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STATE OF SOUTH DAKOTA
George T. Mickelson, Governor

STATE GEOLOGICAL SURVEY
E. P. Rothrock, State Geologist

REPORT OF INVESTIGATIONS
No. 2

A PRELIMINARY REPORT ON THE CHALK OF EASTERN SOUTH DAKOTA

by

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A PRELIMINARY REPORT ON THE CHALK

OF

EASTERN SOUTH DAKOTA

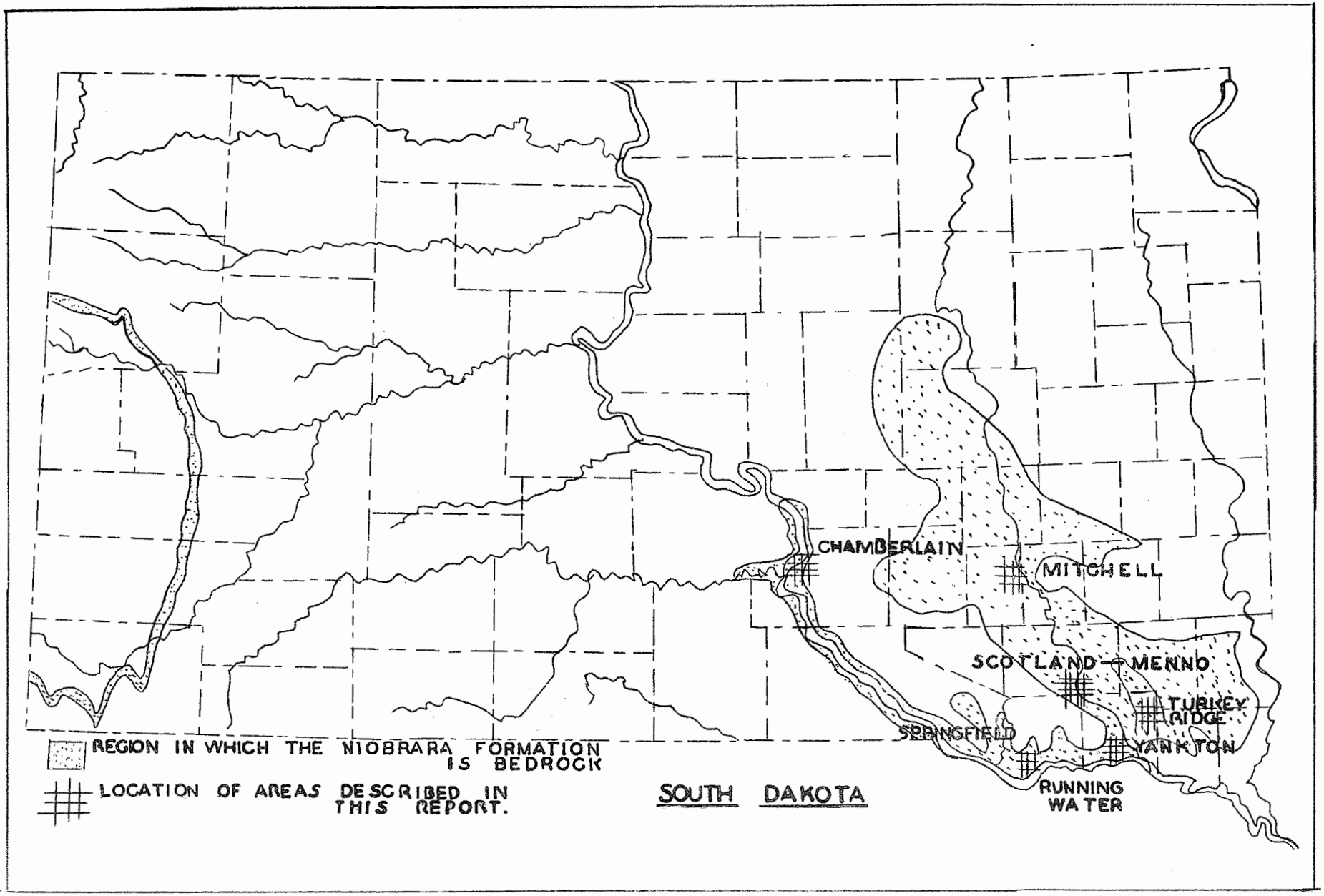
I N T R O D U C T I O N

The presence of chalk in South Dakota has been known since the earliest explorations in the territory, but only desultory attention has been given it. It has been of interest as a geological phenomenon, but its economic possibilities have never been thoroughly investigated. The curtailing of foreign supplies of chalk during the World War stimulated a little investigation by Dr. Freeman Ward, who was then State Geologist. He sent some samples from Yankton to several manufacturers for testing. They pronounced the material usable, and a statement was published in Circular 6 of the South Dakota Geological Survey (1919). Shortly afterwards (1920), Mr. C. G. Carlson and Mr. D. E. Lounsbery investigated the chalk as a possible source of cement material for the South Dakota Cement Commission, under the direction of Mr. Paul E. Bellamy, head of the Commission. This report was not published, but the manuscript is in the files of the Geological Survey, and some of the information has been used in this report.

Considerable amounts of chalk rock have been used in this country, and foreign quarries are supplying all of it. This investigation, therefore was attempted in order to try to stimulate interest in the possibilities of South Dakota chalk. The information is compiled partly from the sources mentioned above, but for the most part was obtained on a reconnaissance survey carried on during the summer of 1929. During this survey the chalk was investigated at several points, where railroad shipment was possible. These regions included:

(1) The vicinity of Yankton and Volin
(2) Springfield and Running Water
(3) Chamberlain and Oacoma
(4) Mitchell

This does not exhaust the places in which chalk might be quarried, but does include those places where it is most easily accessible to the present (1931) railroad system. The chalk was sampled for analysis, sections described, and possible quarry


CHAMBERLAIN
MITCHELL
SCOTLAND
MENNO
TURKEY RIDGE
SPRINGFIELD
YANKTON
RUNNING WATER
REGION IN WHICH THE NIOBRARA FORMATION IS BEDROCK
LOCATION OF AREAS DESCRIBED IN THIS REPORT.
SOUTH DAKOTA

sites noted. Many details had to be left undone, but it is hoped that the information which has been acquired can be used as a guide for further development of this resource.

Acknowledgements

Much of the following information would have been impossible to obtain but for the assistance of the citizens in various regions investigated. The chemical analyses were made in the State Chemical Laboratory at Vermillion, South Dakota, under the direction of Mr. Guy G. Frary, State Chemist. Dr. A. M. Pardee, head of the Chemistry Department of the State University, and Mr. Lloyd Moses, a graduate student in that department, also assisted with valuable suggestions and some experimentation on possible methods of bleaching. Mr. M. E. Kirby's painstaking work in collecting samples and as field assistant did much to bring the work to a successful completion. To Dr. W. V. Searight, of the Survey staff, belongs the credit for the list of fossils given in the paragraphs on paleontology.

Location of Chalk Deposits

Though chalk rock occurs in at least three different formations in South Dakota, only that in the Niobrara has been considered in this survey. It is the thickest of the chalk formations, averaging about two hundred feet, and the most widespread. Although it underlies most of the southern half of the state, it is too deeply buried, beneath other rock to quarry, except in the valleys of the Missouri and James Rivers and in a narrow belt encircling the Black Hills. The formation outcrops in the Missouri Valley from Vermillion to Fort Thompson. Between the latter place and Yankton, the cliffs of chalk lie on both sides of the valley and in the valleys tributary to it. It appears at the surface in the James Valley in many places from Yankton to Redfield, the most northern exposure being in the Redfield hills immediately south of that city, and the most southerly on Spirit Mound, near Vermillion. Though it underlies large areas in this valley, it is seen in only a few places because it is buried beneath a cover of glacial drift and river deposit. It comes to the surface about the Black Hills, but makes outcrops in only a few places, its position being usually marked by a valley, which is easily eroded in such soft material. The approximate locations of these outcrops are given on the accompanying map.

Character of the Chalk

Chalk is a form of limestone made partly from the shells or tests of micro-organisms, and partly of a flocculent limy material which looks like precipitated calcite. Varying amounts of impurities are contained in the rock which are largely clays and organic matter. A small amount of iron is also included as is shown in the following analyses.

An average of the chemical compositions thus far available, would show a rock which contains:

Calcium Carbonate ($CaCO_3$)	85-90%
Alumina (Al_2O_3)	1%
Iron (FeO)	1- 3%
Volatile Matter	2- 4%
Insoluble Material (about)	4%

There are great variations in this average, depending upon the locality and the color of the chalk. The color of the chalk is black, except where it has been exposed to weathering agencies, and in these conditions two distinct zones are usually to be seen, a very white zone on the top and a buff or cream colored zone beneath it with grey or black chalk at the bottom of the cliff.

Chemical analyses shows a rock with about the following composition:

Calcium Carbonate ($CaCO_3$)	85-90%
Alumina (Al_2O_3)	1%
Iron (FeO)	1- 4%
Volatile Matter	2- 4%
Insoluble Matter	4%

Analyses of white chalk run higher in lime and lower in iron than do those of the black. A sample of very white chalk from Turkey Ridge gave the following:

CaO plus CO_2	97.28%
CO_2, calculated as $CaCO_3$	97.30%
CaC_2	42.78%
CaO	54.50%
Al_2O_3	1.25%
FeO	1.57%
Volatile Matter	1.76%
Insoluble Matter	1.61%

A good example of the difference between the black and white chalk appears in the following pair of analyses of white and black chalk, both taken from the old cement quarry four miles west of Yankton.

White chalk:		Black chalk:	
CaO plus CO_2	92.72%	CaO plus CO_2	75.56%
CO_2 as $CaCO_3$	92.00%	CO_2 as $CaCO_3$	70.80%
Excess CaO	.72%	Excess CaO	4.76%
CO_2	40.42%	CO_2	31.16%
CaO	52.30%	CaO	44.40%
Al_2O_3	1.28%	Al_2O_3	1.16%
FeO	1.16%	FeO	2.17%
Volatile Matter	1.57%	Volatile Matter	11.68%
Insoluble Matter	4.12%	Insoluble Matter	5.11%

The chemical difference between the black and white chalk throws some light on the cause of the color differences. The volatile matter and iron content seem to be of most importance. In all the black chalk the volatile matter runs high varying between ten and eleven and a half per cent in the samples that were run. In the white chalk, the volatile matter is reduced to 1.57% in the whitest sample obtainable, and averages about 1.5% for all the white chalk. This volatile matter may be composed largely of organic matter, possibly from the soft parts of the foraminifera which are so abundant in the chalk.

The iron content also shows a similar variation. In the black samples, iron (FeO) ran from 2.17 to 3.69%, with an average of about 3%. In white samples, however, it ran as low as 1.16%, though most of them showed about 1%. It is interesting to note that a buff colored sample from Bon Homme County gave 5.5% FeO

The field relations of the different colored chalks may also throw some light on the process of making white chalk. Wherever chalk is at the surface it tends to bleach so that in narrow valleys, like those of Turkey Creek it is possible to see three distinct zones. The top zone is white, giving a characteristic white color that is supposed to be associated with chalk. Beneath this zone is a buff or cream colored chalk, underlain by a third in which the color is a blue-black.

