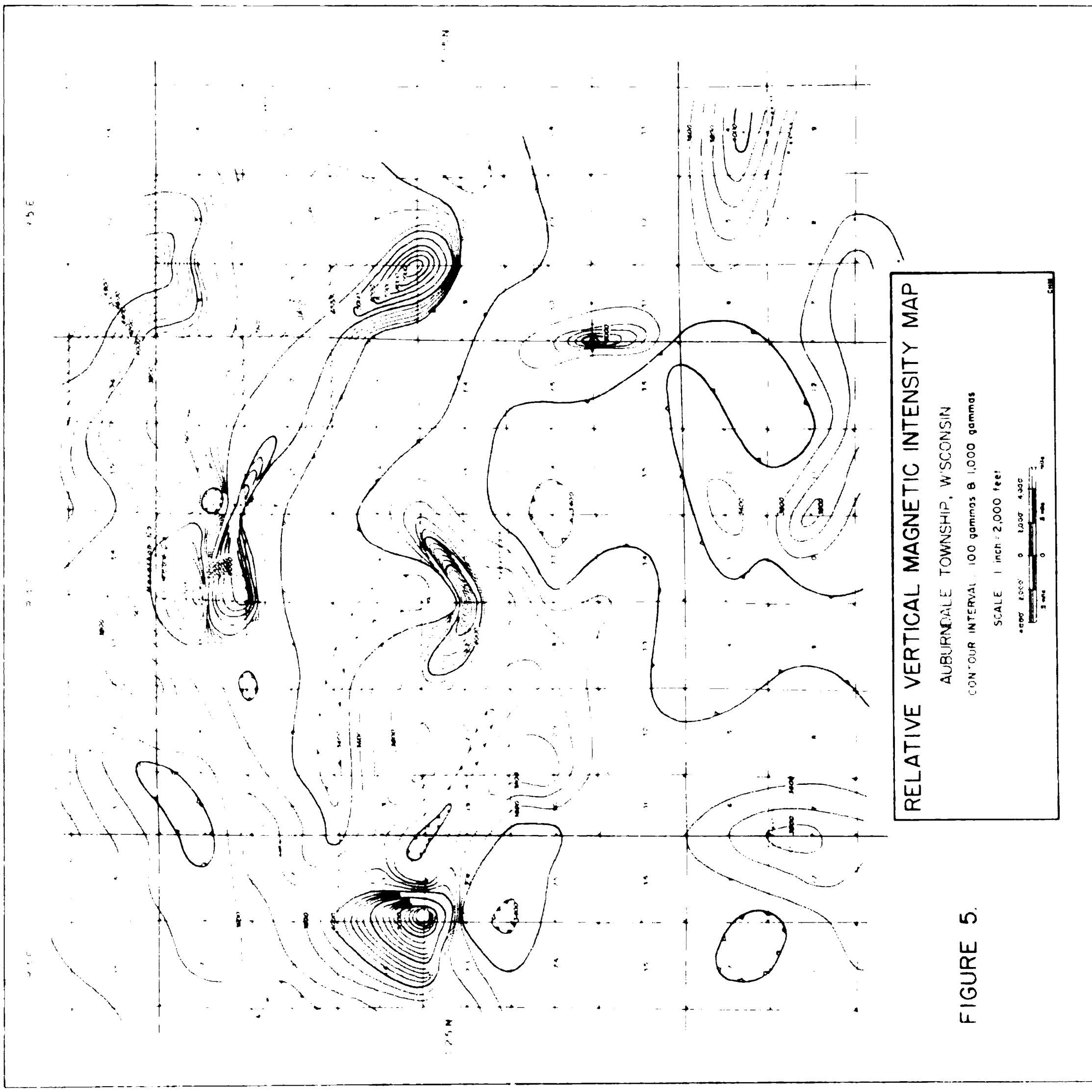
RELATIVE VERTICAL MAGNETIC INTENSITY MAP
AUBURNDALE TOWNSHIP, WISCONSIN
CONTOUR INTERVAL 100 gammas & 1,000 gammas
SCALE 1 inch : 2,000 feet

FIGURE 5.

ACCURACY OF GEOPHYSICAL SURVEYS

Gravity

The accuracy of the gravity data is dependent upon the accuracy of the gravimeters, the meter readings, the drift corrections, the density assumed for the mass correction, station location, and the elevation of each station. The accuracy of the station elevation is the most significant factor in producing error. Collectively considered, the other factors normally do not exceed 0.20 mgals. A five foot error in elevation would create an error of 0.30 mgals. The elevations of this survey are believed to be within five feet of the true elevations. Therefore, the relative error of the gravity survey is thought to be approximately 0.50 mgals and definitely less than 1.0 mgal.

Magnetics

The causes of possible error in the magnetic values are the accuracy of the magnetometers, the accuracy of the meter readings, the effects of non-lithologic magnetic materials, and the accuracy of the drift corrections. The first two factors are believed to be minimal. Areas observed or suspected of having non-lithologic magnetic materials present were avoided; therefore, the error from this factor also is thought to be minimal. The change in the rate of drift in magnetics can be sporadic and sometimes can go undetected even with frequent base checks. This is arbitrarily assigned a value of 25 gammas at a maximum. The maximum total error of the magnetic survey is believed to not exceed 50 gammas.

