WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY
Edw. A. BIRGE, Director Wm. O. HOTCHKISS, State Geologist

BULLETIN NO. XXXIV ECONOMIC SERIES NO. 16

LIMESTONE ROAD MATERIALS

OF

WISCONSIN

BY

W. O. HOTCHKISS AND EDWARD STEIDTMANN

MADISON, WIS.
PUBLISHED BY THE STATE
1914

Wisconsin Geological and Natural History Survey

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By W. O. Hotchkiss.

INTRODUCTION.

One of the important and interesting developments of the past few years has been the almost unbelievable awakening of public interest to the importance of country roads. Ten years ago when this survey desired to treat of the use of the road building materials of the state the bulletin published was necessarily confined to a discussion of city pavements. At that time a bulletin of the character of this one would have been of little value, as nowhere outside of cities were stone roads being built to any extent. In 1906 the survey issued a bulletin on "Rural Highways", which was widely distributed in the state. In connection with other developments this gave sufficient stimulus to the good road movement so that the legislature of 1907 appropriated $10,000 a year for the purpose of furnishing the local people with expert assistance and advice in spending their road and bridge funds. This work was carried on by the highway division of this survey for four years, by which time the public interest in roads had greatly increased. The legislature of 1911 passed a law giving state aid for road building and creating a state highway commission to take charge of the work. The state geologist was made a member of this commission, ex-officio.

The appropriation by the state for highway purposes was only $10,000 a year for the four years from 1907 to 1911. In 1912 it was about $400,000, in 1913 it was over $850,000, and for 1914 it is $1,230,000. The vast amount of work done in improving country roads in Wisconsin can be appreciated when it is remembered that the amount appropriated by the state is less than one-third of the total amount spent for state aided roads.

This report is published for the purpose of helping to conserve the expenditure of these vast sums. It is realized that the largest single item of expense of constructing roads is the stone, and that

the quality of stone and the manner of construction are the chief factors determining the life of a road after it is once completed. Much money has been wasted and some will doubtless be wasted in the future because the local officials do not properly appreciate these facts. Care in construction can easily double the life of a road, as has been demonstrated by experience. Roads have been constructed of the same material in similar circumstances in the same neighborhood, one of which needed rebuilding in 2 years and the other of which needed little repair in 6 years. The quality of stone has also been proven by experience to be of similar importance. The stone, delivered on the road, usually represents two-thirds or more of the total cost of the road. Stone of proper quality will in many cases cost but slightly more than inferior material—in general being not more than 1/7 to 1/5 in excess. This increased investment of 10% to 14% of the total cost of the road will oftentimes result in adding 50% or more to the life of the road—which makes the consideration of the quality of the material to be used a matter of obvious importance, and especially so when the expenditure of millions of dollars is under way.

The principal labor of preparing this report and all the field work of examining quarries and collecting samples for test was done by Mr. Steidtmann. The tests were made by the U. S. Department of Agriculture in the laboratory of the Office of Public Roads. The State Highway Commission assisted in the work by paying a small part of the expense.

GENERAL CHARACTERISTICS OF WISCONSIN ROAD MATERIALS.

Wisconsin is exceedingly fortunate in having a great abundance of road material. There are few states in the Mississippi Valley which have road material of a satisfactory character so widely distributed. Nearly every county in the state has within its boundaries material that will serve for the construction of the major portion of its roads. The saving in expense that this natural distribution effects cannot be estimated, but it is apparent that at present, and always in the future, it will be possible to build roads more cheaply in Wisconsin than in most of the neighboring states where material must be shipped long distances.

The road materials of Wisconsin consist of gravel and field stone, limestone, granite and trap rock, sandstone and quartzite. There is great variation in the quality of these materials. Some limes-

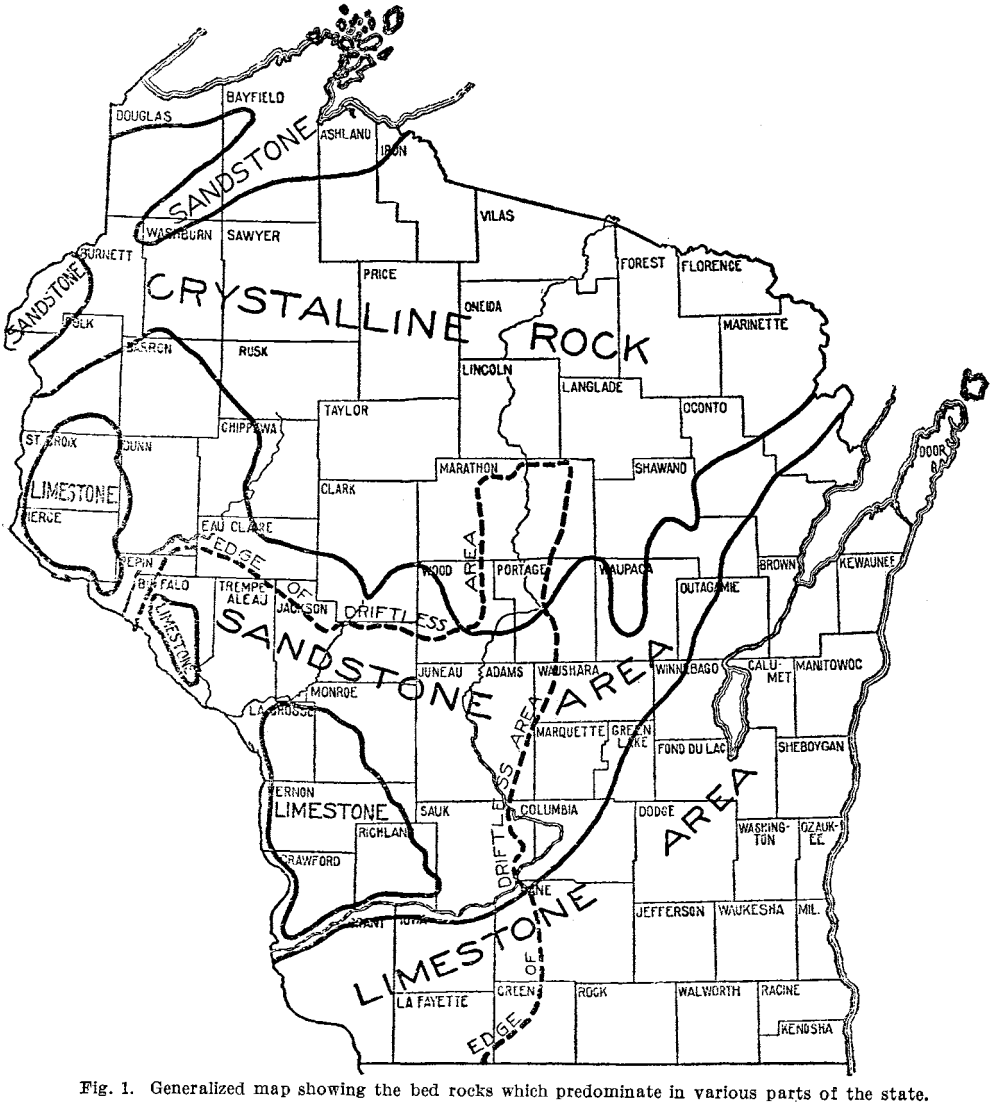


Fig. 1. Generalized map showing the bed rocks which predominate in various parts of the state.

tones of the state are absolutely unfit for use on the roads; others can be used only with very careful treatment in construction, but most of them make a satisfactory road material. The granites and trap rocks also vary greatly in character, but all are good. The most variable road material in the state, and one of the most valuable, is the gravel. This material is so extremely diverse in character that the method of treatment adapted to material from one end of a single pit may not be at all suitable for material from the other end. Furthermore, there are no satisfactory laboratory tests for gravels.

Of the solid rocks of the state the limestones are probably the most diverse in character, and as the limestones furnish by far the greatest amount of crushed stone for road purposes, this bulletin will consider in detail only the limestones of the state.

Distribution: The road materials of Wisconsin are widely distributed. The accompanying outline map of the state, figure 1, shows the areas in which the various kinds of material are to be found. The limestones occur as a broad belt along the eastern side of the state, swinging westward across the southern part of the state and extending up the western side as far as the southern part of Polk county. The sandstone area makes a similar belt lying inside of the limestone belt. The sandstone also occupies areas in the northwestern part of the state. That part of the state lying north of a line drawn through Chippewa Falls, Neillsville, Grand Rapids, Waupaca and Shawano is for the most part underlain by crystalline rocks, comprising granite, trap rock, gneiss and schist, with some slate, quartzite and other sedimentary formations.

The dotted line on the accompanying map marked "Edge of Driftless Area" shows the extreme extent of the great continental glaciers in Wisconsin. It is thus seen that the whole state was covered by the glaciers except the southwest quarter. Everywhere in the glaciated area field stone—bowlders—and gravel are found more or less abundantly.

Origin: The granites, sandstones and limestones, and metamorphic rocks, make up what are known as the solid rocks, which constitute the body of the earth as far down as men have gone with mines or penetrated with drills. The granites and trap rocks were once in a molten state and on cooling crystallized into fine-grained or coarse-grained rocks, depending upon the conditions at the time of solidifying. These igneous rocks, while in their molten condition, for the most part welled slowly upward toward the surface of the earth, intruding the older rocks, remnants of which now occur as schist and gneiss.

Associated with the granite and trap rocks are what are known as metamorphic rocks. The sum of all the processes that go to change the original character of rocks, such as heat and pressure, dissolving and redepositing of material, is known as metamorphism, and the rocks which have been greatly changed by these processes are known as the metamorphic rocks. Originally the metamorphic rocks may have had any origin. They may have been sands or muds or limestones or igneous rocks. By the processes of metamorphism the sands were completely cemented and have become quartzites, the muds by pressure and recrystallization have developed into slates, schists, and some of the volcanic rocks and other igneous rocks have also developed into gneisses and schists.

The two groups of rocks known as igneous and metamorphic make up the crystalline rocks of the northern portion of the state and form the base upon which have been laid down the horizontally-bedded sandstones and limestones of later ages. At various places in the southern part of the state old mountains of these rocks project far above the old crystalline base and are not covered by the flat-lying beds. They are found at the surface at Baraboo and in the region about Berlin and near Waterloo.

The greater part, if not all, of the old surface of igneous and metamorphic rocks was covered by the sea and a series of sediments deposited upon it by the waters. The oldest of these flat-lying sediments, known as the Potsdam sandstone, makes the great sandstone belt of the central portion of the state. Overlying this are chiefly limestones, the order of succession being given in the accompanying geologic column, figure 2.

After the deposition of these flat-lying sediments the material was consolidated into rock. Finally the state was lifted above the waters of the sea and the rain began its regular work of washing the material back to the sea. The waters that fell as rain gathered themselves into streams, which gradually in the course of time cut valleys and eroded away great portions of the material that had been deposited.

When rocks are exposed above water the leaching of the rain begins to change their character. The granites slowly disintegrate into a mixture of sandy clay; the grains of sand that make up the sandstones become loosened from each other and a mass of loose sand results; the soluble parts of the limestones are dissolved by the rain and the insoluble parts remain. In this way, from the solid rocks, there is developed what is known as a residual mantle. This can be seen anywhere in the southwest quarter of

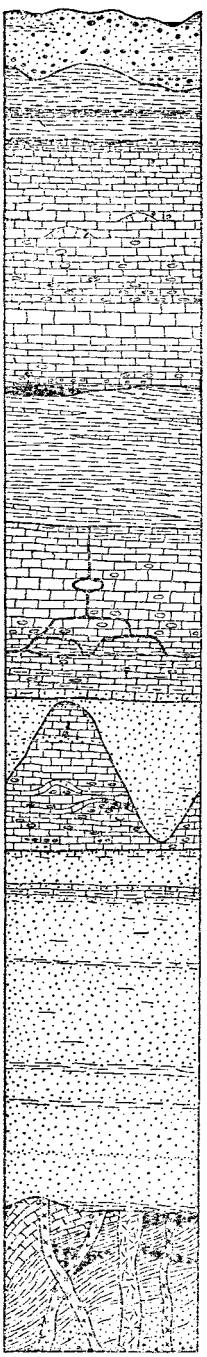
Formation Name.	Section.	Character and Thickness	Economic Products.
Glacial Drift.		Loose till, sand, gravel and boulders. Depth from 0-600 feet.	Sand, clay, gravel.
Milwaukee Cement Rock.		Shales and limestones. From 0-138 feet thick.	Natural cement rock.
Niagara limestone.		Hard, yellowish, gray to blue and white limestone; usually quite pure but some beds contain chert and other shaley impurities. Shaley beds locally at top. Iron ore and red beds locally at base. Thickness 450 to 800 feet.	Building stone, crushed rock, flux, lime, iron ore, mineral spring water.
Richmond, Maquoketa, or "Cincinnati" shale		Blue or green clay shale with shaly limestone and sandy beds. Thickness 165 to 240 feet.	Brick clay.
Galena limestone and Trenton (Platteville) limestone.		The Galena is coarse grained, impure, locally cherty. Shaly at base. 125 to 250 feet thick. The Trenton is a buff to blue limestone, in places cherty. Sandy at base. Thickness 40 to 120 feet.	Lead and zinc ores, road material, lime, building stone.
St. Peter sandstone.		Soft sandstone of various colors. Hardened at surface. Iron nodules common.	Water, sand, and some building stone.
Shakopee-Oneota "Lower Magnesian Limestone."		Coarse, irregular, sandy, flinty, and clayey limestone. Thickness 40 to 250 feet.	Crushed rock, building stone, lime.
Cambrian or "Potsdam" sandstone.		Includes a series of sandstone shales, and limestone. Sandstones are usually soft and light colored. Thickness 700 to 1,000 feet.	Building stone and sand, water, iron ore.
Pre-Cambrian, ancient, sedimentary, metamorphic and igneous rocks.		Includes shales, sandstones, traps, quartzites, limestones, slates, iron ores, gneisses, schists and granites.	Paving blocks, ornamental and building stone, copper, iron ore, crushed stone.

Figure 2.—The geologic column of Wisconsin.

Weathering of Lower Magnesian limestone to soil on top of Mill Hill west of Sauk City. The irregular bedding characteristic of a large part of the Lower Magnesian limestone is shown. The upper beds are frost broken and grade into the soil above, which largely represents the insoluble portions of the limestone.

Limestone exposed in a ravine. Such exposures are characteristic of southwestern Wisconsin. The cut shows thin-bedded, compact Trenton limestone in a small ravine on the north banks of the Rock river about ½ mile up stream from Indian Ford. The storm water which flows through this ravine is deepening it by carrying off block after block of stone.

the state that was not covered by the glaciers. The rain and the streams are continually washing away more or less of this residual material so that a comparatively slight thickness accumulates. The soils of the limestone area in Grant, Iowa, and LaFayette counties are seldom more than a few feet in depth. Plate 1. (A) shows the way in which the limestone disintegrates to form the mantle of residual material that covers it.

This decaying of the rocks and gradual erosion went on for geological ages after the state was lifted above sea level. The area was completely carved by the streams, so that there were no lakes nor swamps anywhere within its boundary. The streams had cut deep valleys that drained everything, just exactly as the streams in the driftless area at the present time completely drain that section of the state. The difference in elevations between the hilltops and the valley bottoms over the whole area were doubtless much the same in magnitude as are found in the southwest quarter of the state at the present time.

Over this area, there advanced great glaciers from the northeast and northwest. As these ice sheets advanced they carried within their mass great quantities of rock and sand and clay, which they had picked up along their course. As they advanced over Wisconsin they plowed off the hilltops to some extent and filled up the valleys to a much greater extent, picking up such of the residual mantle as happened to be conveniently situated and depositing a part in the lower places and riding on over it. At the front of the ice there was of course continual melting. The material in the melted ice was deposited there in great heaps of unassorted material, which make the moraines, or was carried out from the glacier by the streams produced from the melting. Where the material was carried by the streams the coarse material was deposited not far from the front of the ice. The sands and smaller gravels were carried somewhat further, and the clay and other fine materials were carried great distances.

As the ice pushed forward in its advance it rode over these deposits planing them off, and again picked up portions of them and carried them on, so that the material was worked over probably many times both by the ice and by water. This ground most of the soft decayed portions into fine powder and left the harder portions as pebbles and bowlders. Near the extreme edge of the ice sheet, where it halted a very long time, there were left great deposits of sand and gravel, such as those at Janesville and Beloit, that were beautifully assorted by the waters issuing from the gla-

ciers. In other places the glaciers left great quantities of bowlders, chiefly of granite and trap in the northern portion of the state and of granite and trap and limestone in the southern and eastern parts of the state.

This glacial material, both that deposited by the water and left in a stratified condition, and that dumped in irregular fashion, either as moraine or bowlder clay, makes up the mantle rock which covers the glaciated area. In places this glacial mantle reaches a tremendous thickness. The deep pre-glacial valley of the Rock River at Janesville was filled to a depth of 500 feet in places. The large pre-glacial stream channel at Madison is known to be between 300 and 400 feet below the present surface of the ground.

The Occurrence of Outcrops: This is an important matter in connection with finding stone for road building. It will be appreciated from the foregoing description that outcrops of rock in the unglaciated part of the state are much more common than in the glaciated portion. The mantle of residual material never became so deep as to bury the rocks as they are buried by the glacial material. In the driftless area the limestones outcrop commonly in two ways. By looking at the geological map of Sauk county, plate XXVIII, it will be seen that the Lower Magnesian limestone caps the hilltops and that the rock below is the soft Potsdam sandstone. The sandstone is more rapidly weathered away than the limestone, and as a consequence, the limestone forms a protecting cap to the hills. It is likely to outcrop in more or less thin layers, about the edges of which will frequently be found cliffs, as shown in B, plate XXIX, page 108. In Grant county and in the counties to the east of it the streams cut practically their whole channels in the limestone. Here the outcrops occur not as protecting caps to the hills, as there was in general no softer rock exposed below to be eroded more rapidly, but along the stream valleys where the rapid erosion of the water has cut away the covering mantle of residual material. An outcrop of this sort is shown in figure B, Plate 1. In the drift-covered area outcrops are not at all consistent in their locations, as they are in the driftless area. An outcrop may occur one foot below the bed of a swamp, while the hills around it are all of drift, or one may be found in the top of a hill while the swamp may have 300 or 400 feet of glacial drift below it before the solid rock is reached. In the well settled parts of the state many of the easily reached ledges have been opened to secure building stone for farm use and there is no difficulty in finding them.

The files of this survey contain maps showing all the outcrops

Burkhardt Falls on the Willow river below Burkhardt's mill in St. Croix county. They are about 50 feet high and fall over ledges of Lower Magnesian limestone. It resists the cutting action of the stream better than the friable Potsdam sandstone which forms the river's bed farther down stream, and so has caused the development of the falls.

Looking up stream from the hills above Trempealeau on the Mississippi. The cone-shaped peaks and flat-topped ridge on the right are capped by Lower Magnesian limestone. The lowlands are underlaid by the more easily eroded Potsdam sandstone.

in Sheboygan, Fond du Lac, Green Lake, Columbia, and the eastern halves of Dane and Green counties, and all the region east and south of these. If it is desired to know just where outcrops may be found near some particular piece of road, this information will be furnished the county highway commissioner on application.

Testing of Road Materials: In order to have a means for definitely comparing the worth of various rocks for road building, it is necessary to have tests that can be expressed numerically. Tests of stone for road building are useful and significant but they are not entirely satisfactory and in interpreting them we must always use good judgment and remember that the best test of any road material is practical use under circumstances similar to those in which it is planned to use it.

The tests applied to road materials attempt to reproduce on a laboratory scale the destructive agencies to which a road is subjected by traffic. For instance, the hardness of the material is tested to see how it will be able to withstand the friction caused by the rubbing of the stones in the road against each other and by the turning and twisting of traffic. The toughness is tested in such a manner as to determine as nearly as possible the ability of the stone to withstand blows without fracturing, such as from the shod feet of horses. The tests made to determine the cementing quality are planned so as to give as nearly as possible the degree to which the dust worn from the larger pieces will cement them together.

One serious difficulty with the ordinary tests of road material is the difficulty of securing samples for testing purposes which represent accurately the large body of stone which the test purports to represent. As an instance of this, the tests on the Niagara limestone from Hamilton, Fond du Lac county, may be cited (see table I). Samples selected from the same quarry by different persons shows a difference in percentage of wear of practically 50% and yet the Niagara limestone is one of the most uniform limestones we have in the state. This illustration is not cited for the purpose of discouraging the testing of stone but rather for the purpose of emphasizing the necessity of careful selection so that the material sent to be tested may represent as accurately as possible the quality of the stone in the quarry face to be worked.

In collecting samples to be tested for this report the specifications of the Office of Public Roads of the U. S. Department of Agriculture were followed. Each sample consisted of fragments that would pass through a 3″ ring but not through a 1½″ ring, with one piece, approximately 4″x6″x3″. The whole sample weighed not

less than 30 pounds. This sample was taken so as to represent as well as possible the whole quarry face or the whole outcrop from which the material came. This sample was sent to the Office of Public Roads for testing. On the small pieces tests of abrasion, cementation, weight per cubic foot and water absorption were made. From the single large piece samples were taken with a core drill for making the hardness and toughness tests.

It may be well to state at this point that the Office of Public Roads tests material free of charge, providing the samples are shipped freight or express prepaid. Anyone desiring to have tests made should write to the Office of Public Roads at Washington, D. C. for detailed instructions for selecting samples and shipping them, and anyone interested in the testing of rock should not fail to secure their publication dealing with this matter. These publications are distributed free of charge.

One of the most important factors entering into the successful building of a road is the selection of material so that the surface of the road when finished will be exactly fitted to the traffic. The ideal rock is one from which just sufficient fine material will be worn by traffic to keep the larger pieces cemented together. If rock is too hard the traffic will not wear off sufficient fine material to replace that blown or washed away, the stones will become loosened and the road will "ravel." If the stone is too soft, so much material is worn off by the traffic that it makes deep dust or mud. The above statements are made with the fact in mind that the road is properly constructed, for it is quite easy to build a road of material that is really too soft and yet leave it in such shape that it will "ravel." Some of the softer limestones of Wisconsin are no more suited to roads subjected to heavy traffic than the hard granites are suited for construction of side roads on which there is practically no traffic. In either case it is impossible to make a road that is properly durable.

Before proceeding to a detailed description of the tests, made by the Office of Public Roads it is desirable to emphasize again the fact that the test of a road material is actual use. If stone from the quarry in mind has been used locally and has given good satisfaction, there need be no hesitation about using it again without regard to what laboratory tests show. If, however, the stone has proven too soft or too low in cementing quality, it is unsafe to use it, even though laboratory tests may give results that would indicate that the stone would be satisfactory. Actual use in the road is the only *absolutely conclusive* test of stone for road material.

TABLE I.

Road Tests on Wisconsin Limestones.

NOTE.—Samples not given Highway Commission numbers are tests made on samples sent to the Office of Public Roads by quarry owners.

Locality.	Quarry Owner.	Wis. Hy. Com. sample Nos.	Office Public Roads Sample No.	Formation.	Specific Gravity.	Wt. in lbs. per cu. ft.	Pounds water absorbed per cu. ft.	Per cent of wear.	French coefficient of wear.	Hardness.	Toughness.	Cementing Value.	Fitness.
Brown County—													
Greenleaf	Greenleaf Stone Co	84	6542	Niagara	2.75	172	2.30	3.0	13.3	14.8	8	Good	Light traffic.
Calumet County—													
Brillion	Union Lime Co	82	6504	Niagara	2.65	165	1.35	7.5	5.3	12.2	5	Good	Light traffic.
Columbia County—													
Columbus	City of Columbus	57	6161	Trenton	2.65	165	2.75	5.7	7.0	12.7	3	Good	Light traffic.
Crawford County—													
Soldiers Grove	Clayson	28	6209	L. Magnesian	2.60	162	2.96	8.4	4.8	11.3	4	Fair	No good.
Prairie du Chien	City of Prairie du Chien	25	6216	L. Magnesian	2.65	165	2.65	7.0	5.7	15.8	4	Fair	No good.
Bridgeport	Lawyer & Carroll	26	6223	L. Magnesian	2.80	175	.65	.....	.....	12.7	8	Fair	Light traffic.
Bridgeport	Lawyer & Carroll	.....	5788	L. Magnesian	2.60	162	3.10	8.9	4.5	9.8	5	Good	Extremely high traffic.
Dane County—													
Blue Mound	Brigham	24	6207	Trenton	2.60	162	4.75	11.3	3.6	10.7	4	Low	No good.
Madison	City of Madison	78	6438	L. Magnesian	2.60	162	2.09	10.8	3.7	12.5	4	Very good	No good.
Middleton	Wiesenberg & Dahnke	22	6228	L. Magnesian	2.75	172	1.90	5.1	7.9	15.7	10	Fair	Medium traffic.
Oregon	Kelly	1	6062	Trenton	2.80	175	1.21	8.9	4.5	14.0	10	Good	Light traffic.
Oregon	O'Brien	2	6063	Trenton	2.75	172	1.57	6.1	6.6	11.3	6	Fair	Light traffic.
Dodge County—													
Hubbard	Mayville White Lime Works	61	6500	Niagara	2.75	172	1.10	4.5	9.0	14.3	8	Good	Light traffic.
Door County—													
Sturgeon Bay	Leatham & Smith	71	5046	Niagara	2.85	178	.26	4.5	9.0	14.2	12	Low	Light traffic.
Fond du Lac County—													
Marblehead	Union Lime Co	.....	6479	Niagara	2.80	175	.36	4.6	8.7	15.2	10	Good	Light traffic.
Marblehead	Union Lime Co	64	6203	Niagara	2.80	175	.51	3.4	11.9	14.4	7	Fair	Light traffic.
Hamilton	Union Lime Co	63	6202	Niagara	2.60	162	1.67	3.6	11.1	.....	.....	Fair	Light traffic.
Hamilton	Union Lime Co	.....	6807	Niagara	2.80	175	1.01	5.2	7.6	13.4	6	Good	Light traffic.
Hamilton	Union Lime Co	.....	6752	Niagara	2.85	178	0.30	3.7	10.8	13.8	7	Good	Light traffic.
Peebles	C. & N. W. R. R	77	5523	Niagara	2.85	178	.51	5.4	7.5	13.7	8	Good	Light traffic.
Grant County—													
Cassville	Rockefeller	27	6230	Trenton-Galena	2.70	168	1.43	9.6	4.2	12.3	4	Good	Light traffic.
Lancaster	City Park Assn	21	6212	Trenton-Galena	2.60	162	1.67	4.1	9.7	14.8	8	Fair	Light traffic.
Platteville	Enterprise Mine	17	6208	Trenton-Galena	2.75	172	1.57	7.4	5.4	15.	5	Fair	Light traffic.
Green County—													
Brodhead	White	14	6221	Trenton	2.60	162	4.97	8.8	4.5	9.3	3	Good	No good.
Brodhead	Ten Eyck	13	6227	Trenton	2.60	162	4.72	11.1	3.6	14.1	4	Good	No good.
Martintown	Diven	15	6225	Trenton	2.60	162	3.33	11.4	3.5	16.2	5	Good	No good.
Monroe	Town of Richland	12	6215	Galena	2.75	172	1.68	22.5	1.8	.....	.....	Fair	No good.
Iowa County—													
Mineral Point	E. Wiesen	16	6213	Trenton-Galena	2.70	168	.59	5.2	7.7	15.7	6	Fair	Light traffic.
Mineral Point	E. Wiesen	16a	6211	Trenton-Galena	2.65	165	2.96	3.9	10.3	14.5	11	Fair	Light traffic.
Blue Mound	Converse	23	6224	Niagara	2.40	150	3.16	3.3	12.3	.....	.....	Low	Light traffic.
Jefferson County—													
Ft. Atkinson	Fease	51	6160	Trenton	2.75	172	1.68	8.6	4.7	12.8	5	Fair	Light traffic.
Lake Mills	Stiles	49	6185	Trenton	2.70	168	2.99	5.4	7.4	13.2	6	Fair	Light traffic.
Kewaunee County—													
Kewaunee	Nast Bros	72	6244	Niagara	2.85	178	.22	3.8	10.6	12.8	6	Good	Light traffic.
La Fayette County—													
Benton	Frontier Mine	20	6210	Galena	2.70	168	2.16	12.9	3.1	12.8	4	Fair	No good.
Darlington	Wall	76	6257	Trenton-Galena	2.70	168	1.87	5.5	7.3	14.5	5	Good	Light traffic.
Hazel Green	Cleveland Mine	19	6222	Galena	2.65	165	1.88	7.1	5.6	15.2	5	Fair	Light traffic.
Manitowoc County—													
Quarry	Empire Lime & Stone Co	85	6569	Niagara	2.80	175	.51	5.5	7.2	11.1	6	Excellent	Very light traffic
Milwaukee County—													
Wauwatosa	G. D. Francey Stone & Coal Co	.....	1283	Niagara	2.65	165	2.90	3.3	12.	13.4	8	Fair	Light traffic.
Granville	Reichert	.....	1124	Niagara	2.80	174.6	.50	5.7	7.	16.8	4	Fair	Light traffic.
No. Milwaukee	Koenitzer	.....	1285	Niagara	2.55	159	3.92	3.91	4.5	8.2	6	Low	No good.
Town of Greenfield	Trimborn	.....	.....	Niagara	2.59	162.2	2.47	8.50	4.7	5.	8	Low	No good.
Town of Wauwatosa	Zimmerman	.....	.....	Niagara	2.65	165.3	2.9	3.29	12.3	5.5	8	Low	Light traffic.
Town of N. Milwaukee	Zautke	.....	.....	Niagara	2.79	174.6	.59	4.68	8.6	9.8	9	Good	Light traffic.
Outagamie County—													
Kaukauna	Lindauer	69	6248	Galena	2.80	175	1.03	4.1	9.7	.....	.....	Good	Light traffic.
Ozaukee County—													
Belgium	Lake Shore Stone Co	.....	4718	Niagara	2.80	175	.65	5.3	7.5	14.2	8	Low	Light traffic.
Belgium	Lake Shore Stone Co	.....	3265	Niagara	2.80	175	.60	5.4	7.4	15.6	9	Fair	Light traffic.
Grafton	Milwaukee Falls Lime Co	74	6280	Niagara	2.65	165	1.38	6.3	6.3	11.1	5	Good	Light traffic.
Pierce County—													
Ellsworth	Campbell	44	6180	Trenton	2.70	168	2.96	7.3	5.5	15.0	7	Fair	Light traffic.
Prescott		34	6219	L. Magnesian	2.80	175	1.06	5.4	7.4	15.2	7	Fair	Light traffic.
River Falls	Walker	43	6179	Trenton	2.45	153	6.90	7.3	5.5	12.7	5	Fair	Light traffic.
Spring Valley	Spring Valley Furnace	36	6174	L. Magnesian	2.75	172	1.35	5.6	7.1	15.5	11	Good	Light traffic.
Polk County—													
Little Falls		46	6182	L. Magnesian	2.55	159	3.13	11.3	3.5	11.7	4	Good	No good.
Osceola	Wall	45	6181	L. Magnesian	2.70	168	1.86	10.7	3.7	11.7	7	Low	No good.
Racine County —													
Racine	Universal Crushed Stone Co	54	6503	Niagara	2.60	162	1.20	5.6	7.2	.....	.....	Good	Light traffic.
Rock County—													
Beloit	Samp	7	6214	Trenton	2.65	165	3.76	8.9	4.5	14.2	5	Fair	Light traffic.
Beloit	McGavock	6	6220	Trenton	2.70	168	2.83	8.1	4.4	9.4	6	Fair	Light traffic.
Beloit	Barry	5	6217	Trenton	2.55	159	5.89	8.6	4.7	15.3	7	Fair	Light traffic.
Beloit	Peck	4	6226	Trenton	2.70	168	2.36	8.1	4.9	10.5	5	Fair	Light traffic.
Edgerton	Wille	83	6535	Trenton	2.70	168	2.35	5.6	7.1	12.	7	Good	Light traffic.
Evansville	Spencer	3	6186	Trenton	2.70	168	3.01	8.1	4.9	15.	7	Fair	Light traffic.
Janesville	Stout	9	6220	Trenton	2.70	168	2.24	2.3	17.3	15.	8	Fair	Medium traffic.
Janesville	Barnes	8	6218	Trenton	2.75	172	.14	4.3	9.3	14.5	6	Fair	Light traffic.
Sheboygan County—													
Sheboygan	Sheboygan Lime Works	73	6249	Niagara	2.75	172	.50	3.8	10.4	13.3	7	Good	Light traffic.
Sheboygan Falls	Sheboygan Falls Construction Co	75	6247	Niagara	2.75	172	.63	4.8	8.3	12.7	5	Good	Light traffic.
St. Croix County—													
Burkhardt	Burkhardt	40	6176	L. Magnesian	2.65	165	3.59	7.6	5.3	4.0	3	Fair	No good.
Glenwood		47	6183	L. Magnesian	2.60	162	3.68	9.9	4.1	4.5	2	Fair	No good.
New Richmond	McDonald	41	6177	L. Magnesian	2.65	165	2.82	6.1	6.6	12.7	5	Good	Light traffic.
New Richmond	Oakes	42	6178	L. Magnesian	2.60	162	2.51	8.0	5.0	12.0	3	Good	No good.
Prescott Rd		37	6184	L. Magnesian	2.80	175	.86	9.2	4.3	13.7	4	Good	No good.
Prescott Rd		38	6175	Trenton	2.70	168	2.67	7.4	5.4	13.3	12	Good	Light traffic.
Walworth County—													
Whitewater	City of Whitewater	50	6159	Trenton	2.70	168	2.27	6.4	6.3	13.3	7	Good	Light traffic.
Waukesha County—													
Lannon	Wisconsin Stone Co	60	6173	Niagara	2.80	175	.88	3.5	11.6	15.6	10	Fair	Medium traffic.
Lannon	Gumz	59	6171	Niagara	2.70	168	2.03	6.7	6.0	13.3	9	Good	Light traffic.
Lannon	Lake Shore Stone Co	.....	3800	Niagara	2.75	172	1.12	3.2	12.7	16.1	13	Good	Medium traffic.
Lannon		.....	3509	Niagara	2.80	175	.91	3.4	11.7	15.9	13	Fair	Medium traffic.
Pewaukee	Weaver	58	6170	Niagara	2.75	172	1.84	4.1	9.9	15.3	13	Fair	Medium traffic.
Waukesha	Waukesha Lime & Crushed Stone Co	52	6172	Niagara	2.75	172	1.56	3.6	11.	15.	7	Fair	Light traffic.
Washington County—													
Jackson	Stiemke	.....	3491	Niagara	2.6	162	3.39	6.2	6.5	12.3	4	Good	Foundation course or binder.
Winnebago County—													
Appleton	Salter	68	6236	Galena	2.80	175	.53	3.4	11.8	16.5	10	Good	Medium traffic.
Omro	Gilbert	81	6487	L. Magnesian	2.80	175	.62	3.4	11.9	14.7	11	Fair	Light traffic.
Omro	Bronson	66	6246	L. Magnesian	2.75	172	1.65	5.6	7.1	16.3	7	Good	Light traffic.
Oshkosh	Lutz	65	6237	Galena	2.80	175	.65	3.8	10.6	15.5	8	Good	No good.
Neenah	City of Neenah	.....	6573	Galena	2.70	168	2.68	4.1	9.8	14.3	9	Good	Light traffic.

DESCRIPTION OF TESTS.

Hardness Test: This test is made for the purpose of showing the ability of the rock to resist frictional wear. A solid cylinder twenty-five millimeters in diameter (one inch) is cut with a core drill from the rock to be tested and then held against a flat revolving disc under a constant pressure of 1250 grams while sand is fed on the disc to grind the rock away. The disc is run for 1000 revolutions on one end of the specimen which is then turned on the opposite end and tested for another 1000 revolutions. The results of this test are based upon the amount of material ground away in the 2000 revolutions of the disc, the test specimen being weighed both before and after. The numerical result of the test is obtained by subtracting one-third of the loss in weight in grams from 20. Thus the hardness given in the first test of table 1—14.8—means that three times the difference between 14.8 and 20 was worn off the test specimen in the 2000 revolutions, or

$$3 \times 5.2 \text{ grams} = 15.6, \text{ the amount lost.}$$

Rocks having a coefficient of hardness below 14 are called soft, from 14 to 17, medium, and above 17, hard.

Toughness Test: The toughness test is applied to determine the ability of the rock to resist fracture when subjected to blows, such as those from shod hoofs. For this purpose a cylinder of rock, 25 millimeters in diameter (one inch) is used, like that cut for the hardness test. This cylinder is put under a machine like a small pile driver and a hammer is dropped upon it from constantly increasing heights, until the test piece breaks. The number of blows struck is taken as a direct indication of the toughness of the specimen, so that in the first test given in table 1 the toughness coefficient of 8 means that the test specimen broke with the eighth blow. Rocks with a toughness below 13 are called low, from 13 to 19, medium, and above 19, high.

Per Cent of Wear: This test is one of the oldest successful tests of road materials and was developed by a French engineer named Deval. The testing machine consists of a series of cylinders 20 centimeters in diameter and 34 centimeters in depth, each cylinder having its axis inclined 30° to the axis on which it turns. Fifty pieces of stone passing a 3″ ring and held on a 1½″ ring, so selected as to weigh 5 kilograms (about 10 pounds), are put in the cylinder and rotated 10000 turns at the rate of about 30 to the

minute. At each turn the material is dashed from one end of the cylinder to the other. The amount worn off gives a practical test for the combined hardness and toughness of pieces of the size and shape that will be used in the road. The percentage of wear is given by the amount of fine material worn off the stone that will pass through a 1/16″ mesh sieve. Owing to the fact that the softer rocks showed a greater percentage of wear and the higher figures represented much less durable rock, the French engineers selected a method of expressing the results of the abrasion test so that the high numbers would indicate the more durable rocks. This is known as the French coefficient of wear and is found by dividing 40 by the percentage of wear.

$$\text{French coefficient} = \frac{40}{\text{per cent of wear}}$$

Thus, in the first test given in table 1, the percentage of wear 3.0 means that 3% of the weight of the material tested was ground up so fine as to go through a 16 mesh sieve. The French coefficient of wear, 13.3, is obtained by dividing 40 by 3. In interpreting the results of this test a French coefficient of wear below 8 is called low, from 8 to 13, medium, from 14 to 20, high, and above 20, very high. Most Wisconsin limestones of the better grades rank as medium. The granites and traps are the only rocks commonly having French coefficients of "high" or "very high" grade.

Cementing Value: In making this test the material is ground in a ball mill with sufficient water to make a stiff paste. The grinding is continued for 2½ hours at the rate of 2000 revolutions per hour. The paste is then made into cylindrical test blocks 25 millimeters in diameter and 25 millimeters high in a special machine which gives the same amount of compression to each briquette. These briquettes are tested in a machine designed for the purpose, which drops a hammer on the top of the specimen. The number of blows it takes to destroy the specimen is taken directly as giving the cementing value of the material.

Cementing values below 10 are called low, from 10 to 25, fair, from 26 to 75, good, from 76 to 100, very good, and above 100, excellent. Owing to the fact that this test is one of the least satisfactory of those that are ordinarily made, the Office of Public Roads usually does not report the numerical value but simply gives the general results as low, fair, good, or excellent.

Specific Gravity and Weight Per Cubic Foot: The specific gravity is determined by weighing the specimen in air, then immersing

it in water and getting its weight immediately. The specific gravity is then obtained from the following equation:

$$\text{Specific gravity} = \frac{\text{weight in air}}{\text{weight in air—weight in water}}$$

This figure simply expresses the number of times which the weight of the rock exceeds that of an equal volume of water. Thus, in the first test given in table 1 the specific gravity 2.75 means that a cubic foot of the rock weighs 2.75 times as much as a cubic foot of water. The second column in this table, giving the weight per cubic foot, is obtained directly from the specific gravity test by multiplying it by the weight of a cubic foot of water, which is 62.37 pounds. The weight per cubic foot of stone does not mean the weight of a cubic foot of crushed stone but the weight of a solid cube of stone one foot on each side. The specific gravity or the weight of a cubic foot of rock is useful only to give an idea of whether the rock is dense and solid, or porous.

In tests of Wisconsin limestone the specific gravity varies from 2.45 to 2.85. The heavier stone is more than 16% heavier than the lighter. A cubic yard of crushed stone from a quarry where the rock has a specific gravity of 2.85 would weigh more than a cubic yard of crushed stone from a quarry where the rock has a specific gravity of only 2.45. Practically all limestones in the state will vary from 2.60 to 2.75. If a rock has a specific gravity lower than 2.60 it is likely to be so porous as to be unsatisfactory.

These figures on the specific gravity of limestones are used as a basis for the figures on page 16 with regard to the weight of a cubic yard of crushed stone.

Absorption: The absorption test is made with the same specimen that is used to determine the specific gravity. Immediately after this specimen is immersed in water its weight is taken for the purpose of the specific gravity determination. It is then allowed to stay in the water for four days, during which time the water goes in through the pores of the rock and replaces the air. Its weight is then taken. The number of pounds of water which a cubic foot of rock will absorb is then obtained from the following computation:

Let Wa = wt. of specimen in air:
Ww = wt. of specimen in water just after immersion; and
W'w = wt. of specimen in water after immersion for four days.

$$\text{Absorption in pounds per cubic foot} = \frac{\text{W'w—Ww} \times 62.37}{\text{Wa—Ww}}$$

The absorption test gives another method of telling whether the rock is dense and solid or whether it is porous. Its usefulness comes from the fact that rock which absorbs much water may possibly be broken when this water freezes and the roads for this reason grind up more rapidly than they would if built of less porous material. However, very little attention is paid to the absorption test and it is not believed to be of much importance. It is sometimes stated that there is an advantage in having somewhat porous rocks to use with bituminous binders. This idea, however, has not been followed far enough to state definitely what number of pounds of water per cubic foot should be absorbed by rock to make it most advantageous for such use and so the test has little, if any, practical value.

WEIGHT OF A CUBIC YARD OF CRUSHED STONE.

In the first annual report of the State Highway Commission of Illinois there are given the results of a series of tests to determine the weight of a cubic yard of stone. The tests were made by A. N. Johnson, State Engineer, and included tests on carloads as well as on wagonloads. The loads were carefully weighed and measured immediately before shipping and then weighed and measured after hauling various distances.

Table II gives the weight of three different sizes of stone loaded into cars with an 8-foot drop and the percentage of settlement after a railroad haul of 150 miles. Table III shows the settlement in wagon haulage with different methods of loading and different lengths of haul. These measurements were made at hundred foot intervals up to 700 feet and it was found that 50% of the settlement occurred in the first 100 feet, 75% in the first 200 feet, and practically all of the settlement occurred during the first half mile. The foregoing tests show wide variations in the weight of a measured cubic yard of limestone of the various sizes.

TABLE II.

Weight per cubic yard of crushed limestone in carload lots and per cent of settlement in transportation. The haul in each instance was about 150 miles.

Size.	Weight in pounds per cubic yard when shipped.	Per cent of settlement.
Screenings	2,520	0.0
Screenings	2,520	.....
Screenings	2,730	8.3
Screenings	2,610	12.5
Screenings	2,680	8.3
Total	13,060	29.1
Average	2,612	7.3
One and one-half inch	2,570	1.4
One and one-half "	2,210	13.9
One and one-half "	2,360	8.7
One and one-half "	2,300	13.6
One and one-half "	2,180	7.4
One and one-half "	2,200	9.7
One and one-half "	2,250	7.7
Total	16,070	62.4
Average	2,296	8.9
Three inch	2,520	3.8
Three "	2,440	3.4
Three "	2,500	5.0
Three "	2,380	12.9
Three "	2,300	3.7
Three "	2,400	0.0
Three "	2,290	9.0
Three "	2,270	7.4
Three "	2,275	9.2
Three "	2,240	11.1
Three "	2,260	10.5
Three "	2,470	.....
Total	28,345	76.0
Average	2,362	6.9

TABLE III.

Settlement of crushed limestone in wagon loads at end of different length hauls and increase in weight per cubic yard.

Size.	Method of loading.	Length of haul.	Weight per cubic yard in pounds	
			At start.	At finish.
Screenings	15 ft. drop	1 mile	2,518	2,840
"	" " "	1 "	2,518	2,886
"	" " "	½ "	2,450	2,770
"	" " "	¼ "	2,425	2,780
1½ inch	15 ft. drop	2 miles	2,305	2,600
" "	" " "	½ mile	2,380	2,625
" "	" " "	" "	2,450	2,600
" "	Shovels	" "	2,270	2,445
" "	"	1 "	2,305	2,642
3 inch	15 ft. drop	1 mile	2,376	2,638
3 "	" " "	½ "	2,360	2,505
3 "	" " "	¼ "	2,470	2,595
3 "	Shovels	1 "	2,270	2,601
3 "	"	¼ "	2,335	2,510

These tests were all made on the Niagara limestone at Joliet, which is a very uniform material. It varied in specific gravity from 2.63 to 2.73, with an average for seven tests of 2.67. The variation in weight of a cubic yard is shown by these tests to be from 2180 lbs. to 2990 lbs., a variation of 27%. The tests on Wisconsin limestones show the specific gravity varying from 7.35% lower than the lowest test given for the Joliet stone to 4.4% higher than the highest test given for the Joliet stone. According to these tests, therefore the weight of a cubic yard of limestone in Wisconsin should be expected to vary from 2020 lbs. to 3120 lbs. It is important to recall upon just what factors this variation in weight of a cubic yard of crushed stone depends and for this purpose they are tabulated here:

Specific Gravity: The greater the specific gravity the more a cubic yard will weigh.

Size of Stone: The smaller the stone, the better it packs, so screenings weigh more per cubic yard than coarse stone.

Method of Loading: If the stone is dropped from a high loading chute it will be more compact than if dropped only a short distance, and so a yard will weigh more.

Distance Material is Hauled: The material settles due to the shake and jar of shipment and a cubic yard when first loaded settles to less than a cubic yard when delivered.

It is obvious that it is impossible to determine what the proper weight of a cubic yard of stone should be and that the term "cubic yard of stone" really does not signify anything as to the amount of stone that goes to make it up.