The same was noted in sections made about Mitchell with a churn drill. Lounsbery in his report to the State Cement Commission states that, "From holes put down by means of a churn drill it has been found that these chemical reactions are confined mainly to the chalk rock exposed on the bluff, and that where the overburden back from the bluff approaches a thickness of 15 to 20 feet, the buff or yellow chalk is invariably absent because of protection from weathering agents, and that the blue-chalkstone is encountered directly below the drift. With less than a thickness of 15 feet of overlying material, a small layer of buff colored chalk always was encountered before the blue

chalkstone was reached. It was also noted that the thickness of the light colored chalk was greater with glacial drift overlying than with gravel, when both were in equivalent amounts, thus showing the gravel to a better protector against the action of weathering agents. Where drilling started directly on a chalk, that is, where there was no overburden, the white chalk extended down to approximately eighteen feet before the blue unweathered chalkstone was encountered."

It appears, therefore, that the white chalk is a bleached product. The chalk as originally deposited is black, but being porous can be bleached by running water through it. The coloring matter seems to be either in a colloidal form, or mixed with the clay which is an impurity in the chalk. Ordinary weathering should oxidize the iron and dissolve the calcium carbonate, leaving a reddish or brownish residue. Instead, however, the analyses of the white chalk run higher in calcium carbonate and lower in iron than those of the dark chalk. Apparently the ordinary weathering processes have been reversed in this case.

Physical Character of the Chalk

Like the foreign chalk that of South Dakota is physically amorphous. This term is much used by whiting manufacturers, but its meaning is rather vague. It is used in connection with chalk to distinguish certain physical properties of the material which are much desired for many uses to which whiting is put. Whiting made by powdering limestone and marble and precipitating calcite chemically does not possess these characters and is termed crystalline. The amorphous properties therefore are probably due to this non-crystalline character and to the colloidal materials which make up the bulk of the chalk.

The flint or chert nodules such as are abundant in the English chalk are conspicuous by their absence from the chalk of South Dakota. Some concretions of iron ore are to be found in a few outcrops, but this material is very scarce. Gypsum crystals (selenite) are reported by Lounsbery from the chalk about Mitchell, and the same were noted above the chalk at Chamberlain and Yankton, and below the chalk on the south side of the Missouri Valley near Gayville. This gypsum, however, is confined to the shales above and below the chalk, and therefore should not be a detrimental factor in working the material. Most of it occurs as a layer just above or just below the chalk, and therefore the two can easily be separated if it is necessary to quarry them together.

Paleontology

Large fossils are not numerous in the Niobrara Formation. Those that are found are for the most part remains of pelecypods and fish. The characteristic fossil of this formation is a small oyster, Ostrea congesta, which lives in closely crowded communities on fragments of shells of larger pelecypods, or are simply crowded together in small patches in the lime mud of the ancient sea bottom. Small crowds of these oysters can be found on most chalk outcrops often on fragments of the shell of the great pelecypod, Haploscapha grandis, and stray shells are scattered sparingly through the deposit. This fossil is an indicator of the Niobrara, and can be used to separate this chalk from the chalk of other formations.

Scales of fish are common in many places, but no attempt was made to identify them. They are circular in shape and vary from a fraction of an inch to an inch in diameter. Shark teeth are found scattered sparingly through the formation, some of them an inch and a half long. They have been found very abundantly in the sand which immediately underlies the Niobrara Formation at Mitchell, at least a peck of them having been pumped up from the city well and collected from the sand. Larger teeth have been picked up from the outcrops on Turkey Ridge, and also from the outcrops on the south side of the Missouri River south of Gayville. A reptile vertebrae was picked up on an outcrop in the James Valley near Menno.

Micro-fossils are very abundant. A complete list of the fauna is in preparation and will be published some time in the future. The following genera, however, have been identified by Dr. W. V. Searight:

Globigerina
Anomalina
Guembelina
Robulus
Nodosaria
Globotruncana
Truncatulina
Bolivina
Gaudryina
Rotalia
Bulimina
Frondicularia

Preparation of Chalk

The preparation of whiting from chalk is usually a very simple process. The processes now in use depend on a gravity separation of chalk that has been ground in water. Impurities and coarse material will sink more rapidly than the fine chalk.

By regulating the time allowed for settling or the rate of flow of water, it is possible to make separations which give a variety of grades.

A simple method has been described by Maximilian Toch.[1] "Whiting and natural calcium carbonate are prepared from the natural chalk deposits of the cliffs in the south of England, and Paris White, Extra Gilder's White, and Spanish White are all different qualities of whiting depending upon the amount of levigation and fineness of grain. The mode of preparation is very simple. It consists in grinding the cliffstone in water, washing it, and allowing it to settle in large vats. The cream or that which is nearest the surface is dried over steam-pipes, bolted, and sold as Paris White. The next layers are sold under the name of Extra Gilder's White, and the bottom layer as Commercial White, of which putty is made. Whiting is a neutral calcium carbonate, and with the exception of the small percentage of water, which is very variable and depends upon how thoroughly it has been dried, it is remarkably pure and fine. The material at the bottom of the tubs known as Commercial Whiting is never used in the manufacture of mixed paint, because it is coarse, contains silica and iron, and in attempting to grind this grade the mills are ruined."

A more modern type of procedure including the use of classifiers is described by A. B. Parsons.[2] "Crude lump chalk is passed through crushing rolls and disintegrated in a series of mullers. The suldge, consisting of about 11 parts of water to 1 part of solid, is conveyed to a series of modern bowl classifiers, hydroseparators, and thickeners. A large proportion of the water is thus removed. The pulp is dewatered further in a continuous filter, and final drying is accomplished in a rotary dryer which discharges to a storage bin from which the product is taken for disintegrating and bolting. This type of equipment yields only one grade of whiting at a time. Two or more complete units would be required to produce more than one grade simultaneously. The newer type of equipment greatly increases mill capacity, reduces labor requirements and production cost, and provides a very uniform and dependable product."

The process used in the vicinity of Kent, England, has

1-Toch, Maximilian, Chemistry and Technology of Paints, Third Edition, 1925, pp. 130-134
2-Parsons, A. B. Dressing Crude Chalk by Modern Methods: Eng. and Min. Jour., vol. 116, No. 10, 1923, pp. 415-420

been described by Hugh S. Spence.[1] "The industry is centered in Kent. The quarried chalk is placed in a 15-foot washing tank and pulverized by means of iron bars suspended from rotating arms. The slurry passes through a 1/8-inch wire screen to a launder, which feeds it to eight trommels fitted with 180-mesh wire gauze. Only the material that passes through these screens is used for whiting. The fine slurry is conveyed to four series of settling pits with eight pits in each series. The slurry fills the first pit, flows over into the second, and so on until the eight are filled. The finer material is thus carried over and settles in the last four pits, the product of which is classes as No. 1 grade; that deposited in the first four is graded No. 2. The overflow from the pits is conveyed back to the washing tank. The whiting is dug out by hand and placed on drying floors which have heating flues beneath them. After it is dried for 36 hours it is taken by screw conveyor to a swing hammer disintegrator which discharges to a bolting trommel. Some is single-bolted, and some double-bolted; the latter commands a higher price. Much of the chalk mined in Kent is shipped in crude form, chiefly to the United States.

Preparation of South Dakota Chalk

The white zones of the South Dakota chalk could be prepared for market by a process similar to those just described. The same method could be used on the dark chalk to obtain a colored product. There is a prejudice, however, in the trade against chalk or whiting that is not white. For some purposes it is essential to have a white color, but many uses, especially those in which it is used as a filler of colored materials, the material can be supplied as well by colored as by white chalk. Physical tests made some years ago by whiting manufacturers showed that the chalk of this state was usable as a whiting material in every respect except color.[2]

The natural bleaching of chalk in the outcrops suggests that it might be possible to bleach it artificially. If the color is due to colloidal iron or colored collodial clay, a mechanical separation might be effected. Only a few unsystematic experiments have been tried along this line, and as yet they have not produced the desired results. A little expert experimentation, however, should make possible the development of a process by which this chalk could be bleached and sold in competition with chalk from foreign sources.

1. Spence, Hugh S. The Manufacture of Whiting in England: Canadian Min. Jour., vol. 47, No. 38, 1926, p. 907.
2. Ward, F., Chalk, Circular 6, South Dakota Geological and Natural History Survey, 1919.

