

CENTRAL WISCONSIN VOLCANIC BELT



FIELDTRIP GUIDEBOOK
for
FIFTEENTH ANNUAL
INSTITUTE ON LAKE SUPERIOR GEOLOGY
by

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With the collaboration of CARL E. DUTTON

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CENTRAL WISCONSIN

VOLCANIC BELT

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TO: Dr. Carl E. Dutton, who pointed out the significant exposures from his first hand knowledge of the area. He gave freely of his time and knowledge--both of particular areas and from his 40 years experience in the Precambrian of the Lake Superior region. His generous help, encouragement, and thought-provoking approach made preparation of this Guidebook a stimulating learning experience.

L.W.W.

G.L.L.

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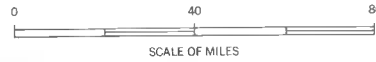
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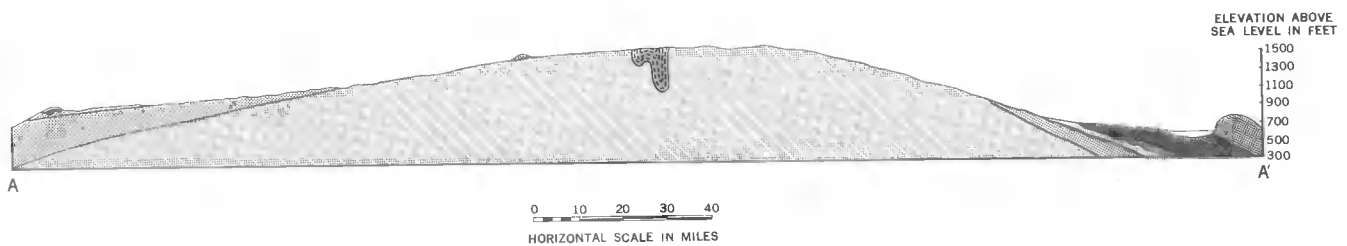
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GEOLOGIC MAP OF WISCONSIN

AFTER BEAN, 1949



University of Wisconsin
Wisconsin Geological and Natural History Survey
 George F. Hanson, Director and State Geologist



SHORT GEOLOGIC HISTORY OF WISCONSIN

The bedrock of Wisconsin is separated into two major divisions: (1) older, predominantly crystalline rocks of the Precambrian Era, which were extensively deformed after their deposition by movements of the Earth's crust; and (2) younger flat-lying sedimentary rocks of the Paleozoic.

The Precambrian Era lasted from the time the earth cooled, over 4,000 million years ago, until the Paleozoic Era which began about 500 million years ago. During this vast period of 3,500 million years sediments, some of which were rich in iron and which now form our iron ores, were deposited in ancient oceans, volcanoes spewed forth ash and lava, mountains were built and destroyed, and the rocks of the upper crust were invaded by molten rocks of deep-seated origin. Only a fragmentary record of these events remains but, as tree stumps attest the former presence of forests, the rocky roots tell the geologist of the former presence of mountains.

At the close of the Precambrian Era most of Wisconsin had been eroded to a rather flat plain upon which stood hills of more resistant rocks as those now exposed in the Baraboo bluffs. There were still outpourings of basaltic lava in the north and a trough formed in the vicinity of Lake Superior in which great thicknesses of sandstone were deposited.

The Paleozoic Era began with the Cambrian Period, the rocks of which indicate that Wisconsin was twice submerged beneath the sea. Rivers draining the land carried sediments which were deposited in the sea to form sandstones and shales. Animals and plants living in the sea deposited calcium carbonate and built reefs to form rocks which are now dolomite—a magnesium-rich limestone. These same processes continued into the Ordovician Period during which, as indicated by the rocks, Wisconsin was submerged three more times. Deposits built up in the sea when the land was submerged were partially or completely eroded at times when they were subsequently elevated above sea level. During the close of the Ordovician Period, and in the succeeding Silurian and Devonian periods, Wisconsin is believed to have remained submerged.

There are no rocks outcropping in Wisconsin that are younger than Devonian. Absence of this part of the rock record makes interpretation of post-Devonian geologic history in Wisconsin a matter of conjecture. Available evidence from neighboring areas, where younger rocks are present, indicates that towards the close of the Paleozoic Era, perhaps some 250 million years ago, a period of gentle uplift began which has continued to the present. During this time the land surface was carved by rain, wind and running water.

The final scene took place during the last million years when glaciers invaded Wisconsin from the north and sculptured the land surface. They smoothed the hill tops, filled the valleys and left a deposit of glacial debris over all except the southwest quarter of the State where we may now still see the land as it might have looked a million years ago.

CENTRAL WISCONSIN VOLCANIC BELT

This field trip represents a progress report in the early stages of the investigation of the Precambrian geology in central Wisconsin. Although we cannot provide many of the answers, we have identified a number of problems in the area. Some of these problems are presented in the following Guidebook with the hope that at least a few answers will be forthcoming.

Introduction

Precambrian volcanic and sedimentary rocks cut by intrusions of a wider range in composition and separated by broad expanses of gneisses and granites were mapped at the beginning of this century in central Wisconsin. Recent investigation suggests that these volcanic and sedimentary rocks are similar in type, arrangement and separation to the greenstone belts which make up a substantial part of the Early Precambrian portions of the Precambrian Shield in many continents. They are lithologically similar, and may be roughly comparable to the "Mobile Belts" of most post-Precambrian geosynclines. Both appear to have formed in areas of prolonged tectonic activity.

The rocks which will be visited are presumably considerably younger than the greenstone belts of Canada, yet their similarity to these belts cause us to believe that central Wisconsin may be part of a heretofore unrecognized greenstone belt.

Lithology

Within a greenstone belt, the volcanic rocks range in composition from basalt to rhyolite, and typically form sequences with pillowed basalts at the bottom and grade upward through andesites to rhyolites at the top. This general sequence may be incomplete, repeated, or reversed in a particular area. Some greenstone belts are composed predominantly of mafic volcanics; some have greater amounts of felsic rocks. The central Wisconsin area appears to have a greater than normal amount of rhyolitic volcanics, but their relationship to the basalts is not clear.

The sediments of a greenstone belt consist largely of graywacke and slates with lesser amounts of chemical sediments (mainly cherty iron-formations). These sedimentary sequences may overlie, underlie, be sandwiched between the volcanic sequences, and some sediments (particularly iron-formations) occur within the volcanic sequences.

Intrusions into the volcanic-sedimentary rocks range in composition from peridotite to granite, and in some areas (as at Wausau) alkaline complexes, including nepheline syenites, are present. Intrusive igneous activity appears to have occurred over a very long period; some intrusions may represent the "feeders" and dikes associated with the volcanism which characterizes the belts. Later batholithic intrusions of more granitic rocks seem to bring the tectonic cycle to a close.

