# Course material for Geology 102 - Wisconsin geology. 1957

Thwaites, F. T. (Fredrik Turville), 1883-1961
[s.l.]: [s.n.], 1957

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Name ______________________________

Lab Instructor ______________________________

# GEOLOGY 102 LABORATORY

# WISCONSIN GEOLOGY

## OBJECTIVES

This exercise has three definite objectives, all equally important. The first is to acquaint you with the general geology of our near surroundings, the second is to introduce you to some of the subsurface methods of acquisiton and analysis of geologic information, and the third is to provide important background for the required field trip during which we shall actually see some of the geology discussed herein.

Ouisconsin was indian for "gathering of the waters" and because of its strategic location between the Great Lakes and the Mississippi River drainage it was an important trading route. Its location is also geological strategic. Wisconsin lies near the center of the North American stable, lowland interior or craton. It illustrates many typical features of cratonic geology. Furthermore, it straddles the boundary between the Precambrian shield (north) and the Paleozoic cratonic cover rocks (south). Finally, it was visited several times by the great continental glaciers of the Pleistocene (or "Ice Age"). All of this gives our state an unusual variety of geology and scenery, a variety difficult to match in most of the middle west. Let us examine this geology more fully through the use of a variety of types of geologic maps.

## SURFACE OF AREAL GEOLOGIC MAP

Examine the geologic map of Wisconsin. Such a map is the most familiar type for the geologist. It shows surface distribution of rocks projected to a plane (the map). Though only two-dimensional, some three-dimenstional relationships can be deduced from the outcrop patterns. Cross-sections are only two-dimensional, too, but together with maps, they provide bases for three-dimensional mental visualization. Block diagrams combine maps on their top surfaces with cross section views on their sides and are truly three-dimensional. Examine the stratigraphic sequence shown on the map. Many of the formations were named and described by the Owen Survey (1839-52) the first systematic geologic study of the Upper Mississippi Valley. Questions 1 - 4 are largely review from beginning geology.

1. Note the very irregular "dendritic" pattern of Paleozoic formational contacts in southwest Wisconsin. This is the same pattern shown by topographic contour lines in dissected, hilly terrain. Considering this similarity, deduce the structural attitude (steeply tilted, gentle, etc.) of these strata:

2. On the other hand, in eastern Wisconsin the Paleozoic strata form long, rather straight outcrop bands. Remembering the Law of Superposition and noting that here the outcrops are narrower than to the southwest, what is the structural attitude of these strata in eastern Wisconsin?

3. Note that where major stream valleys cross the last outcrops en route to debouch into Lake Michigan, the outcrop bands bend to form a "V" pattern. From this area, formulate a rule of thumb for dipping strata (i.e. which way do such "V's" point in relation to dip and stream flow directions?).

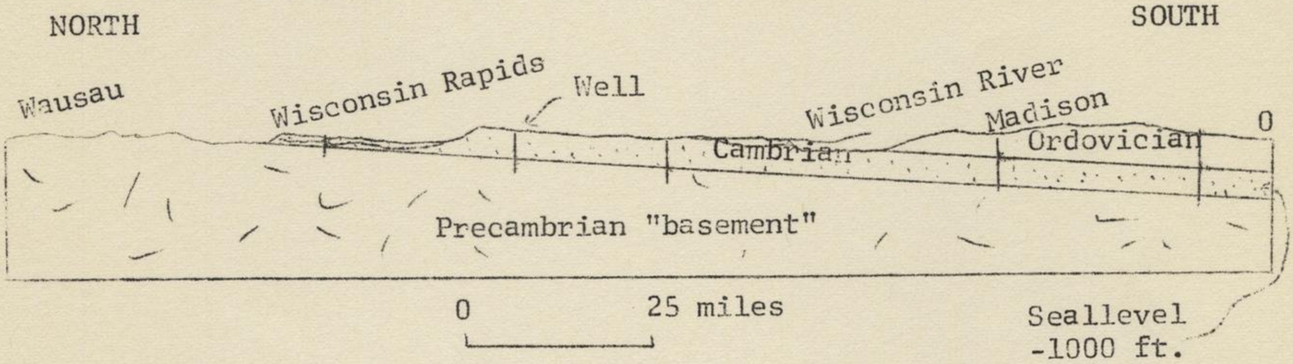
4. Note the large area of oldest rocks in northern Wisconsin. Knowing that the elevation in the state does not vary greatly, and recalling superposition once again, we can infer <u>just from this two-dimensional map</u> that Paleozoic strata dip gently southward. (Note the successively younger rocks southward.) But recall the contrast between answers 1 and 2 above. Apparently the southward dip is not so simple and uniform as assumed above.

   a) Dips are somewhat different in the southwest and east areas, therefore what type of large, cratonic structural feature separates these portions of the state? ______________________

   b) Sketch a cross-section from the Mississippi River to Milwaukee to show the general structure of this feature:

West East

5. Data from deep water wells adds a third dimension to our map. Carefully drilled wells will yield chips of the rock through which they were drilled and if these are saved, they can be studied by the geologist to determine the nature of "buried geology." The deepest wells in Wisconsin penetrate completely through the Paleozoic rocks and encounter the Precambrian "basement" beneath. This tells us not only how deep the "basement" surface is, but also can tell us its rock composition at different points. By comparing a line of wells, we can draw an accurate cross section as is shown below. This is a north-south section from Wausau to the Illinois border (Baraboo Syncline omitted for simplicity). Note the series of north-facing escarpments produced by more resistant strata. Such topography is typical of areas with gently inclined strata.




Madison's water supply is pumped from Cambrian Sandstones at a depth of approximately 500 feet. Assuming that the chief input or re-charge area for this aquifer is around Wisconsin Rapids, 100 miles north of Madison, and that the ground water flows down-dip (south) at about 10 feet per year, when did the water you just drank down the hall fall as rain?

6. Some history also can be inferred even from this generalized map. Most obvious, of course, is the profound unconformity at the base of the UpperCambrian sandstones. Others also are present, though they are less obvious. Note for example the relationships of the Barron Quartzite (northwest Wisconsin). A major disconformity occurs at the base of the Ordovician St. Peter Sandstone, but it is not apparent from this map.

   a) A question of history that always arises from examination of a geologic map is whether or not the distribution shown of sedimentary rocks of varying ages represents their original distribution limits or just the limits resulting from long erosion? Note the long belt of Silurian rocks along Lake Michigan. Now find two small patches called outliers (areas of younger surrounded completely by older strata) of Silurian in southwestern Wisconsin--at Blue Mounds 20 miles west of Madison and 10 miles northwest of Platteville in T. 3 and 4 N., R. 1 E. These represent very cherty dolomite cap rocks on the summits of high conical hills rising above rather flat surroundings which represent the Platteville Formation. Between the Platteville and the Silurian is the Uppermost Ordovician Maquoketa Shale. Do you suppose that these outliers reflect closely the original distribution of the Silurian rocks and what would their relation have been to the eastern Wisconsin Silurian? (Explain your answer.)

b) The Baraboo Quartzite forms an inlier of older rocks surrounded entirely by younger ones 30 miles northwest of Madison. The quartzite stands in hills high above the surrounding terrain, yet the youngest rocks in this area are early Ordovician. Do you suppose this inlier was ever buried by Paleozoic sediments? Explain your answer.

## SURFICIAL MAPS

Most conventional geologic maps are in reality bedrock maps, that is they ignore soil cover and most unconsolidated gravel, till, sand dunes, etc. to show the pattern of distribution of bedrock as though it were exposed completely. But the surficial deposits, if extensive enough and/or economically important, may be mapped separately. The following page shows such a map; it is the glacial map of Wisconsin which differentiates the principle terminal moraines, various tills, drift, etc. T. C. Chamberlin, a former president of the University of Wisconsin and one of the most distinguished early 20th Century geologists, began the systematic study of Wisconsin's glacial geology. He first recognized that ice advanced more than once over the state. The Wisconsin area since has become a classic one for continental glacial studies with the last major glacial stage having been named after the state; most of our glacial features were formed during that stage. Two major groups of tills have been dated by carbon 14; the older about 30,000 years and the younger about 10,000-15,000 years old. Both belong to the Wisconsin stage, but older tills may also exist.

