A FIELD AND PETROGRAPHIC STUDY OF SOME EXTRUSIVE AND SEDIMENTARY ROCKS ALONG THE CARP AND LITTLE CARP RIVERS IN ONTONAGON AND GOGEBIC COUNTIES, MICHIGAN

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Owen Merle Hornstein

1950

THESIS

This is to certify that the

thesis entitled

"A Field And Petrographic Study of Some Extrusive And Sedimentary Rocks Along the Carp And Little Carp Rivers in Ontonagon And Gogebic Counties, Michigan"

presented by

OWEN M. HORNSTEIN

has been accepted towards fulfillment
of the requirements for

M.S. degree in GEOLOGY and GEOG.

Stanard G. Bergquist
Major professor

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A FIELD AND PETROGRAPHIC STUDY OF SOME EXTRUSIVE AND SEDIMENTARY ROCKS ALONG THE CARP AND LITTLE CARP RIVERS IN ONTONAGON AND GOGEBIC COUNTIES, MICHIGAN

by

Owen Merle Hornstein

A Thesis

Submitted to the Graduate School of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

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THESIS

ACKNOWLEDGEMENTS

The writer wishes to express his sincere appreciation to Dr. [illegible]. T. Sandefur, under whose direction this thesis was written. Dr. Sandefur gave freely of his time and knowledge to assist in the laboratory and in the writing.

Dr. W. A. Kelly's assistance in providing a base map and briefing the writer about the area is deeply appreciated.

The writer also wishes to express his thanks to Dr. S. G. Bergquist for checking the manuscript and offering suggestions used in this thesis.

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INTRODUCTION

History and Previous Investigation

For the past 155 years, a number of geologists have written on different portions of the Lake Superior basin. Probably the first report of significance was written by John J. Bigsby, titled, "Notes on the Geography and Geology of Lake Superior", published in the, Quarterly Journal of Science and Arts, 1824-25. Between 1825 and 1883, many geologists wrote copiously upon this subject. Consult R. D. Riving, "The Copper Bearing Rocks of Lake Superior", U.S.G.S. Monograph V, 1883, pages 14-23, for a complete, chronologic list of works from 1825 through 1881, that refer to the Keweenawan rocks.

Until Irving began his field investigations in the summer of 1880, there was little or no knowledge available concerning the structure of the Porcupine Mountains. Irving's work in this area ranks high among the classics, for never before had so much detailed work been done on the lithology, stratigraphy, and structure of the Porcupine Mountain area.

The next important work was done by W. C. Gordon,*

*Gordon, W. C., A Geological Section from Bessemer Down Black River, Published by the Board of Geological Survey as a part of the report for 1906.

when he studied the section down Black River from Bessemer to the Lake Superior shore. He made a detailed study of all outcrops and wrote an excellent description of the lithology, structure, and thickness of the several formations encountered.

Three years later, A. C. Lane*

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*Lane, A. C., The Keweenawan Series of Michigan, Michigan Geological and Biological Survey, Vols. I and II, 1909.

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published a two volume report on the Keweenawan Series of Michigan. In this report, he gave complete descriptions of all rock types in the Porcupine Mountain area and also expressed his ideas as to the structure, age, and correlations that can be determined.

Finally, Van Hise and Leith*

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*Van Hise, C. R. and Leith, C. K., The Geology of the Lake Superior Region, U.S.G.S. Monograph LII, 1911.

---

presented their ideas of the stratigraphy and conditions of formation of the rocks in the Porcupine Mountain area in their classic report of 1911.

Method of Approach

Since there are no roads traversing the Porcupine Mountain area, the writer was forced to hire a boat at Black River Harbor, about thirteen miles southwest of the mouth of the Little Carp River, to carry in the supplies needed. The boat followed the shore of Lake Superior while enroute to the mouth of the Little Carp River. At this time, arrangements were made for the writer to be picked up at the mouth of the Carp River, three weeks later, and taken back to Black River Harbor.

Base camp was set up at the mouth of the Little Carp River and each day's work was started from that point.

The Little Carp River is about 40 feet wide at its mouth and carries very little sediment by normal flow. The water is clear and suitable for drinking. The bed of the stream is covered with large, well rounded pebbles of solidified lava, conglomerate, granite, felsite, and quartz.

The Little Carp River was followed upstream and at each outcrop, a representative sample was taken and labeled.

When the Little Carp River traverse was completed, the camp site was moved one mile northeast, to the mouth of the Carp River. The procedure used along the Little Carp River was followed in collecting samples along the Carp River.

Samples were taken from outcrops along both rivers as long as the direction of flow was across the strike of the formations.

The last day in the field was used to collect samples of extrusive felsite rock, which is abundant near Mirror Lake.

PURPOSE OF STUDY

In the past, little detailed, geological work has been done between the Carp and Little Carp Rivers in the Porcupine Mountains. This presented a good opportunity for the writer to search the area in hopes of collecting some data that would help broaden the knowledge of the geology there.

The formation sampled and studied by the writer has been named the, Outer Conglomerate formation, by Irving.*

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*Irving, R. D., The Copper Bearing Rocks of Lake Superior, U.S.G.S. Monograph V, 1883.

Since 1883, the name Outer Conglomerate has been used by other authors, and the name is well established in the literature.

This name, however, does not conform with the usual rules set up by the United States Geological Survey, in that a formation should be named after a locality. Also, the name Outer Conglomerate is a poorly selected one for the formation is nearly all fine grained sandstone with a few lenses of coarse conglomerate. For the above reasons, the writer feels that this formation should be called the Porcupine Mountain formation. The name Porcupine Mountain sandstone will be used in place of the name Outer Conglomerate in this thesis.

OBJECTIVES OF THIS THESIS

1. To collect samples of outcropping bedrock along the Carp and Little Carp Rivers.
2. To obtain information pertaining to the age of the Porcupine Mountain sandstone.
3. To determine, through sphericity, roundness, sorting, and composition of the particles, the source of the sediments and the direction from which they were derived.
4. To observe the general structure and thickness of the Porcupine Mountain formation.
5. To correlate the stratigraphy, through lithologic characteristics, in the Carp River area with that of the Little Carp River.
6. To observe the general geology of the area.

GEOGRAPHY

Location

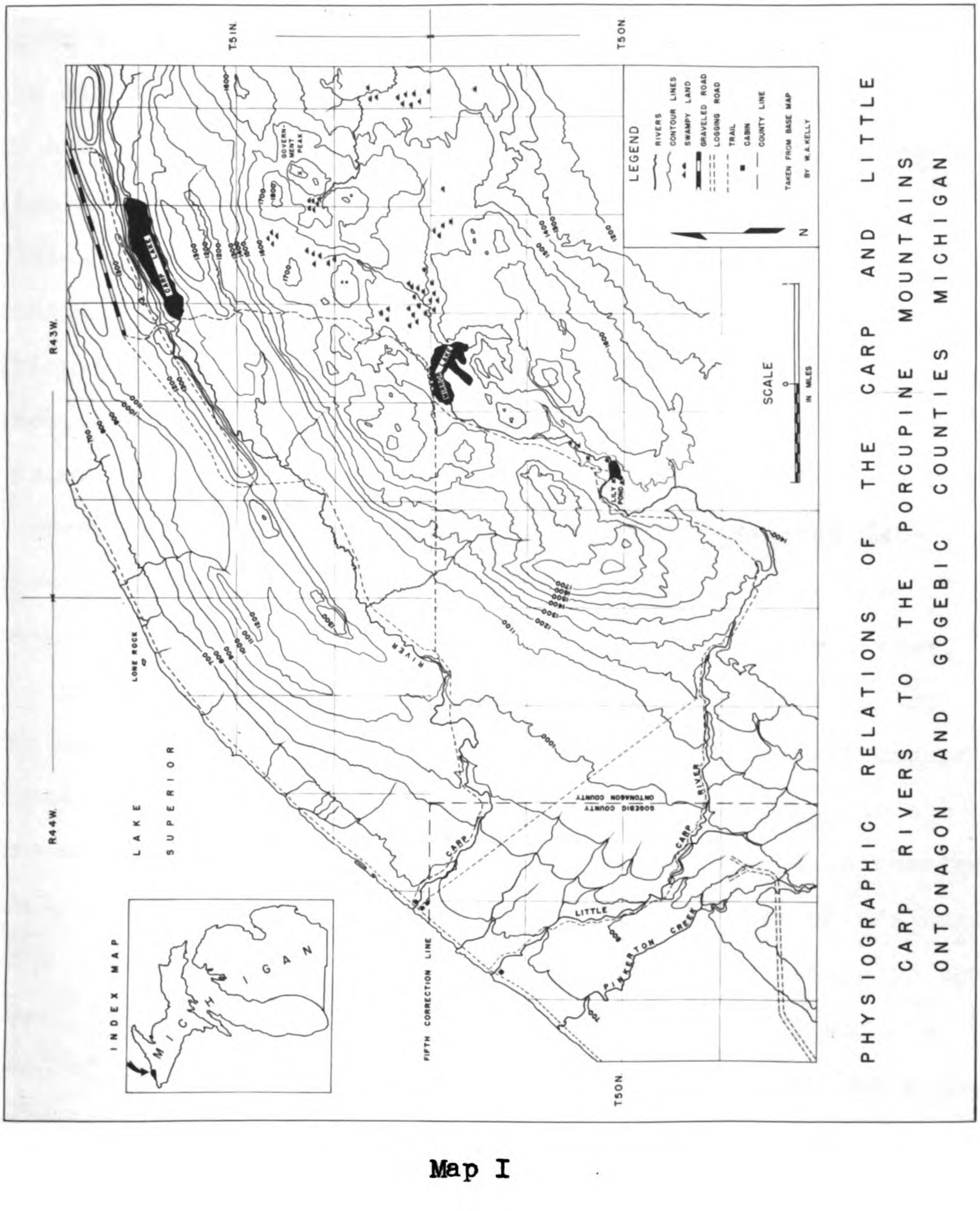
The area described in this thesis is situated in the southwestern part of the Porcupine Mountains State Park. This park includes the extreme northern part of Gogebic and the northeastern part of Ontonagon counties, in the western portion of the upper Peninsula of Michigan. See index map, insert, Map I.