ISOLATION OF ANOMALIES

Gravity

The primary purpose of this survey is the mapping of the rock types close to and/or at the surface. The varying rock types should be reflected in rather abrupt changes in the acceleration of gravity as compared to the gradual changes of large magnitude resulting from deep seated crustal phenomena. The latter is termed the regional anomaly. To isolate the gravity effects of the surface rocks, the regional anomaly must be removed. The deviation of the Bouguer gravity anomaly from the regional anomaly is termed the residual gravity anomaly.

The residual gravity anomaly values for each station were determined by the cross-profiling method. The area was gridded by north-south and east-west profiles. Each of these profiles was separated by approximately one mile. The Bouguer gravity anomaly values were plotted for each of the profiles. A regional anomaly was then "smoothed-in" and adjusted so that the regional was the same at the intersection points for the east-west and north-south profiles. The Residual Gravity Map is shown in Figure 6. The regional anomaly which was determined by the cross-profiling method is shown in Figure 7. The residual map was utilized in the analysis of the anomalous features.

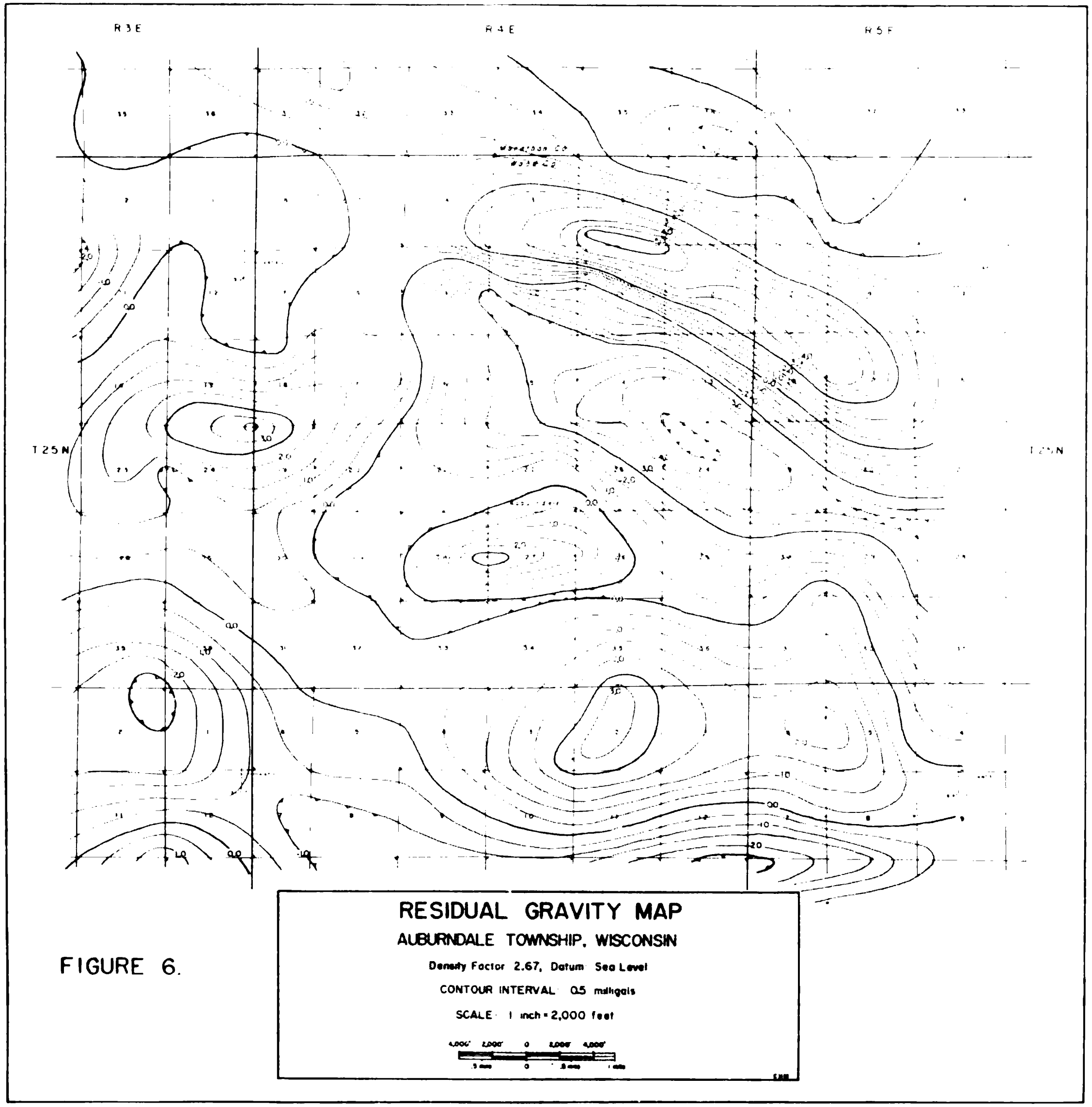
R3E
R4E
R5E
T25N
RESIDUAL GRAVITY MAP
AUBURNDALE TOWNSHIP, WISCONSIN
Density Factor 2.67, Datum Sea Level
CONTOUR INTERVAL 0.5 milligals
SCALE 1 inch = 2,000 feet

FIGURE 6.