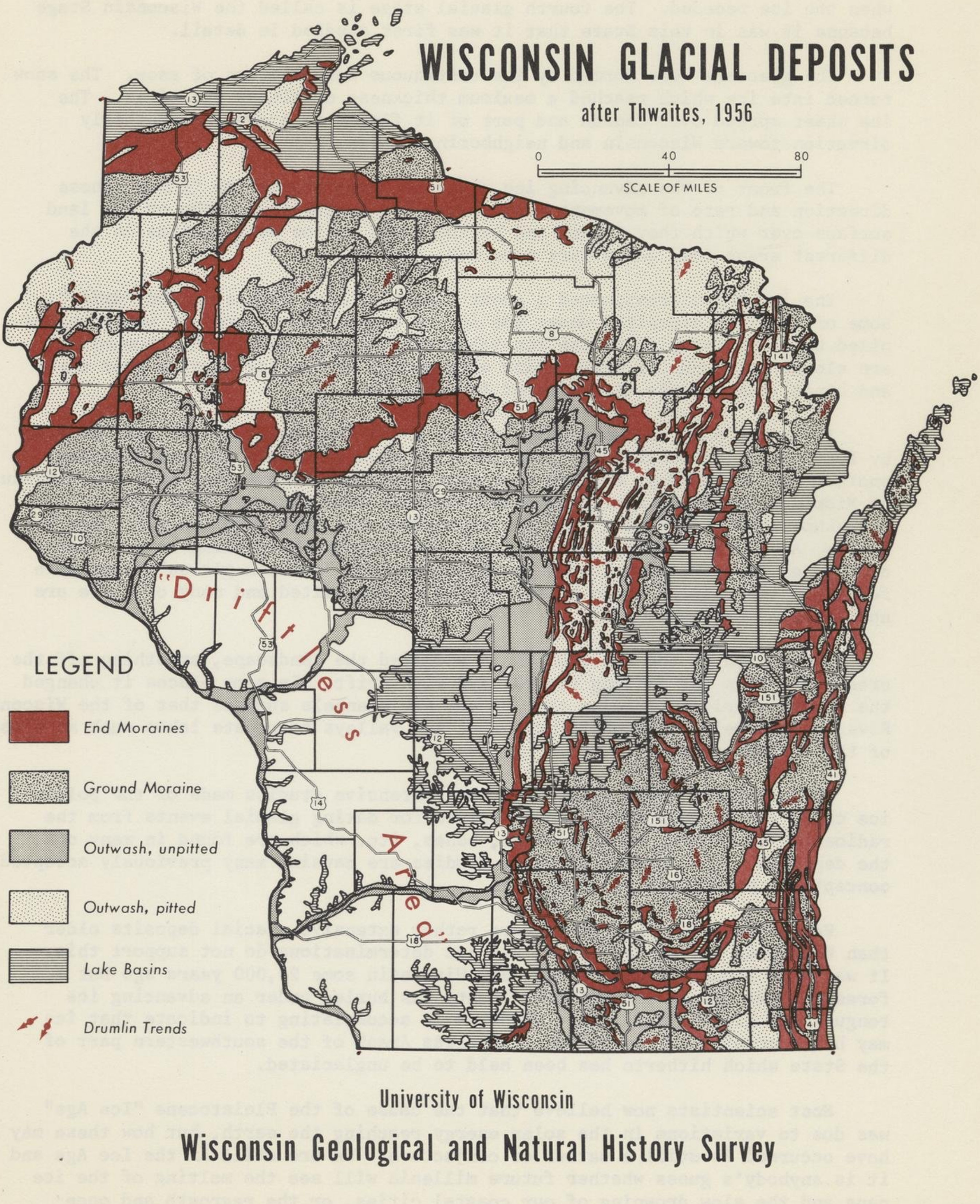
Note the large so-called Driftless Area in southwestern Wisconsin. For many years it was assumed that this area had stood slightly above the ice forming an unglaciated island between two ice lobes. The reason for this long-held belief was the apparent absence of glacial erosion and depositional features and the marked contrast of drainage patterns between this area and its surroundings. In the "Driftless Area" streams have deeply dissected the terrain and drainage is very good in sharp contrast with the poorly drained, swampy, lake-dotted remainder of the state. Many picture some buttes, rock spires and gorges, such as the famous Dells of the Wisconsin River, are found in this region. Recently Professor R. F. Black of our Department has found some evidence suggesting glaciation perhaps 30,000 years ago by a thin sheet of ice that was relatively free of in-frozen abrasive rock debris. Hence such "clean" ice could do little bedrock scouring. He finds local patches of gravel on high ridges which contain fragments of rocks quite foreign to the area; presumably these were ice-transported. Erosion since ice retreat could easily have removed most of the scant glacial debris and have cut the present deep valleys. Location at the "gathering of two great waters," the Mississippi and Wisconsin rivers, means that stream erosion has been unusually vigorous in this region. But Prof. Black's most compelling evidence for glaciation is the presence of some large blocks of St. Peter Sandstone weighing perhaps a ton or more and resting on hills of the Platteville Formation.

1. Consult the geologic map and explain what is wrong with this relative position between these two formations:

The Great Lakes, of course, owe their origin to the effects of glaciers and the composition and structure of the bedrock. In northwestern Wisconsin note the relation of Green Bay and Lake Winnebago to the bedrock structure and stratigraphy. You have already determined the dip of the strata here and it is obvious that both water bodies parallel the strike of the rocks. Now note the stratigraphy and character of the strata. The Silurian Niagaran Dolomite is a resistant rock which forms an escarpment that extends from east of Lake Winnebago and the Door Peninsula north and east all the way around Michigan, through Ontario and into New York where it was named (examine the U. S. geologic map).

# WISCONSIN GLACIAL DEPOSITS

after Thwaites, 1956




University of Wisconsin

## Wisconsin Geological and Natural History Survey

# SHORT HISTORY OF THE ICE AGE IN WISCONSIN

The Pleistocene Epoch or "Ice Age" began about 1,000,000 years ago which, in terms of geologic time, is a very short time ago. There were four separate glacial advances in the Pleistocene each followed by an inter-glacial period when the ice receded. The fourth glacial stage is called the Wisconsin Stage because it was in this State that it was first studied in detail.

The glaciers were formed by the continuous accumulation of snow. The snow turned into ice which reached a maximum thickness of almost two miles. The ice sheet spread over Canada and part of it flowed in a general southerly direction toward Wisconsin and neighboring states.

The front of the advancing ice sheet had many tongues or "lobes" whose direction and rate of movement were controlled by the topography of the land surface over which they flowed and by the rates of ice accumulation in the different areas from which they were fed.

The ice sheet transported a great amount of rock debris called "drift". Some of this was deposited under the ice to form "ground moraine" and some was piled up at the margins of the ice lobes to form "end moraines". "Drumlins" are elongated mounds of drift which were molded by the ice passing over them and hence indicate the direction of ice movement.

The pattern of end moraines, in red, shows the position that was occupied by four major ice lobes. One lobe advanced down the basin of Lake Michigan, another down Green Bay, a third down Lake Superior and over the northern peninsula of Michigan and yet a fourth entered the state from the northwest corner. The well-known "Kettle Moraine" was formed between the Lake Michigan and Green Bay lobes. As the ice melted the drift was reworked by the running water. Large amounts of sand and gravel were deposited to form "outwash plains"; pits were formed in the outwash where buried blocks of ice melted and many of these are now occupied by lakes.

The action of the ice profoundly modified the landscape, smoothing off the crests of hills and filling the valleys with drift. In some places it changed the course of rivers forcing them to cut new channels such as that of the Wisconsin River at the Dells; elsewhere it dammed the valleys to create lakes such as those of the Madison area.

During recent years there have been intensive studies made of the polar ice caps, and methods have been developed for dating glacial events from the radioactivity of the carbon in wood, bones, etc. which are found in many of the deposits. The results of these studies are causing many previously accepted concepts to be changed or challenged.

We once thought that there were rather extensive glacial deposits older than Wisconsin age in the State, but age determinations do not support this. It was also thought that the ice left Wisconsin some 20,000 years ago but a forest at Two Creeks in Manitowoc County was buried under an advancing ice tongue only 11,000 years ago. Evidence is accumulating to indicate that ice may have occupied the so-called "Driftless Area" of the southwestern part of the State which hitherto has been held to be unglaciated.

Most scientists now believe that the cause of the Pleistocene "Ice Age" was due to variations in the solar energy reaching the earth, but how these may have occurred is still a matter of conjecture. We are still in the Ice Age and it is anybody's guess whether future millenia will see the melting of the ice caps and the slow drowning of our coastal cities, or the regrowth and once more the inexorable advance of the glaciers.

Prepared by the University of Wisconsin Geological & Natural History Survey, August 1964

2. What formations underlie these two water bodies (see state geologic map)?

3. Now from the glacial map determine the direction of flow through eastern Wisconsin from the orientation of drumlins. Explain the origin of the Green Bay-Winnebago depression (which, by the way was the great 17th and 18th Century French trading route from the Great Lakes to the Mississippi River via the Fox River and a 1½ mile portage to the Wisconsin River.)