CHALK OUTCROPS IN THE VICINITY

OF

TURKEY RIDGE

Legend

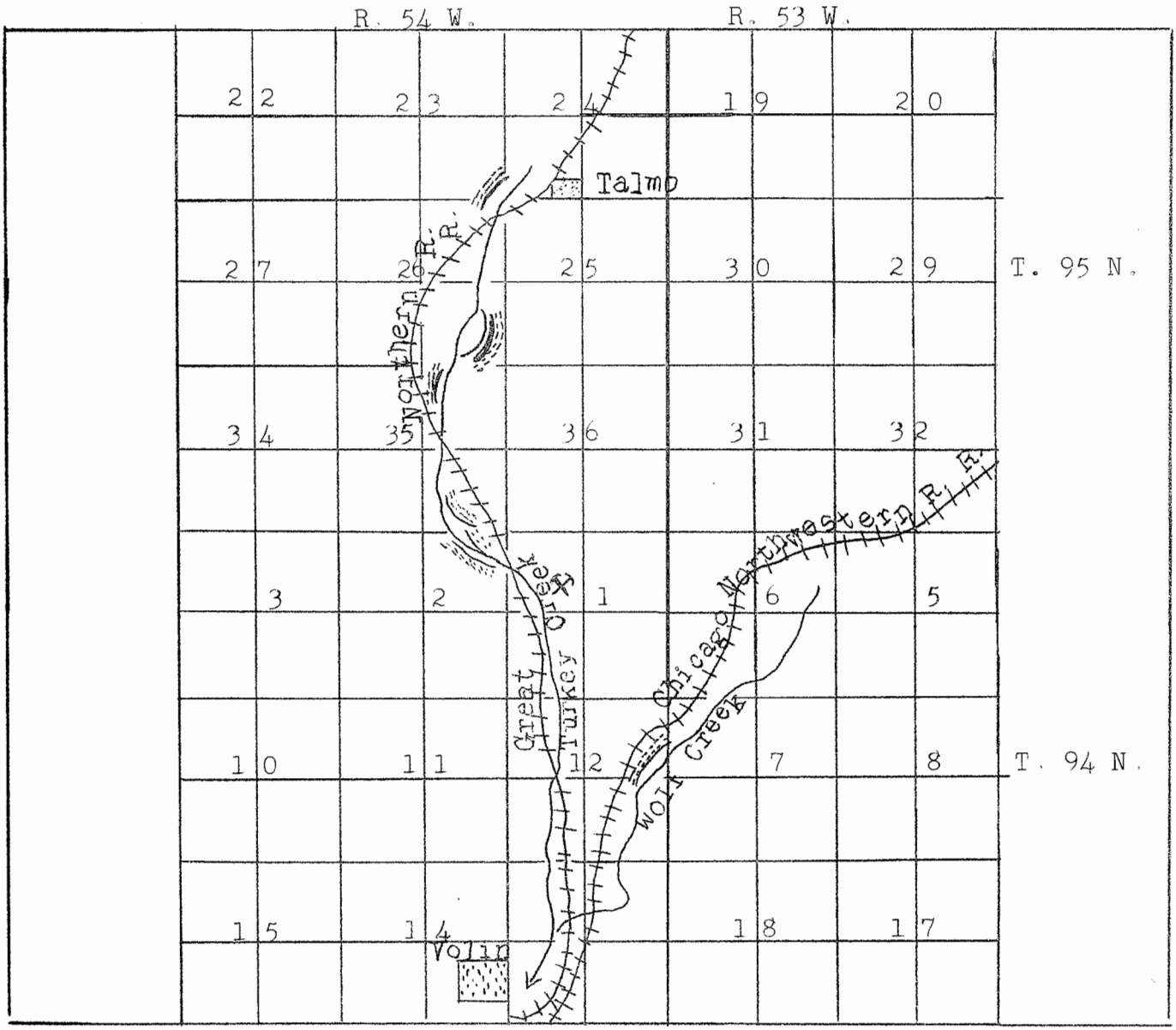
Outcrops of Chalk Described

Quarry

Streams

Towns

Railroads



CHALK OF THE TURKEY RIDGE AREA

The area examined lies in the canyon of Turkey Creek between Volin and Talmo. This region was chosen because it lies along the Great Northern Railroad tracks and the chalk is well exposed in the bluffs along this portion of the valley. The easy access to the chalk and proximity of shipping facilities make it a strategic point if the material is to be used.

The thickness of the formation is about 150 feet, 118 feet being measured near the center of Section 35, T. 95 N., R. 52 W. and 92 feet in the southeast quarter of the same section. The bottom of the formation is not exposed but lies somewhere below the bottom of the valley. The top, however, is exposed in the first named section, since the shales which overlie the chalk appear to belong to the Pierre Formation. If the total thickness of the formation in this region is near 200 feet, which is the usual thickness assigned it, the bottom of the chalk lies some 40 to 50 feet below the bottom of the valley. At any rate the thickness and the position of the chalk in the valley insure a possible working thickness of at least 100 feet.

A veneer of glacial drift overlies the chalk which in some places is quite thick. No borings were available but judging from the evidence of road and stream cuts it appears to reach thicknesses of 50 to 75 feet. Undoubtedly shales cover the chalk in places, lying between it and the drift cover. Only one exposure showed then, however, and it is probable that they occur only in the northern part of the area. In most of the southern part the shale cover has been largely or entirely removed. It is possible to find plenty of locations where quarries could be opened with but little stripping. Such locations are especially abundant in Sections 1 and 2 of T. 94 N., R. 54 W., and also in Sections 26 and 35 of the township to the north.

Character of the Material:

Two kinds of material were noted in the field, a very white zone near the top of the formation and a thick zone of a creamy white or pure white color. This latter was called the "buff zone" for identification in the field because its exposed surface weathered to a dark buff color.

The "white zone" as it was called is readily distinguished by the chalky whiteness of the rock and by the fact that weathering left it white or turned it to light grey. At the old quarry in the N. W. $\frac{1}{4}$, of Section 1, T. 94 N., R. 54 W., this

zone measured 14 feet while a half mile farther north it measured 25 feet. One mile north of the last exposure, in the S.E. corner of Section 26, T. 95 N., R. 54 W., 15 feet is exposed and it is doubtless thicker back under the hill away from the outcrop.

Chemical analysis of the materials of this zone show that there is on an average.

Calcium Carbonate ($CaCO_3$)	90.98%
Aluminum (Al_2O_3)	.89%
Iron (FeO)	1.40%
Volatile Matter	2.00%
Insoluble Matter	5.21%

Detailed analyses were as follows:

Chalk Sample No. 1:

Location: N. E. $\frac{1}{4}$, Sec. 12, T. 94 N., R. 52 W. Cut bank on west bluff of Wolf Creek.

Calcium Carbonate ($CaCO_3$)	84.80%
Aluminum (Al_2O_3)	2.57%
Iron (FeO)	1.29%
Volatile Matter	1.74%
Insoluble Matter	9.45%

Chalk Sample No. 2:

Location: N. W. $\frac{1}{4}$, Sec. 1, T. 94 N., R. 54 W.; high knob on the east bluff of Turkey Creek.

Calcium Carbonate ($CaCO_3$)	93.00%
Aluminum (Al_2O_3)	1.03%
Iron (FeO)	1.37%
Volatile Matter	1.14%
Insoluble Matter	3.70%

Chalk Sample No. 3:

Location: N. W. $\frac{1}{4}$, Sec. 1, T. 94 N., R. 54 W.; high knob on the east bluff of Turkey Creek. Very white chalk.

Calcium Carbonate ($CaCO_3$)	90.54%
Aluminum (Al_2O_3)	1.15%
Iron (FeO)	1.29%
Volatile Matter	1.39%
Insoluble Matter	6.20%

Chalk Sample No. 4:

Location: S. E. $\frac{1}{4}$, Sec. 35, T. 95 N., R. 54 W. Taken 16' above railroad track. Dug through talus to fairly fresh material.

Calcium Carbonate ($CaCO_3$)	86.96%
Aluminum (Al_2O_3)	.35%
Iron (FeO)	1.73%
Volatile Matter	2.29%
Insoluble Matter	7.30%

Chalk Sample No. 5:

Location: S. E. $\frac{1}{4}$, Sec. 35, T. 95 N., R. 54 W. In "buff zone" near its top at the west end of the hill.

Calcium Carbonate ($CaCO_3$)	89.65%
Aluminum (Al_2O_3)	.60%
Iron (FeO)	1.94%
Volatile Matter	3.70%
Insoluble Matter	5.06%

Chalk Sample No. 6:

Location: Center of Section 35, T. 95 N., R. 54 W.; on road up west bluff of Turkey Ridge Creek, $1\frac{1}{2}$ mi. south of Talmo. Taken 40 ft. from bottom of chalk.

Calcium Carbonate ($CaCO_3$)	97.28%
Aluminum (Al_2O_3)	.25%
Iron (FeO)	.57%
Volatile Matter	.76%
Insoluble Matter	1.61%

Chalk Sample No. 7:

Location: N. E. $\frac{1}{4}$, Sec. 35, T. 95 N., R. 54 W., 660 ft. North of road in Great Northern Railroad cut.

Calcium Carbonate ($CaCO_3$)	92.18%
Aluminum (Al_2O_3)	.59%
Iron (FeO)	2.41%
Volatile Matter	1.67%
Insoluble Matter	3.34%

Chalk Sample No. 8:

Location: S. E. ¼, Sec. 26, T. 95 N., R. 54 W.

Calcium Carbonate ($CaCO_3$)	92.74%
Aluminum (Al_2O_3)	.55%
Iron (FeO)	.61%
Volatile Matter	3.30%
Insoluble Matter	5.05%

The "buff zone" is so called because its iron content (average 1 to 3%) gives a decidedly buff to reddish color to the weathered residue. It is also distinguished from the white zone by the fact that it weathers to a red clayey mass while the white chalk zone weathers into little blocks and slabs. When the fresh rock is broken, however, it shows a creamy white to white surface. The buff or red color is formed when leaching has carried off the lime($CaCO_3$) of the rock leaving the included clays and oxidizing the iron. When weathering has gone to the extreme, a sticky red clay is left as a residue.

Patches and layers of black chalk are scattered through the "buff zone" at irregular intervals. This material differs from the other chalk in the zone in its black color which is due to included organic matter. The color leaches out readily where weathering occurs so that it is white or buff along most of the joints. It is more thin bedded than most of the white chalk, in places appearing almost shaley. Some of it also feels more gritty under the fingers.

Fossils and Correlations:

No fossil horizons were discovered though a few types were rather widely distributed throughout the exposures. The most notable were the Ostrea congesta which occur in thin beds at many horizons made of the characteristic masses of crowded shells which gave the species its name. Individual shells are also scattered through the chalk. Slabs of these oysters were most abundant in the lower 20 to 30 feet of the exposures, the best specimens being found along cuts made for the railroad.

A few pieces of a very large pelecypod belonging to the genus Haploscapha occurs in the shaley parts of some of the black chalk zones.

Fish scales are scattered abundantly through the formation, but no masses of scales and no imprints of fish were found. In 1927 two shark teeth were found at the top of the buff zone, in the section exposed in the S. E. ¼, Section 26, T. 95 N., R. 54 W.

Detailed Sections of this Region are as Follows:

Wolf Creek Section:

Location: N. E. ¼, Sec. 12, T. 94 N., R. 54 W.; the cut bank on the west bluff of Wolf Creek.

38 ft. Till
33 ft. Chalk Outcrop, probably thicker under hill. (Chalk Sample No. 1)
Covered Chalk, outcrops to the bottom of the creek, and probably considerably below this level.

Volume: Chalk underlies the hills which occupy nearly all of this quarter section.

Cover: The 38 ft. handleveled to the top of the hill represents the maximum depth. The average depth should be about 15 ft., with 5 to 10 ft. over much of the area.

Material: Cliff not well exposed, but float is very light in color. The darkest being a light buff.

Access: Good dirt roads and Northwestern Railroad run within 100 to 200 ft. of outcrop.

Old Quarry Section (Elmer Dose Farm)

Location: N. W. ¼, Sec. 1, T. 94 N., R. 54 W.

14 ft. White chalk (Chalk Sample No. 3)
6 ft. Chalk bedrock, weathers gray or slightly buff, but white underneath. (Chalk Sample No. 2)
27 ft. Chalk float
27 ft. Covered
30 ft. (Estimated) to bottom of creek.

Volume: 13,600 Tons (most conservative)

Access: Great Northern Railroad runs through the valley, less than one-fourth mile away. Slopes all the way to the tracks.

Section from Railroad Cut in Hill:

Location: S. E. ¼, Sec. 35, T. 95 N., R. 54 W.

33 ft. Silt with glacial pebbles makes knob on highest hill. Probably glacial settling or wash when Turkey Creek was forming. No laminae seen. Pebbles under 3 to 4 inches, but one or two boulders seen, in the railroad cut in the hill.

25 ft. "White zone," so named because it is white when fresh and weathers white. This is the same zone as at the old quarry to the south. (Chalk Sample No. 5)

37 ft. "Buff zone," weathers buff. All cracks near surface show weathering. This is probably a concentrate of iron and clay, for the fresh rock is nearly as white as the white layer. A few shaly patches.

30 ft. Covered.