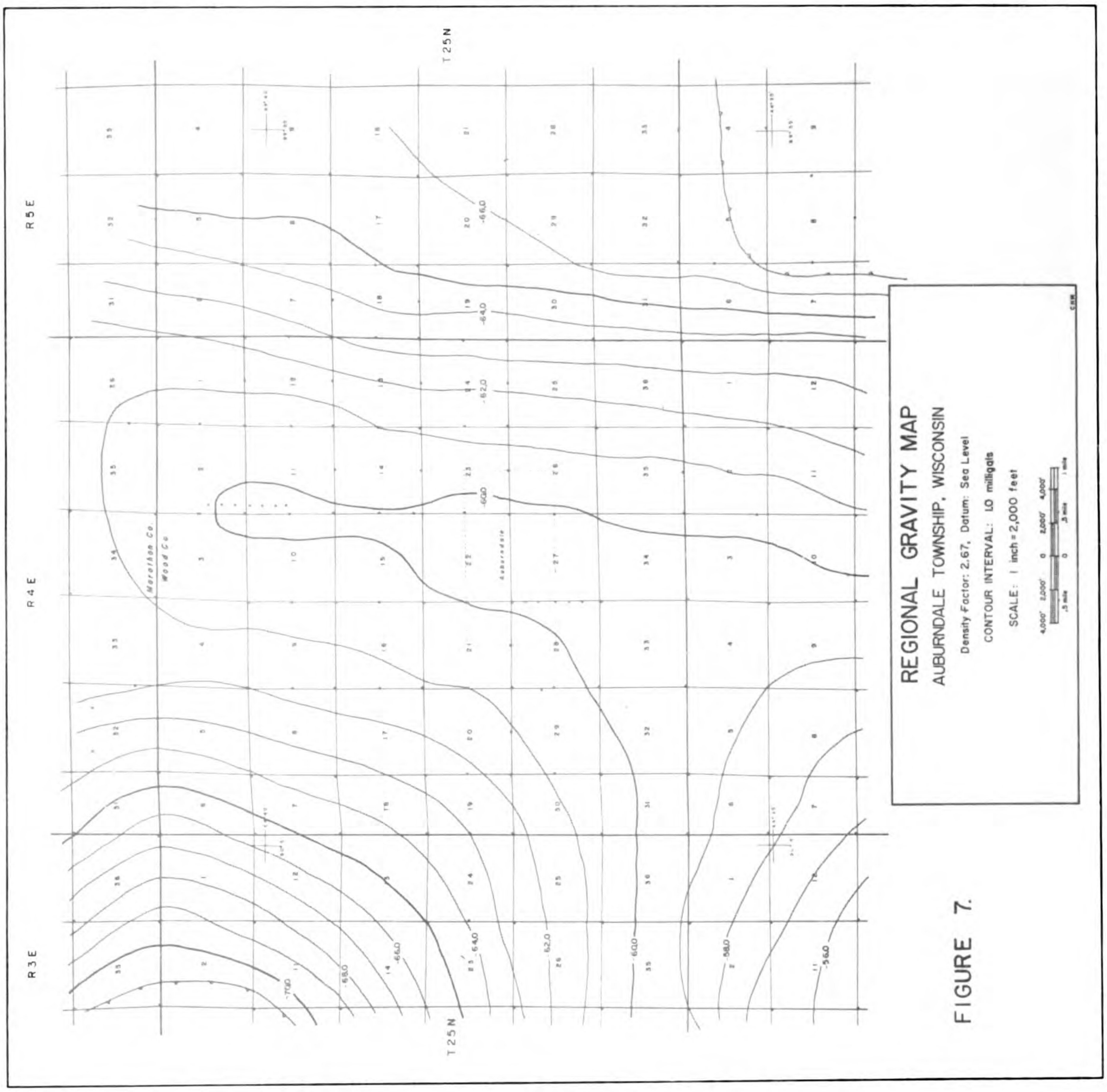
REGIONAL GRAVITY MAP
AUBURNDALE TOWNSHIP, WISCONSIN
Density Factor: 2.67, Datum: Sea Level
CONTOUR INTERVAL: 1.0 milligals
SCALE: 1 inch = 2,000 feet
R 3 E
R 4 E
R 5 E
T 25 N
Marathon Co
Wood Co
Auburndale
-70.0
-68.0
-66.0
-64.0
-62.0
-60.0
-58.0
-56.0

FIGURE 7.

Magnetics

Examination of the Relative Vertical Magnetic Intensity Map revealed that the anomalous features have a common background of approximately 3500 gammas. No regional magnetic anomaly is apparent on the map, therefore, a residual map was not constructed.

RESULTS OF THE GEOPHYSICAL INVESTIGATIONS

Gravity Survey

The Bouguer Gravity Anomaly Map shown in Figure 4 depicts a strong general positive which trends north-northeasterly from the southwestern corner of the map to the north-central portion of the map. This trend is flanked on either side by gravity lows. The anomalies present are distorted by this regional trend. The regional anomaly shown in Figure 7 correlates with the regional gradient determined by Mack (1957) in a study of the regional gravity anomalies of Wisconsin.