Relative Age

Determining the relative age of rocks within a greenstone belt requires unravelling the complex structure so characteristic of these regions. Because there are no fossils available to determine the relative age, it is necessary to resort to various "sequential" features (such as pillow structures and graded bedding) and structural techniques to determine stratigraphic tops (since many beds dip nearly

vertically, the erosion surface is essentially a cross section). The relationship of structure (tectonic activity) and igneous and metamorphic activity which have affected certain parts of the sequence may be interpreted differently by different workers due to shortage of outcrops at critical locations. Thus, a unique solution to the problem of stratigraphic sequence often cannot be found. As new evidence is found and as new concepts and tools are available, the relative age of certain units may be changed-- hopefully toward a more accurate sequence.

On a broader scale, the relative age of one greenstone belt as compared to others in a given area is even more difficult to ascertain because the belts are almost invariably separated from one another by batholithic expanses of gneisses and granitic rocks. Individual bodies of granite are not of sufficiently large size to show age relationships between adjacent belts. Furthermore, radiometric age dating on the granites yields the date of intrusion (or later metamorphism) and gives only a minimum age for the intruded rocks. As a result, the ages of greenstone belts in a particular shield area can be established in only a very general way.

Absolute Age

Absolute (radiometric) age determinations show that almost all the recognized greenstone belts in the Canadian Shield are more than about 2,500 million years old. In fact, they are generally referred to as Archean greenstone belts because of their age.

The absolute age determinations available for a few rhyolite and granite localities in Marathon County indicate that rocks were formed about 1,500 million years ago. Therefore, this greenstone belt may be nearly 1,000 million years younger than most other greenstone belts. If this proves to be true, then an understanding of the rocks in central Wisconsin would contribute significantly to our knowledge of middle

and late Precambrian history of the Canadian Shield. Although we do not yet have anything like a clear-cut picture of the geological history of the central Wisconsin area, we are proposing the "greenstone belt" concept as a working hypothesis for your evaluation. Thus, central Wisconsin may be an important area which will add to the overall story of the development of the North American continent, particularly during middle Precambrian time.

Economic Significance

In the past five to ten years, there has been developing an increasing awareness of the importance of greenstone belts as targets for prospecting activities. This is an outgrowth of the formulation of a new concept of ore genesis. The concept of strata-bound sulfide and volcanic exhalative deposits has given great impetus to prospecting in volcanic-sedimentary sequences which are represented by greenstone belts. In simplest terms, this concept relates the formation of many disseminated and massive sulfide ores to volcanic activity rather than to later hydrothermal activity. Many of the large sulfide deposits (both massive and disseminated) in the Canadian Shield (for example, Manitowadge, Timmins, Noranda, Mattagami, Timagami, and others) as well as many post-Precambrian sulfide deposits have recently been interpreted as volcanic exhalative in origin. In fact, there are relatively few greenstone belts in the Canadian Shield that do not contain important sulfide ore deposits. Therefore, the importance of recognizing central Wisconsin as possibly a greenstone belt seems self evident.

For general features and economic importance of greenstone belts, the interested reader is referred to: "Symposium on Strata-bound Sulfides and their Formative Environment", Canadian Mining and Metallurgical Bulletin, Sept., 1965, and other articles listed in the references.

Previous Work

A comprehensive account of the regional geology in the area, "Geology of North Central Wisconsin", by Samuel Weidman was published in 1907 as Bulletin XVI of the Wisconsin Geological and Natural History Survey. Considering that the field work was done about the turn of the century, it is remarkably thorough in its areal coverage. The publication is very good insofar as outcrop location and description is concerned, but Weidman does not attempt to interpret the geologic setting for the area as a whole. While certain revisions may be possible in the map and stratigraphic sequence presented by Weidman, the changes would presumably be relatively minor and involve both additional data and use of geologic concepts not developed at the time the Bulletin was published.

The geology of the Wisconsin Rapids-Wausau area was examined in 1917 to 1921 as part of a land classification survey by the Wisconsin Geological Survey. Township maps showing location and classification of outcrops and a series of related geologic reports are in files in Madison.

Selected aspects of the geology in the central Wisconsin area were discussed by Emmons (1953b), who was leader of the 17th Annual Tri-State Geological Field Conference in 1953. However, the theme for his work is very different from ours, and we will not be stopping at any of the exposures visited on the 1953 trip.

Particular aspects of the geology in the Wausau area have also been covered in a number of theses prepared at the University of Wisconsin.

Recent work by the U. S. Geological Survey and the Wisconsin Geological Survey has resulted in a series of four open file sheets on the Precambrian geology of northern Wisconsin compiled by Carl E. Dutton and Reta E. Bradley. The interesting variety of formations seen during field checking have led to the present field trip.

The purposes of this field trip are to examine the different rock types in the area and attempt to determine how well they fit a concept which may tie together

all of the rocks into a logical relationship. So far as we know, this is the first attempt to interpret the tectonic setting for the central Wisconsin area. Keep in mind, however, that this is a progress report in the early stages of an investigation, and the greenstone belt concept should be considered as a working hypothesis. Therefore, we will examine some of the rock types in an attempt to determine the tectonic setting of the area.

Because we are trying to show features which suggest that central Wisconsin is part (or all) of a greenstone belt, a brief statement pointing out the relevance of each stop will be given.

Stop 1 illustrates features of felsic intrusions into greenstone belts. Both syenite and granite are intrusive into the greenstone; however, we do not know the relative age of these intrusions to one another.

STOP 1. Assembly Point at Employers Insurance.

This exposure is fairly representative of the syenite in the Wausau area. Most of the syenite at this stop is actually a quartz syenite. A few miles northwest are exposures of nepheline syenite and quarries in gray and in red syenite.

Mineralogically, the syenite contains potassium feldspar, plagioclase, sodic hornblende, biotite, sodic pyroxene, minor apatite, zircon, magnetite, carbonate, with or without quartz. In some samples, the feldspar is highly perthitic, consisting of almost any mixture of sodic plagioclase and potassium feldspar. Highly sutured boundaries between feldspars are common in some samples. Quartz makes up an appreciable percentage of samples from certain localities. The mafic minerals, especially the hornblende, are typically very poikilitic (i.e., include numerous other minerals--especially apatite). Some of the hornblende has been altered to fine-grained biotite, magnetite, and carbonate.

At a number of places immediately west of Wausau, the syenite contains masses of quartzite. In most cases, there appears to have been a reaction between the syenite and quartzite to produce a halo of magnetite-bearing "granite" around the inclusions or pendants of quartzite. The typical syenite is weakly to non-magnetic, and is composed mainly of highly perthitic alkali feldspar and probably sodic hornblende. Quartz may or may not be present. As one approaches a quartzite body within the syenite, the quartz content increases; the hornblende is replaced by biotite, accompanied by a notable increase in the magnetite content.

A small scale example (not containing all the features described above) may be seen in the roadcut on U.S. 51 about 500' (?) east of the parking lot behind Employers Insurance.

Crochiere farm, Sec. 29 T 29N R 6 E Artus Creek Greenstone. (Pillow Lavas)
(1968 Tri-State Stop 3.)