As a result of this test the Illinois Highway Commission adopted 2500 pounds as the weight of a cubic yard of crushed limestone. When their figures are analyzed, however, it is found that the average weight of five shipments of screenings was 2612 pounds per cubic yard at the time of loading and 2849 pounds per cubic yard after shipping a distance of 150 miles. The average weight of seven shipments of 1½" stone was 2296 pounds per cubic yard at the time of shipped and 2523 pounds per cubic yard after shipment, and that the average of twelve shipments of 3" stone was 2362 pounds per cubic yard when shipped and 2531 pounds per cubic yard after shipping a distance of 150 miles. From these figures it is seen that 2500 pounds is less than the average weight of a yard of screenings and more than the average weight of a cubic yard of 1½" and 3" stone.

QUALITIES OF WISCONSIN ROAD MATERIALS.

Granite and Trap Rock: The granites of Wisconsin are in general a very satisfactory road material. Their distribution has been indicated on page 4. In character they vary from finely crystalline to very coarsely crystalline; from a very much weathered condition so that they are used as clay to make brick, through a condition of weathering only sufficient to disintegrate them (such as the rotten granites in the neighborhood of Wausau and Grand Rapids), to the usual hard, dense, unweathered rock. The rotten granites are very desirable for macadam road construction, as they are usually sufficiently decomposed to acquire good cementing properties.

The unweathered granites of Wisconsin as a whole are very hard and durable stone, but it is difficult to bind most of them satisfactorily in plain macadam construction. The coarse-grained granites, in which there are feldspar crystals (recognized by their gray or pink color, and the broad glistening cleavage planes) will grind up with sufficient rapidity under moderately heavy traffic to furnish the proper amount of binding material, and the pieces also have a coarse jagged surface so that they lock together firmly. For macadam construction on the average country road, however, most of

the granites of the state need to be bound with limestone screenings having high cementing properties or with fine clayey gravel, if it is available; or, better still, with a bituminous binder.

While there is of course more or less variation in the hardness of the granites, they are almost without exception very much harder than the hardest limestones of the state. For use in concrete roads granite is undoubtedly one of the best materials we possess. The fine quality of Wisconsin granites for paving blocks is indicated by the fact that they are produced in this state to a total value of about $1,000,000 per year. Wisconsin granite for roads is shipped long distances. It is used in Cleveland, Memphis, and St. Louis, and in many other cities less distant. Chicago consumes the greater part of the paving blocks produced in the state.

Trap rock is a general name for any dark igneous rock, such as gabbro, diorite, or balsalt. These rocks are found as "nigger-heads"—the dark colored bowlders in the glaciated area—and as ledge rock in many places in the northern part of the state. In Iron, Ashland, Bayfield, Burnett, Polk, and Douglas counties there is a large area of trap rock.

Trap rock is an excellent road material, about equal to our Wisconsin granites and better than most granites. It is hard and tough and has excellent cementing qualities under fairly heavy traffic. Under light traffic it is difficult to bind in a satisfactory manner.

Rhyolite may be defined for our present purpose as a granite that solidified before it had time to become thoroughly crystallized. For road purposes it is about the same as granite. The tests on Wisconsin granite and rhyolite are given in the following table:

TABLE IV.

Tests of Wisconsin Granites and Rhyolites.

Locality.	Class.	Weight per cu. ft.	Water absorbed per cu. ft,	Per cent of wear.	French coefficient.	Hardness.	Toughness.	Cementing value.
1. Red Granite	Gr.	.....	.....	.....	.....	19.	14.	.....
2. Red Granite	Gr.	165	.14	1.08	37.	18.8	25.	3
3. Montello	Gr.	.....	.....	2.16	18.5	.....	.....	.....
4. Montello	Gr.	.....	.....	2.26	17.7	.....	.....	.....
5. Montello	Gr.	165	.15	2.1	18.9	.....	.....	11
6. Waupaca	Gr.	.....	.....	1.8	22.2	.....	.....	.....
7. Waupaca	Gr.	.....	.....	1.64	24.2	.....	.....	.....
8. Waupaca	Gr.	162	1.96	1.4	27.8	18.9	29.	6
9. Waupaca	Gr.	168	.15	5.3	7.5	19.	9.	26
10. Glen Rock	Gr.	165	.42	1.46	27.4	19.2	24.	6
11. Lohrville	Gr.	165	.19	2.7	14.6	18.4	21.	9
12. Lohrville	Gr.	168	.26	2.0	20.	19.0	.....	6
13. Marion	Gr.	165	.30	1.5	26.3	18.9	23.	7
14. Utley	Rhy.	.....	.....	3.04	13.1	.....	.....	.....
15. Utley	Rhy.	.....	.....	3.24	12.3	.....	.....	.....
16. Utley	Rhy.	165	.04	5.0	8.0	.....	.....	.....
17. Utley	Rhy.	165	.06	5.6	7.2	.....	.....	35
18. Utley	Rhy.	162	.05	2.5	16.2	18.9	19.	17
19. Berlin	Rhy.	.....	.....	2.76	14.5	.....	.....	.....
20. Berlin	Rhy.	.....	.....	3.06	13.	.....	.....	.....
21. Berlin	Rhy.	165	.05	1.8	22.5	.....	.....	15
22. Berlin	Rhy.	165	.03	4.0	10.1	.....	.....	10
23. Berlin	Rhy.	165	.10	1.9	20.6	19.	23.	5
Limestone								
Highest	.....	178	6.9	22.5	17.3	16.5	13.0	.....
Lowest	.....	153	.14	2.3	1.8	4.0	2.0	.....

Numbers 3, 4, 6, 7, 14, 15, 19 and 29 were tested by E. R. Buckley, Wis. Geol. and Nat. Hist. Survey, Bull. X, p. 295.
Numbers 1, 2, 5, 8-13, 16-18 and 21-23 were tested by Office of Public Roads, Washington, D. C.

Sandstone and Quartzite: The sandstones of Wisconsin are almost without exception too soft to be used for any kind of road construction. Some of the harder varieties can be used for the lower course in macadam construction but it is seldom that sandstone sufficiently hard to stand up under a roller can be found. The difficulty with sandstone for macadam construction is that it is almost wholly devoid of cementing properties and grinds up under traffic into a mass of loose sand. There are sandstones in some localities in the state, however, that are so hard that they make excellent paving blocks. Sandstone blocks are made at Stevens Point and at Ablemans. Both of these quarries are in the Potsdam sandstone. These blocks are preferred by many to granite blocks, because of the fact that they present a gritty surface, on which horses are not so likely to slip, and because they wear at about the same rate as the cement mortar used as a filler. This causes the whole road to wear much more evenly than one built of granite blocks, which are so much harder than the filler that the mortar wears away and the granite blocks wear smooth and rounding. Aside from that used as paving blocks the sandstone is practically worthless as road material.

Quartzite is found abundantly in Sauk county; in Dodge and Jefferson counties near Waterloo; near Wausau; in Barron county; and at other places. It is the most difficult road material to handle that there is in the state. It has a high degree of hardness but is almost wholly lacking in cementing qualities. It has been found exceedingly difficult in Sauk county to hold the quartzite in a satisfactory manner with a clay binder, and while limestone screenings have been tried to some extent, it is not yet certain that they will serve the purpose. It is quite likely that it will be found that the only thoroughly satisfactory way of building a road of quartzite is to use it in concrete or with a bituminous binder.

Tests on Wisconsin quartzite and the sandstone used for paving blocks are given in the following table:

TABLE V.

Tests of Wisconsin Sandstone and Quartzites.

Locality.	Class.	Weight per cu. ft.	Water absorbed per cu. ft.	Per cent of wear.	French coefficient.	Hardness.	Toughness.	Cementing value.
1.* Ablemans	Ss.	153	.82	3.4	11.7	18.4	9.0	Low.
2.* Ablemans	Ss.	153	.81	10.7	3.7	15.7	3.0	Low.
3.* Stevens Point	Ss.	156	.59	5.2	7.7	18.5	12.0	Low.
4. Rice Lake	Qz.	.....	.....	2.36	16.9	.....	.....	.....
5. Rice Lake	Qz.	.....	.....	2.70	14.8	.....	.....	.....
6. Portland, Dodge Co.	Qz.	168	.14	2.8	12.2	19.0	19.0	Low.
7. Ablemans	Qz.	165	.13	3.4	11.9	.....	.....	Low.
Limestone:**								
Highest	.....	178	6.9	22.5	17.3	16.4	13.0	.....
Lowest	.....	153	.14	2.3	1.8	4.0	2.0	.....

Numbers 1, 2, 3, 6 and 7 tested by Office of Public Roads, Washington, D. C.
Numbers 4 and 5 tested by E. R. Buckley. Wis. Geol. & Nat. Hist. Survey, Bulletin X, p. 295.
* These are specially well-cemented sandstones used for the manufacture of paving blocks and must not be construed as giving an idea of the average sandstone of the state, which, with few exceptions, is wholly unfit for use as a road material.
** See Table 9, p. 43

Shale: In Adams, Juneau, Jackson and parts of Trempealeau and Eau Claire counties about the only available road material is what is known locally as shale. This shale is nothing more or less than portions of the sandstone which have a fairly large percentage of clay. The roads built of this shale are practically nothing more than sand-clay roads. Their success depends upon securing a proper mixture of the clay and sand, and too often no attention is paid to this.

Gravel and Field Stone: The field stones of the state are most commonly granite and trap rock and are in no way different from the granite and trap rock obtained from quarries in ledge rock. Their tests would be the same and their usefulness is exactly as described on page 19.

In many localities in the eastern part of the state there is abundant field stone—glacial bowlders—of limestone. This material is usually the hardest limestone that is to be obtained. In the transportation by the glacier and the waters accompanying it only the more resistant part of the limestone survived, while the soft, weathered portions were ground up and carried away with the fine materials. These limestone glacial bowlders have to be crushed and

are then treated exactly as any other crushed limestone in building a road.

The gravels of the state vary so widely in character that it is not practicable to discuss them properly in a brief statement such as this. Their distribution is indicated on page 4.

LIMESTONES.

There are four principal limestone formations which furnish most of the road-building material of Wisconsin. From the youngest to the oldest they are the Niagara, Galena, Platteville (or Trenton) and Lower Magnesian formations. They are generally spoken of as limestone and this term will be used throughout this report. In composition, however, they are dominantly dolomite rather than limestone, since they contain a large percentage of magnesia. True limestone deposits which contain only a small percentage of magnesia are not common in Wisconsin. In addition to these four great formations there are two other limestones which locally afford important supplies of road material. Thus, north of Milwaukee there is a small area of limestone younger than the Niagara, and in the northern part of Dane county and in Columbia and Sauk counties there is a fairly well developed bed of dolomite, known as the Mendota limestone, which is below the Lower Magnesian and is found in regions where the Lower Magnesian has been eroded away.

The distribution of the limestones of the state has been stated in a general way. They occur as a broad belt along the eastern, southern and western parts of the state as indicated in figure 1, page 3. The limestone formations dip in a general way toward the nearest boundary of the state. The formations lie about the dome of old crystalline rock like the outer layers of an onion about the core.

The occurrence of these materials is taken up in detail in connection with the discussion of the road materials of each county, but a general survey of each formation is given here so that the relative characteristics of the formations in the various parts of the state can be pointed out. Averages of tests on road material from the various formations are given in table VI.

TABLE VI.

Averages of Tests of Wisconsin Limestone by Districts and Formations.

Tests made by U. S. Office of Public Roads.

Formation.	No. of samples averaged.	Specific gravity.	Weight per cu. ft.	Water absorbed per cu. ft.	Per cent of wear.	Coefficient of wear.	Hardness.	Toughness.	Cementing Value. No. of tests under each class. Low.	Fair.	Good.	Very good.	Suitable for: No good.	Foundation course only.	Ex. light traffic.	Light traffic.	Medium traffic.
Lower Magnesian average for state	17	2.68	167	2.5	6.4	6.2	12.5	5.0	.....	8	8	1	9	.....	1	6	1
Lower Magnesian of Southern Wis.	6	2.66	164	2.2	8.0	5.0	12.9	5.8	.....	4	1	1	3	.....	1	1	1
Lower Magnesian of Northwestern Wis.	9	2.68	167	2.9	8.2	5.2	11.2	5.1	1	3	5	.....	6	.....	.....	3	.....
Lower Magnesian of Northeastern Wis.	2	2.77	173	1.63	4.5	9.5	15.5	9	.....	1	1	.....	.....	.....	.....	2	.....
Trenton Limestone of Wisconsin	21	2.66	166	3.15	8.09	4.9	12.5	.....	1	12	8	.....	4	....	.....	16	1
Trenton Limestone of Southern Wis.	18	2.62	169	2.84	7.5	6.	13.	6	.....	.....	.....	.....	4	.....	.....	13	1
Trenton Limestone of Northwestern Wis.	3	2.62	163	4.17	7.3	5.4	15.4	9	.....	.....	4	.....	1	.....	.....	2	1
Trenton and Galena Limestones of Southeastern Wisconsin	5	2.67	165	1.70	5.6	7.1	14.3	6.8	.....	3	2	.....	.....	.....	.....	5	.....
Galena Limestone of Northeastern Wis	4	2.8	175	1.22	3.8	10.6	13.6	8	.....	2	1	.....	.....	1	.....	3	.....
Galena Limestone of Southwestern Wis.	3	2.71	169	1.71	12.3	3.2	15.	5	.....	3	.....	.....	1	.....	.....	2	.....
Niagara Limestone of Eastern Wis.	32	2.7	168	1.32	4.55	8.9	13.4	10.5	6	9	16	1	2	1	1	24	4
Niagara Chert of Blue Mound	1	2.4	150	3.16	3.3	12.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Lower Magnesian Limestone: The Lower Magnesian limestone is the principal road building material from St. Croix county down the western side of the state to Dane county. It is the only limestone to be found in most of the area north and west of the Wisconsin River. From Dane county it extends in a much narrower belt through Columbia and Green Lake counties in a northeasterly direction to the Menominee River in Marinette county.

Throughout the area north and west of the Wisconsin River, and in the northwest quarter of Dane county, the Lower Magnesian limestone most commonly occurs as a protecting cap over the hills of Potsdam sandstone. In the belt extending northeast from Dane county it is entirely within the glaciated area and outcrops occur quite irregularly. In places it caps the hills of the Potsdam and in other places it is found in thick ledges.

This limestone is probably the most variable in character of any in the state. One bed will furnish an excellent quality of road material; the beds immediately above and below may furnish an exceedingly poor quality. A short distance away a quarry may be opened in which all the material will be good, and again a short distance beyond that the material may all be bad.

The tests made on the Lower Magnesian limestones are given in tables I and VI. The average for all the tests made on this formation shows that it is of average specific gravity and average porosity. The percentage of wear is rather high, and as a consequence, the French coefficient is low. In cementing value it is quite satisfactory. As a matter of fact, it is one of the best limestones in the state for this purpose. By comparing the tests in tables I and VI, it will be seen that the Lower Magnesian limestone of northeastern Wisconsin appears to be a much better road building material than the Lower Magnesian of southern Wisconsin or of northwestern Wisconsin. This, however, must not be taken as an absolutely sure generalization, because there are only two tests from the northeastern part of the state.

As the Lower Magnesian in a large part of its area is found upon hilltops, it is usually weathered more or less badly. While the formation is in general rather thick-bedded and does not break into thin shaly layers in weathering, it is very irregular in the material that makes up the beds and the softer parts are usually weathered into pockets of loose crystals or grains of dolomite. In many places it is so badly weathered as to be entirely unfit for road material. In other places it has been almost completely weath-

ered away and all that remains of it are hard, cherty nodules or bowlders which could not be dissolved.

Lying upon the Lower Magnesian limestone is the St. Peter sandstone, which is a very soft formation in practically all places where it occurs.

Platteville (or Trenton) Limestone: The Platteville (or Trenton) limestone rests upon the St. Peter sandstone. It is found as capping for hills of this sandstone in Pierce, Vernon and Crawford counties, north of the Wisconsin River, and on hills a short distance south of the Wisconsin River, in Grant, Iowa and Dane counties. In the glaciated portions of the state the Platteville limestone extends as a broad belt up the Rock River valley and to the north and northeast along the western side of Lake Winnebago and Green Bay.

This limestone is a fairly satisfactory road material in most places where it occurs. Parts of it are likely to be somewhat clayey and thin-bedded, but sometimes these thin-bedded portions are made up of quite dense rock that makes fair road material. The tests on this limestone (see tables I and VI) do not show in general any variation from the average in specific gravity, although one sample, the material from River Falls, has a specific gravity of only 2.40. Aside from this the tests are all of a fair average character. The absorption of water indicates a high degree of porosity in the northwestern and southern portions of the state and a decided change for the better in southeastern and northeastern Wisconsin. This change in the variation of water absorbed per cubic foot is paralleled by the percentage of wear and coefficient of wear. The more porous portions of this formation have a high percentage of wear and low coefficient, and the less porous show a lower percentage of wear and a higher French coefficient. All the tests of this formation showed it to have a fair cementing value.

Excepting in Pierce and Crawford counties this formation is weathered comparatively little, as it is immediately underneath the Galena limestone which has served to protect it to a large extent. Where it has been seriously weathered it has broken up into thin shaly material which usually is of little value for road purposes.

Galena Limestone: This formation is found as the surface rock over most of the area of Grant, LaFayette, Green and southern Iowa counties. It occurs as a broad belt reaching up the eastern side of the state through Walworth, Jefferson, Dodge and Fond du Lac counties, and up to Green Bay. This formation is not a satisfactory road material in general. It is a soft, rotten stone

that has no ability to stand up under traffic. On account of an obvious lack of fitness for road purposes, comparatively few samples were taken. The tests made are given in tables I and VI.

The average of the tests of the material from southwestern Wisconsin shows the highest percentage of wear of any formation in the state and the lowest French coefficient. While its hardness is moderately high in tests, its toughness is low, and its cementing properties only fair. As the formation has been the surface rock in southwestern Wisconsin for long geologic ages, it is very badly weathered, and in using it for macadam roads care must be taken to select only the very best that is available, and even that is so poor as to make it in many cases a wise investment to ship in better stone. Throughout the northeastern part of the state, however, the weathered portions of the formation have been eroded by the glaciers and there is much the same change in character to be noted that is found in the Platteville limestone.

In the northeastern part of the state, in the neighborhood of Green Bay, Kaukauna, Neenah, Menasha and Oshkosh, it supplies an excellent road material. In this particular region the rocks were overridden by the glacier and much of the softer portions were carried away.

Niagara Limestone: Immediately overlying the Galena limestone is the Cincinnati shale. It is a very soft formation, easily worn away, and is not exposed, excepting where it is protected by the overlying Niagara limestone. This limestone occupies a broad belt up the eastern side of the state. While the Niagara limestone has been the surface formation in the eastern part of the state for long geologic ages and has been exposed to weathering accordingly, it has been so thoroughly glaciated that practically no weathered material remains. It is without question the best limestone road material to be found in the state. It is very uniform in quality and is, practically everywhere it is found, a hard rock with a low percentage of wear and high coefficient of wear. While a few samples of other limestones show higher tests than the Niagara, the Niagara averages the highest of any formation in the state as to hardness and French coefficient of wear.

While the tests on the cementing value of the Niagara limestone show that over half of the tests were marked good, some difficulty has been experienced in road construction in binding the material satisfactorily. In some places a fine clayey gravel has been found to be better than the screenings of the Niagara limestone itself for this purpose. The discrepancy between the results of the tests, as

shown in tables I and VI, and actual practice in road construction is probably to be explained by the fact that the screenings from the crusher are more largely rock chips than finely-ground material, such as is used in making the tests, and these coarse screenings or chips do not grind up readily enough under light traffic to hold the road from "raveling."

PART TWO

DESCRIPTION OF ROAD MATERIALS BY COUNTIES.

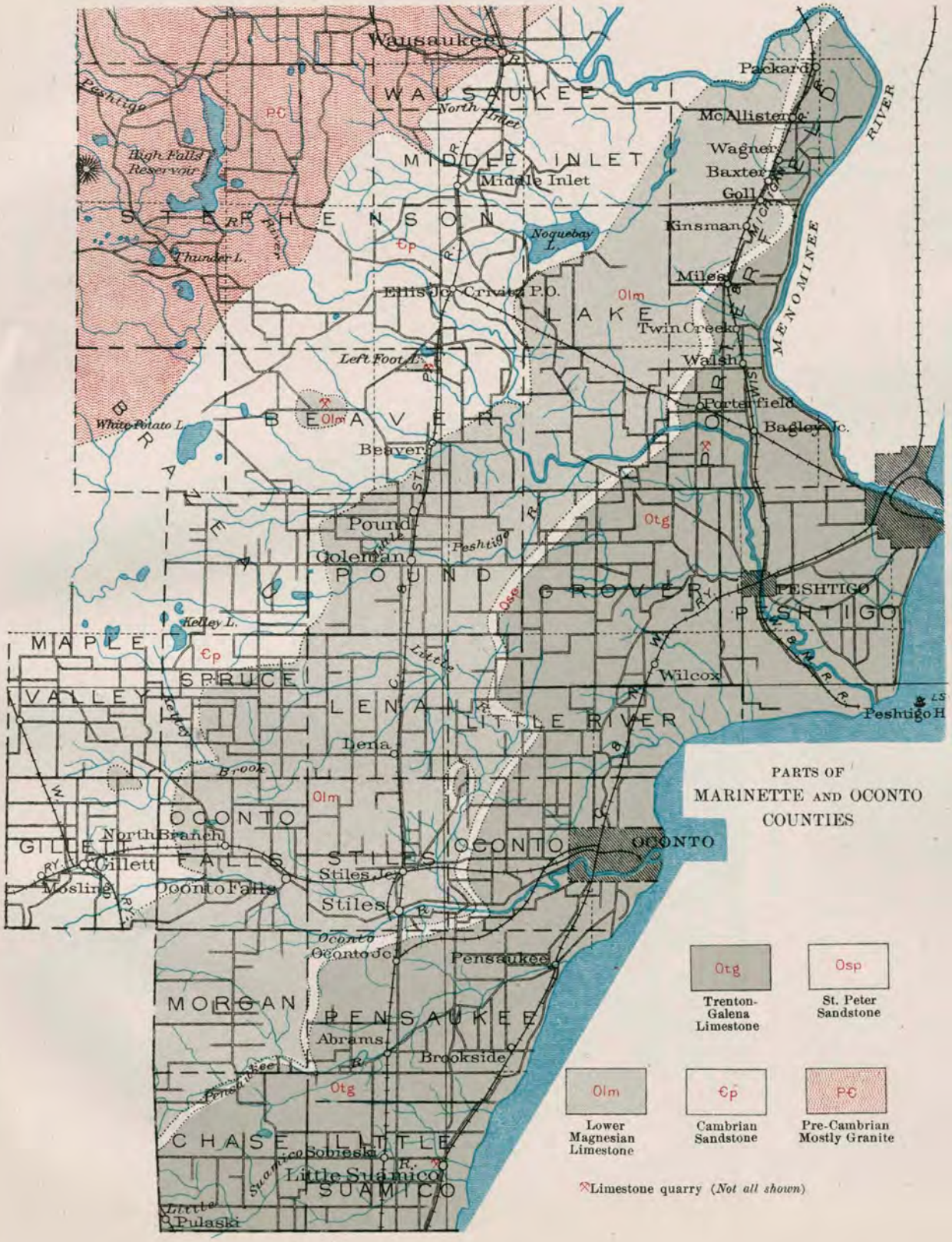
By Edward Steidtmann.

Marinette and Oconto Counties.

The northwestern portion of Marinette and Oconto counties is underlaid by granite, quartzite, and trap rocks which constitute a part of the crystalline area of northern Wisconsin. To the southeast of the crystalline area, there are four strips trending northeast southwest which are underlaid by sedimentary rocks. The sedimentary rocks are in the order of their occurrences from northwest to southeast, the Potsdam sandstone; Lower Magnesian limestone; St. Peter sandstone; and Galena-Trenton limestone. In several places, some of these sedimentary rocks occur in patches, isolated from the main areas. Thus the Lower Magnesian limestone occurs as an outlying area in the town of Beaver, Marinette county, and there is another to the northwest of Oconto Falls. About six miles northwest of Oconto Falls, there is a small outlier of St. Peter sandstone and Galena-Trenton formation. The distribution of these formations at the surface and underneath the soil and loose debris which covers them in most places is shown by Plate III.

Outcroppings of limestones are scarce in these counties, owing to the mantle of glacial drift and soil. The most favorable localities for outcrops are along the stream channels especially where rapids occur, and along the low bluffs which mark respectively, the western edges of the Galena-Trenton and the Lower Magnesian limestones.

Exposures of the Lower Magnesian limestone occur at Oconto Falls; on Jones Creek a few miles north of Stiles; at several points between Angelica and the Oconto river; about 5 miles north of


Wausaukee
WAUSAUKEE
North Inlet
MIDDLE INLET
Middle Inlet
STEPHENSON
Peshtigo
High Falls Reservoir
Thunder L.
Noquebay L.
Ellis Jc.
Crivitz P.O.
LAKE
Twin Creeks
Left Foot L.
White Potato L.
BEAVER
Beaver
BRAZEAU
Pound
Coleman
POUND
GROVER
PESHTIGO
Kelley L.
MAPLE
SPRUCE
VALLEY
LENA
LITTLE RIVER
Lena
Brook
OCONTO
North Branch
GILLETT
Gillett
FALLS
Mosling
Oconto Falls
STILES
Stiles Jc.
Stiles
Oconto
Oconto Jc.
Pensaukee
MORGAN
PENSAUKEE
Abrams
Brookside
CHASE
LITTLE SUAMICO
Sobieski
Little Suamico
Pulaski
Packard
McAllister
Wagner
Baxter
Goll
Kinsman
Miles
Walsh
Porterfield
Bagley Jc.
Wilcox
Peshtigo H
MENOMINEE RIVER
PARTS OF
MARINETTE AND OCONTO
COUNTIES
Otg
Trenton-Galena Limestone
Osp
St. Peter Sandstone
Olm
Lower Magnesian Limestone
Cp
Cambrian Sandstone
PC
Pre-Cambrian Mostly Granite
Limestone quarry (Not all shown)

Stiles; on the south side of the Peshtigo river, from the mouth of the Little river to the vicinity of Potato rapids; and at Grand Rapids on the Menominee river.

At Oconto Falls, a thickness of about 53 feet of Lower Magnesian limestone is exposed. Excepting 2 feet of shale, the greater portion of this section is not easily eroded and therefore may be satisfactory for use on roads. About 16 feet from the top of the section, there is a 4 foot bed which is especially commendable as a road material. Chamberlain's[1] description of this bed is as follows:

"It presents the appearance of having been formed of fragments of siliceous dolomite (limestone) imbedded in a matrix of dolomitic sand and mud, which afterwards cemented, and in a measure, coalesced. On weathering, the constitutents are brought out conspicuously. The more compact fragments seem to contain a considerable percentage of silica disseminated through them, while segregations of quartz, much oftener in the crystalline than the nodular form, are very numerous, and, standing out upon the weathered surface, give it a very rough aspect. This layer by its hardness offers great resistance to erosion from the volume of water pouring over it, but when undermined by the removal of the softer rock below, it falls in huge masses, sometimes 20 feet in maximum diameter which lie in the channel for ages before complete removal. The prevailing color of the rock is dark dray, mottled by the white quartz, and the variously colored fragments of which it is composed. The thickness of the bed is varying, that measured as an average being 4.7 feet."

Outcrops of the Galena-Trenton limestone are known at the lower, and the second series of rapids of the Menominee river; on the Little Suamico river; and along Green Bay south of Pensaukee. The exposures[1] at the last two localities are similar to those on the Big Suamico river near Flintville, in Brown County. They consist of massive limestone and of alternating beds of limestone and shale. At the second series[2] of rapids of the Menominee river, a portion of the rock exposed is a deep blue, thick-bedded crystalline limestone, weathering smooth and breaking into rectangular blocks, while other portions are quite irregular in texture, being composed of combined earthy, crystalline, and shaly material.

The limestones of these counties are quarried in only a few places.

See Geology of Wisconsin, Vol. II, pp. 281–284, 1873–1877.

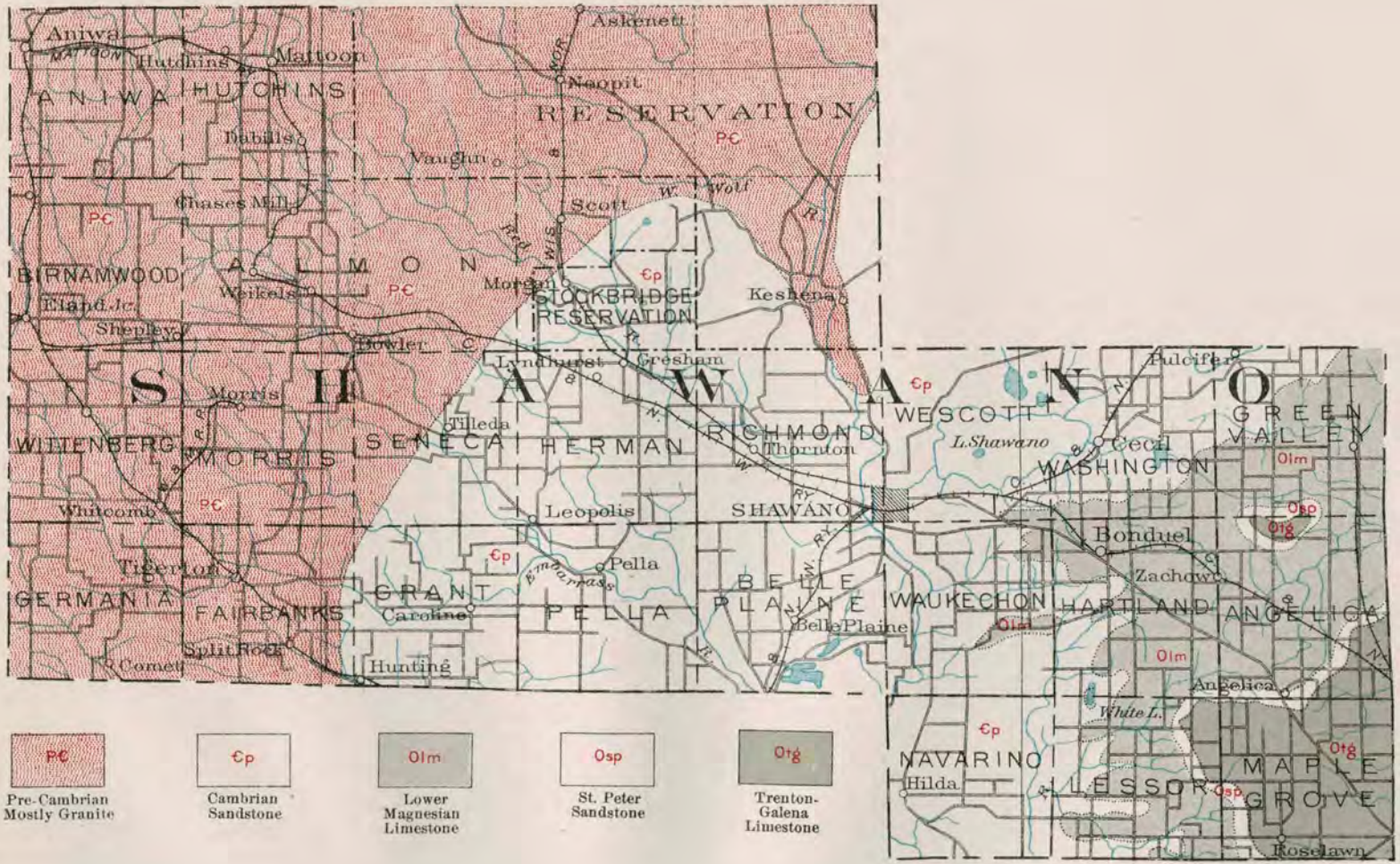
[1] Idem. p. 313.

[2] Idem. p. 304.

In Oconto county, the Galena-Trenton limestone is quarried for lime by L. Drews, west of Sobieski, and by John Grosse at Little Suamico. Several small quarries of Galena-Trenton limestone are located about 1½ miles south of Porterfield, south of the Peshtigo river. The Lower Magnesian limestone is quarried about 1 mile southeast of Coleman; in the vicinity of Gillett; and from the outlying patches of this formation in the town of Beaver.

Very little information bearing directly on the fitness of the various limestone outcrops and quarries of these counties for use on roads is at hand. They have not been tested, nor what is of more importance, their behavior under actual use has not been determined. In the eastern and southern part of Wisconsin, the Lower Magnesian limestone is, at most places, exceedingly variable as a road material. Good and worthless material often occur together in the same quarry. Very little is known about the quality of the lower beds of the Galena-Trenton limestone of northeastern Wisconsin because they are buried in most places. They are the beds which underlie the low bluffs marking the western edge of the formation. Very good road material is obtained from the upper beds at Kaukauna and at Duck Creek. Hence it seems probable that the upper beds in Marinette and Oconto counties, that is those exposed near Green Bay, may also furnish good road materials.

Besides limestones, these counties have a bountiful supply of gravel, field bowlders, and granite for use on roads. Gravel is abundant in the vicinity of Peshtigo, and many extensive hog back ridges of it occur over the entire southeastern part of Marinette county. One of the largest of these deposits, which is located between Pound and Coleman, is being used for road ballast by the C. M. & St. P. Ry. Field bowlders are not plentiful along Green Bay, but in the northwestern portion of these counties, they will prove a valuable source of local road material. Granite, which constitutes perhaps the most desirable road material of these counties is being quarried extensively at Amberg, Athelstane, and Mountain.


Aniwa
Hutchins
Mattoon
ANIWA
HUTCHINS
Askenett
Neopit
RESERVATION
Dubills
Vaughn
Chases Mill
Scott
Wolf R.
Red R.
Wis. R.
BIRNAMWOOD
ALMON
Morgan
Weikels
Eland Jc.
Shepley
Bowler
STOCKBRIDGE
RESERVATION
Keshena
Lyndhurst
Gresham
SHAWANO
Morris
WITTENBERG
MORRIS
SENECA
HERMAN
RICHMOND
Thornton
Tilleda
Whitcomb
Leopolis
Tigerton
Pella
GERMANIA
FAIRBANKS
GRANT
Caroline
PELLA
BELLE PLAINE
BellePlaine
WAUKECHON
Split Rock
Comet
Hunting
Bulcifer
WESCOTT
L. Shawano
Cecil
WASHINGTON
GREEN VALLEY
Bonduel
Zachow
HARTLAND
ANGELICA
Angelica
White L.
NAVARINO
Hilda
ESSO
MAPLE GROVE
Roselawn
Pre-Cambrian Mostly Granite
Cambrian Sandstone
Lower Magnesian Limestone
St. Peter Sandstone
Trenton-Galena Limestone

Shawano County.

Granites and other old crystalline rocks are the rocks found at the surface in the northwestern part of Shawano county. To the southeast of this area, the surface is underlaid by belts of sedimentary rocks trending northeast-southwest, which in the order of their occurrence from the crystalline rocks to the southeastward are as follows: Potsdam sandstone, Lower Magnesian limestone, St. Peter sandstone, and Galena-Trenton limestone. In the town of Waukechon, however, the Lower Magnesian limestone occurs as an outlier surrounded by Potsdam sandstone, and in the towns of Angelica and Green Valley, there is a small detached area of the Galena-Trenton formation and St. Peter sandstone. The distribution of these formations at the surface and underneath the soil and loose debris which covers them in most places, is shown by Plate IV.

Limestone outcroppings are not abundant in Shawano county owing to the thick mantle of glacial drift and soil which obscures the bed rock in most places. The most favorable localities for outcrops are along escarpments and bluffs which mark the western edge of the limestone formations, and in the stream channels.

Several ledges of Lower Magnesian limestone occur in the towns of Lessor and Hartland. In section 34 of the town of Wescott, the Lower Magnesian limestone caps a bluff of Potsdam sandstone. The section in descending order is as follows:

	Feet
1. Earth	
2. Rather thin-bedded, shaly, sandy, magnesian limestone	4
3. Bluish irregular magnesian limestone, containg odes of quartz	3
4. Compact, flinty limestone	1
5. Grayish white, magnesian limestone	⅔
6. Flinty, magnesian limestone	1½
7. Light gray, magnesian limestone	3
8. Layer with fish-roe-like aggregations of flint	2
9. Concealed layers	3
10. Layers with flint in fish-roe-like aggregations	3
11. Light colored magnesian limestone, partially exposed	
12. Slope concealing limestone	

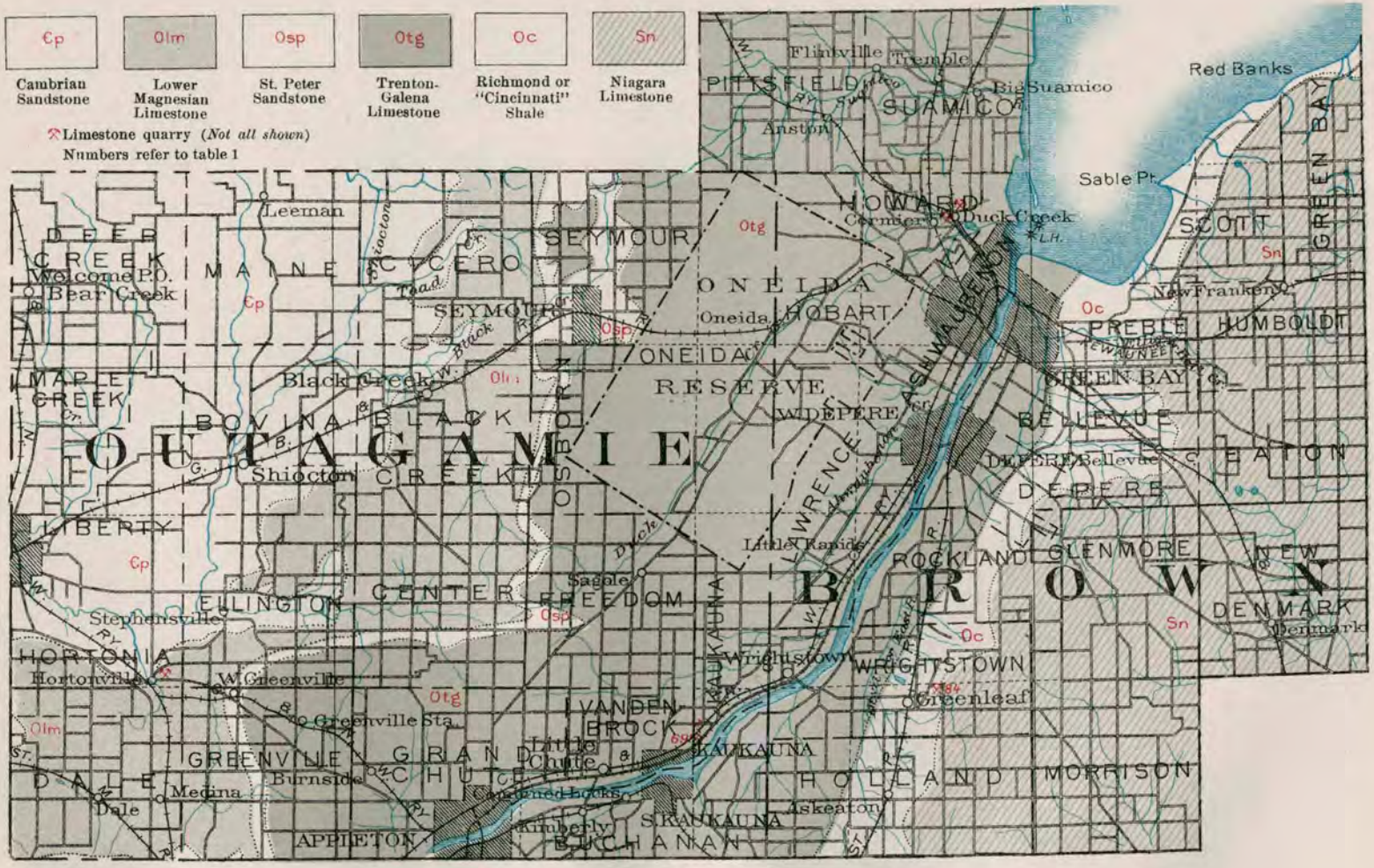
The Lower Magnesian limestone is quarried and burned for lime by Mr. Henry Perschbacher, near Advance; the Wussow Lime Kiln Company near Bonduel; and by Mr. Bert L. Darling at Pulcifer. It is also quarried in the southern part of the town of Maple Valley.

Scattered and meager exposures of the lower beds of the Trenton limestone occur in the towns of Lessor, Maple Grove, and Angelica. As a source of local building material, they have had much value.

No information is available regarding the fitness of Shawano county limestones for use on roads. They have not been tested, nor have they been tried out by actual use. In the southern part of the state, the Lower Magnesian limestone is exceedingly variable in its quality as a road material. Good and worthless material can often be seen in the same quarry. Of the Trenton, only the lower beds occur in this county. Very little is known about their road-making qualities in the northeastern part of the state, but in the southern part, they usually are soft and earthy, and furnish a uniform but rather mediocre road material suited for light traffic.

Shawano county has an abundance of good road materials other than limestone. In the northwestern part of the county there are numerous granite outcrops from which excellent stone for use on roads could be secured. There is a granite quarry at Hunting operated by Mr. James Cheyne. Field bowlders and gravel deposits are plentiful all over the county. The following is an incomplete list of localities where gravel pits have been opened up in Shawano county:

In the town of Maple Valley about 5 miles east of Claywood;
About 2 miles west of the southeast corner of the town of Maple Valley;
In the town of Underhill, about one mile north of the village of Underhill;
About 2 miles east of Berry Lake;
Near the center of the town of Underhill;
About 3 miles east of Shawano;
About 2 miles southeast of Shawano, in the town of Waukechon;
Near the southeast corner of the town of Waukechon;
Several in the vicinity of Clintonville, in the town of Larrabee.


Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Trenton-Galena Limestone
Oc
Richmond or "Cincinnati" Shale
Sn
Niagara Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1
OUTAGAMIE
BROWN
Flintville
Tremble
PITTSFIELD
SUAMICO
Big Suamico
Red Banks
Anston
Sable Pt.
GREEN BAY
HOWARD
Cormier
Duck Creek
SCOTT
Leeman
SEYMOUR
CICERO
DEER CREEK
MAINE
Welcome P.O.
Bear Creek
Toad Cr.
Shioctor Cr.
ONEIDA
Oneida
HOBART
New Franken
PREBLE
HUMBOLDT
SEYMOUR
Brick Cr.
ONEIDA RESERVE
MAPLE CREEK
Black Creek
BOVINA
BLACK CREEK
WIDEPERE
GREEN BAY
BELLEVUE
EATON
DEPERE
Bellevue
Shioctor CREEK
LIBERTY
Little Rapids
ROCKLAND
GLENMORE
NEW DENMARK
Denmark
Sagole
CENTER
FREEDOM
ELLINGTON
Stephensville
HORTONIA
Hortonville
W. Greenville
Greenville Sta.
WRIGHTSTOWN
Wrightstown
Greenleaf
IVANDENBROCK
Little Chute
KAUKAUNA
GREENVILLE
GRAND CHUTE
Burnside
Cauliflower Locks
HOLLAND
MORRISON
DALE
Medina
Dale
Askeaton
Kimberly
APPLETON
BUCHANAN
LAWRENCE
FOX RIVER
ASHWAUBENON

Outagamie and Brown Counties.

Nearly all of Outagamie county is underlaid by northeast-southwest trending belts of Potsdam sandstone, Lower Magnesian limestone, St. Peter sandstone, and Galena-Trenton limestone, whose occurrence from northwest to southeast is in the order named. North of Seymour, there is an outlying patch of Galena-Trenton limestone surrounded by St. Peter sandstone. For the distribution of these formations, as they would appear if the soil and loose debris which covers them in most places were stripped off, see Plate V.

The Galena-Trenton area of Outagamie county extends into Brown county, and is bounded on the east by a narrow strip of Cincinnati shale striking northeast-southwest. To the east of the shale belt, the rock is Niagara limestone.

The greater part of these counties is covered by glacial deposits chiefly red lake clays. Their surface is mostly level, due to glacial cutting and filling, and to the superficial clay deposits. The western edge of the Niagara limestone beds forms a low, but distinct, unbroken escarpment to the east of the C. M. & St. P. Ry., running southwest from Green Bay. West of these bluffs there are lowlands underlaid by the Cincinnati shale and the Galena-Trenton limestone. Here the bed rock formations are also covered by glacial lake clays, into which the Fox River has trenched its channel down to the Galena limestone. Another distinct and fairly continuous escarpment marks the western limit of the Galena-Trenton limestone, and at their western edge, the Lower Magnesian beds in turn constitute a low line of hills overlooking the Potsdam sandstone area to the west.

Limestones outcrop in many parts of Brown and Outagamie counties. The most favorable places for exposures are along the escarpments marking the western limits of the limestone areas, and in the stream channels. The floor of the Fox river is dominantly limestone. Outcrops also occur away from the main valleys and ridges where the drift cover happens to be absent.

The most conspicuous outcrops of Lower Magnesian limestone are along the steep slopes marking its western limit. They represent the lower beds of the formation. Chamberlin[1] has measured a total of about 60 feet of these beds from scattered outcrops in the

[1] Chamberlin, T. C. Idem, p. 277.

town of Hortonia. Judging from his descriptions some of them are probably suitable for road making.

To the south of the small stream running from east to west through the township of Ellington, outcrops of Lower Magnesian limestone become less abundant as one follows the bluffs eastward.

A few feet of Lower Magnesian limestone are found on top of North and South Mosquito Hills, near New London. They are sandy and weak, and unlike the Lower Magnesian limestone beds on the opposite side of Wolf river. Scattered and meager exposures of the Trenton are also found in the towns of Seymour, Freedom, and Osborn.

Outcrops of Galena limestone are common in the stream channel of the Fox river between Appleton and Depere. Before the river was modified by dams, it formed a succession of rapids over the heavier and more resistant beds. The outcrops at Kaukauna, Chamberlain[2] states, are typical of the Galena limestone along the Lower Fox river.