The Little Carp River has its source in the small streams that feed into Mirror Lake, which is located in Sec. 2., T. 50 N., R. 44 W., Ontonagon county. The Little Carp River flows S.-SW. from Mirror Lake until it enters Lily Pond, which is much smaller and more shallow than Mirror Lake. Upon leaving Lily Pond, it makes a large loop to the south and flows northwest until it empties into Lake Superior. The mouth of the Little Carp River is located in the SE¼, NW¼, SW¼ of Section 1, T. 50 N., R. 45 W. in Gogebic county.

The Carp River has its origin in the small streams which flow into Carp Lake (Lake of the Clouds).* The water of these small streams, flows from northeast to southwest through Carp Lake. The Carp River follows the strike of the rocks until it crosses into Gogebic county, where it swings to the

* The U.S.G.S. has never changed the name of Carp Lake to Lake of the Clouds. Personal communication with F. G. Pardee.

northwest and empties into Lake Superior. The mouth of the Carp River is located in the SE¼, NW¼, SE¼ of Section 33, T. 51 N., R. 44 W. in Ontonagon county.


PHYSIOGRAPHIC RELATIONS OF THE CARP AND LITTLE
CARP RIVERS TO THE PORCUPINE MOUNTAINS
ONTONAGON AND GOGEBIC COUNTIES MICHIGAN
LEGEND
RIVERS
CONTOUR LINES
SWAMPY LAND
GRAVELED ROAD
LOGGING ROAD
TRAIL
CABIN
COUNTY LINE
TAKEN FROM BASE MAP
BY W.A.KELLY
N
SCALE
IN MILES
INDEX MAP
MICHIGAN
LAKE
SUPERIOR
LONE ROCK
R44W.
R43W.
T51N.
T50N.
FIFTH CORRECTION LINE
GOVERN-MENT PEAK
LILY POND
CARP
RIVER
LITTLE
PINKERTON CREEK
ONTONAGON COUNTY
GOGEBIC COUNTY

Map I

Topography

The Porcupine Mountains, a prominent landmark of rugged and rocky terrain rising from Lake Superior about fifteen miles west of Ontonagon, have received wide recognition for their scenic beauty and virgin forest stand. The mountains are made up of a series of broken ridges, roughly parallel and concentric to the shore of Lake Superior. The Michigan Department of Conservation lists the highest elevation as Government Peak, which is 2,023 feet above sea level, or 1,421 feet above Lake Superior. More recent surveys of the area indicate that these figures are too high and in error, another peak to the southwest being denoted as the highest. This is the highest range of hills between the Black Hills of South Dakota and the Applachians in the east.

From a distance the slopes seem to be gentle, however, when actually traversing the mountains, one finds very rugged slopes leading to the tops of the ridges. The ridges in the Carp and Little Carp River area have slight surface depressions which trap the meteoric water, and because of lack of drainage, large swamps persist. The swamps are a constant menace to the hiker, in that he has to secure his way across them and they breed millions of mosquitoes. Since the rainfall is heavy and the vegetation thick, there is little evaporation of water in these areas. See Map I, for a contour map of the Porcupine Mountains.

Lakes and Streams

Draining the east side of the Porcupine Mountains are five rivers of importance; the Presque Isle, the Black, the Iron, the Carp, and the Little Carp. The Carp and Little Carp Rivers are of present interest. While they are not exceptionally large or long rivers, they are quite different in that they flow rapidly down deepcut valleys through virgin wilderness, over a series of spectacular waterfalls and foaming rapids.

Carp Lake is really a part of the Carp River because the headwaters of the Carp flow into the northeast end of Carp Lake and out the southwest end. Likewise, the Little Carp River has two lakes through which it flows. The water from the headwaters of the Little Carp River pass through Mirror Lake and again through Lily Pond before reaching Lake Superior. These relationships of drainage are shown on Map I.

Climate

The Upper Peninsula of Michigan, along the coast of Lake Superior, has an entirely different type of climate from the rest of the state. In Ontonagon County, the average annual rainfall is about 31 inches. This is a surplus of water because the average annual growing season is only between 80 and 90 days. Temperatures, however, do not go to extremes because of the proximity to Lake Superior. The average temperature for January is between 10 and 11 degrees Fahrenheit, while the average July temperature is 64 to 65 degrees Fahrenheit.*

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*U. S. Department of Agriculture, Climate and Man, Yearbook of Agriculture, 1941, pp. 914-924.

Timber

Most of the area is thickly covered with virgin stand of the hardwood-hemlock forest, interspersed with scattered colonies of white pine and birch.

Occupations

The three major occupations, in order of their importance are mining, lumbering, and fishing. The largest open pit iron mine in Michigan is located in the town of Wakefield, just a few miles to the southwest of the Porcupine Mountains. Timber is taken from both Ontonagon and Gogebic Counties and cut into lumber in the town of Connorville, Michigan. The main fishing port is located at Black River Harbor.

GEOLOGY

General

The rock strata exposed along the shore of Lake Superior, in the area of the Carp and Little Carp Rivers, were laid down in the Upper Keweenawan period of the Proterozoic era and represent the youngest formations in this area.

This area is in the Lake Superior region, a part of the southern margin of the great pre-Cambrian shield of North America. The pre-Cambrian outcrops are bordered on the east and south by younger Paleozoics and on the west and north by the basin of Lake Superior.

The area under discussion has a complex geologic history which geologists are now attempting to interpret. Briefly, the area was blanketed by hot lavas, folded by diastrophic movements, eroded, intruded by magmas, again eroded, and finally glaciated.

The formations of this area may be separated into several different lithologic units, each originating under different circumstances. It is the geologist's task today to determine these circumstances.

The central core of the Porcupine Mountains, comprises a rhyolite mass.* The beds of sandstone, conglomerate and shale dip away on all sides except where the rhyolite connects on the south with the Main Trap Range. This Range consists of

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* Thaden, R., Personal Communication.

basaltic lava flows with amygdaloidal tops, extending south from Eagle Harbor and paralleling the coast of Lake Superior. The Main Trap Range is believed to be younger than the rhyolite core.

Irving*

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*Irving, R. D., op. cit., 1883, pp. 150-151.

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compares the structure here to the structure in southern Utah. He states,

> "The structure of the Porcupine Mountains has so much in common with that of the laccolitic mountains of Southern Utah, described by G. K. Gilbert, that they might be supposed to owe their existence to an eruption of acid rocks at a time quite subsequent to that of the formation of the latest of the basic flows. But, as shown subsequently, these mountains owe their existence in all probability to a fold, the porphyry of the central portions being one of the usual embedded masses laid bare by subsequent denudation."

Stratigraphy

The age of the Porcupine Mountain formation (Outer Conglomerate) has been classified by Irving*

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*Irving, R. D., ibid., 1883.

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as Keweenawan, belonging to the upper series of the Algonkian system. The Keweenawan period in this area was a time of regional volcanic activity. One-third to one-half the rocks have been classified as extrusive. The formations have been identified as Keweenawan in age, by Irving. Some of the more recent geologists have doubted the validity of Irving's classification and prefer to place the formations in the Cambrian period.

Van Hise and Leith*

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*Van Hise, C. R., and Leith, C. K., op. cit., 1911, pp. 415-416.

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give their reasons for calling it Keweenawan, in the following statements.

1. The absence of middle and lower Cambrian sediments in the region, leaving an unconformity between the Keweenawan and the Cambrian.
2. The lack of fossils of any kind in the so-called Keweenawan.
3. The sedimentary formation is composed of many volcanic fragments which is not typical of other known Cambrian sediments.
4. The Cambrian is largely subaqueous while the Keweenawan is subaerial.
5. The Cambrian lacks volcanism, whereas in Keweenawan time, volcanos were abundant in this area.
6. The Cambrian formations are horizontal in attitude, while the Keweenawan are tilted.

Alfred C. Lane*

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*Lane, A. C., _op. cit._, Vol. II, 1909, pp. 940-941.

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believes that the so-called Keweenawan may be Cambrian in age. In answer to some of the above statements made by Van Hise and Leith, Lane says,

> "That the Cambrian contrasts with the Keweenawan in lacking volcanism, is certainly not true of the Upper Keweenawan...."

In answer to the horizontal attitude of the Cambrian beds, Lane states,

> "Though the 'Upper Cambrian is flat lying,' so in the Lake Superior sandstone of the Apostle Islands, which Thwaites recognizes as conformably above and part of the Upper Keweenawan."

Lane also remarks that any subaerial deposit would be nonfossiliferous, and therefore cannot be used as a criterion for determining age.

C. Leith, R. Lund, and A. Leith*

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*Leith, C., Lund, R., and Leith. A., Pre-Cambrian Rocks of the Lake Superior Region, _U.S.G.S. Professional Paper 184_, 1935, p. 8.

---

take the same view as Lane and explain it thus,

> "Although the Keweenawan is pre-Cambrian in the sense of preceding the Upper Cambrian transgression, having structural and igneous affiliations with the Pre-Cambrian and being nonfossiliferous, it may in part be Cambrian

in the sense that its deposition probably continued into the time when Middle and Lower Cambrian sediments were being laid down in approaching Cambrian seas."

The writer, after spending three weeks in the field, found no information which would contradict the statements made by either Lane or Van Hise. However, clay galls are very numerous in some places, which, the writer believes, supports the statement that the Porcupine Mountain formation is largely a subaerial deposit.

R. D. Irving* states;

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*Irving, R. D., op. cit., 1883, p. 151.

"The most prominent fact in regard to the stratigraphy of the Keweenaw Series is its separation into two divisions; an Upper member, made up chiefly of a succession of flows of basic rocks, but including layers of conglomerate and sandstones nearly to the base, and more or less of original acid rocks."