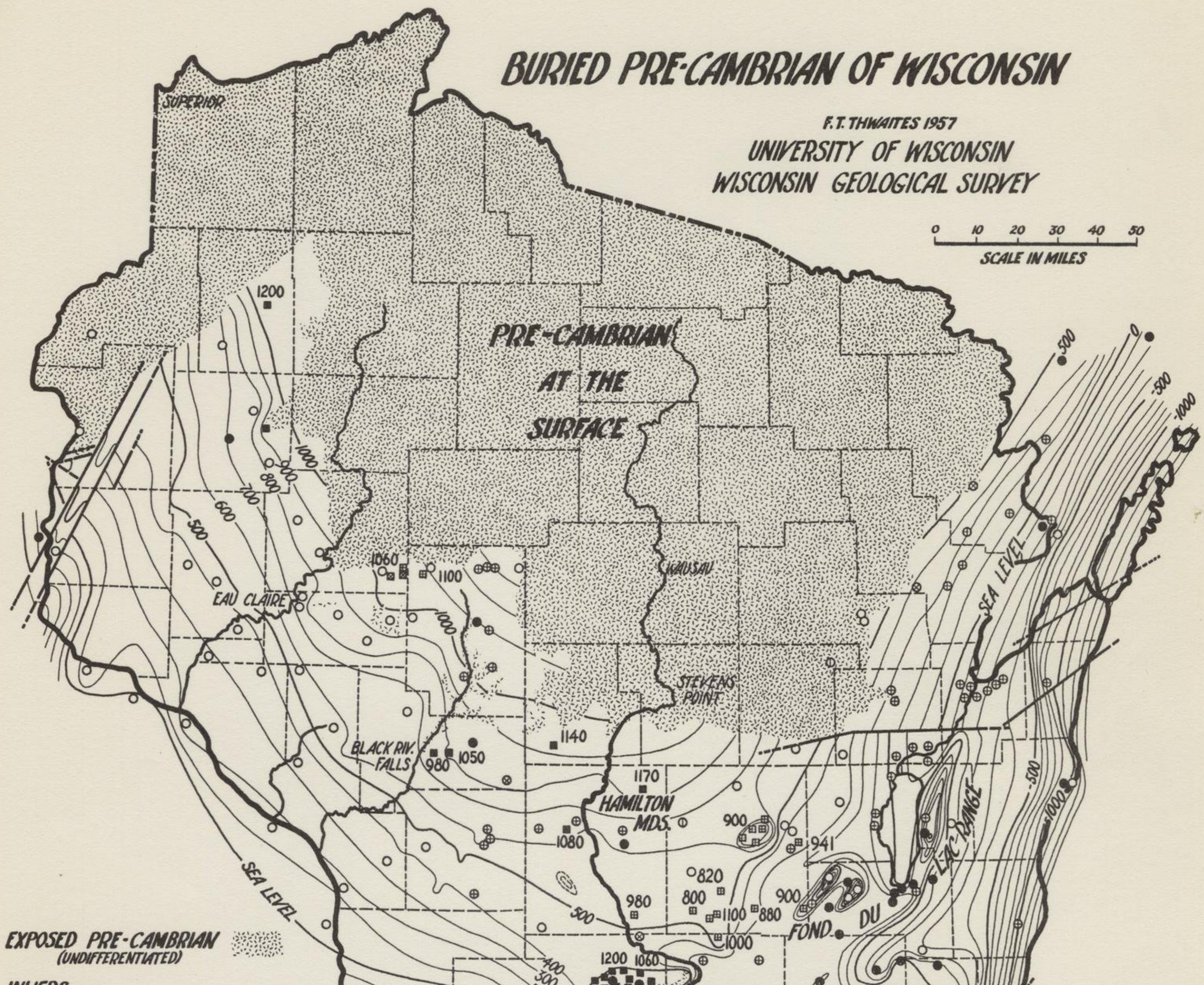
## SUBSURFACE GEOLOGIC MAPS

There is a variety of types of maps constructed by geologists to portray various features of "buried geology." These maps add the third dimension -- depth -- to our fund of information. Maps showing direct information are generally based upon drill hole or mine data which provide direct samples of buried rocks. Geophysical maps, however, show concealed features based upon indirect physical measurements. Both types are extremely useful, especially where they can be used in conjunction.

### Structure Contour Maps:

One of the commonest subsurface devices is the structure contour map. You are already familiar with topographic contour maps, isobaric or equal atmospheric pressure maps of the meteorologist, isotherm or equal temperature maps of the climatologist. Structure contours show equal elevation of points on some buried surface or on the top or bottom of a buried formation.

The map of Wisconsin on the following page is a structure contour map of the Precambrian rock surface unconformable beneath Upper Cambrian strata. It has also been prepared largely from well data. Note that the general southward tilt of Wisconsin Paleozoic strata deduced earlier is reflected in this map of the basal Paleozoic surface too. Also apparent is the structural "warp" in south-central


BURIED PRE-CAMBRIAN OF WISCONSIN
F.T. THWAITES 1957
UNIVERSITY OF WISCONSIN
WISCONSIN GEOLOGICAL SURVEY
0 10 20 30 40 50
SCALE IN MILES
PRE-CAMBRIAN AT THE SURFACE
SUPERIOR
EAU CLAIRE
WAUSAU
STEVENS POINT
BLACK RIV. FALLS
HAMILTON MDS.
BARABOO RANGE
FOND DU LAC RANGE
WATERLOO RANGE
MILWAUKEE
SEA LEVEL
PRE-CAMBRIAN MORE THAN 2000 FT. BELOW SEA LEVEL
EXPOSED PRE-CAMBRIAN (UNDIFFERENTIATED)
INLIERS
SEDIMENTS
ACID IGNEOUS
BASIC IGNEOUS
FIGURES GIVE ELEVATION OF HIGHEST POINT
WELLS (SAMPLES EXAMINED)
SEDIMENTS
ACID IGNEOUS
BASIC IGNEOUS
WELLS (NO SAMPLES)
FAULTS
CONTOUR INTERVAL 100 FEET

Wisconsin that was studied in question 4. Note that in several areas there has been some faulting since Cambrian time, for the basal Cambrian surface has been abruptly raised and/or depressed along several nearly straight lines (see map).

8. In what part of the state would wells seeking water in basal Cambrian sandstones necessarily be deepest?

Paleogeologic Maps:

Note that the Precambrian rock types beneath the Cambrian are indicated at certain points penetrated by deep wells. Sometimes a subsurface geologic map of "outcrop" (literally, subcrop) patterns of older rocks beneath a regional unconformity can be prepared if sufficient data are available. Such a map is called a paleogeologic map. It is an areal geologic map of an ancient, now-buried landscape surface. This kind of map has great value in petroleum exploration and for detailed historical analysis as we see in another exercise.

From the rather meagre rock data available, a pre-Upper Cambrian paleogeologic map has been sketched and is included herein. This is only a gross approximation, but nonetheless shows some useful information. Particularly apparent is the nearly east-west structural trend of the "basement" Precambrian. This is a reflection of great mountain building which occurred prior to the Paleozoic. A Middle Precambrian mobile belt occuppied most of the state prior to the deposition of the Keweenawan sediments and basalts of the northwestern corner of the state. The latter were deposited unconformably upon the Middle and Early Precambrian rocks and then the Upper Cambrian was laid unconformably upon all of these.

1. Note the outlier of Upper Cambrian resting upon Middle Precambrian sediments just across the northeastern Wisconsin border in Michigan. This provides certain knowledge of the rocks exposed there immediately prior to Late Cambrian time. This is also true anywhere along the present unconformable edge of the Cambrian. Obviously where drill hole samples exist there is also definite knowledge (good "control" we say) of the pre-Upper Cambrian.

   a) In what large areas, then, is our map the LEAST reliable? Compare with the original structure contour map and indicate these with large question marks on the map.

b) There are at least two different reasons for this lack of reliability. These reasons neatly summarize the limitations of paleo-geologic mapping, therefore list them below:

(1) (For example north-central Wisconsin)

(2) (For example southwestern Wisconsin)

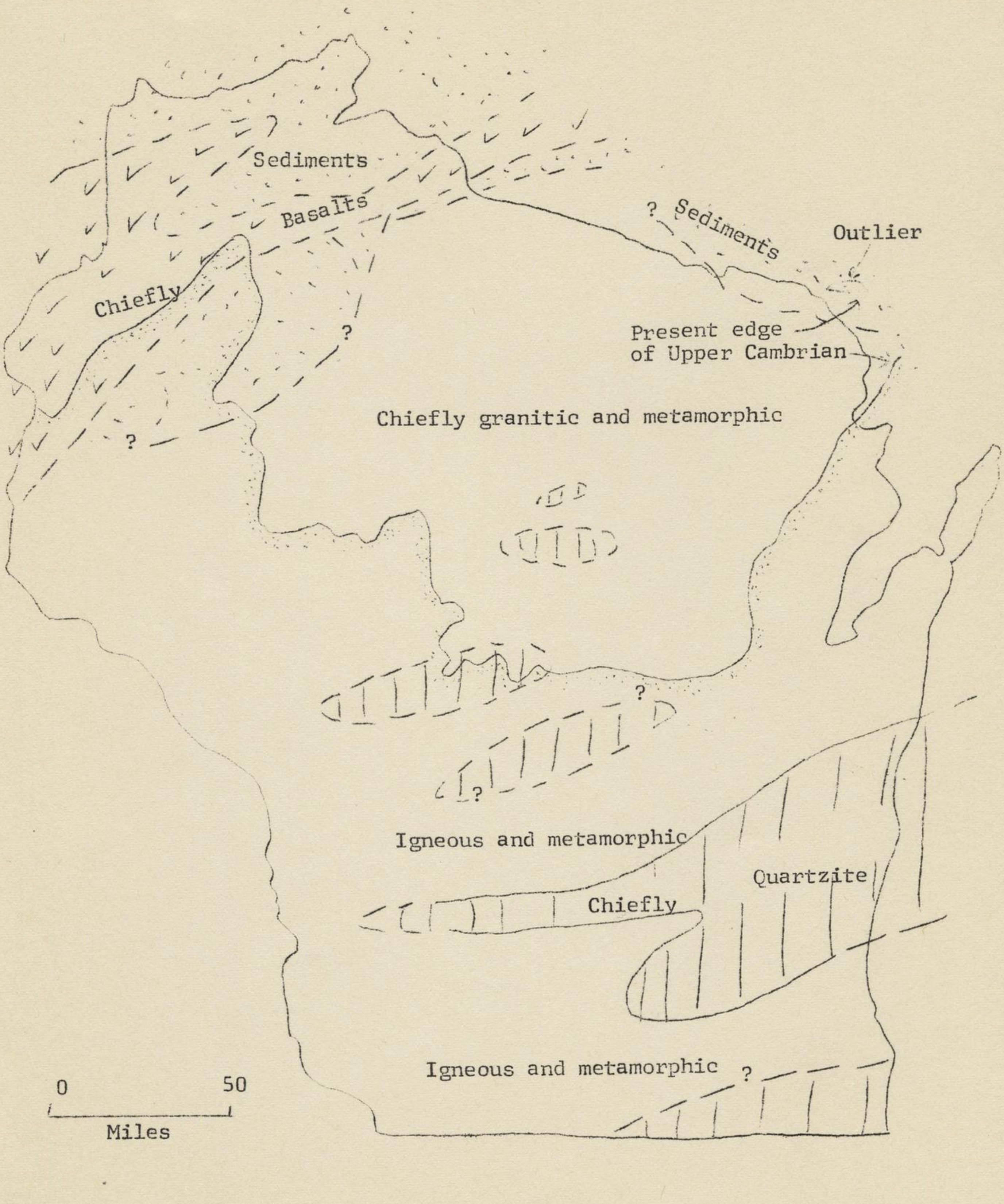
Geophysical Maps:

Basis: Significant information is derivable from the study of properties of earth materials other than the chemical and crystallographic studies of mineralogy, lithology, and petrology or the age and formational study of stratigraphy. Density is such a physical property. Studies of its variation in the earth are accomplished by surface mapping of the variations in acceleration and resultant force of gravity. Another fruitful field involves mapping of variations in magnetic susceptibility, i.e., the ability of a rock to be magnetized, in this case by the earth's permanent magnetic field. The velocity of propagation of waves like sound waves in the earth (here called elastic waves), is still another physical parameter which can be used to characterize rocks and their structure. This study of the variation in velocity of propagation of elastic waves in the earth is called seismology. In addition, electrical properties of earth materials, for example, their conductance (and the inverse, resistivity) are commonly mapped. The measurement and mapping of all of these additional physical properties adds immeasurably to the insight so necessary for the full understanding of the three dimensional geology of any area. They are mandatory where no surface exposures or drill holes exist. The seismic methods are the most expensive, but they also pinpoint buried features with the greatest precision.