His description of them is in part as follows: " . . . the layers vary from 6 to 30 inches in thickness, . . . The rock is of a dull bluish green or gray hue, and is characterized by very thin, shaly partings between some of the layers, and by thin, irregular, clayey laminae through the body of the rock, not sufficient however to impair its strength or power of resisting atmospheric influences, since bowlders which have been exposed since the drift, are still sound. Aside from these laminae, the rock has a crystalline character, impervious, and compact in general, though it contains a few cavities, some of which are lined with calcite, and occasionally pyrite."

Exposures of the Galena limestone are common along Duck Creek. At its mouth near the village of Duck Creek, the character of the outcrops is very similar to those at Kaukauna.

The Big Suamico river has likewise denuded this formation at a few points. The most noteworthy of these is at Flintville. Its nature here is considerably different from what it is at Kaukauna and Duck Creek. The lower seven feet of the outcrop consists of interlaminations of shale and limestone. Above it lies a 3 foot bed of massive dolomite very similar to that at Duck Creek and Kaukauna.

Outcrops of the Niagara limestone are not plentiful. The most favorable region for outcrops lies along the escarpment marking its

[2] Chamberlin, T. C. Idem, p. 312.

western edge. The beds exposed here belong to the lowest part of the Niagara limestone. Their average thickness is about 60 feet; their maximum thickness about a hundred feet. As a rule, only a small part of them is exposed in any one place.

The striking characteristics of these beds, in Chamberlin's words are: "thick bedding, uneven structure, and rough, craggy, pitted surface of the weathered rocks." He recognizes 5 distinct types of beds in this subdivision of the Niagara; viz., the lowest consisting of from 4–10 feet of shaly impure limestone, above which appear from 6 to 12 feet of hard, heavy bedded limestone which is no good for burning lime. The type overlying this is from 5 to 35 feet thick. Its lowest portion consists of broken fragments of limestone, cemented with a yellowish green marly clay. The character of the upper portion is a repetition of the lower. The middle portion consists of from 4 to 14 feet of compact, cherty limestone, excellent as a building stone. This stratum is overlaid by an even bedded limestone, usually quite hard, compact, fine-grained, white or light gray, often nearly a pure dolomite, and a valuable rock. In Fond du Lac county the aforesaid series of beds is overlaid by a granular, reddish yellow, porous, easily decomposed limestone, sandy in grain, but in reality a very pure limestone.

Although there are many limestone quarries in Outagamie and Brown counties, only a few are active at the present time and most of these serve local needs only. The Lower Magnesian limestone is quarried at Dale, Shiocton, Black Creek, Hortonville, and Seymour in Outagamie county. Large quarries in the Galena limestone are located at Duck Creek, De Pere, Kaukauna, and Appleton. The Niagara is quarried at Greenleaf, New Franklin, Askeaton, and Bay Settlement.

Only a few descriptions of quarries are available. Buckley[1] describes the beds of the C. & N. W. Ry. Co.'s quarry at Duck Creek from the top downward as follows:

15 in. considered one of the best beds of the quarry. Below this bed is ¼ to ½ inch of clay.

34 in. Sometimes runs solid, while at other times it is split into two or three courses.

16 in. Solid bed.

19 in. Works into good 18 in. coursing.

28 in. This bed is split up into any desired thickness.

[1] Buckley, E. R., The Building Stones of Wisconsin: Bull. Wisconsin Geological and Natural History Survey, No. IV, Pl. XL, 1898, p. 274.

11 in. This bed is shelly and worthless.

15 in. In places shelly and worthless, in others, suitable for dimension stone.

He states that the beds in the other quarries of the Duck Creek district are very similar to those of this quarry. At the M. Brunette quarry about 40 feet of rock is exposed. No great variation of the beds can be noted. The lower beds are less suited for dimension stone than the top beds, hence they are used for making crushed stone. In 1912, the capacity of the crusher at this quarry was 400 cubic yards per day.

The L. Lindauer quarry at Kaukauna is located on the north bank of the Fox river at the north end of the city. The total thickness of the beds is about 10 feet. Their character is very similar to that of the Duck Creek stone. They are irregularly laminated and contain small vugs and cavities frequently lined with calcite and zinc blende.

The capacity of the crusher in 1912 was about 100 cubic yards a day.

About a half mile north of the Lindauer quarry is the quarry owned by Jas. W. Black. It is situated above the flood tide of the river. The beds of this quarry are similar to those in the Lindauer quarry.

Road tests were made on samples of stone from the Greenleaf Stone Co.'s quarry at Greenleaf and the L. Lindauer quarry at Kaukauna.

TABLE VII.

Tests on Limestone from the Lindauer quarry at Kaukauna, and the Greenleaf Stone Co's quarry near Greenleaf, Wisconsin.

Nature of test.	Lindauer quarry. Wisconsin road sample No. 69.	Greenleaf quarry. Wisconsin road sample 85.	Maximum for Wisconsin limestone.	Minimum for Wisconsin limestone.
Specific gravity	2.80 High	2.75 High	2.85	2.45
Pounds per cu. ft.	175.00 High	172.00 High	178.00	153.00
Pounds of water absorbed per cu. ft	1.03 Low	2:30 Medium	6.9	.14
Per cent of wear	4.1 Medium	3.0 Low	22.50	2.30
French coefficient of wear	9.7 Medium	13.3 Medium	17.3	1.80
Hardness		14.8 Medium	16.5	4.00
Toughness		8 Low	13.	2.00
Cementing value	Good	Good		
Suitable for	Light traffic	Light traffic		

The report of the Office of Public Roads on the sample from the Lindauer quarry is as follows: "Material shows average resistance to wear and good cementing value. Suitable for use on plain macadam roads subjected to light traffic or for use with a bituminous binder."

Its comment on the sample from the Greenleaf quarry is: "A stone of medium resistance to wear and good cementing value, recommended for the construction of roads subjected to light traffic or for use with a bituminous binder."

Besides limestone, Outagamie and Brown counties have gravel and field stone as a source of road material. In the northwestern part of Outagamie county, granite probably could be used to advantage. A hill of excellent granite is located only 4 miles southwest of New London in Waupaca county.

Kewaunee and Door Counties.

The Niagara limestone underlies all of Kewaunee and Door counties, excepting a small fringe along Green Bay which is underlaid by Cincinnati shale. See Plate VI for the distribution of these formations as they would appear if the soil and loose debris which covers them in most places were stripped off. Through the middle of Kewaunee county parallel to the coast lines, the drift cover is especially deep, consisting of hummocky ridges, which are known as the kettle moraine.

The strip of Cincinnati shale on the west coast of Kewaunee county underlies a lowland back of which rise bold bluffs of Niagara limestone. The lowlands become narrower to the north. In Door county, north of Little Sturgeon Bay, they disappear and the limestone bluffs rise from the water's edge, in some places as precipitous cliffs undercut by the waves. The slope on the Lake Michigan side is mostly gentle.

Limestone outcrops are common in these counties. The escarpment along Green Bay consists of bare rock in many places, notably at the mouth of Big Sturgeon Bay, and at each of the harbors to the north of it, as well as at Death's Door at the extremity. To the north of Sturgeon Bay, the drift is thin, and full of limestone bowlders. The bare rock comes to the surface in not a few places. Except on the west coast, outcrops of limestone are not plentiful in Kewaunee county. The most favorable localities are along the largest streams. In the kettle moraine area the chances of finding outcrops are poor.

The Niagara limestone beds along Green Bay as far north as Little Sturgeon Bay are characterized by thick bedding, uneven structure, and a rough craggy, pitted surface on the weathered ledges. To the north of Little Sturgeon Bay, the beds are mostly white, dense, hard, exceedingly fine-grained, but somewhat brittle. Their thickness is about 100 feet. Characteristic exposures of these beds occur at the western gateway of Sturgeon Bay, and along the coast to the northward. They are quarried on the north shore of Sturgeon Bay, by Louis P. Nebel, Leatham and Smith Towing and Wrecking Company, and by Jno. M. Laurie; on the south side of the bay, west of Sawyer City, by the Sturgeon Bay Stone Company, and the Green Stone and Quarrying Company. The quarry of the Leatham and Smith Towing and Wrecking Company is the principal producer of crushed rock for roads and other purposes.


Oc
Richmond or "Cincinnati" Shale
Sn
Niagara Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1
Egg Harbor
Kangaroo L.
EGG HARBOR
Horseshoe Pt.
Monument Pt.
JACKSON
PORT
Clark L.
LITTLE STURGEON BAY
Sherwood Pt.
Snake I.
STURGEON BAY
SEVASTOPOL
LILLY BAY
STURGEON BAY
NASEWAUPEE
STURGEON BAY AND LAKE L.H.
GARDNER
River Bluff
Maplewood
Brussels
UNION
BRUSSELS
FORESTVILLE
CLAY BANKS
Forestville
RED RIVER
LINCOLN
ALGOMA
Rio Creek
Cascoo
CASCO
LUXEMBURG
Clyde
Casco Junction
WEST
KEWAUNEE
MONTPELIER
FRANKLIN
CARLTON

For tests of an average sample of the latter quarry see table VIII. The Office of Public Roads comments on this sample as follows: "Sample shows average hardness and resistance to wear, is a little low in toughness and low in binding power. Should give satisfactory results for roads having light traffic if material is used in plain macadam construction with screenings from some rock having high cementing power to act as a binder."

Along the east coast of Door and Kewaunee counties there are coral-bearing beds about 150 feet thick of which the lower half is probably the better suited for road material. The lower portion of the coral series is characteristically rough, heavy bedded, coarse, crystalline, granular, and usually rather soft. The layers are sometimes marked by clayey seams or scattered bands of flint, or by fossils replaced by flint. The irregular hardness of the rock gives it a craggy, pitted appearance on the weathered surface. Its prevailing color is blue, white, yellow, in places marked with red, pink, and purple.

The upper portions of the coralline beds are generally of a buff color, thin-bedded, fine-grained, compact, hard but occasionally earthy and contain flint in the form of nodules and as a replacement of fossils. They are not used much for either construction or lime.

Vertical cliffs of the coral beds are exposed at the entrance of Porte de Morts. Nearly their full thickness is exposed at Bailey's Harbor. Other exposures are found south of Jacksonport; in sections 5 and 9, near the city of Sturgeon Bay; in section 17 of the town of Forrestville; on Scarabo Creek, town of Casco; in section 28 of the town of Pierce; and in section 14, at the mill on the Kewaunee river.

In the southern part of Kewaunee county, the coral beds are overlaid by the so-called Racine beds, which are well adapted for road making. The name Racine beds has been applied to them because of their characteristic development near Racine, Wisconsin. Their chief outcrop is in section 14 of the town of Kewaunee, where they are crushed for road construction at Nast Brothers quarry. The upper beds, the best suited for use on roads, are hard, compact, fine-grained, and fossiliferous. The lower beds are coarser and softer and more thin-bedded. The total thickness of beds in this quarry is about 10 feet.

The tests on an average sample of rock from the Nast Brothers are given in table VIII. The comment of the Office of Public Roads on this sample is as follows: "Sample is soft, shows low tough-

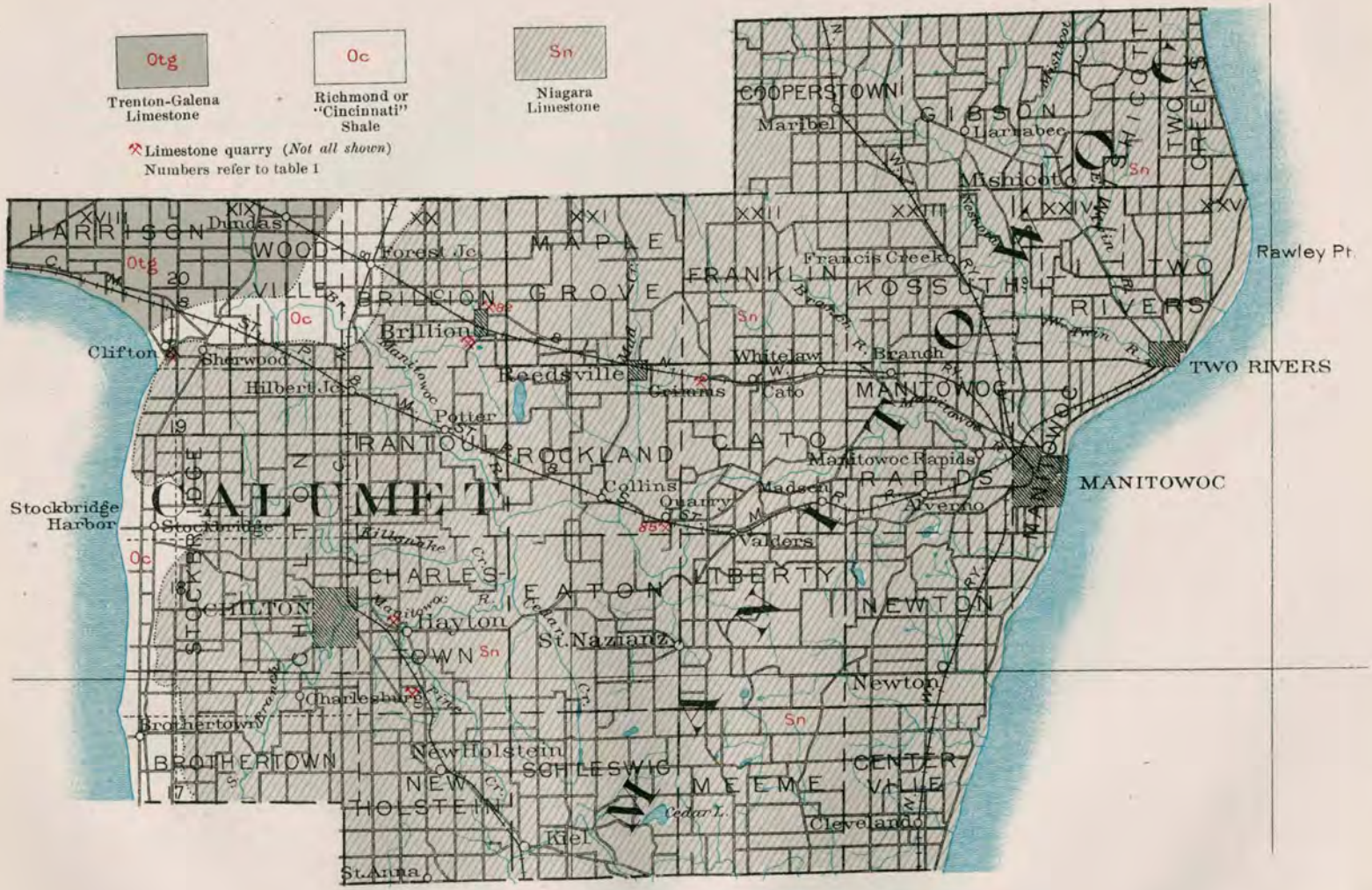
ness, average resistance to wear and good cementing value. Should only be used on plain macadam roads subjected to light traffic, or for use with bituminous binders.''

TABLE VIII.

Tests on Limestone from Nast Bros. quarry, Kewaunee, and from Leatham & Smith's quarry, Sturgeon Bay, Wis.

Nature of test.	Nast Bros. quarry, Kewaunee, Wis. Road Sample 72.	Leatham & Smith's quarry, Wis. Road Sample 71.	Maximum for Wisconsin limestone.	Minimum for Wisconsin limestone.
Specific gravity	2.85 High.	2.85 High.	2.85	2.45
Pounds per cubic feet	178. High.	178. High.		
Pounds of water absorbed per cu.ft.	.22 Low.	.26 Low.	.69	.14
Per cent of wear	3.8 Average.	4.5 Average.	22.5	2.3
French coefficient of wear	10.6 Medium.	9.0 Medium.	17.3	1.8
Hardness	12.8 Soft	14.2 Average.	16.5	4.0
Toughness	6. Low	12. Low	13.	2.0
Cementing value	Good	Low.		
Suitable for	Light traffic	Light traffic		

Besides limestone, Door and Kewaunee counties have some gravel and an abundance of field stone, which are suitable for road construction.


Otg
Trenton-Galena Limestone
Oc
Richmond or "Cincinnati" Shale
Sn
Niagara Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1
COOPERSTOWN
Maribel
GIBSON
Larrabee
Mishicot
TWO CREEKS
Rawley Pt
HARRISON
Dundas
WOOD
Forest Jc.
MAPLE
FRANKLIN
Francis Creek
KOSSUTH
TWO RIVERS
Clifton
Sherwood
Brillion
Reedsville
Hilbert Jct.
Potter
Whitelaw
Branch
Cato
MANITOWOC
TWO RIVERS
RANTOUL
ROCKLAND
CATO
Manitowoc Rapids
CALUMET
Collins
Quarry
Madson
Avenno
MANITOWOC
Stockbridge Harbor
Stockbridge
Valders
CHARLESTON
EATON
LIBERTY
NEWTON
Hayton
St. Nazianz
TOWN
Charlestown
Newton
Brothertown
BROTHERTOWN
New Holstein
SCHLESWIG
MEME
CENTERVILLE
NEW HOLSTEIN
Cedar L.
Cleveland
Kiel
St. Anna

Manitowoc and Calumet Counties.

The northwest corner of Calumet county is underlaid by Galena-Trenton formation, to the east of which there is a narrow belt underlaid by Cincinnati shale. Excepting a narrow strip along the east shore of Lake Winnebago, which is also underlaid by the shale, all the rest of Calumet and all of Manitowoc county is underlaid by the Niagara limestone. The distribution of these formations at the surface and underneath the soil and loose debris which covers them in most places is shown by Plate VII.

Most of the surface of the eastern part of Manitowoc county is a level, monotonous plain, under which the solid rocks are almost completely buried by lake clays. In the western part of the county hummocky ridges of coarse glacial debris cover most of Niagara limestone beds of the Towns of Schleswig, Eaton, Rockland, and Maple Grove.

It is only along the bluffs and cliffs which mark the western edge of the Niagara limestone on the shore of Lake Winnebago and in the northwest corner of Calumet county that outcrops of Niagara limestone are common.

The Galena-Trenton formation underlies a level or gently rolling surface and is probably covered everywhere by glacial debris and lake clays.

The important quarries of Manitowoc and Calumet counties are all in the Niagara limestone. The largest are at Brillion, Hayton, Grimms, Quarry, Clifton, Valders, Cooperstown, and Charlestown. Descriptions of some of these follow.

The quarry at Clifton is located on the bluffs of Niagara limestone at the northeast end of Lake Winnebago. The beds exposed along these bluffs are mostly flint bearing, coarse grained, thick, gray, and rough in exterior. Their average quality for road making is similar to that of the limestone at Mayville, about as good as any limestone in the State. In a few places, however, the top beds of the section along Lake Winnebago are porous, and sandy in grain, and almost worthless for road making.

At the Union Lime Company's quarry at Hayton, the section of Niagara limestone is as follows, in descending order:

	Feet
Soil	thin
Top layers, shelly, easily broken, weathered and soft	5
Hard, blue, compact limestone. Good road material	12
Hard, white, coarsely crystalline. Good road material	5
Soft limestone. Inferior as road material	12

At the present time this stone is used for lime only, but a considerable part of it, as has been indicated, would make good road material.

The supply of stone in this quarry for practical purposes is inexhaustible. The quarry is located on a hill overlooking the C. M. & St. P. Ry. Facilities for shipping crushed rock from here could easily be obtained.

The Union Lime Co.'s quarry at Brillion, is located in the Niagara limestone. The quarry face is about ¼ mile long. The section is as follows:

	Feet
Soil	A few feet
Top layers, fine-grained, slightly earthy. Poor road material	25
Coarse-grained limestone of slightly sandy texture. Poor road material	10
Coarse-grained, very compact rock	4
Reddish limestone, with flints in bands, and nodules parallel with the bedding. A good road material	10

The lower ten feet were crushed for road material in 1912. The capacity of the crusher was 150 yards per day. For tests on an average sample of the crushed stone see table IX.

The report of the Office of Public Roads on this stone is as follows: "This is a soft rock, showing low toughness, and resistance to wear and good cementing value. Should only be used on roads subjected to very light traffic."

At the Union Lime Co.'s quarry at Grimms about 26 feet of Niagara limestone are exposed. The rock is used for lime only, but most of it would make good road material as well. The section in descending order is as follows:

	Feet
Soil	A few feet
Hard, compact limestone. Beds 1 to 2 feet thick. Would make good road material	6
Cavernous, soft, coral-bearing limestone. Cavities lined with calcite crystals. Very thick beds, 12 or more feet thick. Inferior for road constructions	20

A sample from the Empire Lime & Stone Co.'s quarry at Quarry was tested by the Office of Public Roads. For tests see table IX. The Office of Public Roads reported on this sample as follows: "The tests show this rock to have a rather low resistance to wear and excellent cementing value. Should make a suitable material for roads subjected to very light traffic or to be used with bituminous binder."

These tests were made on stone from the upper 15 feet of the

quarry, which beds are very much broken, and are used for quicklime only. The lower 12 to 15 feet, which are crushed for road material are uniformly bedded, hard, well crystallized, and even in texture. Undoubtedly, they would have shown better tests than the sample which was taken.

At Cooperstown, about 15 miles northwest of Manitowoc, there are numerous outcrops of Niagara limestone. They have been used to some extent for local building purposes, and may be considered as a possible source of local road material. The limestone is even-grained and has a fine crystalline texture. The upper beds are usually very much broken, but below the stripping, a stone of fair quality can be obtained in most places.

At Cato Falls on the Manitowoc river, outcrops of thin, wavy, bedded, homogeneous Niagara limestone appear. Two miles down the river from this locality, similar thin, broken ledges form a wall along the bank of the stream about 15 feet high. A short distance below this outcrop, there are several outcrops, one of a flinty limestone, the other consisting of 20 to 25 feet of fragmental limestone overlaid by 12 feet of flinty rock, the hardness of the latter giving rise to rapids. To the south of the Manitowoc river, outcrops are scarce, the formation being covered in most places by glacial drift.

The kettle moraine area of Manitowoc county has an abundance of field bowlders and gravels which could be used on roads. Gravel pits are so numerous in this county that a detailed discussion of their location seems unnecessary.

TABLE IX.

Tests on Limestone from Manitowoc County.

Nature of Test.	1	2	3	4
Specific gravity	2.80 High	2.65 High	2.85	2.45
Pounds per cubic foot	175. High	165. High	178	153
Pounds of water absorbed per cubic foot.	.51 Low	1.35 Low	6.9	.14
Per cent of wear	5.5 High	7.5 High	22.5	2.3
French coefficient of wear	7.2 Low	5.3 Low	17.3	1.8
Hardness	.....	12.2 Soft	16.5	4.0
Toughness	.....	5 Low	13	2.0
Cementing value	Excellent	Good	.....	.....
Suitable for	.....	.....	.....	.....

1. Limestone from Empire Lime & Stone Co.'s quarry at Quarry.
2. Limestone from quarry of Union Lime Co., at Brillion.
3. Maximum tests for Wisconsin limestone.
4. Minimum tests for Wisconsin limestone.

WINNEBAGO COUNTY.

The eastern portion of Winnebago county is underlaid by the Galena-Trenton formation; the western portion by belts and patches of St. Peter sandstone, Lower Magnesian limestone, and Potsdam sandstone. The distribution of these formations at the surface and beneath the soil and loose material which covers them in most places is shown by Plate VIII.

The surface of nearly all of Winnebago county is level or gently rolling. Most of the eastern portion is level, being covered by lake clays. About the only prominent surface features of the county are the bluffs which mark the western edge of the Lower Magnesian limestone to the south of Lake Poygan.

Outcrops and quarries of limestone are not abundant in Winnebago county. The best exposures occur at or near the escarpment which marks the western edge of Lower Magnesian formation. Many of the other outcrops are not associated with conspicuous surface features. The principal exposures of the Galena-Trenton formation are west of Neenah and Menasha. Descriptions of some of the limestone outcrops and quarries follow.

The Lower Magnesian limestone is exposed at several points west of Rush Lake; in section 15 of the town of Nepeuskum, northwest of Winneconne, near the village of Eureka; and in the NW¼ of section 26 of the town of Poygan.

The Lower Magnesian limestone which outcrops west of Rush Lake and to the northwest of Winneconne is exceedingly variable in composition, grain, hardness, and bedding. It is doubtful whether road material of good quality can be secured from it. Near the village of Eureka, the thickness of Lower Magnesian limestone exposed is 32 feet. The section in descending order is as follows:

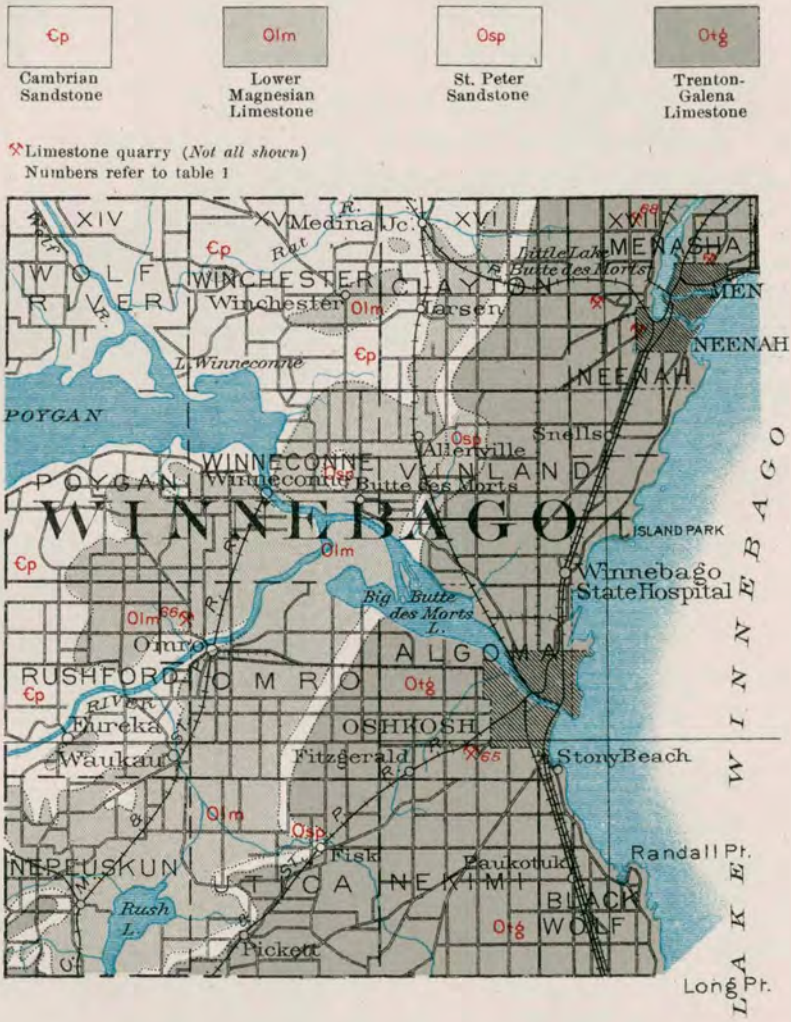
Thin bedded, even grained, limestone, of medium hardness. Contains cavities lined with druses of quartz.....	10 feet
Soft, shaly layers, not fit for use on roads.....	16 "
Thick bedded, compact, even grained limestone of medium hardness	6 "

The lower layers appear to be best adapted for use on roads.

The section of Lower Magnesian limestone southwest of Eureka in descending order is as follows according to Chamberlain.[1]

1. Heavy irregular beds of impure limestone containing many

[1] Chamberlin, T. C., Geology of Wisconsin, Vol. II, p. 276, 1873–1877.


Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Trenton-Galena Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1
WINNEBAGO
POYGAN
WINNECONNE
VINLAND
WOLF RIVER
WINCHESTER
CLAYTON
MENASHA
NEENAH
Medina Jc.
Little Lake Butte des Morts
L. Winneconne
Larsen
Allenville
Snells
Winneconne
Butte des Morts
ISLAND PARK
Winnebago State Hospital
Big Butte des Morts L.
Omro
ALGOMA
RUSHFORD
OMRO
OSHKOSH
Eureka
Waukau
Fitzgerald
Stony Beach
Fisk
Rush L.
Pickett
Paukotuk
Randall Pt.
BLACK WOLF
Long Pt.
LAKE WINNEBAGO

cavities, more or less filled with quartz crystals of the transparent and milky varieties; texture varying; bedding uneven and somewhat undulatory; rock weathers to a very rude ragged aspect. Thickness 10 feet.

2. Reddish shale, variegated with gray and green, the lower portion mostly soft, breaking and crumbling easily; some parts quite arenaceous; the upper portion more calcareous, and containing many aggregations of quartz crystals, usually of the opalescent variety. The layers are irregular and somewhat undulating. Thickness 15 feet.

3. Very heavy beds, nearly uniform in thickness, and horizontal in bedding. The rock contains many almond-sized but irregular cavities, only a small proportion of which are filled with crystals. It is uneven but distinctly granular crystalline in texture, medium in hardness, and dirty gray or buff on the exterior, but mottled bluish on the interior. It is well adapted to heavy masonry, as foundations, piers and locks. It is used for the latter purpose in the construction of the adjacent locks on the Fox river. Thickness exposed 6 feet."

The following section of an old lime quarry in the NW¼ of section 26 in the town of Poygan is also taken from Chamberlin.[1]

In descending order the beds are as follows:

Thin-bedded, wavy limestone	3 feet
Layer exceedingly variable in its characteristics	
Soft, earthy, granular limestone. Beds below medium in thickness	16 feet
Yellowish gray limestone	1 foot
Rotten limestone	8 inches
Hard limestone—only surface exposed.	

The Lower Magnesian limestone is quarried at Gilbert's quarry south of Lake Poygan and near Winneconne. These quarries have produced very little road material.

It is also exposed in a small pit on the farm of E. E. Bronson at Omro. The rock at this place is soft and porous, and does not show bedding. So little of it is exposed that no safe estimate of the amount available could be made. For tests on an average sample from this locality see Table X.

The report of the Office of Public Roads on this stone is as follows:

"Sample shows average hardness, low resistance to wear and toughness, and good cementing value. Should only be used on plain

[1] Chamberlin, T. C., Geology of Wisconsin, Vol. II, p. 277, 1873–1877.

macadam roads subjected to light traffic or with a bituminous binder."

A sample of the Lower Magnesian limestone from the quarry of H. E. Gilbert, about 4 miles northwest of Omro, near Lake Poygan, was tested by the Office of Public Roads. For results, see Table X.

The comment of the Office of Public Roads on this stone is as follows:

"This rock shows average hardness and resistance to wear, low toughness and fair cementing value. Should prove satisfactory for plain macadam roads subjected to light traffic or for use with a bituminous binder."

At the Robert Lutz quarry southwest of Oshkosh about 37 feet of the Galena-Trenton formation are exposed. The section is as follows in descending order:

Soil	
Thin bedded, frost-broken limestone	A few feet
Fine grained, bluish colored limestone with numerous quartz lines cavities	15 "
Bluish, fine grained limestone alternating with shaly layers	10 "

The amount of stone in this quarry is for practical purposes unlimited. The quarry is easily accessible, and has railroad facilities.

An average sample from this quarry was tested by the Office of Public Roads. For results see Table X. Its comment on this sample is as follows:

"Material shows average hardness and resistance to wear, low toughness and good cementing value. Only suitable for use in foundation course in plain macadam construction, or suitable for use with a bituminous binder."

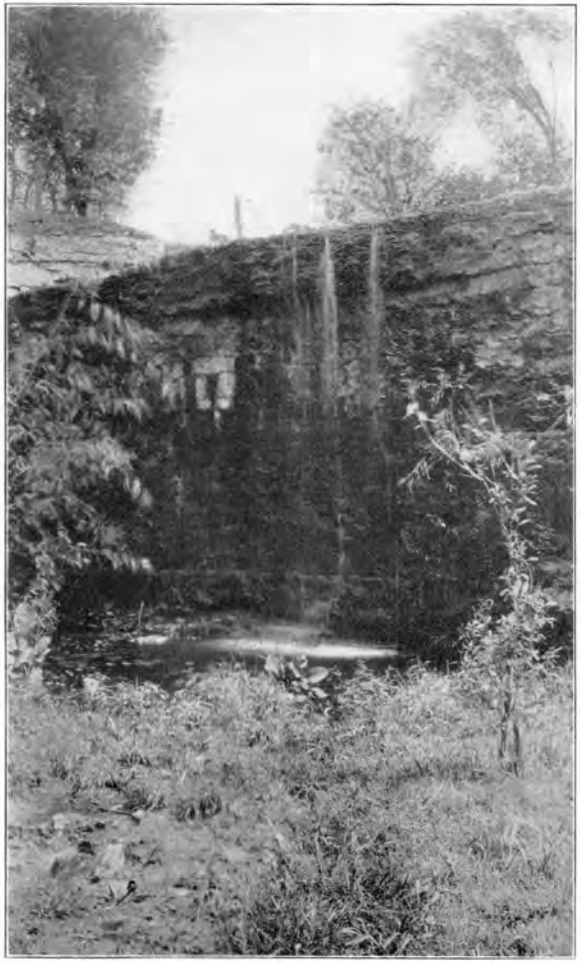
To the west of Neenah and Menasha there is a series of quarries, of which the most important are the G. H. Salter quarry and the City quarry of Neenah. The Salter quarry is located about 3 miles south of Appleton. The stone is being excavated from below the general level of the country, and has to be hoisted to the crusher. The rock section in descending order is as follows:

	Feet
Fine grained, buff, thin bedded limestone with flint nodules	6
Dense, thick bedded, bluish limestone	12

An average sample from this quarry was tested by the Office of Public Roads. For results see Table X. Its report is as follows:

"This rock shows average hardness and resistance to wear, rather low toughness and good cementing value. Should be satisfactory

North of Trempealeau. A cone-shaped hill of Potsdam sandstone capped by Lower Magnesian limestone. Hills of this type retain their steep sides and pointed summit as long as the limestone cap remains. When the limestone cap disappears the hill is rapidly reduced to a low, rounded, dome-shaped swell with gentle slopes.



The Niagara Falls miniature. This tiny stream is falling over an old quarry face of Niagara limestone near Peebles. The soft, Cincinnati shale occurs at the foot of the falls but does not show in the picture. At Niagara Falls the waters also leap over an escarpment capped by Niagara limestone with shale below.

for plain macadam roads subjected to medium traffic or with bituminous binders.''

Tests on an average sample of Galena-Trenton formation from the city quarry of Neenah by the Office of Public Roads are shown in Table X. Its report on this stone is:

''Material shows average hardness and resistance to wear, low toughness and good cementing value. Should be satisfactory for use on plain macadam roads subjected to light traffic or with a bituminous binder.''

Winnebago county has very little road material besides limestones. In the western part there may be some localities where field bowlders are sufficiently abundant to constitute a road material. In the eastern portion, there are a few gravel pits. One is located in the town of Nekimi about 3 miles south of Oshkosh.

TABLE X.

Tests on Limestone from Winnebago County.

Nature of Test.	Specific gravity.	Weight per cubic ft.	Water absorbed per cubic ft.	Per cent of wear.	Coefficient of wear.	Hardness.	Toughness.	Cementing value.	Suitable for.
Limestone from Lutz Quarry, Wis., Road sample No. 65	2.8 High	175	.65 Low	3.8 Med.	10.6 Med	15.5 Med.	8. Low	Good	
Limestone from Bronson Quarry, Wis. Road Sample No. 66	2.75 Med.	172	1.65 Med.	5.6 Low	7.1 Low	16.3 Med.	7. Low	Good	Light traffic.
Limestone from Gilbert's Quarry. Wisconsin Road. Sample No. 81	2.8 High	175	.62 Low	3.4 Med.	11.9 Med.	14.7 Med.	11. Low	Fair	Light traffic.
Limestone from Salter's Quarry. Wisconsin Road. Sample No. 68	2.8 High	175	.52 Low	3.4 Med.	11.8 Med.	16.5 Med.	10. Low	Good	Medium traffic.
Limestone from City Quarry of Neenah	2.70 Med.	168	2.68 High	4.1 Med.	9.8 Med.	14.3 Med.	9. Low	Good	Light traffic.
Maximum for Wisconsin (limestone)	2.85	178	6.9	22.5	17.3	16.5	13.		
Minimum for Wisconsin (limestone)	2.45	153	.14	2.3	1.8	4.0	2.		


Calumetville
Calumet Harbor
Oc
CALUMET
Long Pt.
Van Dyne
FRIEND
Malone
Silica
Calvary
MARSHFIELD
TAYCHEEDAH
Mt. Calvary
Peebles
St. Cloud
Sn
Taycheedah
Eldorado
N. Fond du Lac
Otg
Osp
Olm
RIPON
W. Rosendale
Rosendale
ROSENDALE
ELDORADO
SHIP
Reeds Corners
FOND DU LAC
METOMEN
SPRINGVALE
LAMARTINE
EMPIRE
FOREST
Brandon
Lamartine
S. De Neveu
Mullet L.
Oakfield
Harrison
Eden
Long L.
OSCEOLA
Alto
WAUPUN
ALTO
OAKFIELD
BYRON
EDEN
Oak Center
Byron
S. Byron
New Prospect
L. Fifteen
Campbellsport
ASHFORD
AUBURN
Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Trenton-Galena Limestone
Oc
Richmond or "Cincinnati" Shale
Sn
Niagara Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1

Fond du Lac County.

The eastern part of Fond du Lac county is underlaid by Niagara limestone to the west of which there is a narrow strip underlaid by Cincinnati shale. A broad belt of Galena-Trenton limestone trending north and south underlies the central portion from Fond du Lac to Ripon. West of Ripon there are narrow belts underlaid by St. Peter sandstone, Lower Magnesian limestone, and Potsdam sandstone. The distribution of these formations at the surface and underneath the soil and loose material which covers them in most places is shown by Plate X.

The western edge of the Niagara limestone is marked by a prominent escarpment, which follows the east shore of Lake Winnebago. From the south end of Lake Winnebago, it swings southwestward and appears about ½ mile east of the village of Oakfield. The Galena-Trenton limestone underlies a level, gently rolling, in places low stretch of country, a part of which is an old lake plain. The Lower Magnesian beds appear on the hill tops in the northwest corner of the county.

Limestone outcrops and quarries are found chiefly along the escarpments which mark the border of the Niagara and Lower Magnesian limestone. The Galena-Trenton formation is nearly lacking in conspicuous surface features, and is almost completely buried by soil, glacial drift, and lake clays.

The Lower Magnesian limestone is quarried at the Kroll & Benzel quarry west of Ripon. In this quarry, about 28 feet of the Lower Magnesian limestone are exposed. The section in descending order is as follows:

Soil	about 2 feet
Thin-bedded, buff limestone	6 feet
Buff and blue limestone	8 feet
Alternating beds of flint, clay and limestone	10 feet
Fine-grained, dense limestone	2 feet
Alternating bands of clay, sandstone and limestone	3 feet

Rock from this quarry is crushed for road material, which has been used in the city of Ripon. No tests on this material are available. It appears to be as good in quality as the Lower Magnesian limestone at Middleton or Bridgeport. See page 86 of this report.

It has already been stated that outcrops and quarries of the Galena-Trenton formation are scarce in Fond du Lac county.

Nearly all of it is covered by soil, glacial drift, or lake clays. Small exposures occur along Silver Creek in and near the city of Ripon; on a road 2 miles southeast of Ripon; and about ½ miles to the west of Waupun. It is quarried about 2½ miles west of Brandon, and a short distance northwest of Waupun.

No facts regarding the quality of the Galena-Trenton formation in this county for road making are at hand. In Columbia county, it is a uniform, but weak, mediocre material. The upper part of the formation furnishes good road material from a number of quarries in the Upper Fox river valley, whereas in southwestern Wisconsin, it is nearly worthless for road construction. The lower part throughout southern Wisconsin is generally a usable, but rather soft road material. In the northeastern part of the state, it is rarely exposed.

Some of the most important limestone quarries in the state are located on the escarpment at the western edge of the Niagara limestone area in Fond du Lac county.

The following is a partial list of the principal quarry owners:

The C. & N. W. Ry. Quarries at Peebles and at Oakfield.

Nast Bros. Lime & Stone Co. Quarry at Marblehead.

Union Lime Co. Quarries at Marblehead and Hamilton.

The beds exposed at Oakfield and Peebles are characterized by thick-bedding, uneven, coarse grain, and a rough appearance of the weatherd surface. The section at the C. & N. W. Ry. Co's quarry at Peebles is as follows, in descending order:

	Feet
Soil	Very thin
Cavernous, flinty limestone	15 feet
Compact limestone	3 feet
Hard, dense, flinty limestone	15 feet

For tests on this stone see table XI.

In the Union Lime Company's quarry at Hamilton, Wis., about 45 feet of Niagara limestone are exposed. The upper 25 feet of the section consist of a rather soft, medium-grained rock, with an irregular billowy structure. Below this a thickness of 20 feet of thin-bedded, fine-grained, bluish colored limestone with shaly partings is exposed.

The stone from this quarry is crushed for road-making, and other purposes. In 1912 the capacity of the crusher was about 200 cubic yards per day.

For tests on this stone see table XI. The Office of Public Roads reports that the rock from this quarry shows "average hardness

and resistance to wear, rather low toughness and good cementing value. It should be satisfactory for plain macadam roads subjected to light traffic or for use with a bituminous binder."

The Niagara limestone beds in the quarry of the Union Lime Co. and of Nast Bros., Lime & Stone Co. at Marblehead, Wis. are nearly identical. About 55 feet of Niagara limestone are exposed at this locality.

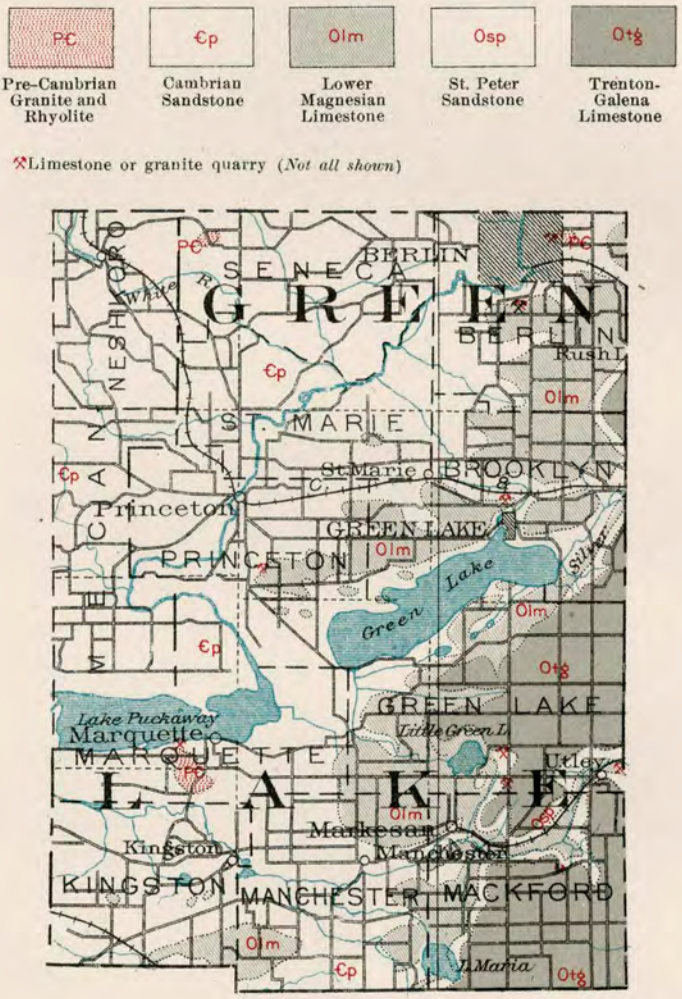
Tests on a sample of stone from the Union Lime Company's quarry at Marblehead are given in Table XI. The report of the Office of Public Roads on this sample is:

"The sample shows average hardness and resistance to wear, low toughness and fair cementing value. Should be suitable for plain macadam roads subjected to light traffic or for use with bituminous binders."

TABLE XI.

Tests on Limestone from Fond du Lac County.

Nature of test.	Specific gravity.	Weight per cubic foot.	Water absorbed, per cu. ft.	Per cent of wear.	Coefficient of wear.	Hardness.	Toughness.	Cementing value.	Suitable for.
Limestone from Union Lime Co., Hamilton, Wis. Road Sample No. 63	2.6 Med.	162.	1.67 Med.	3.6	11.1 Med.			Fair	Light traffic.
Limestone from Union Lime Co., Marblehead. Office of Public Roads Sample No. 6479	2.8 High.	175.	.36 Low.	4.6	8.7 Med.	15.2 Med	10. Low.	Good	Light traffic.
Limestone from Marblehead, Wisconsin Road Sample No. 64	2.80 High.	175.	.51 "	3.4	11.9 Med.	14.4 "	7. "		
Limestone from C. & N. W. R. R. Quarry, Peebles, Office of Public Roads Sample No. 5523	2.85 High.	178.	.51 "	5.4	7.5 Low.	13.7 Soft.	8. "	Fair	Light traffic.
Maximum for Wisconsin limestone	2.85	178.	6.9	22.5	17.3	16.5	13.		
Minimum for Wisconsin limestone	2.45	153.	.14	2.3	1.8	4.	2.		


PC
Pre-Cambrian Granite and Rhyolite
Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Trenton-Galena Limestone
Limestone or granite quarry (Not all shown)
SENECA
BERLIN
GREEN
BERLIN
Rush L.
ST. MARIE
St. Marie
BROOKLYN
Princeton
GREEN LAKE
PRINCETON
Silver
Green Lake
GREEN LAKE
Little Green L.
Lake Puckaway
Marquette
MARQUETTE
Utley
LAKE
Markesan
Manchester
Kingston
KINGSTON
MANCHESTER
MACKFORD
L. Maria
CANESHOD
White R.

GREEN LAKE COUNTY.

Nearly all of the western portion of Green Lake county is underlaid by the Potsdam sandstone. The eastern portion is underlaid by strips of Lower Magnesian limestone, St. Peter sandstone, and Galena-Trenton limestone trending northeast southwest, and by outlying patches of Lower Magnesian limestone. In the vicinity of Berlin, Utley, Marquette, and in the northwestern part of the town of Seneca, knobs of old volcanic rocks project through the sedimentary rocks. Plate XI shows the distribution of these formations as they would appear if the soil and loose debris which covers them in most places were removed.