The residual anomalies which remained are shown on the map in Figure 6. The magnitude of the major positive residual anomalies are primarily in the range from +2.5 to +5.0 mgals. There is a noticeable trend of the strike of the anomalies, either westerly or northwesterly. The largest magnitude anomalies are approximately one by five and two by five miles in extent. The other positive anomalies are more limited in extent. The gravity highs are separated by gravity minima, mostly of the magnitude of -2.5 mgals, but one major negative anomaly attains -4.5 mgals. Many of the negative anomalies are incompletely defined because they lie near or at the edge of the area of study.

Magnetic Survey

The Relative Vertical Magnetic Intensity Map shown in Figure 5 discloses a common magnetic background level of about 3500 gammas. If the 3500 gammas is accepted as the background level, the anomalies can be differentiated into relative highs and lows. As with the residual gravity anomalies, the trend of the strike of most of the magnetic highs and lows is westerly or northwesterly. The magnetic positives are commonly 300 gammas above background, but locally some anomalies attain higher magnitudes, up to 5500 gammas above the background. Very local positive features exceed a relative +600 to +1400 gammas. Relative magnetic lows are found between the positive anomalies. These lows are commonly only 100 gammas below the background, but in a limited area are as great as a -400 gammas. The magnetic anomalies generally correlate with the residual gravity anomalies.

INTERPRETATION OF THE RESULTS OF THE INVESTIGATIONS

General Statement

The purpose of the gravity and magnetic survey is to aid in mapping the Precambrian geology. This requires that the geology be interpreted from the geophysical anomalies by empirical and/or analytical methods. However, the interpretations of the anomalies, gravity and magnetic, are not unique for this survey because of the limited geologic control for the area of study. Geologic control is necessary because various combinations of parameters for hypothetical geologic bodies can result in the same or very similar anomalies.

There are five main variables of geologic bodies which affect gravity anomalies: volume, density contrast, depth, shape, and isolation (Romberg, 1958). The magnitude of an anomaly varies directly with the product of the volume and the density contrast. Sharpness is a function of depth of the disturbing body and decreases with depth one power faster than the magnitude. If more than one anomalous body is present, the disturbing bodies must be sufficiently isolated to produce distinct anomalies. The shape of the body is critical in that a large magnitude anomaly will not be produced unless the body is concentrated, even though, the depth is shallow and the volume is great. These variables must be considered in order to present a reasonable interpretation. Other than density contrast, all the factors mentioned above, plus magnetic susceptibility, affect the vertical magnetic intensity anomalies.

The paucity of geologic control in the area of study makes possible many interpretations from the gravity and magnetic maps. But, through careful analysis of the geophysical data, coupled with the available geological information, the various possible interpretations should be reduced to yield a reasonable solution to the geology. Even though the gravity and magnetic anomaly positions correlate quite well, the gravity data will be more heavily weighted in the geological interpretation. The magnetic data generally are more difficult to interpret than the gravity data. The magnetic data are complicated by the dipolar effect, by the possibility of effects of natural remanent magnetization, and by the variance of the magnetite content within a single rock type. Grant and West (1965) state, ". . . magnetic properties of rocks are subjected to sudden and violent fluctuations over short distances . . . magnetic properties depend, in the main, upon trace rather than on bulk constituents."

Physical Properties of the Rock Types

The physical properties of interest are density and magnetic susceptibility. The density for each rock type was determined in the laboratory by the volume displacement method. The densities of the samples of each rock type were averaged and are shown in Table 10. The magnetic susceptibilites of the rock types also were measured in the laboratory using a magnetic susceptibility bridge. The measured values also are shown in Table 10. Even though there would be more variance in the magnetic susceptibility of a rock type than in the density, the susceptibilities measured can be utilized to predict the general order of magnitude of a magnetic anomaly which may be expected from a particular rock type assuming a constant source.

Table 10.--Mean rock type densities and magnetic susceptibilities.

Rock Type:	No. of Samples:	Density g/cc:	No. of Samples:	Mag. Suscept. $X10^{-6}$ c.g.s.:
Greenstone	5	3.10	4	135 to 3965*
Hornblendite	2	3.01	1	84
Magnetiferous "quartzite"	5	2.79	2	104 to 6055*
Gneissic quartz diorite	9	2.77	3	56
Metagraywacke	3	2.71	2	78
Granite-diorite contact rocks	8	2.69	1	44
Feldspathic quartzite	2	2.64	1	11
Granite and pegmatite	2	2.64	1	9

* Where such a range exists, an averaged magnetic susceptibility would be meaningless.