16 ft. Gray chalk; mass of black chalk at the north of cut. (Chalk Sample No. 4)

Economic Notes:

The white zone and the buff zone can be traced far up Turkey Creek Canyon.

The white zone immediately underlies the surface on the east end of this hill and across the valley to the west. There is plenty of area to make an excellent quarry with a minimum amount of stripping.

Access:

This lies right along the Great Northern tracks, and the fact that it is in the hills makes gravity loading possible.

Section in Railroad Cut:

Location: N. E. ¼, Sec. 2, T. 94 N., R. 54 W.; cut through chalk by Railroad.

20 ft. Chalk, light buff cast due to recent weathering. Only one small patch of shaly material. All the rest is good solid chalk.

Section on Road up West Bluff of Turkey Ridge Creek, 1½ miles south of Talmo:

Location: Center of Section 35, T. 95 N., R. 54 W.

Shale and bentonite.
6 ft. Chalk.
50 ft. Covered. Chalk exposed in hills across valley on north side of road.
18 ft. Chalk outcrop. Mostly talus, but very close to bedrock. (Chalk Sample No. 6)
44 ft. Covered, chalk.
Total thickness of chalk, probably 118 feet. Shales and bentonite are probably Pierre; they are not chalky black shales such as occur in the chalk.

Section from Great Northern Railroad Cut:

Location: N. E. ¼, Section 35, 660 ft. north of road, T. 95 N., R. 54 W.

25 ft. Chalk. No shale or other foreign substance exposed in cut, 240 ft. long and 25 ft. high. Vertical jointing makes blocks from two inches to a couple feet and has allowed some weathering to penetrate parts of exposure, but most of it is a very pure white. (Chalk Sample No. 7)

Turkey Creek Section:

Location: S. E. ¼, Section 26, T. 95 N., R. 54 W.; 2550 ft. north of road along railroad. Then turn left a few hundred feet, following bend of creek into tributary gullies. Excellent exposure.

15 ft. "White zone," heavy beds 1 to 2 inches thick, and dense for chalk. Probably thicker back under the hill. Color--chalk white. (Chalk Sample No. 8)
40 ft. "Buff zone." It weathers to a buff or red. Final product of alteration where much water has affected it is a red clay. When fresh, it has a creamy color. Some masses of black chalk which usually feel more gritty than ordinary chalk. Does not weather into blocks as the white zone does, but goes to a clay.
5 ft. Black chalk.
River level.

CHALK IN THE VICINITY OF YANKTON

Chalk underlies much of the region to the west and north of Yankton, but is easily accessible only near the Missouri west of the city. Outcrops of chalk occur in the bluffs of the river on the western side of Yankton underlying the Sacred Heart hospital, and can be followed up the valley as far as it would be practical to haul it. The most westerly section examined in this region was nine miles west from Yankton.

Quarry locations are not difficult to find even though there is a great thickness of cover above the chalk in this region for the erosion caused by the Missouri and its tributaries has left many shoulders projecting into the tributary valleys and at their junction with the Missouri valley, on which much of the overburden has been removed. Under the higher parts of the upland the overburden consists of black shales which can be seen above the quarry at the old cement plant, and over the shale lies a heavy cover of glacial drift. The eastern end of the upland indicated on the map of the Yankton region has only a drift cover. At the hospital this had a maximum depth of forty feet. In the road cut just west of the Hospital (in the N. E. ¼, Section 14, T. 93 N., R. 56 W.) the cover was only 15 feet deep. An average depth of 25 to 30 feet may be expected in this area.

Character of Materials:

The most noticeable characteristic of the chalk near Yankton is the abundance of the "black chalk." The exposures on the road cut just west of the hospital and at the old cement plant quarry both show an abundance of black to grey rock on the fresh surfaces. This rock color, however, bleaches out rapidly on weathering, so that on partly weathered surfaces and along joint planes and cracks where water has had a chance to flow, the rock is grey or light buff. Further weathering gives a buff to red residue as in the case of the "buff zone" on Turkey Ridge. The red color is the characteristic color of the quarry face at the old cement plant quarry, and along most of the bluffs near Yankton.

The chalk exposed in the cliff nine miles west of Yankton shows a notable absence of "black chalk" in the entire 145 feet of the rock which is exposed. It evidently differs considerably in iron content since it has weathered to a white or only very light buff, though its material has been exposed for a much longer time than has that at the cement plant quarry.

CHALK OUTCROPS IN VICINITY

OF

YANKTON

Legend

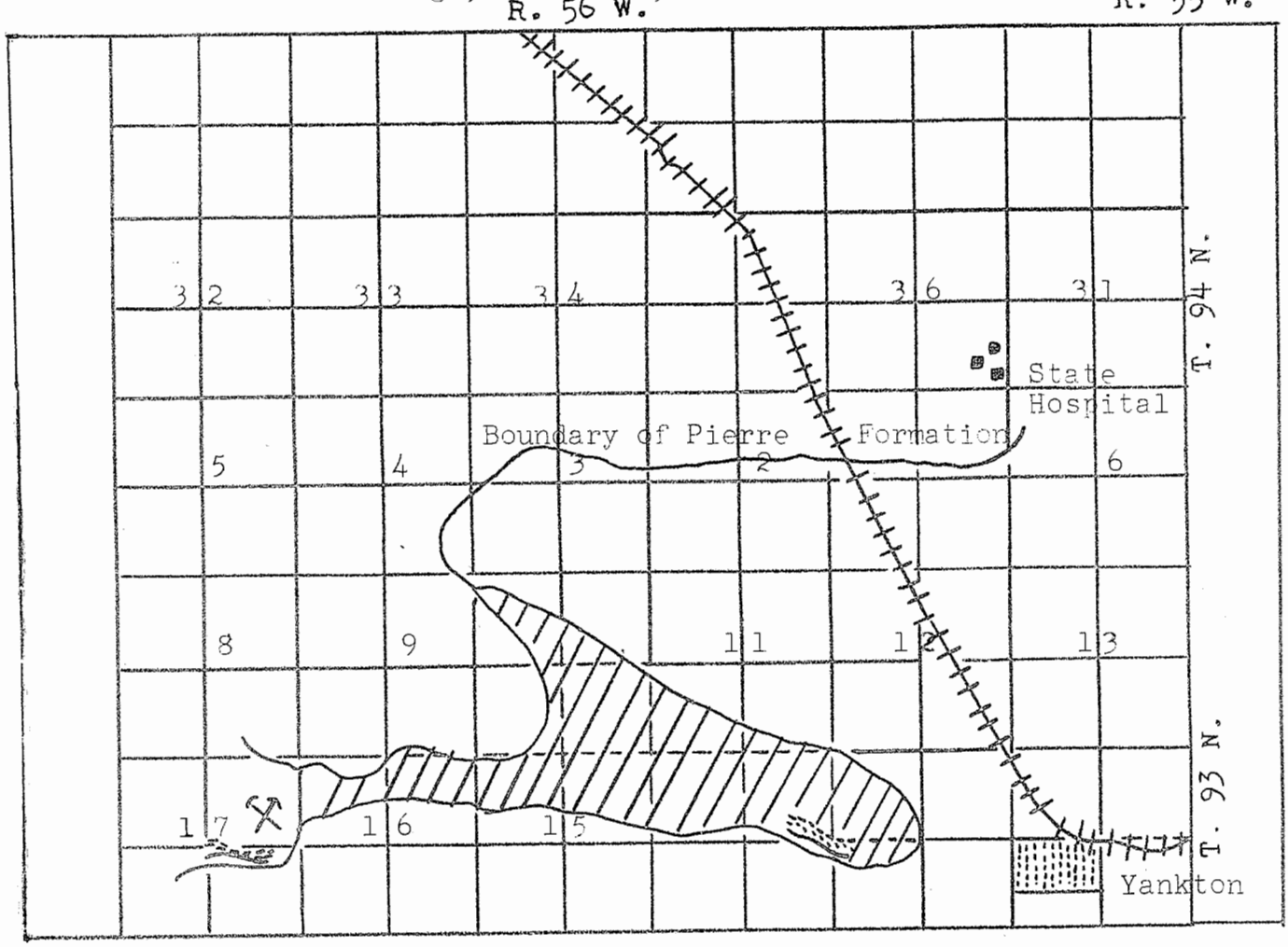
Chalk Outcrops Described

Area without Shale Cover

Old Quarry

Towns

Chicago, Milwaukee, St. Paul and Pacific R.R.



Chemically the Yankton chalks average as follows:

Calcium carbonate ($CaCO_3$)	84.33%
Aluminum (Al_2O_3)	.81%
Iron (FeO)	1.55%
Volatile Matter	5.10%
Insoluble Matter	6.66%

Detailed analyses were as follows:

Chalk Sample No. 9:

Location: N. E. ¼, Sec. 17, T. 93 N., R. 56 W.; at old cement plant.

Calcium carbonate ($CaCO_3$)	92.72%
Aluminum (Al_2O_3)	1.28%
Iron (FeO)	1.16%
Volatile Matter	1.57%
Insoluble Matter	4.12%

Chalk Sample No. 10:

Location: N. E. ¼, Sec. 17, T. 93 N., R. 56 W.; at old cement plant (dark chalk).

Calcium Carbonate ($CaCO_3$)	75.56%
Aluminum (Al_2O_3)	1.16%
Iron (FeO)	2.17%
Volatile Matter	11.68%
Insoluble Matter	5.11%

Chalk Sample No. 11, (Ground fine)

Location: Big cliff in the N. E. ¼, Sec. 22, T. 93 N., R. 57 W. North bluff of Missouri Valley.

Calcium Carbonate ($CaCO_3$)	92.76%
Aluminum (Al_2O_3)	1.19%
Iron (FeO)	1.44%
Volatile Matter	1.14%
Insoluble Matter	3.84%

Chalk Sample No. 12:

Location: N. E. ¼, Sec. 14, T. 93 N., R. 56 W. One mile west of Yankton on valley road where it descends to valley.

Calcium Carbonate ($CaCO_3$)	83.27%
Aluminum (Al_2O_3)	------
Iron (FeO)	1.26%
Volatile Matter	6.08%
Insoluble Matter	7.51%

Chalk Sample No. 13:

Location: N. E. ¼, Sec. 14, T. 93 N., R. 56 W. One mile west of Yankton on valley road.

Calcium Carbonate ($CaCO_3$)	77.36%
Aluminum (Al_2O_3)	.44%
Iron (FeO)	1.73%
Volatile Matter	5.02%
Insoluble Matter	12.74%

Detailed Sections:

Section at Sacred Heart Hospital.

Location: N. E. ¼, Section 14, T. 93 N., R. 56 W.

50 ft. Oxidized drift
40 ft. Chalk
10 ft. Covered - chalk.

Section at Road Cut West of Yankton.

Location: N. E. ¼, Sec. 14, T. 93 N., R. 56 W. One mile west of Yankton on valley road, in cut where road descends into the valley.