Most of the outcrops of the Lower Magnesian limestone occur along a distinct line of bluffs which mark the western limit of this formation. The following is a list of localities where it is known to outcrop:

The southeastern part of the town of Kingston.
About 1½ miles west of Lake Maria.
About 2 miles west of Markesan.
East of Little Green Lake.
Along the creek between Little Green Lake and Green Lake.
The southeast end of Green Lake.
Near the mouth of Dover Creek.
Southwest of the mouth of Dover Creek.
South of the C. & N. W. Ry. south of St. Marie.
Between Green Lake and Berlin.

Quarries of the Lower Magnesian limestone are located as follows:

Near Markesan.
About ½ mile north of the Village of Green Lake.
Southeast of Little Green Lake.
About 2 miles southeast of the Village of Princeton.

The composition and physical make up of the Lower Magnesian limestone in Green Lake county are extremely variable. In many places it consists of alternating beds of sandstone and flinty limestone, or of limestone and sandstone beds grading into one another horizontally. It is therefore to be expected that its quality for roads would vary considerably from quarry to quarry, or even from bed to bed.

The principal exposures of the Galena-Trenton formation are along a line of bluffs which mark its western edge. Most of the

beds exposed belong to the lower portion of the formation. They are generally earthy and fine-grained. Sandy and shaly layers are also found occasionally.

Very little information is available which bears directly on the fitness of the limestones of Green Lake county for road construction. They have not been tested, and no data are at hand regarding their behavior when tried out by actual use. In other parts of the state excepting along the Mississippi river the Lower Magnesian limestone usually is exceedingly variable as a road material. Good and worthless material often occur in the same quarry. Judging from published descriptions of its characteristics in Green Lake county, it seems certain that it is as variable here as elsewhere.

Besides limestones, Green Lake county has an abundance of field bowlders and some gravels. Its best road materials for heavy traffic are among the best in the state. They are the volcanic rocks which outcrop at Berlin, Utley, and other localities. At Berlin the granite is crushed on a large scale by the Wisconsin Granite Co., and shipped all over the upper Mississippi valley for use on roads and for city streets.


Sn
Niagara Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1
RUSSELL
RHINE
HERMAN
MOSEL
Seven Mile Creek
Sn
Elkhart L.
Elkhart
Franklin
Howards Grove
Hulls Crossing
Sn
Milwaukee R.
Johnsonville
Glenbeulah
Greenbush
SHEBOYGAN FALLS
SHEBOYGAN
GREEN BUSH
PLYMOUTH
PLYMOUTH
Sheboygan R.
Sheboygan Falls
SHEBOYGAN
Weedens
WILSON
MITCHELL
Waldo
LYNDON
LIMA
Cascade
Gibbsville
Sheboygan R.
Hingham
Crooked L.
Adell
Oostburg
Sn
Beechwood
SCOTT
SHERMAN
HOLLAND
CEDAR GROVE
Random Lake
Random L.

SHEBOYGAN COUNTY.

Sheboygan county is underlaid by the upper beds of the Niagara limestone. They are generally buff, blue, or gray, thick bedded, rough on the weathered surface, and relatively free from impurities. Unless damaged by weathering, they make a very satisfactory road material.

Limestone outcrops are scarce in this county. In the western part, the ledges are nearly all buried under hummocky ridges of glacial drift. Along Lake Michigan there are thick deposits of reddish colored lake clays, which conceal the underlying rocks in most places. The most favorable localities for outcrops are where wave and stream action have removed the surface mantle of loose material down to bed rock.

At Light-house point near Sheboygan, there is a hard, mottled, bluish, compact limestone. A similar rock is exposed near Sheboygan Falls, which in places shows a slightly granular structure.

Chamberlin has described the beds of quarries located on the NW.¼ of SE.¼ of Section 9 (Roth's quarry); N.½ Section 7 (Rabie's quarry); and of Howard's quarry on the Sheboygan river. These localities were not examined and nothing was found out regarding the availability of stone from them at the present time.

The following quotations from Chamberlin's descriptions are presented because they indicate in a measure the quality of the stone in these quarries for road purposes: "The limestone at Roth's quarry is a thick-bedded, bluish, hard dolomite, quite free from cavities but with a few patches of calcite, and more rarely iron pyrites. Some portions are beautifully laminated, others are granular."

"At Rabie's quarry, the vertical exposure is slight. The upper layers are even and compact, but below they consist of fragments of limestone cemented with earthy matter. They are full of cavities lined with druses of calcite."

"In Howard's quarry, at the rapids of the Sheboygan river, the rock is irregular in bedding and structure. It varies from a soft, granular, to a hard almost flint-like limestone. It contains many cavities and weathers to an exceedingly rough, pitted surface."

The principal quarries operating in Sheboygan county at the present time are the Sheboygan Lime Works quarry northwest of Sheboygan, and the Sheboygan Falls Construction Company's quarry at Sheboygan Falls.

At the Shebogan Lime Works quarry over a hundred feet of strata are exposed. At the top the formation is thick-bedded and cavernous. The lower beds are more compact and thick-bedded. The rock generally has a rough appearance and a hackly fracture.

For road tests on this stone see table XII. The comment of the Office of Public Roads regarding it is as follows:

"This rock is rather soft, showing low toughness, average resistance to wear and good cementing value; suitable for use on plain macadam roads subjected to light traffic, or for use with a bituminous binder."

At the Sheboygan Falls Construction Co.'s quarry about 20 feet of limestone are exposed. The top beds are frost broken and the rock on the average is somewhat softer than that of the Sheboygan Lime Works.

For road tests on a sample of stone from the Sheboygan Construction Co.'s quarry, see table XII.

The report of the Office of Public Roads regarding its characteristics is as follows:

"This material is rather soft, showing low toughness, average resistance to wear and good cementing value; only suitable for roads subjected to light traffic but may be satisfactorily used with a bituminous binder."

Besides limestone Sheboygan county has an abundance of gravel. Gravel pits are located in every township, so that it is not necessary to give their locations. They are very numerous along the line of the C. M. & St. P. Ry. through Elkhart Lake and Plymouth. Although the quality of gravel deposits for road-making is extremely variable, some of these deposits undoubtedly contain good road material. In the western part of the county field bowlders are very abundant.

TABLE XII.

Tests on Limestone from Sheboygan County.

Nature of Test.	Specific gravity.	Weight per cu. ft.	Water absorbed per cu. ft.	Per cent of wear.	French coeff.	Hardness.	Toughness.	Cementing value.	Suitable for
Limestone from Sheboygan Lime Works quarry. Wis. road sample No. 73...	2.75 Med.	172	.50 Low	3.8	10.4 Med.	13.3 Soft	7.0 Low	Good	Light traffic.
Limestone from Sheboygan Falls construction Co.'s quarry. Wis. road sample No. 75.....	2.75 Med.	172	.63 Low	4.8	8.3 Med.	12.7 Soft	5.0 Low	Good	Light traffic.
Maximum for Wisconsin limestone.....	2.85	178	6.9	22.5	17.3	16.5	13.		
Minimum for Wisconsin limestone.....	2.45	153	.14	2.3	1.8	4.0	2.0		

Washington and Ozaukee Counties.

The chief underlying rock of Washington and Ozaukee counties is the Niagara limestone. The Galena-Trenton formation and the Cincinnati shale underlie a part of Washington county, and the Hamilton cement rock underlies a narrow strip along the lake shore in Ozaukee county extending from Port Washington several miles to the northward. The distribution of these rocks, as they would appear if the soil and loose material which covers them in most places were stripped off, is shown by Plate XIII.

Outcrops of limestone are not abundant in these counties, owing to the thick mantle of glacial material which covers the ledges in most places. In the western portion of Washington county, the drift is especially thick, and probably covers the Galena-Trenton formation completely. The most favorable localities for exposures of the Niagara limestone are along the stream channels. Outcrops of the Hamilton cement rock may be disregarded since this rock is too soft and weak to be used as a road material.

Quarries of Niagara limestone are located along Stoney Creek in the town of Fredonia, at Drucker, a few miles north of Port Washington, at Grafton, Cedarburg, Germantown, Kewaskum, West Bend, Hartford, and on the lake shore east of Belgium.

The quarry of the Lake Shore Stone Co., about 3 miles east of Belgium on the shore of Lake Michigan is one of the largest producers of crushed stone road material in the state. The report of the Office of Public Roads on an average sample from this quarry is as follows:

"A rock of medium hardness, medium toughness, medium resistance to wear and good cementing value. Should give satisfactory results under ordinary conditions of traffic."

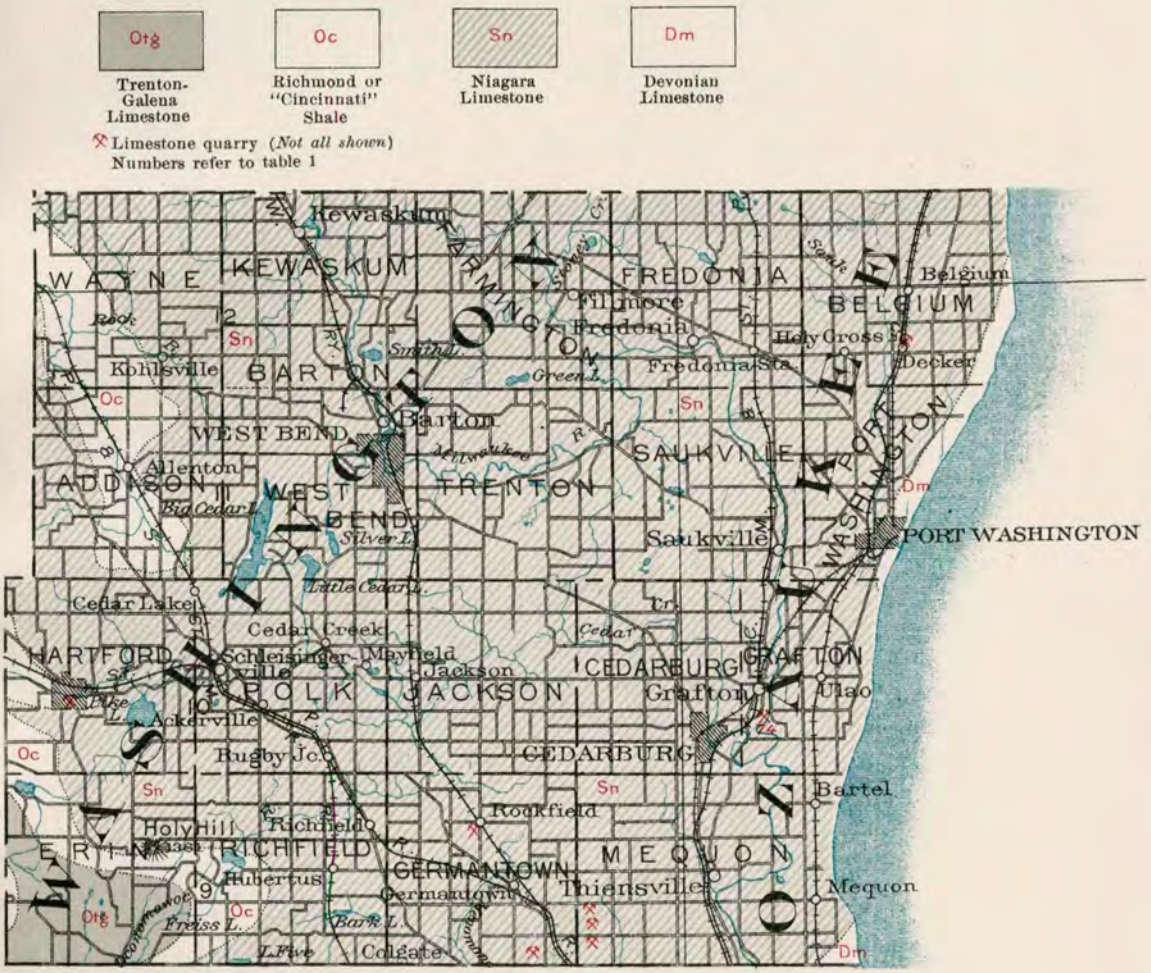
For tests see table XIII.

In the quarry of the Milwaukee Lime Co. at Grafton about 30 feet of Niagara limestone are exposed. The stone is somewhat softer than of most Niagara limestone quarries in the eastern part of the state. The rock section in descending order is as follows:

Fine grained, soft, thin bedded limestone..... 20 feet
Very massive limestone, somewhat harder than overlying beds 10 "

The report of the Office of Public Roads on an average sample from this quarry is as follows:

"This material is rather soft, shows low toughness and resistance


Otg
Trenton-Galena Limestone
Oc
Richmond or "Cincinnati" Shale
Sn
Niagara Limestone
Dm
Devonian Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1
WASHINGTON COUNTY
OZAUKEE COUNTY
WAUKESHA COUNTY
Kewaskum
KEWASKUM
WAYNE
FREDONIA
Fillmore
Fredonia
Fredonia Sta.
BELGIUM
Belgium
Holy Cross
Decker
Kohlsville
BARTON
Barton
WEST BEND
Allenton
ADDISON
Big Cedar L.
Silver L.
TRENTON
SAUKVILLE
Saukville
PORT WASHINGTON
Cedar Lake
Little Cedar L.
Cedar Creek
HARTFORD
Schleisinger
Mayfield
Jackson
POLK
JACKSON
CEDAREURG
GRAFTON
Grafton
Ulao
Ackerville
Rugby Jct.
CEDARBURG
Bartel
Holyhill
Richfield
RICHFIELD
Rockfield
MEQUON
Hubertus
GERMANTOWN
Germantown
Thiensville
Mequon
Freiss L.
Bark L.
L. Five
Colgate

to wear and good cementing value. Only suitable for roads subjected to very light traffic, unless used with a bituminous binder."

For tests see table XIII.

Field bowlders, which would make excellent road material are found in great abundance in the western part of Washington county. Gravel pits have been opened up in the towns of Grafton, Cedarburg, Germantown, and in the northeastern part of the town of Mequon, west of Bartel. Their quality for road-making will probably be found to vary widely but the gravels of this region are excellent road material when properly selected and used.

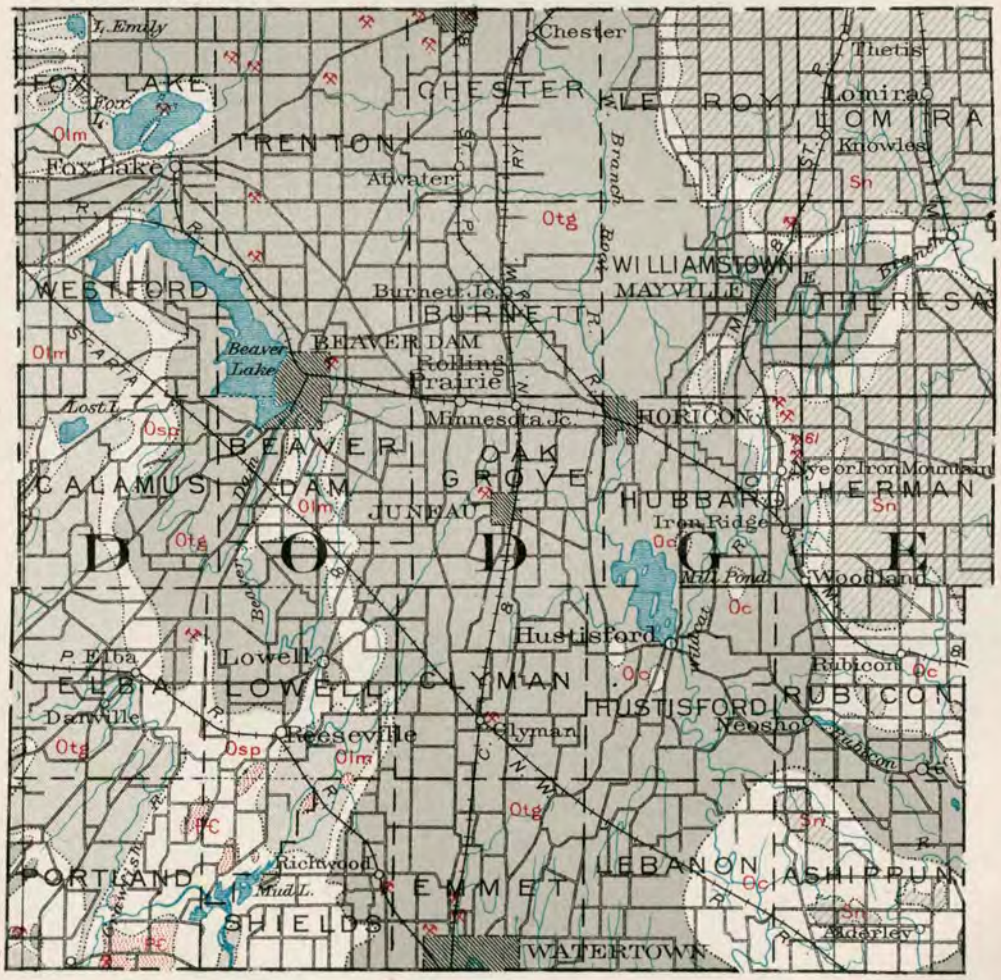
TABLE XIII,

Tests on Limestone from Ozaukee County.

Nature of Test.	Specific gravity.	Weight per cubic foot.	Water absorbed per cubic foot.	Per cent of wear.	Coefficient of wear.	Hardness.	Toughness.	Cementing value.	Suitable for
Limestone from Lake Shore Co.'s quarry, Ozaukee county.....	2.80 High	175	.65 Low	5.3	7.5 Low	12.4 Soft	8. Low	Low	Light traffic.
Limestone from Milwaukee Falls Lime Co.'s quarry, Grafton, Wis....	2.65	165	1.38 Med.	6.3	6.3 Low	11.1 Soft	5. Low	Good	Very light traffic.
Maximum for Wisconsin limestone..	2.85	178	6.9	22.5	17.3	16.5	13.	.....	.....
Minimum for Wisconsin limestone...	2.45	153	.14	2.3	1.8	4.0	2.0	.....	.....

PC	Olm	Osp	Otg	Oc	Sn
Pre-Cambrian Waterloo Quartzite	Lower Magnesian Limestone	St. Peter Sandstone	Trenton-Galena Limestone	Richmond or "Cincinnati" Shale	Niagara Limestone

⚒ Limestone quarry (*Not all shown*)
Numbers refer to table 1



DODGE COUNTY.

The uplands of the eastern part of Dodge county are underlaid by the Niagara limestone; the lowlands by the Cincinnati shale. In the central part of the county, the underlying rock is the Galena-Trenton limestone, which constitutes a broad belt trending north and south. The hill tops of the western part of the county are usually occupied by the Lower Magnesian limestone; most of the hillsides, valleys, and lowlands by St. Peter sandstone. In the southwestern part of the county, there are several outcrops of quartzite. The distribution of these formations as they would appear if the soil and loose material which covers them in most places were stripped off, is shown by Platt XIV.

Limestone outcrops and quarries are located chiefly along escarpments which mark the western borders of the limestone beds. Escarpments of this kind are especially prominent along the edge of the Niagara limestone. The conspicuous elevation which can be seen east of Iron Ridge, Mayville, and Oakfield is of this type. The detailed descriptions of outcrops and quarries which follow are based partly on published reports and partly on personal observations.

In the town of Ashippun, there are several scattered, outlying ledges of Niagara limestone of which the most noteworthy is in sections 6 and 7. They appear on an escarpment about 50 feet high. Only about 26 feet of limestone are exposed. The section is as follows:

	Feet
Fragments of limestone, cemented by yellow, granular limestone...	6
Reddish buff, granular, somewhat friable, porous limestone, evidently a poor road material.....	8
Very hard, compact, flint like limestone.....	6
Hard, porous limestone, made up of fine and coarse patches.....	6

These beds belong to the basal portion of the Niagara limestone. Their quality for road construction is probably similar to some of the beds near Mayville which also belong to the lower part of this formation.

At Iron Ridge, about 10 feet of Niagara limestone was found overlying a bed of iron ore. The upper six feet of the limestone were frost broken, and probably of little value for road construction. The lower layers were in part shaly. Heaps of broken limestone at this locality, left by mining, will be of some value for local use.

From Iron Ridge northward, there is no dearth of outcrops of the Niagara limestone. About 2 miles south of Mayville there is a precipitous cliff of Niagara limestone nearly 100 feet in height. The section in descending order is as follows:

	Feet
White, fine grained, crystalline limestone.....	
Soft, white granular, crystalline limestone.....approximately	30
Massive limestone cut by prominent vertical fissures.....	
Shaly and flinty limestone, easily chipped.....	23
Thick bedded limestone.....	4
Shaly and flinty limestone.....	7
Massive limestone rifted by prominent vertical fissures.....	12
Thin bedded, soft, shelly layers.....	5

At the quarry of the Mayville White Lime Co., the following section is exposed:

Soil	A few feet
Buff, weathered rock.....	20 feet
Porous, cavernous limestone used for lime.....	4 "
Hard, thick-bedded limestone said to be poor material for lime because of hardness.....	4 "
Buff, cavernous limestone.....	10 "

This stone is used quite extensively as a road material. In 1913 the capacity of the crusher at this quarry was about 200 tons a day. The road tests on an average sample from the quarry are as follows:

TABLE XIV.

Tests on Limestone from Quarry of the Mayville White Lime Works, Mayville, Wis.

Nature of Test.	Limestone from Mayville White Lime Works Quarry. Wisconsin Road Sample No. 61.	Maximum for Wisconsin limestone	Minimum for Wisconsin limestone.
Specific gravity.....	2.75 High	2.85	2.45
Pounds per cubic foot.....	172.00 High	178.	153.
Pounds of water absorbed per cubic foot.....	1.10 Low	6.9	.14
Per cent of wear,.....	4.5 Average	22.5	2.3
French coefficient.....	9.0 Medium	17.3	1.8
Hardness.....	14.3 Medium	16.5	4.0
Toughness.....	8. Low	13.	2.0
Cementing value.....	Good		
Suitable for.....	Light traffic...		

The comment of the Office of Public Roads on this sample is:

"This rock shows average hardness and resistance to wear, low toughness, and good cementing value. Suitable for roads subjected to light traffic, or for use with a bituminous binder."

At Nast Bros. quarry about 2 miles to the south of Knowles, about 18 feet of Niagara limestone are exposed. The rock is uniformly hard and unaltered. It has the appearance of a very satisfactory road material.

In 1912, the capacity of the crusher at this quarry was about 200 cubic yards per day. The rock is used chiefly for road construction.

At Nast Bros. quarry at Nasbro, 2½ miles north of Knowles, a section of Niagara limestone about 25 feet high is exposed. The quarry face is about ¼ mile long. A practically unlimited quantity of stone is available here. The section in descending order is as follows:

	Feet
Weathered, soft, and broken limestone	15
Unaltered, hard limestone	10

In 1912, a crushing plant with a capacity of about 5 cars per day was installed at this quarry. Unless the stone for crushing is taken from the lower ten feet of the quarry, an inferior road material will be produced.

Outcrops of the Galena-Trenton and the Lower Magnesian limestones are scarce. In the town of Chester, west of Waupun, there are a number of outcrops and quarries of the Galena-Trenton formation. The outcrops are situated on the road along the north line of the town of Trenton, and several others occur to the east of Beaver lake. In the town of Emmet, north of Watertown, there are a number of exposures. One of these is where the road crosses the town line, about 2½ miles to the northeast of Richwood. The others can be seen along the creek bottom, about a mile north of Watertown, to the west of the C. and N. W. Ry. track. Outcrops are also found in the towns of Field, Portland, Elba, Wales, Calamus, Beaver Dam, Westford and Fox Lake, but all of them are very small. The beds exposed are generally very much weathered and very few of them will probably furnish good road material.

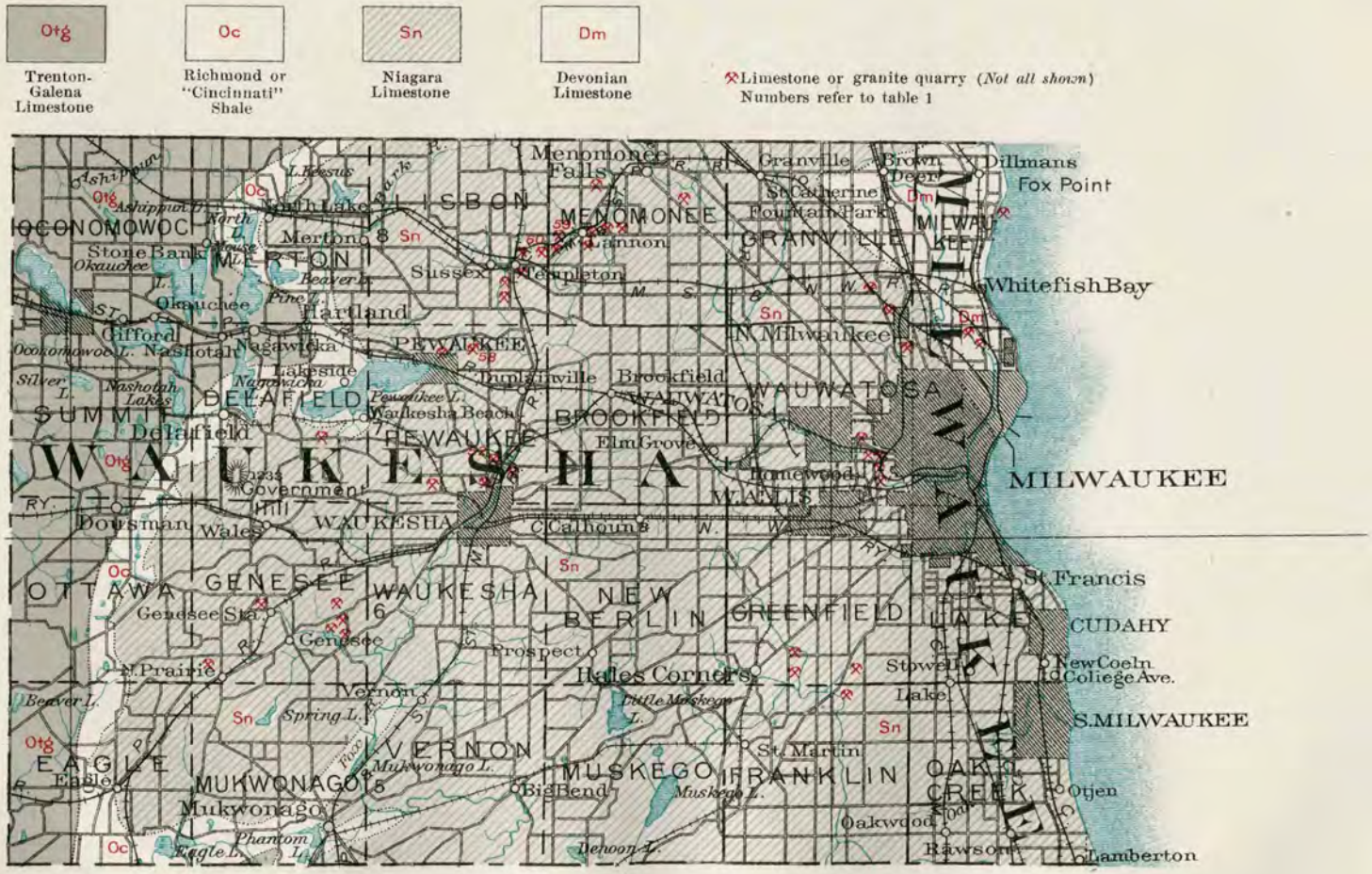
At the Cowen quarry, about one mile north of Watertown, 6 feet of Galena-Trenton limestone are exposed. The beds are hard, compact, fine-grained and show very little weathering. A small crusher has been operated here, for supplying local needs.

At the Herman Tetzlaff quarry, about one-half mile to the northwest of the Cowen quarry, about 15 feet of buff colored, rather soft and disintegrated Galena-Trenton limestone is exposed. The rock from this quarry has been crushed and used for local purposes. No tests of this stone are available. It is not likely that it would make a good material for roads subjected to heavy traffic, but it will most probably make a satisfactory country road.

Several small quarry openings in the Galena-Trenton limestone are located in the city of Beaver Dam, north of Juneau; and in the town of Trenton between Beaver Dam and Fox Lake.

One of the best known outcrops is in the center of the southeast quarter of section 19, in the town of Elba. Here about 21 feet of limestone are exposed. The beds are mostly cavernous, flinty, fragmental, and in part sandy. It is not probable that good road material can be gotten from them.

Besides limestone Dodge county has an abundance of glacial field bowlders, particularly in the higher portions of the county. There is also some gravel, although it is not so abundant as farther east along the kettle moraine in Sheboygan county. A gravel pit is located about 2 miles to the northeast of Beaver Dam and several have been opened up to the east of Clyman. In the town of Portland, in the southwest part of Dodge county, there are large outcrops of quartzite.


Otg
Trenton-Galena Limestone
Oc
Richmond or "Cincinnati" Shale
Sn
Niagara Limestone
Dm
Devonian Limestone
Limestone or granite quarry (Not all shown)
Numbers refer to table 1
WAUKESHA
MILWAUKEE
OZAUKEE
WASHINGTON
WAUKESHA
RACINE
KENOSHA
Menomonee Falls
Granville
Brown Deer
Dillmans
Fox Point
St Catherine
Fountain Park
MENOMONEE
GRANVILLE
MILWAUKEE
Whitefish Bay
N. Milwaukee
Merton
Sussex
Lannon
Hartland
Stone Bank
Okauchee
Okauchee L.
Ashippun
Ashippun L.
North L.
South Lake
L. Keesus
Beaver L.
Pine L.
Ocooomowoc L.
Nashotah
Nashotah Lakes
Silver L.
Lakeside
Nemahbin L.
Pewaukee L.
Waukesha Beach
Dunlap Ville
Brookfield
WAUWATOSA
Elm Grove
Homewood
WALLIS
Delafield
SUMMIT
DELAFIELD
PEWAUKEE
BROOKFIELD
Government
Doyslman
Wales
WAUKESHA
Calhoun
St. Francis
CUDAHY
New Coeln
College Ave.
Lake
S. MILWAUKEE
Genesee Sta.
Genesee
Prospect
Prairie
Vernon
Spring L.
Beaver L.
Little Muskego L.
Muskego L.
St. Martin
Hales Corners
Stowell
OTTAWA
GENESEE
NEW BERLIN
GREENFIELD
LAKE
EAGLE
VERNON
MUSKEGO
FRANKLIN
OAK CREEK
Eagle
Mukwonago
Mukwonago L.
Big Bend
Phantom L.
Eagle L.
Oakwood
Rawson
Ojen
Lamberton

Waukesha and Milwaukee Counties.

The eastern part of Waukesha county, and the greater part of Milwaukee county is underlaid by the Niagara limestone. North of the city of Milwaukee, there is a small area underlaid by the Hamilton cement rock. In Waukesha county, a narrow north and south trending strip, west of the Niagara limestone area is underlaid by the Cincinnati shale. The extreme western portion of this county is underlaid by the Galena-Trenton formation. The distribution of these formations at the surface and underneath the soil and loose material which covers them in most places is shown by Plate XVI.

The Niagara limestone is the only formation which need be considered as a source of road material. The Galena-Trenton formation is probably completely buried by glacial drift, and the Hamilton cement rock is too soft for use on roads. The principal exposures of the Niagara limestone are along the Menomonee and Milwaukee rivers, and along the low bluffs which mark the western edge of the Niagara limestone beds in the vicinity of Eagle in Waukesha county. For a map showing the distribution of limestone outcrops in Milwaukee county, see United States Geological Survey, Folio 140, by W. C. Alden.

In this part of the state, the Niagara limestone presents three distinct phases. The commonest phase is well bedded, fine-grained, compact, and hard. It is easily quarried and generally makes a good road material. The other two phases consist of (1) massive, coarse or fragmental mound-like masses without stratification or with obscure stratification, which grade into (2) well defined beds of soft, porous, granular limestone.

The largest exposures of the Niagara limestone are along the bluffs of the Menomonee river between Milwaukee and Wauwatosa. Here also are some of the most important quarries. Going westward from the mouth of the Milwaukee river, the first outcrop met with is that on the north side of the Menomonee river at the foot of Washington avenue in the city of Milwaukee. This was formerly Moody's quarry. The rock face is about 20 feet high and 60 feet long. This outcrop is of the massive type; only a slight trace of bedding is visible at the west end. It is a mound-like mass which dips down under the clay that covers it. In places it is slightly broken—perhaps by blasting, but as a whole it is a hard, exceedingly irregular, coarse-grained, gray, pure dolomitic limestone.

No tests of this stone are available, but it seems probable from the descriptions that a stone of fair quality could be gotten here.

The next exposure up the river is about 1¼ miles to the west of Moody's quarry, on the west side of the river, at the National Soldiers' home. Here a drift-covered slope about 80 feet high rises above the valley floor. On its northeast side the lower 35 to 40 feet presents a vertical face of rock. It is a section of a limestone mound, coarse, uneven, gray in color, massive without stratification.

Story Bros. quarry is on the south side of the river about two-thirds of a mile northeast of the exposure at National Soldiers home. Here the limestone exposed is even-bedded, coarse-grained beds alternating with fine-grained ones. At the quarries of Manegold Bros. and the Monarch Stone Co., about two-thirds of a mile to the northwest, the stone exposed is of a similar quality. No test of the stone has been made.

To the east of Wauwautosa are the old Busack and Shoonmaker quarries. At the Busack quarry to the west, the beds are mostly heavy, well defined and somewhat clayey, rather fine and even-grained with a shell-like fracture. At the east end the upper layer becomes irregular in bedding, rather soft and granular in texture. In the Shoonmaker quarry the bedding is mostly obscure or lacking. The rock is generally a massive, coarse-grained, hard, bluish-gray dolomite. In places it is a breccia in which the fragments and cement are alike. In the eastern part of the quarry the upper part of the section is clayey, porous, and weak.

The massive, compact portions of the Shoonmakers quarry are evidently the best fitted for road material.

The G. D. Francey Coal, Stone and Supply Co.'s quarry is located in Wauwautosa. The section exposed when examined in 1912 was about 40 feet thick. The longest face is east and west, on the north side of the opening. Here a core of a limestone mound is exposed. The rock is massive, without bedding, cavernous and pitted, the cavities frequently lined with calcite crystals.

Tests on this limestone show that it is of fair quality for light traffic roads. See Table XV for tests. The comment of the Office of Public Roads on this stone is "a soft stone with a medium per cent of wear, low toughness and fair cementing value."

Zimmerman's quarry is located in the valley of the Menomonie river, about 3 miles northwest of Wauwautosa. The limestone here

is buff colored, thin-bedded, only slightly fractured, even grained, and shows minute pores filled with a pitchy asphalt.[1]

W. N. Smith [2] reported to the Milwaukee County Board of Supervisors in 1905, that about 400,000 cubic yards of stone could be quarried here. His estimates were based on a quarry 70 feet deep, 1500 feet long and 300 feet wide, the amount actually in sight.

He states that there is danger from flooding during highwater, and that the thickness of the overburden on this property is uncertain.

Tests were made on this stone by the United States Department of Agriculture. The tests as reported by Logan W. Page, Chief of Division of Tests, is given in Table XV. It is a soft rock of low toughness and medium per cent of wear.

The old Trimborn quarries are located on Section 28 in the town of Greenfield. Descriptions of the quarry are not available. Tests on the stone show that it is far below the average as a road metal and that it should not be used. For tests see Table XV. Taken from report given in Proc. of Supervisors of Milwaukee county, p. 87, 1905–1906.

South and west of the old Trimborn quarries in Section 28 of the town of Greenfield, a practically unlimited amount of road material could be gotten according to Smith. About 10–20 feet of rock are above water level. The drift burden varies from 0–10 feet. Since the Trimborn stone seems to be poor according to tests, the fitness of this stone is questionable unless tests and actual use have shown it to be usable.

The quarry of F. A. Zautke is located one mile northwest of North Milwaukee. Alden states that from 6–10 feet of limestone is exposed. It is a mound-like, unstratified mass of irregular, coarse grain, and open, porous and cavernous structure. At the bottom of the quarry, the limestone is hardest. The fracture is uneven. For tests on this stone see Table XV. They were made by the United States Department of Agriculture, for Milwaukee county. See Proc. of Supervisors of Milwaukee county, 1905–1906, p. 87. It is a stone of fair quality, but rather soft, and has a medium per cent of wear.

Smith reports that in section 26 of the township of North Milwaukee, a quarry could be opened up, and that an abundance of stone

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[1] See Alden, W. C. Milwaukee Special Folio 140, U. S. Geol. Survey, p. 2, 1906.

[2] Smith, W. N. Proc. of the Board of Supervisors of Milwaukee County, 1905, pp. 29–31.

is available. The water level is near the surface, however, and the thickness of soil is unknown.

He states that a few feet of limestone are exposed on Koenitzer's property in section 1 of the town of North Milwaukee near the creek, but that there is danger of flooding here. The thickness of soil was not determined. For tests by the Department of Agriculture on this stone see Table XV. The data was gotten from the Proc. of the Supervisors of Milwaukee county, page 87, 1905–1906. The tests show that the quality of the stone is fair. The per cent of wear is rather high, and the cementing power is fair.

Alden reports that there is a limestone quarry 1 mile east of Hales' Corners on the west side of the Root river valley. The rock is thin-bedded near the top, and the beds are from 1 to 3 feet thick at the bottom of the face. It is porous, weathered, and irregular in grain. About 10 to 25 feet of drift overlie the limestone strata. Judging from this description, the quality of this rock for road-making is doubtful.

Rock of the same character as above is reported by Alden to occur at the small quarry of Mr. Anderson ¼ mile to the south.

He also states that there are some small outcrops and a quarry 3 miles southeast from Hales' Corners, and that limestone is exposed farther down the valley, 1½ miles from the latter place.

To the north of Milwaukee, the Niagara limestone is overlaid by limestones of younger age. It is not probable, however, that any of it is as good as the Niagara for road making. The beds all appear to be weak and clayey. Limestones of this character are exposed at Petzold's quarry on Mud Creek; 1 mile south of North Milwaukee, and ¼ mile farther west on Mud Creek; at the quarries of the Hamilton Cement county, ½ mile north of the city limits of Milwaukee; and 3 miles north of the latter place on the shore of Whitefish bay.

In spite of the heavy drift mantle in the western part of Waukesha county, outcrops of Niagara limestone are common. Chamberlin[1] states that in the southwest quarter of section 10 of the town of Genesee, the lowest beds of the formation are exposed. In what was at the time of his report (1877) Hinckley's quarry, 4 feet of thin-bedded, impure magnesian limestone overlaid by 9 feet of thicker-bedded, coarse, cavernous, ragged appearing limestone were exposed. He also reports that outcrops of flint-bearing limestone are found in sections 11 and 14 of the town of Ottawa. In

[1] Chamberlin, T. C., Idem, p. 342.

section 11, one outcrop consisted of 3 feet of moderately hard, compact limestone, with some shaly and rotten limestone layers beneath.

Near the village of Delafield, he found the limestone beds about the same as in the town of Ottawa. In the SE.¼ of section 20 of the town of Delafield, there were exposed a few feet of cherty, crystalline limestone.

Around Pewaukee, the outcrops and quarries generally show a fine-grained, dense, white limestone interlayered with flint. No tests have been made on the stone from this vicinity but it seems probable that the combination of flint and limestone would make a satisfactory material for roads.

The principal quarry localities of Waukesha county at the present time are Templeton, Lannon, and Waukesha. The quarry operators at Lannon are Davis Bros. Stone Co., R. H. Gumz Quarry Co., John Flanagan & Son; H. Harmon & Son, John Sheridan, Hartkopf & Seefeld, Louis Schneider, Wisconsin Stone Co.; at Waukesha, the Waukesha Lime & Stone Co.; at Templeton, the Templeton Lime & Stone Co. The chief producers of road material are the Waukesha Lime & Stone Co. and the R. H. Gumz Quarry Co.

The R. H. Gumz quarry is located a short distance west of Lannon. The quarry is equipped with a crusher. In 1912 its capacity was 200 cubic yards a day. Most of the crushed rock produced here is used in the city of Milwaukee.

In 1912, the beds of the quarry consisted from the bottom upward of 15 feet of very dense, hard, fine-grained, and 25 feet of slightly decomposed, buff-colored limestone pitted with small cavities lined with calcite crystals. Thin clay seams separate the limestone beds here and there. Occasionally small masses of native copper have been found in the clay. For road tests on a sample of crushed rock from this quarry see table XV. The Office of Public Roads comments on this sample as follows: "This is a soft rock, showing less toughness and resistance to wear and good cementing value. Should only be used on waterbound roads subjected to light traffic or for use with bituminous binders."

At the Wisconsin Stone Co.'s quarry at Lannon an 18 foot section of Niagara limestone was exposed in 1912. The rock is distinctly and regularly bedded, and of compact, uniform, fine grain. The lower beds have a bluish tint; the upper are bleached to a gray. The stone is crushed for roads and concrete work. Most of it is used in the city of Milwaukee.

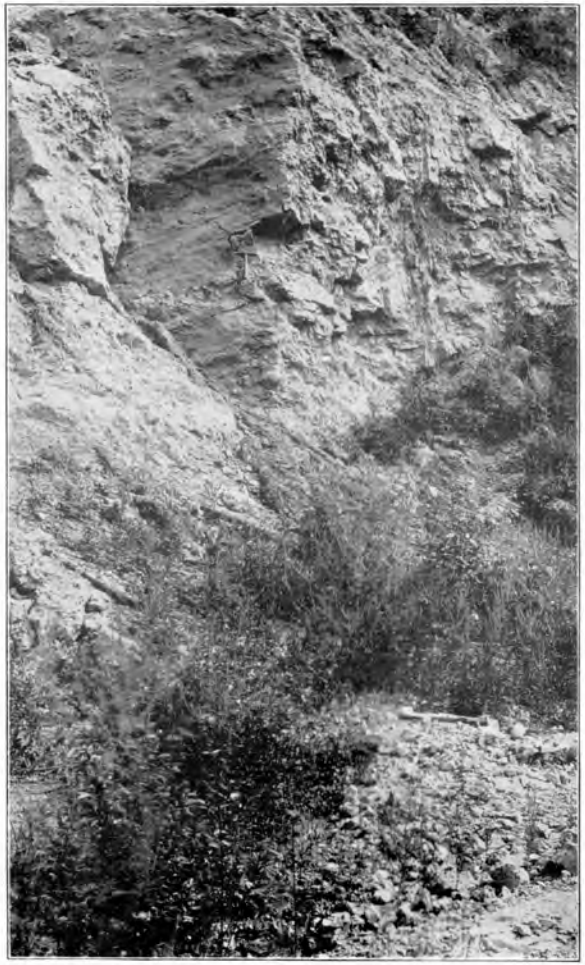
For tests on an average sample of crushed rock from this quarry see table XV. The Office of Public Roads reports that "the sample shows average hardness and resistance to wear, rather low toughness and fair cementing value. Should be satisfactory for waterbound macadam roads subjected to medium traffic for use with bituminous binders."

Weavers quarry is located in section 35 of the town of Lisbon northeast of Pewaukee. In 1912 it was temporarily abandoned, and the lower beds were under water. A sample from this quarry was tested and probably indicates the general quality of the stone from this vicinity for road making. A considerable amount of rock has been crushed here for local road purposes. For tests see table XV. of this report. The Office of Public Roads comments as follows on this sample. "This material shows average hardness, toughness, and resistance to wear and fair cementing value. Should be satisfactory for waterbound macadam roads subjected to medium traffic or for use with bituminous binders." The quarry beds above water consisted of 8 feet of very fine-grained, dense, compact, brittle, pure limestone. No weathered zone was developed, and the overburden was almost nil.

The Waukesha Lime and Crushed Stone Company at Waukesha produces both gravel and crushed stone for road purposes. The quarry is located about ½ mile north of the city. About 30 feet of gravel overlies the Niagara limestone, which here consists of very fine-grained, bluish, thick, even beds. The entire quarry face, about 20 feet high, was used for crushed stone in 1912. See Plate XV for view of quarry and gravel pit above it.

For tests on an average sample of crushed rock from this quarry see table XV of this report. The comm ment of the Office of Public Road on this sample follows: "Sample shows average hardness and resistance to wear, low toughness and fair cementing value. Should only be used for water bound roads subjected to light traffic or for use with bituminous binders."

Besides limestone, Waukesha and Milwaukee counties have an abundance of field bowlders and gravel in certain localities. The kettle moraine country of the northwestern part of Waukesha county is the most favorable locality for field bowlders. Gravel pits are most numerous around Waukesha in the towns of Waukesha, Pewaukee, and Brooklyn. For a map showing the location of gravel pits in Milwaukee county see Geologic Folio 140 of the U. S. Geological Survey.



Francey Stone & Coal Co.'s quarry, at Wauwatosa. The beds shown in this quarry belong to the coral reef type of the Niagara limestone. They are coarse-grained and porous, in part massive without visible bedding. Where the hammer appears the beds dip about 15 degrees away from the center of the reef.

Waukesha Lime & Stone Co.'s quarry, at Waukesha. The limestone beds in the foreground belong to the dense, fine-grained, compact, even-bedded type of Niagara limestone. The bank of loose material in the back ground is a gravel deposit of glacial origin, made up largely of limestone pebbles.

TABLE XV.

Tests on Niagara Limestone from Waukesha and Milwaukee Counties.