From examination of Table 10 generalizations can be made concerning gravity and magnetic anomalies which may be expected from the various rock types. Gravity anomalies of the greatest magnitude would be expected from the greenstone; the magnetic susceptibility suggests that moderate to high magnetic anomalies would be expected. The hornblendite has a density which would be expected to result in gravity anomalies of second order and possibly accompanying low to moderate magnetic anomalies. The magnetiferous "quartzite" would possibly be represented by intermediate gravity anomalies and moderate to very high, first order, magnetic anomalies. The gneissic quartz diorite also would be expected to produce intermediate gravity anomalies and relatively low magnetic anomalies. The metagraywacke would be expected to yield low to intermediate gravity anomalies associated with low to moderate magnetic anomalies. The granite-diorite contact rocks would be expected to be associated with gravity lows and low value magnetic anomalies. The granite, pegmatite, and feldspathic quartzite, geophysically speaking, could not be distinguished; all would be expected to be associated with gravity and magnetic minima anomalies.

Regional Geologic Setting

Geological field studies indicate that granite occurs throughout the region surrounding the area of investigation and strongly suggest granite is or underlying the Precambrian basement rocks. A core of granite and pegmatite was obtained from a water well in the east 1/4 sec. 10, T. 25 N., R. 3 E. Near the center of sec. 19, T. 25 N., R. 5 E., a profusion of vitreous, white quartz fragments were found, some nearly two feet in diameter; these were not in outcrop and would be classed as "rubble outcrop." Aplite diklets were found in a very good exposure in the northeast corner of sec, 8, T. 25 N., R. 5 E.; the host rock is the gneissic quartz diorite. In the north 1/4 sec. 13, T. 24 N., R. 3 E., decomposed granite was observed as "rubble outcrop." A weathered, sheared granite was found in the east 1/4 sec. 5, T. 25 N., R. 4 E. and also in the northeast corner of sec. 6, T. 25 N., R. 4 E. In the southeast corner of sec. 31, T. 26 N., R. 4 E., large angular boulders of granitic pegmatite were found scattered abundantly on a hillside.

The regional gravity anomaly removed by the cross-profiling method does not contradict the interpretation that granite underlies the area. The regional anomaly shown in Figure 7 is an arched-shaped gravity high trending north-northeasterly. The regional can be explained as a thinning of the granite and a thickening of the denser layer below. This denser layer is commonly given a density of 2.84 gm/cc. Mack's (1957) regional gravity anomaly in this area is interpreted by him to have a similar origin.

Interpretation of Residual Gravity and Magnetic Anomalies

Analytical Interpretation

A quantitative evaluation is desirable for the interpretation of the gravity data to establish a geologic cross section. If the geology of the cross section is related to the residual gravity, the relationships can be utilized to extrapolate the geology from areas of geologic control.

The profile selected for quantitative evaluation had to meet the following conditions: geologic control must be available; the gravity and magnetic coverage must clearly define the anomalies present; and, the section must be perpendicular to the strike of the anomalies. The section selected (section A-B in Figure 9) extends north from the southeast corner of sec. 27, T. 25 N., R. 4 E., through the west portions of sections 11 and 2 and midway into sec. 35, T. 26 N., R. 4 E.

The causative geologic bodies can be assumed to be two-dimensional for the purposes of calculation of gravity because of the linear nature of the majority of the anomalies. A two-dimensional gravity method outlined by Talwani, Worzel, and Landisman (1959) was used in these computations utilizing the CDC. 3600 computer.

In these calculations the observation surface is assumed to be a horizontal plane and the upper boundary of the Precambrian bedrock. Neither of the assumptions is correct, but the error imposed upon the results is negligible considering the magnitude of the anomalies and the inherent ambiguity of the results.

Geologic contacts were selected by examination of the residual gravity and magnetic profiles. The geologic bodies were first approximated by rectangular forms. The density contrasts were held constant through the course of calculations. Ultimately a close fit was obtained between the calculated gravity and the residual gravity profile by varying the parameters of volume, depth, and shape of the geologic bodies. The resulting geologic bodies and accompanying profiles are shown in Figure 8.

The rock types associated with the anomalies shown in Figure 8 are as anticipated from the anomalies. The first order magnitude gravity anomalies are attributed to greenstone and are associated with a high magnitude magnetic anomaly. Referring to Figure 8, the surface dimension of the greenstone is 2800 feet in width and has a vertical extent of 2500 feet. The second order magnitude gravity anomalies are attributed to a hornblendite which has a wedge-shape. At the surface the exposed width is only 1000 feet, and the depth of the lower boundary varies from 2800 to 1000 feet. The gneissic quartz diorite lies below the slopes of the higher order magnitude gravity anomalies and is associated with an intermediate magnitude gravity anomaly. The lower extent of the gneissic quartz diorite varies from