Geophysical methods are generally used with geologic information to infer likely structures for the accumulation of economic concentrations of important minerals....principally oil fields, but also for example, lead and zinc deposits whose concentration is directly related to structure as in the southwestern portion of Wisconsin. In this manner, many economically important deposits have been discovered....deposits which probably could not have been discovered by the application of any single method. A buried iron deposit, which may prove of economic importance, was recently discovered in western Wisconsin.

Seismic Mapping: Seismic techniques map in three dimensions the variations in the velocity of propagation of compressional elastic (sound) waves. The velocity of these waves radiating from small explosions depends principally and in direct proportion to the square root of the elastic moduli, especially compressibility and rigidity,

# PRE-UPPER CAMBRIAN PALEOGEOLOGIC MAP



for those waves used in prospecting techniques. For common earth materials these velocities have been found empirically to be closely related to their densities. The connection between the individual grains is often the dominant factor in determining the velocity of propagation of rocks. In unconsolidated or poorly consolidated materials like soils, the connection between the grains is loose, transmitted elastic waves propagate slowly (500 to about 8,000 ft. per second). In well consolidated rocks (well cemented sandstones, dense limestones, highly compacted shales, metamorphic and igneous rocks) the speed of propagation is higher (9,000 to 22,000 ft. per second). The speed of propagation does not uniquely characterize the lithology, but combined with what we know from geologic studies, inferences can be successfully drawn as to the likely lithologic units characterized by seismic velocities observed. If a few drill holes have been made in an area, then the task is greatly simplified.

As in any form of wave motion i.e., light, radio waves, sound, these waves are refracted and reflected as they pass between materials having different velocities of propagation. Using reflection and/or refraction of these waves as deduced by transit times between surface explosion sources and energy receivers, seismologists determine the paths which the sound energy took and reconstruct the inferred velocity layering. As a consequence, thickness, inclination and probable composition of buried layers may be deduced. Figure 3 shows, in cross section, the paths for sound waves moving and refracted from a shot at the surface to detectors at the surface. At points 1 through 6, as one might expect, compressional waves arrive successively later at increasingly distant points between the source and receivers. The "travel-time" graph of first arrival of energy at each station indicates an abrupt change in slope as energy from the <u>physically longer</u> but <u>faster time path</u> through the higher-velocity $V_2$ medium arrives (i.e., the path through $V_2$ returns energy to the surface in a lesser time than the direct wave through $V_1$ only. Illustrated here is also the effect caused by dipping buried layers (see graph). A third layer, $V_3$, whose velocity is still greater than either $V_2$ or $V_1$ would produce on the travel time plot of first arrivals another line segment of different slope (characterized $\frac{1}{V_3}$) had the measurements been carried to sufficient range from the shot point. The velocity layering revealed through seismic measurements is often directly relatable to unconformities, for rocks even of the same original lithology will tend to have increasing velocities with increasing age. In the older rocks, cementation in general will have proceeded further, resulting in a higher velocity due chiefly to increased rigidity.