Nature of Test.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Specific gravity	2.65 Med.	2.75 High.	2.80 High.	2.70 High.	2.75 High.	.....	.....	.....	.....	2.85	2.45
Pounds per cu. ft	165.00 Med.	172.00 High.	175.00 High.	168.00 High.	172 00 High.	162.20 Med.	165.3 Med.	174.60 High.	159.00 Med.	178 00	153 00
Pounds of water absorbed per cu. ft	2.90 Med.	1.56 Low.	.88 Low.	2.03 Med.	1.84 Low.	2.47 Med.	2.9 Med.	.59 Low.	3.92 High.	6.90	.14
Per cent of wear	3.30 Med.	3.60 Med,	3.50 Med.	6.70 High.	4.10 Med.	8,50 High.	3.29 Med.	4.68 Med.	8.91 High.	22.50	2.30
French coefficient of wear	12.20 Med.	11.00 Med.	11.60 Med.	6.00 Low.	9.90 Med.	4.70 Low.	12.3 Med.	8.60 Med.	4.50 Low.	17.30	1.80
Hardness	13.40 Soft.	15.00 Med.	15.60 Aver.	13.30 Soft.	15.30 Aver.	5.00 Soft.	5.5 Soft.	9.80 Soft.	8.20 Soft.	16.50	4.00
Toughness	8.00 Low.	7.00 Low.	10.00 Low.	9.00 Low	13.00 Aver	8.00 Low.	8.00 Low.	9.00 Low.	6 00 Low.	13.00	2.00
Cementing value	Fair.	Fair.	Fair.	Good.	Fair.	Low.	Low.	Good.	Low.	.....	.....
Suitable for	Light traffic.	Light traffic.	Medium traffic.	Light traffic.	Medium traffic.	No good.	Light traffic.	Light traffic.	No good.	.....	.....

1. G. D. Francey Coal, Stone and Supply Co , Wauwautosa, Wis.
2. Waukesha Lime & Stone Co., Waukesha, Wis.
3. Wisconsin Stone Co., Lannon, Wis.
4. R. H. Gumz Quarry Co., Lannon, Wis.
5. M. Weaver, Pewaukee, Wis.
6. Trimborn farm, town of Greenfield, Milwaukee County.
7. Zimmerman Quarry, town of Wauwautosa, Milwaukee County.
8. Zautke Quarry, town of North Milwaukee.
9. Koenitzer Quarry, town of North Milwaukee.
10. Maximum for Wisconsin limestone.
11. Minimum for Wisconsin limestone.

Racine and Kenosha Counties.

Racine and Kenosha counties are underlaid by the Niagara limestone. See Plate XVII.

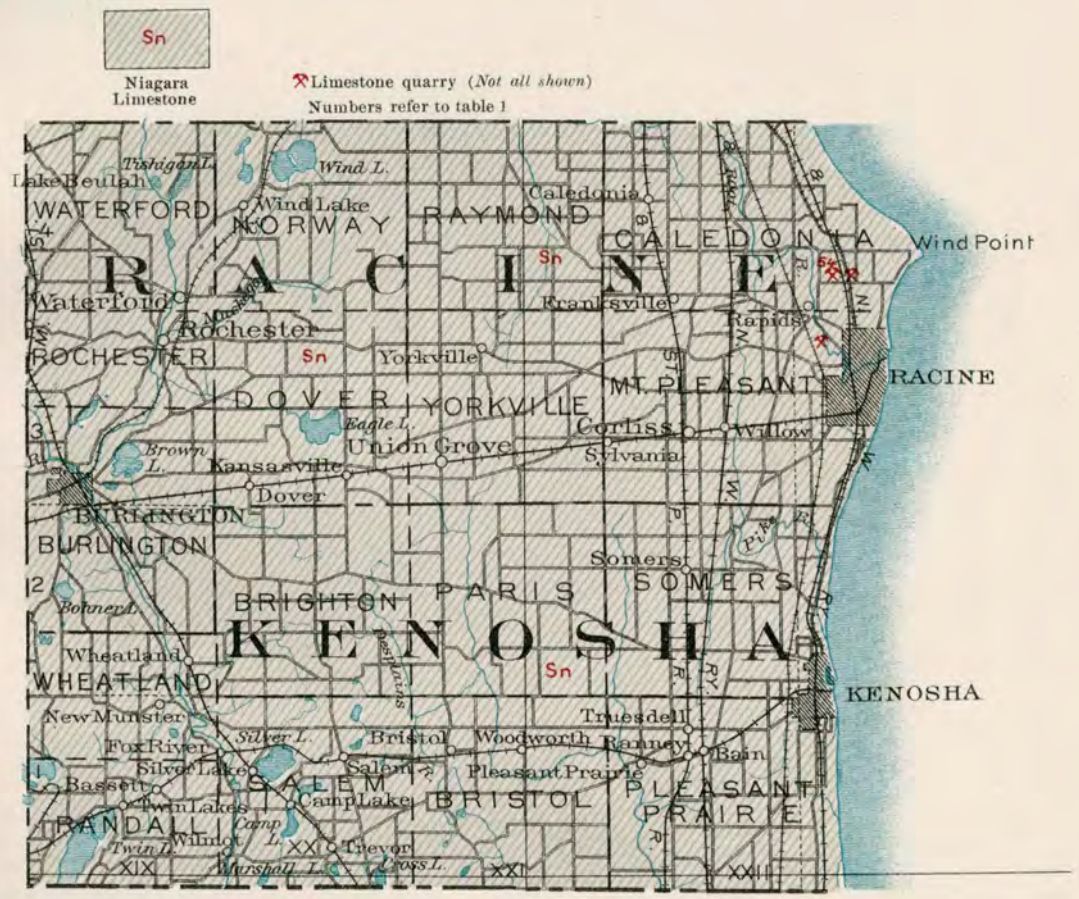
The surface of the eastern part of these counties is level. The western portion is covered with a thick mantle of glacial drift. Its surface is undulating, even hummocky in places, and is dotted by numerous lakes, ponds and swampy stretches.

Outcrops of the Niagara limestone occur along the Root River in the vicinity of Racine. The exposures usually show rapid alternation of bedding, grain, and structures. Conglomeratic, massive, coarse-grained limestone can be seen to grade into even-bedded, compact, hard, fine-grained phases. These characteristics are peculiar to some of the highest beds of the Niagara limestone of Wisconsin, which have received the name Racine beds because of their typical development in the vicinity of Racine.

The most important quarries of these counties are those of the Universal Crushed Stone Company at Ives. There also are quarry openings northwest of Racine, and to the west of Burlington.

The beds in Quarry No. 2 of the Universal Crushed Stone Co. at Ives are fine-grained, compact and even. In 1912, the quarry face was about 100 feet high and the supply in sight was, for practical purposes, unlimited. The thickness of limestone found by drilling has been reported to be 600 feet.

The quarry is equipped with a crusher, with a capacity in 1912 of about 2000 cubic yards per day, making it one of the leading crushed stone producers of the state.


Sn
Niagara Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1
Lake Beulah
Tiskigon L.
Wind L.
WATERFORD
Wind Lake
NORWAY
RAYMOND
Caledonia
CALEDONIA
Wind Point
RACINE
Waterford
Rochester
ROCHESTER
Sn
Yorkville
Franksville
Rapids
MT. PLEASANT
RACINE
DOVER
YORKVILLE
Eagle L.
Union Grove
Corliss
Willow
Sylvania
Brown L.
Kansasville
Dover
BURLINGTON
Somers
SOMERS
PARIS
BRIGHTON
Bohner L.
KENOSHA
Wheatland
WHEATLAND
New Munster
Silver L.
Bristol
Woodworth
Ranney
Bain
Truesdell
KENOSHA
Fox River
Silver Lake
Salem
Pleasant Prairie
Basset
SALEM
Camp Lake
BRISTOL
PLEASANT PRAIRIE
Twin Lakes
RANDALL
Camp L.
Twin L.
Wilmot
Trevor
Marshall L.
Cross L.
XIX
XXI
XXII

Tests made on a sample from this quarry are given below.

TABLE XVI.

Tests on Limestone from Quarry at Ives, Wis.

Nature of test.	Limestone from Universal Crushed Stone Co., Racine, Wis. Road Sample No. 54.	Maximum for Wisconsin limestone.	Minimum for Wisconsin limestone.
Specific gravity	2.6 Low	2.85	2.45
Weight per cubic foot	162. Medium	178.	153.
Water absorbed per cubic foot	1.20 Low	6.9	.14
Per cent of wear	5.6 High	22.5	2.3
French coefficient of wear	7.2 Low	17.3	1.8
Hardness		16.5	4.0
Toughness		13.	2.
Cementing value	Good		
Suitable for	Light traffic		

The report of the Office of Public Roads on this sample is: "This rock has low resistance to wear and good cementing value. Suitable for the construction of roads subjected to light traffic or with a bituminous binder."

In the western part of Racine and Kenosha counties, in the kettle region, fieldstones including granites, traps and limestones are locally available for road-making. Where they can be obtained cheaply, they may be more satisfactory than the limestone. Gravels are also very common, and have been used successfully in many places. Their quality for road-making, however, is so variable, that their fitness can only be determined as a rule by actual use. Gravel pits are located in the southern part of the town of Pleasant Prairie, in the southwestern part of the town of Paris of Kenosha county, and in other places.

WALWORTH COUNTY.

The eastern part of Walworth county is underlaid by the Niagara limestone; the western portion, by the Galena-Trenton formation. Between these two areas there is a narrow strip underlaid by the Cincinnati shale. Plate XVIII shows the distribution of these formations underneath the soil and loose material which covers them in most places.

Outcrops and quarries of limestone are scarce in this county because of the thick mantle of drift and soil. In the town of Spring Prairie there are several small quarries of Niagara limestone. Descriptions of them are not available. It is probable, however, that road material of good quality could be gotten from them, since the Niagara limestone is remarkable for its uniform quality as a road material.

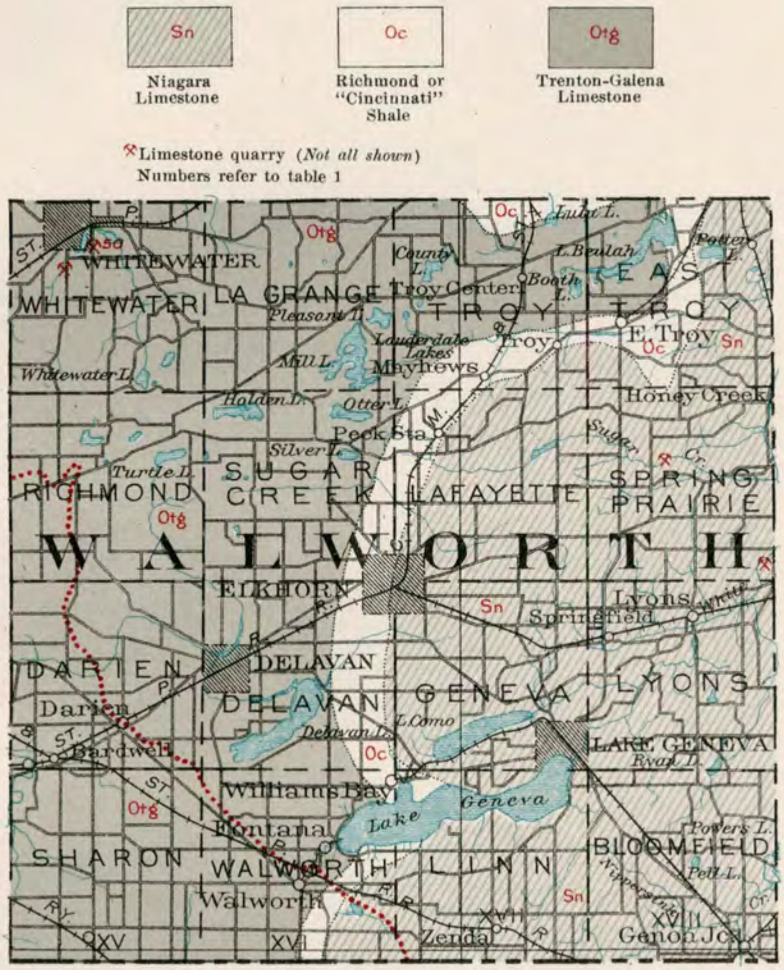
The Galena-Trenton formation is quarried near Whitewater. It is also exposed in the vicinity of Sharon. The latter locality was not examined, and nothing definite can be said as to the quality of the stone for road making. As a rule, outcrops of the Galena-Trenton formation of southern Wisconsin are usable for local road construction, although earthy and mediocre in quality.

In the Whitewater City Quarry, 17 feet of Galena-Trenton formation are quarried and crushed for local roads. The appearance of the rock is soft and somewhat earthy, but it seems to bear traffic fairly well. For tests of an average sample from this quarry see table XVII below.

TABLE XVII.

Tests on Limestone from Whitewater City Quarry.

Nature of test.	Limestone from Whitewater City Quarry. Wisconsin Road Sample No. 50.	Maximum for Wisconsin limestone.	Minimum for Wisconsin limestone.
Specific gravity	2.70 Medium	2.85	2.45
Pounds per cubic foot	168. Medium	178.	153.
Pounds of water absorbed per cubic foot	2.27 Medium	6.9	.14
Per cent of wear	6.4 High	22.5	2.3
French coefficient of wear	6.3 Low	17.3	1.8
Hardness	13.3 Soft	16.5	4.0
Toughness	7. Low	13.	2.0
Cementing value	Good		
Suitable for	Very light traffic		


Sn
Niagara Limestone
Oc
Richmond or "Cincinnati" Shale
Otg
Trenton-Galena Limestone
Limestone quarry (*Not all shown*)
Numbers refer to table 1
WHITEWATER
LA GRANGE
TROY
EAST TROY
RICHMOND
SUGAR CREEK
LAFAYETTE
SPRING PRAIRIE
WALWORTH
ELKHORN
DELAVAN
DARIEN
GENEVA
LYONS
SHARON
LINN
BLOOMFIELD
LAKE GENEVA
Whitewater L.
Troy Center
Mayhews
Honey Creek
Peck Sta.
Lyons
Springfield
Darien
Bardwell
Williams Bay
Fontana
Walworth
Zenda
Genoa Jct.
Lake Geneva
L. Como
Delavan L.
Turtle L.
Silver L.
Otter L.
Holden L.
Mill L.
Lauderdale Lakes
Pleasant L.
County L.
L. Beulah
Booth L.
Lulu L.
Potter L.
Ryan L.
Powers L.
Pell L.
E. Troy
Troy
XV
XVI
XVII
XVIII

This sample was reported on by the Office of Public Roads, as follows: "This is a soft rock, showing low toughness and resistance to wear and good cementing value. Only suitable for very lightly traveled waterbound macadam roads. Suitable for use with bituminous binders."

Field bowlders and gravels are found in most parts of Walworth county, but are especially abundant along the margin of the last drift sheet, which is marked by a belt of prominent, undulating drift hills, extending across the towns of Richmond, Darien, Sharon, Delevan, Walworth, and Linn.

JEFFERSON COUNTY.

The eastern part of Jefferson county is underlaid by Galena-Trenton limestone; most of the western portion by St. Peter sandstone, Lower Magnesian limestone, and Potsdam sandstone. Within the St. Peter sandstone areas, there are a number of isolated patches of the Galena-Trenton limestone. For the distribution of these formations, as they would appear if the soil and loose material which covers them in most places were stripped off, see Plate XIX.

The edges of the limestone beds, particularly those of the Galena-Trenton, form low bluffs or escarpments. Where the Galena-Trenton limestone occurs in isolated patches surrounded by sandstone, it appears as a capping of low bluffs.

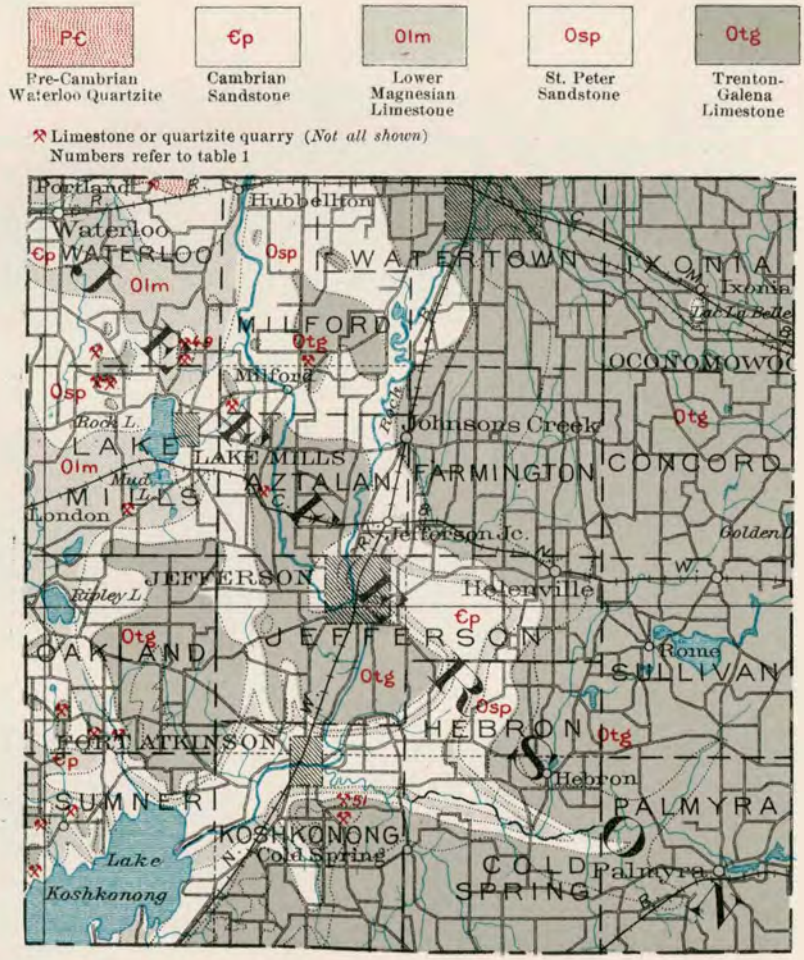
The most favorable localities for outcrops of limestone are along the escarpments which mark the edge of the beds, and in the Rock River valley. Numerous small quarries in the Galena-Trenton limestone are found along the sides of low bluffs in the towns of Sumner and Oakland. This limestone has also been quarried about 2 miles southeast of Fort Atkinson; in the city of Jefferson; along the Rock river in the town of Aztalan; in the southeastern part of the town of Waterloo; and in the vicinity of Lake Mills. Most of these quarries are small, and serve local needs only. Many of them have been abandoned for some time, and a few are worked intermittently.

At the John Luneck quarry, west of the Crawfish river about 3 miles southeast of Lake Mills, about 11 feet of Trenton limestone is exposed. The drift burden is slight. The lower 5 feet consist of thick-bedded bluish colored, fine-grained, hard but slightly clayey limestone, immediately overlying St. Peter sandstone. These beds are separated from those overlying them by thin, oily seams of shale. The upper beds are thin, fine-grained, and fossiliferous.

This stone was not tested but its quality appears to be as good as any seen in the county.

A limestone similar to that of the Luneck quarry is exposed in a quarry on the west banks of the Crawfish River, about ½ mile south of Milford. It is not probable, however, that a large supply of stone could be gotten here. The quarry seems to be exhausted, but the ground would need to be tested to make this certain.

On a hill about 1 mile northeast of Lake Mills on the road to Milford, there is a small outcrop of very rotten Trenton limestone


PC
Pre-Cambrian Waterloo Quartzite
Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Trenton-Galena Limestone
Limestone or quartzite quarry (Not all shown)
Numbers refer to table 1
Portland
Hubbelton
Waterloo
WATERLOO
WATERTOWN
IXONIA
Ixonia
Lac La Belle
MILFORD
Milford
OCONOMOWOC
Rock L.
Johnsons Creek
LAKE MILLS
AZTALAN
FARMINGTON
CONCORD
Mud L.
MILLS
London
Jefferson Jc.
Golden L.
Ripley L.
JEFFERSON
Helenville
OAKLAND
Rome
SULLIVAN
HEBRON
FORT ATKINSON
Hebron
SUMNER
PALMYRA
KOSHKONONG
Lake Koshkonong
Cold Spring
COLD SPRING
Palmyra

which has been used for building a short stretch of the road nearby.

In the southeast corner of the town of Waterloo about 2½ miles north of Lake Mills, there is an extensive quarry opening in the Trenton limestone on the farm of Wilbur Stiles. The quarry face is about a thousand feet long, and 13 feet high. There is very little drift burden. The lower four feet consist of thick-bedded, dense, fine-grained limestone, above which there is a bed of shaly limestone with brown oil rock seams. The upper 8 feet consist of thin-bedded, brittle, fine-grained, compact limestone.

For road tests on an average sample from this quarry see table XVIII.

The report of the Office of Public Roads on this sample is as follows: "This material is a little low in hardness and resistance to wear, has low toughness and fair cementing value. Suitable for plain macadam roads subjected to light traffic, or for use with bituminous binders."

About 1½ miles southeast of Fort Atkinson there is a quarry alongside of the public road running east and west. This quarry has been reported to this Survey as the Sam Fease quarry. A portable crusher had been in operation here in 1912, and the stone was used on roads. The quarry face is about 200 feet long and 20 feet high. The drift burden is only about 4 feet thick. The lower ten feet of the quarry face consist of 10 feet of porous, coarsely crystalline, stratified limestone. The upper 10 feet are composed of the same material with flint nodules and lenses.

For tests on an average sample of limestone from this quarry, see table XVIII.

The report of the Office of Public Roads on this sample is as follows: "This is a soft rock showing low resistance to wear and toughness and fair cementing value. Only suitable for lightly travelled, waterbound roads and for use with bituminous binders."

TABLE XVIII.

Tests on limestone from Fease quarry, Fort Atkinson, Wisconsin, and from Stiles quarry, Lake Mills, Wis.

Nature of test.	Limestone from Wilbur Stiles quarry, Lake Mills, Wis.	Limestone from Sam Fease quarry, Fort Atkinson, Wis.	Maximum for Wisconsin limestone.	Minimum for Wisconsin limestone.
Specific gravity	2.70 Medium	2.75 High	2.85	2.45
Pounds per cu. ft.	168. Medium	172. High	178.	153.
Pounds of water absorbed per cu.ft.	2.99 Medium	1.68 Low	6.9	.14
Per cent of wear	5.4 High	8.6 High	22.5	2.3
French coefficient of wear	7.4 Low	4.7 Low	17.3	1.8
Hardness	13.2 Soft	12.8 Soft	16.5	4.0
Toughness	6. Low	5. Low	13.	2.
Cementing value	Fair	Fair	.....	.....
Suitable for	Light traffic	Light traffic	.....	.....

Southwest of the Sam Fease quarry, about ½ mile, is the Dan Hyse quarry. The limestone in this quarry was formerly burned for lime. No description of this quarry can be given as it was not visited. The beds seem to lie at a lower level than those of the Fease quarry, and probably differ from them in character.

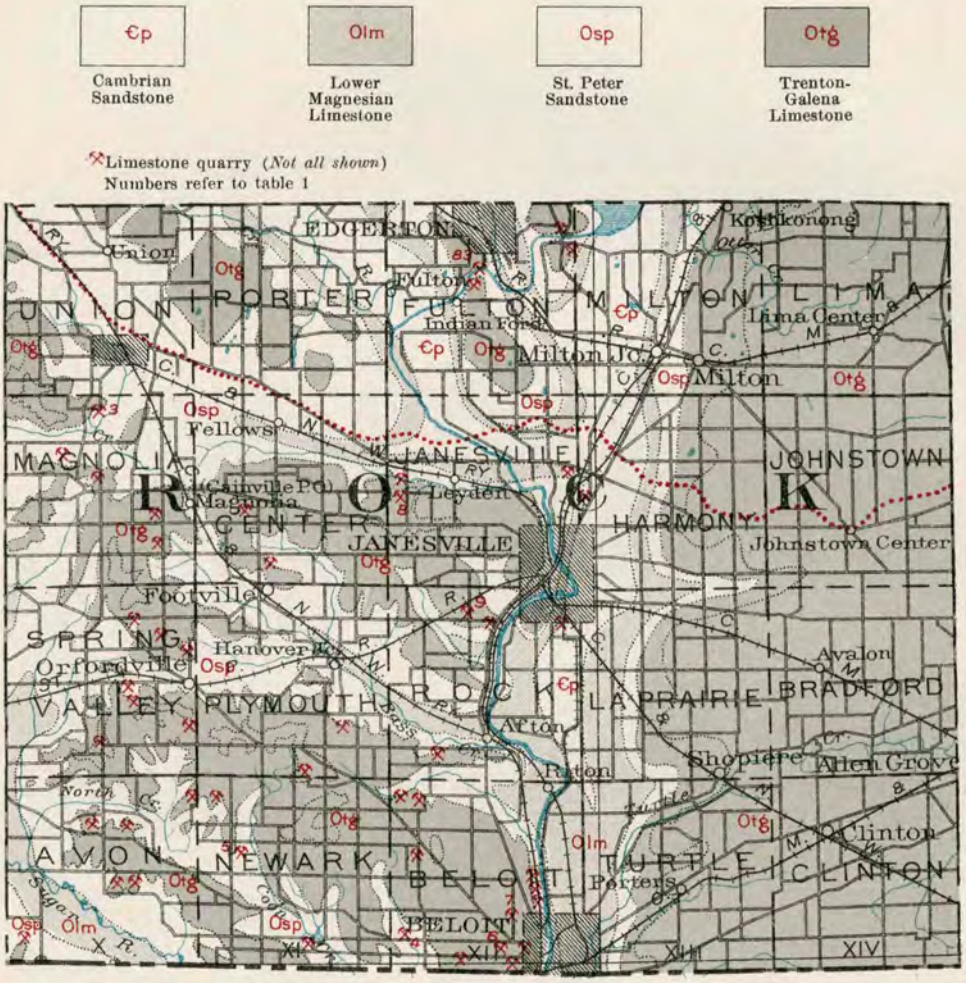
The Lower Magnesian limestone is poorly exposed in Jefferson county. In the stream below the bridge, at the village of Waterloo, there is a low ledge of it, which consists of coarse, flint-bearing, buff, porous, granular beds of medium thickness. It would not make a desirable road material. A quarry about 1½ miles southwest of Mud Lake near Lake Mills is probably in this formation. No description of this quarry is available. From what information has been secured, it seems certain that the Lower Magnesian limestone will not be an important source of road material in Jefferson county.

Besides limestones, some parts of Jefferson county have an abundance of field bowlders which could be used in preference to limestone for road construction.

Both field bowlders and gravel deposits are common around Lake Mills and to the north of Lake Mills.

The McGavock quarry near Janesville. The lower beds of this quarry are compact and of fair quality for road construction. The upper beds are broken into a rubble by frost action and grade into the soil which overlies them.

The Andrew Barnes quarry at Janesville. The rock is Trenton limestone. It is of uniform quality for road construction. Although not as good a road material as the best grades of Niagara limestone from the eastern part of the state, it is very satisfactory for local purposes.


Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Trenton-Galena Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1
EDGERTON
Union
Fulton
Indian Ford
Milton Jc.
Milton
Lima Center
Koshkonong
UNION
PORTER
FULTON
MILTON
LIMA
Fellows
MAGNOLIA
Cainville P.O.
Magnolia
CENTER
JANESVILLE
Leyden
ROCK
JOHNSTOWN
HARMONY
Johnstown Center
Footville
SPRING VALLEY
Orfordville
Hanover
PLYMOUTH
Afton
Avalon
LA PRAIRIE
BRADFORD
Shopiere
Allen Grove
Ryton
North
Turtle
Porters
M. C. Clinton
CLINTON
AVON
NEWARK
BELOIT
XII
XIII
XIV

Rock County.

The eastern part of Rock county is nearly all underlaid by the Galena-Trenton formation. In the western portion, this formation only caps the highest hills and uplands. The St. Peter sandstone underlies the hill sides and valleys excepting portions of the Rock river and Sugar river valleys, and the low country between Lake Koshkonong and Janesville which are underlaid by the Lower Magnesian limestone and the Potsdam sandstone. The distribution of these formations beneath the soil and loose debris which covers them in most places is shown by Plate XXI. The red dashed line in this plate indicates the margin of the last glacial drift sheet. North of this line outcrops are few and scattered because of the thick surface mantle of glacial till and soil.

South of this line, the outcrops are more numerous, but in most places the rocks are covered by residual soil, and old glacial deposits. In the larger stream valleys the rocks are buried under stream wash.

The beds of the Galena-Trenton formation are the only limestones which outcrop. The principal exposures are along the sides of the Rock river valley; in the minature canyon of Turtle Creek in the town of Brandon; and on the edge of the hill tops in the western part of the county.

Limestone quarries are numerous in Rock county. None of them, however, have railroad facilities, and nearly all are very small. In 1912 only two, the McGavock quarry of Beloit and the Barron quarry near Janesville were equipped with stationary rock crushers.

The Galena-Trenton formation in Rock county is generally a compact but slightly earthy limestone. Although distinguished for its uniformity, it cannot be regarded as either very good or very bad for road construction. For local use, it is undoubtedly satisfactory in most places. Several descriptions of quarries and outcrops follow.

Peck's quarry is located about 2 miles west of Beloit. It is easily accessible, being along side of the public road, and for practical purposes, seems to contain an unlimited quantity of stone. The face of the quarry is about 400 feet long and 22 feet high. It presents the following section in descending order:

Soil	2 feet
Thin-bedded, fine grained, weathered limestone	12 "
Blue-colored beds each 1 foot thick	4 "
Thin-bedded, buff limestone	5 "
Dense fine-grained limestone	2 "

Whether this stone would make a good material has not been demonstrated by actual use. The character of the lower beds is such as to make it probable that they would make a satisfactory material for local roads. For tests on an average sample from this quarry see table XIX. It is commented upon by the Office of Public Roads as follows:

"This rock shows low toughness, hardness and resistance to wear and fair cementing value. Suitable for roads subject to light traffic or with bituminous binders."

Limestone from a quarry along side of the road on the Barry farm, on the SE.¼ of the SW.¼ of the section 30 in the town of Beloit was used in constructing a road across a stretch of lowland east of the quarry. In 1912, the quarry section was about 12 feet high and 75 feet long. The available supply of stone which could be gotten at this depth seemed quite limited. The beds were soft, thin, buff colored, and earthy. For tests on an average sample from this quarry see table XIX. The Office of Public Roads commented on this sample as follows:

"Sample shows average hardness, low toughness and resistance to wear and fair cementing value. Only suitable for use on plain macadam roads subjected to light traffic, or for use with bituminous binders."

At McGavocks quarry about 1 mile west of Beloit, 35 feet of Galena-Trenton formation is exposed. The section in descending order is as follows:

Soil	A few inches
Decayed rock	10 feet
Thin-bedded, fine grained limestone	10 "
Thick beds of buff-colored limestone, fine-grained	5 "
Blue beds, each about 1 foot thick	6 "

The rock is somewhat earthy near the top, but the lower beds probably would make a good road material.

For tests on an average sample from this quarry see table XIX. The report of the Office of Public Roads regarding it is as follows: "This is a very soft rock showing low toughness and resistance to wear and fair cementing value. Not recommended for plain macadam construction except for extremely light traffic, but might be used with a bituminous binder."

The Chas. Samp quarry is located about 1 mile northwest of Beloit. A practically unlimited quantity of Galena-Trenton formation is exposed here. The overburden is very slight. The section in descending order is as follows:

Buff, thin-bedded limestone	8 feet
Buff, thick-bedded limestone	10 "
Brittle, fine-grained, dense bed	2 "
Buff, thick-bedded coarser-grained limestone	3 "
	23 feet

For tests of an average sample from this quarry, see table XIX. The report of the Office of Public Roads regarding it is as follows: "This rock shows average hardness, low toughness, and resistance to wear and fair cementing value. Only suitable for macadam roads subjected to light traffic or for use with bituminous binders."

The Andrew Barron quarry is located a short distance west of Janesville, south of the Monroe branch of the C. M. & St. P. Ry. About 40 feet of compact, fine-grained, but slightly earthy Galena-Trenton beds are exposed in this quarry. The section in descending order is as follows:

Buff, thin-bedded, weathered limestone	3–6 feet
Buff, thin-bedded limestone	10 "
Buff, thick-bedded limestone	4 "
Clay bed	A few inches
Blue, thin-bedded fossilferous limestone	12 feet
Clay seam	
Buff-colored, thick-bedded limestone	10 "

The quarry is equipped with a crusher and has furnished road material for the city of Janesville. For tests of an average sample of crushed rock from this quarry see table XIX.

The report of the Office of Public Roads on this sample is as follows: "Sample shows average hardness and resistance to wear, low toughness and fair cementing value. Only suitable for plain macadam roads subjected to light traffic or for use with bituminous binders."

Stout's quarry is located on a bluff rising from the north side of the Rock river valley, at the west end of Janesville, and within a stone's throw of the C. M. & St. P. Ry. and C. & N. W. R. R. tracks.

In this quarry, the Trenton-limestone directly overlies the St. Peter sandstone. The lowest limestone bed is sandy. This is overlaid by 24 feet of fine-grained, fairly compact, clayey limestone. The lower beds are blue; the upper beds buff. The drift covering is slight.

Road tests on an average sample from this quarry are given in table XIX. The report of the Office of Public Roads regarding it is as follows: "This rock shows average hardness, rather high

resistance to wear, low toughness and fair cementing value. Should be satisfactory for use on plain macadam roads subjected to medium traffic or with bituminous binders."

The quarry known as the Rieck quarry is located about 1½ miles north of the city of Janesville and near the Rock river. The lower 5 feet of Galena-Trenton formation in this quarry are buff-colored, solid and apparently of good quality. About 25 feet consists of broken, thin-bedded weathered limestone which probably would not make good road material. The drift mantle is several feet deep. The stone from this quarry has not been tested.

About ½ mile south of Edgerton on the west banks of the Rock river there are numerous quarry openings, of which the principal one is the Wille quarry. In this quarry, 20 feet of Galena-Trenton limestone are exposed. The surface mantle is thin. The beds are buff-colored, of medium thickness, fine-grained, and earthy in appearance. The rock has been quarried for building purposes chiefly, but some of it was donated by Mr. Wille to the county for road-making.

Road tests made on an average sample from this quarry are listed in table XIX. This sample was reported on by the Office of Public Roads as follows: "Soft rock with low toughness and resistance to wear and good cementing value. Only suitable for roads subjected to very light traffic."

The Spencer quarry, 1½ miles south of Evansville in the township of Magnolia has been reported permanently closed. A few descriptive notes regarding it are given below. The character of the stone in this quarry is similar to that of the other exposures of the Galena-Trenton beds in this vicinity.

The quarry face is about 25 feet high, and shows alternating buff and blue, clayey, compact limestone layers, capped with thin-bedded, weathered limestone. The soil covering is thin.

An average sample from this quarry was tested, and the results are given in table XIX. It was reported on by the Office of Public Roads, as follows: "This rock is of average hardness, low toughness and resistance to wear and fair cementing value. Only suitable for very lightly travelled waterbound macadam roads or for use with bituminous binders."

The Galena limestone which constitutes the low cliffs along the banks of Turtle Creek in the town of Bradford has not been tested for road making properties. It is thick-bedded, coarse, and granular in texture, and contain nodules of flint. In southwestern Wisconsin, the Galena generally is a porous, weak material which is not very satisfactory for road construction.

Besides limestone, portions of Rock county have an abundance of field bowlders and gravel. Field bowlders are abundant to the north of the margin of the last drift sheet; stream gravels to the south of it.

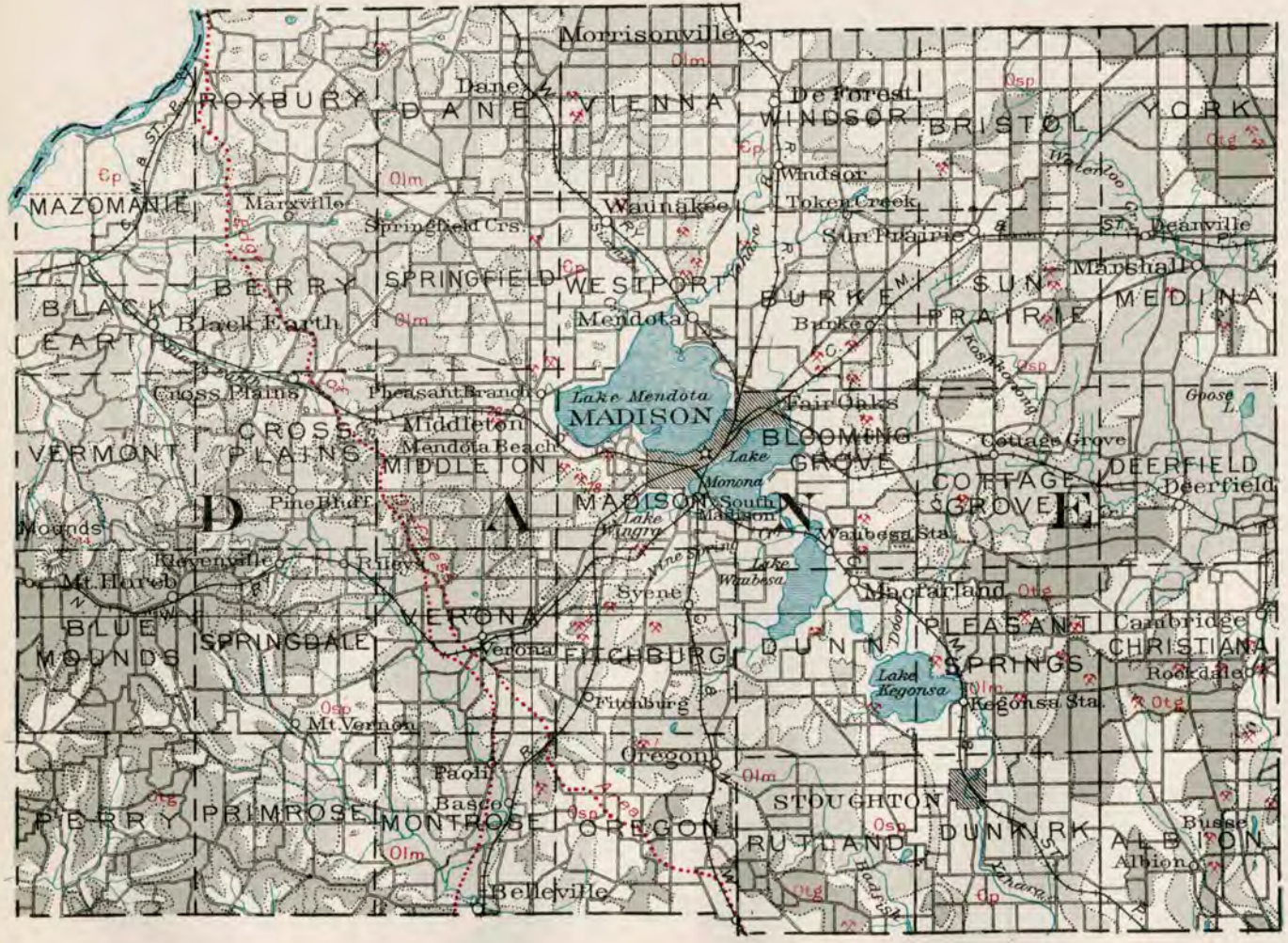
The chief producers of gravel are the Beloit Sand and Gravel Company of Beloit which operates a pit 5 miles north of Beloit on the C. M. & St. P. Ry. and the Janesville Sand and Gravel Company of Janesville. The latter operates gravel pits on both the C. M. & St. P. Ry. and the C. & N. W. Ry. at Janesville.

TABLE XIX.

Tests on Limestone from Rock County, Wis.

Nature of Test.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Specific gravity	2.70 High.	2.70 Med.	2.70 Med.	2.55 Low.	2.70 Med.	2.65 Med.	2.75 High.	2.70 High.	2.85	2.45
Pounds per cubic foot	168.00 High.	168.00 High.	168.00 High.	159.00 Low.	168.00 High.	165.00 Med.	172.00 High.	168.00 High.	178.00	153.00
Pounds of water absorbed per cubic foot.	2.35 Med.	3.01 Med.	2.36 Med.	5.89 High.	2.83 Med.	3.76 Med.	.14 Low.	2.24 Med.	6.90	.14
Per cent of wear	5.60 High.	8.10 High.	8.60 High.	8.60 High.	8.10 High.	8.90 High.	4.30 High.	2.30 Low.	22.50	2.30
French coefficient of wear	7.10 Low.	4.90 Low.	4.90 Low.	4.70 Low.	4.40 Low.	4.50 Low.	9.30 Low.	17.30 High.	17.30	1.80
Hardness	12.00 Soft.	15.00 Med.	10.50 Soft.	15.30 Med.	9.40 Soft.	14.20 Ave.	14.50 Ave.	15.00 Ave.	16.50	4.00
Toughness	7.00 Low.	7.00 Low	5.00 Low.	7.00 Low.	6.00 Low.	5.00 Low.	6.00 Low.	8.00 Low.	13 00	2.00
Cementing value	Good.	Fair.	Fair.	Fair.	Fair.	Fair.	Fair.	Fair.	.....	.....
Suitable for	Light traffic.	.....	Light traffic.	Very light traffic.	Very light traffic.	Very light traffic.	Light traffic.	Medium traffic.	.....	.....

1. Limestone from Wille Quarry, Edgerton, Wis. Wisconsin road sample No. 83.
2. Limestone from Spencer Quarry, Evansville, Wis. Wisconsin road sample No. 3.
3. Limestone from Peck's Quarry, Beloit, Wis. Wisconsin road sample No. 4.
4. Limestone from Barry Quarry, Beloit, Wis. Wisconsin road sample No. 5.
5. Limestone from Mediavock Quarry, Beloit, Wis. Wisconsin road sample No. 6.
6. Limestone from Samp Quarry, Beloit, Wis. Wisconsin road sample No. 7.
7. Limestone from Barron Quarry, Janesville, Wis. Wisconsin road sample No 8.
8. Limestone from Stouts' Quarry, Janesville, Wis. Wisconsin road sample No. 9.
9. Maximum for Wisconsin limestone.
10. Minimum for Wisconsin limestone.



Otg
Trenton-Galena Limestone

Osp
St.-Peter Sandstone

Olm
Lower Magnesian Limestone

Cp
Cambrian Sandstone

⚒ Limestone quarry
(*Not all shown*)

Numbers refer to table 1

DANE COUNTY.

The principal valleys of Dane county, including the Four Lake region, the Wisconsin River valley, and the Black Earth valley, are underlain by the Potsdam sandstone. See Plate XXII. The first bench of hills, which rises above these valleys is usually composed of the Mendota limestone, typical exposures of which can be seen at Maple Bluff and Eagle Heights on Lake Mendota. Although more resistant than the sandstone, it is a soft rock, and so far as known of little use as a road material.

The Lower Magnesian limestone gives rise to another bench or escarpment which appears at a higher level than that of the Mendota beds, and usually some distance from the valleys which are underlain by the Potsdam sandstone. It caps the high bluffs overlooking the Wisconsin River such as Black Hawk bluff opposite Prairie du Sac. It also outcrops in many places along the top of the bluffs which hedge in the Black Earth valley most of the way from Madison to Mazomanie.

In the western and eastern part of the county some of the highest uplands are underlaid by the Galena-Trenton formation. Their edges are marked by escarpments along which there are numerous outcrops and quarries of this formation. Along the foot of the escarpent there is a narrow strip underlain by the St. Peter sandstone.

At Blue Mounds the cap rock is a flint formation, a mere scrap of the Niagara limestone which erosion has failed to remove, The lower, more gentle slope of the mound is underlaid by the Cincinnati shale. Scattered all over the surface of the Mound, there are huge bowlders of flint which have broken away from the main ledge.

The distribution of the quarries of Lower Magnesian limestone known to this Survey are shown on Plate XXII. Some of the localities where outcrops occur are as follows:

Sec. 31, town of York.

Secs. 18 and 19, town of Bristol.

Secs. 3, 12, and 13, town of Dane.

Sec. 36, town of Burke.

Railroad cut, Section 6, town of Medina.

The bluffs overlooking Black Earth valley.

One of the striking characteristics of the Lower Magnesian limestone is its variability. From an almost pure limestone it varies

locally to almost pure sandstone or shale. The purest limestone beds show a crystalline texture and a shell-like fracture. The bedding also varies much. Layers from 40–60 feet above the base are usually the heaviest. The upper and lower beds are much thinner as a rule, more distinct, although commonly very irregular and rough surfaced, and internally porous and cavernous. Highly concretionary structure is apparent in certain beds and not in others immediately adjacent. The weathered surfaces are remarkably rough, jagged, and pitted. Some beds show an abundance of flint in nodules or seams. In others, flint is lacking. The beds also change their character from place to place. It is not surprising, therefore, that it also is extremely variable as a road material.

West of Madison, the Lower Magnesian limestone is quarried by the City of Madison, E. F. Paunack, and the David Stephens estate. At the city quarry a rock crusher has been operated for a number of years, although the product seems to be a distinct failure on heavily travelled streets. Its cementing power is good, but its per cent of wear high. Consequently, streets paved with it which are subjected to heavy traffic are dusty in dry weather and muddy when wet.

The section exposed in the city quarry is about 20 feet high and has several feet of soil over it. The upper ten feet are very much broken, and in a rotten condition while the lower beds contain much flint.

For tests on an average sample from this quarry see table XX.

The report of the Office of Public Roads on a sample from this quarry is as follows: "This is a soft rock, showing low toughness and resistance to wear and very good cementing value. Not recommended for road construction."

The Wiesenburg and Dahnke quarry is located on the C. M. & St. P. Ry., about 350 feet west of the station at Middleton. The quarry is equipped with a crusher, which in 1912 had a capacity of about 4 cars a day.

The section of Lower Magnesian limestone in this quarry, in descending order, is as follows:

Soil	several feet
Sandy limestone	6 feet
Cavernous flinty layer	1 foot
Sandy limestone	3 feet
Fractured, brecciated limestone	1 foot
Flint	1½ feet
Loose sand	2 inches
Flint	1 foot
Flint and limestone	1 foot

Green clay	1 inch
Limestone with flint lenses	2 feet
Fine-grained limestone with dome-like structures, ripple marks, and sun cracks	a few feet
Limestone, flint and sand grains	6 inches

The combination of flint and limestone makes a desirable road material, which as a rule is found more satisfactory than the tests would seem to indicate.

The tests on an average sample from this quarry are among the best gotten from any quarry in this part of the state. See table XX. The report of the Office of Public Roads on this sample states: "This rock is of average hardness, rather low in toughness and resistance to wear and fair cementing value. Should be satisfactory for use on plain macadam roads subjected to medium traffic or with bituminous binders."