The situation is far from being proven, but under any hypothesis, the Keweenawan beds constitute a marked local variation from preceding conditions.

Legend

The stratigraphic column below, was taken from the Centennial Geologic Map of the Northern Peninsula of Michigan, compiled by Helen M. Martin, Publication 39, Geological Series 33, which is a part of the annual report for 1936, by the Michigan Geological Survey. The writer has added to this column, the Porcupine Mountain formation, which does not appear in the report. The possibility that the Procupine Mountain formation is a facies equivalent of the Freda sandstone must not be neglected.

Proterozoic Era

Algonkian System

Keweenawan Series

Upper Group

Freda sandstone

Nonesuch shale

Porcupine Mountain sandstone

Lower Group

Lake Shore Traps

Description of Formations

Freda sandstone

The geologically highest rock in the Keweenawan Series is the Freda sandstone. Irving considered this, "the main body of sandstone", but it does not outcrop in the area between the Carp and Little Carp Rivers, along Lake Superior. This formation is composed of red sandstone, arkose, and shale, with a composite thickness of some 400 feet.

Nonesuch Shale

This shale lies beneath the Freda sandstone, but does not outcrop along Lake Superior in the Carp and Little Carp Rivers area. This formation has a thickness of 550 feet in the Black River section.

Porcupine Mountain Sandstone

The youngest rock which outcrops in this area is the Porcupine Mountain sandstone. It is composed of a section of sandstone overlying a conglomerate base, which constitutes about 20 percent of the total formation. In this section, the measured thickness is more than 5,000 feet. More detailed descriptions of this formation are given in the section on Sedimentary Petrology.

Lake Shore Traps

Lying conformably beneath the Porcupine Mountain sandstone, and in contact with it, is a formation made up of a series of flows of eruptive rocks. These eruptives were divided into five separate flows by Gordon and assigned a thickness of 400 feet. This formation can be described briefly as thin basaltic lava flows, amygdaloidal on top, and intercalated with amygdaloids and felsitic conglomerates.

Descriptions will not be given to the remaining Lower Keweenawan rocks, as the writer did not encounter them in the sections taken along the Carp and Little Carp Rivers. A detailed account of these can be found in, "The Keweenawan Series of Michigan", Michigan Geological and Biological Survey, Vol. II, 1909, by A. C. Lane.

Thickness and Structure

Overlying the Lake Shore Traps is a sedimentary formation, grading from conglomerate at the base to sandstone at the top. This formation is not uniform in texture throughout, the upper beds are fine grained sandstone, while the lower portion is a true conglomerate.

A. C. Lane*

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*Lane, A. C., op. cit. Vol. I, 1909, p. 39.

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calculated the thickness of the writer's Porcupine Mountain formation, Lane's Outer Conglomerate, to be 1,000 feet at Keweenaw Point, near Copper Harbor.

W. C. Gordon*

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*Gordon, W. C., op. cit., 1907, p. 429.

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measured the thickness to be 5,000 feet along the Black River, about 12 miles southwest of the Little Carp River.

R. D. Irving*

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*Irving, R. D., op. cit., 1883, p. 151.

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determined a thickness of 3,000 feet in the Porcupine Mountains.

The writer, however, calculated the thickness of the Porcupine Mountain sandstone to exceed the figures of Irving and Lane. The section of rock outcrop along the Little Carp River was followed very carefully and the horizontal distance perpendicular to the strike, actually exposed was found to be 10,800 feet. Allowing for an average dip of 27.5 degrees, this results in a minimum thickness of about 5,000 feet, because neither the top nor the bottom of the formation was actually observed.

The possibility of repitition by faulting is not possible here, however, the writer saw no indication of faulting in either the Carp or Little Carp River sections. The rocks between the two rivers are completely concealed by soil and thick vegetation. At the lake shore, the beds may be seen outcropping above the lake level for a distance of some fifty yards. The contact between the Porcupine Mountain sandstone and the Lake Shore Traps is not exposed along the Little Carp section. Because of the above reasoning, the thickness will have to be over 5,000 feet, and may have a much greater thickness in places.

W. C. Gordon* states;

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*Gordon, W. C., _op. cit._, 1907, pp. 425-426.

> "Descending through the formation we get in succession sandstone, sandstone with conglomerate phases, mixed sandstone and conglomerate, conglomerate with sandstone phases, and pure conglomerate. The change from sandstone above to coarse conglomerate below is a gradual one, and there is no sharp dividing line, but in a general way, it may be said that the upper one-quarter is sandstone, and the remaining three-quarters is conglomerate."

In the section along the Little Carp River, the upper eighty percent of the Porcupine Mountain formation is sandstone, and the lower twenty percent is conglomerate. This is just the reverse of what Gordon found in the Black River section. The writer believes that there are pronounced facies changes with lateral extent, in the Porcupine Mountain formation.

Lenses of conglomerate occur near the top of the sandstone phase, and thin beds of sandstone are associated with the conglomerate phase, which cannot be traced laterally for any great distance. It is believed from field observations, that these lens-shaped beds thin out in both directions. All the lenses observed by the writer are probably less than 100 feet thick and have very sharp contacts with the surrounding beds on either side. The largest lens noted was at the mouth of the Carp River where the hard, resistant conglomerate causes a sharp bend in the river. See Plate III, Fig. 1. The actual dimensions of the outcrop are, 75 feet by 25 feet. This conglomerate cannot be traced laterally, since it enters the side of a hill and is covered completely. There is no indication of such a conglomerate along the strike, in the banks of the Little Carp River, merely a mile away.

Well defined jointing is prevalent in the lower portion of the Porcupine Mountain formation. Fracture planes cut through the large pebbles, while there is very little breaking in the cement, around the pebbles.

M. P. Billings* states,

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*Billings, M. P., Structural Geology, Prentice-Hall, Inc., New York, New York, 1942, p. 125.

> "It is often supposed that tension fractures break around the pebbles of conglomerates, and that only shear fractures cut indiscriminately across pebbles and matrix. Although this may be true for loosely-consolidated conglomerates, apparently it is not a reliable criterion in well-cemented conglomerates."

The joints trend in several directions, but generally strike N. 20 W. to N. 25 W. and S. 50 W. These joints are significant in that the force which caused them was directed along a line which bisects the angle made by any two intersecting joint planes.*

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*Billings, M. P., ibid., p. 126.

They also assist the geologist to realize the great forces exerted during diastrophism.

The strike of the Porcupine Mountain formation changes from N. 20 E. to N. 30 E. as it extends northwardly. The average dip is 27.5 degrees northwest. See Map II.

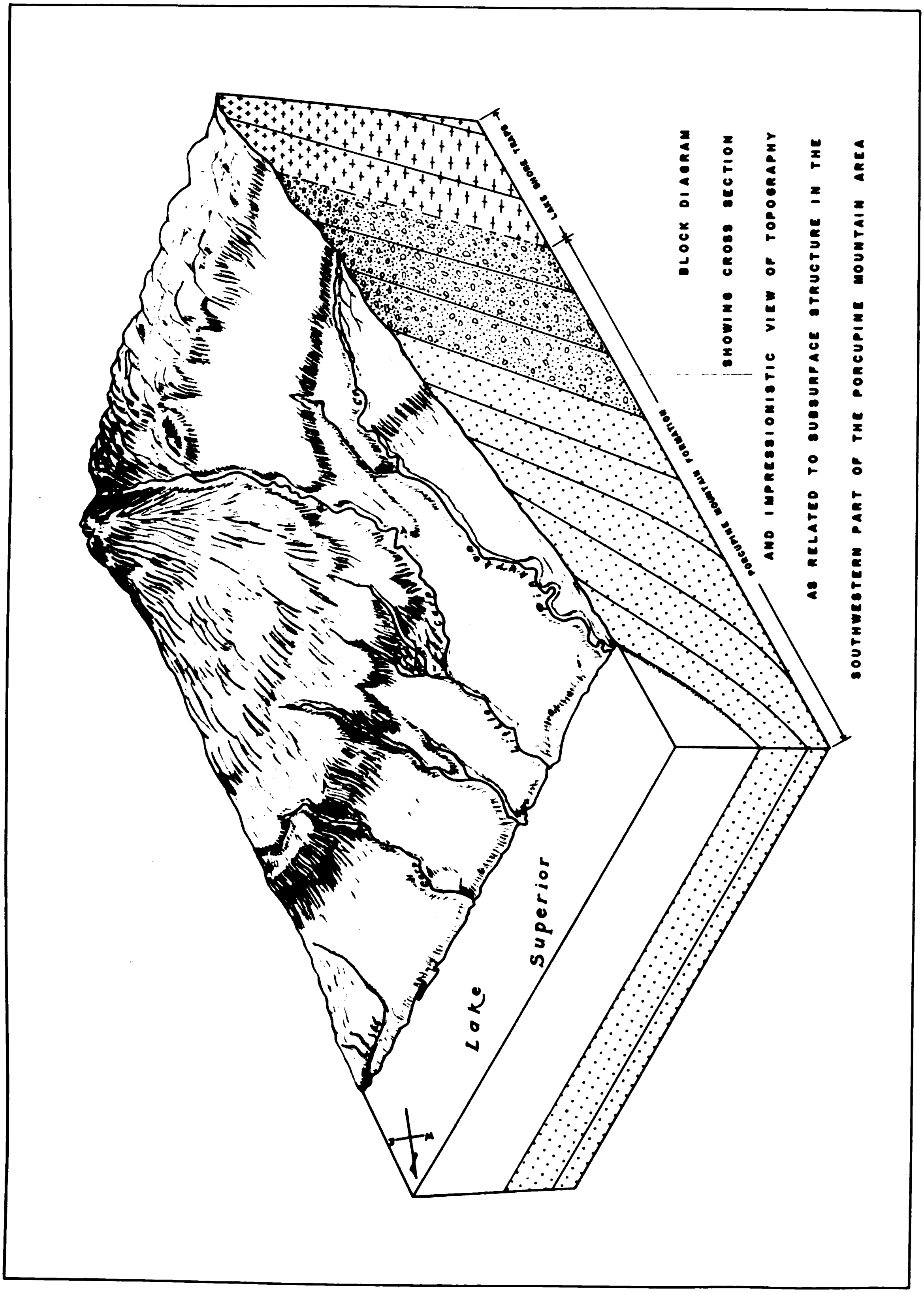
BLOCK DIAGRAM
SHOWING CROSS SECTION
AND IMPRESSIONISTIC VIEW OF TOPOGRAPHY
AS RELATED TO SUBSURFACE STRUCTURE IN THE
SOUTHWESTERN PART OF THE PORCUPINE MOUNTAIN AREA
LAKE SHORE TRAPS
PORCUPINE MOUNTAIN FORMATION
Lake Superior

Diagram I

PETROLOGY

Igneous Rocks

All the igneous rocks observed by the writer in the Porcupine Mountains are extrusive. The Lake Shore Traps, exposed in the Little Carp River at location A-43, are described in detail. These conform quite well with the findings of W. C. Gordon*

*Gordon, W. C., ibid., 1907, pp. 430-432.

in the Black River section. The main difference being that, the vesicles of the amygdaloids in the Little Carp River section are filled with secondary chlorite while those in the Black River section, are filled with secondary calcite.