One of the most abundant rocks in many greenstone belts is pillowed basaltic and andesitic lavas. In fact, as it is used in the Lake Superior region, the term greenstone denotes a somewhat metamorphosed intermediate to basic volcanic rock. The greenish color derives from the abundance of chlorite, epidote, and actinolite in most examples. You will notice on the colored geologic map that the major area of mafic volcanics in this region lies west of Wausau. Although there are exposures of basic volcanics east of the Wisconsin River (northeast of Wausau), they are presumably of more limited extent.

At this stop, there are numerous exposures of pillowed greenstone with pillows better exposed in the outcrops farther south from the road. Figure 2 shows an example of the pillows at this stop. Due to the irregular fracture pattern on the surface of the outcrops, the pillows are best seen on the southwest-facing ledges formed by joint surfaces.

The pillows range in size from less than one foot to at least three feet in diameter. Pillow shape indicates top to the southeast, and in some places, it appears that the dip may also be to the southeast. Note that all exposures (all flows?) are not pillowed. Pillowed greenstones are typically interlayered with non-pillowed greenstone, and at least some of the non-pillowed material is a basaltic tuff as illustrated at the next stop (Figure 3).

The rock consists of sodic plagioclase, amphibole (actinolite?), epidote, chlorite, and minor quartz; a typical greenstone mineralogy. Epidote and amphibole are the major minerals in some samples, and carbonate is common in some. At the time of formation, the selvages around the pillows were probably a hydrous basaltic glass (palagonite); however, the selvages are now dominantly quartz and epidote. The rock probably owes its present mineralogy to the metamorphism it has undergone.

Greenstone belts are commonly intruded and separated by granitic rocks. This greenstone is intruded by granite at Hwy. 29 and Co. Rd. O.



Figure 2. Pillow structures in greenstone at Artus Creek. Top of flow is toward the upper right hand side of the photo.

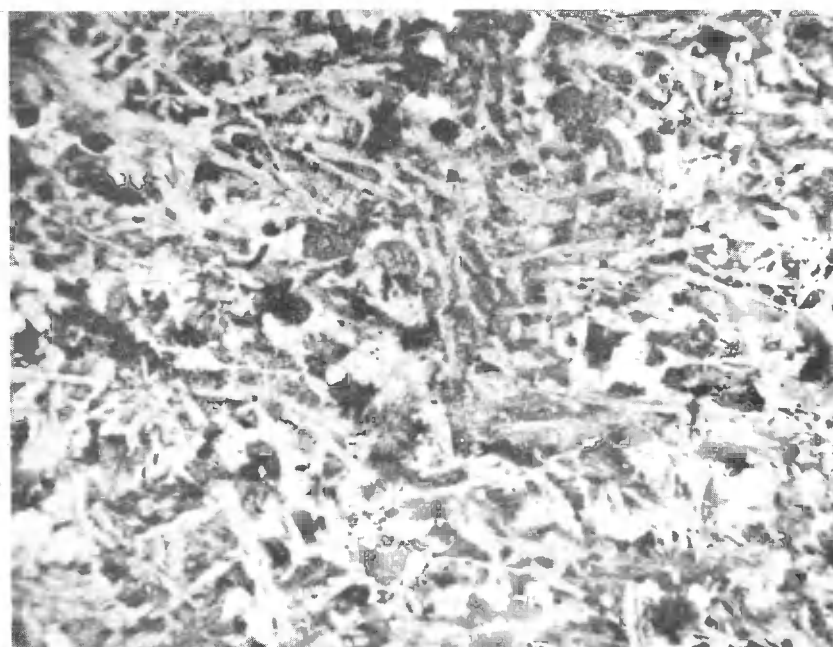


Figure 3. Tuffaceous phase of Artus Creek greenstone. Magnification is approximately 100x.

STOP 2. Artus Creek Greenstone. (Massive Phase)

KEEP OFF THE OUTCROP!! THIS IS AN EXTREMELY DANGEROUS PLACE BECAUSE OF POOR FOOTING AND IS HAZARDOUS FOR THE PEOPLE BELOW YOU.

A relatively new roadcut has exposed massive greenstone in which it is nearly impossible to determine the attitude. Several parallel slabby zones on the north side of the road strike N60°E and dip 30°SE and may represent original layering of the unit. Inasmuch as definite shear zones are present, the slabby zones may also be formed by shearing.

Poorly formed, and poorly preserved, pillow structures may be seen at several places on the exposure. Some flows--or parts of flows--do not develop pillow structures; they simply crystallize as massive greenstone. At the western end of the cut on the north side of the road are the "best" pillows. Other pillows elongated N60°E can be seen on the top of the eastern end of the cut on the north side of the road, but they are not well enough preserved to determine stratigraphic tops.

In the central, massive, part of the exposure is a tuffaceous phase of the greenstone. A number of thin sections of this material reveal relatively well preserved shard structures (Figure 3). To see the shards, break the rock to get a fresh surface, wet the surface, and examine it with your hand lens (your TONGUE is an indispensable geologic field tool!!). Massive greenstone may also be flow material which does not contain shards.

Petrographically, the rock consists of chlorite, carbonate, relict plagioclase laths (near albite in composition), amphibole (actinolite?) and extremely fine grained epidote and zoisite. Quartz is not especially uncommon. Some sections show extensively uralitized pyroxene. (Pyroxene altered to fine grained amphiboles.)

More or less circular patches of chlorite or carbonate may represent vesicle filling. Some fractures are filled almost entirely with epidote-zoisite. In most slides, the intergranular texture is well preserved, even though the mineralogy has been.

modified considerably. In general, this seems to have been a rather coarse grained basalt alternating with tuffaceous material.

The occurrence of fragmental material interbedded with pillowed greenstone is not uncommon, but it poses problems as to the environment of eruption and deposition. Some of the fragmental layers have a texture similar to graywacke and a composition nearly the same as the pillowed layers; other layers contain sharply angular fragments which may represent basaltic tuff. Because pillow lavas are generally taken to indicate subaqueous eruptions, or at least flowing of lava into a body of water, the following questions may now be raised: 1) Do the fragmental layers represent material from subaerial eruptions ("lava fountains") which was carried by wind and/or water to the site of deposition? 2) To what extent are the fragmental layers derived from the erosion of adjacent volcanic islands? 3) May the fragmental material (and the pillow lavas) be formed during subaqueous eruptions?

STOP 3. Marshall Hill Conglomerate.

This exposure is an example of what seems to be the youngest Precambrian rock in the Wausau area, and although it illustrates no principle of greenstone belts, it is important in interpreting the geologic history of the area. At different places where it crops out, the formation is variously a conglomerate and/or a "quartzite". The conglomerate at this locality contains pebbles and boulders up to eight inches in diameter of rhyolite, greenstone (basalt), trachyte, chert (or jasper), and quartzite. It is of interest that granite pebbles are conspicuously absent, even though there are abundant glacial boulders less than half a mile to the north, and outcrops of granite within a mile.

Until recently, the only readily accessible exposures of Marshall Hill conglomerate occurred two miles east northeast of here. The roadcuts here expose a much fresher part of the Marshall Hill conglomerate.

In thin sections, the rock shows abundant sericite, both within the pebbles and in the matrix. Fine hematite is abundant and disseminated. In the samples examined, most of the fragments are rounded and range in size up to about one-half an inch in diameter. Angular to rounded quartz grains occur in the matrix, and occasional pebbles of "dirty quartzite" were found.