15 ft. Oxidized drift
22 ft. Thin bedded and jointed chalk, mostly making little blocks one to three inches. A dirty grey to white, but no real fresh faces seen.
28 ft. Only major bedding planes prominent, making beds one to three feet thick predominate. This is the freshest section of the cut. Color is prevailingly dark grey to black on fresh faces.

But weathers lighter, to a chalk white in places. (Chalk Samples No. 12 and 13).

10 ft. Thin bedded and weathered. Color light grey to white.

11 ft. Partly covered with talus. Ledge of chalk here and there. All weathered to a cream or white.

Note: The original color of this chalk seems to be a dark grey to black, may be due to organic matter. This color apparently bleaches easily to a creamy white or chalk white. This would seem to favor the use of this chalk especially if a little bleaching could be carried on commercially.

Section at Old Cement Plant Quarry.

Location: N. E. ¼, Section 17, T. 93 N., R. 56 W.

Silt

38 ft. Pierre shale, typical black gumbo. Few lenses of chalk at base. Highest ten feet above base, bentonite-like clays, none over 3" thick, spaced through section about equally.

41 ft. Buff weathering zone. Much of it black when fresh. Black color leaches rapidly on weathering. Ostrea congesta.

39 ft. White zone. Chalk very white most places. Some grey patches. Ostrea congesta. (Chalk Sample No. 9)

7½ ft. Black slabby chalk. Bottom of quarry. Ostrea congesta. (Chalk Sample No. 10)

Total 120 ft., 83 ft. chalk.

Note: It is possible to locate quarries at many places where stripping is not excessive for many shoulders project into surrounding valleys from which glacial drift and till have been largely removed.

Section at Big Cliff, Nine Miles West of Yankton.

Location: Big Cliff in N. E. ¼, Section 22, T. 93 N., R. 57 W.; North bluff of Missouri Valley.

13 ft. Pebbly drift.
(Note: Absence of shale)

145 ft. Chalk, not divisible into zones, as all looks about alike. This differs from the chalk at the cement plant in the notable absence of black chalk. The cliff has weathered to a very light buff, though it has been many years

since the river undercut here, but the outcrops on the tributary bluffs to the north are a deeper buff. (Chalk Sample No. 11)

Economic Considerations: Chalk is readily accessible because it underlies many shoulders in this region where the cover is slight.

Access is good: (1) the river is near; (2) good haul roads to Yankton and Janousek; (3) four railroads at Yankton, 9 miles distant; one (C. M. St. P. and P.) at Janousek, 6 miles north.

Section one-half mile east of the Big Cliff.

Location: Approximately on the east line of Section 22, T. 93 N., R. 57 W. Cliff goes to the river, and will add a few feet to that given in other section.

25 ft. Chalk, partly covered, but still outcrops.
77 ft. Chalk, weathers a light buff, little or no black.
(Bottom of the Big Cliff section)
30 ft. Light colored chalk, white or cream. Few patches of black chalk.
River level.
Total, 132 feet.

CHALK IN THE SPRINGFIELD-RUNNING WATER AREA

The chalk of this region was examined because it is served by a branch of the Chicago, Milwaukee, St. Paul and Pacific Railroad, and because it is on the Missouri River. Either of these means of transportation would make an outlet for the chalk if quarries should be opened in this region.

Chalk outcrops are to be found in the bluffs of the Missouri Valley and in the lower end of the valley of Emanuel Creek. In both places the rock forms conspicuous bluffs and can also be traced by small weathered outcrops on the hillsides and in road cuts. In general it makes the lower parts of the hills and probably floors the valleys of both the Missouri and Emanuel valleys though in these places it is covered by a thick deposit of alluvium. Above it lies a cover of drift and black shale 10 to 100 feet thick. This cover has been largely removed, however, in many places along the outcrops so that quarry sites are not difficult to find.

Character

The predominant color of the chalk of this region is a dark grey to black. This chalk weathers to the reddish buff which characterized the black chalk at Yankton. The end product of weathering is also a red clay. The deep red coloring seems to be a good indicator for the black chalk. This black chalk was especially well exposed in the big cliff about a quarter mile southwest of the Springfield railroad station where recent slides have exposed fresh rock for a thickness of about 90 feet.

Not all of the chalk in this valley is dark, however, for an outcrop, half a mile upstream from the one just mentioned, showed 25 feet of a cream colored chalk underlaid by 20 to 30 feet of very white chalk. A white zone lies along the railroad for four or five miles in the bluffs of the Missouri between Running Water and Springfield.

Samples of the characteristic black chalk and of the white chalks gave the following compositions on analysis:

Chalk Sample No. 18:

Location: N. W. ¼, Section 27, T. 93 N., R. 60 W. Cliff on west of railroad tracks. From middle of "buff zone".

Calcium Carbonate ($CaCO_3$)	83.04%
Aluminum (Al_2O_3)	2.31%

CHALK OUTCROPS IN THE VICINITY

OF

SPRINGFIELD ** RUNNING WATER

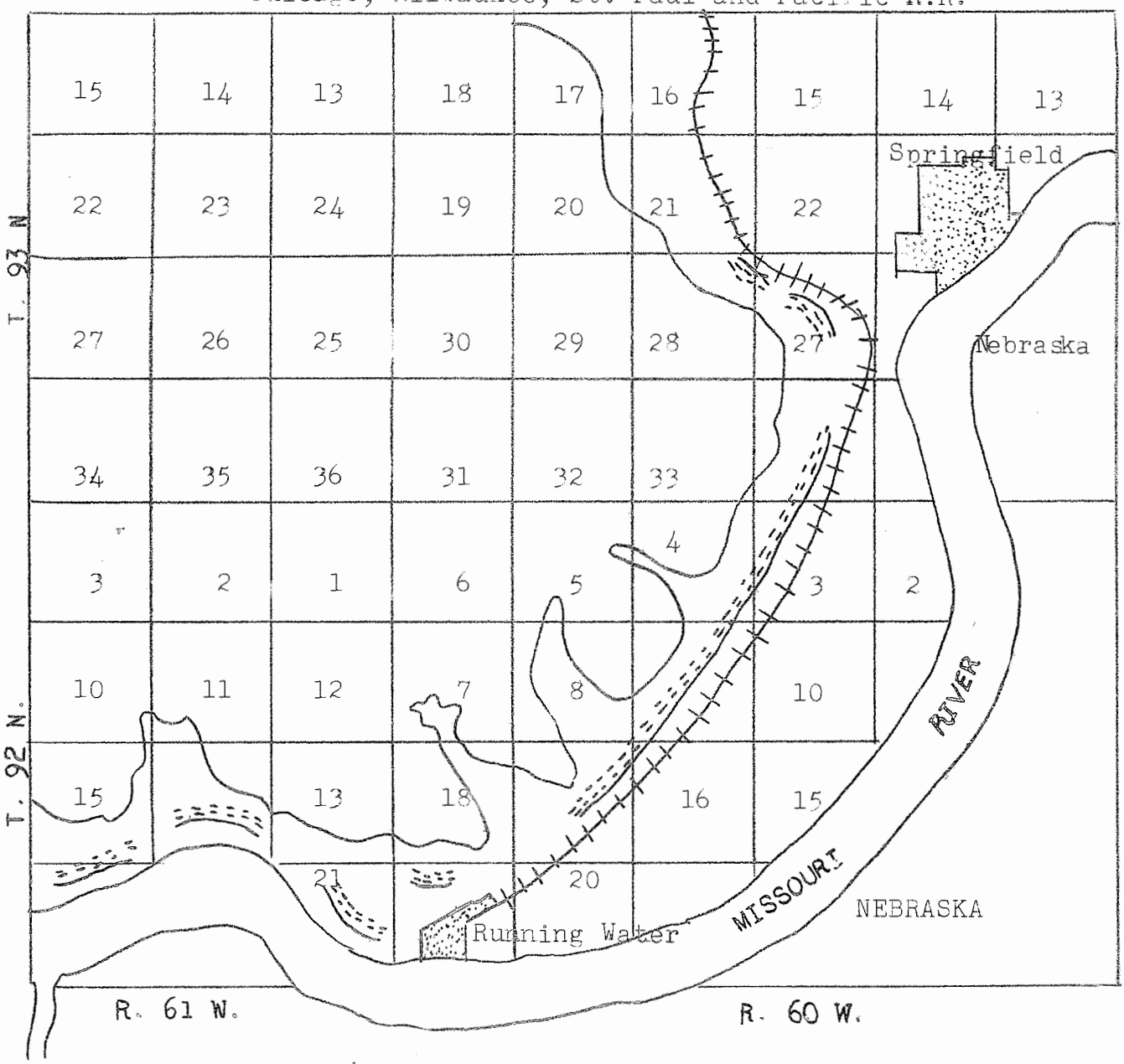
Legend

Boundary of the Pierre Shale Formation

Chalk Outcrops Described

Towns

Chicago, Milwaukee, St. Paul and Pacific R.R.



Iron (FeO)	5.50%
Volatile Matter	3.15%
Insoluble Matter	3.58%

Chalk Sample No. 19:

Location: N. W. $\frac{1}{4}$, Sec. 27, T. 93 N., R. 60 W. Cliff on west side of railroad tracks. Taken from bottom of white zone.

Calcium Carbonate ($CaCO_3$)	90.64%
Aluminum (Al_2O_3)	.81%
Iron (FeO)	2.45%
Volatile Matter	1.74%
Insoluble Matter	4.98%

Chalk Sample No. 20:

Location: N. W. $\frac{1}{4}$, Sec. 27, T. 93 N., R. 60 W. Cliff on west side of railroad tracks. Taken above creek level.

Calcium Carbonate ($CaCO_3$)	88.88%
Aluminum (Al_2O_3)	1.25%
Iron (FeO)	1.04%
Volatile Matter	1.13%
Insoluble Matter	6.39%

Chalk Sample No. 21:

Location: S. W. $\frac{1}{4}$, Sec. 27, T. 93 N., R. 60 W.; big cliff about one-fourth mile southwest of Springfield railroad station. Sample taken at base of massive bedded section, and is very fresh rock, a representative piece.

Calcium Carbonate ($CaCO_3$)	69.18%
Aluminum (Al_2O_3)	.21%
Iron (FeO)	1.40%
Volatile Matter	11.50%
Insoluble Matter	7.69%

Chalk Sample No. 22:

Location: S. W. $\frac{1}{4}$, Sec. 27, T. 93 N., R. 60 W. Big cliff about one-fourth mile southwest of Springfield railroad station. Taken from cliff about 700' west of big cliff. Chalk exposed here to water's edge. Sample taken ten feet above water level.

Calcium Carbonate ($CaCO_3$)	85.51%
Aluminum (Al_2O_3)	.80%
Iron (FeO)	1.37%
Volatile Matter	6.74%
Insoluble Matter	4.69%

Chalk Sample No. 23:

Location: About northwest corner of Section 22, T. 92 N., R. 61 W., three miles up the river from Running Water, cliffs on bluffs on Missouri. Sample taken one-fourth mile east of place where section was taken because fresher rock obtainable. Taken 15 ft. above base of cliff.