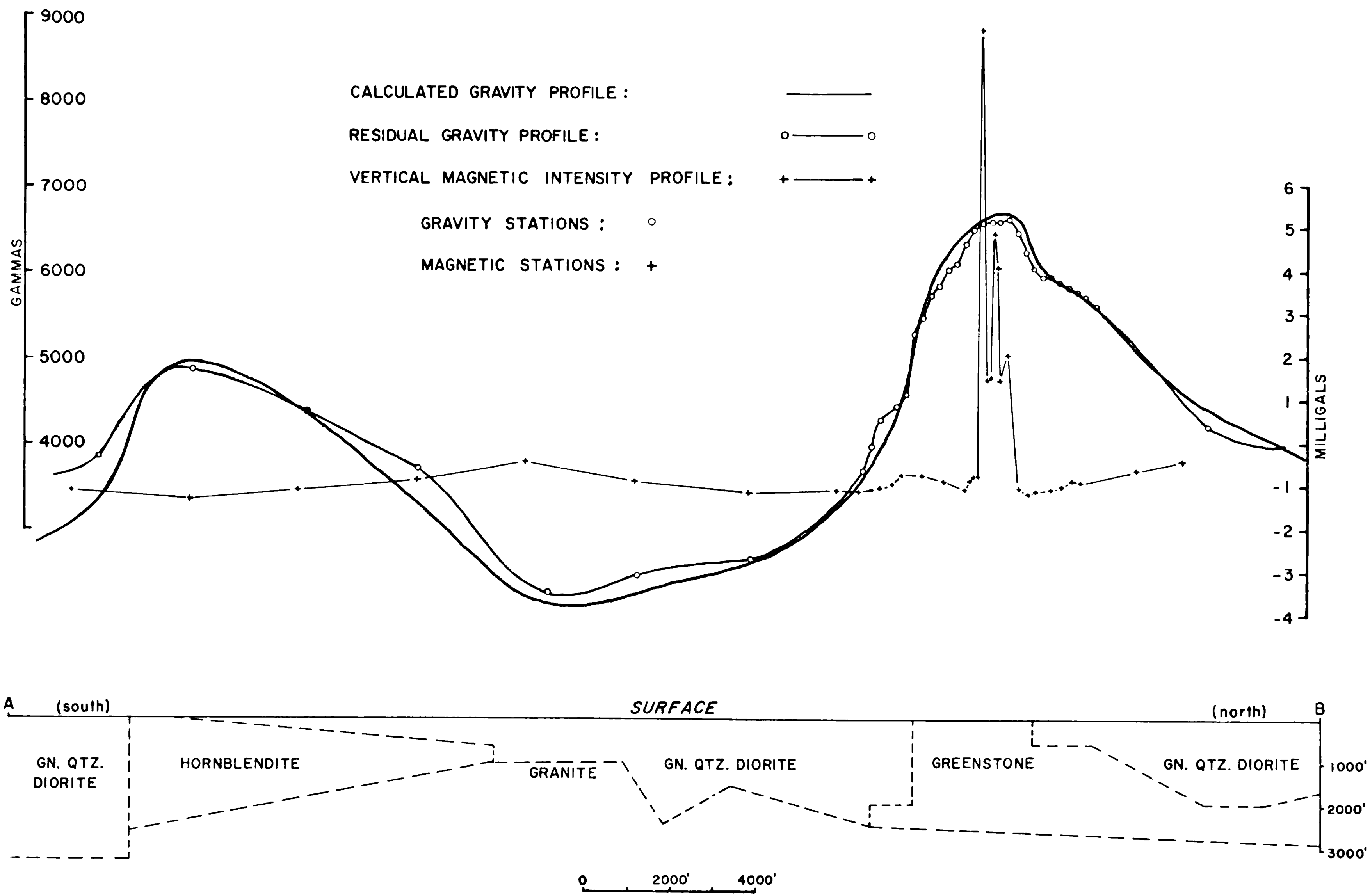

FIGURE 8. COMPARISON OF GRAVITY AND MAGNETIC PROFILES OVER A PROPOSED GEOLOGIC CROSS SECTION.

3300 to 1000 feet below the surface. The entire cross section is underlain by granite. Gravity minima occur where the granite is closest to the surface. A sharp boundary is drawn between the granite and the other rock types, but in actuality the boundary probably would be gradational.

The magnetic profile provides limited information. However, the greenstone is clearly revealed by a relative positive magnetic anomaly of approximately 5300 gammas. The magnetic high located over the gravity minimum is not related to any feature shown in Figure 8 but is an end effect of a magnetic high to the west which is shown in Figure 5. A magnetic low is shown over the hornblendite; the low also is an end effect of a magnetic low lying to the east.

All the rock types found in the area of study are not represented in the proposed geologic bodies in Figure 8. Also, the "rubble outcrop" evidence of granite-diorite contact rocks is not shown in Figure 8. These rocks could represent an apophysis of the granite below. The geophysical data do not indicate its presence and, therefore, the apophysis is not included among the proposed geologic bodies. Hornblendite is not found in outcrop along section A-B, but hornblendite is found to the south and is associated with a second order magnitude gravity anomaly. Hence, hornblendite is proposed to be the causative body of the positive gravity anomaly at the southern end of the section.

There is a significant difference between the calculated gravity and the residual gravity at the southern end of the section. This was unavoidable because the hornblendite situated two miles south of the profile was not accounted for in the calculations. The gravity effects of the southern hornblendite cause the residual gravity values at the southern end of the profile to be higher than the calculated values.

The calculated gravity profile illustrates that the proposed geologic bodies can produce gravity anomalies which very closely approximate the residual gravity anomalies. The proposed geologic bodies are believed to represent a reasonable interpretation of the geophysical data.

