UNIVERSITY OF MINNESOTA

Minnesota Geological Survey

George M. Schwartz, Director

Summary Report No. 8

MINNESOTA LIMESTONE SUITABLE FOR PORTLAND CEMENT

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Nikola Prokopovich
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ABSTRACT

A regional study of possible deposits of high grade limestone suitable for the manufacture of Portland cement was made by the Minnesota Geological Survey in the summer of 1955. Special attention was given to the area located close to railroad lines and to the Twin Cities. Over 160 samples of limestone from about 62 localities and 45 samples of the Decorah shale from the same or nearby locations were collected and analyzed. Magnesium oxide (MgO), Calcium oxide (CaO), Carbon dioxide (CO_2), total iron (Fe), ferrous iron (Fe^{++}) and the insoluble content in hydrochloric acid were determined for all limestones. In addition aluminum oxide (Al_2O_3) or combined aluminum oxide and ferric oxide (Fe_2O_3) as R_2O_3 were determined for the shale samples. The following report contains all the data obtained during this study and a brief summary of the previous work on high grade limestones in Minnesota by the Minnesota Geological Survey.

The most important conclusions are as follow: 1) The state of Minnesota possesses excellent deposits of high grade limestone. Some of them are very large and located close to railroad lines. 2) The high grade limestone occurs mostly in the Prosser member of the Galena formation. The basal part of this member is composed of shaly limestone resembling a "natural cement rock" and is almost always low in magnesia. The upper, less shaly part of the member is high in calcium in Fillmore and south-central Olmsted counties, but becomes dolomitic toward the north (northwestern Olmsted and Goodhue counties). 3) High grade limestones occur also in certain areas of the Cedar Valley, Maquoketa and Platteville formations but their practical importance is doubtful because of the small size of the deposits and their location too far from the Twin Cities.

Dakota County. The only known deposits of the Prosser limestone in Dakota County are of non-commercial size and are located in a densely populated area of St. Paul. The rock is high in insoluble content and cannot be used alone for making Portland cement.

Goodhue County. A large area in the southwestern part of the county is underlain by Prosser limestone but the rock is usually high in MgO (up to 17.7%). Only the lower part of the basal shaly Prosser limestone is, at places, low in MgO. Such deposits, however, do not seem to be of commercial size, are mostly covered with a thick overburden, and are too high in insoluble materials for the manufacture of Portland cement.

Olmsted County. There are large deposits of high grade Prosser limestone in the southern and eastern parts of the county. Both basal shaly parts of the member and its upper part are usually low in MgO. The most promising deposits are located southeast and east of Rochester, at Predmore and at Cummingsville. The amount of MgO in some samples is as low as 0.53 to 0.33%. At Cummingsville a unit about 80 - 100 feet thick was sampled and analyses showed the average amount of MgO to be less than 1 per cent.

Winona County has rather small areas underlain by Prosser limestone. The rock is of a good quality, but deposits are small and are far from a railroad line.

Mower County has high calcium limestone in the Cedar Valley formation at LeRoy, however, the total thickness of high grade rock is too small for a large cement industry and the deposits are far from the Twin Cities.

Fillmore County has probably the largest deposits of high calcium limestone in the state. Some of them are located close to railroads (at Fountain, Harmony, Canton, etc.).

Houston County has only small areas in its southwestern corner which are underlain by high grade Prosser limestone. The deposits are rather small to be of commercial value.

GENERAL STATEMENT

In recent years the recurrent shortages of Portland cement has stimulated interest in establishing a cement plant in Minnesota but such a plant requires large quantities of limestone or marl. The possible utilization of Minnesota marl has been investigated by one of the cement companies but not much had been done to furnish additional information on the limestones suitable for the manufacture of Portland cement. It was decided, therefore, that a thorough sampling of many exposures, especially of the Prosser member of the Galena formation, would be carried out to supplement the earlier work of the Minnesota Geological Survey. It was known from previous work that the Prosser member contained large amounts of high calcium limestone (Stauffer and Thiel 1933, 1947). The following report includes a tabulation of all recent analyses and pertinent analyses from previous work.

The general requirements of limestone for use in Portland cement include the following:

(1) Proper chemical composition, especially with regard to the magnesium content, but also alumina, silica, and iron oxide are important. The limestone should contain less than 5 per cent magnesium carbonate ($MgCO_3$), equivalent to not over 3 per cent magnesia (magnesium oxide, MgO).

(2) Large quantity available -- on the order of 30,000,000 tons of limestone.

(3) Suitable deposits of clay or shale nearby to furnish the necessary alumina and silica.

(4) Thin overburden.

(5) Location close to a railroad and as close as possible to the main market, that is, in Minnesota, close to the Minneapolis-St. Paul area.

Limestone and dolomite have many other uses to which some of the above requirements do not apply, but these are not discussed in this report.

METHODS OF STUDY

The field investigation was made during the period from July 20 to August 25, 1955, by Dr. Nikola Prokopovich and his assistant Mr. David Hoeft. Each county to be investigated was first traversed by car and outcrops of the bedrock were marked on the county road maps. The most suitable outcrops were then selected for sampling. Most attention was given to the area known to be underlain by the Galena limestone and located near railroad lines, but an attempt was made also to study general changes in the composition of the Prosser limestone in each county.

The sampling was done by chipping small, more or less uniform, fragments of the rock about 1" x 1/2" x 1/2" from each exposed layer. In a thick-bedded limestone samples were taken from the lower, middle and upper parts of each bed. Chips were collected in cloth sacks and labeled. The thickness sampled was measured by a pocket tape or hand level and stadia rod. In large exposures samples were taken separately from the lower, middle, and upper parts of the exposure. In some quarries the rock face was too high to be sampled without erecting a stage and inaccessible parts were not sampled. Only grab samples (in tables marked "G.S.") were taken from the Decorah shale. In general about 160 samples of limestone, and 45 samples of the Decorah shale from the same or nearby locations, were collected and analyzed during the investigation.

The samples collected were crushed in a jaw crusher and run through mechanical rolls, mixed about 100 times and reduced in a splitter to an amount of about 200 gr. Reduced samples were spread on a sheet of paper and small portions were taken by a spatula from different spots of the sample, pulverized, screened through a 100 mesh screen and mixed 100 times. The chemical analyses of the samples were completed by Mr. V. Bye of the Mines Experiment Station of the University of Minnesota under compound numbers 10775-1 to 10775-179. In the following tabulation only the parts of these numbers to right of hyphen (1-179) are given, in column headed M.E.S., whereas the complete numbers, for example 10736-3, are given for a few other samples previously analysed by the Mines Experiment Station.

The experience obtained during the sampling showed that chip-sampling gives a rather good average, though some beds of shaly limestone may be missed during the chipping because of poor exposure and this may decrease somewhat the total amount of "insolubles" in the sample. On the other hand, the leaching of such shaly beds during weathering increases somewhat the insoluble content in comparison with fresh rock. Many of the samples were taken from old, more or less weathered outcrops, roadcuts and quarry walls. The effect of weathering on the magnesia content in the limestone is not certain but in some cases the selective leaching of more soluble calcium carbonate during weathering seems to increase the relative amount of magnesia in the rock as shown by the following data.

Sample	M.E.S.	CaO	MgO	Ign.	SiO_2	Fe	Fe^{++}
Olmsted County							
Station 10							
Prosser Ls., blue-gray, from fresh quarry wall.	10727-3	50.50	2.58	41.28	3.52	n.d.	n.d.
" buff, weathered, from same level in road cut several hundred feet away.	10727-2	48.86	3.05	40.39	5.04	n.d.	n.d.

Sample	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	R_2O_3
Olmsted County							
Station 6							
Galena Ls., blue-gray, fresh	178	45.03	5.85	40.60	7.01	0.64	2.79
" same bed, but weathered.	177	43.89	7.07	39.16	10.20	0.73	3.21

The determination of total iron (Fe) and ferrous iron (Fe^{++}) was made on two separate samples (about 0.4 gram) by the usual volumetric methods using barium diphenylamine sulfonate as an internal indicator.

Insolubles, CaO, and MgO were determined on the same sample (about 0.5 gram). For convenience the terms insoluble or insolubles is used to designate the material which is insoluble in hydrochloric acid. The insoluble content was obtained by the digestion of the samples in dilute hydrochloric acid which was warmed slightly in order to dissolve all of the carbonate minerals. After this the samples were taken to dryers and baked for one hour at 105° C and the insolubles were determined on the residium. Silica in the insolubles was removed with HF, the residium was fused with Na_2CO_3, leached with 1:1 HCl and added to the filtrate. Ca and Mg were run on the filtrate from insolubles. Ca was precipitated twice as the oxalate and determined gravimetrically. After CaO and all other salts and interferring elements such as Al, Si, NH_4Cl, etc. were removed, Mg was precipitated as Mg--pyrophosphate and run gravimetrically.

Carbon dioxide was determined gravimetrically on separate 0.5 gram samples with a complete train to absorb all interfering elements. Samples were run in groups of 10 to 12 samples in each group. A Bureau of Standards sample 1-A ("argillaceous limestone") was carried as a check with every 10 samples and correction was introduced for the possible presence of Ca and Mg in the distilled water. CO_2 was checked on each 5 samples with Bureau of Standards sample #88 ("dolomitic limestone").

Aluminium oxide (Al_2O_3) was determined from the filtrate after SiO_2 had been removed by fusion with sodium carbonate. The fusion cake was dissolved in diluted hydrochloric acid. After filtration and dehydration with $HClO_4$, SiO_2 was removed with HF. The small amounts of residue left were re-fused and added to the main filtrate. The alumina was determined as $AlPO_4$ using $Na_2S_2O_3$ as a reductant. The R_2O_3 was determined in the usual way in the filtrate by the precipitation with ammonium-hydroxide.

Three check samples were analyzed in the Rock Analysis Laboratory of the University of Minnesota. The data obtained were comparable with those obtained by the Mines Experiment Station.

Some chemical data published in earlier reports is also included in the tables in this report, with corresponding references as follows: The number twenty three (#23) means that the figures were taken from the corresponding analyses in Minnesota Geological Survey Bulletin 23 (Stauffer and Thiel, 1933); the numbers #S1 and #S4 means that the figures were taken from the Minnesota Geological Survey Summary Reports number 1 and 4, respectively (Stauffer and Thiel, 1947; Stauffer, 1950).

In most cases the Ca and Mg in limestone are present as the carbonates $CaCO_3$ and $MgCO_3$. In the tables in the text they are given as CaO and MgO. The percentage of $MgCO_3$ can be determined by multiplying the percentage of MgO by the factor 2.0915. The percentage of $CaCO_3$ can be determined in the same way by multiplying the percentage of CaO by the factor 1.7848. In shale samples both Ca and Mg may be present partly as carbonates and partly as silicates. Iron is expressed in the tables as total iron (Fe) and ferrous iron (Fe^{++}). The percentage of ferric iron may be obtained by subtraction of the percentage of ferrous iron from the total iron. The percentage of FeO and Fe_2O_3 may be obtained by multiplying corresponding percentages of ferrous and ferric iron by the factors 1.2864 and 1.4298.

The insoluble portion includes quartz and silicates. The iron included in these silicates is repeated under Fe^{++} and total iron. The Ca and Mg in silicates is repeated in the CaO and MgO content.

In the tables to save space, the abbreviation "Ls." is used for limestone, "Dol." for dolomite, "Sh." for shale and "Ls.-Sh." for shaly limestone. Likewise in this report S.A.R. is used for State Aid Road and C.A.R. for County Aid Road. Locations are abbreviated as follows: from northeast quarter of Section 21, Township 111 north, Range 18 west to NE1/4 Sec. 21:111-18.

ACKNOWLEDGEMENTS

Most of the analyses listed in this report were made by the chemical laboratory of the Mines Experiment Station of the University of Minnesota. The writers are greatly indebted to Mr. Henry H. Wade, Acting Director, for generous cooperation throughout the investigation and to Mr. Vernon Bye for much help with analytical work. Professor Samuel S. Goldich of the Department of Geology, University of Minnesota, gave generously of his time on problems involving the analytical work. Professor George A. Thiel, Department of Geology, gave freely of his detailed knowledge of the Paleozoic stratigraphy of Minnesota in planning and carrying out the work.

STRATIGRAPHY

The limestones and dolomites of Minnesota are confined to the southeastern part of Minnesota essentially in the area between the Minnesota and Mississippi rivers (Fig. 1). The rocks of the area are all of early Paleozoic age with sandstones predominant in the lower part and limestone and dolomite beds more abundant in the upper part. In the eastern part of the area the glacial drift is thin and consequently there is very little overburden to interfere with quarry operations.