Calcium Carbonate ($CaCO_3$)	80.53%
Aluminum (Al_2O_3)	.60%
Volatile Matter	7.28%
Iron (FeO)	2.30%
Insoluble Matter	5.43%

Chalk Samples No. 24 and No. 25:

Location: N. E. $\frac{1}{4}$, Sec. 17, T. 92 N., R. 60 W. 1.7 miles along railroad toward Springfield from Running Water. This is the first place at which the chalk makes cliffs east of Running Water. Taken near base of cliffs.

Sample No. 24:

Calcium Carbonate ($CaCO_3$)	85.23%
Aluminum (Al_2O_3)	.68%
Iron (FeO)	1.37%
Volatile Matter	5.60%
Insoluble Matter	2.67%

Sample No. 25:

Calcium Carbonate ($CaCO_3$)	84.62%
Aluminum (Al_2O_3)	.76%
Iron (FeO)	1.62%
Volatile Matter	3.93%
Insoluble Matter	4.35%

Detailed Sections were measured as follows:

Emanuel Creek Valley

Section in the N. W. ¼, Sec. 27, T. 93 N., R. 60 W. From cliff on the west side of the railroad.

5 ft.	Shale
10 ft.	White chalk
25 ft.	"Buff zone", many calcite veins. Some black chalk seen. Ostrea congesta. Weathers a dark reddish buff. (Chalk Sample No. 18)
25 ft.	White chalk, weathers only light buff (Chalk Sample 19)
15 ft.	Partly covered but belongs to white zone.
20 ft.	Exposed in creek wall just east of track. Chalky white zone. (Chalk Sample No. 20) A little black chalk in bottom three feet of section.

Section in the S. W. ¼, Sec. 27, T. 93 N., R. 60 W. Big cliff about one-fourth mile west of railroad station at Springfield.

5 ft.	Pierre shale
55 ft.	Dark gray ("black chalk"). Weathers a reddish buff. Some calcite beds (1"-3") lying horizontally. Jointing vertical with minor fractures of 40° making slabby pieces. (Chalk Sample 21 taken at base of this section)
25 ft.	Dark chalk much like above but thinner bedded.
15 ft.	Talus covered from recent slide. 700 ft. upstream rock exposed is the same as 25 ft. above. (Chalk Sample 22 taken 10 ft. above river level, at latter outcrop.)
	River level.

Barometer Sections on Highway:

S. E. ¼, Section 28, T. 93 N., R. 58 W. From top of uplands to Emanuel Creek level at Springfield station.

80 ft.	Yellow drift; no unoxidized seen in road cuts.
90 ft.	Chalk, weathered dark buff color.

Section on east bluff of Emanuel Creek along highway. East of Springfield station.

20 ft. Drift
80 ft. Chalk. Like that at Springfield Station in S. W. ¼, Section 27, T. 93 N., R. 60 W.

Missouri Bluffs

Section East of Running Water, about three miles up the Mo. River, in the Northwest Quarter, Section 22, T. 92 N., R. 61 W. Cliffs on the bluffs of the Missouri.

40 ft. Drift
3 ft. Shale
50 ft. Chalk, weathers dark buff. Wherever fresh, shows "black chalk". (Chalk Sample 23 taken one-fourth mile east of this section--freshest rock obtainable.
Base of cliff at road level.

Section two miles northeast of Running Water. In the N. E. ¼, Section 17, T. 92 N., R. 60 W.; about 1.7 miles along the railroad toward Springfield from Running Water.

10 ft. Drift
11 ft. "Buff chalk", weathers buff
27½ ft. Creamy to chalky white, fairly thick bedded chalk. Some patches dark grey. (Chalk Samples No 24 and No. 25 both from near the base of the cliffs.) Weathers white or grey.

CHALK IN THE VICINITY OF MITCHELL

The following descriptions and analyses were taken from Mr. D. E. Lounsbery's report to the State Cement Commission:-

"The only available lime material in the vicinity of Mitchell is the Niobrara chalkstone. This outcrops in a number of places near Mitchell, and is easily recoginized by its white or buff color. There are four general localities in which the chalkstone outcrops in abundance, viz:

(1) Along the James River
(2) Firesteel Creek
(3) Enemy Creek
(4) Twelvemile Creek near Ethan

Maps showing the location of these deposits are included near the back of this report.

"The chalkstone consists largely of shells of minute animals, all microscopic fossil organisms, mixed with a small amount of clay When weathered, the chalkstone is of a white or buff color; the unweathered chalk which has a blue or dull grey color is rarely found in this region except at the lower part of exposures along stream banks."

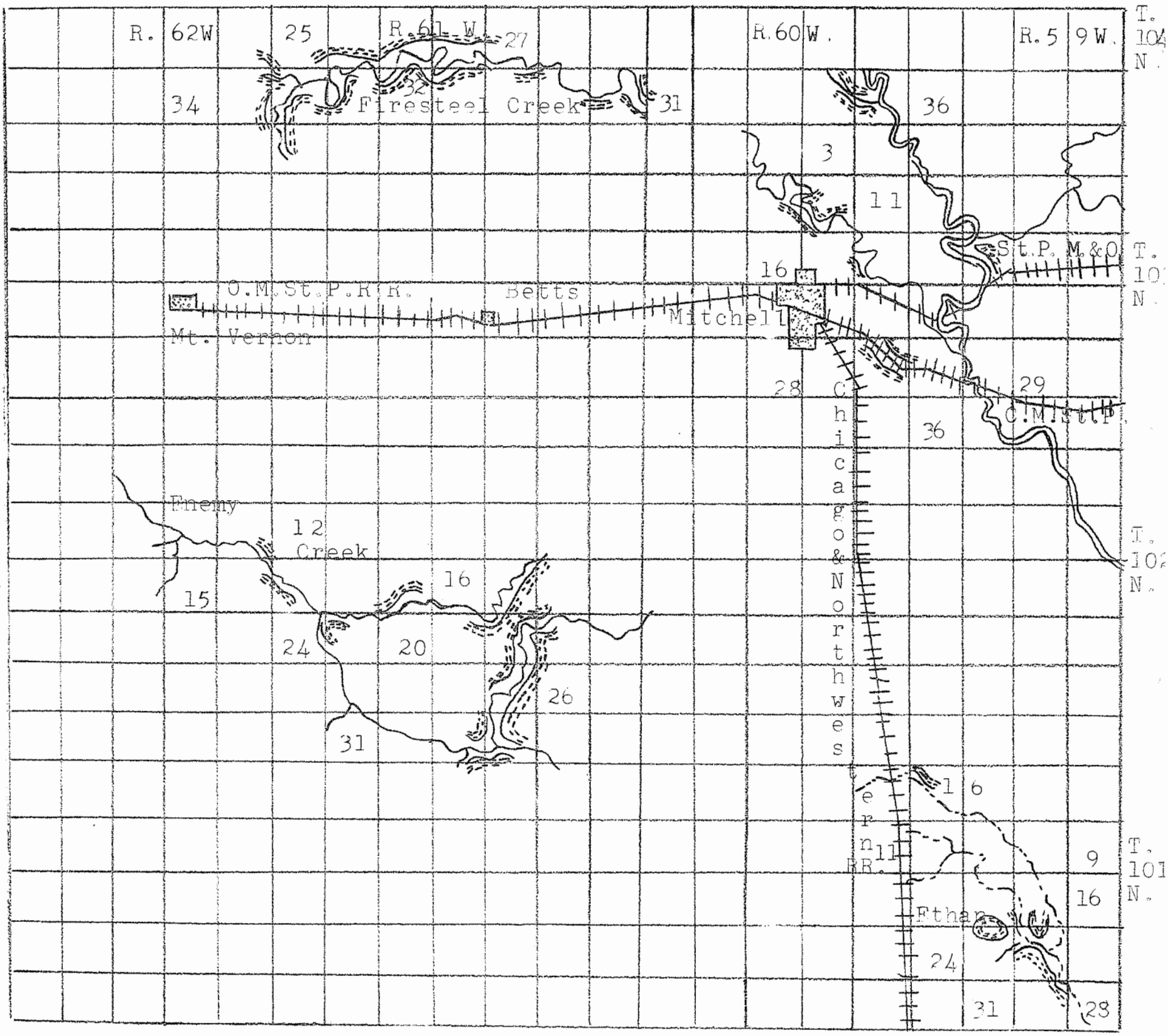
"1-Outcrops along the James River

"The Niobrara Chalkstone is exposed at intervals along the James River from Rockport in Hanson County, to the mouth of Morris Creek, four miles north of Mitchell, the most northernly outcrop being Section 34 of Perry Township. The average thickness of chalk above the water level is approximately twenty-five feet. The overburden in most places averaging thirty-five feet. The faces of all exposures are white, due to leaching out of the iron pyrites by the action of weathering agents."

"Due to the depth of overburden, no samples of the blue unweathered chalk were taken."

"Concretions of pyrite are present only in small amounts and the texture and composition of the white chalk are suitable for cement manufacture; however, the large amount of drift over the chalk makes it undesirable."

"West of the town of Riverside, an exposure occurs along the banks of the James River at the old mill site. The overburden is approximately sixty-five feet, a short distance from the river, which would prohibit the use of the chalk as a cement raw material at this point."



CHALK OUTCROPS IN THE VICINITY OF MITCHELL

Legend

- James River
- Chalk Outcrops
- Streams
- Towns
- Railroads

Chalk was used for building several buildings in the city about fifty years ago. The quarry which furnished this material lies in the northeast corner of the city.

Fifteen feet of chalk were exposed at the old quarry under a cover of thirty feet or more of glacial drift. The quarry has been abandoned since 1881 and was so slumped in and weathered at the time of the visit that no detailed information on the character of its materials was possible. The weathered material is white clay, but with many chunks of partly weathered chalk in it. No evidence of black chalk or of the reddish colored weathered material was present.

Old Quarry Section:

Location: N. E. $\frac{1}{4}$, Section 23, T. 103 N., R. 60 W.

30 ft. Drift
15 ft. Typical chalk. Grey when wet, white when dry.

Access: Chicago and Northwestern Railroad 300 ft. to the south.

Ostrea congesta were found rather abundantly scattered over this outcrop.

"The following analyses are typical of the white chalk:

Location: S. W. Cor., N. E. $\frac{1}{4}$, Sec. 34, Perry Twp. A thirty-foot exposure of drift and chalk. (13 ft. drift, 22 ft. of chalk) Sample taken from the South bank of the tributary to the James River 5 ft. from the top of the exposure.

SiO_2	4.92%
Fe_2O_3	1.40%
Al_2O_3	2.10%
CaO	50.42%
MgO	.78%
SO_3	.19%
S in FeS_2	.00%
Ign. Loss	40.36%

Location: Same as above, but sample taken from the lower part, 5 ft. from the water surface.