The rhyolite found along the northwest side of Mirror Lake varies from that found in other localities, such as Chippewa Hill and other localities in the Porcupine Mountains. This, however, is not surprising, since an aphanitic rock may vary considerably in composition with lateral extent.

The igneous rocks studied by the writer, have been assigned a number and named according to the classification of Johannsen.*

*Johannsen, Albert, A Descriptive Petrography of the Igneous Rocks, Vol. I, The University of Chicago Press, 1931, pp. 141-161.

Johannsen developed this classification for igneous rocks, on the basis of the percentages, by volume, of the minerals present. The writer believes this is the most straight-forward and logical classification yet presented. The petrographer, when studying a thin section, can easily estimate the percentages of each mineral present.

The following are detailed petrographic descriptions of the rhyolite and the Lake Shore Traps.

Rhyolite (226E)

This specimen was collected from an outcrop on the southwest side of Mirror Lake, just a few feet to the west of the cabins shown on Map I.

Megascopic:

The specimen is reddish to chocolate-brown. There are no phenocrysts apparent in the hand specimen. The texture is so fine that the rock breaks with a conchoidal fracture, leaving knife-like edges. The weathered surface is smooth and takes on a light gray color.

Microscopic:

The thin-section shows a microcrystalline-granular texture, with a granular microfelsitic groundmass, changing into a cryptocrystalline mass in places. Under crossed nicols, the groundmass appears as jumbled aggregate of felty material composed of quartz, glass, and sanidine. Although no distinct automorphic crystals can be seen, the groundmass shows distinct anisotropism. Under ordinary light, fine lines of brown, hairlike grains appear in random orientation. Opaque particles of hematite and magnetite are equally distributed through the thin-section.

Andesite (2212E)

This specimen was collected in the Little Carp River section at location A-43. It is a representative sample of the Lake Shore Traps in this area.

Megascopic:

The rock has a dark, grayish-black overall appearance. There was no reaction with dilute hydrochloric acid, which indicates that no carbonate minerals are present. It has an aphanitic, granular texture, so fine that no minerals can be identified.

Microscopic:

The thin-section displays a very fine-grained texture with lath-shaped crystals of andesine (microlites) in random orientation, giving a log-jam appearance. Some grains of pigeonite, a pyroxene in the clinoenstatite-diopside series, are equally distributed throughout the slide. Small magnetite particles partially cover the thin-section. The rock is micro-amygdaloidal, with secondary chlorite filling the vesicles. Minor amounts of rutile and muscovite were recognized. The alteration of the plagioclase into sericite and kaolin, and the large amount of magnetite present, give the slide a very dirty appearance.

Sedimentary Rocks

The only sedimentary formation sampled was the Porcupine Mountain sandstone. Considerable work was done with these samples to determine some method by which the formation could be subdivided and these subdivisions in turn be correlated between the Carp and Little Carp Rivers.

Preparing the Samples:

Samples A-1, A-13, A-15, A-23, A-30, B-3, B-16 and B-30 were selected as representative samples to be used in laboratory studies. See Map II. More samples were taken from the section along the Little Carp River than from the Carp River because the former exposes a much better and more complete section.

Each sample was placed in a large iron mortar and tapped gently with a pestle until it was thoroughly disintegrated. The unconsolidated material was then placed in a beaker and dilute hydrochloric acid added to dissolve all carbonate cement. The acid was filtered off and the sediments were washed and put in an electric oven to dry. After drying, each sample was sieved through a 35 mesh Tyler screen to remove the larger pieces. The particles which passed through the 35 mesh screen were then sieved in a ro-tap machine for eight minutes, using a tier of Tyler screens with 48, 65, 100, 150, and 200, mesh to the inch.

Below is a table of size openings of the different Tyler screens.

Meshes to the inch.	Opening in inches.	Opening in millimeters.
35	0.0164	0.417
48	0.0116	0.297
65	0.0082	0.208
100	0.0058	0.149
150	0.0041	0.105
200	0.0029	0.074

Each size collected was weighed to the nearest one-thousandth of a gram for future use in constructing cumulative curves for comparison.

From each sample sieved, the 65-100 size was placed in bromoform ($CHBr_3$), and the heavy minerals allowed to sink. The specific gravity of bromoform (2.89 at 10° Centigrade) is higher than quartz and lower than the ferro-magnesium minerals. Consequently, the quartz will float while the heavier minerals sink. This left the light minerals, mainly quartz, free so they could be mounted in Canada Balsam and studied with a petrographic microscope to determine their roundness and sphericity.

Roundness and Sphericity

The roundness is calculated by using the method described by H. Wadell.*

*Wadell, H., Volume, Shape, and Roundness of Quartz Particles, Journal of Geology, Vol. 43, 1935, p. 267.

$$\frac{\Sigma(r/R)}{N} = P$$

r is the diameter of each corner.

R is the diameter of the inscribed circle.

N is the number of corners in the given plane.

P is the total degree of roundness.

The sphericity is calculated by the use of the formula developed by N. Riley.*

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*Riley, N. A., Projection Sphericity, Journal of Sedimentary Petrology, Vol. II, 1941, pp. 94-97.

$$\emptyset = \sqrt{\frac{i}{Dc}}$$

i is the diameter of the inscribed circle.

Dc is the diameter of the circumscribed circle.

Ø is the total degree of sphericity.

The roundness and sphericity of the quartz grains were measured with the aid of a camera lucida and a concentric circle protractor, which was made of concentric circles with a radius difference of one millimeter. This protractor, first used by G. T. Schmitt and R. L. Erickson, is seen in the tube of the microscope and may be moved about so that all corners of any quartz grain in focus, can be measured. Fifty grains on each slide were measured.

The roundness and sphericity of the quartz grains from locations A-1, A-15, B-3, B-16, and B-30, were measured. The values found are tabulated below.

Location	Roundness	Sphericity
A-1	0.423	0.784
A-15	0.402	0.805
B-3	0.478	0.787
B-16	0.408	0.795
B-30	0.432	0.784

The roundness and sphericity values appear to have little significance as an aid in correlating zones of the Porcupine Mountain formation between the Carp and Little Carp Rivers. They do, however, bring out the fact that the Porcupine Mountain formation is one of widespread divergence as regards roundness increasing consistently with distance from the source. It was noted by megascopic observation that as the size of the particle increased, so did the roundness, but as the size increased, the sphericity decreased.

Sorting

Cumulative curves were plotted for samples from locations A-1, A-13, A-15, A-30, B-3, and B-16, so that the coefficient of sorting could be calculated.

Quartile measurements are widely used in comparing sediments statistically. Three values read from the cumulative curve usually suffice for the computation of the measures needed in comparisons. These are the median and the first and third quartiles.

The median is defined as that diameter which is larger than 50 per cent of the diameters in the distribution, and smaller than the other 50 per cent. To determine the size median, it is necessary to construct a cumulative curve, from which the value can be read directly.

The first quartile is the diameter which has 25 per cent of the distribution larger than itself, and 75 per cent smaller than itself. This value can be read directly from the cumulative curve.

The third quartile is the diameter in the distribution which has 25 per cent smaller and 75 per cent larger than itself. This too, can be read directly from the cumulative curve.

The coefficient of sorting is calculated by the formula introduced by P. D. Trask.*

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*Trask, P. D., Origin and Enviornment of Source Sediments of Petroleum, (Houston, Texas, 1932), pp. 67 ff.

$$So = \sqrt{\frac{Q_1}{Q_3}}$$ where:

So is the coefficient of sorting.

Q_1 is the first quartile measurement. (large size)

Q_3 is the third quartile measurement. (small size)

The size of the sieve openings in the Tyler screens are purposely arranged in geometric progression to decrease the number of sieves needed to analyze a sand. The interval between each consecutive Tyler sieve size used in this study is the square root of two (1.414). Example: Tyler screen number 150 has openings of 0.105 millimeters. The next larger screen, number 100, has 0.105 multiplied by 1.414, or 0.149

millimeter openings.

The values of, "So", are therefore geometric and cannot be compared directly. The logarithms to the base ten, of these values for, "So", are taken to obtain arithmetic values of, "So". These arithmetic values can be compared directly.

The sorting, calculated for the Porcupine Mountain formation, a probably subaerial deposit, were compared with the sorting in the Marshall sandstone of western Michigan, a submarine deposit, calculated by R. A. Hobbs.*

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*Hobbs, R. A., The Application of Roundness and Sphericity Measurements to Subsurface Samples of the Marshall Formation of Western Michigan, Unpublished Master's Thesis, Department of Geology and Geography, Michigan State College, 1949.