Empirical methods

Having proposed a reasonable geologic interpretation for the geophysical anomalies shown in Figure 8, the geology is extrapolated from and interpolated between areas having geologic control. The Residual Gravity Map shown in Figure 6 and the magnetic map shown in Figure 5 were carefully examined as was the Outcrop Location Map shown in Figure 2. A geologic map was drawn using the Outcrop Location Map for geologic control and utilizing the profiles over proposed geologic bodies as an interpretational guide. The Interpretative Geologic Map is shown in Figure 9.

Reference is made to the residual gravity and magnetic maps, Figures 6 and 5, respectively, in the following discussion. The greenstone is mapped in areas of first order

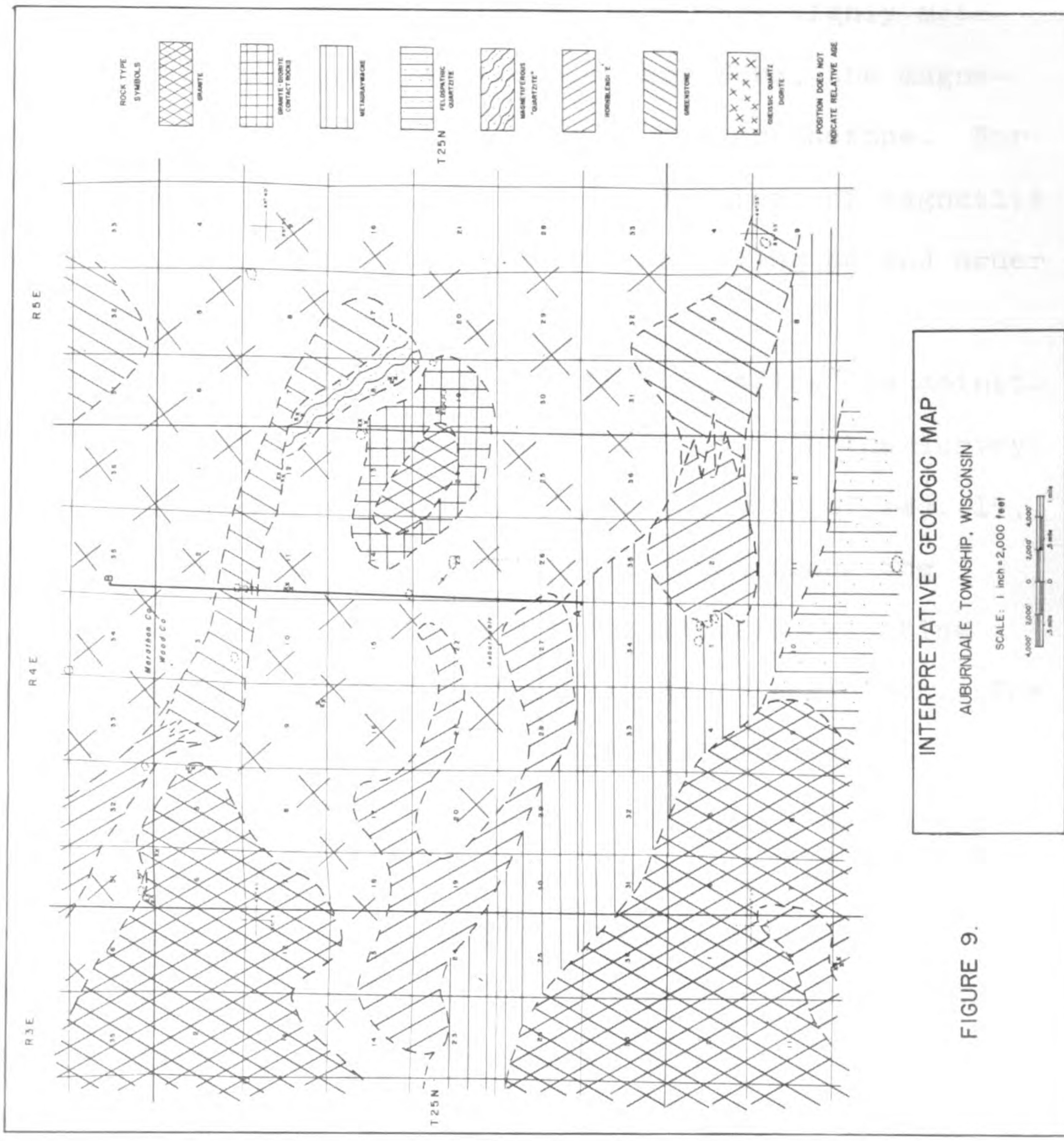

FIGURE 9.

INTERPRETATIVE GEOLOGIC MAP

AUBURNDALE TOWNSHIP, WISCONSIN

positive gravity anomalies and very strong magnetic anomalies; these areas also contain numerous outcrops and "rubble outcrops" of greenstone.

Hornblendite is considered to be a more highly metamorphosed equivalent of greenstone. Therefore, the magnetite content should vary as it does in the greenstone. For this reason the hornblendite is mapped in areas of magnetite anomalies of varying magnitude and areas having second order positive gravity anomalies.