SiO_2	3.06%
Fe_2O_3	1.12%
Al_2O_3	1.52%
CaO	51.38%
MgO	.32%
SO_3	.03%
S in FeS_2	.00%
Ign. Loss	41.64%

"2--Outcrops along Firesteel Creek

"Due to uplift and erosion, the Niobrara and Benton formations are exposed along the bank of Firesteel Creek at intervals from its junction with the James River, westward as far as Section 35, Blendon Township. Thickness of the chalkstone varies considerably, but at no place is it greater than fifty feet, the upper portion of the formation having been eroded away. In certain places, erosion has entirely removed the chalkstone, and the upper Benton sandstone is exposed along the bank of the creek with glacial drift directly overlying it."

"The structure throughout the overcropping area consists of minor folds and faults, the prevailing dip being to the southwest. The chalkstone rests on the uneven surface of the Benton sandstone and often occurs at the same elevation with the chalkstone only a short distance away."

"Impurities found in the chalkstone of this area are of two kinds, viz:-iron concretions and gypsum bearing clayey bands. The iron concretions are present in large quantities in the layers which lie close to the contact with the Benton Formation. Considerable variation in size of the concretions is found, the largest having a diameter of twelve inches or so while the smaller ones approach the size of sand grains. Provided the material were to be used for cement manufacture, the largest concretions would undoubtedly be picked out either before passing through the crusher or directly afterward, but the smaller ones would pass unnoticed as they are often coated over with chalkstone which makes them undistinguishable from the rest of the chalk. Due to the extreme hardness of the concretions, considerable difficulty in grinding would be introduced were they admitted to the tube mill. In addition to causing grinding difficulties, their presence would also tend to raise the iron and sulphur content beyond the desirable percentage."

"The clayey layers encountered above the concretionary zone are present as bands varying from one to five inches in thickness. They occur between the bedding planes and apparently have a persistent lateral extent. In quarrying the

chalkstone, it would be almost impossible to exclude these impure layers. Their presence in the raw mixture would raise the sulphur content to such an extent as to make the material unfit for cement manufacturing."

"Analyses of the material in these layers gave the following results:

SiO_2	44.66%
Fe_2O_3	4.89%
Al_2O_3	12.35%
CaO	3.61%
MgO	3.59%
SO_3	9.44%
S in pyrite	.00%
Ign. Loss	26.15%

"The overburden has been found in all cases to be approximately equivalent to the amount of chalkstone available. The thickness near the bluff of the creek is often low, but back from the bluff a gravel ridge is always encountered which varies from five to ten feet in thickness of drift, makes approximately eighteen to twenty feet of chalkstone. Overburden on the north side of the creek was found from churn drill records to be greater in most cases than that on the south side."

"Analyses of the chalk from the Firesteel Creek gave the following analyses:

"Location: N. W. Cor., of Sec. 34, Badger Twp. Lower part of the exposure in unweathered and unleached zone, 6 ft. above the water surface.

SiO_2	6.38%
Fe_2O_3	1.40%
Al_2O_3	3.56%
CaO	46.93%
MgO	.31%
SO_3	.46%
S in pyrites	.48%
Ignition Loss	40.03%

"Location: Same location as the above, but from the white leached portion of exposure; 5 ft. below the top, 8-12 ft. of gravel overlies the chalk, medium grade.

SiO_2	4.56%
Fe_2O_3	2.38%
Al_2O_3	1.26%
CaO	50.85%
MgO	.33%
SO_3	.04%
S in pyrites	.00%
Ignition loss	40.57%

"Location: In the road between Sections 22 and 27, Lisbon Twp., 1500 ft. west of bridge, road cuts through the chalk. White sample taken 15 ft. from the top of and exposure 30 ft. thick.

SiO_2	3.16%
Fe_2O_3	1.68%
Al_2O_3	.62%
CaO	53.17%
MgO	.26%
SO_3	.03%
S in pyrites	.00%
Ignition Loss	41.37%

"Location: Same area as above sample, but taken across the creek near the base of the exposure.

SiO_2	2.10%
Fe_2O_3	2.24%
Al_2O_3	.88%
CaO	51.91%
MgO	.22%
SO_3	.02%
S in pyrites	.01%
Ignition Loss	43.03%

"Location: Badger Twp. 1200 ft. south of the N. W. Cor. of Sec. 33. Sample of Chalk 15 to 30 ft.

SiO_2	24.08%
Fe_2O_3	4.72%
Al_2O_3	9.18%
CaO	8.69%
MgO	.56%
SO_3	.91%
S in pyrites	1.31%
Ignition Loss	31.74%

"Location: Same location as above sample. Sample of blue chalk 30-45 ft.

SiO_2	13.10%
Fe_2O_3	3.30%
Al_2O_3	1.70%
CaO	40.59%
MgO	.52%
SO_3	1.10%
S in pyrites	2.64%
Ignition Loss	37.64%

"Location: Badger Twp. 300 ft. east of above sample. Sample of blue chalk 19 to 33 ft.

SiO_2	22.94%
Fe_2O_3	1.40%
Al_2O_3	9.50%
CaO	30.56%
MgO	.64%
SO_3	1.60%
S in pyrites	3.33%
Ignition Loss	31.60%

"Location: Same location as above. Sample of blue chalk 33 to 41 feet.

SiO_2	24.12%
Fe_2O_3	2.83%
Al_2O_3	5.73%
CaO	32.49%
MgO	1.89%
SO_3	1.21%
S in pyrites	3.35%
Ignition Loss	28.44%

"Location: Badger Twp. in the S. E. Cor. of the N. E. $\frac{1}{4}$, Sec. 33. Sample of blue chalk 20 to 34 ft.

SiO_2	24.00%
Fe_2O_3	3.14%
Al_2O_3	6.70%
CaO	30.95%
MgO	1.34%
SO_3	1.39%
S in pyrites	3.26%
Ignition Loss	30.10%

"Location: Badger Twp. in the S. E. Cor. of the N. E. ¼, Sec. 31; Sample of chalk 20 35 ft.

SiO_2	41.56%
Fe_2O_3	1.88%
Al_2O_3	1.90%
CaO	20.42%
MgO	1.36%
SO_3	.80%
S in pyrites	.78%
Ignition Loss	20.32%

"Location: Badger Twp. 1400 ft. east from the bridge across the Firesteel Creek, between Sections 31 and 32. Sample of blue chalk 15-40 ft.

SiO_2	23.16%
Fe_2O_3	3.46%
Al_2O_3	9.76%
CaO	30.02%
MgO	.52%
SO_3	.85%
S in pyrites	.55%
Ignition Loss	31.56%

"Location: Badger Twp. 1300 ft. east of above sample on one-half section line. Sample of blue chalk 13-40 ft.

SiO_2	25.34%
Fe_2O_3	3.46%
Al_2O_3	5.40%
CaO	34.70%
MgO	1.57%
SO_3	1.13%
S in pyrites	3.60%
Ignition Loss	29.74%

"3--Enemy Creek Outcrops

The Enemy Creek outcrops were examined on the 1929 survey in Section 32, T. 102 N., R. 61 W. and in Section 24, T. 102 N., R. 62 W. In the S. W. ¼, of Section 32, T. 102 N., R. 61 W., the top of the chalk was measured 20 ft. below the surface of the upland, being covered entirely with glacial drift and two to four feet of shale. There are many shoulders and slopes where this cover has been largely removed in the valley so that stripping would not be as great to reach the chalk.

The thickness of the chalk in this region is about 130' to 135'. A well in the N. E. $\frac{1}{4}$, of Section 24, T. 102 N., R. 62 W., reached the bottom of the chalk at 127 ft. The top of the chalk lies in the bluffs about ten feet above the top of the well. Of this thickness, however, only about 30 ft. can be counted accessible since the rest is far enough below the bottom of the streams to make water troubles probable.

The chalk as seen in the outcrops was a white or light cream color, but weathered a light to medium buff. Chemical analyses gave the following:

Chalk Sample No. 16:

Location: Taken in big outcrop on south bluff of Enemy Creek.

Calcium Carbonate ($CaCO_3$)	93.18%
Aluminum (Al_2O_3)	.88%
Iron (FeO)	1.37%
Volatile Matter	1.25%
Insoluble Matter	3.41%

Chalk Sample No. 17:

Location: N. E. $\frac{1}{4}$, Section 24, T. 102 N., R. 62 W., North bluff of Enemy Creek.

Calcium Carbonate ($CaCO_3$)	92.36%
Aluminum (Al_2O_3)	1.60%
Iron (FeO)	1.98%
Volatile Matter	1.72%
Insoluble Matter	4.72%

The Lounsbery report continues:

"The Niobrara Formation is exposed along the banks of Enemy Creek and tributaries in Lisbon Township from Section 19, eastward as far as Section 23. The available thickness is about 20 feet, with an average of 15 to 18 feet of drift overlying. The chalk in this vicinity belongs to the middle part of the Niobrara formation."

"Impurities are restricted to clayey bands often containing gypsum, similar to those described from Firesteel Creek."

"The face of the exposures invariably are reddish and buff color. Secondary gypsum is often found in large quanti-

ties between joints and bedding planes. While this fact is of little significance when the unweathered portion is considered, it points to a high iron content of chalkstone; the gypsum being a secondary product from the reduction of iron sulphide. The exposure in Section 27 of Lisbon Township along Enemy Creek, has the least amount of overburden to be removed as revealed by the churn drilling holes. The approximate amount of drift to be removed would be 20,000,000 cubic feet foran available 35,000,000 cubic feet of chalkstone."

"The C. M. & St. P. RR can be reached at a distance of five and one-half miles to the north, or six miles to the E.; the topography to the north being the best suited for railroad building as a minimum amount of filling would be necessary."

"Some analyses of samples taken by the churn drill gave the following results:

Location: Between Sections 33 and 28, Lisbon Township in the road 2400 ft. west of the school house corner. Sample taken from the blue unleached zone 27-49 ft. average of the 22 ft.

SiO_2	13.12%
Fe_2O_3	5.03%
Al_2O_3	5.81%
CaO	41.53%
MgO	.33%
SO_3	1.72%
S in Pyrites	1.97%
Ignition Loss	31.82%

Location: Section 34, Lisbon Twp., 1200 ft. east of N. W. Corner of Section. Sample taken from the blue unleached part of the chalk 29-50 ft., average of the 21 ft.

SiO_2	24.40%
Fe_2O_3	3.77%
Al_2O_3	7.15%
CaO	30.84%
MgO	.50%
SO_3	.53%
S in Pyrites	1.48%
Ignition Loss	26.96%

Location: Section 27, Lisbon Twp., 2200 ft. east of the Northwest Corner of the Section (near the half-section line). Sample taken from the leached and white chalk, 13-17½ ft.

SiO_2	17.34%
Fe_2O_3	3.92%
Al_2O_3	.12%
CaO	40.66%
MgO	1.06%
SO_3	4.01%
S in pyrites	.12%
Ignition Loss	31.07%

Location: Same location as above sample. Sample taken from the unweathered and unleached chalk, 18-40 ft., average of the 22 ft.