	Average, "So".	Log_{10} "So".
Marshall sandstone	1.20	0.0792
Porcupine Mt. sandstone	1.58	0.1987

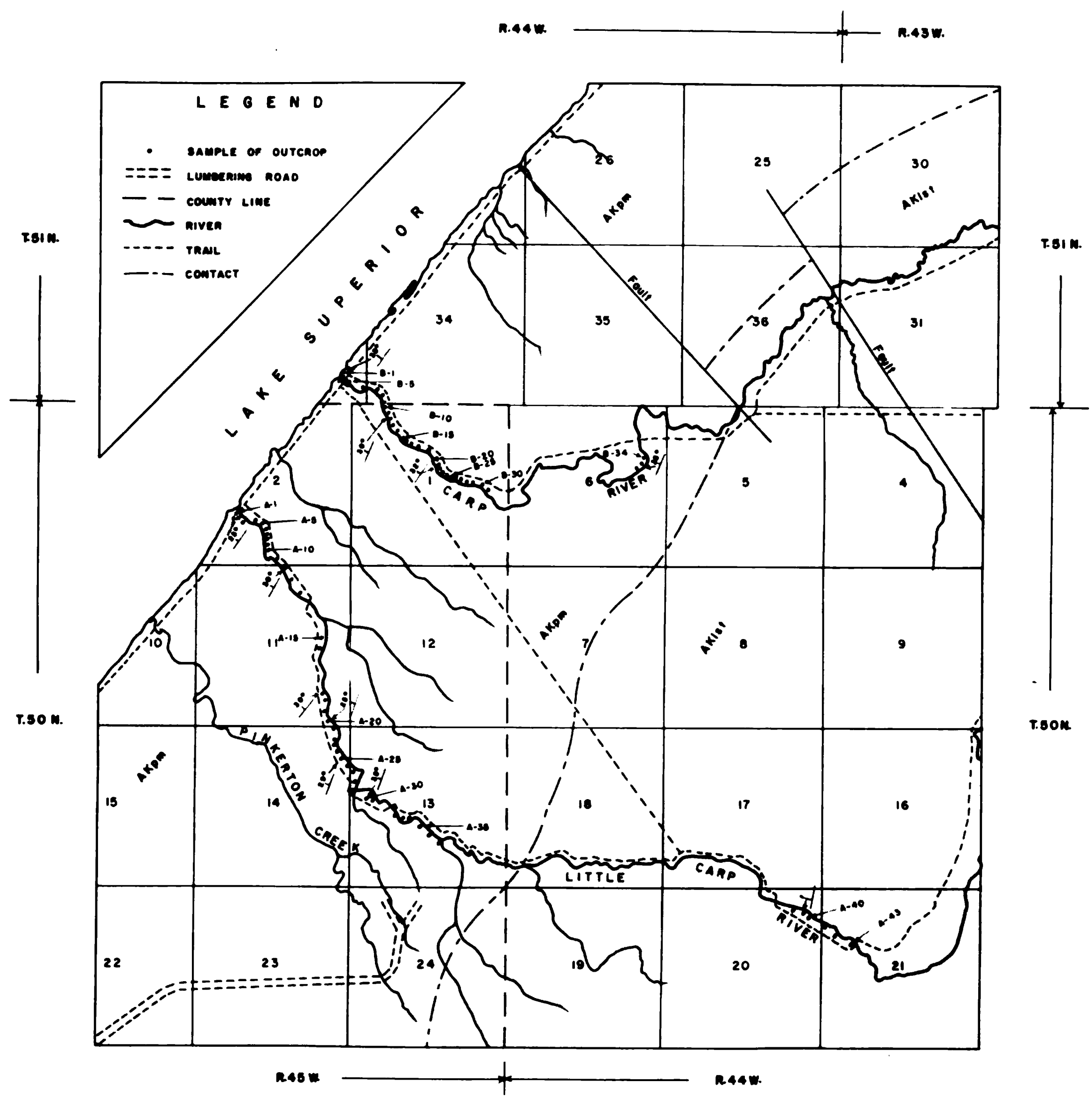
0.1987/0.0792 = 2.508

It is found that the sand in the Marshall formation of western Michigan is 2.5 times better sorted than the sand in the Porcupine Mountain formation. This is in keeping with the fact that a subaerial formation is more poorly sorted than a submarine formation.

The value 2.5 is based on Tyler screen sizes 35 through 200, only. The larger grains were not used in this comparison, to conform with the sizes used by R. A. Hobbs.

If the larger grains had been used in obtaining sorting values of one sand and not another, the two sands could not be compared by this method.

The writer knows that if the larger sand grains, those which did not pass through Tyler screen 35, had been used in determining sorting values of the Porcupine Mountain formation, a much larger value for, "So", would have been obtained.



WESTERN PART OF THE PORCUPINE MOUNTAINS

SHOWING THE AERIAL DISTRIBUTION OF THE PORCUPINE MOUNTAIN FORMATION AND LAKE SHORE TRAPS, THE LOCATION OF TRAVERSES, AND THE POSITION OF SAMPLES

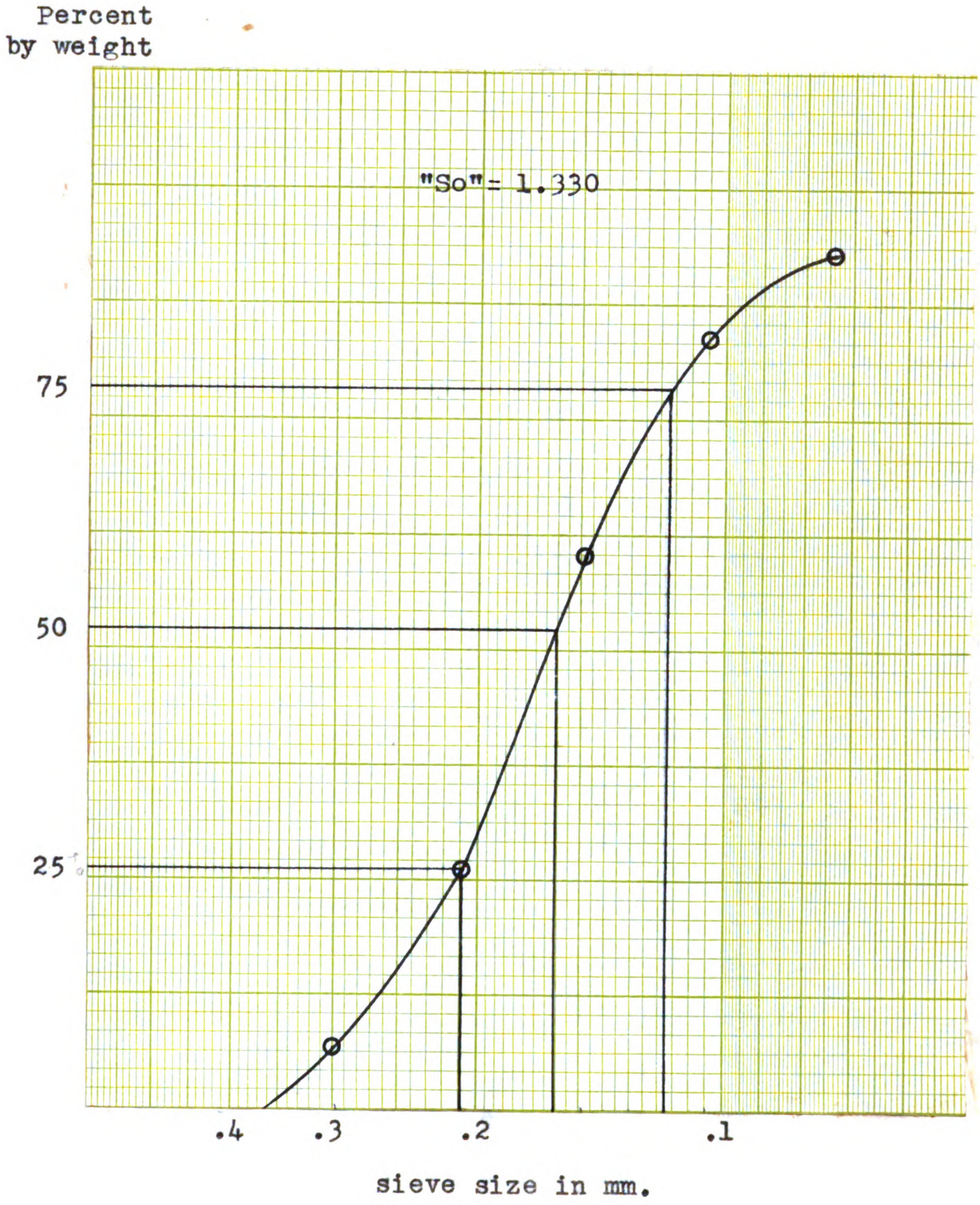
KEWEENAWAN SERIES

AKpm — PORCUPINE MOUNTAIN SS.