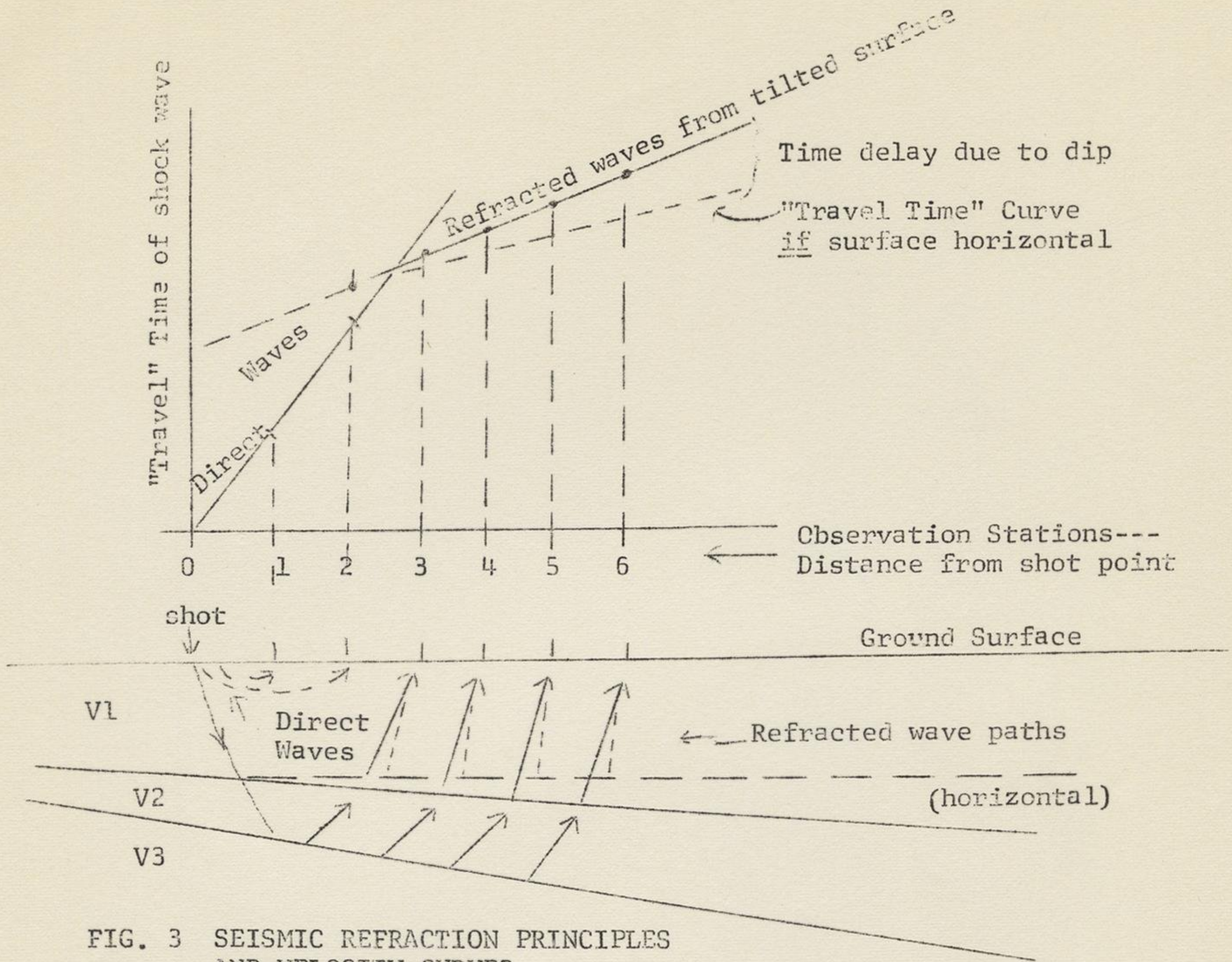



FIG. 3 SEISMIC REFRACTION PRINCIPLES AND VELOCITY CURVES

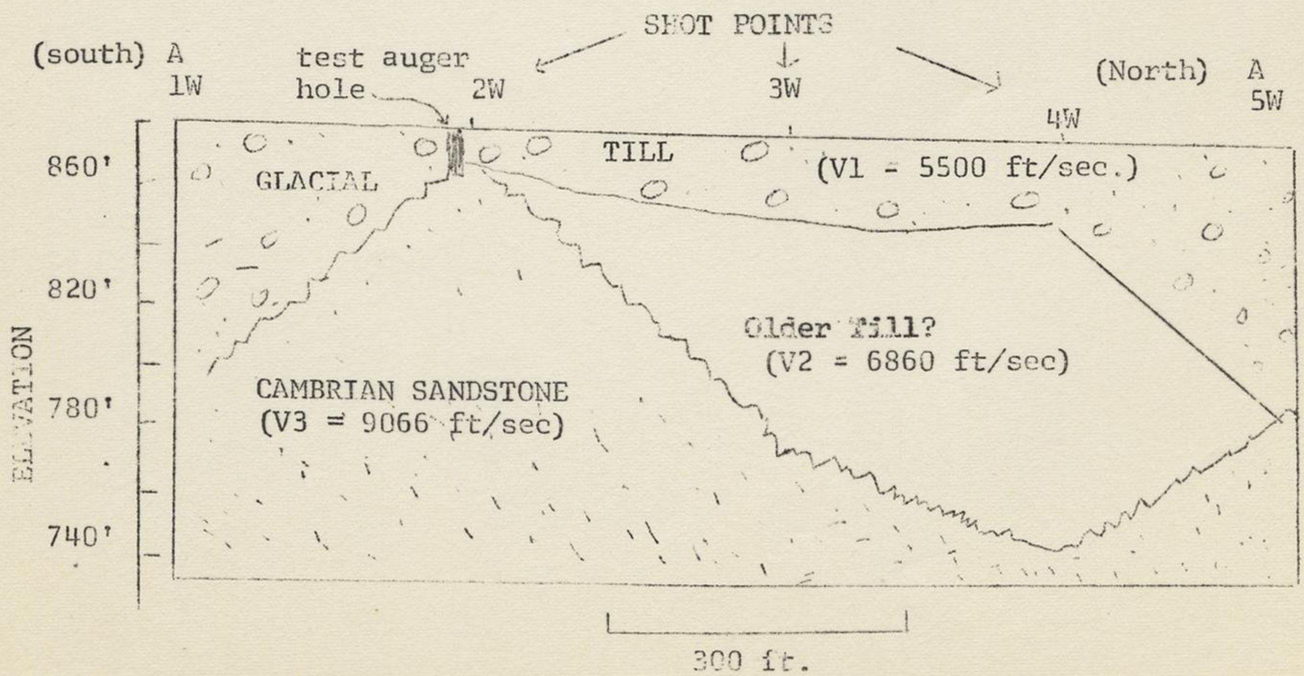
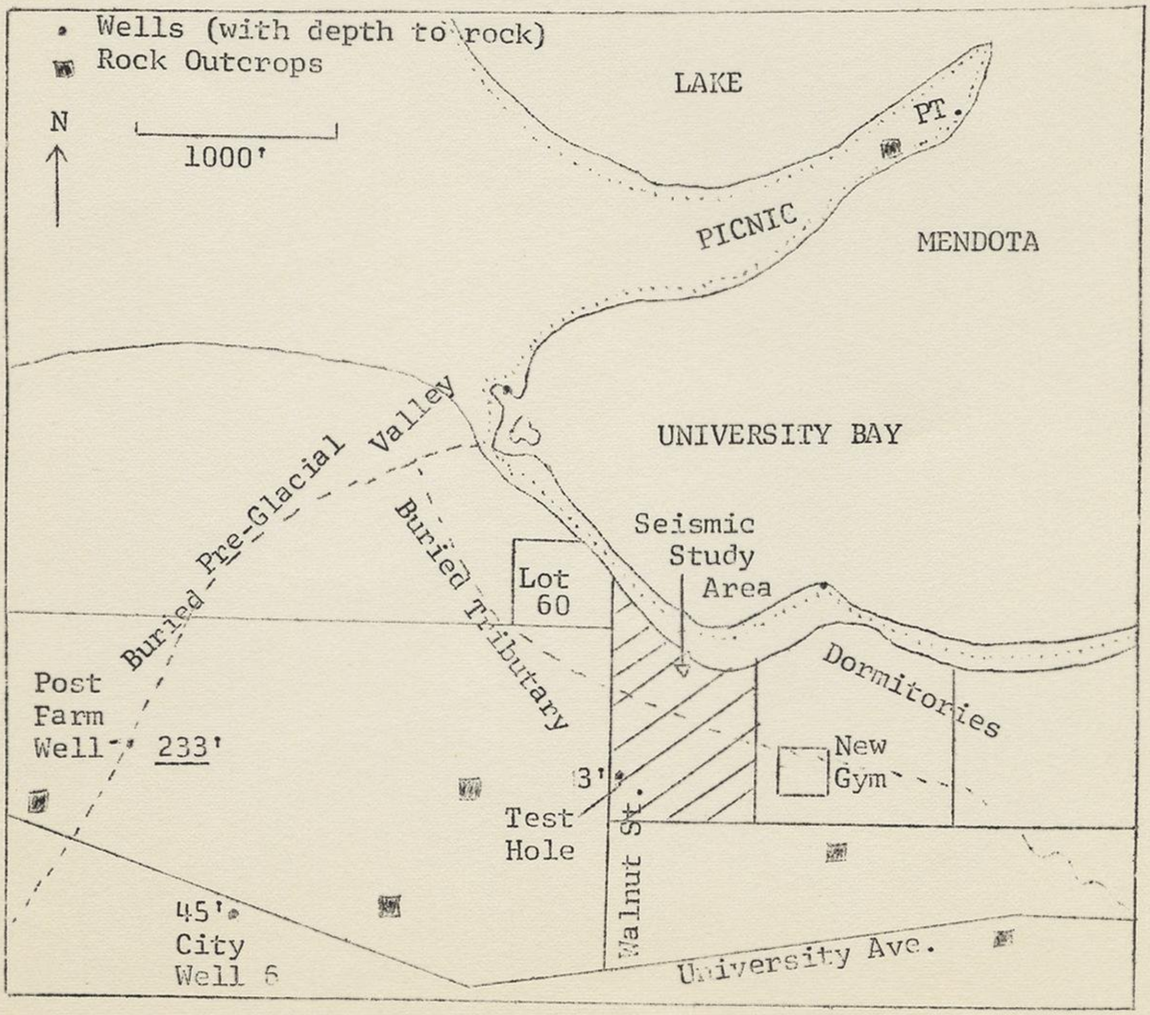


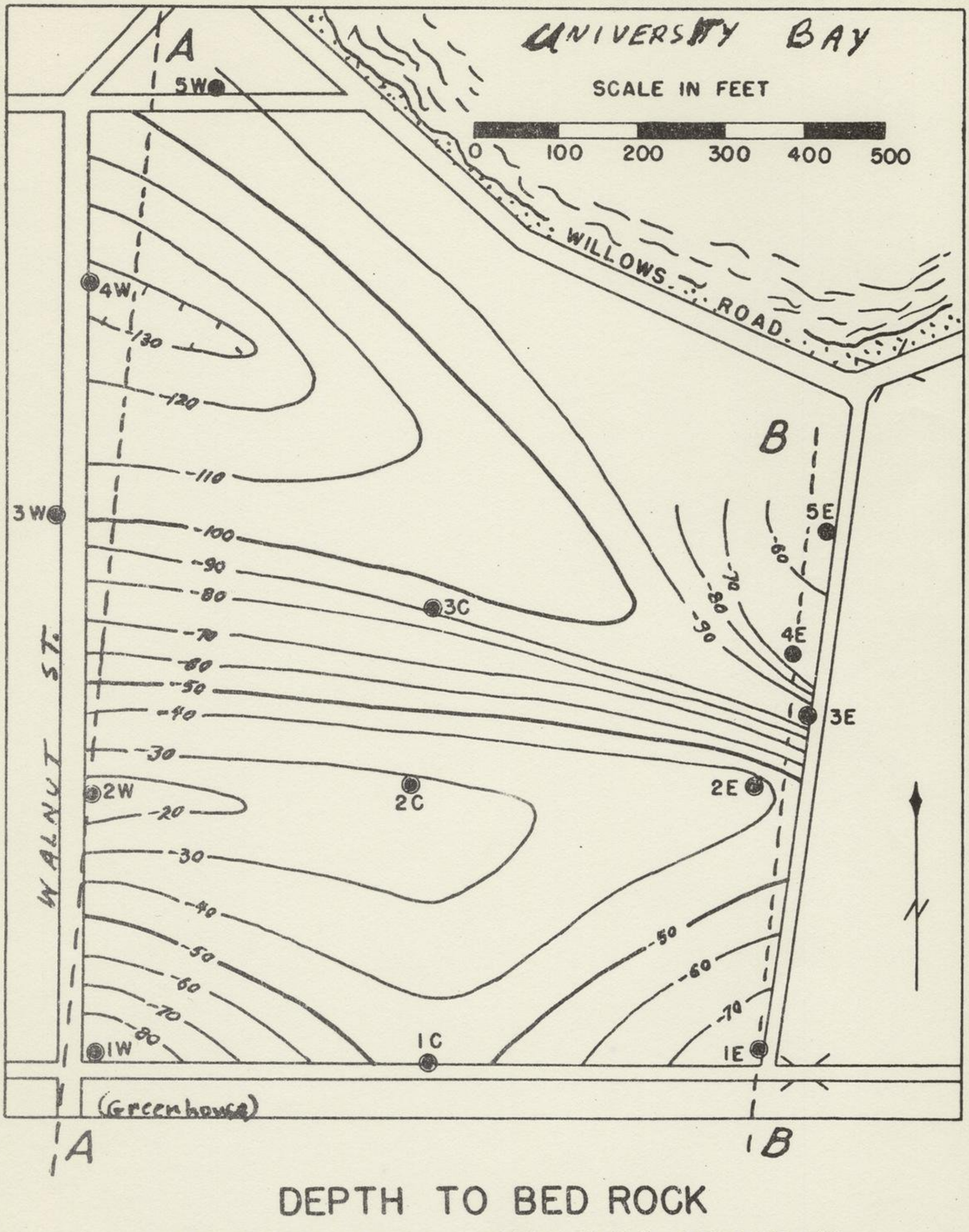

FIG. 4 SEISMIC CROSS SECTION ALONG WALNUT STREET, MADISON

Example:

A few years ago the University wanted to know if it was feasible to obtain ground water in the Willows Athletic Field Area. Little was known of subsurface geology, therefore our geophysicists "shot" the area seismically (see Figure 5). Their results revealed three distinct seismic velocity layers (see cross section, Figure 4). The highest velocity was taken to represent Upper Cambrian bed rock and its surface, as determined seismically, was then contoured (Fig. 45). A check was made by drilling a hand auger hole at shot site 2W along Walnut Street. Water-saturated, hard sandstone was encountered at 13 feet which confirmed the seismic results.