O'Malley's quarry S. E. ¼ of Section 10 in the Town of Westport has shown [1] Lower Magnesian limestone different from the general run. The following section has been reported:

1. Thin-bedded to shaly yellow limestone	6 feet
2. Three heavier layers of the same	2½ "
3. Broken yellow limestone with much oolitic chert and geodic calcite	4 "
4. Very heavy layers, interstratified with 2 or 3 thin cream-colored layers of dense, granular limestone	10 "

Layer No. 4 has furnished good building material, and deserves consideration as a road material.

Veerhusen's quarry N. E. ¼ of the S. W. ¼ of Section 25, town of Westport, is on the top of a narrow ridge of Lower Magnesian limestone. The following section [1] was reported from there in 1877, beginning at the top:

1. Rough, brecciated, yellow, fine-granular limestone, with 3 per cent of impurities. (Limestone with a low percent of impurities is usually better as a road material than one with a high percent, unless the impurities are flint)	8 feet
2. Very heavy layers, some 4–5 feet in thickness, of pale yellow, close-textured, granular limestone, which on solution leaves a large residue of fine gray sand; quarry layers	15 feet
3. Greenish sandy layer; a specimen on solution left 41.17 percent of very fine gray sand	1 foot
4. Thinner-bedded limestone, like No. 2, but finer-grained, of greenish tint, and profusely marked with dendritic oxide of manganese; below the base of the main quarry	8½ feet

[1] Irving, R. D., Geology of Wisconsin, Vol. II, p. 602.
[1] Irving, R. D., Idem, p. 602.

No. 2 is like No. 4 of O'Malley's quarry, and has been used very successfully as a building stone.

In the railroad cut in section 26 of the town of Westport near Mendota, 20 feet of Lower Magnesian limestone resting on Potsdam sandstone are exposed. The basal beds of the limestone are flinty. The upper layers are porous, broken, moderately thin, and are composed of earthy limestone. They are all below the beds of the Veerhusen quarry, and from the description are not as promising for road material as those of O'Malley's and Veerhusen's quarries.

In the N. W. ¼ of Section 25, town of Springfield there are extensive quarries, which have shown the following section.

	Feet
1. Concretionary and brecciated yellow limestone	5
2. Heavily-bedded white layers with much chert, burnt for lime	10
3. No exposure	25
4. Irregularly thin-bedded, porous, white-and-yellow-mottled limestone, with geodic cavities, many black dendritic markings, and 6.11 per cent of insoluble ingredients	15

The upper beds of this quarry deserve consideration for local road purposes.

On the south line of the town of Madison, Section 33, an old quarry has shown 19 feet of Lower Magnesian limestone. The description given below makes it seem deserving of consideration as a road material.

	Ft.	In.
1. Concretionary and iregularly bedded, yellowish-gray limestone	10	
2. Chert layer; sometimes forming a continuous nodular-surfaced layer, at others occurring in a row of separate nodules; internally, the chert is brown-and-white-banded, and jaspery; externally it has a soft, white, siliceous coating		3
3. Compact, heavily bedded, flinty-textured, gray limestone containing a few geodic cavities lined with dolomitic crystals	4	
4. Chert layer, like No. 2		2
5. Very heavily bedded limestone, like No. 1	5	

Plate XXII shows the locations of quarries in the Galena-Trenton limestone which are known to this Survey. They are chiefly in the towns of Bristol, Sun Prairie, Deerfield, Cottage Grove, Oregon, Fitchburg, and Blue Mounds; most of them in the beds immediately above the St. Peter sandstone. The lowest bed is usually more sandy than the rest. The general aspect of the beds is earthy, but crystalline particles constitute the greater part of the mass. For road material they are quite uniform, being neither very good as a rule

nor very poor. On the average, they are inferior to the best grade of Lower Magnesian limestone in this part of the state.

Fifteen feet of the lowest part of the Galena-Trenton formation is exposed[1] on the edge of the formation in Section 35, town of Pleasant Springs. The upper layers are thin, while the lower six feet consist of two heavy, firm layers between which is a persistent, thin seam 2 inches thick.

In the north part of section 4, in the town of Cottage Grove, 20 feet of thin-bedded, dense Galena-Trenton limestone is exposed.

In Section 23, town of Sun Prairie, there are a number of quarries which show a total thickness of about 20 feet of Galena-Trenton limestone. The upper beds are thin and shaly. Beneath them are heavy, buff-colored layers. This stone has been used both for building purposes and the manufacture of lime.

In the town of Bristol, there are large quarry openings in Section 34. These show 8 feet of bluish-colored limestone with a flinty texture, at the top and 10 feet of buff-colored, close-grained, thick-bedded limestone below.

At the Kelly quarry, 3 miles west of Oregon, in Section 3 of the town of Oregon, 12 feet of Galena-Trenton limestone are exposed. These beds cap a hill, of which the base is St. Peter sandstone. The latter outcrops on the road leading up to the quarry. Because of its topographic position, the quarry is somewhat difficult to reach by wagon. The stone is of fairly good quality, and has been used by the town of Oregon for local roads.

The section shown at the quarry from the top down is as follows:

	Ft.	In.
Soil	2	6
Thin-bedded, buff limestone	7	
Dense, thick-bedded, buff limestone	3	

For road tests of this stone see table XX. The report of the Office of Public Roads on this sample follows: "This rock shows average hardness, low toughness and resistance to wear and good cementing value. Best suited for roads subjected to light traffic. Probably satisfactory for use with bituminous binders."

The O'Brien quarry is located in section 8 of the town of Fitchburg, 4 miles west of Syene. About 27 feet of soft, earthy, buff Galena-Trenton limestone is exposed. The section is as follows:

	Feet
Soil and weathered rock	6
Decayed, thin-bedded limestone of poor quality for roads	10
Thin-bedded limestone of better quality than that above	5
Massive bedded, buff, fine-grained, dense limestone	12

[1] Irving, R. D. Idem, p. 600.

Tests on an average sample are given in table XX.

The Office of Public Roads reports as follows on this sample: "This is a soft rock, showing low toughness and resistance to wear and fair cementing value. Should only be used on roads subjected to very light traffic. Probably satisfactory for use with bituminous binders."

Stone for building a macadam road extending from the village of Blue Mounds to the northeastward, has been gotten from the quarry of Chas. Brigham in section 5 of the town of Blue Mounds. The quarry face is about 15 feet high and 75 feet long. The beds are a buff, earthy, soft limestone belonging to the Galena-Trenton formation.

For tests on a sample from this quarry see table XX. The Office of Public Roads reported on this sample as follows: "This is a soft rock, showing very low toughness and resistance to wear and low cementing value. Not recommended for plain macadam construction, but might prove satisfactory when used with bituminous binders."

Only a portion of Dane county was glaciated. The western limit of glaciation is shown on Plate XXII by the dotted red lines which unite in the town of Verona and continue as one line to the northward. Of the two lines the one to the east indicates the margin of the most recent drift; the other that of an older drift. Within the area of the youngest drift field bowlders including granites, traps, and other crystalline rock are abundant, and may be found more satisfactory as a road material than the local limestones. Gravel deposits are not abundant, but may be looked for in the valleys leading away from the terminal line of the glacial drift, such as the Black Earth valley and others.

TABLE XX.

Tests on Limestones from Dane County, Wis.

Nature of Test.	1.	2.	3.	4.	5.	6.	7.
Specific gravity	2.6 Medium	2.8 High	2.75 Medium	2.75 High	2.6 Medium	2.85	2.45
Pounds per cubic foot	162. Medium	175. High	172. Medium	172. High	162. Medium	178.	153.
Pounds of water absorbed per cubic foot.	2.09 Medium	1.21 Low	1.9 Low	1.57 Low	4.75 High	6.9	.14
Per cent of wear	10.8 Very high	8.9 High	5.1 High	6.1 High	11.3 High	22.5	2.3
French coefficient of wear	3.7 Very low	4.5 Low	7.9 Low	6.6 Low	3.6 Low	17.3	1.8
Hardness	12.5 Soft	14. Medium	15.7 Medium	11.3 Low	10.7 Soft	16.5	4.0
Toughness	4. Very low	Low	10. Low	6. Very low	4. Low	13.	2.
Cementing value	Very good	Good	Fair	Fair	Low	.....	.....
Fitness	No good	Light traffic.	Medium traffic.	Very light traffic.	No good	.....	.....

1. Sample from Madison City quarry. Wisconsin road sample No. 78.
2. Limestone from Kelly's quarry, Oregon, Wis. Wisconsin road sample No. 1.
3. Limestone from Wiessenburg & Dahnke's quarry, Middleton, Wisconsin. Wisconsin road sample No. 22.
4. Limestone from O'Brien'squarry, Fitchburg, Wisconsin. Wisconsin road sample No. 2.
4. Limestone from Brigham's quarry, Blue Mounds, Wis. Wisconsin road sample No. 24.
6. Maximum for Wisconsin limestone.
7. Minimum for Wisconsin limestone.

GREEN COUNTY.

The eastern part of Green county lies within the region of old glacial drift. The western margin of this drift sheet is indicated on Plate XXIII by a dotted red line which runs a little south of Browntown, west of Monroe, and east of New Glarus. Within this region field bowlders of granite, trap, and other foreign rocks occur locally but are probably not abundant enough to constitute a source of road material. Gravel deposits are also found here and there. Usually they are perched on uplands near the margin of the drift sheet. Their use as road material probably never will be important.

The valleys and the sides of the valleys in Green county are all underlaid by the St. Peter sandstone excepting certain portions of the Sugar river valley and its tributaries between New Glarus and Monticello ; and the region between Albany and the county line, which are underlaid by the Lower Magnesian limestone. The level or gently rolling uplands are underlaid by the Galena-Trenton limestone. The distribution of these formations, as it would be if the soil and loose material which covers them in most places were stripped off, is shown by Plate XXIII.

The Lower Magnesian limestone probably does not outcrop. The Galena-Trenton formation is commonly exposed along the edges of the bluffs and uplands which it caps, or where streams have sunk their channels into it. Most of the outcrops are too earthy to be fit for use on roads. Some of the lower beds, however, may make a fair road material. Nearly every part of the county has limestones which are adequate for local needs, but whose quality is too inferior to warrant shipping to other parts of the state.

The town of Jefferson has operated a crusher at a small quarry in the Galena-Trenton limestone south of the C. M. & St. P. Ry. on Richland Creek. The exposure at this quarry is 18 feet high and 50 paces long. It consists of a coarse, porous, earthy limestone with numerous flint nodules and seams. It is said that the road built with this material has not given good results.

For tests on an average sample from this quarry see table XXI. The comment of the Office of Public Roads on this sample is as follows: "This rock shows extremely low resistance to wear and fair cementing value. Not recommended as a road building material."

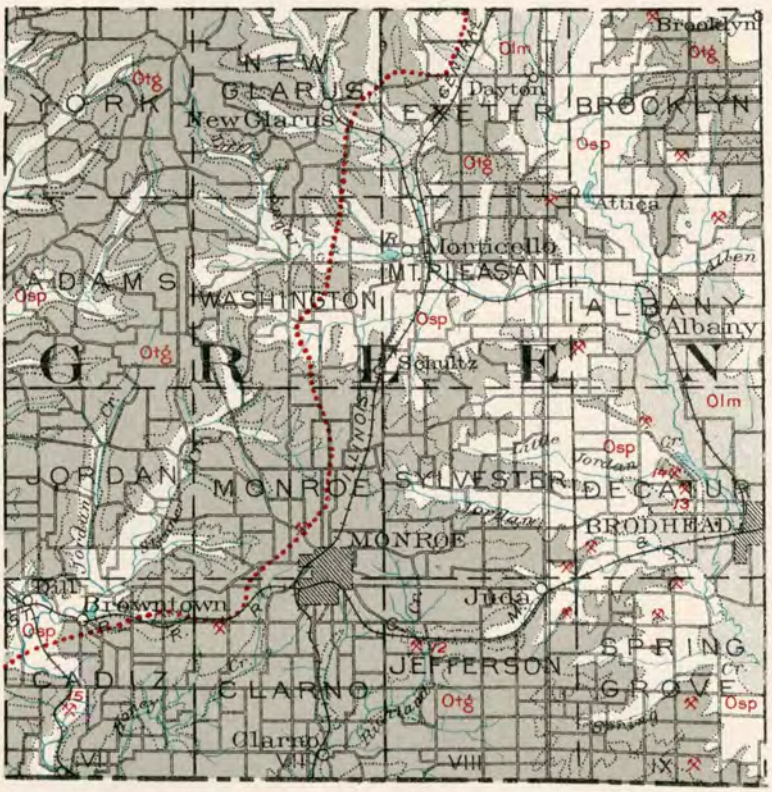
About 1½ miles upstream from the last mentioned quarry on the

Olm — Lower Magnesian Limestone

Osp — St. Peter Sandstone

Otg — Galena Limestone above and Trenton or Platteville Limestone below

⚒ Limestone quarry (*Not all shown*)
Numbers refer to table 1



hills on the west side of Richland Creek there are several small quarries, which were worked for foundation stone in 1912. Here also the limestone is soft, earthy, porous, and decayed, and would not make good road material.

About 2½ miles southwest of Brodhead on the west side of the Sugar river there are several quarries in beds near the base of the Galena-Trenton limestone. One of these, the Ten Eyck quarry, is perched on a steep-sided bluff in Section 3 of the town of Spring Grove. The base of the bluff is composed of St. Peter sandstone, of which 3 feet are exposed in the quarry. The quarry face, about 14 feet high, presents a section of soft, earthy rotten limestone. A crusher has been installed, and the rock has been used on local sandy roads, no doubt greatly improving them despite the inferior quality of the rock.

The following by the Office of Public Roads is on an average sample from this quarry: "Material is rather soft, shows very low resistance to wear and toughness and good cementing value. Not recommended as a road-building material." For tests see table XXI.

Urban White's quarry is located about ½ mile west of the Ten Eyck quarry. The section from the top down is as follows:

Soil	a few feet
Very rotten limestone	5 "
Buff, thick-bedded, earthy limestone with clay bed near base	10 "

For tests on this stone see table XXI. The report of the Office of Public Roads on it is as follows: "This material runs very low in hardness, toughness and resistance to wear, and shows good cementing value. Not recommended for use in road construction."

About 1 mile south of the White quarry, there is a limestone quarry on top of a high hill. About 10 feet of earthy, thick-bedded, rotten limestone are exposed. Because of its position, hauling from this quarry would be difficult. The quality of the stone is poor, about the same as in the Ten Eyck quarry.

In the southeast corner of section 14 of the town of Spring Grove, near the road crossing there is a small quarry opposite a cheese factory. The section exposed is in descending order as follows:

Soil	several feet
Thin-bedded, buff, fine-grained limestone	10 feet
A cream-colored shaly layer	6 inches
Fine-grained, dense, light-colored bed	2 feet
A slightly sandy layer	6 inches

No tests have been made on this stone. The quality, while not first class, is somewhat better than that of the limestone in the quarries of the northern part of the town. It would not be expedient, however, to use it for other than local roads.

About 1 mile west and ½ mile north of Brodhead, there is a small quarry on top of a hill overlooking the Sugar river valley. The base of the hill is composed of St. Peter sandstone. The quarry section consists of 10 feet of thin-bedded, broken, rotten Trenton limestone. Stone from this quarry was formerly used for road material in Brodhead. The quarry is hard to reach by team.

About 1 mile northwest from the latter quarry, on the hill top overlooking the farm of G. W. Atherton, about 3 feet of the basal beds of the Galena-Trenton limestone are exposed. They are very much broken, and most of the material in sight is not in place. Although of fair quality, it is doubtful if a large supply of stone could be gotten here.

In the quarry about 3 miles southwest of Albany (see Plate XXIII for location) only a few feet of very rotten limestone overlying the St. Peter sandstone are exposed. It would not be possible to get road material here.

In the given quarry on the east bank of the Pecatonica river in section 21 of the town of Cadiz, the following section of Galena-Trenton formation is exposed in descending order:

	Feet
Thin-bedded, flint-bearing limestone	6
Heavy-bedded, compact limestone	4

The soil covering is slight, and it is probable that a large supply of stone could be gotten here, although the exposure is not big enough to make this certain. The quarry is near the public road, and can be reached without difficulty.

The tests on this stone are given in table XXI. They show that this material is much better than the sample from Monroe, which gave the poorest tests of any Wisconsin limestone, and probably would be fairly satisfactory for local use. The comment of the Office of Public Roads on this sample is as follows: "This material shows average hardness, low toughness and resistance to wear and good cementing value. Not recommended as a road building material."

The quarry of Wood Booker at the north end of Martintown presents a face of Galena-Trenton formation about 26 feet high and about 300 feet long. The section from the top down is as follows:

Soil	several	feet
Thin-bedded, fine-grained, weathered rock which would make poor road material	6	"
Thick-bedded, buff, fine-grained limestone	10	"
Same as preceding, blue in color	10	"

The lower 20 feet would make satisfactory road material for local use.

In a quarry about 3 miles southwest of Browntown, about 10 feet of Galena-Trenton limestone are exposed. The beds are each about 1 foot in thickness, and fairly compact and hard. They would make a satisfactory road material for local use.

In the SE.¼ of section 11 of the town of Mt. Pleasant, there is an old quarry formerly known as the Marble quarry, because of the polish which the limestone from here would take on. This quarry was not examined, but may be considered a possible source of local road material.

TABLE XXI.

Tests on Limestones from Green County.

Nature of test.	1.	2.	3.	4.	5.	6.
Specific gravity	2.75 Medium.	2.6 Medium.	2.6 Medium.	2.6 Medium.	2.85	2.45
Pounds per cubic foot	172. Medium.	162. Medium.	162. Medium.	162. Medium	178.	153.
Pounds of water absorbed per cu. ft.	1.68 Low.	4.72 High.	4.97 High.	3.33 Medium.	6.9	.14
Per cent of wear	22.5 High.	11.1 High.	8.8 High.	11.4 High.	22.5	2.3
French coefficient of wear	1.8 Low.	3.6 Low.	4.5 Low.	3.5 Low.	17.3	1.8
Hardness	Not tested.	14.1 Medium.	9.3 Soft.	16.2 Average.	16.5	4.0
Toughness	Not tested.	4. Low.	3. Low.	5. Low.	13.	2.
Cementing value	Fair.	Good.	Good.	Good.	.....	.....
Fitness	No good.	.....	No good.	.....	.....	.....

1. Limestone from Richland Creek near Monroe, Wis. Wis. Road Sample No. 12.
2. Limestone from Ten Eyck Quarry, Brodhead, Wis.
3. Limestone from White's Quarry, Brodhead, Wis. Wis. Road Sample No. 14.
4. Limestone from Diven Quarry, Browntown, Wis. Wis. Road Sawple No. 15.
5. Maximum for Wisconsin limestone.
6. Minimum for Wisconsin limestone.

Iowa and LaFayette Counties.

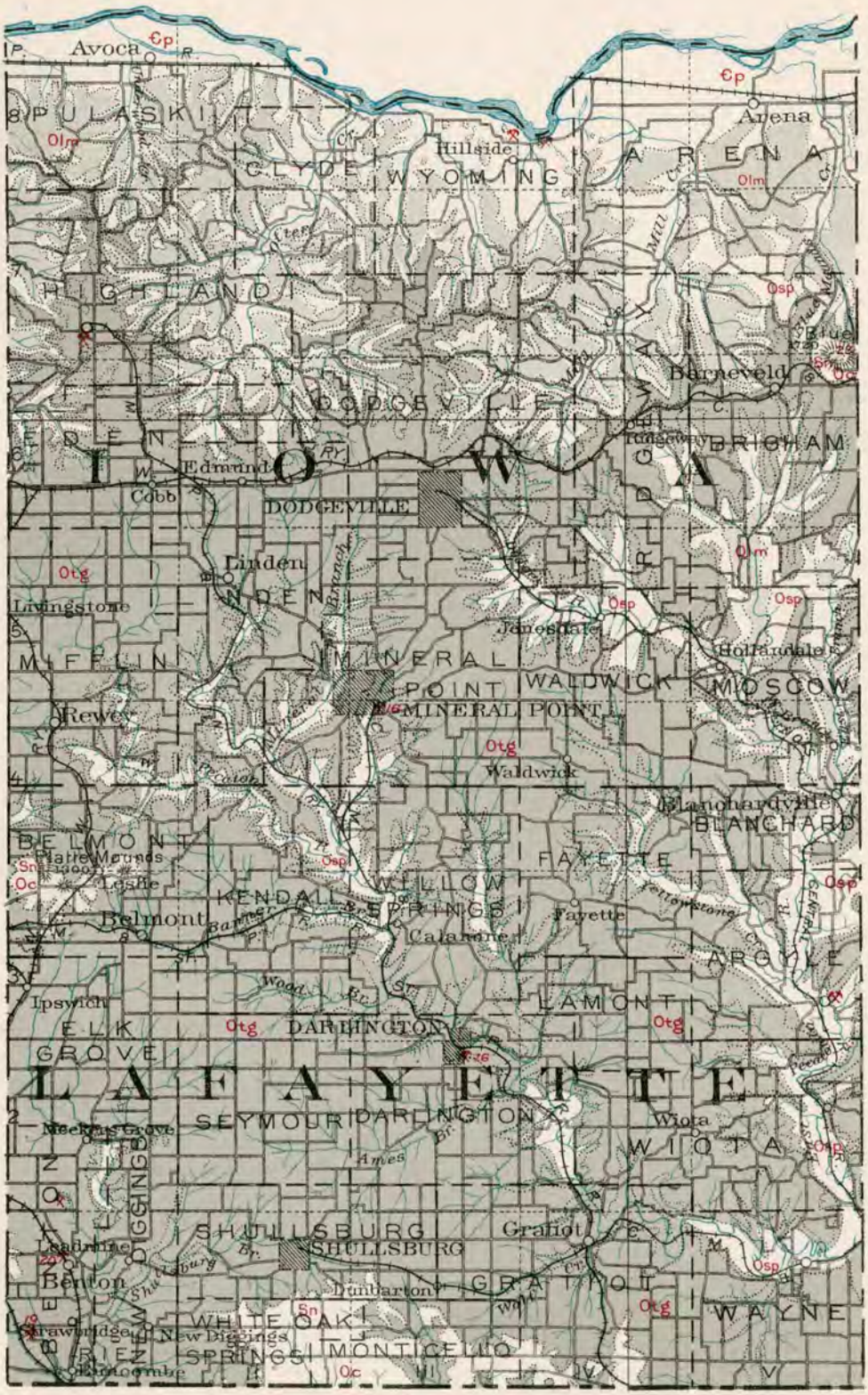
The Wisconsin river valley and parts of its tributary valleys in the northern part of Iowa county are underlaid by the Potsdam sandstone. The bluffs which overlook these valleys are capped with Lower Magnesian limestone. This limestone disappears to the south beneath the St. Peter sandstone and the Galena-Trenton limestone, the latter occupying nearly all of the stream divide known as the Military Ridge. The St. Peter sandstone reappears to the south of Military Ridge in the valleys of some of the branches of the Pecatonica river, notably in the towns of Brigham and Hollandale. It underlies very little territory. In the northern part of Iowa county, it usually appears on the sides of valleys, on steep sided bluffs, and at the head of ravines and gullies. In LaFayette county it constitutes more commonly the floor of valleys, but also appears on the hill sides.

In the southern part of LaFayette county there is a considerable area underlaid by soft Cincinnati shale. The gentle slopes of the lower portions of Platte and Blue Mounds are also underlaid by this formation. Their steep-sided caps are composed of the Niagara limestone. For the distribution of the formations which underlie these counties, as they would appear if the soil and loose debris were stripped off, see Plate XXIV.

Along the bluffs south of the Wisconsin river outcrops and quarries of Lower Magnesian limestone are numerous, many of which would furnish a satisfactory road material for local needs. Sliter's quarry south of Spring Green is situated about 1 mile northwest of Hillside. The rock in this quarry is the Mendota limestone. It is an earthy, weak material, which is inferior as a road material to the Lower Magnesian limestone which occurs in ledges and loose bowlders on the hill above the quarry. The total thickness of the Lower Magnesian limestone is about 30 feet. At the surface it is coarse-grained, and exceedingly rough. Loose bowlders of it have been used for road construction.

In King's quarry, which is situated on the top of a high, steep hill, ½ mile east of Sliter's quarry, about 7 feet of soft, frost-broken, crumbly, Lower Magnesian limestone are exposed. There is very little chance of finding a large supply of stone here. Furthermore, the quarry is hard to reach by team.

One of the most extensive exposures of the Lower Magnesian limestone occurs along the streams in sections 2, 3 and 10, T. 4 N.,


Sn
Niagara Limestone
Oc
Maquoketa Shale
Otg
Galena Limestone above and Trenton or Platteville Limestone below
Osp
St. Peter Sandstone
Olm
Lower Magnesian Limestone
Ep
Cambrian Sandstone
Limestone quarry (Not all shown)
Numbers refer to table 1
Avoca
Arena
Hillside
CLYDE
WYOMING
ARENA
PULASKI
HIGHLAND
DODGEVILLE
BRIGHAM
IOWA
Edmund
Cobb
Linden
Livingstone
MIFFLIN
MINERAL POINT
WALDWICK
MOSCOW
Rewey
Waldwick
Blanchardville
BLANCHARD
BELMONT
Platte Mounds
Lesha
Belmont
KENDALL
WILLOW SPRINGS
Fayette
Calamine
ARGYLE
Ipswich
ELK GROVE
DARLINGTON
LAMONT
LAFAYETTE
SEYMOUR
Wiota
WIOTA
Ames
SHULLSBURG
Graniot
Benton
GRATIOT
Drumbarton
WHITE OAK SPRINGS
MONTICELLO
WAYNE
New Diggings

R. 3 E., near Mineral Point. Some 30 feet of it can be seen in one cliff. The upper ten feet consists of hard, rough looking, broken beds; while the lower part is more thick-bedded and smooth in appearance. Flints are scattered throughout the mass.

North of Mineral Point in the NE.¼ of Section 24, T. 5 N., R. 2 E., about 11 feet in thickness of the Lower Magnesian limestone outcrops on the east bank of the creek. The outcrop consists of alternating sandstone and thin, fine-grained limestone layers, which are no good as a road material.

Around Dodgeville, Linden, Mineral Point and Highland, there are numerous mine dumps of the Galena-Trenton limestone. Probably very little of this stone is desirable for road building. As a rule, it is honey-combed, soft, and rotten. It is possible, however, that some of it may be used on roads and give good results. Mining is generally carried on only in the open-textured, porous, broken parts of the formation, and is stopped when compact, hard rock such as would make a good road material, is reached.

In the J. H. Wall quarry at Darlington, the section of Galena-Trenton limestone exposed is as follows:

Soil	about 2 feet
Porous, cavernous, fine-grained, rotten limestone	15 "
Medium-grained, buff, fossiliferous limestone	2 "
Buff, coarse-grained limestone	4 "
Alternating layers of limestone and brown, oily shale	6 "
Brittle, dense, fine-grained, thin-bedded limestone	15 "
Buff and blue, fine-grained, compact but slightly earthy limestone	50 "

The lower buff and blue beds would furnish the best road material. From them an average sample was taken and tested. For tests see table XXII.

The report of the Office of Public Roads on this sample is as follows: "This rock shows average hardness, low toughness and resistance to wear and good cementing value. Suitable for use on plain macadam roads subjected to light traffic or for use with a bituminous binder."

At the city quarry of Mineral Point, the following section of Galena-Trenton limestone is exposed:

Soil	about 5 feet
Rotten, buff limestone	5 "
Thick-bedded buff and blue beds	12 "
Blue, thin-bedded, hard, brittle, compact beds	14 "
Buff and blue thick-bedded limestone	15 "

The lower 19 feet are the best adapted for road material.

Rock from this quarry is being used with satisfactory results on the streets of Mineral Point. For tests of an average sample from this quarry see table XXII. The Office of Public Roads reports on this sample as follows: "This rock shows average hardness, low resistance to wear and toughness, and fair cementing value. Only suitable for plain macadam roads subjected to light traffic or for use with bituminous binders."

About ¼ mile south of the city quarry of Mineral Point, nearly 50 feet of Galena-Trenton limestone is exposed in a quarry. The character of the section is as follows:

Limestone debris	3 feet
Compact fine-grained magnesian limestone	2 "
Thin-bedded, wavy, brittle glass rock like limestone	25 "
Coarser, thick-bedded limestone	14 "
Unexposed	6 "
St. Peter sandstone	10 "

Galena-Trenton limestone from the Cleveland mine dump about ¼ of a mile south of Hazel Green station was crushed for a stretch of road between Hazel Green and Benton. The dump pile is near the tracks. The rock on this dump was in fairly good condition, and if the best were taken a satisfactory road material could be obtained. In 1912 about 80,000 cubic yards of stone were available at this mine.

For tests on an average sample from this mine dump see table XXII. The report of the Office of Public Roads on this sample is as follows: "Material shows average hardness, low toughness and resistance to wear and fair cementing value. Only suitable for plain macadam roads subjected to light traffic or for use with bituminous binders."

Close to 100,000 cubic yards of Galena-Trenton limestone were available for road material at the Frontier mine dump north of Benton in 1912. The dump being located within 50 feet of the C. & N. W. R. R. track is close to excellent shipping facilities. In 1912, 1½ miles of road north of Benton were built with stone from this dump. For tests on this stone see table XXII. The report of the Office of Public Roads on this sample is as follows: "This is a soft rock, showing very low toughness and resistance to wear and fair cementing value. Not recommended for plain macadam construction but might be used with bituminous binders."

A stretch of road between the Wilkinson mine and the C. & N. W. Ry. northeast of Benton was built with refuse from the Wilkin-

son mine which consisted almost wholly of flint fragments and iron sulphides. The results gotten with this material are very unsatisfactory. The sulphides have changed to the light brown oxide, which makes the road disagreeably dusty in dry weather, and muddy when wet.

The Niagara formation on top of Blue Mounds consists wholly of flints. It forms a bold but easily accessible outcrop at the east end of the mound. Huge blocks of it litter the sides of the mound and have even found their way into the gullies and valleys at the foot of the mound.

It has never been crushed for road material, but tests made on a sample of it seem to indicate that it would make an excellent road material. For tests of this material see table XXII.

The Office of Public Roads report on this sample is as follows: "This material shows average resistance to wear and low cementing value. Should be satisfactory for use on roads subjected to light traffic or with a bituminous binder."

On Platte Mound, there are extensive outcrops of flinty Niagara limestone. No tests of this stone have been made, nor has it been tried out by actual use on roads. It is a hard, compact rock which appears to have the qualities of a good road material. There is no doubt that it would be much better for roads than the rotten Galena limestone which outcrops on the plain around the mound. Barring the difficulty of getting the Niagara limestone down from the mound, it probably is the most desirable road material in southwestern Wisconsin.

TABLE XXII.

Tests on Limestone and Flint from Iowa and La Fayette Counties.

Nature of Test.	1.	2.	3.	4.	5.	6.	7.
Specific gravity	2.70 Medium	2 65 Medium	2.65 Medium	2.7 Medium	2.4 Average	2.85	2.45
Pounds per cubic foot	168. Medium	165. Medium	165. Medium	168. Medium	150. Average	178.	153.
Pounds of water absorbed per cu. ft.	1.87 Low	2.96 Medium	1.88 Low	2.16 Medium	3.16 Low	6.9	.14
Per cent of wear	5.5 High	3.96 Megium	7.1 High	12.9 High	3.3 Average	22.5	2.3
French coefficient of wear	7.3 Low	10.3 Medium	5.6 Low	3.1 Low	12.3 Medium	17.3	1.8
Hardness	14.5 Medium	14.5 Average	15.2 Medium	12.8 Soft	.....	16.5	4.0
Toughness	5. Low	11. Low	5. Low	4. Low	.....	13.	2.0
Cementing value	.....Good	Fair	Fair	Fair	Low	.....	.....
Suitable for	Light traffic.	Light traffic.	Light traffic.	No good	Light traffic.	.....	.....

1. Limestone from Wall quarry, Darlington, Wis. Wis. road sample No. 76.
2. Limestone from Wiesen quarry, Mineral Point, Wis. Wis. road sample No. 16.
3. Limestone from Cleveland Mine, Hazel Green, Wis. Wis. road sample No. 19.
4. Limestone from Frontier Mine, Benton, Wis. Wis. road sample No. 20.
5. Flint from West Blue Mound, Wis. Wis. road sample No. 23.
6. Maximum for Wisconsin limestone.
7. Minimum for Wisconsin limestone.


Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Galena Limestone above and Trenton or Platteville Limestone below
Oc
Maquoketa Shale
Limestone quarry (Not all shown)
Numbers refer to table 1
Muscoda
Blue River
WATTERSTOWN
MUSCODA
BOSCOBEL
CASTLE ROCK
HICKORY GROVE
MARION
WOODMAN
Andersons Mills
Millville
MILLVILLE
Bridgeport
MOUNT HOPE
Mt. Ida
FENNIMORE
Fennimore
WINGVILLE
Preston
Montfort
Centerville
Castle Rock
PATCH GROVE
WYALUSING
Wyalusing
Patch Grove
Mt. Hope
Stitzer
Bagley
LITTLE GRANT
NORTH LANCASTER
CLIFTON
BERTY
Liberty
BLOOMINGTON
Bloomington
GRANT
LANCASTER
Arthur
Glen Haven
SOUTH LANCASTER
ELLENBORO
N. Andover
GLEN HAVEN
BEETOWN
Beetown
CASSVILLE
Cassville
WATERLOO
POTOSI
Potosi
British Hollow
Dutch Hollow
McCartney
HARRISON
PLATTEVILLE
Bigpatch
SMELSER
Elmo
PARIS
Dickeysville
Georgetown
Cuba
Louisburg
JAMESTOWN
HAZEL GREEN
Jefferson
Hazel Green
Fairplay
Sinsinawa Mound
DUBUQUE
R. I. W.

GRANT COUNTY.

Grant county is in the driftless region of Wisconsin. Field bowlders, which constitute a valuable road material in many parts of the glaciated area of the state are therefore absent in this county. For the same reason, gravel deposits are scarce. Farther north, deposits of sandy, waterworn gravel are found along the sides of the Mississippi River valley and up some of its tributaries, but whether similar deposits of commercial importance occur in Grant county is doubtful.

Limestones, however, are more available for local use in this county than in any other county of the state. Hardly a community but has access to limestone ledges from which satisfactory road material for local use can be gotten. Up in the northern part of the county, the steep bluffs which rise above the Wisconsin River valley are capped by Lower Magnesian limestone excepting near the mouth of the river where they are capped by the Galena-Trenton formation. The Lower Magnesian limestone underlies the mouth of the river valley. Up stream, where this limestone rests on the hill tops, the river valley is underlain by the Potsdam sandstone. The St. Peter sandstone underlies a very narrow strip north of the area underlaid by the Galena-Trenton formation, and usually appears in valleys and on hillsides. The distribution of the solid rocks as they would appear if the soil which covers them in most places were stripped off, is shown by Plate XXV.

Where the Lower Magnesian limestone lies on top of the bluffs, it frequently forms cliff like exposures. At the mouth of Green River, west of Woodman, about 50 feet of it outcrop on top of a precipitous hill overlooking the road to Fennimore. It is a tough, fine grained, thick-bedded rock, full of flint nodules, which probably would make a good road material unless its habit of breaking into jagged fragments gives it too high a per cent of wear.

The bluffs which border the Mississippi River valley are composed of the Galena-Trenton formation, which also underlies nearly all of the uplands east of the river. A few high patches in the southern part of the county are underlain by the Cincinnati shale, and on Sinsinawa Mound, there is a small body of Niagara limestone.

In the central part of the county, many valleys are underlaid by St. Peter sandstone or by Lower Magnesian limestone. It is not probable, however, that ledges of the latter which would be fit for

road material occur. They are small, and usually consist of rotten, weak material.

Outcrops of the Galena-Trenton formation are too numerous to be listed. Attention will be called to a few of the quarries and mine dumps, and to the fitness of the road materials which could be gotten from them. The outcrops of the Trenton will on the average furnish better road material than those of the Galena limestone.

The mine dumps in and around Platteville afford an abundance of road material. A great deal of it, however, is of poor quality, the limestone being porous, and honey-combed with cavities. Some material of good quality can be seen on the dumps of the Enterprise mine, See table XXIII. The report of the Office of Public Roads on an average sample from the Enterprise mine dump is as follows: "This rock shows average hardness, low toughness and resistance to wear and fair cementing value. Should prove satisfactory for plain macadam roads subjected to light traffic or for use with bituminous binders."

Northwest of Platteville, at the old city quarry, and at the quarry on the west bank of the Little Platte river, in section 8 of the town of Platteville, limestone of good quality for local roads could be gotten. At the latter place about 54 feet of limestone is exposed. It is easily accessible and the supply is practically unlimited.

The city of Lancaster has gotten its supply of crushed rock from the City Park Association quarry north of Lancaster. The rock at this quarry is the Galena-Trenton limestone, the following section of which is exposed.

	Feet
Soil and broken limestone	about 1
Blue and buff limestone beds with clay seams	13
Clay	3
Thin-bedded limestone with clay and oil rock partings	3
Thick-bedded limestone, compact but slightly clayey	6

The report of the Office of Public Roads on this sample is as follows: "This rock shows average hardness and resistance to wear, low toughness and fair cementing value. Should be fairly satisfactory for plain macadam roads subjected to light and medium traffic or for use with bituminous binders." For tests see Table XXIII.

Numerous quarries are located on the cliffs of Galena-Trenton limestone which rise above the Mississippi river valley back of Cass-

ville. The following are reported as operating quarries at Cassville:

Kirchenberg and Titus
Jacob B. Ortscheid
Jacob J. Bernhardt
A. B. Teasdale
E. Rockefeller
W. G. Welch

The upper beds of the Cassville section are very soft and porous, and would make an inferior road material, but the lower beds are of better quality. The material of the section as a whole has not proven satisfactory as a railroad ballast.

The section at the E. Rockefeller quarry of Cassville in descending order is as follows:

Soil	stripped off
Open, cavernous, thick-bedded limestone with flint nodules	30 feet
Same as above, without flint	8 "
Clay bed	3 inches
Cavernous limestone with calcite-lined openings	5 feet
Blue, coarsely crystalline limestone	2 "
Earthy blue limestone	1 "
Clay and oil rock	6 inches
Thin, white glass rock like beds, brittle and compact	16 feet
Unexposed	6 "
Blue, medium-grained, compact limestone in creek bed	2 "

An average sample of this section was tested, with results as given in Table XXIII.

The office of Public Roads reports on this sample as follows: "This is a soft rock, showing low toughness and resistance to wear and good cementing value. Not recommended for plain macadam construction, except for extremely light traffic, but might be used with a bituminous binder."

Along the valley leading up to the village of Potosi from the Mississippi river, there are several quarries of Galena-Trenton limestone from which very satisfactory road material for local purposes could be gotten. In the quarry owned by Adam Schumacher, the following section is exposed in descending order:

Stripping	a few feet
Alternating layers of coarse and fine grained limestone	7 "
Thin-bedded layers, fine grained, dense, and brittle. Have appearance of the glass rock of the lead and zinc region	20 "
Buff and blue thick-bedded limestone	20 "

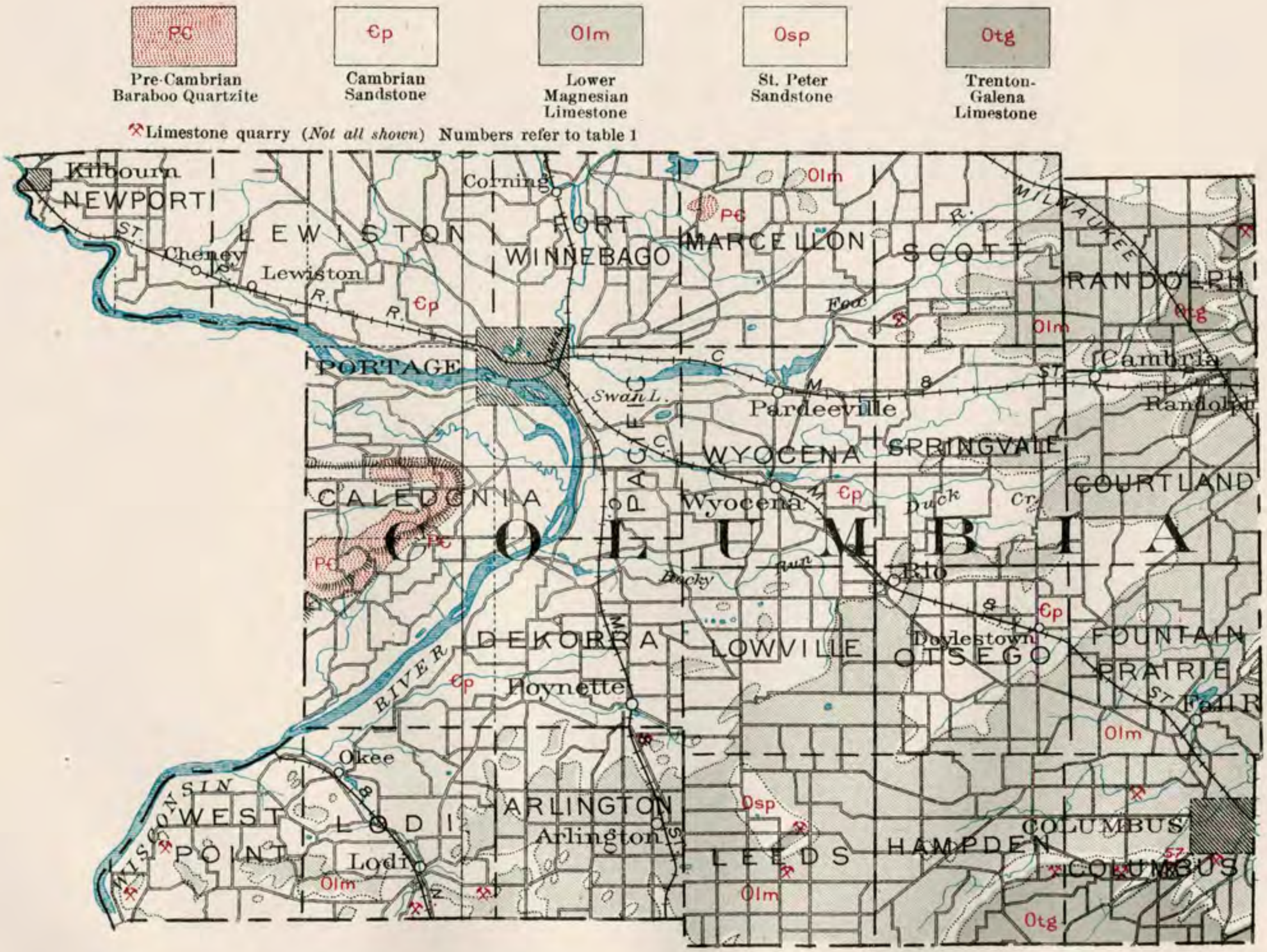
The quarry, although near the top of a bluff is not difficult to reach by team, and contains for practical purposes an unlimited quantity of stone.

TABLE XXIII.

Tests on Limestones from Grant County.

Nature of Test.	1.	2.	3.	4.	5.
Specific gravity	2.75 High	2.60 Medium	2.70 Medium	2.85	2.45
Pounds per cubic foot	172. High	162.00 Medium	168.00 Medium	178.	153.
Pounds of water absorbed per cubic foot	1.57 Low	1.67 Low	1.43 Low	6.9	.14
Per cent of wear	7.4 High	4.1 Medium	9.6 High	22.5	2.3
French coefficient of wear.	Low	9.7 Medium	4.2 Low	17.3	1.8
Hardness	15.0 Medium.	14.8 Medium	12.3 Soft	16.5	4.0
Toughness	5. Low	8. Low	4. Low	13.	2.0
Cementing value	Fair	Fair	Good	.....	.....
Suitable for	Light traffic	Light and medium traffic	Light traffic	.....	.....

1. Limestone from Enterprise Mine, Platteville, Wis. Wis. road sample No. 17.
2. Limestone from Lancaster, Wis. Wis. road sample No. 21.
3. Limestone from Rockefeller quarry, Cassville, Wis. Wis. road sample No. 27.
4. Maximum for Wisconsin limestone.
5. Minimum for Wisconsin limestone.



PC
Pre-Cambrian Baraboo Quartzite
Єp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Trenton-Galena Limestone
Limestone quarry (Not all shown) Numbers refer to table 1
COLUMBIA
Kilbourn
NEWPORT
LEWISTON
Cheney
Lewiston
Corning
FORT WINNEBAGO
MARCELLON
SCOTT
RANDOLPH
Cambria
Randolph
PORTAGE
Pardeeville
WYOCENA
Wyocena
SPRINGVALE
COURTLAND
CALEDONIA
Rio
DEKORRA
Poynette
LOWVILLE
OTSEGO
Doylestown
FOUNTAIN PRAIRIE
Fall R
Okee
WEST POINT
LODI
Lodi
ARLINGTON
Arlington
LEEDS
HAMPDEN
COLUMBUS
WISCONSIN RIVER

COLUMBIA COUNTY.

The northwestern portion of Columbia County is underlaid by the Potsdam sandstone; the southwestern part by Potsdam sandstone and Lower Magnesian limestone. In the eastern part of the county the chief underlying rock is the Lower Magnesian limestone, but several small patches are underlaid by Galena-Trenton formation and St. Peter sandstone. The distribution of these formations at the surface as well as beneath the soil and loose debris which covers them in most places is shown by Plate XXVI.

Where an area underlaid by Lower Magnesian limestone borders an area which is underlaid by Potsdam sandstone, the limestone beds occupy the tops of steep sided bluffs. The Potsdam sandstone underlies the lowlands adjacent to the bluffs and sometimes the lower slopes of the bluffs. It is along bluffs or escarpments of this kind that most of the outcrops and quarries of Lower Magnesian limestone occur.

The J. E. Johnson and L. G. Thompson quarries both near Lodi, were the only ones examined in this county. The Johnson quarry is located about 3 miles east of Lodi on the side of a bluff. It is easily accessible, and contains a practically unlimited quantity of stone. The section exposed consists of about 10 feet of thick bedded, compact limestone, free from flints. Tests on this stone are not available, but it appears to be of good quality. For local use on roads it probably would be satisfactory.