Both texture and composition suggest that a vast majority of the fragments are altered volcanics (probably rhyolite). Fragments of definitely non-volcanic material are decidedly subordinate. The abundance of sericite in the matrix suggests that it too may be derived from volcanic material. A large volcanic component in the conglomerate is not surprising considering the close spatial relationship of the conglomerate to rhyolite.

Because the contacts are not exposed, the relationship of the conglomerate to the underlying rocks is uncertain at this stop. However, on the west side of the Wisconsin River at the Brokaw Dam (Figure 4), a similar conglomerate and "quartzite"

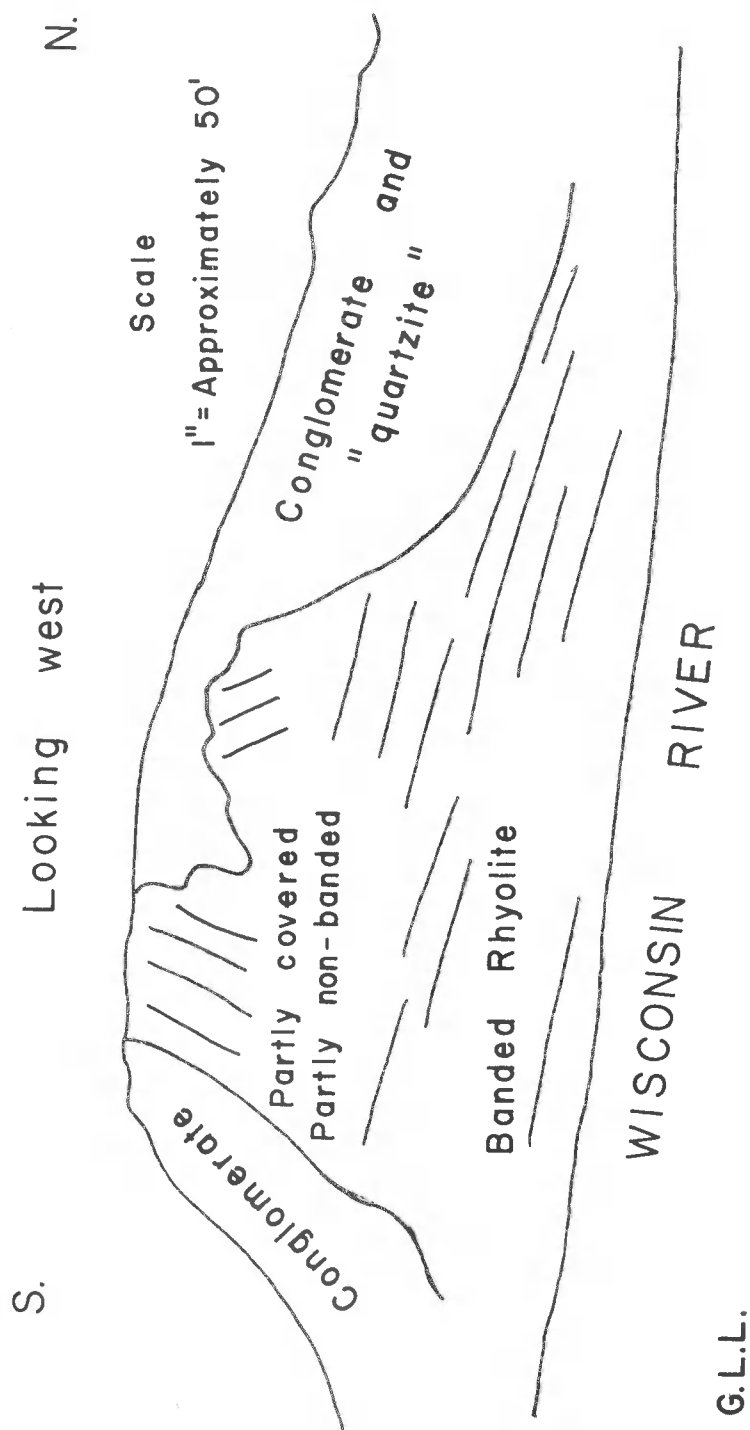


Figure 4. Sketch of the relationship between rhyolite and conglomerate on the west side of the Wisconsin River at Brokaw.

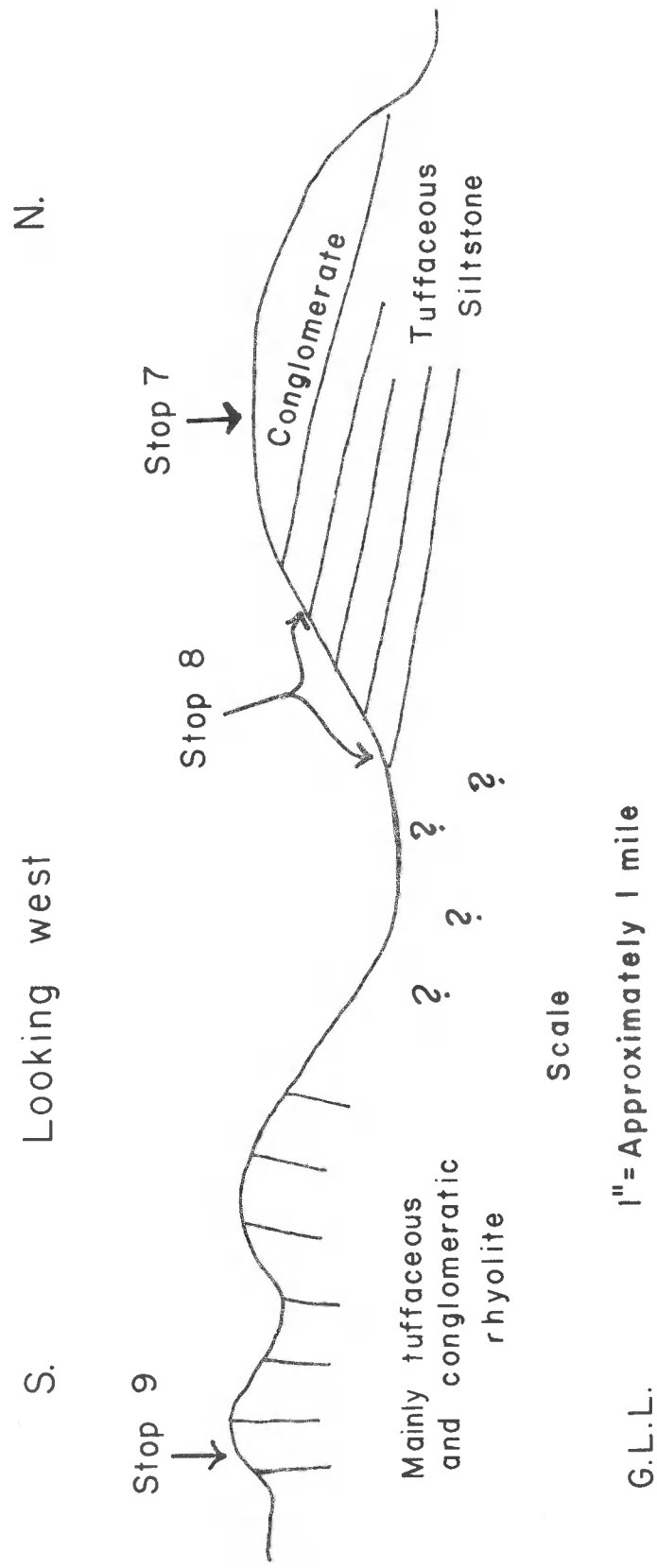


Figure 5. Diagrammatic sketch showing the structural relationships of the rock types on the east side of the Wisconsin River.

unconformably overlies fresh, unmetamorphosed, rhyolite with almost vertical flow(?) banding. The clastic rocks are, therefore, younger than the rhyolite at that locality.