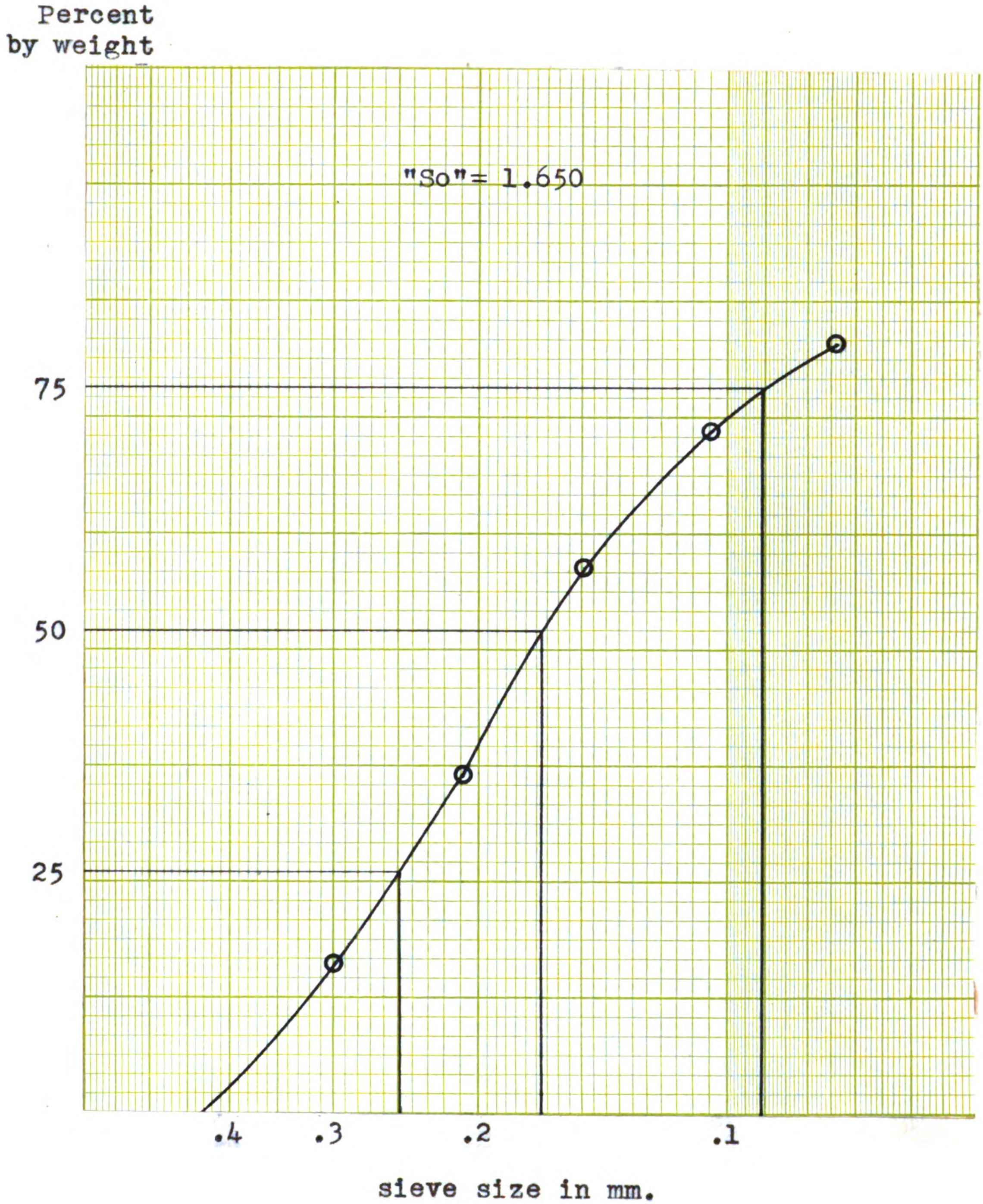
AKlst — LAKE SHORE TRAPS

GEOLOGY AFTER A. C. LANE

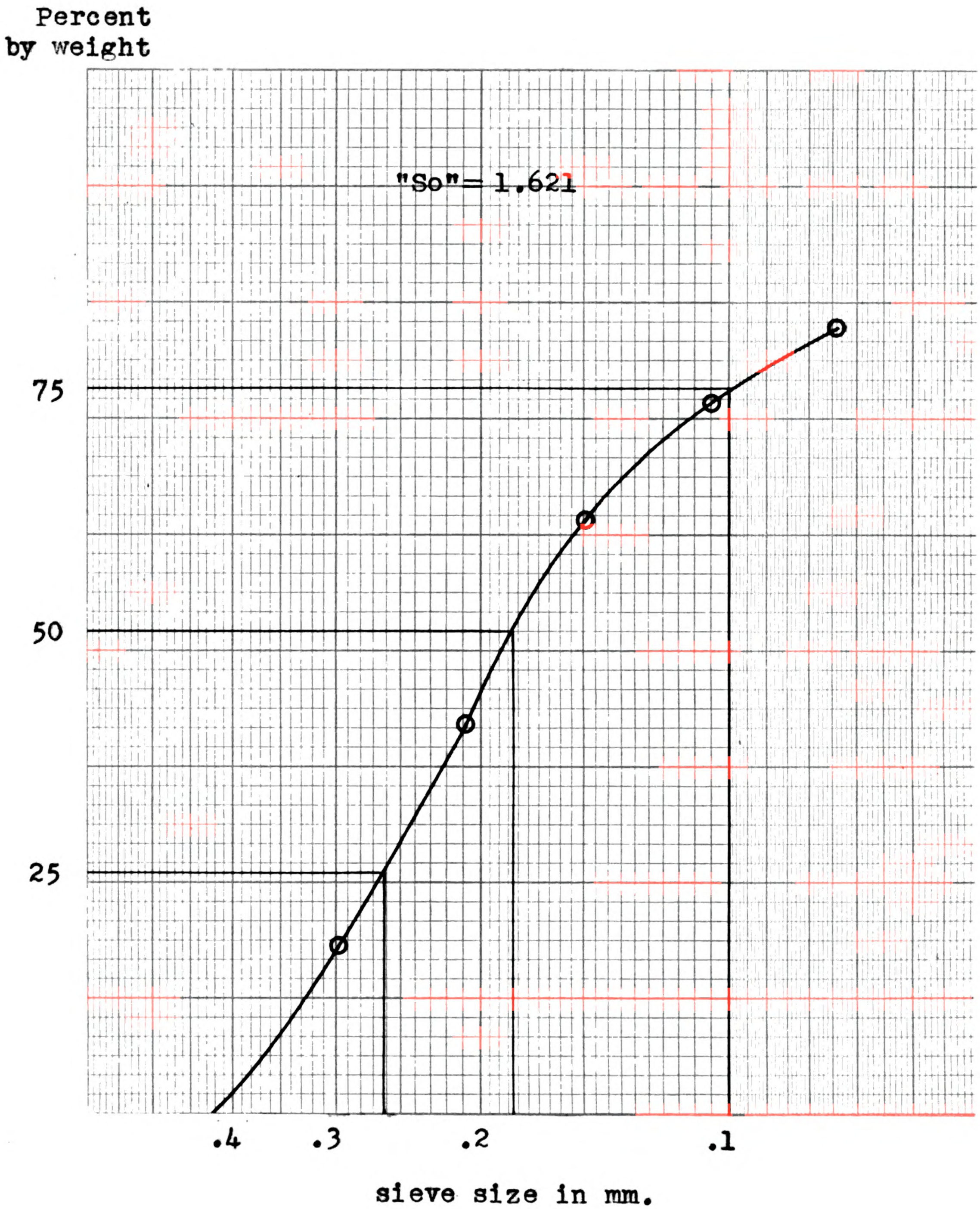
Map II



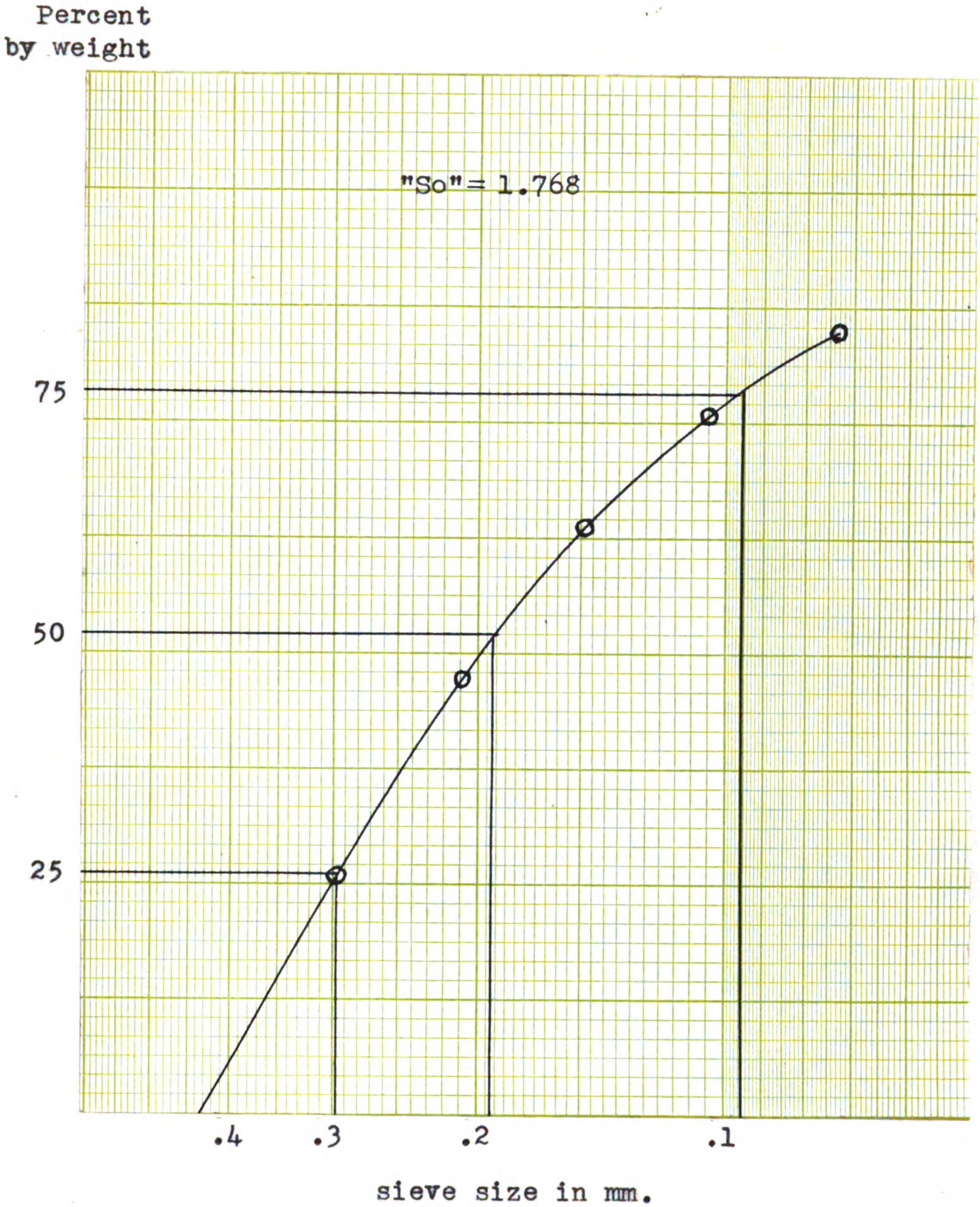
Cumulative Curve, Location A-1.