The buried valley in the north Willows Area (Fig. 45) probably was a tributary to a larger valley to the west beneath the field beyond Parking Lot 60. That valley is indicated by depths to bed rock of 225' in the Post Farm Well but only 45' in nearby City Well No. 6 (Fig. 5). Rock in natural outcrops or very shallow excavations south of these valleys (Fig. 5) reflect partially buried ridges adjacent to the valleys. Finally, note that University Bay represents the drowned lower part of the same stream system. Picnic Point was a ridge between two pre-glacial major streams.






# DEPTH TO BED ROCK

## MADISON AREA - WILLOWS PROJECT

CONTOUR INTERVAL - TEN FEET

◉ SHOT POINT

AUGER CHECK HOLE AT SHOT 2W

FIG. 45

1. On Figure 45, sketch a line along the buried valley axis. Where would _you_ recommend the most economical drilling site for swimming pool water for the new gymnasium? (Consider both depth _and_ proximity to the gym.)

2. What were the chief effects of glaciation in the University Bay area?

_Gravity Mapping_: Gravity mapping can also yield clues on the location of buried structures that bring into juxtaposition materials of differing density. In this case the physical property of prime importance is the relative density (or density contrast) of these different materials. The depth of burial of the zone where the contrasting density materials exist is revealed by the shape, i.e., sharpness or wave length of the anomalies produced. The magnitude or size (amplitude) of the anomaly is a function principally of the magnitude of the density contrast. In general the well consolidated sedimentary rocks, the crystalline igneous and metamorphic rocks will be of greater density then the poorly consolidated sedimentary rocks including such low density materials as glacial till. The gravity map produced usually compares the difference between the value observed and a value theoretically calculated for an earth without lateral density contrasts. (The effects of elevation and the centrifugal force due to rotation are taken into account in the theoretical value calculated.) If the anomaly (observed minus theoretical values) is positive this implies that the observed value was greater than the theoretically calculated value and that the density of the rocks under the observation station is higher than those used in the theoretical calculation. A combination of a knowledge of the geology of the area, the density of the strata involved (either through direct measurement from outcrop, mine or well samples or through seismic velocity study) allows a calculation of the anomaly to be expected. Sensible variations of the structure and density in this "mathematical model" are then made until the calculated anomaly agrees in shape and size with the observed one. Gravity mapping is often useful to indicate areas where additional, more precise exploration methods should be employed. In some cases gravity is directly used for prospecting. Circular negative anomalies in regions of thick sediment have located literally hundreds of salt domes in the Gulf Coast area. Unlike the magnetic field, the gravity field in general, cannot be surveyed from airplanes because the vertical accelerations of the airplane are indistinguishable from the acceleration of gravity.

Example 1:

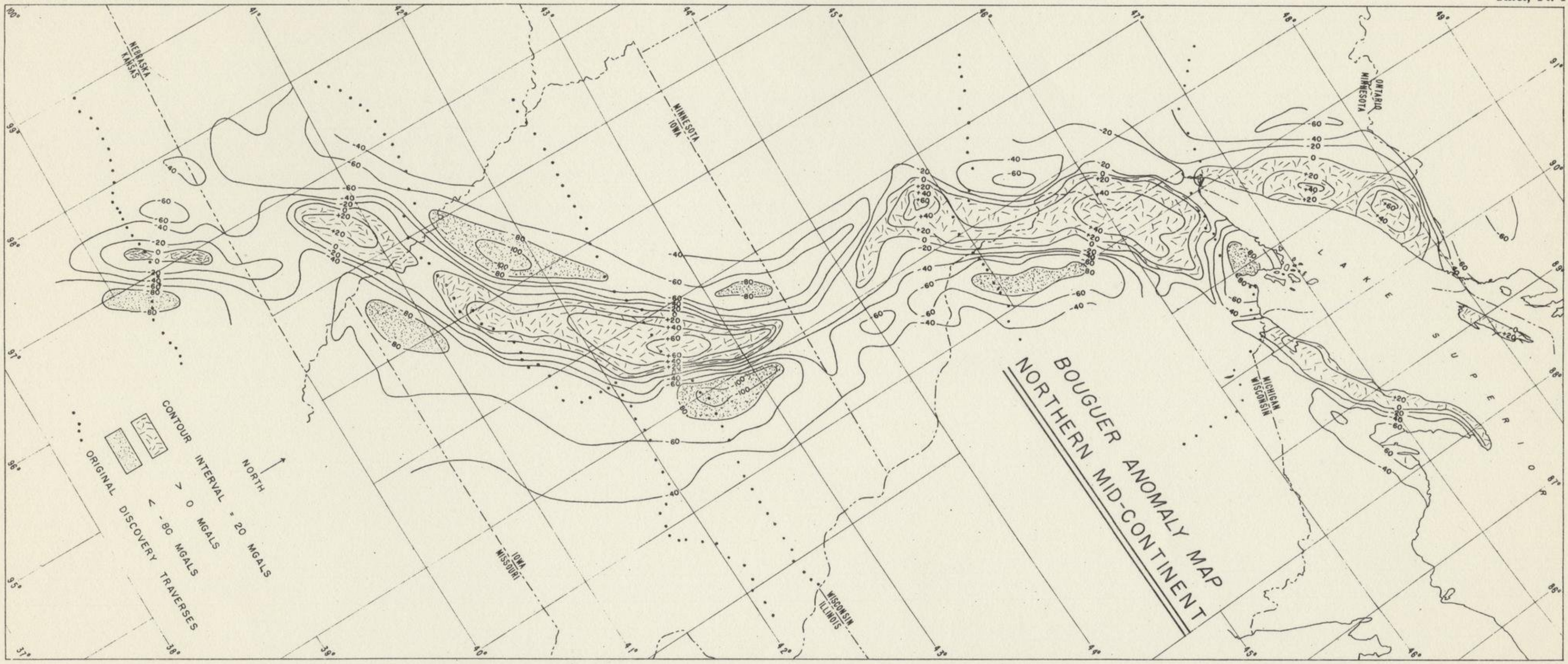
The accompanying map of the Lake Superior region compares gravity anomalies and surface geology. This study was made by a former UW geophysicist, Dr. Edward Thiel, who died in Antarctica in 1961. Note the very large and sharp positive anomalies paralleling the north shore of the lake (40-60 milligals) and south of the lake (20-50 milligals.) (The gal is a standard unit of measure of gravitational acceleration named after Galileo; one gal = 1 cm/sec and 1 milligal = .001 gal). Note that negative anomalies flank the positive ones.

3. Note carefully the relationships of the two types of anomalies to the Precambrian rocks. Also compare this map with the Wisconsin state geologic map. How can you geologically account for the anomalies? (Note: Keewenawan basic igneous rocks have an average density of 2.90 grams/cc; the overlying sediments 2.33 g/cc).

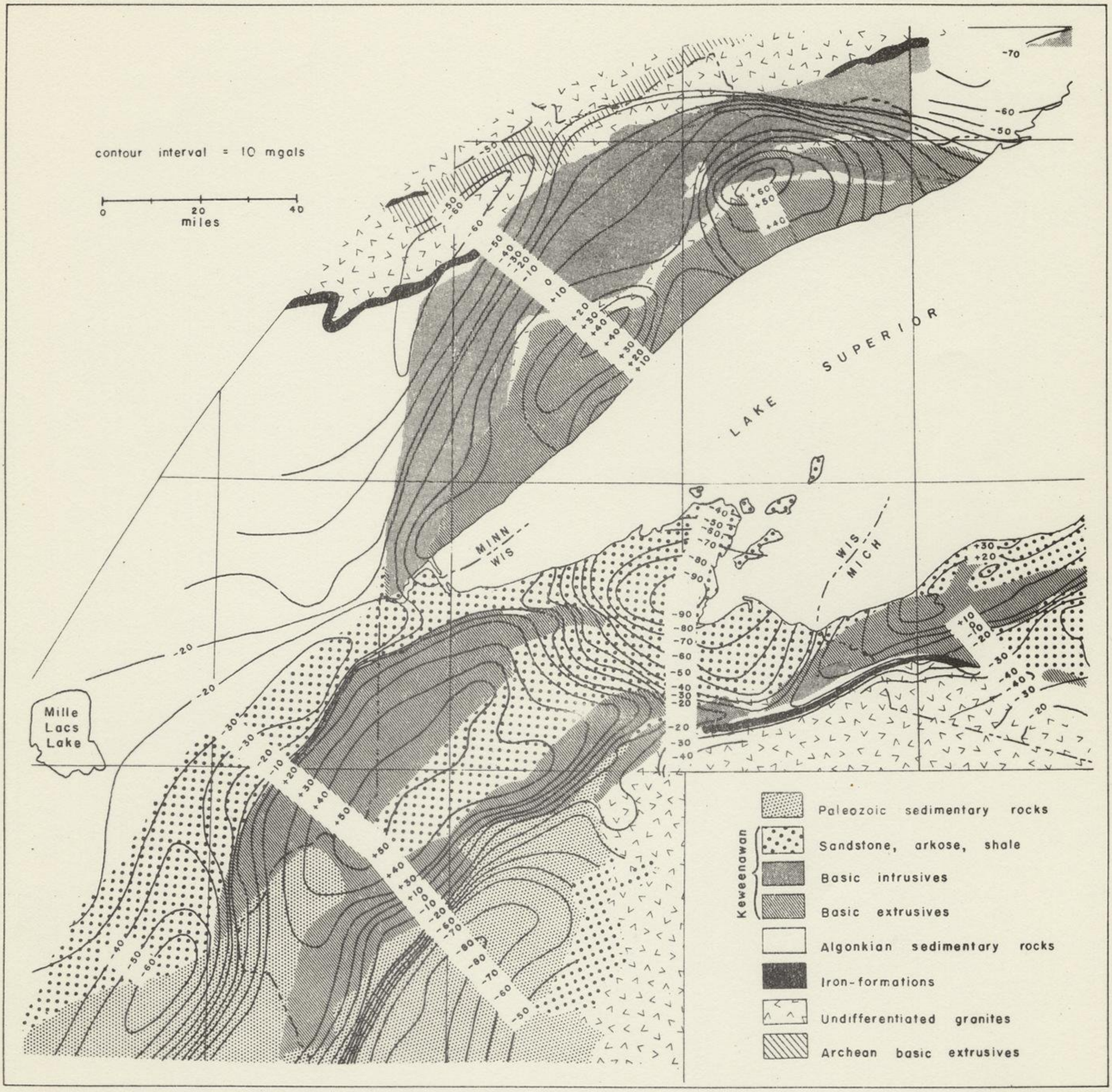
Example 2:

The final map shows extension of the Lake Superior gravity anomalies southwest. This, the largest gravity anomaly in the world which has no topographic expression, is called the "mid-continent gravity high" because of the great, long positive anomaly. It was first revealed through the study of a magnetic anomaly and later through the study of regional gravity by the Wisconsin group. It is thought to be caused by igneous intrusives or extrusives now buried to depths perhaps as much as 10 kilometers below the surface. This (like the previous map) is called a Bouguer Anomaly Map (named for an early French geophysicist). A Bouguer anomaly represents the residual gravity values after correction for position on earth, elevation and for the thickness and layering of the earth's crust. These residual anomalies, then reflect geological effects in the uppermost crust, and are useful for subsurface geological interpretation.

4. Nothing is known at the surface or in Paleozoic strata from extensive deep drilling that could cause the anomaly, therefore the cause must lie in the Precambrian basement. From analysis of the gravity anomaly and from seismic data, the source probably lies between 5 and 10 kilometers (approximately 3-6 miles) below the surface. Remembering rock and gravity relations of the Lake Superior map, what is the probable character of the subsurface Precambrian along the "gravity high"?




BOUGUER ANOMALY MAP OF THE NORTHERN MIDCONTINENT




GRAVITY AND GEOLOGY OF THE WESTERN LAKE SUPERIOR REGION

# ECONOMIC ASPECTS OF WISCONSIN GEOLOGY

The first U. S. settlement of Wisconsin occurred in 1819 soon after the Louisiana Purchase and was motivated largely by rich lead and zinc deposits in the southwest corner of the state. These had been long known to and exploited by the Indians. The ores occur primarily in Ordovician carbonate rocks (chiefly Platteville and Galena Formations). Much ore still exists, but the present low prices of lead and zinc make mining uneconomical. A measure of the former importance of this economic resource is suggested by the fact that the first Wisconsin capital was located in the lead-zinc district near Mineral Point. The Wisconsin lead was a major source of shot for the Union Army during the Civil War; much of the shot was made at Tower Hill State Park.

Iron ore from the Middle Precambrian of northern Wisconsin was also a major resource for 100 years. The ore is typical Precambrian banded "iron formation" associated with chert and other sediments. Interest stimulated largely by discovery of rich iron deposits in the Lake Superior region led to establishment of an important office of the U. S. Geological Survey at the University of Wisconsin. Its mission was to undertake a massive geologic investigation of the Precambrian of the entire Lake Superior region with special emphasis on the iron. The director of this important venture was C. R. Van Hise, first recipient of the Ph. D. from the University of Wisconsin and later one of the University's most famous presidents. Today iron, like the lead and zinc, is no longer important economically, though geophysical surveys may yet discover new deposits in areas where no outcrops exist. Glacial deposits and soil cover north-central Wisconsin so extensively that many rich treasures could lie hidden there.

Stone products are important, though less publicized than ores. Building stone includes the Silurian dolomites ("Lannon Stone"), Wausau Granite, Baraboo Quartzite and others. Crushed rock is used all over the state for road material and concrete aggregate. It is generally obtained from whatever local source is available. Crushed Baraboo Quartzite is used for ballast in which the ties are laid along the right-of-way of the Chicago and Northwestern Railway.

Today the most important mineral or rock resources are sand and gravel! Gravel is needed in large quantities today for road and other construction; both sand and gravel are used extensively as concrete aggregate. In Wisconsin most of the material for these uses can be obtained relatively easily from glacial outwash deposits or from modern river beds. In either case, they have already been washed and sorted by natural stream processes so that little treatment is required before use. Geologists have been instrumental in locating adequate deposits of these.

Search for and conservation of both surface and underground water is also an important concern of state and federal geologists in Wisconsin. These investigations are largely headquartered here in Science Hall (1st floor). We are endowed with a humid climate and, therefore, abundant water. But even here we must be increasingly concerned about pollution and proper utilization of this precious resource. Geologists are destined to play an increasing role in this activity.

## COLUMNAR SECTIONS

A columnar section is the most versatile graphic method for presenting stratigraphic information for a single outcrop locality or deep well. Cross sections, or two-dimensional, vertical-plane "maps", generally represent composite diagrams prepared from several scattered columnar sections. These can reveal correlations, thickness changes, facies and structure.

If properly organized and carefully executed, a columnar section can record all significant physical and biologic data derived from field or drill hole observations. Columnar sections described from surface outcrops generally are drawn with "character" to show accurately many physical details, including the erosional expression, stratification and sedimentary structures. Sections described from subsurface (well) data cannot show so much "character."

You are to prepare a columnar section from the rock descriptions that follow. This is, in part, preparatory to the field trip. The form and scale you use in drawing a section will depend on what you want to show, the amount of detail desired, the total thickness of the rocks, etc. The attached example is given only as an illustration of one possible form. Draw your column for southwest Wisconsin in the space provided with a vertical scale of 1" = 200 ft.

For comparison, a subsurface column for Beloit, Wisconsin is shown next to your outcrop column. Draw correlation lines between the two columns. Note that the structure of southern Wisconsin discussed earlier is reflected here by: (1) thinning (convergence) of strata eastward and (2) increase of dolomite eastward.

Note the drawer of samples of several of the formations. After you have completed the columnar section, examine all of the specimens and identify the formation represented by them. Write the specimen number in the left margin beside the formation represented on your column. YOU must decide which specimen best matches the lithologic description provided on the following pages. A few formation specimens are already identified.

MEASURED SURFACE STRATIGRAPHIC SECTION
LOWER WISCONSIN RIVER REGION

| Unit No. | Lithologic Description | Thickness, Feet |
|---|---|---|
| Top | (soil and residual gravel above) | -- |
| | "NIAGARAN DOLOMITE": | |
| 18. | Dolomite, gray, fine to coarsely crystalline; very cherty; thickly stratified; rare silicified Halysites and Favosites corals | 95 |
| | "MAQUOKETA SHALE": | |
| 17. | Shale, gray or brown; silty with some interstratified thin dolomite; phosphatic nodules at base; abundant Michelinoceras and other fossils, | 150 |
| | "GALENA DOLOMITE:" | |
| 16. | Dolomite, gray to buff; very vuggy ("honey-combed") weathering; thick-stratified below and thinner at top; several thin cherty units with Receptaulites | 200 |
| | "DECORAH SHALE": | |
| 15. | Shale, blue-gray; abundant fossils | 20 |
| 14. | Limestone, brown; thin to medium-stratified; thin blue-gray shale interstratified; betonite layer 10' below top; abundant Rafinesquina, Strophomena, Isotelus, Leperditia, Hormotoma, Sowerbyella. | 35 |
| | "PLATTEVILLE FORMATION": | |
| 13. | Dolomite and limestone interstratified; blue gray to buff; some brown shale and thin limestone conglomerate; abundant fossils (as above). | 75 |
| 12. | Quartz sandstone, coarse, white, rounded to sub angular; thin green shale interstratified | 20 |

Thickness, Feet

"ST. PETER SANDSTONE":

| | | |
|---|---|---|
| 11. | Quartz sandstone, medium-grained, white to tan, well rounded and well sorted; very friable, permeable; massive outcrops, but with internal cross-stratification prominent. (Thickness known to vary greatly elsewhere.) | 200 |

"PRAIRIE DU CHIEN GROUP":

| | | |
|---|---|---|
| 10. | Dolomite, gray to buff; locally oolitic; some glauconite and quartz sand grains; local breccia zones and small algal reefs; generally thinly stratified | 40 |
| 9. | Quartz sandstone, white, medium-grained; cross-stratified; with dolomitic lenses. | 10 |
| 8. | Dolomite, buff; dense, medium-crystalline; medium bedded; basal oolitic zone; algal cryptozoan masses scattered throughout. | 200 |

"ST. LAURENCE FORMATION":

| | | |
|---|---|---|
| 7. | Quartz sanstone, tan, dolomitic; coarse grained, well sorted; cross-stratified; rare fossil fragments. | 40 |
| 6. | Quartz siltstone, tan or brown; with interstratified thin dolomite beds; Dikelocephalus, Saukiella, Osceolia fragments. | 35 |
| 5. | Quartz sandstone, yellow to white; fine grained, well sorted, cross-stratified; some Prosaukia. | 120 |

"FRANCONIA FORMATION":

| | | |
|---|---|---|
| 4. | Quartz sandstone, fine-grained, green to brown; abundant glauconite in many zones; ripple mark and cross-stratification; micaceous shale at top; Dikelocephalus fragments, (very rare); burrows. | 145 |