On the east side of the Wisconsin River (Figure 5), the structural relationships indicate that the conglomerate is not only younger than the rhyolite, but a siltstone-tuff sequence (Stop 5) occurs between them. This sequence is further confirmed by exposures along the railroad track between Wausau and Brokaw (on the west side of the hill at Stop 5); however, time will not permit visiting these exposures on this trip. Thus, the conglomerate may be the youngest Precambrian rock in this area.

STOP 4. Tuffite.

This exposure illustrates one of the features associated with acid volcanism; that is, the mixing of volcanic and fine detrital material in water laid deposits. The rock is primarily a tuffite (tuffaceous siltstone) or a bedded tuff. We will see at least one lapilli tuff layer as we proceed down the hill. Along the railroad track at the west side of the hill are good exposures of tuff and agglomerate stratigraphically underlying, and trachyte and conglomerate overlying the tuffite. Lapilli tuff layers are interbedded with the fine grained material, much of which is also tuffaceous.

In thin section, these rocks consist of various size fragments of quartz and feldspar (plagioclase is the dominant recognizable variety) in a fine grained matrix of quartz, altered feldspar(?), sericite, chlorite, and carbonate. Many fragments consist of a fine mosaic of minerals which are virtually indistinguishable from the matrix material. Most or all of the fragments are very angular and at least some are almost certainly of volcanic origin.

The rock, therefore, is herein classified as a tuffite. Others may classify it as a volcanic-rich graywacke, or argillite, or a bedded tuff with appreciable detrital material.

The beds generally strike nearly N-S and dip from 30-40°W, although there are local variations in the attitude. Therefore, the roadcut is almost parallel to the strike so that we are seeing a rather restricted stratigraphic sequence. Slump structures (folds) ranging in size from a fraction of an inch to nearly a foot high are at several horizons (Figure 6). At least one of the massive units appears to be a slumped bed, with randomly oriented blocks within a massive layer. It is possible that these slump structures were caused by earthquakes accompanying the volcanic activity during the deposition of the layers.

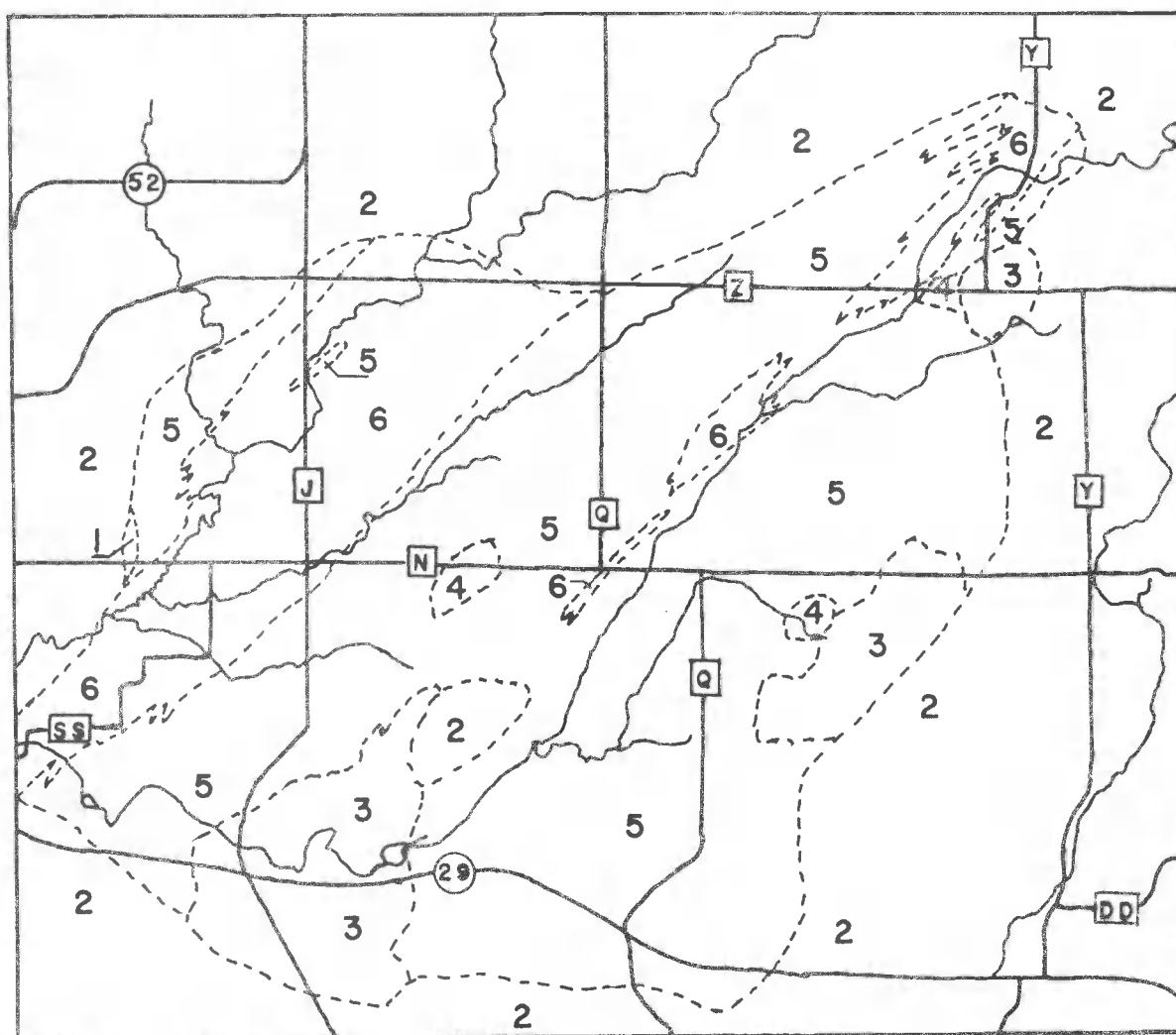


Figure 6. Slump structures in the tuffite at Stop 4. Most layers are relatively straight and evenly bedded; however, slumped layers are not uncommon.



Figure 7. "Conglomeratic rhyolite" representative of much of the rhyolite at Highland Grove (Stop 8) and in the Wausau area in general.