Generalized Geologic Column
of Paleozoic Formations in Minnesota

Formation	Rock types
Devonian	
Cedar Valley formation	Dolomite, limestone
Ordovician	
Maquoketa formation	Shaly limestone
Galena formation	
Stewartville member	Dolomite
Prosser member	Limestone, shaly limestone & dolomite
Decorah formation	Shale, with thin limestone beds
Platteville formation	Dolomitic limestone
St. Peter sandstone	Sandstone
Shakopee dolomite	Dolomite
Root Valley sandstone	Sandstone
Oneota dolomite	Dolomite
Cambrian	
Jordan sandstone	Sandstone
St. Lawrence formation	Silty dolomite
Franconia formation	Sandstone
Dresbach formation	Sandstone, shale

It has long been known that most of the carbonate rocks of Minnesota have a high content of magnesium carbonate. Many of the beds are essentially dolomite, that is, they consist of the mineral dolomite which is a combination of equal molecular amounts of calcium carbonate and magnesium carbonate for which the chemical formula is $CaMg(CO_3)_2$. This contrasts with calcite the chief component of a pure limestone which has a formula of $CaCO_3$. High calcium limestones are known to occur in the Cedar Valley, Maquoketa and Galena formations.

The Cedar Valley limestone contains some beds of high grade limestone but these are too thin to furnish material for a large operation. The Maquoketa formation is so poorly exposed in Minnesota that few analyses are available. These are generally low in magnesium but large amounts of rock are not readily available.

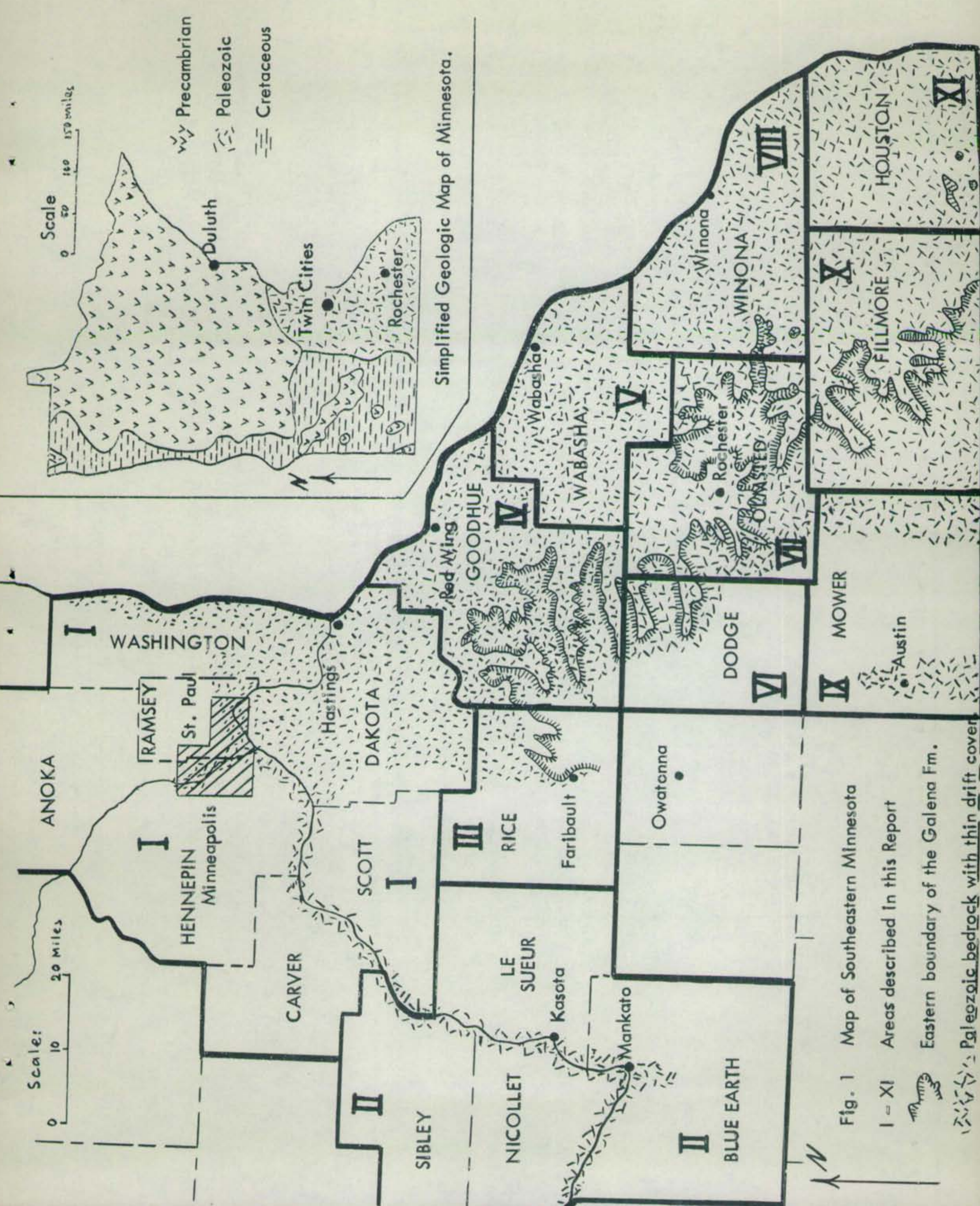

Fig. 1 Map of Southeastern Minnesota

I – XI Areas described in this Report

Eastern boundary of the Galena Fm.

Paleozoic bedrock with thin drift cover

The upper part of the Galena formation is called the Stewartville member. It is a gray to yellow, dolomitic limestone which averages about 50 feet in thickness. It ranges widely in content of magnesium carbonate but most analyses fall between 10 and 30 per cent. It is, therefore, not suitable for Portland cement.

The Prosser member of the Galena formation is generally a hard, compact limestone. The lower part consists of interbedded limestone and shaly limestone and is referred to in the tables as basal shaly limestone. The Prosser ranges up to 100 feet in thickness but its entire thickness is rarely exposed at any one locality. There is some chert in the Prosser in the southern part of the area but generally it is not abundant and is probably not a serious problem from the standpoint of suitable rock for Portland cement. The Prosser beds in Fillmore, and most of Olmsted counties are generally low in magnesia as shown by many analyses quoted below. Northward in Goodhue County the limestone contains more magnesia and investigations in the county have not revealed the necessary quantity of high calcium limestone to justify the establishment of a cement plant.

The following are three analyses of Prosser limestone analyzed by the Rock Analysis Laboratory, Department of Geology, University of Minnesota. These are more complete analyses than others given in the body of this report.

Lab. No.	R2176	R2177	R2178
SiO_2	6.20	7.01	7.96
Al_2O_3 1/	1.43	1.74	1.97
Fe_2O_3	.44	.53	.72
FeO	.05	.16	.26
MnO	.00	.04	.05
MgO	.62	17.81	8.61
CaO	50.10	29.28	38.97
Na_2O	.02	.03	.04
K_2O	.89	.89	1.17
CO_2	39.66	42.20	39.68
P_2O_5	.08	.11	.11
	99.49	99.80	99.54

R2176 the same as MES#4: Somewhat weathered Prosser limestone, Olmsted county, Station 16, Upper quarry, 15 ft. section.
R2177 the same as MES #33: Somewhat weathered Prosser limestone, Goodhue county, Station 7, uppermost 19 feet.
R2178 the same as MES #42: Somewhat weathered Prosser limestone, Goodhue county, Station 5, uppermost 3 to 5 feet.

1/ Includes TiO_2 C. O. Ingamells, analyst

The Decorah shale typically consists of about 60 feet of greenish shale interbedded with thin limestone beds which are often highly fossiliferous. The Decorah beds are of interest because they may furnish the necessary shale for mixing with the Prosser beds to supply the Al_2O_3 and SiO_2 for the production of Portland cement. The Decorah generally contains less than 3 per cent magnesia, but at places has a rather high potash content. Four analyses of the shale were reported by C. M. Riley (1950).

Sample	$R8_2$	$R8_3$	$R25_3$	$R25_4$
SiO_2	40.35	48.94	48.50	43.10
Al_2O_3	16.62	20.33	20.78	15.16
Fe_2O_3	4.85	4.97	3.75	3.59
FeO	.55	.71	1.40	1.22
MgO	1.95	2.53	2.83	2.84
CaO	12.19	2.89	2.26	10.68
Na_2O	.12	.20	.12	.12
K_2O	6.63	7.64	7.69	6.66
H_2O+	4.18	5.16	4.97	3.37
H_2O-	2.59	3.33	4.06	2.50
CO_2	8.96	2.25	2.05	8.95
TiO_2	.59	.78	.79	.60
P_2O_5	.32	.31	.20	.40
SO_3	-	-	.07	.14
S	.04	.02	.81	.94
MnO	.10	.04	.03	.07
BaO	.01	.01	.01	.00

$R8_2$ and $R8_3$ - Decorah shale, sec. 21: 110-16, Goodhue County.
$R25_3$ and $R25_4$ - Decorah shale, Twin City Brick Company pit, St. Paul.

I. TWIN CITY AREA

(Washington, Ramsey, Anoka, Hennepin, Carver, Scott, Dakota Counties).

The Twin Cities (Fig. 1) area is the largest consumer of cement in the state. Several limestone formations---St. Lawrence, Oneota, Shakopee, Platteville and Galena crop out in this vicinity but according to the data previously collected (Stauffer and Thiel, 1933; Stauffer, 1950) practically all of them are dolomitic. The only low-magnesian limestone occurs in the Prosser member of the Galena formation which caps the Decorah shale over a small area in and south of St. Paul. The upper part of the Prosser limestone is completely eroded and only a part of the basal shaly Prosser limestone remains as small isolated outliers. Its maximum thickness in the best exposure at the Twin City brick plant in St. Paul is only 25 to 30 feet below 100 feet of drift. The known deposits are too small and too shaly to be considered for a cement plant.

No special sampling of this deposit was made during the recent investigation but four channel samples previously collected by D. H. Hansen (1951) were analyzed with the results given below.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Basal Prosser Ls-Sh.									
" upper	10 ft.	135	15.49	2.24	12.84	59.06	1.93	0.44	10.49
" middle	10 ft.	140	35.44	1.38	27.92	25.72	1.20	0.48	6.47
" bottom	10 ft.	134	30.02	1.77	23.54	35.24	1.61	0.56	6.96
Decorah Sh., upper	10 ft.	133	17.36	2.87	14.36	49.89	2.57	0.81	12.97

II. MANKATO AREA

(Blue Earth, Le Sueur, Nicollet, and Sibley Counties)

There are three limestone formations within this area (Fig. 1): -- St. Lawrence, Oneota, and Shakopee. The Oneota rock has been quarried extensively between Mankato and Kasota where it is an excellent building stone. (Thiel and Dutton, 1935). Formerly it was also used for manufacturing lime and natural cement. Previous investigations (Stauffer and Thiel, 1933; Stauffer, 1950) showed that all of these formations are highly dolomitic, and, therefore, cannot be used for manufacturing Portland cement. For this reason the Mankato area was not sampled during the present investigation.

III. RICE COUNTY

There are only a few outcrops of bedrock in Rice county (Fig. 1) which is mostly covered by thick drift, especially in its southern and western parts. The Shakopee dolomite crops out in several places at Northfield and the Platteville dolomitic limestone caps several outliers in the northeastern part of the county and is exposed at several places along the Cannon and Straight Rivers at Faribault. Both formations are dolomitic (Stauffer and Thiel, 1933). The southern and south-eastern parts of the county are underlain by the Galena formation but there are no known natural outcrops of this formation and its boundaries as shown on the geologic map of Minnesota (1932) are uncertain. Drilling at Nerstrand (Fig. 2) indicates that the Galena limestone has been eroded completely in that area. Farther eastward, in Goodhue County, the upper part of the Prosser limestone is dolomitic, while the basal shaly-beds contain less magnesia. Similar relationships may be present also in Rice County. No samples were taken in Rice county because there are no known outcrops of the Prosser beds.