The L. G. Thompson quarry is situated on a bluff 2 miles south of Lodi, west of the C. & N. W. Ry. The quantity of stone available at this quarry seems to be limited. Its quality, however, is about the same as that of the Johnson quarry.

The Galena-Trenton limestone of Columbia county has been quarried for road purposes at the Columbus city quarry, about 8 miles west of Columbus. The quarry has been abandoned, however, because of its distance from the city and because of the inferior quality of the stone. The section exposed in this quarry is as follows:

	Feet
Soil	About 2
Thin-bedded limestone	6
Thin-bedded, brittle, fine-grained limestone similar in appearance to the glass rock of the "lead and zinc" region	4
Thick-bedded, blue, fine-grained, clayey limestone	4

For tests on an average sample from this quarry see table XXIV.

TABLE XXIV.

Tests on Limestone from Columbus City Quarry, Columbus.

Nature of test.	Columbus City Quarry, Wisconsin Road Sample No. 57.	Maximum for Wisconsin limestone.	Minimum for Wisconsin limestone.
Specific gravity	2.65 Medium	2.85	2.45
Pounds per cubic foot	165. Medium	178.	153.
Pounds of water absorbed per cubic foot	2.75 Medium	6.9	.14
Per cent of wear	5.7 Medium	22.5	2.3
French coefficient of wear	7.0 Low	17.3	1.8
Hardness	12.7 Soft	16.5	4.0
Toughness	3. Very low	13.	2.
Cementing value	Good		
Suitable for	Very light traffic.		

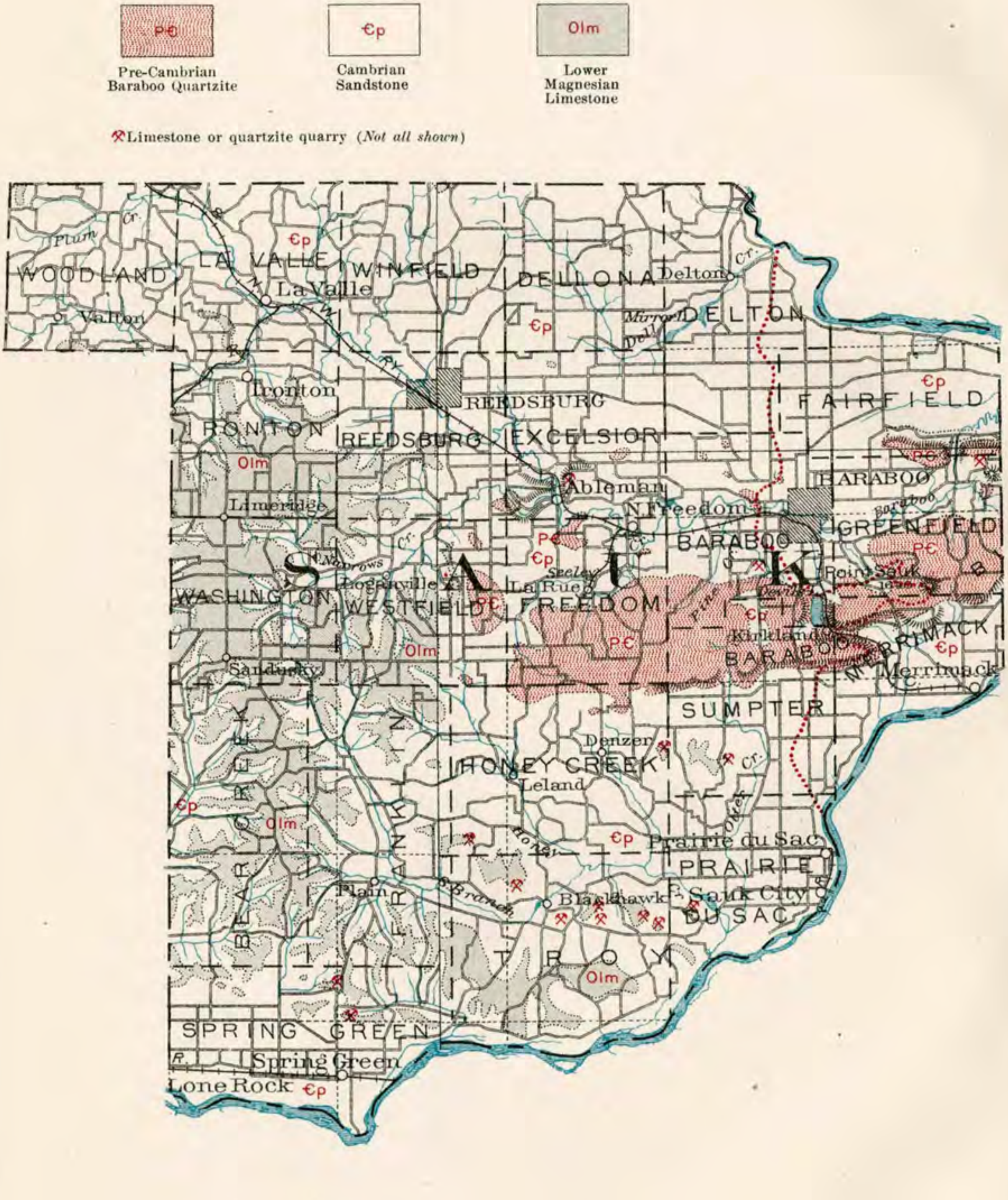
The report of the Office of Public Roads on this material is as follows: "This is a soft rock, showing low toughness and resistance to wear and good cementing value. Only suitable for very lightly traveled waterbound macadam roads. Suitable for use with bituminous binders."

At the Wm. Fritz quarry about 3 miles southeast of the Columbus city quarry, about 12 feet of Galena-Trenton limestone are exposed. The quarry is easily accessible, although located in a field about ¼ mile from the public road. The quality of the stone is about the same as that of the city quarry.

Glacial field bowlders are common throughout Columbia County, and in many localities they are sufficiently abundant to constitute a source of road material. For use on roads they are superior to the limestones. Gravels, although not as abundant in this county as in parts of Rock County, are found in many places. A gravel pit has been opened near the middle of the Town of Arlington, and another in the southwest corner of the Town of Courtland. The fitness of gravels for use on roads is extremely variable, and much care must be exercised in their selection.

Whitewater city quarry. Flat-lying layers of Trenton limestone, a uniform but rather mediocre road material. The quarry faces are parallel to joint planes which cut the rocks in two directions at right angles to each other.

The Columbus city quarry. The rock is the Trenton limestone, soft, thin-bedded, and of inferior quality for road making. The position of the quarry faces is controlled by vertical fissures (joint planes) which cut the rock into rectangular blocks.


P€
Pre-Cambrian
Baraboo Quartzite
€p
Cambrian
Sandstone
Olm
Lower
Magnesian
Limestone
Limestone or quartzite quarry (*Not all shown*)
WOODLAND
LA VALLE
WINFIELD
DELLONA
DELTON
Delton
La Valle
Valton
Mirror L.
IRONTON
Ironton
REEDSBURG
EXCELSIOR
FAIRFIELD
Ableman
BARABOO
N. Freedom
GREENFIELD
Limeridge
Narrows
Loganville
Seeley
La Rue
WASHINGTON
WESTFIELD
FREEDOM
Kirkland
MERRIMACK
Merrimack
Sandusky
SUMPTER
Denzer
HONEY CREEK
Leland
BEAR CREEK
FRANKLIN
Prairie du Sac
PRAIRIE DU SAC
Plain
Blackhawk
Sauk City
TROY
SPRING GREEN
Spring Green
Lone Rock
S A U K

Sauk County.

The low lying portions of Sauk county are mostly underlaid by the Potsdam sandstone, while most of its ridges, excepting the Baraboo range are capped by the Lower Magnesian limestone, which is at present the chief source of limestone road material in the county.

The Mendota limestone constitutes rock benches and ridges which appear at lower levels than the lower Magnesian limestone, but in most places it is too soft and weak for use on roads, excepting possibly as a binder for quartzite roads. Nevertheless, it may be considered as a possible source of road materials. In the Baraboo quartzite range of the central part of the county, quartzite underlies much of the surface, and also appears in numerous outcrops. As a road material, however, it has not given very satisfactory results. At various points along the edge of this range, volcanic rocks appear which deserve careful consideration as sources of road material. They are located northwest of Denzer on the Mellenthien farm, in section 10 of the town of Denzer, northeast of Denzer on Markert's farm, north of Myers Mill on Otter Creek, at Alloa, and west of the Lower Baraboo Narrows. The distribution of these formations as they would appear if the soil and loose material which covers them in most places were removed, is shown by Plate XXVIII.

East of the red dotted line running north and south through the eastern part of the county map the rocks are mostly covered with glacial drift. To the west of it lies the driftless area in which the soil is residual. Gravels are rare; and loose bowlders are seldom seen far from ledges. In the glacial drift area, however, bowlders of granite, trap, and other crystalline rocks are abundant and have been used very effectively in road construction. Gravel deposits have also been utilized to a slight extent, but less successfully.

The best exposures and quarries of Lower Magnesian limestone which may become important sources of road material, are in the southern part of the county. For location of limestone quarries see Plate XXVIII.

About 4 miles west of Sauk City, roughly 43 feet of Lower Magnesian limestone cap the precipitous bluff known as Mill Hill. The section from the top down is as follows:

Soil with limestone fragments	4 feet
Rotten, greenish, thin-bedded limestone (Poor road material)	2 "
Dense, thin-bedded limestone; good road material	3 "
Dense, buff limestone; good road material	3 "
Coarse-grained rotten limestone with a few chert seams; poor road material	29 "

The upper 12 feet of this section have been used in building a road between Sauk City and Mill bluff, which was in excellent condition in 1912.

On Ferry bluff at the mouth of the Honey Creek, west of Sauk City, there is the largest sections of Lower Magnesian limestone in this part of the state. From the top down it is constituted as follows:

Fine-grained, dense limestone	3 feet
Earth	12 "
Limestone, same as above	2 "
Soil	4 "
Limestone, same as above	6 "
Fine-grained, dense, thin-bedded limestone	23 "
Thick-bedded limestone	24 "

No road tests of this stone are available, but it appears to be well fitted for road material.

The bluff is about 310 feet high with precipitous sides towards the river, which would make it possible to roll rock which had been blasted from the top, down to the road at the foot of the hill.

Lower Magnesian limestone has been gotten for road material from a quarry on the hilltop north of Spring Green to the east of the public road. The section exposed consists of:

Soil	2 feet
Limestone with flint	4 "
Porous, rotten layers of limestone interstratified with hard resistant beds	8 "

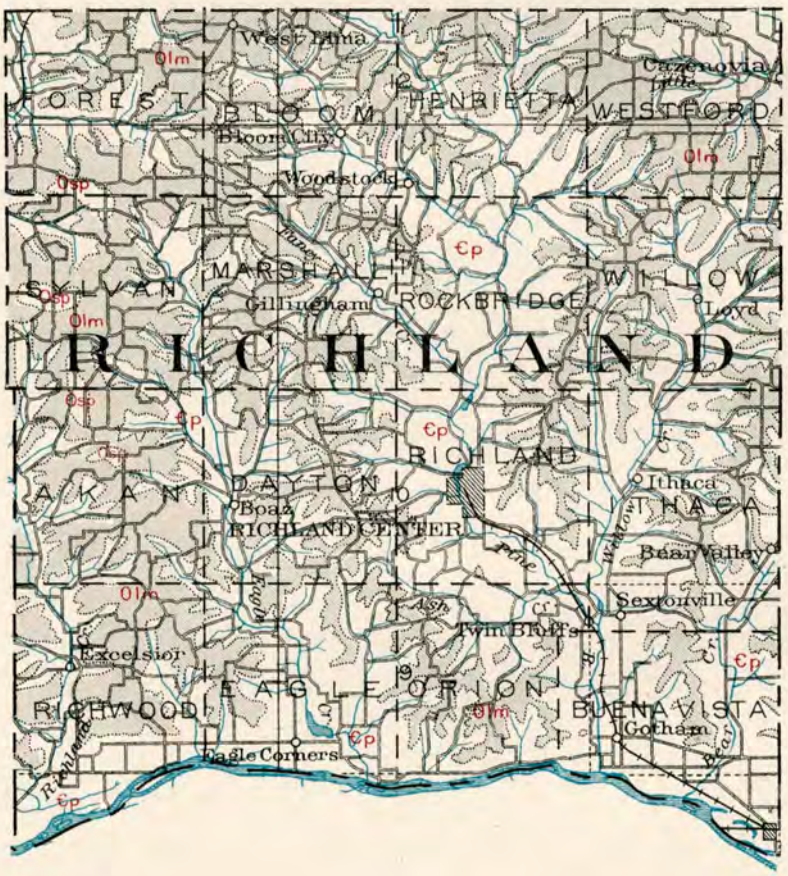
No tests of this stone are available, but its appearance is very unpromising.

The Mendota limestone is exposed at Wood's quarry in section 10 of the town of Baraboo and at Eiky's quarry in section 25 of the town of Greenfield. At Wood's quarry, 10 or 15 feet of earthy, porous, finely crystalline and rough surfaced limestone cap a small ridge. At Eiky's quarry, the beds are similar to those of Wood's quarry. Their thickness is about 25 feet. The individual layers run from 1 to 6 inches, in thickness, and are rough-textured, brown, and slightly earthy. No road tests on stone from these quarries have been made. The descriptions indicate, however, that the material is not very good for use on roads.

In the towns of Washington and Ironton in the western part of the county, the Lower Magnesian limestone caps the ridges and is so deeply decomposed, that outcrops are probably lacking. Between Reedsburg and Limeridge, outcrops of Potsdam sandstone and Mendota limestone can be seen along the road leading to the top of the ridge southwest of Reedsburg. Along the top of the ridge, flint residual bowlders are very numerous, sufficiently abundant locally to be used on roads.

View north of Spring Green. The high bluff in the distance is capped by Lower Magnesian limestone. Its steep slopes are underlaid by hard layers which form the cliffs. The gentle slopes are underlaid by weak rocks which rapidly crumble into soil. The low ridge on the center and left is a sand dune, which completely blocks the valley. The water has been checked sufficiently by the dune to form the small pond on the right.

View of the Wisconsin Valley from the hill north of Spring Green. The flatness of this valley is due to its being filled with river wash to an unknown depth. The river has made a number of terraces, on one of which is built the Village of Spring Green. The high ridge in the distance is capped by Lower Magnesian limestone.


Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
West Lima
Olm
FOREST
BLOOM
HENRIETTA
Czechoslovia
WESTFORD
Bloom City
Woodstock
Osp
Olm
Cp
MARSHALL
SYLVAN
Gillingham
ROCKBRIDGE
WILLOW
Loyd
Olm
RICHLAND
Osp
Cp
Cp
RICHLAND
AKAN
DAYTON
Boaz
RICHLAND CENTER
Ithaca
ITHACA
Bear Valley
Olm
Sextonville
Twin Bluffs
Excelsior
Cp
EAGLE
ORION
RICHWOOD
Olm
BUENA VISTA
Gotham
Eagle Corners
Cp
Cp

Richland County.

Richland county lies wholly within the unglaciated region of Wisconsin. Practically its only source of road material is the Lower Magnesian limestone which caps nearly all the high ridges and level uplands of the county. On some of the highest, the St. Peter sandstone immediately underlies the surface. The Potsdam sandstone underlies the valleys but one of its limy layers, known as the Mendota limestone, usually appears on the sides of bluffs, where it forms benches and projecting ledges. So far as known this stone is too soft to make any but a poor road material, but it may be regarded as a possible source of material. The distribution of these formations as they would appear if the soil and loose material which covers them in most places were stripped off is shown by Plate XXX.

Exposures of the Lower Magnesian limestone are known in the N. W. ¼ of Section 19, town of Eagle; N. E. ¼ of Section 30; town of Henrietta; on the N. E. ¼ of Section 19, town of Orion; and in several places in the vicinity of Richland Center.

There is very little information at hand concerning the fitness of the Lower Magnesian limestone of Richland County for road building. It has not been tested nor used extensively. In the southern part of the county, its quality is probably the same as in the southern part of Sauk county, and therefore may be counted upon as a source of fair road material, but in the northeast part of the county, it probably is too badly decayed to be valuable for road construction.

Crawford County.

The chief source of road material in Crawford county is the Lower Magnesian limestone, which caps most of the bluffs and highlands of the county. The Galena-Trenton formation underlies most of the ridge between Seneca and Prairie du Chien. There is also a small outlier on a high ridge in the town of Marietta. For distribution of the formations which underlie Crawford County see Plate XXXI. The St. Peter sandstone underlies narrow strips flanking the Galena-Trenton limestone areas. The valleys of the county are nearly all underlaid by Potsdam sandstone.

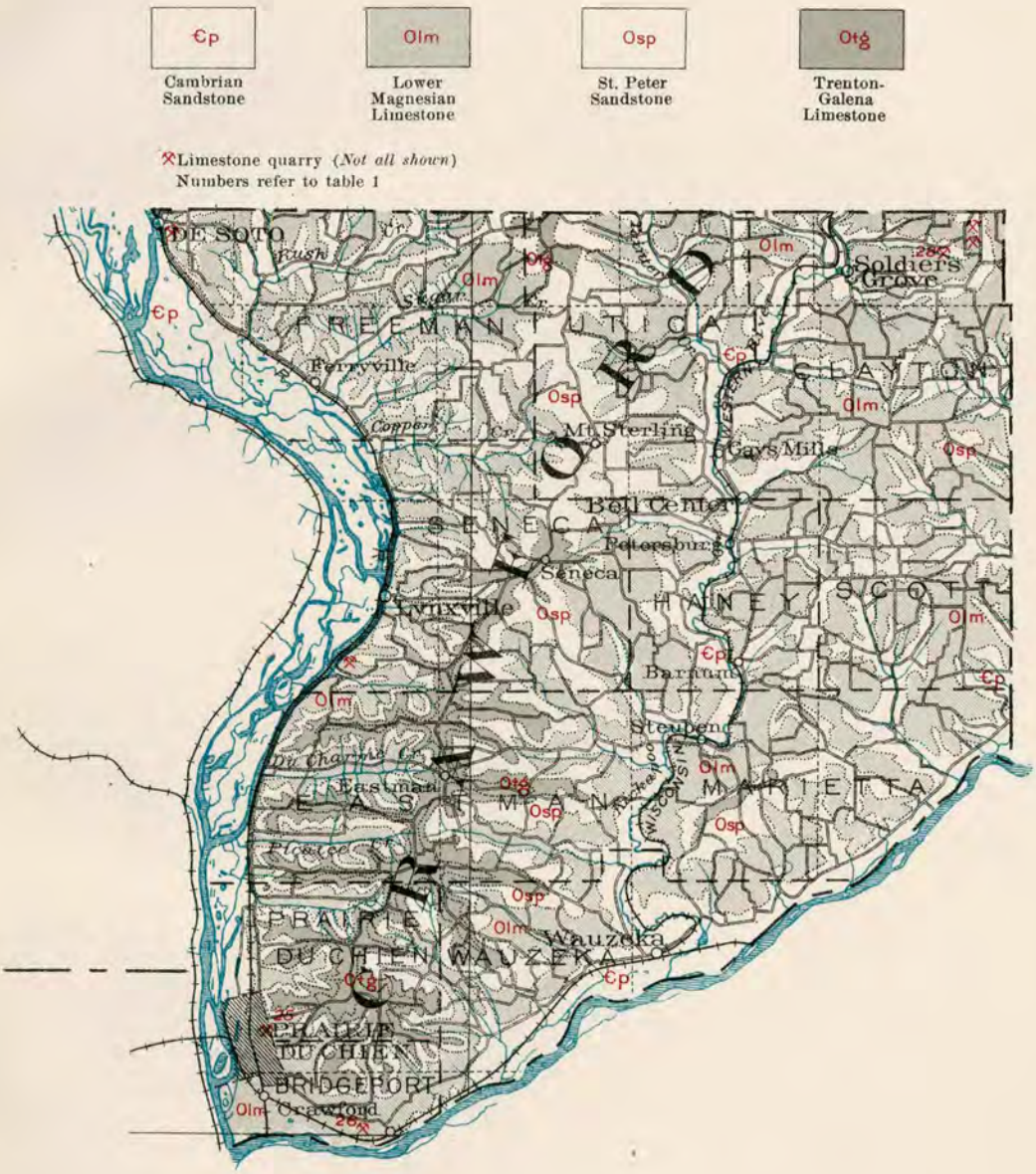
Crawford county does not appear to have been glaciated with the possible exception of the southwest corner of the county. Field bowlders, such as granites, traps, gneisses and other crystalline rocks which furnish an abundance of excellent road material in certain parts of the glaciated region of the state are lacking here. Gravels also are scarce. Small deposits are known along the Mississippi river. Usually they are situated near the mouths of valleys tributary to the Mississippi. It is not probable that any of them with well rounded pebbles, and their content of limestone or other well rounded with pebbles, and their content of limestone or other cementing material is so small that they probably would be unsatisfactory as a road material.

Deposits of sandy gravel have been observed at the village of De Soto and at the mouth of Sugar Creek below Ferryville and along the valley of the Mississippi for some distance above and below this locality. These beds usually occur at an elevation of 20 feet above the river.

The largest outcrops of the Lower Magnesian limestone are along the Mississippi river. Quarry openings are numerous, and many of them would furnish an excellent road material. The most durable and resistant beds are those which form bold precipitous outcrops.

At the Prairie du Chien city quarry, the following section is exposed, beginning at the top.

	Feet
Porous, coarse, crystalline limestone with flint layers	20
Compact limestone with flint nodules	7
Banded limestone	5
Limestone with quartz openings parallel to the bedding	4
Coarse, porous, limestone known as "lead layer" by local quarrymen	3½
Compact limestone	13


Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Trenton-Galena Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1
DE SOTO
Rush Cr.
Otg
Olm
Steam Cr.
Soldiers Grove
FREEMAN
UTICA
Ferryville
Cp
CLAYTON
Osp
Olm
Copper Cr.
Mt. Sterling
Gays Mills
Osp
Bell Center
SENECA
Petersburg
Seneca
HAINEY
SCOTT
Lynxville
Osp
Olm
Cp
Barnum
Olm
Steuben
Du Charme Cr.
Otg
Olm
Eastman
MARIETTA
Osp
Osp
Prairie Cr.
Osp
PRAIRIE DU CHIEN
Olm
Wauzeka
WAUZEKA
Otg
Cp
PRAIRIE DU CHIEN
BRIDGEPORT
Olm
Crawford

For tests on an average sample from this quarry see Table XXV. The report of the Office of Public Roads on this sample is as follows: "This is a very soft rock, showing low toughness and resistance to wear and fair cementing value. Not recommended as a road-building material in plain macadam construction, but might be used with bituminous binders."

For 93 feet up the bluff from the top of the quarry beds there are no outcrops. At this elevation 28 feet of limestone are exposed. Persistent outcrops appear at this level along all the bluffs within sight. This appears to be a horizon of very resistant rock, which probably would furnish an excellent road material, although more inaccessible than the ledge at the foot of the hill where the city quarry is located.

On the high bluff to the north of the city quarry at Prairie du Chien, 10 feet of thin-bedded Galena-Trenton limestone is exposed. It is a fine-grained pure limestone, and would make a satisfactory road material.

In the vicinity of Lynxville there is one of the best sites for a large road material quarry along the Mississippi river. It is situated about 1¾ miles south of Lynxville. The thickness of the Lower Magnesian limestone is about 210 feet. Its quality is excellent and quite uniform from the top of the hill down nearly to the bottom. The stripping would probably average 4 or 5 feet on top and practically nothing on the sides. When the great thickness which this would uncover is considered its cost would be negligible.

The quantity is extremely large. An area 1000 feet wide and 2000 feet long parallel to the C. B. & Q. Ry. track could be quarried and more if desired. With a thickness of 60 yards this would give nearly 15 million cubic yards of stone in the ledge or from 22 to 26 million yards of crushed stone.

In the S. E. ¼ of Section 6, town of Prairie du Chien, the following section of Lower Magnesian limestone is exposed on a bluff overhanging the Mississippi river valley.

		Feet
1.	Slope of hill covering Lower Magnesian limestone	45
2.	Hard, flinty, light-colored limestone	15
3.	Heavy-bedded limestone; with disseminated flints	10
4.	Beds of yellow limestone from one to two feet thick containing no flint	8
5.	Limestone containing numerous flints	5
6.	Beds of limestone without flint. Layers from one and a half to two feet thick. Good building stone	7
7.	Heavy-bedded limestone with irregularly disseminated flints. Hard and compact	14
8.	Limestone containing regular layers of flint	24
9.	Alternating beds of limestone and flint	15

10.	Fine-grained, light-colored limestone	3
11.	Slope of hill covering limestone	16
12.	Quarry rock, consisting of thin beds of limestone, each one foot thick, containing no flints	3
13.	Heavy beds of limestone, streaked with light-colored bands	7
14.	Alternating beds of limestone and flint, the latter being in layers sometimes three feet thick	22
15.	Hard, light-colored limestone	3
16.	Beds of flint, from six inches to two feet thick, alternating with thin layers of limestone to the bottom of the hill	10
	Total	207

In the N. W. ¼ of Section 18 of the town of Eastman along the Mississippi river, there are long continuous cliff-like exposures of the Lower Magnesian limestone, overlying the upper beds of the Potsdam sandstone, and affording excellent quarry sites.

At De Soto, there is a quarry in the Lower Magnesian limestone about ¼ of a mile south of the village. It is owned by O. G. Lewis, cashier of the bank of De Soto. At this locality, the Lower Magnesian limestone first appears about 300 feet above the river, the lower portions of the bluff being Potsdam sandstone.

The thickness of limestone exposed here is about 35 feet. The stripping is slight. It is a fine-grained, compact, flint-bearing limestone of good quality for road material.

The quarry owned by Lawyer and Carrol at Bridgeport is the only shipping quarry in the western part of the state. It is an old quarry, having furnished some of the stone for the old Capitol building at Madison. About 35 feet of Lower Magnesian limestone are exposed in the quarry. The lower beds consist chiefly of coarse, sandy, rotten limestone and flint beds. The upper 14 feet are thick-bedded, compact, and of good quality for road building. In 1912, the quarry produced about 3 cars of crushed rock per day. Most of this came from the lower beds. When the upper beds are crushed a better quality of road material will be gotten.

The road tests of an average sample of crushed rock from this quarry see Table XXV.

The following is the report of the Office of Public Roads on this sample: "Material is rather soft and shows low toughness with fair cementing value. Only suitable for plain macadam roads subjected to light traffic or for use with bituminous binders."

In the Kickapoo valley, Lower Magnesian limestone can be gotten from the tops of the bluffs which overlook the valley. On the ridges and high uplands away from the valleys, outcrops are scarce. Weathering has penetrated to considerable depths. Residual flint bowlders are about the only solid rocks near the surface.

About 1½ miles northwest of Wauzeka, there is a small quarry at the road side. The rock exposed is the Lower Magnesian limestone. At this place it is a soft, weathered rock, and does not appear to be a good road material.

To the north, around Soldiers Grove, the Lower Magnesian limestone also appears to be weakened by decay. At the Clayson quarry 2 miles east of Soldiers Grove in section 26, about 10 feet of Lower Magnesian limestone are exposed about 40 feet above a creek bottom where the Potsdam sandstone can be seen. The limestone is soft, fine-grained and very compact. There are several small quarries, similar to this one, near the road about ¾ of a mile north from here.

For tests on an average sample from the Clayson quarry see Table XXV. The report of the Office of Public Roads on this material says: "This is a soft rock, showing very low toughness and resistance to wear, and low cementing value. Not recommended for plain macadam construction, but might prove satisfactory when used with bituminous binders."

TABLE XXV.

Tests on Limestones from Crawford County.

Nature of test.	1.	2.	3.	4.	5.
Specific gravity	2.65 Medium	2.8 High	2.6 Medium	2.85	2.45
Pounds per cubic foot	165. Medium	175. High	162. Medium	178.	153.
Pounds of water absorbed per cubic foot	2.65 Medium	.65 Low	2.96 Medium	6.9	.14
Per cent of wear	7.0 High	.....	8.4 High	22.5	2.5
French coefficient of wear	5.7 Low	.....	4.8 Low	17.3	1.8
Hardness	5.8 Low	12.7 Soft	11.3 Soft	16.5	4.0
Toughness	4. Low	8. Low	4. Low	13.	2.0
Cementing value	Fair	Fair	Fair	.....	.....
Fitness	No good	Light traffic	No good.	.....	.....

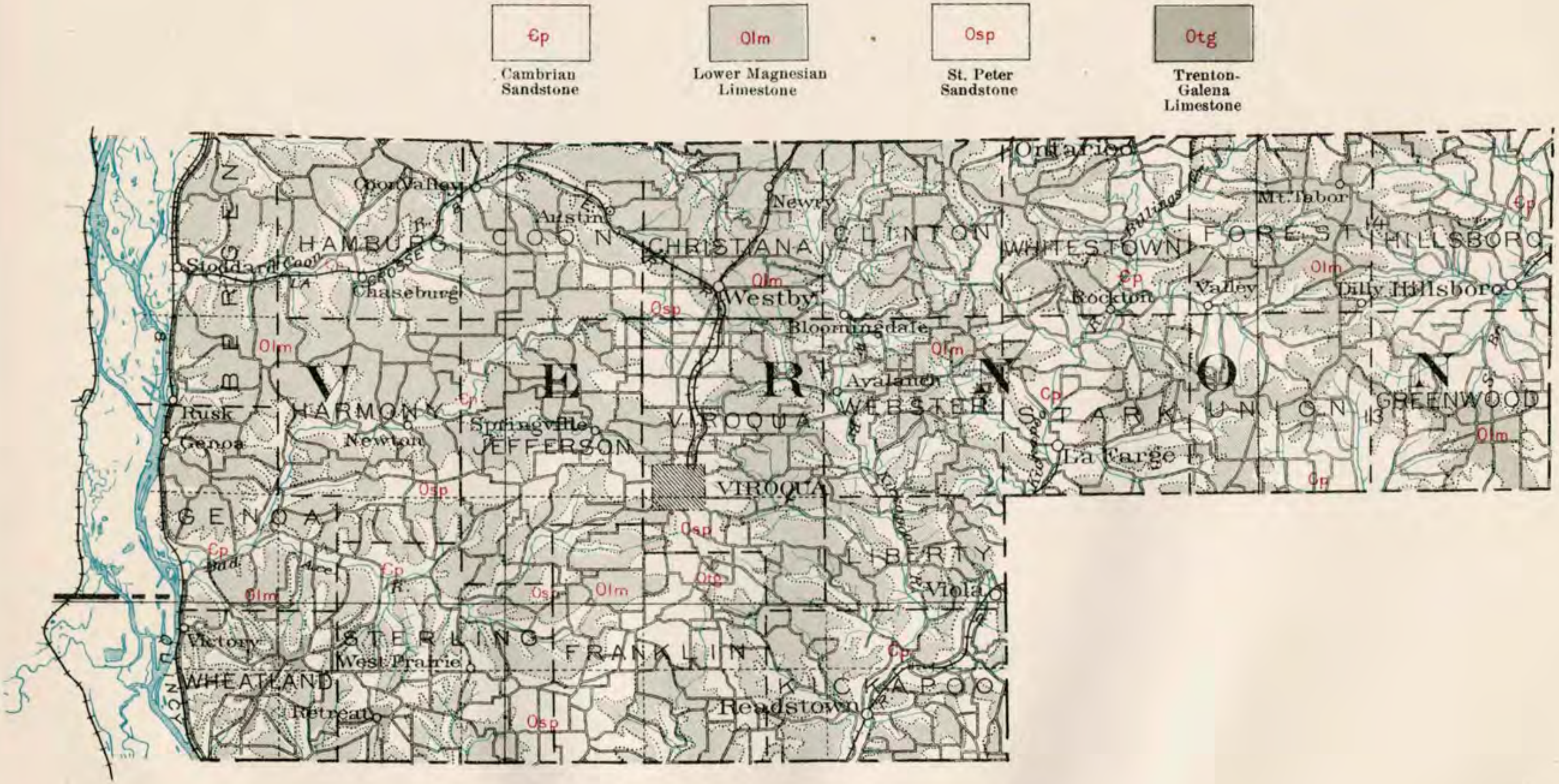
1. Limestone from Prairie du Chien city quarry, Prairie du Chien, Wis. Wisconsin Road Sample No. 25.
2. Flinty limestone from Bridgeport quarry, Bridgeport, Wis. Wisconsin Road Sample No. 26.
3. Limestone from Clayson quarry, Soldiers Grove, Wis. Wisconsin Road Sample No. 28.
4. Maximum for Wisconsin limestone.
5. Minimum for Wisconsin limestone.

Attention is called to a number of old quarry sites in the Lower Magnesian limestone, where lime has been burned. They have not been examined, but they may be regarded as possible sources of road material. Their locations are as follows:

On the west side of one of the small branches of Knapp creek in Section 35, town of Scott.

On Horse creek, a tributary of the Kickapoo river, in the N. W. ¼ of Section 19, and the S. W. ¼ of Section 21, of the town of Haney.

At the head of a ravine, emptying into Coopers creek, 1 mile west of the village of Seneca, in the S. W. ¼ of Section 9 of the town of Seneca.



Ꞓp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Trenton-Galena Limestone
V E R N O N
HAMBURG
COON
CHRISTIANA
CLINTON
WHITESTOWN
FOREST
HILLSBORO
BERGEN
HARMONY
JEFFERSON
VIROQUA
WEBSTER
STARK
UNION
GREENWOOD
GENOA
LIBERTY
STERLING
FRANKLIN
KICKAPOO
WHEATLAND
Coon Valley
Austin
Newry
Ontario
Mt. Tabor
Stoddard
Chaseburg
Westby
Bloomingdale
Rockton
Valley
Dilly
Hillsboro
Avalanche
Rusk
Genoa
Newton
Springville
La Farge
VIROQUA
Viola
Victory
West Prairie
Retreat
Readstown
Bad Axe R.
Billings Cr.
Olm
Osp
Ꞓp
Otg

VERNON COUNTY.

The high ridges and gently rolling uplands of Vernon County are mostly underlaid by the Lower Magnesian limestone. See Plate XXXII. The highest elevations are underlaid by St. Peter sandstone. The edges of the uplands and ridges are usually marked by abrupt slopes or cliffs, which descend to broad, flat valleys underlaid by the Potsdam sandstone. Along the tops of the bluffs and cliffs overlooking these valleys there are numerous exposures of Lower Magnesian limestone.

Vernon County lies wholly within the driftless or unglaciated area. Hence drift bowlders of granite, trap, and other crystalline rocks which constitute an important source of road material in many parts of the glaciated portions of Wisconsin are lacking here. Gravel deposits are also scarce. Some are known along the higher levels of the Mississippi river plain. They have also been found at slight elevations above the river plain at the mouths of the tributary valleys. These deposits usually lack the characteristics desirable in a good road gravel. The pebbles are smooth, rounded, and water worn instead of angular and jagged. They consist almost entirely of non-cementing materials—trap, granite, quartz and other hard, resistant materials. Usually, the pebbles are mingled with a great deal of sand, which woud necessitate screening, an additional item of cost.

Deposits of sandy gravel have been observed about the sides of the valley of a small stream, at an elevation of 20 feet above the Mississippi river in section 4, town of Wheatland, and between Genoa and Coon Slough, the deposits are continuous, and as high as 50 feet above the Mississippi river.

On the high bluffs, along the Mississippi river, there are almost continuous exposures of Lower Magnesian limestone. These would furnish excellent road material for local purposes. The superior quality of certain beds of this limestone along the Mississippi might even warrant the expense of shipping to distant parts of the state. This is not advisable, however, until it can be shown that the advantages in durability and general satisfaction gained by using the Mississippi river stone more than offset the expense of shipping. Local materials even though somewhat inferior are frequently found cheapest and most satisfactory in the end.

Along the Mississippi river, the Lower Magnesian limestone consists of 3 well defined parts. The lower part is from 30 to 40 feet thick and is made up of a soft easily quarried rock that makes

excellent building stone and flagging. This soft rock is porous and generally not well suited for road material. Above this is a thick layer of what some of the local quarrymen call "Niggerheads." It is a very hard, dense, resistant stone, which constitutes the tops of the bluffs along the river from a short distance south of Lynxville in Crawford county northward to Prescott in Pierce county.

The topmost layer of the Lower Magnesian limestone, which is a weak, soft, thin-bedded material of moderate thickness, has all been stripped off by erosion in the western part of Vernon county.

From the thickness of the Lower Magnesian limestone at the following localities an estimate can be made of the thickness of the top beds, which are most desirable for road materials.

On bluffs north of Stoddard	60 feet
North of Genoa	40 feet
South of Victory	120 feet

Towards the eastern part of the county, outcroppings of Lower Magnesian limestone become less numerous and occur along the escarpments which overlook the valleys underlaid by Potsdam sandstone. The soil covering becomes deeper, and weathering has extended to considerable depth beneath the surface. The quality of the stone towards the east is therefore less satisfactory.

The following is a list of owners of limestone quarries in Vernon county, and of the locations of the quarries. These quarries have all been operated in recent years, although some of them may be abandoned now.

Isaac Mornson, Viroqua.
Geo. Flick, Genoa.
Jac. Stroek, near Stoddard.
Jacob Beans, Stoddard.
John Brittlich, Stoddard.
Village of LaFarge, LaFarge, Wis.
H. Seidal, Stoddard.
Ludwig Scheck, Stoddard.

The Scheck qaurry is the only one which is reported to have furnished road material in 1912.

Large outcrops of Lower Magnesian limestone exist in the village of Springville of the town of Jefferson, and along the banks of the stream below the village. Extensive quarries were formerly opened up in this locality. The limestone occurs in beds from one to four feet thick, of a light yellow color, free from flints, and is a handsome building stone. These outcrops were not examined but

from the descriptions[1], it seems probable that they would furnish excellent road material for local purposes.

Along Coon Creek, in the town of Hamburg, there are numerous good exposures of the lower beds of the formation. In this part of the state the lower 30 feet of this limestone are usually softer than that above. Notwithstanding this fact, it is probable that road material of satisfactory quality for local purposes can be gotten from these ledges.

It seems probable that limestone for road material could be secured from the sites of some of the old lime kilns which formerly dotted this region. None of these localities were examined, however, and no facts can be given as to the location and character of the stone from which the lime was made. To aid prospecting for limestone road materials, the following list of former lime kiln sites are given:

Near the forks of the Bad Axe river in Section 12 of the town of Genoa.

One and a half miles north of the village of DeSoto.

Near the head of a small branch of Coon Creek in the NE.¼ of Section 24 of Coon township.

In the SE.¼ of Section 27 of the town of Franklin.

At the head of small tributaries of the Kickapoo, about 3½ miles northeast of Viroqua.

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[1] See Geology of Wisconsin, Vol. IV, p. 68.

La Crosse and Monroe Counties.

LaCrosse and Monroe counties lie wholly within the driftless or unglaciated part of Wisconsin. Hence the characteristic glacial field bowlders which constitute so important a source of road material in the glaciated portions of the state are lacking in these counties. Gravel deposits also are scarce. Deposits of sandy gravel are known along the bluffs east of the city of La Crosse. They seldom attain an elevation of 50 feet above the river. This gravel so far as known is not well adapted to road building. The pebbles are well rounded and smooth instead of rough and angular. They consist almost entirely of non-cementing materials such as granite, traps, quartz and other hard crystalline rocks. Their intimate mixture with sands would make it necessary to screen them, which would probably involve an expenditure hardly warranted by the results.

Nearly all of the northern parts of Monroe and La Crosse counties are underlaid by the Potsdam sandstone. The same formation underlies most of the deep valleys of the southern portion of these counties. The Lower Magnesian limestone caps the high hills, ridges, and table lands. Most of it occurs in the southern part of the counties. For distribution of these formations as they would appear if the soil and other loose material which covers them in most places were stripped off, see Plate XXXIII.

Whether a certain locality is underlaid by Lower Magnesian limestone or by Potsdam sandstone can easily be discerned as a rule from the surface features. The hills of the sandstone region are generally low and gently rounded. Outcrops are uncommon. As a rule the sandstone is covered with soil. Hills of this type are common along the road between Sparta and La Crosse. Hills that are capped by Lower Magnesian limestone are always steep-sided, even precipitous. They can be seen in all stages of erosion. Some of them are worn down to a steep cone with only a small cap of Lower Magnesian limestone. Once this cap is removed, the hills are rapidly reduced to a gently rolling swell. Others appear as long, steep-sided ridges which are topped by a few feet of limestone. Occasionally, one can be seen where the top has been worn to a mere ridge-line, barely wide enough for a foot path, and from which the sides descend at a steep angle, like the roof on a house. On others, the top is wider, or even expands into a gently rolling table land several square miles in extent.


Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Limestone quarry (Not all shown)
LA CROSSE
MONROE
FARMINGTON
HOLLAND
ONALASKA
HAMILTON
BURNS
CAMPBELL
BARRE
SHELBY
GREENFIELD
WASHINGTON
BANGOR
LITTLE FALLS
NEW LYME
GRANT
LINCOLN
SCOTT
LAFAYETTE
GREENFIELD
LAGRANGE
BYRON
SPARTA
ANGELO
ADRIAN
TOMAH
OAKDALE
LEON
WELLS
RIDGEVILLE
WILTON
CLIFTON
PORTLAND
JEFFERSON
SHELDON
WELLINGTON
GLENDALE
Warrens
Cataract
Valley Jc.
Wyeville
Shennington
Tunnel City
Raymore (Bacon P.O.)
Oakdale
Angelo
Mindoro
Holmen
Lytle
Midway
Onalaska
West Salem
Bangor
Rockland
Leon
Summit
Norwalk
Medary
La Crosse
Melvina
Wilton
Glendale
Portland
Cashton
Oil City
Calvert
Fleming Cr.
Half Way Cr.
Bostwick Cr.
Mormon Cr.
Big Cr.
La Crosse R.
Silver Cr.
Mill Cr.
Dead Cr.
Bear Cr.
Lemonweir

In some localities limy, well-cemented layers occur in the Potsdam sandstone which resist erosion very effectively, and give rise to ledges which stand out as steep-sided or even precipitous hills. Of this type are the many isolated cliffs in the eastern part of Monroe county.

The largest exposures of the Lower Magnesian limestone are along the tops of the bluffs east, and to the south of La Crosse. On Grandfather Mountain east of La Crosse, about 150 feet of Lower Magnesian limestone overlie the Potsdam sandstone. The lower 100 feet of this are quarried by the La Crosse Stone Company.

The section from the top down is approximately as follows:

Soil and unexposed rock.....
A weathered, porous, soft, flint-bearing limestone. This was crushed for road material by the La Croses Stone Co. in 1912, ...about 30 feet
Very compact, dense, white limestone used for building stone 20 feet
Limestone with flint nodules, not used in 1912..... 12 feet
Limestone, most of it soft and weathered. Not quarried when seen in 1912.....about 48 feet

In the vicinity of La Crosse, quarries are also operated by Wm. Hass, Goldish and Salamonitz, E. S. Mead Stone Co., H. Roesler, Ole Wold and L. Kriebach (8 miles east of La Crosse).

At Onalaska, north of La Crosse a number of quarries are opened up but most of them have been idle in recent years. Owners of quarries in Onalaska are Wm. Kenyon, L. W. Hohmann, Geo. Pierce.

Limestone quarries are also operated at Holmen, West Salem, and Mindoro in La Crosse county.

Lime is said to have been burned in the SE.¼ of Section 26 of the town of Greenfield, at the head of Mormon Coolie. This locality was not examined but it is likely that limestone outcrops or old quarries exist in this vicinity.

In Monroe county, outcrops and quarries of Lower Magnesian limestone are not so common as in La Crosse county. Those which do exist however, may therefore prove all the more important as future sources of road material for local purposes. Limestone quarries are operated by August Schmeichel, John Nichols, A. E. Smith, and J. J. Ewers in the vicinity of Sparta. There are other limestone quarry openings around Sparta, besides those mentioned. Quarries are also operated at Tomah and Rockland.

The J. J. Ewers quarry is located about 9 miles to the northwest of Sparta on top of a high, steep-sided hill. Rock quarried here has been rolled to the valley below, and hauled 9 miles to Sparta

where it was crushed for road material. The section at the quarry consists of:

Soil and limestone fragments	4 feet
Porous, weathered limestone with flints	2 feet
Compact limestone	3 feet
Shaly, friable, sandy layers	3 feet
Flint bed	4 inches
Thick-bedded limestone, a fair road material	3 feet

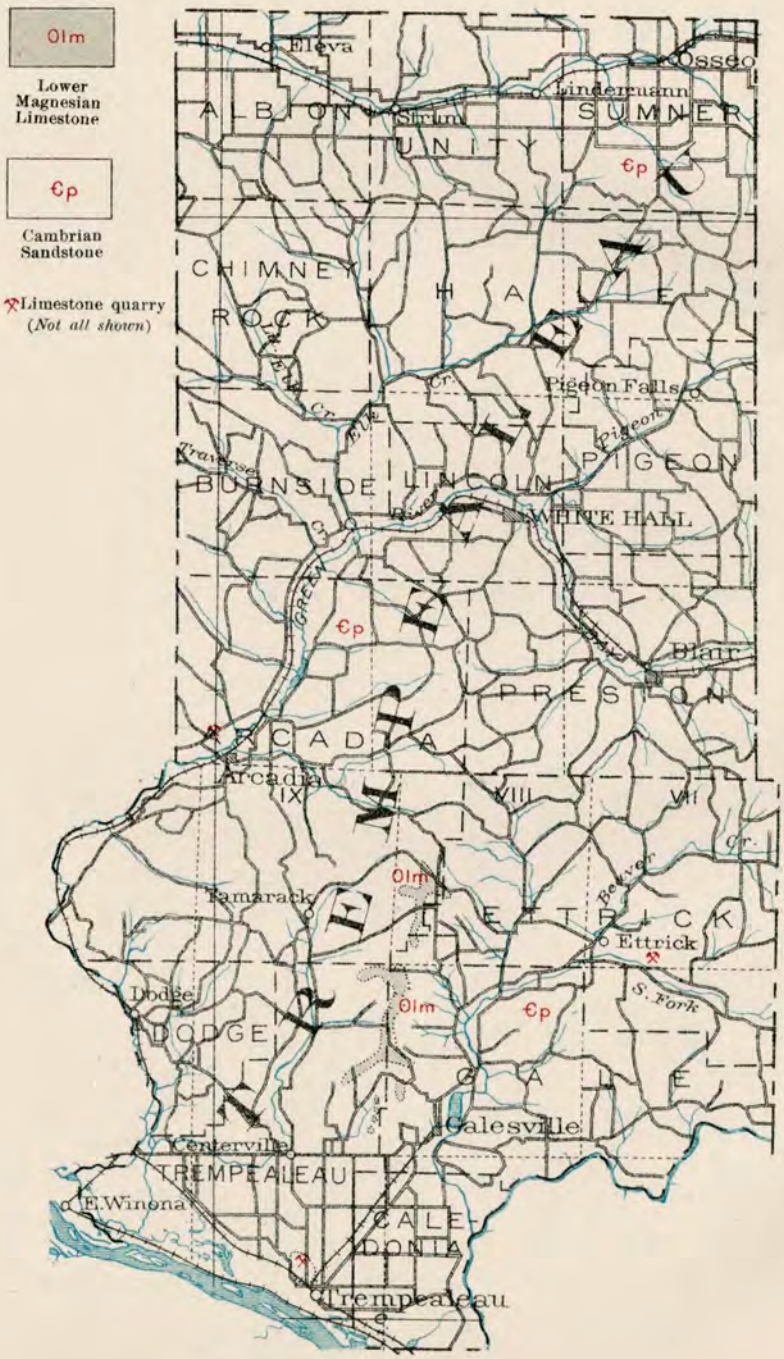
The following locations in Monroe county where lime has been burned are given because they may be useful in prospecting for limestone road material, as no doubt each kiln was closely connected with a limestone quarry.