Near the north end of the exposure (at the top of the hill) is a quartz feldspar porphyry dike with an exposure width of about 40 feet. The contacts are not well exposed, so we do not know the true width of the dike.



PRELIMINARY GEOLOGIC MAP OF THE AREA EAST OF WAUSAU, WISCONSIN

Adapted from Thomas A. Henricksen & Robert J. Stevenson

- | | |
|----------|-----------------------------------|
| 1 | HYBRID GRANITE |
| 2 | GRANITE |
| 3 | META-GABBRO |
| 4 | META-DIABASE |
| 5 | GREENSTONE |
| 6 | FELSIC META-VOLCANICLASTIC |

0 1 2
Miles

Stop 5. Dells of the Eau Claire River.

At the Dells of the Eau Claire River we have our most extensive exposure of felsic volcanoclastic rocks. The abundant vertical and horizontal surfaces show the principal joint systems, which are approximately normal to each other. One set of joints is generally parallel to the banding. The banding is vertical with a strike of N35-40E. A few mafic bands are present.

Several textures are seen in the volcanoclastic rocks. Some bands are granular with grains mostly in the coarse silt to very fine sand range. Others have large grains set in a fine grained groundmass and, according to Weidman, are all porphyries. In some bands schistosity occurs with the long dimensions of the micas and amphiboles aligned.

The abundant minerals are quartz, feldspar, mica and amphibole. Minor constituents include carbonates and opaque minerals. Biotite is more abundant than muscovite. On stained slabs potassium feldspar is far more abundant than plagioclase.

From preliminary study, we think it possible that the banding is parallel to original layering and that some of these layers are sedimentary in origin. Most suggestive for a sedimentary origin is the granular texture of some bands. The micas and amphiboles are aligned only in some of the bands. Volcanic origin for many bands, especially those in which the large grains are clearly phenocrysts, is recognized. However, comparison of the texture of granular bands here with some bands at other locations, particularly Stop 6, cause us to continue the search for conclusive evidence of sedimentary origin. Orientations at Stops 5, 6 and 7 show a slight curving for this volcanoclastic belt, with the trend more northerly to the east. The possibility that Stops 5 and 6 are at similar stratigraphic positions can be seen on Figure 8, p. 23.

STOP 6. Felsic volcanoclastic rocks and greenstones

The rocks exposed along the Eau Claire River in section 27, T 29 N, R 9 E include both felsic volcanoclastic rocks and greenstones. In the vicinity of the bridge the rocks exposed along the banks are generally volcanoclastic; a quarter of a mile to the southwest the rocks exposed along the river are greenstones, with patches of felsic volcanoclastic rocks occurring beside greenstones and on the side away from the river. On the west of the river felsic volcanoclastic rocks occur in a belt roughly a half mile wide. The relationship to the granitic rocks to the northwest is described following the description of this stop.

The felsic volcanoclastic rocks vary in banding from very thin bands about $\frac{1}{2}$ mm. thick to bands about 2 cm. thick. They are usually very fine to fine grained. The greenstones do not show clear banding or layering. The strike of the volcanoclastic units varies from N35E to N50E, while dip is vertical to very steep towards the west. South of the stop a few partial pillows were seen in the greenstones, but they are not well enough developed for determining orientation. Shearing with an orientation parallel to the layering of the volcanoclastic units occurs many places. It shows best where there are micaceous minerals.

The felsic volcanoclastic rocks consist primarily of fine silt size grains of feldspar, quartz, biotite, hornblende, carbonates and opaques. Both potassium feldspar and plagioclase occur. They are usually clear and frequently untwinned, requiring staining to tell them apart and from quartz. We have just started staining the samples and do not have relative percentages yet. In the sheared bands biotite and hornblende are more common than in the unsheared ones.

The greenstones have a varied mineralogy. Preliminary study shows that amphibole and plagioclase are the most abundant minerals, with grain sizes up to .3mm., although usually not over .1 mm.. Opaque minerals, including pyrite, occur, as do epidote and chlorite.

To the west and north of Stop 6, along Pleasant View Road, felsic volcaniclastic rocks and granitic rocks occur, with the latter north of the former. The volcaniclastic rocks are similar to those of Stop 6. The contact between the granitic rocks and the volcaniclastics is buried. The granitic rocks are exposed in a ditch-crop at the junction with East Tower Road, and here they look like "granite". On the crest of the hill the material was exposed by the telephone company when it buried its cables. The samples were collected this April. The granitic rock shows great variability in hand specimen, particularly in color, but prior experience in the area shows that a noticeable color variation may be independent of similarity of major mineralogic content.

Although age relation of the units is unknown, yet we suggest the following possibilities as the most likely. The variability of the "granite" (i.e., rocks) and its close relation to the volcaniclastics, which contain significant amounts of potassium feldspar, give the following possibilities: the volcaniclastics and "granite" are related in origin, or the granite is younger than the volcaniclastics and we see a border phase which is variable because of the incorporation of older volcaniclastics. The absence of recognizable granitic pebbles in the volcaniclastics suggests that the granite was not exposed at the time of formation of the volcaniclastics, although we recognize the possibility that pebble-bearing volcaniclastics can occur in the five hundred feet between the northernmost exposure of the felsic volcaniclastics and the southernmost exposure of the "granite."

STOP 7. Big Sandy County Park

The felsic volcanoclastic sequence here is steeply tilted with an orientation of roughly N65E65NW. Mafic units up to a foot thick occur at various intervals and have the same orientation as the felsic bands. Some units seem to be sheared parallel to the banding. Feldspar grains are visible in many bands.

The groundmass of the felsic volcanoclastic rocks is composed of grains in the very fine silt range while the large grains are in the coarse silt to very fine sand range. In some sections the large grains are phenocrysts, while in some they may be sedimentary particles. The groundmass is composed principally of biotite, feldspar and quartz, with opaque minerals up to 5% (estimate) in some bands. The large grains are predominantly plagioclase. From stained slabs we found that plagioclase is far more abundant than potassium feldspar.

The mafic units have a similar mineralogy, with biotite far more abundant and quartz much less abundant. The grain size is more uniformly silt size. Included in the opaque minerals is pyrite, which is easily seen in the hand specimen.

Comparison of the felsic volcanoclastic rocks in the belt visited at Stops 5, 6 and 7 shows potassium feldspar more abundant to the southeast and plagioclase more abundant to the northwest. Despite this mineralogic difference, the grain size and band thickness is generally the same. Some mafic units within the felsic volcanoclastic bands presumably owe their greenish black color to the abundance of biotite plus, perhaps, very fine opaque minerals. As mapping has proceeded, we have enlarged the area of felsic volcanoclastic rocks at the expense of the greenstones shown on Weidman's map. However, in his text he describes many of the localities we have mapped.

Corrections to Figure 5.

The Stop numbers on Figure 5 are for the 32nd Annual Tri-State Geological Conference, 1968. The table shows the corresponding stop numbers for this field conference.

I. L. S. G.	Tri-State
Stop 3	Stop 7
Stop 4	Stop 8
Stop 8	Stop 9

The Institute is visiting the Marshall Hill conglomerate on the west side of the Wisconsin River because the exposures are fresher and larger than those on the east side.