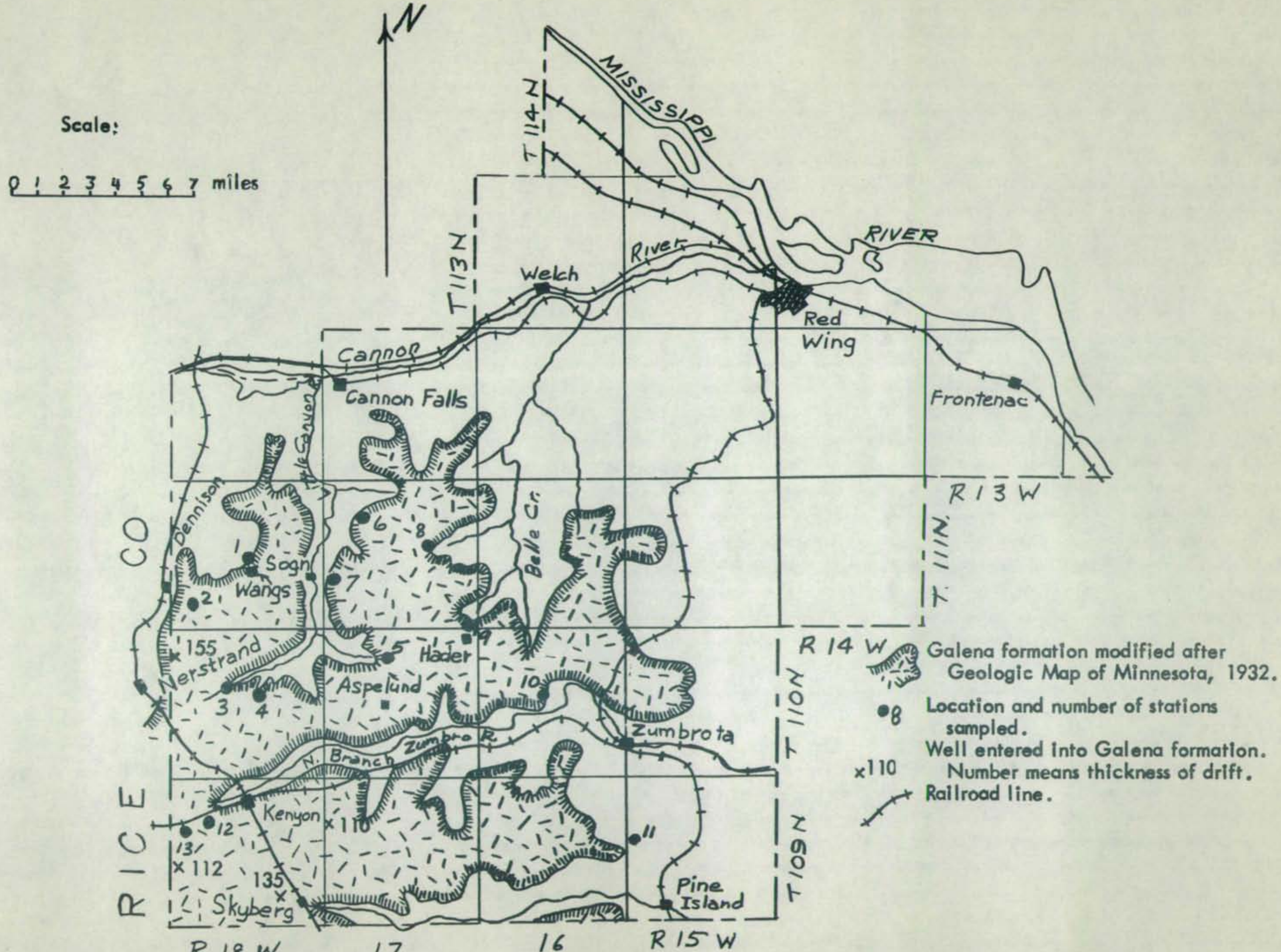

Fig. 2. Map of Goodhue County showing the distribution of the Galena formation and stations sampled.

IV. GOODHUE COUNTY

Goodhue County (Fig. 2) is the closest source of large quantities of limestone for the Twin City area. The only possibility for a low magnesian rock in the county is the Prosser member of the Galena formation which underlies a plateau over a large area in the southwestern half of the county. The bedrock is well exposed in several road cuts, quarries and natural outcrops. The formations older than Prosser are exposed at many places between the Prosser-capped plateau and the Mississippi River. The Platteville, Shakopee, Oneota and St. Lawrence formations are composed of limestone but, as previously stated, cannot be used for manufacturing Portland cement because of a high magnesia content. This is particularly true for the large deposits of dolomitic limestone along the bluffs of the Cannon and Mississippi rivers at Welch, Red Wing, Frontenac, etc. During the present study 28 samples of the Prosser limestone were collected from 13 locations. These together with 9 samples of the Decorah shale at or near the same locations were analyzed. The analytical results are tabulated for the stations that follow.

STATION 1. - About 3/10 of a mile north of Wangs on the east side of State Highway 56 in the NE1/4 sec. 21: 111-18 there are two roadcuts showing about 15 feet of weathered, shaly, basal Prosser limestone which overlies a thick section of the Decorah shale.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Basal Prosser Ls.-Sh.	15 ft.	43	38.38	1.39	30.62	22.84	0.88	0.19	n.d.
Decorah Sh. upper	G.S.	144	0.29	2.16	0.06	73.92	3.86	0.44	26.97
" " lower	G.S.	145	1.11	2.01	0.70	73.32	4.58	0.55	27.15

Though the limestone at this locality is low in MgO it has limited commercial importance because of the small size of the deposit and the high content of insoluble material. The rock may be suitable for "natural cement".

STATION 2. -- There is a poor exposure of bedrock, probably Prosser limestone, in the NE1/4, NE1/4 sec. 31: 111-18. Here 12 feet of buff-colored, thin-to-medium bedded limestone crops out on the southern bank of a creek.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser? Ls.	12 ft.	118	40.64	8.08	40.32	7.20	1.86	0.81

STATION 3. -- The Prosser limestone is exposed in several road cuts along State Highway 56 in the valley of the Little Cannon River near the northeast corner sec. 16: 110-18. The cuts show basal, shaly Prosser limestone overlying greenish-blue Decorah shale. A section 18 to 20 feet thick of weathered shaly Prosser limestone was sampled in the western roadcut in the NE1/4, NE1/4 of sec. 16, and a grab sample of similar limestone from somewhat lower beds was taken in another roadcut in SE1/4, sec. 9. A grab sample of Decorah shale was collected from exposures below the Prosser beds.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Basal Prosser Ls.-Sh.	18-20 ft.	44	29.03	3.06	22.64	42.03	0.96	0.16	n.d.
" lowermost part	G.S.	127	29.82	1.53	23.22	33.58	1.85	0.32	8.48
Decorah Sh. upper	G.S.	123	5.03	2.53	3.96	65.02	3.23	0.64	17.55

STATION 4. -- An outcrop of bleached, thin-bedded, somewhat shaly Prosser limestone is located in the SW1/4 of sec. 15: 110-18 just north of the county road in the upper part of the western bank of a small valley. Decorah shale is poorly exposed at the creek level. The section sampled probably belongs to the upper part of the basal, shaly beds of the Prosser.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls.-Sh.	8 ft.	34	35.50	7.33	34.04	20.73	1.12	0.40

STATION 5. -- There is an active quarry in the Prosser limestone in the NE1/4, SW1/4 sec. 8: 110-17 about 1 1/2 miles north of Aspelund on the south bank of a small creek on the west side of S.A.R. No. 1. The quarry rock face is about 40 feet high but only the upper and lower parts were sampled. Here the drift is only 8 to 10 feet thick. The rock in the quarry is a fresh, thick-bedded, gray limestone. Near the surface it is weathered to moderate-to-thin beds and is buff-colored.

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls./Top (weathered)	3-5	42	39.50	8.21	37.38	10.77	0.64	0.24
" Middle	20-22	(not sampled)						
" Lower (fresh)	13-15	40	36.37	7.32	34.20	17.36	0.72	0.40

STATION 6. -- Several road cuts along U. S. Highway 52 near the northeastern corner of section 7: 111-17 expose the following section at the margin of the Prosser-capped plateau south of the city of Cannon Falls.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Drift	5 ft.								
Prosser Ls.	10-15 ft.	35	45.42	5.74	39.16	8.72	0.56	0.19	n.d.
Covered	14 ft.								
Basal Prosser Ls.-Sh.	13-15 ft.	51	31.79	3.91	27.82	30.06	1.21	0.23	n.d.
Covered	38ft.								
Decorah Sh.	G.S.	126	14.68	1.96	10.42	48.04	5.31	0.48	14.40

Two analyses of rocks from this area were reported by Stauffer and Thiel (1933). The first is on U. S. highway 52 (old State highway 20) 4.9 miles south of Cannon Falls. The second is a limestone bed in the Decorah formation in section 31: 112-17.

Formation	Sample	#23	Silica	Fe oxide	CaO	MgO
Galena Ls.	G.S.	20	12.16		42.10	5.65
Decorah Ls. bed	Composite	132	4.6	1.6	45.33	6.12

STATION 7. -- Samples were collected from the road cuts and ditches along S.A.R. 9 in the SW1/4, SW1/4 of sec. 19: 111-17. The rock is weathered, thin-to-moderate bedded, and bleached to a light buff color.

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Prosser Ls., top	19	33	29.16	17.70	41.96	9.32	0.48	0.16	n.d.
"	10	36	37.62	10.89	40.48	9.07	0.72	0.27	n.d.
"	10	49	39.43	8.72	39.50	9.61	0.72	0.31	n.d.
"	10	50	35.24	8.37	35.40	18.35	1.04	0.35	n.d.
Basal Prosser Ls.-Sh. Covered									
Decorah Sh. upper	G.S.	143	1.44	2.55	0.62	67.65	4.34	0.56	28.76 x)
" middle	G.S.	125	0.07	1.91	0.15	76.09	3.38	0.47	20.47
" lower		131	0.32	1.95	0.40	76.10	3.30	0.48	17.33

x) as R_2O_3

STATION 8. -- There is a good exposure of Prosser limestone in an active quarry in the SW1/4, SW1/4 of sec. 14: 111-17 on the northern slope of a creek. About 45 feet of blue-gray Prosser limestone are exposed under 4 to 10 feet of drift. Near the surface and along some bedding planes, the rock is partially leached and oxidized to a rusty color. The oxidized zone shows a slight increase in magnesia and other impurities.

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls. weathered								
upper part	5-6	48	38.72	12.05	42.36	5.50	0.56	0.08
" middle	12	Not sampled						
" "	10-12	38	38.29	6.87	36.14	15.14	0.64	0.43
" lower	15	47	36.29	6.60	34.28	19.84	0.89	0.32

STATION 9. -- There is a group of quarries at Hader in the SE1/4, SW1/4 sec. 36: 111-17. Two are active and one is abandoned. The main lower quarry is located along the eastern slope of a small valley where 1 to 10 feet of drift occur over 15 to 25 feet of the Prosser limestone. The limestone beds are 1 to 4 inches thick and strongly bleached in the uppermost 5 to 7 feet but grade downward into less weathered gray beds 8 to 12 inches thick. The upper quarry is located at the southwestern corner of the main quarry somewhat higher on the slope and has a rock face about 16 feet high. Here the upper surface of the rock is very irregular and the overburden is about 10 feet thick.

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls., upper quarry	16	39	44.88	7.35	40.48	7.03	0.56	0.11
" lower quarry	20	46	47.46	3.36	37.46	10.02	0.63	0.08
" " "	G.S.	10727-1	44.74	6.91	49.90 x)	5.12 x)	n.d.	n.d.

x) as loss and as SiO_2

STATION 10. -- In the western part of the Prosser-capped plateau there is an old quarry in limestone south of U. S. Highway 52 in the SW1/4 sec. 15: 110-16. The quarry walls expose 12 to 13 feet of grayish, thick-bedded limestone weathered at the top into bleached beds of moderate thickness. The overburden is 2 to 10 feet. The Decorah shale is well exposed in the same vicinity in a large old quarry on the north bank of the Zumbro River in about W1/2 sec. 21: 110-16.

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Limestone	12-13	37	40.52	6.51	38.26	11.00	1.27	0.72	n.d.
Decorah Sh. Upper part	G.S.	132	0.51	2.35	0.34	68.55	4.99	0.64	20.00

STATION 11. -- There are only a few rock exposures south of the north branch of the Zumbro River. The boundaries of the Prosser formation in this vicinity on the Geologic Map of Minnesota (1932) are in error as there is an outcrop of St. Peter sandstone in SE1/4 sec. 18: 109-15. Westward from this point in SW1/4, NW1/4 sec. 18: 109-15 there is an old quarry in grayish limestone which probably belongs to the Platteville formation. Two grab samples of this limestone were analyzed.

Formation	Sample	M.E.S.	CaO	MgO	SiO_2	Fe	Fe++
Platteville ? Ls. Blue interior part of bed.	G.S.	10736-2	28.89	2.50	7.94	1.60	1.28
" - yellow exterior crust.	G.S.	10736-1	26.22	11.36	14.02	2.39	0.96

STATION 12. -- There is an active quarry in the Prosser limestone on the right bank of a short, but deep valley in about the SE1/4, SW1/4 sec. 8: 109-18, southwest of Kenyon. The rock face is about 18 feet high and is covered by 5 to 25 feet of drift. The upper part of the face is somewhat weathered but the main part of the rock is rather fresh, grayish blue and thick-bedded (4 to 8 inches). Some of the beds have an oxidized crust showing a slight increase in magnesia caused by the selective leaching of calcium carbonate. The Decorah shale does not outcrop in this vicinity but was well exposed in Kenyon during the excavation for a new highway junction.