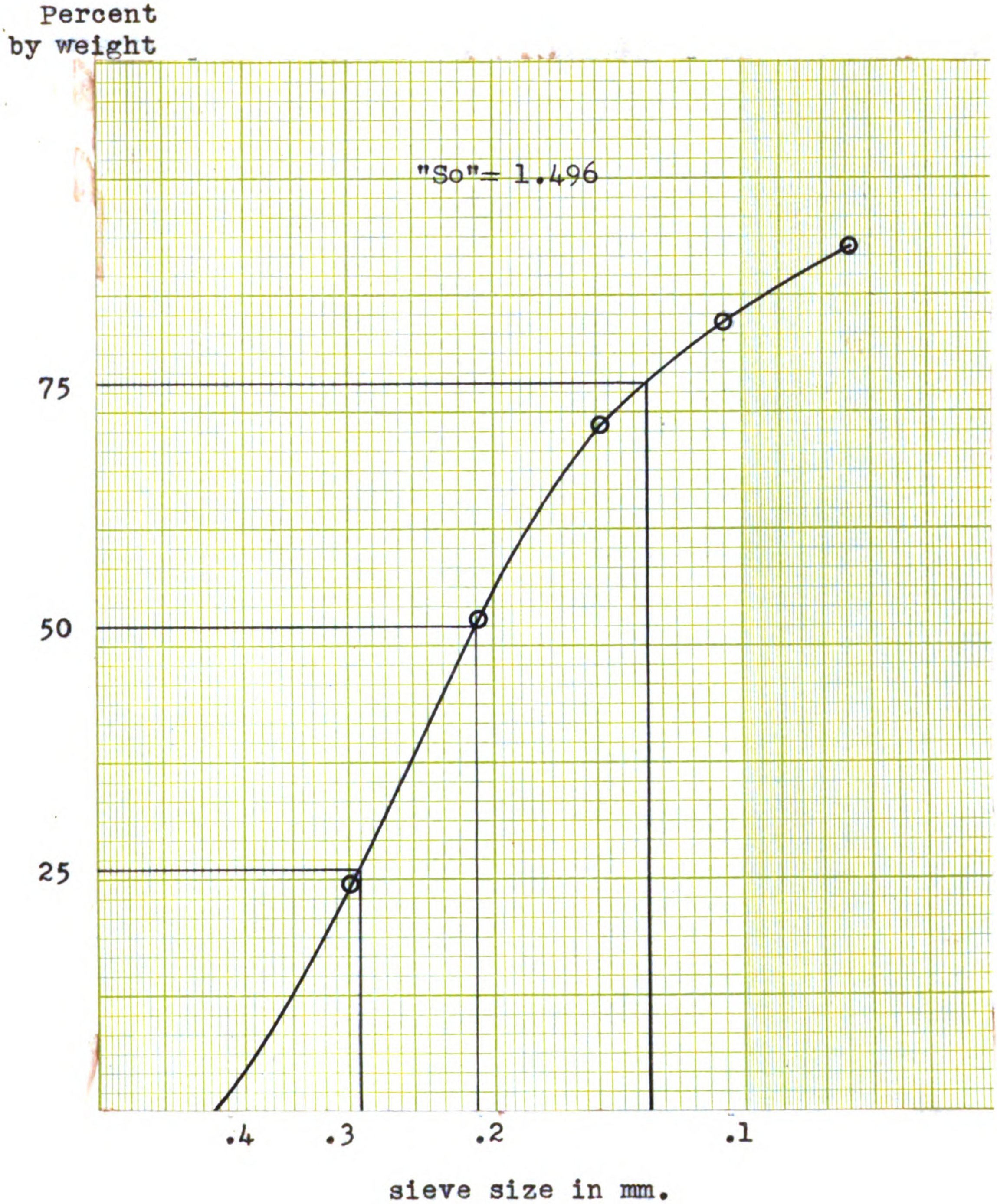
Cumulative Curve, Location A-13.



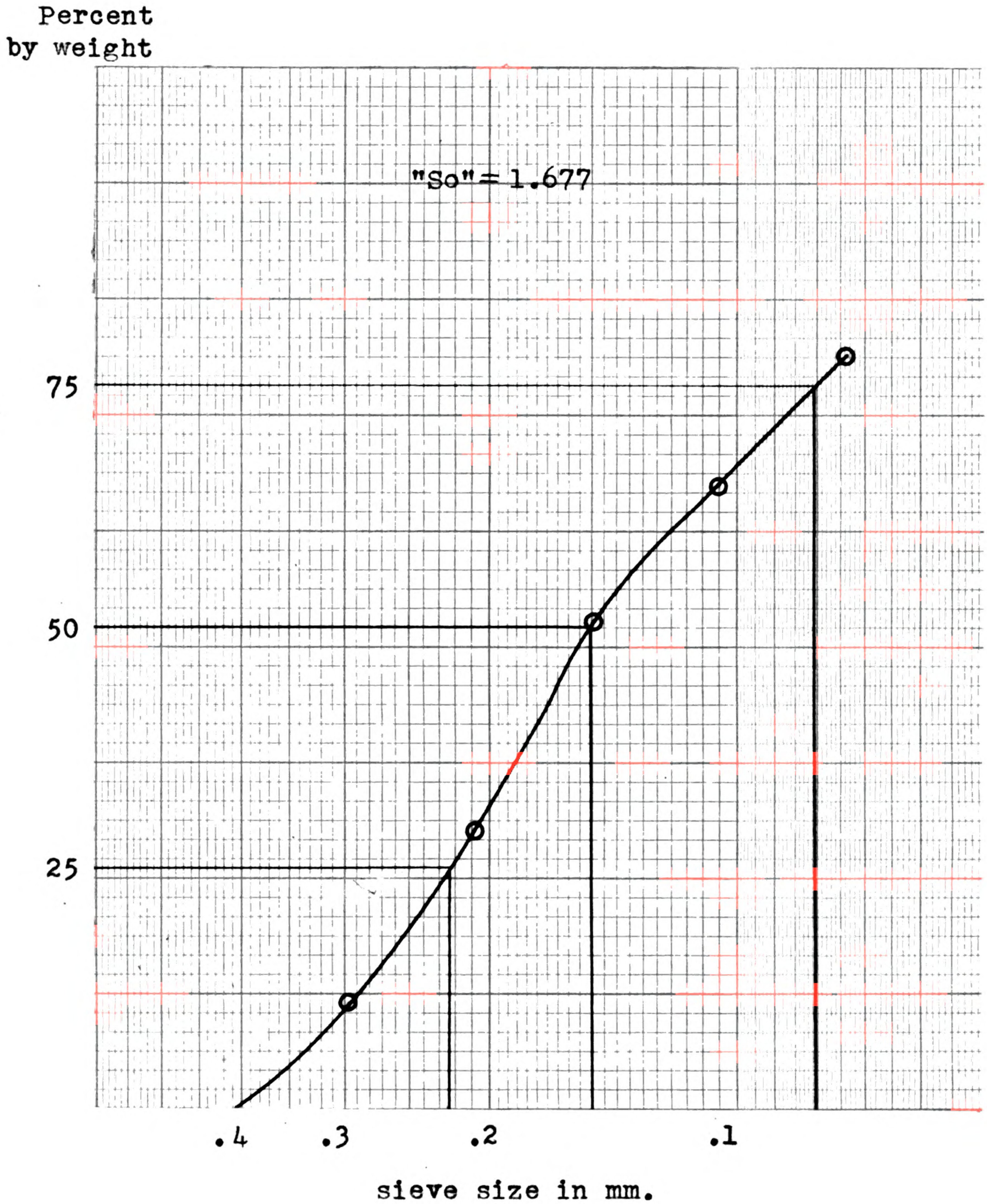
Cumulative Curve, Location A-15.



Cumulative Curve, Location A-30.



Cumulative Curve, Location B-3.



Cumulative Curve, Location B-16.

Petrography of the Porcupine Mountain sandstone

Following, are detailed petrographic descriptions of samples taken from outcrops of the Porcupine Mountain formation, in both the Carp and Little Carp River sections.

Sample A-1

This specimen was collected from an outcrop at the mouth of the Little Carp River.

Megascopic:

The sample is reddish with a uniform fine texture. It is made up of angular fragments and cemented with calcite, which reacts with dilute hydrochloric acid. Quartz and feldspar can be detected with the aid of a hand lens. The red stain, caused by iron oxide, masks the nature of the grains.

Microscopic:

The particles are quite angular and none exceed one millimeter in diameter. The most abundant mineral is quartz, some being cryptocrystalline, while a few other grains have gas bubble inclusions. Most of the quartz shows undulatory extinction. The feldspars are sodic-andesine and microcline, the latter being in lesser amounts. Most of the feldspar is dirty looking because of its alteration into sericite and kaolin. There are a few particles of felsite and minor amounts of chlorite and hornblende. The cementing agent, calcite, may be identified easily, but it is not in the quantity expected from observation of the hand specimen. Magnetite grains and hematite masses are scattered through the slide. The red iron oxide obscures most of the slide and gives it a dirty appearance.

Sample A-13

This specimen was collected from an outcrop in the Little Carp River section.

Megascopic:

The sample is reddish-brown with uniform texture and breaks with an uneven fracture. Quartz and feldspar can be recognized with the aid of a hand lens and are cemented with calcite. The reddish-brown coloration, caused by iron oxide, masks the nature of the particles. One small clay gall was noticeable.