STOP 8 . Highland Grove "Conglomeratic Rhyolite".

PLEASE FOLLOW INSTRUCTIONS CAREFULLY. WE WOULD BE SORRY TO LOSE YOU IN THE WOODS!!!

This exposure illustrates a variety of rocks present in the "rhyolite" area as mapped by Weidman and may be typical of the features associated with rhyolitic volcanic activity in general. They include: massive fine-grained rhyolite, some of which may be flow banded; porphyritic rhyolite, with a variable amount of quartz and feldspar phenocrysts; and conglomeratic rhyolite.

At least three types of rhyolite, with the relationships shown in the accompanying sketch (Figure 9), are present in exposures in the woods south of the school. A massive, fine grained, generally non-porphyritic rhyolite forms the small cliff and the break in slope of the hill. South of this massive unit are porphyritic rhyolite and "conglomeratic" rhyolite in that order. To the north is more porphyritic and "conglomeratic" rhyolite. In the conglomeratic phases, both pebbles and matrix are rhyolitic, and both angular and rounded fragments occur. The contact between the massive (non-porphyritic) unit and the porphyritic unit is a vertical cliff suggesting that the sequence may be standing nearly vertically.

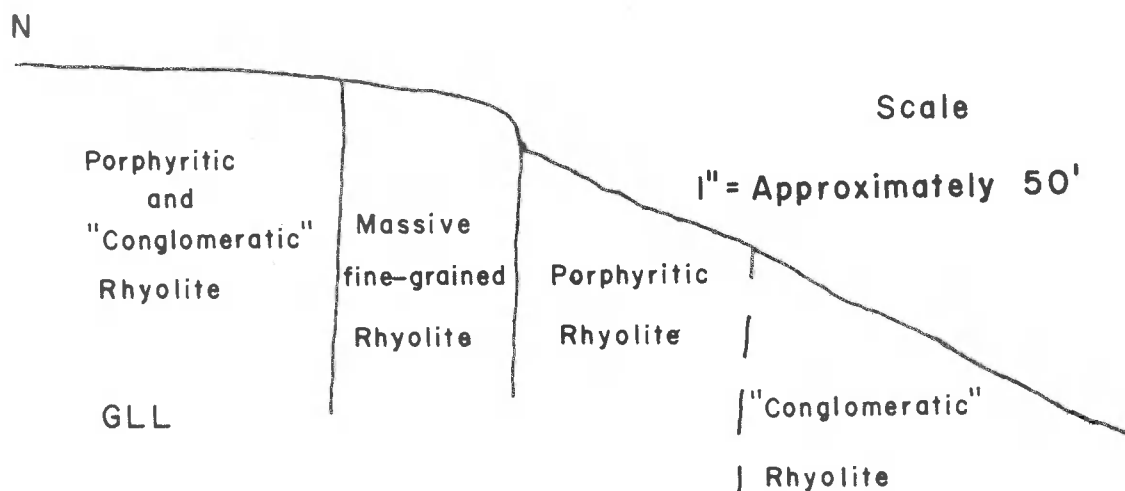


Figure 9.

In the farmyard east of the woods, the "conglomeratic" rhyolite contains a block of flow(?) banded material about 5' long in a coarsely fragmental matrix. Note that many fragments have good flow banding, although definite flow banding has not been seen in outcrop.

Note that the conglomeratic units so well developed in the woods are not exposed along the road.

Fragmental texture is present in nearly all material from this locality. Approximately 75% of the exposure is conglomeratic. The finer grained material is largely tuffaceous. Some samples of porphyritic rhyolite contain deformed shards and other features suggestive of welded tuffs, and non-porphyritic rhyolite contains probable shard structures. Glacial boulders with good flow-banding may be found in the woods and farmyard, but as stated above, we have not observed definitely flow-banded rhyolite in outcrop.

Thin sections of the rhyolite reveal a fine quartz-feldspar matrix, more or less sericitized. Patches of carbonate and quartz veins are relatively common in some samples. Although the fragmental nature is evident in most hand specimens, the similarity in composition between fragments and matrix make thin section determination of grain boundaries difficult. Thin sections of the fine grained rhyolite generally show shard structures. Similar rhyolite from the outcrop at Ninth St. and Winton Ave. in Wausau contain unusually well preserved shard structures (shown in Figures 10 and 11). Spherulitic and axiolitic structures are present in some slides.

Asquith (1964) reported shard structures in rhyolite from the Brokaw Quarry on the west side of the Wisconsin River north of Wausau in the NW-1/4 Sec. 11, T.29N., R.7E. (Minnesota Mining & Manufacturing operates the quarry to obtain roofing granules) and in a number of Precambrian rhyolites farther south in Wisconsin. He interprets them as welded tuffs. The shard-bearing phases of the rhyolite in the Wausau area may also be, at least in part, welded tuffs.



Figure 10. Shard structures in rhyolite from Ninth Street and Winton Avenue, Wausau. Magnification approximately 140x.

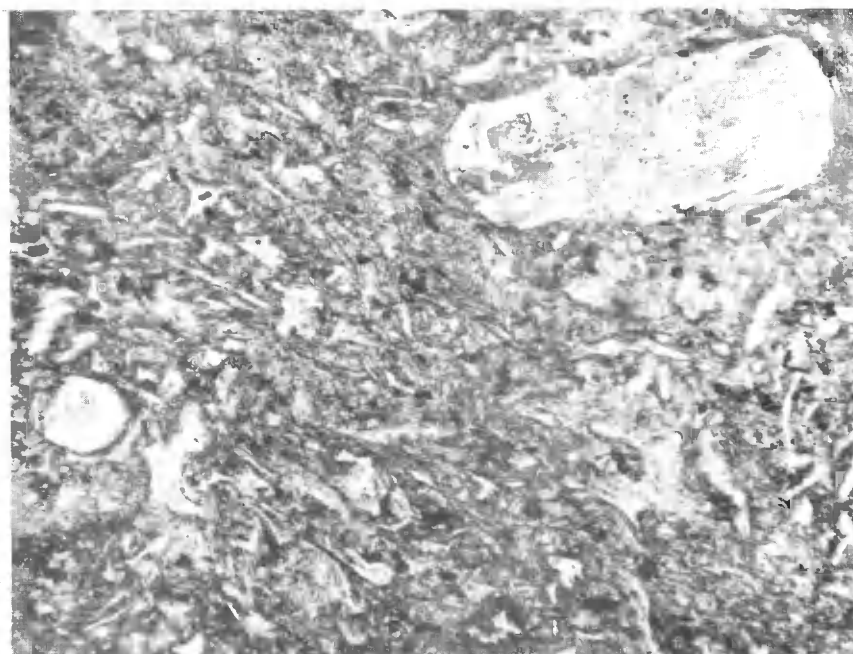


Figure 11. Shard structures with phenocrysts in rhyolite from Ninth Street and Winton Avenue. Magnification approximately 140x.