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Prosser Ls./weathered Top	3-4	Not sampled							
" fresh Ls.	12-15	45	32.14	7.08	31.28	24.31	0.87	0.39	n.d.
" Decorah Sh.	G.S.	128	4.34	2.45	3.48	67.60	2.90	0.73	18.74

STATION 13. -- About an 8 to 10 foot exposure of a badly weathered, thin-bedded Prosser limestone is located in the lower part of the west bank of a small valley in the northern part of sec. 18: 109-18.

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls.	8-10	41	39.00	6.56	35.94	14.85	0.87	0.32

In general in the western, and especially in the southwestern part of Goodhue county in the area underlain by the Galena limestone the drift is rather thick and the information on bedrock must be obtained by drilling. Thiel (1944) reports the following data on the thickness of drift over Prosser limestone in farm wells in this vicinity.

Location	Drift in feet
SE1/4 sec. 17: 110-17 - - - - - - -	80
NW1/4 sec. 7: 110-18 - - - - - - -	155
SE1/4 sec. 7: 109-17 - - - - - - -	110
NW1/4 sec. 19: 109-18 - - - - - - -	112
SE1/4 sec. 26: 109-18 - - - - - - -	135

V. WABASHA COUNTY

Wabasha county (Fig. 1) was not sampled during the present investigation. The main carbonate formations in this country are the Oneota and Shakopee. They underlie at least 75% of the county and are exposed in numerous bluffs along the Mississippi and Zumbro rivers. Both formations are composed of high magnesian limestone (Stauffer, 1950) and cannot be used for the manufacturing of Portland cement. Beside the Oneota and Shakopee formations there are several outcrops of shaly, dolomitic limestone of the St. Lawrence formation along the main valleys. A few small outliers at Elgin are capped by Platteville limestone. This rock is also dolomitic. A small area covered by the Prosser limestone is shown on the Geologic Map of Minnesota (1932) in the southwestern part of T. 108-12. Field work in 1950 in this vicinity by Thomas Holmes shows that the actual size of this area is much smaller than it is shown on the general map---probably only a few acres.

VI. DODGE COUNTY

Dodge County (Fig. 1) was not sampled during the present investigation. The bedrock formations within this county are largely covered by rather thick drift. There are only few bedrock exposures in the northeastern and eastern parts of the county along several branches of the Zumbro River. The limestones belong to the Platteville, Galena and Maquoketa formations. Maquoketa shaly limestone and Stewartville dolomite have been quarried at Wasioja and at Mantorville. Three partial chemical analyses of limestone from this county reported by Stauffer and Thiel (1933) show a rather high magnesia content.

VII. OLMSTED COUNTY

The large deposits of low magnesian limestone nearest to the Twin Cities are those in Olmsted County. Several analyses of the high grade limestones were reported by Stauffer and Thiel (1933, 1947). During the present investigation over 60 samples of limestone from 23 locations (Fig. 3) and 13 samples of underlying Decorah shale from the same, or nearby locations, were collected and

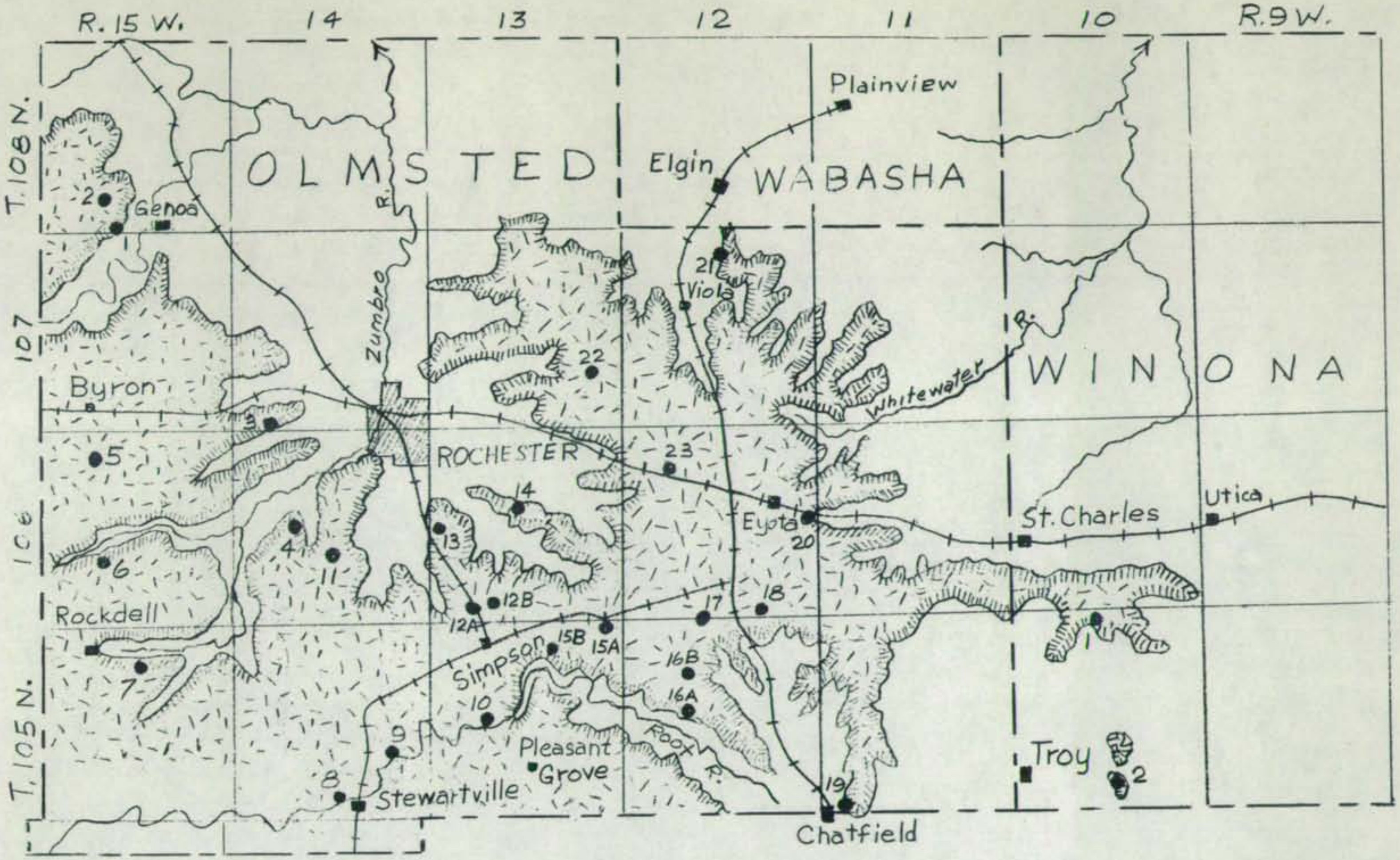

Fig. 3. Map of Olmsted and Western Winona Counties showing the distribution of Galena formation and stations sampled.

Galena formation modified after Geologic Map of Minnesota, 1932.

Location and number of stations sampled.

Railroad line.

0 3 6 Miles.

N

analyzed. All known low magnesian rock in this county occurs in the Prosser member of the Galena formation, whereas the Platteville, Oneota and Shakopee formations are dolomitic (Stauffer, 1950, Stauffer and Thiel, 1933). The Galena formation caps a plateau and occurs either as outcrops or beneath thin drift along a wide belt running from the northwestern corner of the county to the southeast (Fig. 3). This belt is deeply dissected by river valleys which leave a large irregularly shaped promontory in the central and eastern parts of the county at Viola-Eyota-Dover. In the west and south parts of the county the Prosser limestone is covered by the Stewartville dolomite.

STATION 1: The northwestern part of a plateau capped by Prosser beds is well exposed west of Genoa in several road cuts along S. A. R. 14 in the SE1/4 Sec. 33: 108-15. There 40 to 45 feet of bleached light-buff, moderate, to thin-bedded limestone outcrops on the marginal slope of the plateau above a 27 foot section of basal, shaly Prosser limestone. A terrace with poor exposures of Decorah shale extends eastwards from the slope in the SW1/4 Sec. 34: 108-15.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe^{++}	R_2O_3
Prosser Ls. upper	27-30 ft.	56	26.50	12.63	39.96	12.57	0.73	0.16	n.d.
" " middle	15 ft.	55	29.24	6.67	34.98	19.94	1.23	0.38	n.d.
" basal Ls-Sh.	27 ft.	54	30.09	4.01	26.70	31.98	1.05	0.25	n.d.
Decorah Sh.	G.S.	153	21.64	2.33	19.26	48.53	2.25	0.40	13.56

A somewhat lower magnesia content was reported for this vicinity by Stauffer and Thiel (1933: #23:133) in a composite analysis of three limestone samples along a county road one mile west of Genoa. (2.7% MgO).

STATION 2: About a 20 to 30 foot thickness of shaly, basal Prosser limestone is well exposed in a small valley in the SW1/4 Sec. 28: 108-15 and at Plum Creek in the NE1/4 Sec. 30: 108-15. A grab sample of the first sections shows

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	R_2O_3
Basal Prosser Ls.	G.S.	147	47.91	2.58	39.16	5.65	0.57	2.10

STATION 3: Numerous loose plates of thin-bedded, light-buff Prosser limestone were sampled on the upper part of a hill south of U. S. Highway 14 west of Rochester close to the SW corner of Sec. 32: 107-14. Decorah shale is poorly exposed lower on the slope at the highway.

Formation	Sample	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe^{++}	R_2O_3
Prosser Ls.	composite	32	49.49	4.21	37.86	9.41	0.55	0.11	n.d.
Decorah Sh. upper	G.S.	148	5.56	2.46	3.58	64.00	3.86	0.48	26.27
" " lower	G.S.	149	2.24	2.69	1.32	65.29	4.50	0.49	28.57

STATION 4: There is a large active quarry in the Prosser limestone in the SW1/4 Sec. 16: 106-14, west of S.A.R. "P". The rock is light gray, and thick-bedded. Some limestone beds are 2 to 3 1/2 feet thick. Poor exposures of shaly, basal Prosser limestone are located below at the quarry and along the road in the

NW1/4 Sec. 21: 106-14. Decorah shale is exposed nearby in the NE1/4 Sec. 16, at a small abandoned quarry in the Platteville limestone.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe^{++}	R_2O_3
Prosser Ls. upper	Not sampled								
"	15 ft.	65	41.64	3.95	31.88	14.25	0.72	0.16	n.d.
"	10 ft.	64	45.97	2.28	36.66	10.54	0.63	0.08	n.d.
"	10 ft.	63	38.61	1.24	29.42	25.34	0.96	0.07	n.d.
"	10 ft.	62	42.13	1.40	32.92	18.46	0.72	0.15	n.d.
" lower	10 ft.	61	43.68	4.29	36.94	9.93	0.56	0.22	n.d.
Decorah Sh.	G.S.	151	4.42	2.20	3.20	67.32	4.59	0.47	24.95

Stauffer and Thiel (1933) report the following data on a composite of 9 samples of Prosser limestone along the Highway in Sec. 21: 106-14 and Stewartville dolomite from W1/2 Sec. 18: 106-14.

Formation	Sample	# 23	CaO	MgO	Silica etc.	Iron oxide, etc.
Stewartville Dol.	G.S.	120	41.0	8.6	6.6	1.9
Prosser Ls.	composite	122	50.3	1.3	7.0	0.5

STATION 5: There is an area of high grade Prosser limestone south of Byron in the central part of the south half of Sec. 5; 106-15 along S.A.R. 5, south of the bridge about one and one-half miles from the railroad. The exposure consists of about 10 feet of badly weathered thin-bedded, light-buff limestone. Limestone interbedded with shaly limestone is exposed at the base of the section. Small seepage spots on the northern bank of the creek indicates the presence of the Decorah shale.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe^{++}
Prosser Ls. Top	10 ft.	57	46.25	1.71	36.50	11.33	0.81	0.08
" basal Ls.-Sh.	12-15 ft.	58	38.17	1.35	29.44	26.09	0.97	0.16
Covered to the creek level								

The Stewartville dolomite is not exposed in the section sampled, but Stauffer and Thiel (1933) report an analysis of this rock from a location 1 mile south of Byron.