Microscopic:

The texture is uniform and the most abundant mineral is quartz, most of which is quite angular. The feldspars present are orthoclase, andesine, and microcline. The calcite cement and particles of felsite are abundant and scattered throughout the slide. Opaque magnetite and hematite cover the slide and the iron oxide stain gives a dirty appearance to the particles.

Sample A-15

This specimen was collected from an outcrop in the Little Carp River section.

Megascopic:

The rock is deep red and appears almost oolitic. The cementing material is gray calcite, which reacts with dilute hydrochloric acid. Quartz and feldspar can be recognized with the aid of a hand lens. The specimen is stained with iron oxide, which masks the character of the grains.

Microscopic:

The texture is fine and uniform. The most abundant mineral is quartz, some of which show undulatory extinction and are quite angular. There is evidence of secondary quartz growing about the primary quartz grains. The feldspars are microcline, oligoclase and andesine, however, not all the feldspars are altered, a few being very fresh in appearance. There are fragments of felsite and trap rock, the latter showing small amygdules. Occasional particles of chlorite are present. The opaque minerals are magnetite and hematite. The whole slide is colored with red iron oxide.

Specimen A-23

This specimen was collected from an outcrop in the Little Carp River section.

Megascopic:

The specimen is reddish-brown and has a uniform texture. Clay galls are numerous and reach the size of two by two by one-tenth centimeters. These clay galls have a darker color than the sandstone and are orientated parallel to the bedding planes of the sandstone. The weathered surface penetrates about three-tenths centimeter into the exposed portion, and is quite porous. The sandstone is made up of angular particles, all probably under one millimeter in diameter. The calcite cement reacts with dilute hydrochloric acid, while the clay galls do not. Particles of quartz and feldspar can be recognized, but the coloring caused by iron oxide masks the nature of the grains.

Microscopic:

The texture is uniform and the particles are not well rounded. The most abundant mineral is quartz, most grains of which contain gas bubble inclusions. Some grains are of cryptocrystalline quartz, which appear exactly like the quartz in the rhyolite, found near Mirror Lake. Some felsite particles are present. The feldspars are oligo-andesine and microcline, the latter being in minor amounts. All the plagioclase has a dirty appearance due to its alteration into sericite and kaolin. Calcite, the cementing agent, displays abundant parallel lines due to repeated lamellar twinning. Chlorite is present in minor amounts and opaque magnetite and hematite dot the thin section. The whole slide is covered with iron oxide, masking the characteristics of most minerals. One very fine-grained clay gall runs the length of the slide.

Specimen A-30

This sample was collected from an outcrop in the Little Carp River section.

Megascopic:

The specimen is reddish-brown with some gray calcite cement showing on the freshly broken surface. The texture is coarser than in the other specimens already described, and all the grains are quite angular. Some of the particles have diameters up to three millimeters. The weathered surface is darker and more porous than the fresh surface.

Microscopic:

The larger particles are more rounded than the smaller ones. The most abundant mineral is quartz. The feldspars are microcline, orthoclase, and andesine, which are generally dirty in appearance because of alteration into sericite and kaolin. Throughout the slide are particles of felsite and grains of magnetite. An occasional small piece of augite can be seen. The whole slide is covered with iron oxide, which obscures portions and gives a reddish color to the thin-section. The calcite cement is not too apparent.

Specimen B-3

This specimen was collected from an outcrop near the mouth of the Carp River.

Megascopic:

The sample is reddish-brown and has a uniform texture. Bedding planes range from one to three inches in thickness. The particles are of all diameters, up to about one millimeter. The most abundant mineral is quartz, although feldspar can be seen. The calcite cement reacts with dilute hydrochloric acid and is present in sufficient amount to give a gray tinge to the freshly broken surface.

Microscopic:

The particles are not well rounded and the most abundant mineral is quartz, some grains of which are quite angular. A few quartz grains contain gas bubbles, which seem to be arranged in definite rows. Some felsite particles are present. The plagioclases are andesine and oligoclase, most of which has begun to weather. There are occasional particles of microcline and hornblende. Magnetite and hemetite are present in large quantities. The slide is covered with iron oxide, giving a reddish appearance to, and obscuring portions of, the thin-section.

Specimen B-16

This specimen was collected from an outcrop in the Carp River section.

Megascopic:

The rock is reddish-brown and has two distinct types of texture, fine and very fine. The part composed of very fine grains is much lighter in color than the part composed of fine grains, the latter being a small lens. The lighter, finer sediments react slightly, while the darker, coarser sediments react readily with dilute hydrochloric acid. The few clay galls present are in random orientation. The weathered surface displays a darker color and more porosity because the calcite cement has been dissolved. Quartz and feldspar can be recognized with aid of the hand lens.

Microscopic:

Most of the grains are angular, but vary somewhat in size. The most abundant mineral is quartz. The feldspars are orthoclase, microcline, and andesine, all of which are quite fresh. A small amount of hornblende is present. The opaque minerals are magnetite and hematite. The whole slide has a reddish appearance due to iron oxide.

Specimen B-30

This specimen was collected from an outcrop in the Carp River section.

Megascopic:

The rock is reddish-brown and has a fine, uniform texture. Bedding planes in the hand specimen are about two centimeters apart. The particles are of variable diameters up to one millimeter. The freshly broken surface shows a tinge of gray due to the calcite cement. The cement reacts with dilute hydrochloric acid. Parallel to the bedding planes are streaks, up to two millimeters in width, which have a darker color due to slightly more clay material. Quartz and feldspar can be determined with aid of the hand lens.

Microscopic:

The slide shows a very fine texture, the rock being composed of small, angular particles. The most abundant mineral is quartz, some of which contain gas bubble inclusions. Some felsite particles are present. The plagioclase is andesine, of which some is slightly weathered. One grain of microcline and a few slivers of mica were noticed. The slide is covered with iron oxide, giving a reddish appearance to, and obscuring portions of, the thin-section.

PLATE I

Fig. 1, Little Carp River Flowing into Lake Superior.

Fig. 2, Flooded Carp River Flowing into Lake Superior.

PLATE II

Fig. 1, Waterfalls in Porcupine Mountain formation at location B-31, in Carp River.

Fig. 2, Same falls as above, after a heavy rain.

PLATE III

Fig. 1, Large outcrop of coarse conglomerate lens, near mouth of the Carp River.

Fig. 2, Thin-bedded sandstone at location B-17, along Carp River.

PLATE IV

Fig. 1, Location A-5, in Little Carp River. The dip of the sandstone beds is noticeable.

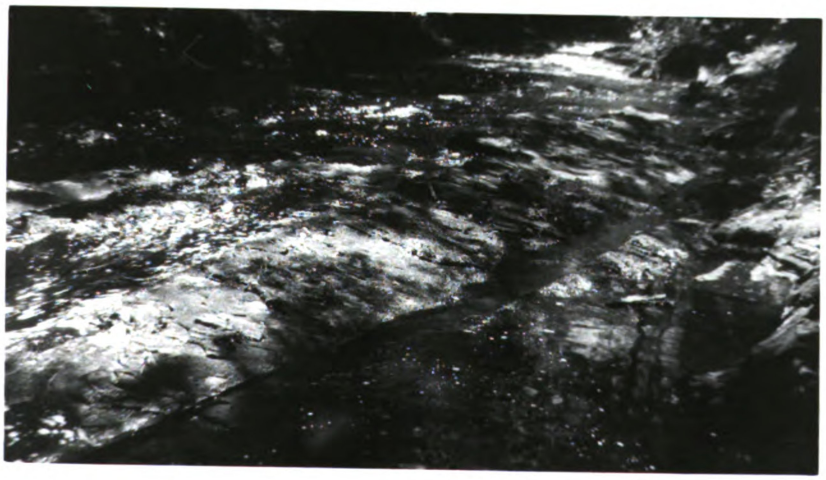


Fig. 2, Between locations A-19 and A-24, in the Little Carp River. Note how the strike of the beds can be easily recognized.

CONCLUSIONS

The conclusions reached, in detailed study of the Porcupine Mountain formation, are not exactly what the writer expected before he began the field work.

Since this sedimentary formation is composed essentially of fine-grained sandstone with a few conglomerate lenses, the name Outer Conglomerate, given by Irving in 1883, is not appropriate. The writer refers to this sandstone as the, Porcupine Mountain formation, which is in keeping with naming formations after localities, and does not give a false impression as to the lithology of the formation.

The sandstone and conglomerate beds lie conformably on the older, Lake Shore Traps. Both formations strike essentially N. 20 E. and dip to the northwest, with the dip increasing as the Lake Shore Traps are approached. The average dip is 27.5 degrees. See Diagram I.

Roundness and sphericity measurements taken on samples from both the Carp and Little Carp River sections, do not conform to the idea, advanced by many students of sediments, that sand grains become more rounded and less spherical as they are carried away from their source. These roundness and sphericity measurements do not conform to the above idea because the lateral distance in which outcrops occurred is too short, and this is a probable subaerial deposit. Also, these measurements give no clue as to the direction from which the sediments were derived and could not be used to determine, or correlate, different members of the Porcupine Mountain formation.

Poor sorting is typical of a non-marine formation, however, exceptions do occur, such as wind-blown sand. It was found that the Marshall formation of western Michigan is 2.5 times better sorted than the Porcupine Mountain formation. Because the Porcupine Mountain formation is poorly sorted and because numerous clay galls are imbedded in the sandstone, the writer feels certain that this formation is of subaerial origin. Clay galls are dried mud flakes which have been blown into the sediments immediately prior to diagenesis. The writer fails to visualize how clay galls could be blown out to sea and preserved. They would be destroyed in the process.

From the study of thin-sections of the Porcupine Mountain formation, it can be said that the sediments were derived, in part, from the weathering of the rhyolite which outcrops near Mirror Lake. Thus, the sediments must have come from the southeast. The occurrence of two plagioclases, andesine and oligoclase, suggest an origin from two different igneous masses.

The writer was unable to subdivide the Porcupine Mountain formation on the basis of lithology, roundness, or sphericity. Consequently, no beds or members were correlated between the Carp and Little Carp Rivers.

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