An outcrop of the magnetiferous "quartzite" is coincident with the maximum magnetic value recorded in the survey. The outcrop is situated in the northeast corner of sec. 19, T. 25 N., R. 5 E. The outcrop is positioned along the southern flank of the positive gravity anomaly resulting from the gravity effect of the greenstone to the north. The geophysical data and geological evidence indicate the "quartzite" is of limited extent.

The gneissic quartz diorite is mapped in areas on the flanks of the first and second order positive gravity anomalies and where the magnetics are of low magnitude and where indicated by geologic evidence.

The metagraywacke, because of its physical properties, is expected to be expressed geophysically similarly to the gneissic quartz diorite. The metagraywacke is mapped where low to moderate magnitude gravity and low magnitude magnetic anomalies occur and on the basis of outcrops. The low magnitude positive gravity anomaly trending northwesterly from the outcrop evidence in sec. 3, T. 24 N., R. 4 E., is arbitrarily defined as the westward manifestation of the graywacke.

The granite-diorite contact rocks are mapped only in the immediate area surrounding the gravity minimum in sec. 24, T. 25 N., R. 4 E. Contact rocks also must be present in zones where the granite is in contact with other rock types. The area around the gravity minimum, mentioned above, is the only area where the granite-diorite contact rocks were found in outcrop. A possible explanation for the lack of extensive contact rocks in other areas is that the granite formed vertical contacts with the country rocks. In the zone where the granite-diorite contact rocks are present, the contact may be gently inclined resulting in a thin cap of the gneissic quartz diorite over the granite. This would produce an extensive exposure of the contact rocks.

The feldspathic quartzite has nearly identical density and magnetic susceptibility as the granite. There is geologic evidence for the granite and the feldspathic quartzite at the southern edge of the area of study. Here, the gravity and magnetic anomalies are of very low magnitude, and there is nothing to indicate the location of the contact between the two rock types. The contact is mapped midway between the exposures of each rock type. Granite is, elsewhere, mapped where gravity minima and magnetic low occur.

A feature of the magnetic map not included in the previous discussions is the magnetic high of very limited extent found in the northwest corner of sec. 31, T. 25 N., R. 5 E. This high is speculated to be caused by local mineralization of a fracture or small fault in the gneissic quartz diorite.

Identification of the relative ages of the rock types is not possible on the basis of field evidence. No rock contacts were found as a result of the field observations. However, from examination of the literature of the older surveys (Weidman, 1907, and Eidemiller, 1918), some of the age relationships may be inferred. The gneissic quartz diorite and greenstone apparently are the rock types shown in the stratigraphic column in Table 1 which belong to the Basal Group. The Basal Group rocks are of Laurentian and Keewatin age. The magnetiferous "quartzite" also may be of the Basal Group. The "quartzite," which possibly may be recrystallized iron formation, may be associated with the greenstone as the Soudan iron formation is associated with the Ely greenstone in Minnesota. Or, the "quartzite" may be recrystallized chert and of the Lower Sedimentary Series of the stratigraphic column. The nature of the "grains" of the quartz in thin section is very similar to the description given by Weidman (1907) for the Powers Bluff quartzite. The magnetite may have been introduced by hydrothermal solutions. The latter explanation is preferred.

The feldspathic quartzite and the matagraywacke are tenuously correlated with the Lower Sedimentary Series.

The granite is thought to be the youngest crystalline rock type in the area. The granite is probably a portion of the widely spread granite, nepheline syenite series shown in Table 1. According to Weidman, the granite constitutes one-half to two-thirds of the surface rock in the north-central Wisconsin region.

The hornblendite is considered to be the result of thermal metamorphism of the greenstone. The granite could have possibly been the main source of heat. Therefore, the hornblendite may have metamorphically developed during the emplacement of the granite.

One can only speculate on the interpretation of the structural geology. If the relative ages of the rocks presented are correct, the gneissic quartz diroite and greenstone may represent the remains of anticlinal features and where the metasediments occur, synclinal features. Contacts between rock types derived from the study may, in large part, represent fault contacts. However, it is difficult, if not impossible, to distinguish the type of contact on the basis of geophysical results.

The geophysical maps of the area of study, no doubt, can be interpreted differently from the interpretation presented. The interpretation of some areas, namely the central, west central, and the southwest central, is almost solely based on the gravity and magnetic data. Nevertheless, the interpretational reasoning for these areas, as well as the entire area of study, is believed to be valid.

The gravity and magnetic survey resulted in the definition of the general limits of the rock types, the regional geologic picture, and approximations of the lower limits for some of the rock types.

Not only did the gravity and magnetic survey prove of value in mapping Precambrian bedrock in an area of limited geologic control, but also provided information which would not be possible from geologic field mapping techniques.

CONCLUSIONS

A gravity and magnetic survey integrated with a geological investigation, and utilizing the measured physical properties of the rock types, proved the importance of a gravity and magnetic survey in mapping geology in a Precambrian terrane of limited geologic control.

The resulting geologic map shows the areal distribution of rock types and increases the knowledge of the Precambrian geology of this area. Metamorphosed igneous and sedimentary rocks are found associated with, and surrounded by, granite which in part may be intrusive into these rocks.

Calculations performed on the gravity anomalies suggest that the lower limit of the metamorphosed rocks is at approximately 3300 feet below the surface.

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