Formation	Thickness	#23	CaO	MgO	SiO_2 etc.	Fe_2O_3 etc.
Stewartville Dol.	G.S.	121	46.3	5.0	6.3	0.7

STATION 6: Between Byron and Rockdell, Galena limestone is poorly exposed in the ditches along the county road between Secs. 20-21: 106-15. At the summit of the slope the rock is thin-bedded and bleached to a light-buff color. Below on the slope limestone seems to be interbedded with shaly beds and the rock is similar to the basal Prosser limestone but is high in magnesium.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Galena Ls. top of hill	10 ft.	66	45.42	3.25	33.88	9.72	0.80	0.09
Covered	5-7 ft.	Not sampled						
Galena Ls. shaly	14 ft.	67	42.01	5.96	34.96	9.44	0.63	0.13
" " "	10 ft.	68	43.80	3.11	32.68	10.00	0.64	0.15
" " "	10 ft.	69	43.87	4.60	38.20	9.54	0.73	0.24

STATION 7: Along the south branch of the Zumbro River at Rockdell the Prosser limestone is buried under the Stewartville dolomite (Stauffer and Thiel, 1947). Two large active quarries are located on the north and south sides of C.A.R. "W" about 1 1/2 miles east of Rockdell. The southern quarry in the NE1/4 Sec. 9: 105-15 exposes rather fresh gray limestone with beds up to 3 and 4 feet thick. Toward the top of the quarry, and on the slope, the rock weathers to a buff color and is thin-bedded. The drift is only a few feet thick.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Galena Ls. top weathered	10 ft.	74	32.62	16.06	43.06	3.88	0.40	0.18
" fresh	5 ft.	73	35.65	12.39	40.32	6.46	0.48	0.24
" "	5 ft.	72	43.32	6.26	40.36	7.03	0.53	0.05
" "	11 ft.	71	43.97	3.99	37.76	10.28	0.57	0.27
" very thick-bedded bottom	15 ft.	70	45.88	3.94	39.64	7.31	0.19	0.16

STATION 8: A high content of magnesia is present in the Stewartville dolomite at the type locality 1/2 mile above the dam on the north shore of Lake Florence in Stewartville. The rock is thick-bedded, buff-colored and has a pitted surface. It has weathered toward the top to thin beds.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Stewartville Dol.	24-25 ft.	29	44.57	8.29	42.58	2.44	0.49	0.03

STATION 9: Northeast of the village of Stewartville there is a good exposure of Galena limestone in an old quarry and natural outcrops on the north bank of the North Branch of the Root River at the bridge on both sides of S.A.R. No. 15 near the quarter corner between Secs. 23 and 26: 105-14. The rock is weathered, bleached and rather thin-bedded. The drift cover is only a few feet, but the upper part of the rock is dolomitic.

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Galena Ls. upper part	10-11	27	38.88	12.79	43.36	3.97	0.41	0.17
" " middle	9	25	40.81	8.38	40.00	9.12	0.49	0.15
" " "	9	23	47.91	1.61	37.25	11.14	0.55	0.07
" " lower	8	30	47.09	0.94	40.16	5.50	0.50	0.08

STATION 10: One of the best exposures of the Prosser limestone is located near the Root River along the S.A.R. No. 1, northwest of Pleasant Grove, Stauffer and Thiel (1933, #23:123-129) give several analyses mostly of grab samples of the

limestone exposed in a quarry in Sec. 20: 105-13. These are superceded by systematic samples collected by the same workers (1947).

Formation	Thickness	# Sl	CaO	MgO	SiO_2	R_2O_3
Prosser Ls., weathered	5 ft.	Not sampled				
" partly weathered	10 ft.	53D	47.76	2.83	6.22	2.22
"	10 ft.	53C	48.40	2.01	6.48	2.50
"	10 ft.	53B	49.02	2.06	5.92	2.16
" to river level	10 ft.	53A	44.94	11.61	12.50	3.20

During the present investigation a continuous 88 foot section beginning at river level was obtained by sampling in the lower part of the quarry and along S.A.R. No. 1 on both sides of the Root River in the N1/2 Sec. 20 and S1/2, S1/2 Sec. 17: 105-13 beginning at river level. Decorah shale is not exposed in this section and was sampled in the SW1/4 Sec. 15: 105-13 on the west bank of the river.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Galena Ls. top	8 ft.	86	42.48	9.13	40.24	5.83	0.33	0.15	n.d.
"	10 ft.	85	41.77	7.86	39.02	9.14	0.46	0.13	n.d.
"	10 ft.	84	45.25	5.24	38.26	6.40	0.32	0.07	n.d.
"	10 ft.	83	43.31	5.58	37.48	11.22	0.49	0.14	n.d.
"	10 ft.	82	44.98	4.02	36.60	10.63	0.47	0.09	n.d.
"	10 ft.	81	46.10	3.25	36.48	10.75	0.41	0.16	n.d.
"	10 ft.	80	47.58	1.89	36.76	9.28	0.40	0.08	n.d.
"	10 ft.	79	48.40	1.84	37.34	7.97	0.48	0.15	n.d.
" at river	10 ft.	78	41.04	1.42	31.34	20.54	0.59	0.12	n.d.
Decorah Sh.	G.S.	152	0.71	2.72	0.56	71.10	3.94	0.58	26.90

The quality of the rock in a horizontal direction within short distances seems to be constant. On the north bank of the river a three foot section was sampled twice from the same bed at a distance of about 200 feet and showed only slight variation in the chemical composition.

Sample	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
1st sample	3 ft.	76	39.69	1.32	30.60	24.21	0.66	0.17
2nd sample	3 ft.	77	39.01	1.29	30.80	24.69	0.83	0.14

<u>STATION 11</u>: There are several flat outcrops, probably of basal Prosser limestone, along the county road on hill slopes in S1/2 of Sec. 27: 106-14 close to U. S. Highway 63. The rock has bleached to a light-buff color and is thin-bedded. Some layers appear shaly.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Basal? Prosser Ls.-Sh.	35 ft.	136	42.87	0.70	31.62	20.28	1.20	0.16	2.94

STATION 12A and B: North of Simpson there are several exposures of high grade Prosser limestone mostly under thin drift. Locally there may be a thin capping of dolomite.

12A: One such exposure is located at the railroad underpass on both sides of the county road between the S1/2 of Secs. 31 and 32: 106-13. The rock exposed in this 20 foot section is thin-bedded and weathered to a light-buff color.

12B: About 3/4 miles eastwards from Station 12A a 7 to 10 foot thickness of similar thin-bedded, light-buff limestone was sampled in a creek bed south of C.A.R. "L" in the SE1/4 Sec. 32: 106-13.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Prosser Ls (12A)	20 ft.	137	49.70	0.53	36.22	9.00	0.64	0.15	1.02
Prosser Ls (12B)	7-10 ft.	31	50.63	1.75	38.98	6.82	0.39	0.15	n.d.

STATION 13: Prosser limestone is well exposed in an old quarry in the SW 1/4, NW1/4 Sec. 19: 106-13. The rock is weathered, thin to moderate-bedded, and light colored. About 20 feet below the floor of the quarry on the slope there is a terrace caused by the presence of the Decorah shale. A grab sample of this shale was collected in a small gully.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Covered	10 ft.	Not sampled							
Prosser Ls.	30-35 ft.	7	44.64	1.20	33.11	14.37	0.80	0.09	n.d.
Covered		Not sampled							
Decorah Sh.	G.S.	179	3.18	2.01	7.45	51.46	5.63	n.d.	26.44

STATION 14: Several deposits of high grade limestone occur in the large irregularly shaped promontory of the Prosser formation east of Rochester. A good exposure of topmost, bleached, light-buff, thin-bedded limestone overlying 50 feet of basal, shaly, interbedded limestone and shaly limestone was sampled on the slope along the secondary road between Sec. 15-16: 106-13 in the SW1/4 Sec. 15. The underlying Decorah shale does not crop out in this section, but its basal part is well exposed and has been sampled together with the limestone in a crushed rock quarry in Platteville formation close to the center of Sec. 21 north of U. S. Hy. 52.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Covered	10-15 ft.								
Prosser Ls.	20 ft.	10	46.87	0.46	32.89	15.43	0.64	0.08	n.d.
" basal Ls.-Sh.	45-50 ft.	5	41.81	0.39	28.92	20.62	0.81	0.17	n.d.
Covered									
Decorah Sh. lower	G.S.	154	0.68	2.51	0.32	70.06	4.18	0.46	28.21
Platteville Ls.	20 ft.	26	39.47	4.93	37.40	11.53	0.80	0.72	n.d.

STATION 15A and B: A. There is a small exposure of thin-bedded, light buff Prosser limestone in a small valley at Predmore in the NE1/4, NW1/4 Sec. 1: 105-13 only a few tenths of a mile from the railroad line south of U.S. Hy. 52.

B: On the Geologic Map of the State of Minnesota (1932), the Galena formation at Predmore is incorrectly shown as a very narrow strip. Actually the Prosser capped plateau extends almost to the Root River where there are a few exposures of the basal, shaly Prosser limestone in roadcuts along the county road in the central part of the S1/2 Sec. 3: 105-13 on the north side of the River.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls. (15A)	6-10 ft.	2	49.82	1.67	36.78	7.83	0.33	0.07
" basal Ls.-Sh. (15B)	10-15 ft.	75	44.40	0.89	33.82	16.32	0.71	0.16

STATION 16: The best section of the Prosser limestone is that along S.A.R. 7 on the north side of the Root River north of Cummingsville in the SE1/4 Sec. 21 and SW1/4 Sec. 22: 105-12. There are two quarries close to the top of the slope with good exposures of moderate to thick-bedded, gray Prosser limestone. Toward the top of the quarry the rock is weathered, thin-bedded and a light buff color. Several limestone slabs are also scattered on the surface on the slope higher than the quarry, while three road cuts on the slope below the quarries show an excellent exposure of the basal shaly Prosser limestone overlying the Decorah shale. At this location over 80 feet of limestone contains less than one per cent magnesia as shown below.

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Prosser Ls. top of hill, float	50-75 chips	9	51.02	0.73	36.01	7.30	0.39	0.07	n.d.
Prosser Ls., weathered upper part	15	4	50.60	0.33	35.74	8.14	0.32	0.06	n.d.
" middle	18-20	3	47.52	0.42	32.81	12.91	0.56	0.15	n.d.
" at entrance of quarry	3-4	28	49.36	1.23	37.66	10.35	0.48	0.08	n.d.
" basal Ls.-Sh.	45 ft.	1	46.49	0.68	31.46	13.81	0.64	0.16	n.d.
Decorah Sh. upper	G.S.	146	4.10	2.56	2.44	63.14	4.50	0.64	28.12
" lower	G.S.	147	0.75	2.45	0.16	72.05	4.02	0.60	28.49

Spot samples from the same section	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Basal Prosser Ls.-Sh.	G.S.	8	47.73	0.51	34.35	12.46	0.56	0.16	n.d.
" single Ls. bed	G.S.	11	50.23	0.65	37.22	9.76	0.55	0.16	n.d.
" lowermost Ls. bed	G.S.	6	48.53	2.32	37.00	4.81	0.72	0.64	n.d.

STATION 16A: There are several good exposures of the Prosser limestone, especially its basal shaly part, along U. S. Hy. 52 (old state highway 20) in Sections 9, 10 and 15: 105-12. Stauffer and Thiel (1933) report several analyses of high grade limestone as follows.

Formation	Samples	# 23	CaO	MgO	Oxide (Fe, etc.)	Silica
Prosser Ls. upper	G.S.	45	52.45	0.59	0.56	5.33
" " lower	G.S.	46	52.45	0.69	0.66	4.94
" basal Ls.-Sh.	G.S.	44	52.65	0.74	0.46	4.69
" " "	G.S.	43	51.60	0.81	0.53	5.88
" " "	G.S.	42	52.70	0.80	0.50	4.31
Decorah Ls. bed	G.S.	13	51.95	1.09	4.96	

STATION 17: In the vicinity of Planks, a railroad junction, the drift is thin and there are many flat outcrops of the Prosser limestone in road ditches. The best exposure was sampled on a gentle slope along the road between Sec. 33: 106-12 and Sec. 4: 105-12. The rock is thin-bedded and is bleached to a light buff color.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls.	15-20 ft.	24	50.41	0.74	38.32	8.16	0.38	0.04

STATION 18: There is an old quarry in the Prosser limestone on the eastern slope of a steep valley in the SE1/4, SW1/4 Sec. 35: 106-12. The rock is moderate to thick-bedded rather fresh, light gray limestone. Numerous flat outcrops of weathered thin-bedded, bleached limestone are present along the road in the SW1/4 SW1/4 of Sec. 35 on the western slope of the same valley.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls. top	30 ft.	21	50.32	0.86	36.50	8.52	0.40	0.05
	few feet covered							
" " bottom	15 ft.	22	38.13	9.45	39.34	10.77	0.56	0.08

STATION 19: Several analyses of grab samples of the Prosser limestone of excellent quality are reported by Stauffer and Thiel (1933) at Chatfield on Waterworks hill.