About 7 miles southeast of Tomah in the town of Oakdale, on the northern line of outcrop of the Lower Magnesian limestone on the SW.¼ of Section 31.

On an isolated outlier of limestone about six miles southwest of Tomah in the SW.¼ of Section 22 of the town of Adrian.

In the NW.¼ of Section 12 of the town of Wells.

At the foot of a high isolated, outlying bluff capped with Lower Magnesian limestone in the SW.¼ of Section 28 of the town of Little Falls.


Olm
Lower Magnesian Limestone
Cp
Cambrian Sandstone
Limestone quarry (Not all shown)
Eleva
Osseo
Lindermann
ALBION
Strum
SUMNER
UNITY
Cp
CHIMNEY ROCK
HALE
Pigeon Falls
Pigeon Cr.
Trempealeau R.
BURNSIDE
LINCOLN
PIGEON
WHITE HALL
Beaver Cr.
Cp
Blair
PRESTON
ARCADIA
Arcadia
IX
VIII
VII
Olm
Tamarack
ETTRICK
Ettrick
Beaver Cr.
Dodge
Olm
Cp
S. Fork
DODGE
GALESVILLE
Galesville
Centerville
TREMPEALEAU
E. Winona
CALEDONIA
Trempealeau

TREMPEALEAU COUNTY.

The Lower Magnesian limestone is about the only source of road material in Trempealeau county. The county lies wholly within the driftless area; hence it lacks the glacial field bowlders which constitute a valuable source of road material in most parts of the glaciated area of Wisconsin, nor is it known to have gravel deposits of good quality.

Most of the Lower Magnesian limestone which once underlaid Trempealeau county has been removed by erosion. Only a few of the highest ridges and hills are still capped by it. See Plate XXXIV. The Potsdam sandstone now underlies most of the county. Hills capped by Lower Magnesian limestone can readily be distinguished from those which are constituted of Potsdam sandstone by their steep-sided or even precipitous character. Those underlaid by the sandstone have gently rounded contours.

The principal areas of Lower Magnesian limestone are between the town of Trempealeau and the mouth of the Trempealeau river, and to the northwest of Galesville.

On the hills north of the village of Trempealeau, Lower Magnesian limestone of fair quality for road material could be gotten. One difficulty here is that the ledges are almost inaccessibly high. The section at this locality is as follows:

	Feet
Dense, thick-bedded Lower Magnesian limestone, lower beds sandy. The upper beds would make the better road material.	35
Potsdam sandstone	

There are many small limestone quarries in the county which supply local building material. Many of these might also furnish road material which would be satisfactory for local use.

The following own limestone quarries in Trempealeau sounty:

Near Arcadia—George Ziegler, Wenzel Kreibich, Herman Schreiber, John Rohn, Gustav Rube, George Motzko, Christ George, Martin Rebhahn, John Roesch.

Near Galesville—Nicholas Perkins, L. S. Keith.

Near Dodge—C. George.

Buffalo County.

Buffalo county is underlaid by Lower Magnesian limestone and Potsdam sandstone. The Potsdam sandstone underlies most of the valleys, and low, gently rounded hills. The Lower Magnesian limestone caps the steep-sided hills, ridges, and high table lands of the southern portion of the county. For distribution of the formations which underlie Buffalo county see Plate XXXV.

The principal exposures and quarries of the Lower Magnesian limestone in Buffalo county are along the tops of the bluffs facing the Mississippi river. Here also the quality of the limestone for road making is on the average better than to the northeast. Away from the river, outcrops are less numerous, the soil mantle becomes deeper and the exposures are more decayed.

On the bluffs near Fountain City, limestone quarries are owned by the Badger Stone Co. and H. F. Murr.

About 130 feet of Lower Magnesian limestone caps the bluff directly north of Fountain City. The section is as follows:

	Feet
Unexposed	about 40
Fine-grained, thick-bedded limestone with numerous cavities lined with calcite. Flints occur in lense-shaped nodules also in honey-combed forms having cavities	40
Unexposed	about 10
Thick-bedded limestone without flints. Sandy seams near bottom	40

Most of the rock of this section is rather soft, and porous. While much of it would make fair road material, it is not as good as the best Lower Magnesian limestone exposed along the river in Crawford and Vernon county.

About 1½ miles north of Cochrane there is an excellent quarry site. The thickness of the Lower Magnesian limestone is about the same as at Fountain City, approximately 140 feet. The quality also is about the same or a shade lower. Opposite Cochrane, and about 1 mile south of it, there also are very good quarry sites.

The following own quarries at Alma—John F. Harry, Wm. Sellers, Butzman and Stenger, and John Eberle.

The section of Lower Magnesian limestone on the hill just north of the town, where the Eberle quarry is situated, is as follows:

	Feet
Soil with limestone fragments	4
Fine-grained, compact limestone with flint nodules and lenses	10
Massive compact limestone, nearly devoid of bedding	12
Thick-bedded limestone mostly coarse-grained	12
Quarry floor.	


Cp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Limestone quarry (Not all shown)
MAXVILLE
CANTON
MONDOVI
NAPLES
Savoy
Misha Mokwa
MODENA
Modena
GILMANTON
Gilmantone
DOVER
NELSON
Trevino
Nelson
BUFFALO
MONTANA
WABASHA
Tello
ALMA
ALMA
LINCOLN
Cream
Waumandee
BELVIDERE
GLENCOE
WAUMANDEE
Cochrane Sta
Buffalo City
MILTON
CROSS
Fountain City
BUFFALO
Marshland
WINONA

The stone exposed in this section is not so porous and cavernous as that at Fountain City. It appears to have better qualities for road construction than the latter.

The region to the west of the dotted red line on Plate XXXV of Buffalo county has been glaciated, and has a few deposits of gravel and some field bowlders. The gravels will be of local value for road construction. It is not probable that field bowlders are sufficiently abundant to constitute a source of road material.

Pepin County.

The formations which underlie Pepin county are the Lower Magnesian limestone and the Potsdam sandstone. For the distribution of these formations as they would appear if the soil and loose material which covers them in most places were stripped off, see Plate XXXVI.

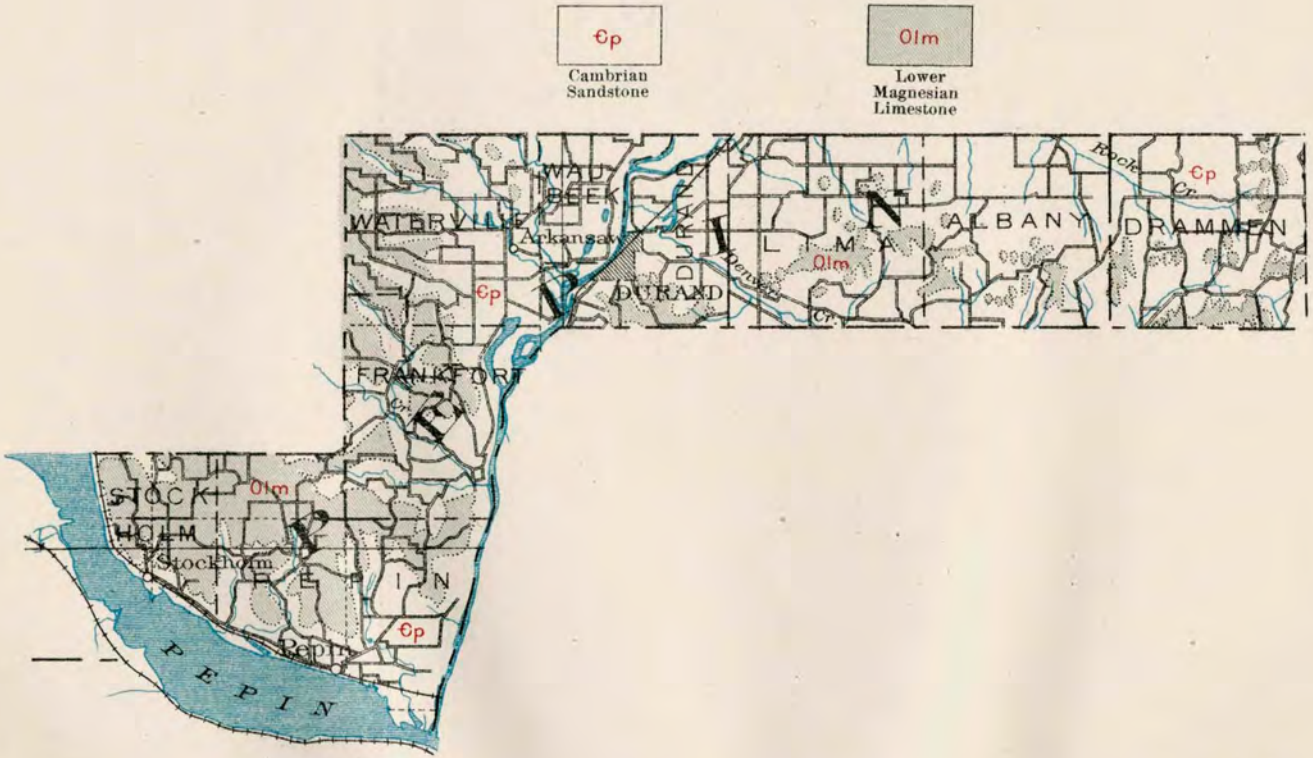
The Lower Magnesian limestone caps steep-sided or even precipitous hills, ridges, and table lands, whose lower slopes are composed of Potsdam sandstone. These are especially prominent along the Mississippi river. A hill in which the lower layers are Potsdam sandstone, and the cap rock is Lower Magnesian limestone, can almost always be recognized by its steep-sidedness. As soon as the protecting limestone ledge has been removed by erosion, the hill is rapidly reduced in elevation, and assumes a gently rounded form. These differences between the surface feature of hills capped by Lower Magnesian limestone and those which are constituted of sandstone may be of some use in prospecting for limestone road material.

The best outcrops of limestone for road material are near the Mississippi river. Here the limestone is thickest and least weathered. It attains its maximum thickness in this county to the north of Stockholm, where it is about 100 feet thick. The exposures are nearly all at the edge of the beds, that is, along the rim of the bluffs which the limestones cap. The quality of the Lower Magnesian limestone for road-making in this part of the county is generally fair and more uniform than in the south central part of the state. It is softer as a rule than the best Lower Magnesian limestone which can be had from the bluffs along the Mississippi River in Crawford and Vernon counties.

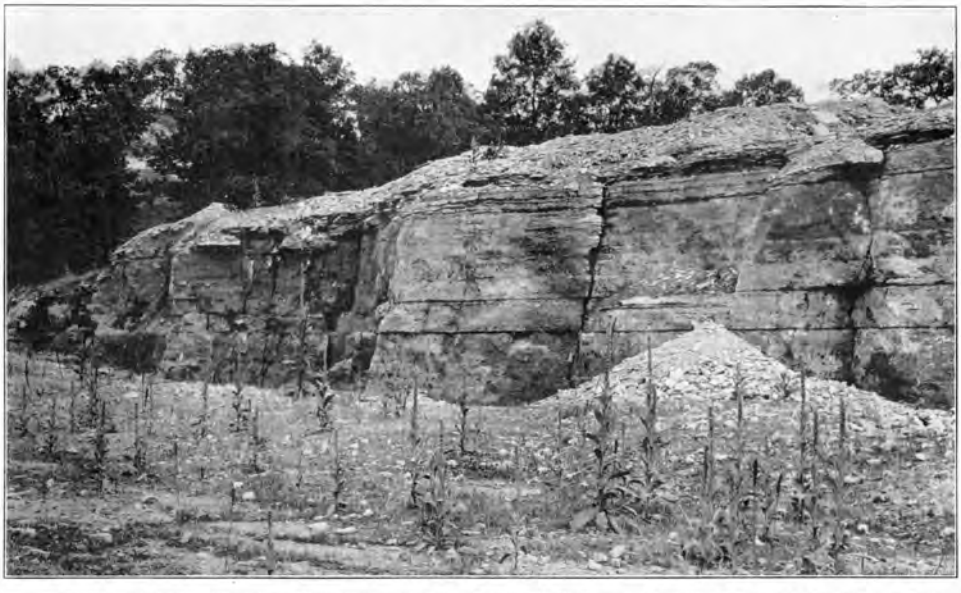
Away from the river, the Lower Magnesian limestone is usually found only on small, isolated outlying bluffs. Generally only its lowest layers are present. These are usually softer and more sandy than the layers between 40 and 100 feet above the base of the formation. These thin outlying ledges are also on the average more weathered than those which appear near the river.

Numerous small limestone quarries have been opened up in Pepin county, especially along the river. Only a few of them have been worked in recent years, and these only intermittently.

The region to the west of the dotted red line running through the town of Lima, as shown on Plate XXXVI and to the northeast of


Cp
Cambrian
Sandstone
Olm
Lower
Magnesian
Limestone
WAUBEEK
WATERVILLE
Arkansaw
DURAND
Cp
Olm
ALBANY
DRAMMEN
Rock
Cr.
FRANKFORT
STOCKHOLM
Stockholm
PEPIN
Pepin
Olm
Cp

A flat-topped mound capped by Trenton limestone north of Prescott. This hill resembles the mesas of the western deserts. It consists of soft, friable St. Peter sandstone capped by a few feet of Trenton limestone. Dill's quarry is situated on this hill.



Dill's quarry. Trenton limestone on top of the bluff shown above. The rock is soft and weak, but uniform in quality for road construction. Flat-topped hills capped by Trenton limestone like this one are characteristic of part of western Pierce county.

a similar line passing through Pleasant Valley has been glaciated. Drift bowlders, however, are probably not abundant enough in any part of this region to constitute an important source of road material. Gravel deposits may be looked for within the glaciated portion of Pepin county, especially along the flood plain of the Chippewa river. There is at hand no data on the quantity, quality, or availability of these deposits for road-building.

Pierce County.

In Pierce county, the Potsdam sandstone is the surface rock formation only in the lowest lands. By consulting Plate XXXVIII, it can be seen to underlie a narrow strip along Lake St. Croix and the Mississippi river, and portions of the small stream valleys of the county, such as the Trimbelle River, Isabelle Creek, Rush River, Plum Creek, and Cady Creek. The Lower Magnesian limestone underlies the greater portion of the county.

Away from the stream valleys, the surface underlaid by Lower Magnesian limestone is gently rolling or nearly level. The limestone itself is mostly covered with drift and soil, and outcrops are scarce. Where the Potsdam sandstone underlies the stream valleys, the Lower Magnesian caps steep or even cliff-like bluffs, which hem in the valleys on each side. Striking cases of this kind can be seen along the Mississippi River, Trimbelle River, along Cady Creek, and other streams. Outcrops of limestone are numerous along such bluffs, and quarries have been opened up in many places. Along the Kinnikinnic river there are numerous outcrops in the river bed, which at River Falls are the cause of a series of rapids.

The Galena-Trenton formation underlies several high and nearly level table lands, chiefly between Ellsworth and River Falls. As shown by Plate XXXVIII, there are many small isolated outlying patches of this formation. In all cases they appear on flat-topped, steep-sided butte-like mounds or on the top of steep cone shaped hills. All the areas underlaid by this formation are surrounded by belts which are underlaid by St. Peter sandstone. Outcrops of the Galena-Trenton formation occur chiefly along escarpments which mark the edge of the areas underlaid by it.

It is reported that the Lower Magnesian limestone has been quarried on the hills overlooking Lake St. Croix between Prescott and the Kinnikinnic River. In one of the gorges on the south banks of the Kinnikinnic River north of Prescott, in the SW.¼ of Section 13, of the town of Clifton, about 50 feet of this limestone are exposed. The beds are well exposed at the head of the gorge, which is easily accessible, and nearly on a level with the surrounding country. The upper portion of the section is thick bedded, compact, and very hard to break. It would supply a good quality of road material. From eye inspection, it would appear that this limestone would make a far better road material than any of the


Єp
Cambrian Sandstone
Olm
Lower Magnesian Limestone
Osp
St. Peter Sandstone
Otg
Trenton-Galena Limestone
Limestone quarry (Not all shown)
Numbers refer to table 1
RIVER FALLS
CLIFTON
RIVER FALLS
MARTELL
Martell
GILMAN
Spring Valley
SPRING LAKE
Oliver
PRESCOTT
HASTINGS
Beldenville
OAK GROVE
TRIMBELLE
ELLSWORTH
Ellsworth
EL PASO
Rock Elm
ROCK ELM
PIERCE
DIAMOND BLUFF
Diamond Bluff
TRENTON
HARTLAND
SALEM
UNION
Ono
Plum City
Hager
ISABELLE
Bay City
MAIDEN ROCK
Maiden Rock
Lund
RED WING
LAKE

Galena-Trenton formations seen in the county. An average sample of the upper beds of this quarry was tested by the Office of Public Roads. For results see table XXVI.

The Office of Public Roads reported on this sample as follows: "This rock shows average hardness, low toughness and resistance to wear and fair cementing value. Only suitable for plain macadam roads, subjected to light traffic or for use with bituminous binders."

South of Spring Valley on Section 27 of the Town of Spring Lake, there is an abandoned quarry of Lower Magnesian limestone, from which the local furnace formerly got its supply of flux. An unlimited supply of road material of good quality could be gotten here. The accessibility of this quarry makes it especially recommendable. It is on a spur track of the C. & N. W. Ry. Cars could be loaded by gravity, since the quarry floor is some 40 feet above the track. About 50 feet of very thick bedded- flint bearing, and slightly cavernous limestone is exposed in this quarry.

An average sample from this quarry was tested by the Office of Public Roads. For results see table XXVI.

The report of the Office of Public Roads on this sample is as follows: "Average hardness, rather low toughness, low resistance to wear and good cementing value. Should only be used on water-bound roads subjected to light traffic or for use with bituminous binders."

The Galena-Trenton formation has been quarried in many localities in the vicinity of River Falls, Ellsworth, Beldenville, and Prescott. Detailed descriptions can be given of only a few.

Dill's Quarry is located in the Galena-Trenton formation about three miles northeast of Prescott. At this locality, about 15 feet of the Galena-Trenton formation caps a small butte-like hill which rises to a height of about 100 feet above the surrounding country.

About 10 feet of buff, soft, weathered limestone is exposed. The upper layers are frost broken. The lower layers are thick-bedded and in fair condition. This rock may be very satisfactory for certain building purposes, but for the average country road it would be too soft.

The Thos. Walker Quarry is in the Galena-Trenton limestone which caps the bluffs east of River Falls. The section exposed is as follows:

Soils	
Thin bedded, brittle, frost broken limestone.....	10 feet
Thick bedded, buff limestone—a fair road material.....	4 feet

For tests of an average sample from this quarry see table XXVI.

The report of the Office of Public Roads on this sample is as follows: "This material is low in hardness, toughness and resistance to wear, and shows a fair cementing value. Should be suitable for use in waterbound macadam under extremely light traffic or for bituminous macadam construction."

The Campbell Quarry is located in the Galena-Trenton limestone about ¼ of a mile north of the railway station at Ellsworth. About 12 feet of limestone are exposed. The upper 4 feet are thin-bedded and frost broken. The lower portion is thick-bedded and fine-grained. The rock is medium in hardness, and probably would make a fairly good road material. The supply at this place for practical purposes is probably inexhaustible. The soil burden is slight. A good road with an easy grade leads to the quarry.

For tests of an average sample from this quarry see table XXVI.

The Office of Public Roads reported on this sample as follows: "This rock shows average hardness, low toughness and resistance to wear, and fair cementing value. Suitable for use on plain macadam roads subjected to light traffic, or with bituminous binders."

The J. Holman Quarry about ½ a mile north of the Campbell Quarry is also located in the Galena-Trenton formation. The beds here are about the same as in the Campbell Quarry.

The city of Ellsworth has a small limestone quarry about ¼ mile west of the C. & N. W. Ry. station. The beds exposed belong to the Galena-Trenton formation. The quality of this rock for road construction is the best of any which was seen in the vicinity of Ellsworth. The section is as follows:

Earth	4 feet
Thin bedded, bluish, fine grained, dense limestone	4 feet
Shale	1 foot
Thick bedded, bluish limestone	6 feet

The Jasper Miller Quarry is opened up in the Galena-Trenton formation ½ mile west of Ellsworth. About 12 feet of rock are exposed. The lower 8 feet are thick-bedded, dense, and fine-grained. The upper beds are thin and frost broken. The soil burden is about 3 feet thick. The quality of this stone for road-making is fair. For practical purposes, the amount of stone in this quarry is probably unlimited. It is accessible, being about 100 feet from the main road. This quarry could be a valuable source of road material for local purposes.

Pierce county has been glaciated, and field bowlders may be sufficiently abundant in some parts of the county to constitute a source

Gorge and rapids of the Apple river below Little Falls. The rock composing the cliffs is the Lower Magnesian limestone, which here is thick-bedded and fairly uniform in character, but rather soft for road construction. The rapids are caused by the river deepening its channel more rapidly in the easily eroded Potsdam sandstone which forms the river bed a short distance down stream.

of road material. Glacial gravels also occur in many places. Usually they constitute ridges on hill tops.

TABLE XXVI.

Tests on Limestone from Pierce County, Wis.

Nature of Test.	1.	2.	3.	4.	5.	6.
Specific gravity	2.80 High	2.75 High	2.45 Low.....	2.7 Medium.	2.85	2.45
Pounds per cubic foot.....	175. High	172. High	153. Low.....	168. Medium.	178.	153.
Pounds of water absorbed per cubic foot.....	1.06 Low.....	1.35 Low.....	6.9 Low.....	2.96 Medium.	6.9	.14
Per cent of wear.....	.54 High	5.6 High	7.3 High	7.3 High,....	22.5	2.3
French coefficient of wear..	7.4 Low.....	7.1 Low.....	5.5 Low.....	5.5 Low.....	17.3	1.8
Hardness.....	15.2 Medium.	15.5 Medium.	12.7 Soft.....	15. Average.	16.5	4.0
Toughness.....	7. Low.....	11. Low.....	5. Low.....	7. Low.....	13.	2.0
Cementing value.....	Fair.....	Good.....	Fair.....	Fair.....	.....	.....
Suitable for....	Light traffic...	Light traffic...	Very light traffic.	Light traffic...	.....	.....

1. Limestone from Prescott, Wis. Wisconsin road sample No. 34.
2. Limestone from Spring Valley, Wis. Wisconsin road sample No. 36.
3. Limestone from Walker Quarry, River Falls, Wis. Wisconsin road sample No. 43.
4. Limestone from Campbell Quarry, Ellsworth, Wis. Wisconsin road sample No. 44.
5. Maximum for Wisconsin limestone.
6. Minimum for Wisconsin limestone.

POLK AND ST. CROIX COUNTIES.

The low-lying portions of St. Croix and Polk counties are underlaid by Potsdam sandstone. Plate XL shows the distribution of the bed rock formations of St. Croix county and a part of Polk, at the surface, and beneath the soil and loose material which covers them in most places. The Potsdam sandstone is confined mainly to the northern and western parts of this area. However, in the towns of Glenwood and Springfield, of the eastern part of St. Croix county, it underlies the valleys of Sandy, Tiffany, and Beaver Creeks.

Where the Potsdam sandstone disappears beneath the Lower Magnesian limestone the edge of the Lower Magnesian limestone beds forms a distinct escarpment. Along this escarpment outcrops and quarries are common. The surface underlaid by this limestone is gently rolling.

In the southwestern part of St. Croix county there are a number of high, isolated, flat-topped, steep-sided hills and stretches of high table land, which are capped by the Galena-Trenton formation. Each of these areas of limestone is surrounded by a strip which is underlaid by St. Peter sandstone. Limestone quarries and outcrops are common along the margin of the Galena-Trenton formations, where the beds appear on the sides of bluffs.

The northwestern part of Polk county is underlaid by a broad belt of volcanic trap rocks, which outcrop in many places. Picturesque exposures of these rocks occur along the Dalles of the St. Croix river. These trap rocks are the best road material in the county.

One of the largest exposures of Lower Magnesian limestone in St. Croix county is at the falls of the Willow River, west of Burkhardt. In descending order, the beds at this locality are as follows:

Lower layers of St. Peters sandstone	25 feet
Alternating layers of reddish sandstone and limestone. A poor road material	10 feet
Buff to fawn colored limestone. Many layers are porous. Heavy layers above. Thin compact layers below. Poor road material	20 feet
Buff, granular, crystalline compact layers. Fair road material	15 feet
Fawn colored, very compact, thin bedded limestone, in part slightly sandy, in part a nearly pure limestone. Fair road material	20 feet

PЄ — Pre-Cambrian Keweenawan Trap

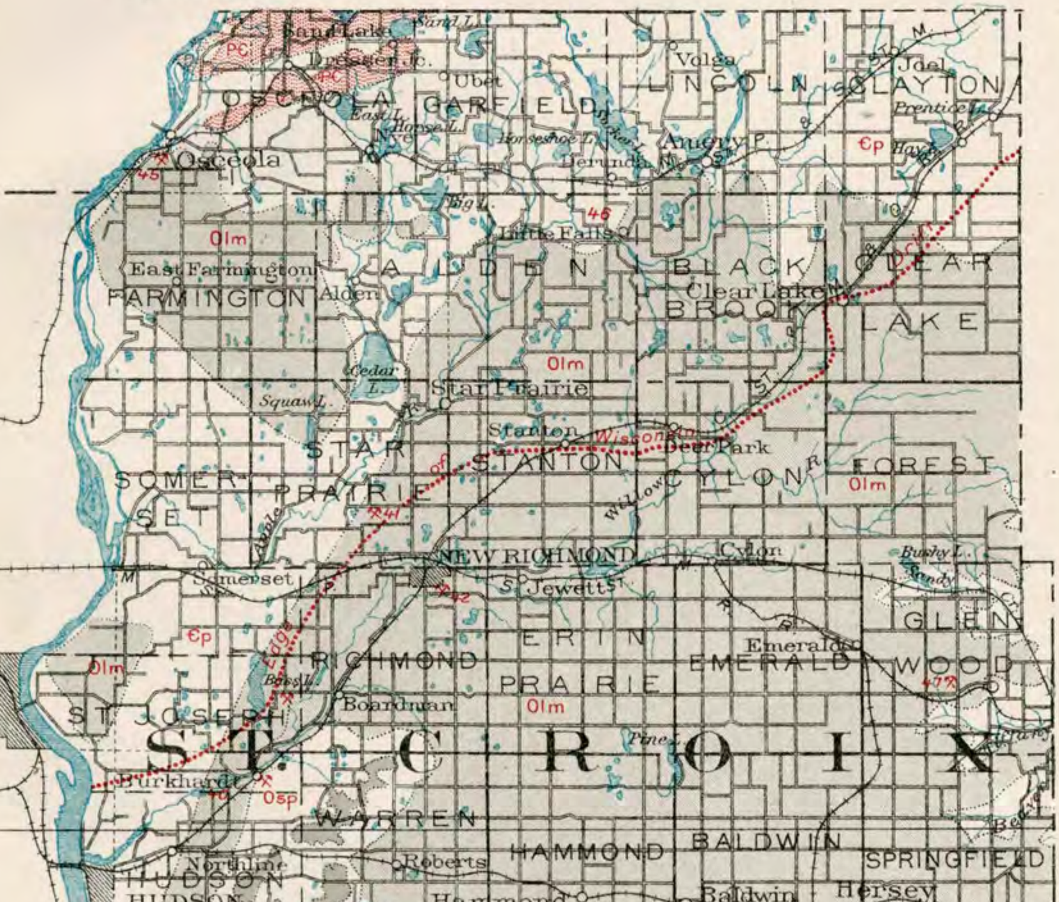
Єp — Cambrian Sandstone

Olm — Lower Magnesian Limestone

Osp — St. Peter Sandstone

Otg — Trenton-Galena Limestone

⚒ Limestone quarry (*Not all shown*)
Numbers refer to table 1



Similar to preceding. More porous and broken. Numerous flint layers. Poor road material	30 feet
Heavy buff beds, showing between several layers, numerous cavities. Fair road material	25 feet
Heavy uniform beds. Good road material	30 feet
Massive buff beds, fine grained. Good road material	20 feet

An average sample taken from the lower 80 feet of this section was tested by the Office of Public Roads. For tests see table XXVII.

The Office of Public Roads reported on this sample as follows: "This is a very soft rock, showing low toughness and resistance to wear, and fair cementing value. Not recommended for plain macadam construction, but might prove satisfactory when used with a bituminous binder."

About 8 feet of Lower Magnesian limestone are exposed on a hill top to the north of the road about ½ mile east of Prescott Road, in the NE.¼ of Section 6, town of Troy. The rock was very difficult to break, and seemed to be exceedingly tough and hard. It was accessible, being on a low hill overlooking a sandy, public road. As to its quantity nothing definite could be said. The amount in sight is small. There is very little soil on top of the rock here, but a fair estimate of the quantity could only be made after the ledge had been uncovered in a number of places.

An average sample from this quarry was tested with results as shown in table XXVII. The Office of Public Roads reported on it as follows: "This is a rather soft rock, showing very low toughness and resistance to wear, and good cementing value. Not recommended for plain macadam construction, but might be suitable for use with bituminous binders."

The McDonald Quarry is located 1½ miles to the northwest of New Richmond. In this quarry there are about 5 feet of very compact, tough, thick, limestone beds, which would make good road material. They are overlaid by 12 feet of decayed limestone and soil. The amount of stone available from this quarry is considerable, and would warrant the installation of a small crusher. The accessibility of the quarry leaves little to be wished for. It is connected with the public road by a level stretch of private road about ¼ mile long.

An average sample from the lower 5 feet of this quarry was tested by the Office of Public Roads with the results as shown in table XXVII. Its report on this sample is as follows: "Soft rock, with low toughness and resistance to wear, and good cementing value.

Should only be used on waterbound macadam roads subjected to light traffic or for use with bituminous binders."

The Levi Oakes quarry, about 1 mile southwest of New Richmond, presents a section of Lower Magnesian limestone, which is about 10 feet high, and several hundred feet long. It is capped by about 5 feet of soil. Unfortunately, the rock in this quarry is mostly soft and weathered, and the lower beds are quite sandy. The supply of stone for practical purposes is inexhaustible. The quarry is only about 300 feet from the public road, and only a short distance below it in elevation.

An average sample from this quarry was tested with the results as shown by table XXVII. It was reported on by the Office of Public Roads as follows: "This is a soft rock, showing very low toughness and resistance to wear, and good cementing value. Not recommended for plain macadam construction, but might be used with a bituminous binder."

Low cliffs of Lower Magnesian limestone are exposed in the gorge of the Apple river, about ½ mile west of Little Falls, in Polk county. This small canyon is cut below the general level of the surrounding country. The limestone beds begin to appear about 30 paces north of the public road, and a little below it in elevation. An inexhaustible supply of road material of fair quality could be gotten from this locality. The section exposed is as follows in descending order:

Thick bedded limestone with flint nodules	30 feet
A very much weathered bed of limestone	4 feet
A dense, compact, white limestone	4 feet
At water's edge, a bed of weathered limestone	

For view of this locality see Plate XXXIX.

An average sample from this section was tested by the Office of Public Roads. For results see table XXVII. Its report is as follows: "Sample shows low hardness, very low toughness and resistance to wear, and good cementing value. Not recommended for plain macadam construction but might be suitable for use with bituminous binders."

Alongside of the public road, about 1 mile west of Glenwood, in the eastern part of St. Croix county, about 20 feet of Lower Magnesian limestone are exposed in a small quarry. The quarry face is about 30 feet long. The beds are capped by several feet of soil. The upper layers are thin and frost broken, and contain numerous flint nodules. The lower beds are fine-grained and thick. The rock is soft and weathered, and would not make a good road material. It

is improbable that there exist in this part of the county ledges of limestone which would bear traffic satisfactorily.

The J. Wall quarry is located about 2 miles south of Osceola on the bluffs overlooking the St. Croix river. About 20 feet of thick-bedded, soft, decomposed, flint bearing limestone are exposed. It is a poor road material, but probably is as good as any limestone in this vicinity. The supply of stone, is, for practical purposes, inexhaustible and the quarry can easily be reached from the main road.

An average sample from this quarry was tested by the Office of Public Roads. For results see table XXVII. Its report is as follows: "This a soft rock, with low toughness and resistance to wear, and low cementing value. Not recommended for plain macadam construction, but is suitable for use with bituminous binders."

About 70 feet of the Lower Magnesian limestone are exposed on Apple river near Star Prairie, 20 miles northwest of Hudson. Most of the section consists of alternating layers of green sand and thin bedded limestone, which would not do for road material. In descending order the beds are as follows:[1]

Coarse, brecciated, non-uniform limestone. Much green material near the top	15 feet
Compact, dark gray, angular limestone. Lower portion thin bedded with greensand between layers and in cavities	10 feet
Compact, heavy beds below, with green particles uniformly distributed	10 feet
Medium beds composed of wave-like laminae. Dark gray, compact to cherty	5 feet
Heavy layers with one containing hummock-like elevations five feet from the base	10 feet
Coarse, crystalline limestone, dark buff to gray. A fair road material	10 feet
Alternating layers of limestone and sandstone. The upper layers of limestone are somewhat regular, but the lower ones are very irregular and hummocky. The middle layer of sandstone is argillaceous and friable, while the lower one is composed of coarse sand, and is of medium hardness. The colors are buff to reddish yellow	10 feet

At Rose Lake in Section 18 of the Town of Stanton, St. Croix county, there is an exposure of massive, heavy bedded, coarsely crystalline limestone, which would make a fair road material for local purposes.

On the railroad at Wilson, flinty Lower Magnesian limestone is exposed. The section is as follows in descending order.[1]

[1] Geology of Wisconsin, Vol. 4, page 127.
[1] Geology of Wisconsin, Vol. 4, page 128.

Compact layers, fine grained at top, crystalline below. Cavities in lower portion lined with quartz. Interbedded masses of flint	38 feet
Similar to above but more heavy bedded	30 feet
Heavy beds quite regular, free from flint. Granular and crystalline	14 feet
Irregular, fragmental limestone. Locally cavernous and without stratification. Thin beds of sandstone at bottom	8 feet
Buff, fragmental and cross laminated layers	5 feet

The upper 80 feet probably would make a fair road material.

East, south and southwest of Wilson, the layers of the Lower Magnesian limestone cap many of the bluffs and ridges. Exposures are numerous, but all are quite similar to the limestone at Wilson.

The Galena-Trenton formation is quarried on top of a high mound east of Bass Lake, in the Town of St. Joseph, St. Croix county.

The section in descending order is as follows:

Broken, thin bedded, fine grained brittle rock	4 feet
Shaley beds	4 feet
Fine grained, thick bedded buff limestone	4 feet

The material is soft, and weathered, but the lower 4 feet probably would make a fair road material. A large supply of stone could be gotten here, but hauling from this quarry would be somewhat difficult because of its situation on a high hill.

On the high mound, about 1 mile southeast of Burkhardt, 10 feet of Galena-Trenton formation are exposed in a quarry. The character of the beds is similar to those of the quarry east of Bass Lake. They are soft and would not make good road material. Their quality is inferior to the Lower Magnesian limestone exposed at the falls of the Willow river near Burkhardt.

About 3 miles south of Prescott Road, at the Ryan quarry, about 12 feet of Galena-Trenton formation are exposed. The section in descending order is as follows:

Soil	very little
Thick bedded limestone	5 feet
Thin bedded, cream colored limestone	3 feet
Thick bedded limestone	4 feet

The quality of this stone for road making is about as good as any limestone from the Galena-Trenton formation in northwestern Wisconsin. For tests of this stone see table XXVII. The sample tested was reported on by the Office of Public Roads as follows: "This sample shows rather low hardness and toughness, low resistance to wear, and good cementing value. Only suitable for lightly trav-

elled, waterbound macadam roads or for use with bituminous binders."

A large supply of stone could be gotten from this quarry. Although situated on a bluff about 100 feet high above the public road, it is accessible, having a good road leading up to it.

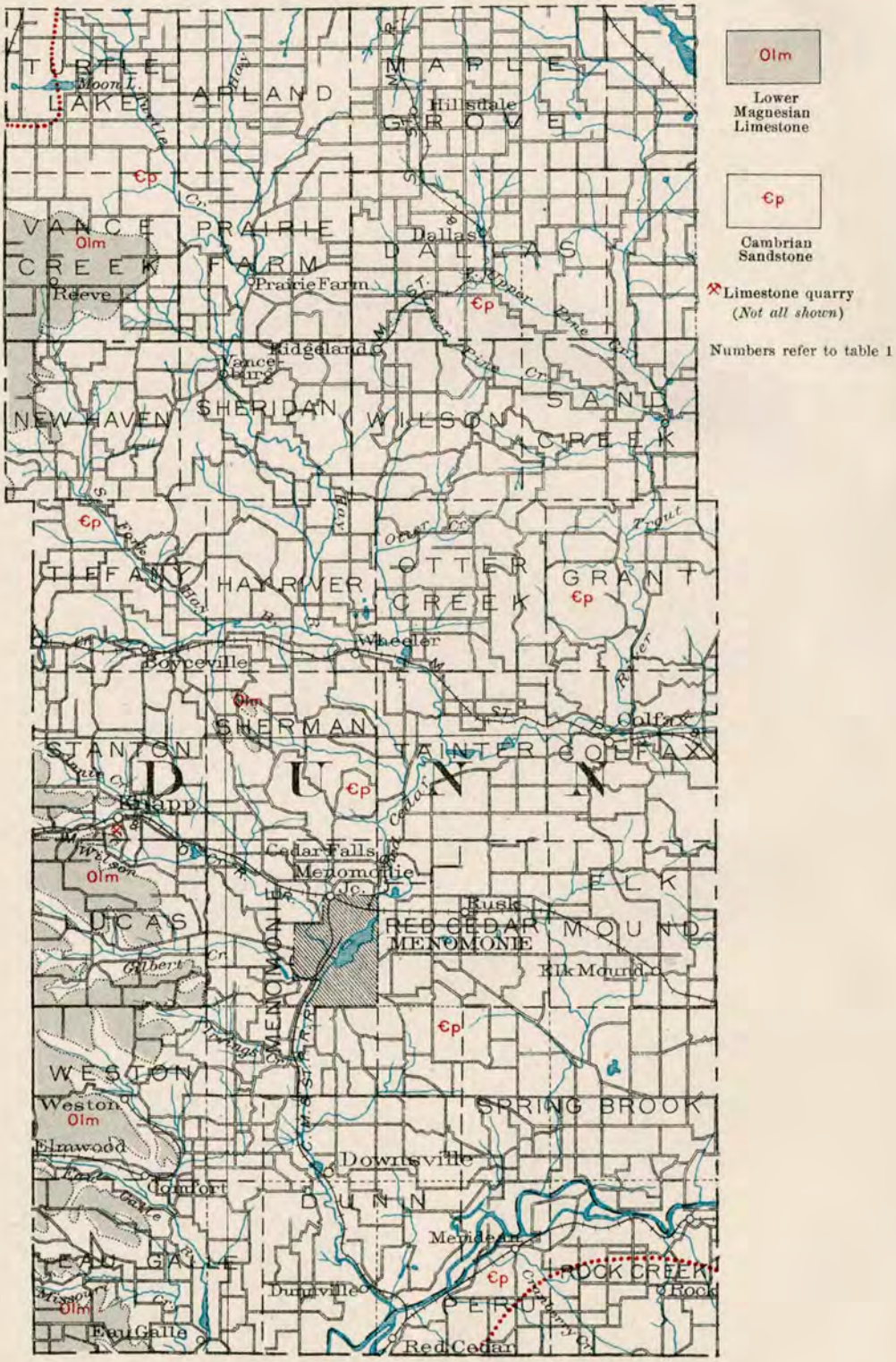
Besides limestone, field bowlders and gravels are available for road material in many parts of St. Croix and Polk counties. While all of these counties have been glaciated, only the area north of the red dotted line on Plate XL was covered by moving ice during the last glacial epoch. Gravels are most common along the margin of the last drift, and in many localities will constitute an important source of road material. The trap rocks of Polk county make excellent road materials well suited for heavy traffic. On the Minnesota side of the St. Croix river, they are being utilized for this purpose.

TABLE XXVII.

Tests on Limestone from Polk and St. Croix Counties.

Nature of Test.	1.	2.	3.	4.	5.	6.	7.	8.	9.
Specific gravity	2.65 Med.	2.80 High.	2.65 Med.	2.60 Med.	2.55 Med.	2.70 Med.	2.70 Med.	2.85	2.45
Pounds per cubic foot	165.00 Med.	175.00 Med.	165.00 Med.	162.00 Med.	159.00 Med.	168.00 Med.	168.00 Med.	178.00	153.00
Pounds of water absorbed per cubic foot	3.59 Med.	.86 Low.	2.82 Med.	2.51 Med.	3.13 Med.	1.86 Low.	2.67 Med.	6.90	.14
Per cent of wear	7.60 High.	9.20 High.	6.10 High.	8.00 High.	11.30 High.	10.70 High.	7.40 High.	22.50	2.30
French coefficient of wear	5.30 Low.	4.30 Low.	6.60 Low.	5.00 Low.	3.50 Low.	3.70 Low.	5.40 Low.	17.30	1.80
Hardness	4.00 Soft.	13.70 Soft.	12.70 Soft.	12.00 Soft.	11.70 Soft.	7.00 Low.	13.30 Soft.	16.50	4.00
Toughness	3.00 Low.	4.00 Low.	5.00 Low.	3.00 Low.	4.00 Low.	Low.	12.00 Low.	13.00	2.00
Cementing value	Fair.	Good.	Good.	Good.	Good.	?	Good.	.....	.....
Fitness	No good.	No good.	.....	.....	No good.	No good.	.....	.....	.....

1. Limestone from Burkhardt Mill, Wis. Wisconsin sample No. 40.
2. Limestone from Prescott Road Ledge, Wis. Wisconsin road sample No. —.
3. Limestone from McDonald Quarry, New Richmond, Wis. Wisconsin road sample No. 41.
4. Limestone from Oakes Quarry, New Richmond, Wis. Wisconsin road sample No. —.
5. Limestone from Little Falls, Wis. Wisconsin road sample No. 46.
6. Limestone from Walls Quarry, Osceola, Wis. Wisconsin road sample No. 45.
7. Limestone from Ryan Quarry, near Prescott Road. Wisconsin road sample No. —.
8. Maximum for Wisconsin limestone.
9. Minimum for Wisconsin limestone.


Olm
Lower Magnesian Limestone
€p
Cambrian Sandstone
Limestone quarry
(Not all shown)
Numbers refer to table 1
TURTLE LAKE
MAPLE GROVE
UPLAND
Hillsdale
Moon L.
VANCE CREEK
PRAIRIE FARM
Dallas
DALLAS
Prairie Farm
Reeve
Ridgeland
Vance Creek
NEW HAVEN
SHERIDAN
WILSON
SAND CREEK
TIFFANY
HAY RIVER
OTTER CREEK
GRANT
Wheeler
Boyceville
SHERMAN
Colfax
STANTON
TAINTER
COLFAX
DUNN
Knapp
Cedar Falls
Menomonie Jc.
ELK MOUND
DICAS
RED CEDAR
MENOMONIE
Rusk
Elk Mound
WESTON
SPRING BROOK
Weston
Elmwood
Downsville
Comfort
Meridean
EAU GALLE
Dunnville
ROCK CREEK
Rock
PEPIN
Eau Galle
Red Cedar

Dunn and Barron Counties.

Along the western border of Dunn county and in the southwest corner of Barron county, there are high bluffs capped by Lower Magnesian limestone, overlooking a nearly level region to the east which is underlaid by the Potsdam sandstone. The distribution of these formations, as they would appear if the soil and loose material which covers them in most places were removed, is shown by Plate XLI.

Wherever examined, the Lower Magnesian limestone of this region was found badly decayed. It rarely outcrops, and is not quarried excepting for local uses which do not require a good grade of stone. On the hills south of Knapp, it has been quarried in a number of places, but none of it would do for road making. It is improbable that good road material can be gotten from any part of the Lower Magnesian limestone of these counties.

Although the greater part of Dunn and Barron counties has been glaciated, drift bowlders are common only within the area of the last glacial drift which lies in the northwestern part of Barron county.

Gravels may be looked for along the margin of this drift sheet. The dashed red line in the northwest corner of Plate XLI indicates the edge of the ice sheet.