Therefore, the rhyolites in the Wausau area seem to have formed in more than one way--some may have been flows, some presumably are welded tuffs (ignimbrites), some may have formed from "mud flows", and some may be intrusions. Bedded (water laid) material such as that at Stop 4 may represent eroded volcanic material or may have resulted from direct volcanic (tuff) contribution to the sedimentary basin.

If this is a subaerial deposit, how is it related to the bedded tuffs we saw at Stop 4?

Both east and west of the Wausau area are large exposures of metamorphosed, sheared rhyolite. Due to the almost complete lack of shearing and metamorphism of the rhyolites in the immediate Wausau area, we feel that these rocks are younger than the altered rhyolites and may represent a renewal of acid volcanism within the greenstone belt.

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ITINERARY FOR 15th ANNUAL INSTITUTE ON LAKE SUPERIOR GEOLOGY FIELD TRIP

Section 1.

Stop 1 and Assembly Point are at Employers Insurance. Go north on Westwood Dr., turn right on Bridge St., cross over U.S. 51, turn north onto U.S. 51. Turn west on Co. A, go 5 miles to Stop 2.

From Stop 2, go east on Co. A to U.S. 51, turn south to Co. WW, turn east. Go $1\frac{1}{2}$ miles to Stop 3 on west side of Wisconsin River.

From Stop 3 continue east on Co. WW to Co. W., turn south, go 1 mile to Stop 4.

From Stop 4 continue south on Co. W to Wis. 52 (Wausau Ave.), turn east. At Co. Y turn south, go 2 miles to Marathon County Park at the Dells of the Eau Claire, Stop 5. Lunch will be served after visiting the outcrop.

From Stop 5, continue south on Co. Y to Co. Z, turn west for $1\frac{1}{2}$ miles to Eau Claire Rd., turn south $1\frac{1}{2}$ miles to Forestville Rd., turn east, cross bridge to Stop 6. NO SMOKING AT STOP 6.

From Stop 6, return to Eau Claire Rd., turn south $\frac{1}{8}$ mile to Pleasant View Rd., turn west. Notice ditch crops. Turn west on Co. Z, turn south on Co. J and park in Marathon County Park on the Big Sandy, Stop 7.

From Stop 7, go north on Co. J, go west on Co. Z. Continue west on Hamilton Rd. about $\frac{1}{2}$ mile. Turn north on 25th St., go $\frac{3}{4}$ mile to Stop 8.

From Stop 8 continue north to Wis 52, turn west. Turn south at 6th St. (Co. W), west on Bridge St., cross Wisconsin River, U.S. 51, and return to Assembly Point.

Section 2.

Stop 1 and Assembly Point are at Employers Insurance. Go north on Westwood Dr., turn east on Bridge St., cross U.S. 51, Wisconsin River, to Wis. 52. Turn north, then east and northeast on Wis. 52 to 25th St., turn south to Stop 8.

From Stop 8, go south on 25th St., turn east on Hamilton Rd. Continue east on Co. Z, turn south on Co. J and park in Marathon County Park on the Big Sandy, Stop 7.

From Stop 7, go north on Co. J, turn east on Co. Z to Pleasant View Rd., turn south. Notice ditch crops. Turn north at Eau Claire Rd., go $\frac{1}{8}$ mile, turn east on Forestville Rd., cross bridge to Stop 6. NO SMOKING AT STOP 6.

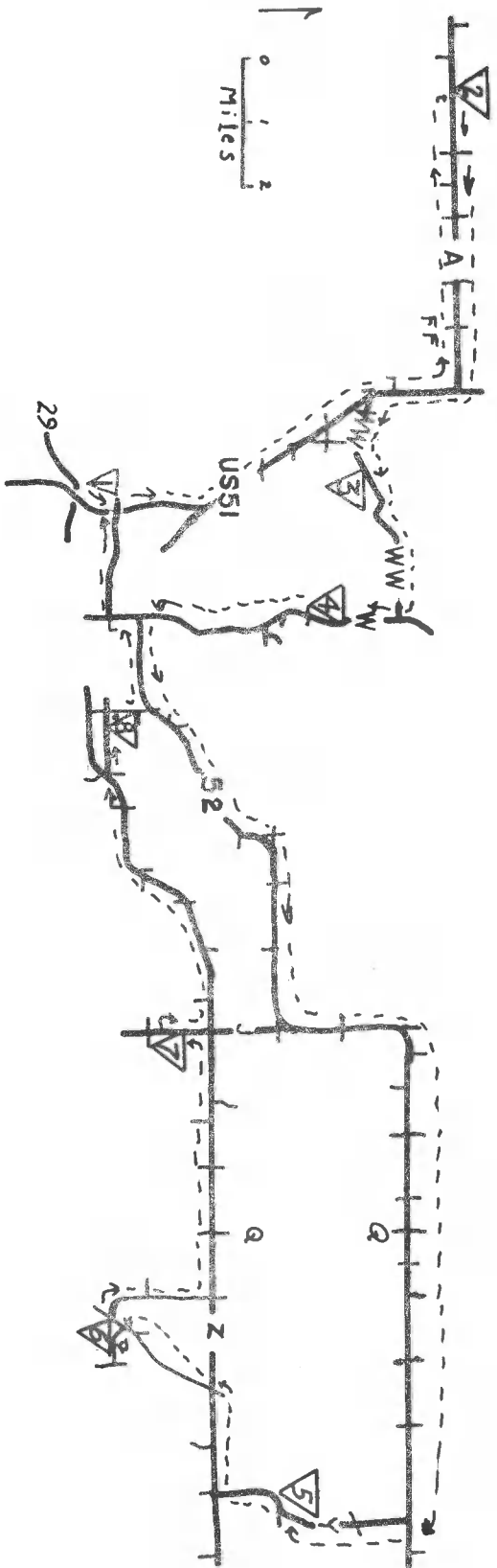
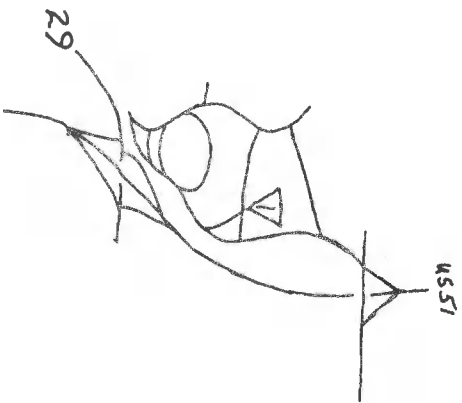
From Stop 6, return to Eau Claire Rd., turn north to Co. Z, turn east to Co. Y, turn north to Marathon County Park at the Dells of the Eau Claire, Stop 5. Lunch will be served after visiting the outcrop.

From Stop 5 go north on Co. Y to Wis. 52, go west. In Wausau turn north on Co. W (Sixth St.) and go about $2\frac{1}{2}$ miles to Stop 4.

From Stop 4, go north on Co. W to Co. WW, turn west, cross Wisconsin R. to Stop 3.

From Stop 3, go west to U.S. 51, go north to Co. A, go west 5 miles to Stop 2.

From Stop 2, go east on Co. A to U.S. 51, south on Belt Line, exit to Assembly Point.



ROUTE MAP
15th Annual I. L. S. G.