Formation	Sample	# 23	CaO	MgO	Silica etc.	oxide (Fe, etc.)
32 ft. Prosser Ls.						
upper	G.S.	38	54.25	0.59	1.96	0.49
middle	G.S.	39	52.55	0.46	4.47	0.87
lower	G.S.	40	52.10	0.51	4.75	0.54
21 ft. Prosser partly covered						
upper	G.S.	36	51.70	0.38	6.01	0.74
lower	G.S.	37	52.40	1.35	2.13	1.09
Decorah Ls. beds	G.S.	35	51.60	0.43	5.61	0.59
" "	G.S.	34	52.30	0.70	4.17	0.71
" "	G.S.	33	52.50	0.77	3.75	0.88

The area around Chatfield was not examined during the present work nor during the study report in Summary Report #1 because of a lack of good outcrops, but one grab sample of the lower part of the Decorah shale was taken from the overburden of a crushed rock quarry in Platteville limestone south of State Highway 74 in S1/2 of SE1/4 Sec. 32: 105-11.

Formation	Sample	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Decorah Sh. lower	G.S.	150	0.73	2.54	0.16	65.47	4.57	0.61	29.02

STATION 20: In the vicinity of Eyota the drift is rather thin and several small outcrops of the Prosser limestone are scattered over a wide area. One of the best exposures is located on the slope of the south bank of the south branch of Whitewater River along the county road close to the SE corner of Sections 13: 106-12. The rock is thin-bedded, light buff Prosser limestone. The Decorah shale is not exposed in this section but probably occurs at river level.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls. top	10 ft.	18	50.08	0.96	36.42	7.80	0.64	0.07
" basal Ls.-Sh.	15-20 ft.	20	44.41	1.00	31.88	16.32	0.72	0.16

STATION 21: There is a flat exposure of shaly Prosser limestone south of the county road on a hill slope in the NW1/4, NW1/4 of Sec. 10: 107-12. The rock is thin-bedded and bleached to a light buff color. The Decorah shale is not exposed in this section, and was sampled on a hill in the NE1/4 of Sec. 9: 107-12.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Basal? Prosser Ls.-Sh.	15-20 ft.	16	50.71	0.67	38.34	7.21	0.48	0.16	n.d.
Decorah Sh. upper	G.S.	156	3.16	2.17	2.04	63.48	5.47	0.59	27.04
" " middle	G.S.	155	1.75	2.64	0.58	63.84	4.66	0.55	29.97

STATION 22: An old quarry in the Prosser limestone is located on the north bank of Silver Creek in the middle part of W1/2 of Sec. 25: 107-13. The rock is gray, moderate to thick-bedded, with some shaly layers but is thin-bedded and buff where weathered.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Drift and weathered Ls.	5-8 ft.	Not sampled						
Prosser Ls. upper	10-15 ft.	59	40.98	1.46	31.76	20.26	0.64	0.17
" " lower	15ft.	60	45.12	1.24	33.92	13.74	0.14	0.32

A composite analysis of four samples taken from 2 beds of the Prosser limestone in Sec. 29: 107-13 along county road of 11th Avenue, 2 1/2 miles NE of Rochester is reported by Stauffer and Thiel (1933) (#23:131) together with a grab sample of a limestone layer from the Decorah shale on State Highway #7 (probably U.S. 14) 3 1/2 miles east of Rochester (#23:14).

Formation	Sample	# 23	CaO	MgO	Silica, etc.	Oxide (Fe, etc.)
Prosser Ls.	composite	131	51.5	0.8	6.2	0.6
Decorah Ls. bed	G.S.	14	51.8	0.6	6.34	

STATION 23: There is an active crushed rock quarry in the central part of Sec. 8: 106-12, north of U. S. Highway 14 at the railroad underpass. The rock exposed is thin to medium-bedded, gray to buff, somewhat shaly Prosser limestone. Stauffer and Thiel (1947) report the following chemical data on the rock in this quarry.

Formation	Thickness	# S1	CaO	MgO	SiO_2	R_2O_3
Drift	5 ft.	Not sampled				
Prosser Ls. top-most weathered	4 ft.	Not sampled				
Prosser upper	10 ft.	49c	49.22	1.94	5.98	2.46
" middle	10 ft.	49b	47.40	2.30	7.34	2.92
" lowermost	10 ft.	49a	36.72	1.58	22.74	6.20

VIII. WINONA COUNTY

There are five limestone formations which crop out in Winona county. (Fig. 3). The St. Lawrence formation occurs as a narrow belt on steep bluffs along the main river valleys. It is dolomitic and high in insoluble material. The Oneota and Shakopee formations cover large areas in the county and are exposed in numerous bluffs, but previous investigations showed a high magnesia content in both (Stauffer and Thiel, 1933; Stauffer, 1950). The Platteville formation forms small outliers of dolomitic limestone in the southwestern corner of the county.

The only deposits of high calcium limestone are present in the Prosser member of the Galena formation which occurs as one large and two or three smaller erosional remnants in T: 105-10 and the south 1/2 of T: 106-10 between St. Charles, Utica and Troy. The remnants are the easternmost extensions of the large area of Prosser east of Rochester. During the present investigation 3 samples of the Prosser limestone and 2 samples of the underlying Decorah shale were collected from 2 localities (Fig. 3) because there are no other good outcrops or active quarries suitable for better sampling.

STATION 1: A poor exposure of Prosser limestone is located on the southern margin of the plateau in the NW1/4, NW1/4 Sec. 3 and NE1/4, NE1/4, Sec. 4: 105-10 on both sides of C.A.R. 17 close to the top of a slope. The rock is exposed in small roadcuts and road ditches and on a hill slope west of the road. It is bleached to a light buff and consists of moderate to thin-bedded limestone. To the south, lower on the slope at a small spring east of the road in the SW1/4, NW1/4 Sec. 3, there is a poor exposure of underlying Decorah shale.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Prosser Ls.	15 ft.	15	52.04	0.95	38.06	4.76	0.32	0.11	n.d.
Decorah Sh.	G.S.	129	1.98	2.50	1.23	65.97	4.34	0.56	21.26

STATION 2: A small old quarry in an isolated outlier of the Prosser limestone occurs in the middle of the E1/2 Sec. 34: 105-10, some hundreds of feet west from the road in a small wooded valley. The quarry exposes 7 to 10 feet of thin-bedded, light buff limestone probably belonging to the lowermost part of the Prosser formation.

Numerous limestone slabs and a poor exposure of shaly limestone are present higher on the opposite valley slope. At the bottom of the valley there is a small spring which probably indicates the presence of the underlying, but unexposed, Decorah shale. This shale was sampled a few tenths of a mile to the north along the road in the NE1/4 of Sec. 34.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Prosser Ls. float	15 ft.	17	51.63	0.81	38.18	5.04	0.49	0.08	n.d.
" in the quarry	10 ft.	19	49.13	1.94	37.44	8.06	0.65	0.15	n.d.
Decorah Sh.	G.S.	124	0.51	2.57	0.14	67.31	4.26	0.49	20.87

A similar outlier of the Prosser limestone seems to be present also in Secs. 26-27: 105-10.

IX. MOWER COUNTY

Most of Mower County (Fig. 1) is covered with drift and gravel deposits overlying the Cedar Valley limestone of Devonian age. There are only a few natural outcrops and rock quarries within the county. Both high and low-magnesian limestone have been reported in the Cedar Valley formation (Stauffer and Thiel, 1933, 1947; Stauffer, 1950). The best exposures of high grade Cedar Valley limestone were described by Stauffer and Thiel (1933, #23; 23, 24, 25, 41) at the Fowler and Pay quarry and (1947) at the Hickok quarries in the SE1/4 Sec. 27: 101-14, and at Fowler and Pay quarry in Sec. 35: 101-14.

Rock	Thickness	# Sl	CaO	MgO	SiO_2	R_2O_3
Hickok quarries						
Soil and Ls. gray to white Ls.	4 ft.	Not sampled				
Ls. gray to white	5 ft.	42G	55.66	0.35	1.24	0.62
" brown	5 1/2 ft.	42F	37.72	13.34	2.88	2.00
" light gray	4 ft.	42E	54.86	0.63	1.36	0.66
" impure	1 ft.	42D	41.83	10.62	2.08	1.70
" gray	3 1/3 ft.	42 C	54.96	0.74	1.00	0.52
" brown sandy	3 1/3 ft.	42 B	36.48	13.26	4.90	2.24
Covered	1 ft.					
Ls. brown	10 ft.	42A	37.56	14.16	2.82	1.16
Fowler and Pay Quarry						
Soil and limestone	5 ft.	Not sampled				
Limestone gray	8 3/4 ft.	43A&B	55.54	0.35	1.24	0.60

As the available exposures in Mower County were sampled by Stauffer and Thiel only a few additional grab samples of Cedar Valley limestone were collected during the present investigation.

Rock and Location	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Buff cavernous Ls. central part Sec. 36: 104-14	141	30.29	20.05	45.68	1.74	0.47	0.25	0.07
Hard dense white Ls, quarry SW1/4 Sec. 27: 101-14	138	54.38	0.35	38.74	1.44	0.32	0.12	0.21
Hard dense white Ls. SW1/4 Sec. 35: 101-14	139	54.03	0.36	35.86	2.05	0.31	0.14	0.06
Dense Ls. from a quarry in N1/2 Sec. 9: 103-14	142	52.55	1.90	40.12	1.95	0.64	0.26	0.04

X. FILLMORE COUNTY

According to Stauffer and Thiel "Fillmore county is foremost in the state in its supply of high-grade limestone" (1933, p. 55, 1947). During the present investigation in this county 31 samples of limestone from 16 localities and 15 grab samples of underlying shale from the same or nearby localities (Fig. 4) were collected and analysed. The main deposits of high grade limestone occur in the Prosser member of the Galena formation, and appear at the surface in a belt which extends diagonally across the county westwards of the line from Chatfield to Mabel. The belt, especially in its easternmost part, is deeply dissected by stream valleys. Toward the west and southwest the Galena formation is overlapped by the younger Maquoketa and Cedar Valley formations, while toward the east and northeast the older limestone formations, namely the Platteville, Shakopee, Oneota and St. Lawrence are exposed. Though locally the St. Lawrence and Platteville limestones are low in magnesium (Stauffer and Thiel, 1933), their practical importance is limited because of large content of insolubles or by the small size of the deposits. No high grade limestone has been found in the Cedar Valley formation in this county, but some occurs in the Maquoketa formation.

STATION 1: There are two large old quarries and road cuts in S1/2 Sec. 9: 106-12 along State Highway 74 north of Lost Creek. The rock in the quarries is rather thick-bedded and gray but it weathers to a light buff and becomes thin-bedded toward the top of the quarry and in road cuts on the slope. The sampling was done in the western quarry and in the road cuts. The lowest 5 to 6 feet of the quarry wall were covered by rubble and could not be sampled. The basal shaly Prosser limestone and the Decorah shale are not exposed in this area. The shale was sampled about 2 1/2 miles west-southwest of the quarry in the SW1/4, NW1/4 Sec. 13: 106-12.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Prosser Ls. upper	17-20 ft.	97	48.05	2.41	39.48	7.76	0.40	0.16	n.d.
" lower	8-10 ft.	96	47.08	2.13	37.32	9.87	0.42	0.17	n.d.
Decorah Sh. upper	G.S.	163	10.18	1.83	7.62	53.28	3.99	0.65	27.64
" " middle	G.S.	164	1.28	1.96	0.34	67.52	4.83	0.57	23.76