"DRESBACH FORMATION":

| | | |
|---|---|---|
| 3. | Quartz sandstone, white to tan, medium-grained, well sorted; massive, cross-stratified; trilobite and inarticulate brachiopod fragments. | 80 |

| | | Thickness, Feet |
|---|---|---|
| 2. | Quartz sandstone, yellow, medium to fine-grained; with interstratified siltstone and clay shale; Trilobites, Dicellomus, Lingulella. | 240 |
| 1. | Quartz sandstone, white to yellow; cross stratified, ripple marked; lacks fossils. | 280 |
| | | 1,985 TOTAL |

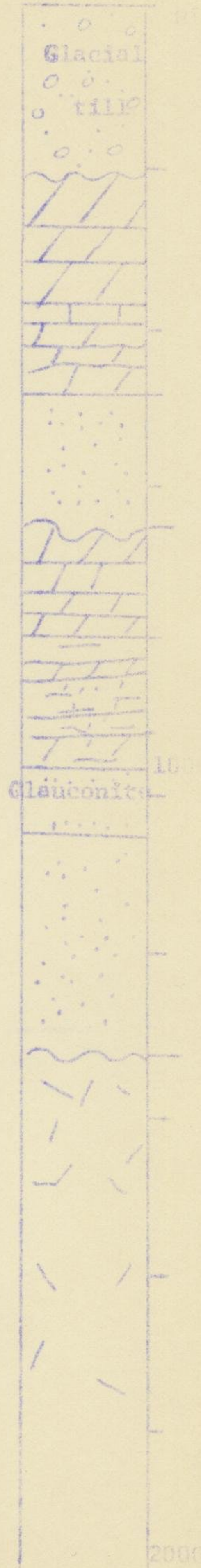
("AUGULAR UNCONFORMITY")

BASE Precambrian basement complex (igneous and metamorphic)

# COLUMNAR SECTIONS - SOUTHERN WISCONSIN

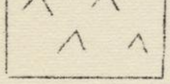
| Sys-tem | Forma-tion | Depth | Lithology |
|---|---|---|---|
| | | 200' | |
| | | 400' | |
| | | 600' | |
| | | 800' | |
| | | 1000' | |
| | | 1200' | |
| | | 1400' | |
| | | 1600' | |
| | | 1800' | |
| | | 2000' | |

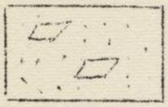
Beloit Area

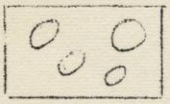


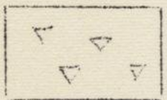
# LITHOLOGIC SYMBOLS FOR COMMON ROCK TYPES

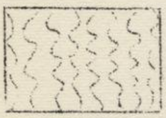
## Sedimentary Rocks

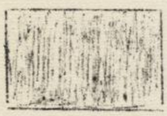

Anhydrite

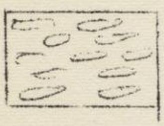

Arkose

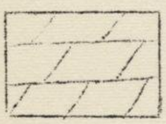

Breccia

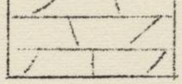

Chert


Clay

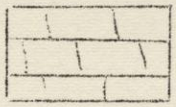

Coal

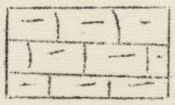

Conglomerate

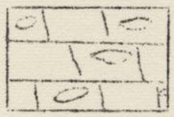

Dolomite

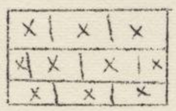

Dolomitic Limestone

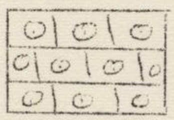

Gypsum

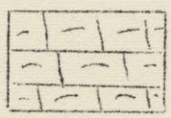

Limestone

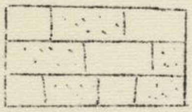

Limestone, argillaceous


Limestone conglomerate


Limestone, crystalline

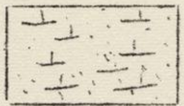

Limestone, oolitic


Reef limestone

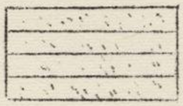

Limestone, sandy


Sandstone, argillaceous

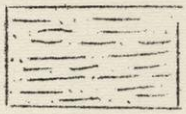

Red Beds (can be drawn across other symbols)

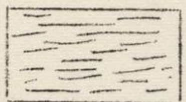

Sandstone, calcareous


Rock Salt


Sandstone, thin bedded


Sandstone

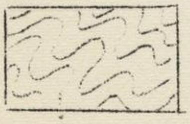

Siltstone

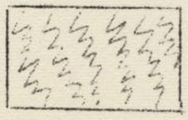

Shale

## Igneous and Metamorphic Rocks


Extrusive rocks in general


Intrusive rocks in general


Folded basement (may be combined with other symbols)


Metamorphic rocks in general

## STANDARD COLORS FOR COLUMNAR SECTIONS

### Sedimentary rocks

| | | |
|---|---|---|
| Anhydrite | - | Purple |
| Clay | - | Blank |
| Coal | - | Black |
| Conglomerate | - | Yellow |
| Dolomite | - | Green |
| Gypsum | - | Purple |
| Limestone | - | Blue |
| Red Beds | - | Red |
| Rock Salt | - | Light Purple |
| Sandstone | - | Yellow |
| Siltstone | - | Gray and Yellow |
| Shale | - | Gray |

### Igneous and Metamorphic rocks

| | | |
|---|---|---|
| Extrusive rocks in general | - | Orange |
| Intrusive rocks in general | - | Red |

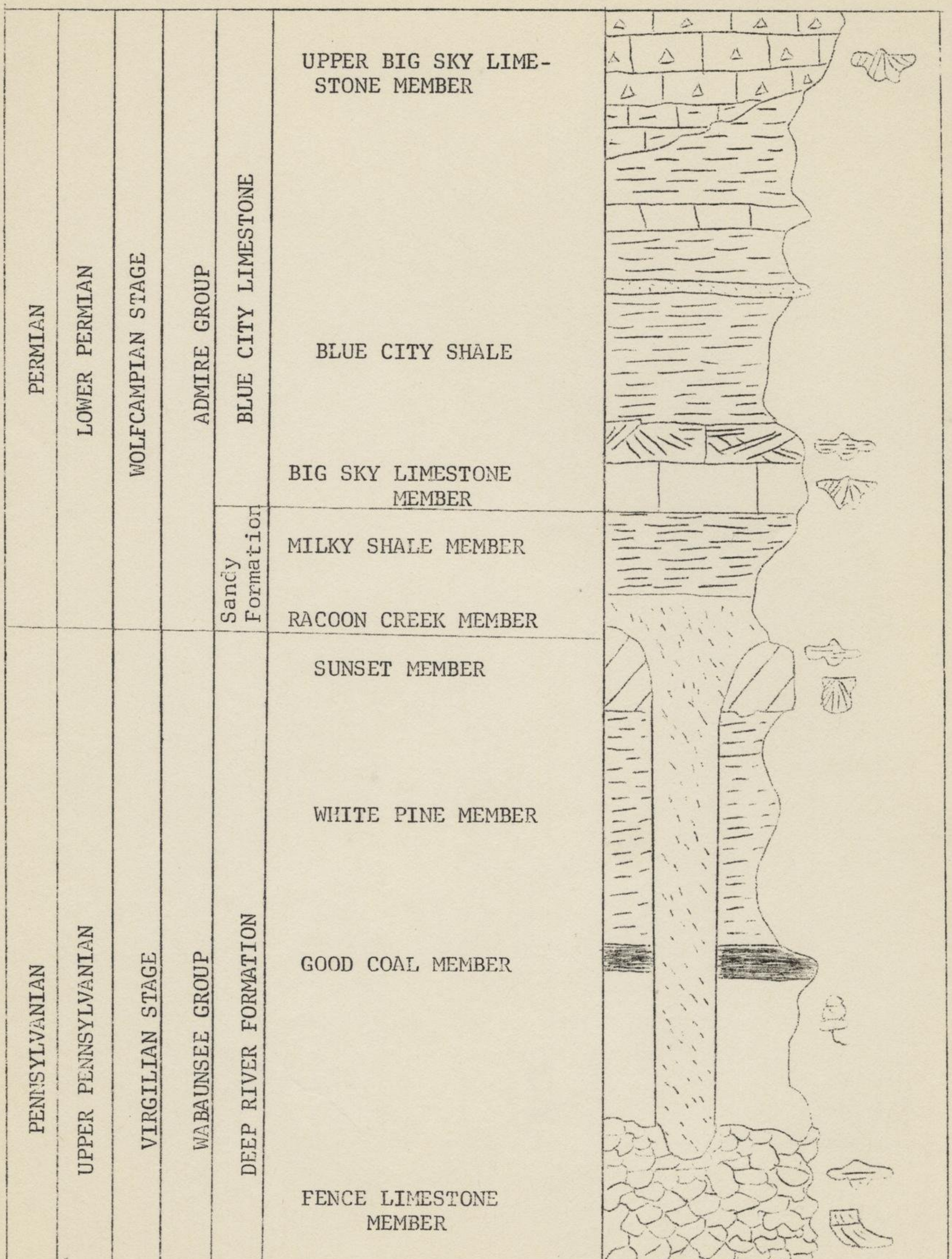

PERMIAN
LOWER PERMIAN
WOLFCAMPIAN STAGE
ADMIRE GROUP
BLUE CITY LIMESTONE
UPPER BIG SKY LIME-
STONE MEMBER
BLUE CITY SHALE
BIG SKY LIMESTONE
MEMBER
Sandy
Formation
MILKY SHALE MEMBER
RACOON CREEK MEMBER
PENNSYLVANIAN
UPPER PENNSYLVANIAN
VIRGILIAN STAGE
WABAUNSEE GROUP
DEEP RIVER FORMATION
SUNSET MEMBER
WHITE PINE MEMBER
GOOD COAL MEMBER
FENCE LIMESTONE
MEMBER

FIGURE #1