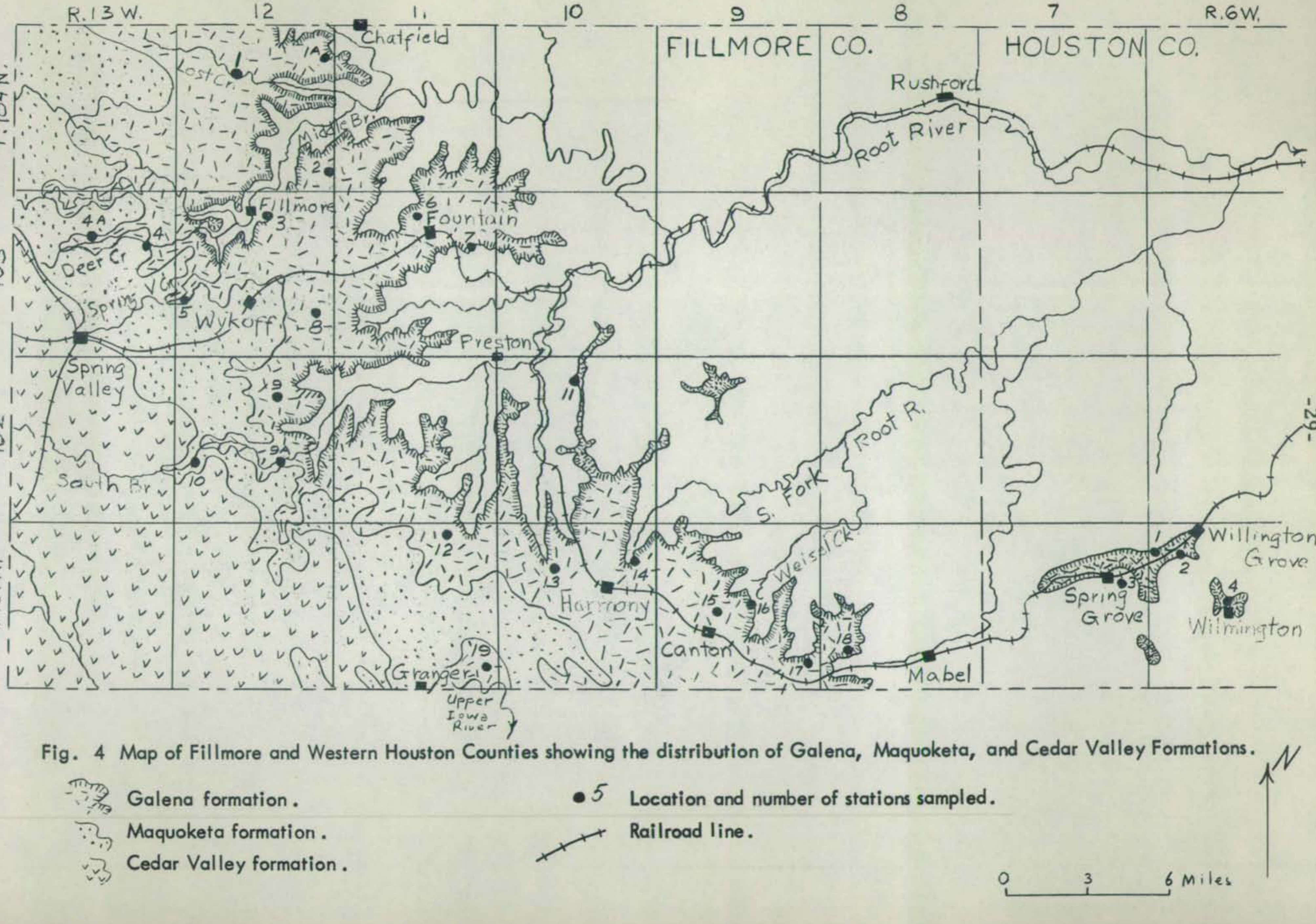

Fig. 4 Map of Fillmore and Western Houston Counties showing the distribution of Galena, Maquoketa, and Cedar Valley Formations.

Galena formation.

Maquoketa formation.

Cedar Valley formation.

● 5 Location and number of stations sampled.

Railroad line.

0 3 6 Miles

N

The same area was previously sampled by Stauffer and Thiel (1947) who reported:

Formation	Thickness in feet	# S1	CaO	MgO	SiO_2	R_2O_3
Drift	10					
Stewartville dol.	21					
"	7	46F	44.50	5.77	7.22	2.28
"	5	} 46E	42.86	6.72	7.60	2.32
Prosser Ls.	5					
"	10	46D	46.86	3.09	8.04	2.32
"	10	46C	49.68	2.82	4.90	1.94
"	10	46B	49.10	2.63	5.06	1.96
"	7	46A	41.66	3.44	14.28	4.12
Covered	10					

STATION 1A: An exposure of the Prosser limestone above a crusher along the old S.A.R. #6 west of Chatfield, was sampled by Stauffer and Thiel (1933)

Formation	Sample	# 23	CaO	MgO	Silica etc.	Oxides (Fe, etc.)
Stewartville dol. (probably a mistake)	G.S.	107	50.4	1.6	5.9	0.4
Prosser Ls.	G.S.	108	50.6	1.8	4.9	0.3

STATION 2: There is a good exposure of high-grade Prosser limestone in a large quarry on the south bank of the Middle Branch of the Root River in the NE1/4 Sec. 36: 106-12 west of C.A.R. "C". The rock is thick-bedded, light gray limestone but becomes thin-bedded and buff colored toward the top. In its upper part it is somewhat cherty. The basal shaly Prosser limestone and the underlying Decorah shale are not exposed in the quarry. A grab sample of the shale was collected along a road in the NE1/4 Sec. 30: 104-12.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Prosser Ls. upper	Not sampled								
" middle cherty	15 ft.	101	50.87	1.12	39.20	6.69	0.38	0.06	n.d.
" lower	10 ft.	100	49.33	1.67	39.48	7.16	0.24	0.09	n.d.
Decorah Sh. upper	G.S.	165	4.47	1.64	2.04	68.77	4.85	0.31	27.60

STATION 3: Prosser limestone is exposed in the vicinity of Fillmore north of C.A.R. "E" at an old quarry in the SE1/4 SW1/4 Sec. 3: 103-12. The rock is light-gray and thick-bedded but weathers to a buff color and becomes thin-bedded toward the top. Some road cuts below the quarry expose basal shaly Prosser limestone. Below these cuts at the entrance into the village there is a small terrace with a few springs over the beds of Decorah shale in the S1/2 SW1/4 Sec. 3.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Drift	3-5 ft.								
Prosser Ls., top weathered	3 ft.	Not sampled							
Prosser middle	15 ft.	103	50.82	0.62	38.46	7.08	0.40	0.03	n.d.
" lower	8 ft.	102	49.68	0.70	38.41	8.12	0.47	0.08	n.d.
" basal Ls.-Sh.		Partially covered							
Decorah sh.	G.S.	157	1.65	1.28	0.59	76.34	5.46	0.40	26.71

STATION 4: Stauffer and Thiel (1933, 1947) report deposits of high grade Prosser limestone on the south bank of Deer Creek in Sec. 11-12: 103-13. The Prosser is overlain by a rather thick covering of Stewartville dolomite. Several analyses reported in 1933 (#23: 114, 19, 18, 16) were superceded by systematic samples (1947) as shown below.

Formation	Thickness	# S1	CaO	MgO	SiO_2	R_2O_3
Prosser Ls.	50-60 ft. above creek	44F	49.40	3.11	5.06	1.70
" "	40-50 " "	44E	46.20	4.22	6.86	2.10
" "	30-40 " "	44D	50.00	2.11	5.34	1.74
" "	20-30 " "	44C	51.22	1.83	4.22	1.60
" "	10-20 " "	44B	50.32	1.74	4.54	2.00
" "	0-10 " "	44A	50.68	1.09	5.68	2.00

STATION 4A: Upstream from Station 4 the Prosser limestone is capped by the Stewartville dolomite and Maquoketa formation. One of the best sections of these beds is described by Stauffer and Thiel (1933) at Lime City 2.8 miles north of Spring Valley along Deer Creek.

Formation	Sample	#23	CaO	MgO	Silica, etc.	Oxide (Fe, etc.)
Maquoketa Ls.-Sh.	G.S.	66	52.0	0.6	5.3	0.3
" "	G.S.	65	45.5	0.9	16.0	0.8
Stewartville dol.						
" upper	G.S.	64	47.8	6.1	1.7	0.4
" middle	G.S.	63	45.7	7.5	2.4	0.3
" lower	G.S.	62	41.7	11.0	2.3	0.3
Prosser Ls.	G.S.	61	48.6	5.1	2.5	0.3

STATION 5: The type section of the Prosser limestone is located west of Wykoff along Spring Valley (Prosser) Creek. Several chemical analyses of rock were reported from this vicinity by Stauffer and Thiel (1933).

Formation	Sample	# 23	CaO	MgO	SiO_2	Oxide (Fe, etc.)
Stewartville basal	G.S.	32	50.20	2.41	4.68	0.94
Prosser Ls. upper	G.S.	31	52.35	1.20	4.16	0.37
" upper middle	G.S.	30	49.40	2.90	6.15	0.20
" middle	G.S.	29	53.40	0.86	2.78	0.23
" lower middle	G.S.	28	53.40	0.85	2.87	0.12
" basal	G.S.	27	44.70	0.81	17.90	0.58
Prosser Ls.	composite	113	50.2	1.7	6.8	0.5

STATION 6: There is a large active quarry at Fountain in the SW1/4 SW1/4 Sec. 3; 103-11 north of C.A.R. "E". Over 55 feet of a thick-bedded, gray, argillaceous limestone are well exposed in 4 benches. The Decorah shale is also well exposed about a mile eastwards in the road cuts at the crossing of Rice Creek and C.A.R. "E" in NE1/4 NW1/4 Sec. 9: 103-11.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Drift	8 ft.								
Prosser Ls. weathered	about 15 ft.	Not sampled							
" upper	18 ft.	113	49.46	1.33	37.94	8.42	0.39	0.07	n.d.
" middle	18 ft.	112	48.98	1.65	37.62	8.00	0.24	0.15	n.d.
" lower	10 ft.	111	43.18	2.23	33.38	16.23	0.40	0.16	n.d.
Decorah sh. upper	G.S.	171	7.03	2.10	2.80	61.40	3.66	0.61	26.82
" " middle	G.S.	170	3.35	2.03	2.68	65.34	3.54	0.63	27.08

Stauffer and Thiel (1947, 1933) report the following chemical data on the rock sampled in the same area along U. S. Highway #52 (old #20) at the railroad underpass and in a quarry at the northwest corner of town.

Formation	Thickness	# S1	CaO	MgO	R_2O_3	SiO_2
Drift	27 ft.	Not sampled				
Prosser Ls. top	10 ft.	48C				
"	10 ft.	48B	52.48	0.67	1.46	4.52
"	10 ft.	48A	52.22	0.83	1.60	4.34
"	3 ft.	47C	52.78	0.49	1.68	4.04
"	10 ft.	47B	54.12	0.51	1.30	2.54
" bottom	10 ft.	47A	53.38	0.57	1.80	2.76

Formation	Sample	#23	CaO	MgO	Oxide (Fe, etc.)	Silica, etc.
Prosser Ls. on Hy. 1 mile south of Fountain	composite	105	53.6	0.4	0.4	2.9
Lower Galena Ls.	G.S.	17	52.77	0.96	3.08	
Decorah Ls. bed on Hy. 1 mi. south of Fountain	G.S.	93	51.8	1.0	0.5	5.1
Platteville Ls. on Hy. 1 mi. south of Fountain	composite	106	49.7	0.7	0.6	8.5

STATION 7: About 17 feet of weathered basal shaly Prosser limestone is exposed east of Fountain in an old small quarry at the W1/4 corner of the section line between Secs. 12 and 13: 103-11 west of the county road. There is a small terrace and a poor outcrop of Decorah shale somewhat below the quarry on the opposite side of the valley.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Basal Prosser Ls.-Sh.	17 ft.	92	49.63	0.78	38.02	7.75	0.41	0.14	n.d.
Decorah shl, upper	G.S.	166	0.66	2.12	0.40	68.48	4.10	0.63	27.06

STATION 8: There is a quarry in the Prosser limestone in the SE1/4 NW1/4 Sec. 25: 103-12 north of C.A.R. "C" about 1 1/2 miles south of the railroad line. The rock appears as beds of gray limestone 1 to 2 feet thick. Toward the top it weathers into thin-bedded, buff limestone.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls. top weathered	Not sampled							
" upper weathered	5 ft.	110	52.52	0.57	38.44	4.75	0.32	0.11
" middle, fresh	10 ft.	109	50.48	0.70	38.22	7.21	0.40	0.06
" bottom, fresh	10 ft.	108	50.60	0.98	38.70	6.82	0.33	0.08

STATION 9: High grade Prosser limestone occurs along the south branch of the Root River. An old quarry in the SE1/4 NE1/4 Sec. 10: 102-12, was sampled. The rock exposed is a thick-bedded, light gray limestone but thin-bedded, and light buff when weathered. There are some thin cherty layers and nodules in the upper part of the section.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls. upper	10 ft.	95	51.42	0.57	38.76	5.89	0.31	0.04
Prosser Ls. lower	10 ft.	94	51.19	1.29	39.44	5.43	0.33	0.09

STATION 9A: High grade Prosser limestone was sampled by Stauffer and Thiel (1947) in a quarry several hundred feet downstream from the "Stone Arches" bridge across the South Branch of the Root River in the S1/2 of Sec. 22: 102-12

Formation	Thickness	#S1	CaO	MgO	SiO_2	R_2O_3
Prosser Ls. top	6 ft.	45B	48.28	3.66	5.54	1.58
" bottom	16 ft.	45A	50.12	2.31	4.96	1.46

STATION 10: Upstream from Stations 9 and 9A Prosser limestone becomes buried under the Stewartville dolomite and Maquoketa formation. About a 7 foot section of the Maquoketa formation occurs at the entrance of Mystery Cave in the SE1/4 Sec. 19: 102-12. It is composed of numerous limestone and shaly beds.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Maquoketa form.	7 ft.	91	37.30	2.01	30.08	25.44	0.80	0.32

STATION 11: South and southeast of Preston the Galena capped plateau is deeply dissected in narrow ridges. A deeply weathered, thin-bedded and bleached Prosser limestone is exposed in a roadcut on the northern side of U. S. Highway 52 at a schoolhouse in SW1/4 of SW1/4 of Sec. 3: 102-10. Samples of the Decorah shale were taken a few miles to the east in the E1/2 of Sec. 7: 102-9 on the north side of S.A.R. 5.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Prosser Ls.	10 ft.	90	53.21	0.65	38.72	3.04	0.32	0.05	n.d.
Decorah Sh.	G.S.	168	2.48	1.50	1.68	72.16	4.66	0.36	27.62

High grade Prosser limestone from an area 2 1/2 miles southwest of Preston was reported by Stauffer and Thiel (1933) as follows.

Formation	Sample	# 23	CaO	MgO	Oxides (Fe, etc.)	Silica, etc.
Prosser Ls.	G.S.	26	53.85	0.51	0.42	2.50

STATION 12: The Prosser limestone is well exposed in a large active quarry east of S.A.R. 10 in the W1/2 of NW1/4 of Sec. 2: 101-11. Only the lowest 25 feet of the quarry was sampled. The exposed rock is a very thick-bedded, gray, argillaceous limestone. Single beds range from 1 1/2 to 3 feet in thickness. The upper part of Decorah shale was sampled at section line between Sec. 24 and 25: 102-11 westward from S.A.R. 11.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Prosser Ls.	25 feet	93	50.81	1.25	38.96	6.08	0.24	0.12	n.d.
Decorah sh. upper	G.S.	167	3.02	2.25	1.92	61.35	4.53	0.51	28.67

Several grab samples were reported by Stauffer and Thiel (1933) as follows:

Formation and location	Sample	# 23	CaO	MgO	Oxides (Fe, etc.)	Silica, etc.
Stewartville Dol. Sec. 12:101-11	G.S.	92	37.0	13.6	0.5	5.1
" S.A.R. 10 Sec. 3:101-11	G.S.	110	45.4	6.7	0.5	5.2
Upper Prosser or lower Stewartville Sec. 11:101-11	G.S.	96	43.2	5.8	0.6	10.0
Upper Prosser Ls. Sec. 11:101-11	G.S.	95	52.4	1.0	0.2	4.1
Prosser Ls. S.A.R. 10, Sec. 3:101-11	?composite	109	53.9	0.7	0.2	2.4
Prosser Ls. SW1/4 Sec. 1:101-11	G.S.	91	52.5	0.9	0.4	4.1

STATION 13: A large quarry is located at the village of Big Spring on the upper part of the slope of the valley of Camp Creek in the N1/2 SW1/4 Sec. 9: 101-10, south of the C.A.R. "F". The rock is gray, thick-bedded Prosser limestone but is buff and thin-bedded where weathered. Decorah shale was sampled on the eastern side of C.A.R. "F" in the NE1/4 Sec. 5: 101-10.

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Prosser Ls. weathered	13-15	Not sampled							
" fresher	13	117	51.12	0.62	39.64	7.26	0.34	0.08	n.d.
"	15	116	51.50	0.78	39.10	5.91	0.23	0.04	n.d.
"	20	115	44.18	1.30	33.91	16.69	0.31	0.17	n.d.
" lowermost	15	114	48.40	1.25	36.82	9.44	0.32	0.08	n.d.
Decorah sh.	G.S.	169	1.59	1.62	0.28	72.52	4.65	0.50	26.25

Channel samples from the same quarry was reported by Stauffer and Thiel (1947) as follows:

Formation	Thickness	# S1	CaO	MgO	SiO_2	R_2O_3
Covered etc.	8 ft.	Not sampled				
Prosser Ls. Top	10 ft.	50C	53.24	0.41	3.82	1.28
" middle	10 ft.	50B	51.10	0.74	6.16	1.96
" bottom	10 ft.	50A	45.24	1.33	12.32	3.62

STATION 14: A section of high grade Prosser limestone from a roadside quarry in the NW1/4 Sec. 12: 101-10 near Harmony was reported by Stauffer and Thiel (1947).

Formation	Thickness	# S1	CaO	MgO	SiO_2	R_2O_3
Overburden	8 ft.	Not sampled				
Prosser Ls. top	10 ft.	51B	52.18	1.40	3.88	1.04
" bottom	10 ft.	51A	52.98	0.49	4.06	1.22

STATION 15: The basal shaly Prosser limestone is exposed along Wisel Creek east of C.A.R. "G", north of the village of Canton in the NW1/4 NW1/4 Sec. 21: 101-9. The rock exposed is weathered, buff-colored limestone interbedded with shaly limestone beds at the base of the section.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls. and Ls.-Sh.	10-15 ft.	105	47.92	0.67	36.82	11.58	0.49	0.05
Covered	about 5 ft.							
Prosser basal Ls.-Sh.	5 ft.	104	46.06	0.95	37.91	12.03	0.43	0.16

STATION 16: A large exposure of Prosser limestone is present in an old quarry at Canton in the S1/2 Sec. 15: 101-9 north of S.A.R. 6. The quarry face is 55-60 feet high. The rock is mostly very thick-bedded (3 to 5 ft.), gray limestone with few shaly layers. In the uppermost part of the wall it is bleached and thin-bedded because of the weathering. The drift is 9 to 10 feet thick. Grab samples

of the Decorah shale were taken at the road between Secs. 22 and 23: 101-9 (M.E.S. #161, 162) and in a roadcut NW1/4 SW1/4 Sec. 32: 102-9 (M.E.S. #162).

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Prosser Ls. upper	Not sampled								
" middle part	20-25 ft.	107	47.98	1.83	37.36	9.26	0.31	0.10	n.d.
" lower part	10 ft.	106	53.10	0.62	40.00	2.59	0.32	0.04	n.d.
Decorah upper	G.S.	162	1.57	1.76	0.80	68.99	4.02	0.47	28.78
" "	G.S.	161	1.20	1.93	0.38	68.15	4.10	0.34	25.42
" lower part	G.S.	160	1.99	1.62	1.14	74.22	3.70	0.32	26.00

The same locality was previously sampled by Stauffer and Thiel (1947) who reported:

Formation	Thickness	#S1	CaO	MgO	SiO_2	R_2O_3
Stripping	5 ft.	Not sampled				
Prosser Ls.						
shaly topmost	13 ft.	Not sampled				
Prosser Ls. fresh	10 ft.	52C	51.18	0.43	6.24	1.98
" "	10 ft.	52B	52.76	0.88	3.30	1.24
" "	10 ft.	52A	51.20	0.46	7.26	1.08

STATION 17: Small exposures of the Prosser limestone are present in the road cuts along State Highway 44 at Prosper in the N1/2 Sec. 36: 101-9. A 13 foot section of weathered, thin-bedded, bleached limestone was sampled at the bridge south of the highway.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls.	13 ft.	89	49.25	1.57	36.94	9.05	0.48	0.07

STATION 18: The farthest east exposure sampled in Fillmore County is in the south half of the Sections 29 and 30: 101-8 along the county road. There are several outcrops of the Prosser limestone on both slopes of a small valley. Just north of the creek crossing on the eastern side of the road there is an old quarry in a thick-bedded, somewhat cherty, shaly limestone which becomes thin-bedded where weathered. The same, and a somewhat lower zone composed of similar shaly rock are exposed south of the quarry along the road near the creek, while on the northern slope of the valley a somewhat higher, less shaly horizon is exposed. The Decorah shale was sampled about half a mile to the southwest at a creek bed in the N1/2 NE1/4 Sec. 31: 101-8 (M.E.S. #158) and in NE1/4 Sec. 21: 101-8 (M.E.S. #159).

Formation	Thickness in feet	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	R_2O_3
Prosser Ls.	10-12 ft.	88	54.27	0.62	39.97	3.28	0.39	0.08	n.d.
Basal? Prosser Ls.-Sh.	8-10	87	50.14	0.79	37.80	8.45	0.40	0.06	n.d.
Decorah sh. upper	G.S.	158	16.84	1.69	12.62	49.25	3.22	0.42	21.09
" lower	G.S.	159	0.95	1.78	0.38	77.23	4.10	0.38	18.56

STATION 19: There is a small area covered with Galena formation on the south county line along the Upper Iowa River. An old large limestone quarry in the NE1/4, NW1/4 Sec. 36: 101-11 at the junction on S.A.R. 6 north of the road has a face about 55 feet high.

Formation		Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Prosser Ls.	upper		Not sampled						
"	middle	10 ft.	99	51.44	2.46	40.28	2.64	0.32	0.07
"	lower	15 ft.	98	47.46	5.62	42.12	2.18	0.25	0.08

Stewartville dolomite and Maquoketa formation crop out high on the slope away from the river. A grab sample of the Maquoketa limestone 1 mile northwest of Granger was reported by Stauffer and Thiel (1933) as follows:

Formation	Sample	# 23	CaO	MgO	Oxides (Fe, etc.)	Silica, etc.
Maquoketa Ls.	G.S.	21	44.97	0.78		18.62

XI. HOUSTON COUNTY

Several limestone formations crop out in Houston County. The St. Lawrence formation occurs as a narrow belt along the main valleys and is dolomitic (Stauffer and Thiel, 1933).

Oneota and Shakopee formations are exposed in numerous bluffs and ridges along the valleys. Several partial chemical analyses of these limestones reported by Stauffer (1950) show a high magnesia content, hence no low magnesia rock is present in the county along or close to the Mississippi River. The high-grade limestones, however, occur in the Platteville and Galena formations. The latter is represented only by its lower part --- the Prosser member. Both formations have been eroded in the eastern, northern and central parts of the county, but still cap some high portions of the plateau in the southwestern corner of the county in T. 101-6 and T. 101-7. The Prosser limestone caps a long, narrow ridge occupied by State Highway 44 and the Chicago Milwaukee, St. Paul and Pacific railroad at Spring Grove and Wilmington Grove. Two or three smaller outliers of the Prosser limestone are present at Wilmington and in the southeastern corner of T. 101-7 but are at a distance from the railroad and the highway. The lower part of the Prosser limestone shows typical interbedding of pure and shaly limestone. At many places the rock contains chert layers or nodules. The Platteville limestone occurs in the same areas and caps several small ridges and mesa. During the present study 5 samples of the limestones and 4 nearby samples of the Decorah shale, were collected from 4 localities (Fig. 4).

STATION 1: An old small quarry in the NW1/4, NW1/4 Sec. 7: 101-6 is located on the northern margin of the main ridge capped by the Prosser limestone. The rock exposed is badly weathered basal, thick-bedded shaly Prosser limestone. The overburden is 1 to 2 feet thick. Somewhat lower on the slope there is a terrace on the Decorah shale.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++
Basal Prosser Ls.-Sh.	10-12 ft.	14	47.01	0.64	37.45	9.38	0.41	0.08

STATION 2: There are poor exposures of Prosser limestone on the southern slope of the narrow ridge at the NE section corner of Sec. 7: 101-6. Weathered, thin-bedded and bleached limestone is exposed in the road bed and ditches along a secondary north-south road south of State Highway 44 and in a small gully between the highway and the turn on the secondary road. The Decorah shale was sampled at Wilmington Grove south of Highway 44 in SW1/4, NE1/4 Sec. 5: 101-6.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Basal? Prosser Ls.-Sh.	15-20 ft.	13	53.12	0.66	37.93	4.75	0.35	0.06	n.d.
Decorah Sh. middle	G.S.	119	1.96	2.39	1.04	67.38	3.78	0.48	20.46

STATION 3: There is a good exposure of fresh thick-bedded, gray Platteville limestone overlain by 15 feet of greenish-gray Decorah shale in an active quarry north of C.A.R. 27 at Spring Grove in the SE1/4, SW1/4 Sec. 12: 101-7. Drift ranges up to 5 feet in thickness. The Platteville limestone shows an unusually low content of magnesia for the formation.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Decorah sh. upper	G.S.	120	2.45	2.28	1.22	70.74	3.76	0.46	20.37
" " lower	G.S.	121	4.06	1.82	3.04	71.42	3.70	0.41	17.98
Platteville ls. upper	13 ft.	53	41.80	2.98	37.18	11.03	0.56	0.40	n.d.
" " lower	10 ft.	52	43.61	2.57	36.36	11.95	0.48	0.24	n.d.

STATION 4: There is a small outlier of the Prosser limestone at Wilmington where poor exposures of bleached thin-bedded limestone are present in the road ditches along C.A.R. 24 at the south 1/4 corner, Sec. 15: 101-6. About 20 to 25 feet below the base of the limestone section and southward there is a small seepage caused by the presence of the Decorah shale just north of the church.

Formation	Thickness	M.E.S.	CaO	MgO	CO_2	Insol.	Fe	Fe++	Al_2O_3
Prosser Ls.	25 ft.	12	52.87	0.77	37.38	4.88	0.23	0.09	n.d.
Decorah sh.	G.S.	122	9.59	1.62	5.82	58.14	4.12	0.15	16.62

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