SiO_2	7.92%
Fe_2O_3	3.36%
Al_2O_3	2.24%
CaO	43.33%
MgO	.53%
SO_3	.36%
S in Pyrites	1.90%
Ignition Loss	36.78%

Location: Same location as above sample. Sample taken from the blue unweathered and unleached chalk 40-50 ft., average of the 10 ft.

SiO_2	12.04%
Fe_2O_3	5.02%
Al_2O_3	5.94%
CaO	36.65%
MgO	.59%
SO_3	.82%
S in pyrites	4.03%
Ignition Loss	31.48%

"These analyses show that the silica and iron oxide content of the chalkstone is rather high, while the lime content is low. These factors together with the amount of overburden and distance from transportation would render the chalkstone undesirable for use as a cement raw material in this locality."

"4--Twelvemile Creek

"In this locality the upper part of the Niobrara formation is exposed; only a slight amount having been removed by

erosion. The thickness of the formation shown by well logs of various wells drilled in the vicinity is between one hundred and one hundred twenty-five feet."

"One and one-half miles east of Ethan, the chalkstone comes to the surface with practically no overburden except two or three feet of clay which is a decomposition product resulting from weathering. The chalkstone is exposed two and one-fourth miles east of Ethan along the bank of Twelvemile Creek. At this point, it is overlain by a sandstone which is a representative of Pierre deposition. Overburden here consists of six feet of sandstone and six to ten feet of glacial drift. Available chalk above the water level is twenty-two ft."

"In the northeast corner of Section 29, Worthen Township, an exposure of chalk thirty feet in thickness exists which is overlain by an equivalent amount of overburden in the form of glacial drift. Apparently in this locality, the lower part of the formation is present as the content of iron concretions in the form of pyrite would indicate. The Benton formation comes to the surface a distance of one mile to the southeast, and the Niobrara is absent. Dip of the formation is northwest which would account for the greater thickness near Ethan."

"Impurities found in the chalk are iron concretions and silica. The concretions while not as abundant as in the Firesteel Creek locality, are present in a quantity sufficient to cause difficulty in cement manufacture. Silica is present in the chalk in amounts varying from ten to thirty per cent."

"From the standpoint of amount of averburden to be removed and the nearness to transportation facilities, this area is the most favorable in which to obtain calcareous material for cement manufacture."

"Analyses of the chalk which are given below bring out the following points:

That the silica contents are rather high for use as a raw material in Portland cement manufacture.

That the lime content is lower than that desired for calcareous raw material.

That the material is best suited for use in making natural cement.

That the variation in composition both laterally and vertically is considerable

Analyses of samples taken gave the following results:

Location: Worthen Twp., 200 ft. east of the Northwest corner of the N. E. $\frac{1}{4}$, Section 19, in the road. Sample of blue chalk 19 35.

SiO_2	17.94%
Fe_2O_3	3.06%
Al_2O_3	8.76%
CaO	37.08%
MgO	1.37%
SO_3	.10%
S in pyrites	.13%
Ignition Loss	31.93%

Location: Worthen Twp. in the road 1700 ft. west of the North east Corner of Section 19. Sample of the white chalk 4--16 ft.

SiO_2	20.53%
Fe_2O_3	2.66%
Al_2O_3	3.78%
CaO	36.01%
MgO	.71%
SO_3	.08%
S in pyrites	.01%
Ignition Loss	31.07%

Location: Worthen Twp., 1700 ft. west of the Northeast Corner of Section 19. Sample of blue chalk 20 35 ft.

SiO_2	19.12%
Fe_2O_3	2.80%
Al_2O_3	9.38%
CaO	35.27%
MgO	1.27%
SO_3	.04%
S in pyrites	.07%
Ignition Loss	31.44%

Location: Worthen Twp 1200 ft. N., 300 ft. east of South west Corner of the S. E. $\frac{1}{4}$, Section 18. Average Sample of white chalk 4--16 ft.

SiO_2	19.98%
Fe_2O_3	2.66%
Al_2O_3	9.16%
CaO	36.44%
MgO	.71%
SO_3	.10%
S in pyrites	.13%
Ignition Loss	31.77%

CHALK IN THE VICINITY OF SCOTLAND AND MENNO

Scotland

Chalk outcrops in the valley of Dawson Creek east of Scotland. The best exposures being at the dam of the State lake one mile east of the city. They may be followed down the valley for at least another mile. Most of these are on shoulders which project into the valley and they show from 15 to 25 feet of chalk under a cover of 8 to 20 feet of drift. The cover on the uplands is thicker than on the shoulders by 20 to 30 feet, but sufficient areas can be found on the shoulders to permit the opening of quarries without excessive stripping.

The following section was taken at the spillway for the dam which was cut into the chalk:

8 ft. Cover
16 ft. White or light grey chalk. Weathers white. (Chalk Sample No. 15)
Bottom of spillway.
15 ft. Covered but shows in stream cut at this level 600 ft. away. Same character as section above.

Note: Thick till over chalk on uplands, but shoulders projecting into the valley have most of it stripped off. In general the cut banks expose 15 to 25 ft. of chalk under a cover varying from 8 to 20 ft. Chalk all weathers white.

Character

It is to be noted that the chalk exposed in this region is all white in color and does not show the red or deep buffs of weathering which were noted in other places. Neither does the exposure show any black or dark grey chalk. The character of the weathering and color of the rock corresponds to that of the "White zone" on Turkey Ridge and it is thought this rock will be very similar in character.

Chemically it gave the following analysis:

Calcium Carbonate ($CaCO_3$)	80.65%
Aluminum (Al_2O_3)	.57%
Iron (FeO)	.76%
Volatile Matter	2.54%
Insoluble Matter	12.55%

CHALK OUTCROPS IN THE VICINITY

OF

MENNO

Legend

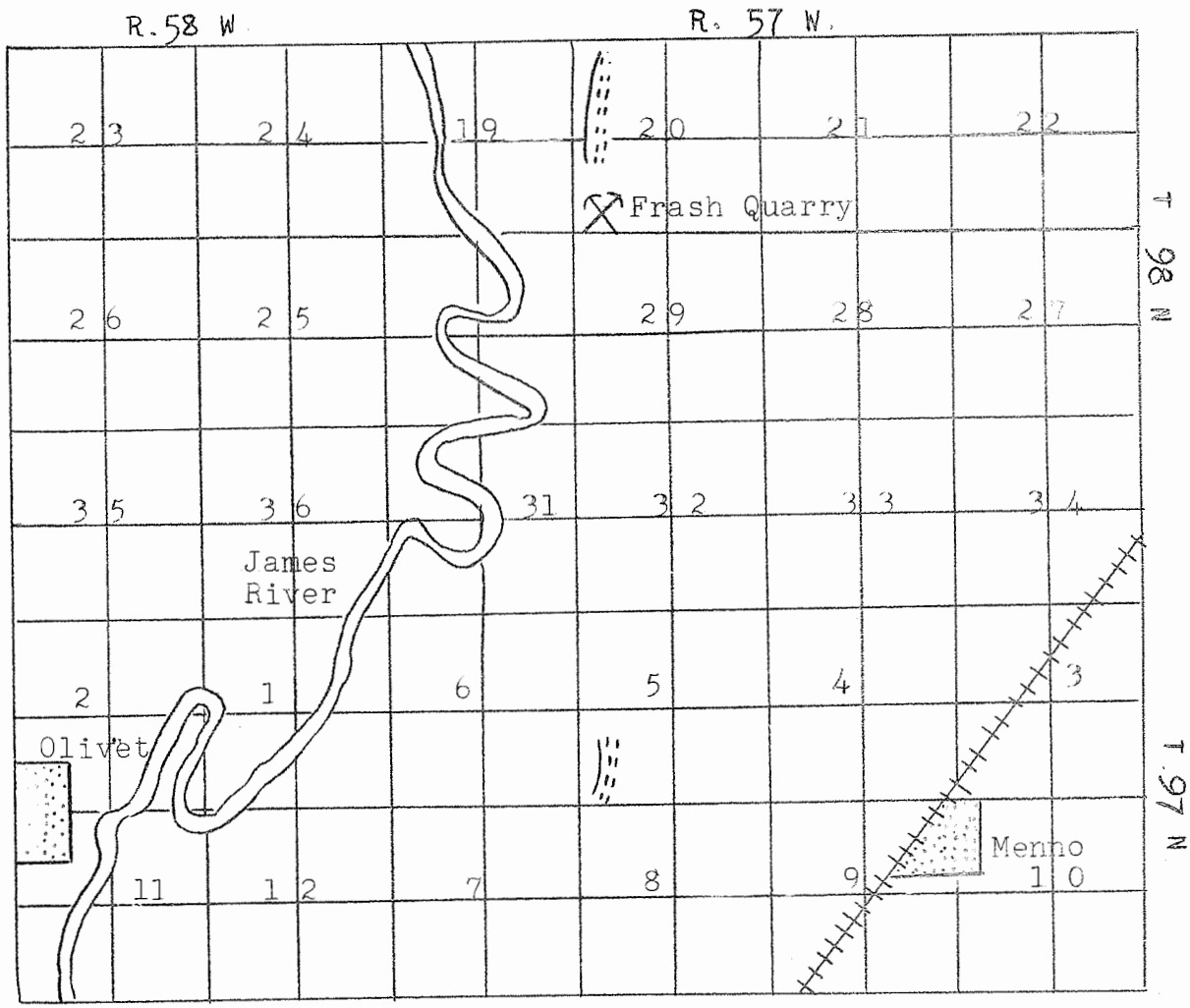
Chalk Outcrops Described

James River

Frash Quarry

Towns

Chicago, Milwaukee, St. Paul and Pacific R.R.



Fossils:

Ostrea congesta are plentiful but no other microscopic fossils were noted. No careful search was made for them.

Menno

Chalk outcrops in the lower part of the banks of the James Valley in the vicinity of Menno, the best outcrop being a road cut four miles north and two miles west of Menno in the S. W. Corner of Section 20, T. 98 N., R. 57 W. This cut was used as a quarry for obtaining chalk to be used in a commercial hog feed made in Menno by Mr. Adolph Frash. This exposure showed the following section:

30 ft. Drift and float. Float gravelly.
45 ft. White chalk. Weathers white. Lower six ft. slightly buff. (Chalk Sample No. 14)

The chalk is similar to that near Scotland in appearance. It is white in color and weathers to a chalky white. This color is characteristic for all the exposures seen along the east bluffs of the valley from a distance of three miles south of this exposure. It is possible that the chalk of this region is characteristically white and contains little if any of the dark grey or black chalk found in the vicinity of Yankton in the zones that might be used in quarrying.

Chemically this chalk is:

Calcium Carbonate ($CaCO_3$)	80.52%
Aluminum (Al_2O_3)	3.70%
Iron (FeO)	1.62%
Volatile Matter	2.51%
Insoluble Matter	12.98%

Fossils:

Ostrea congesta were extremely abundant especially on an outcrop less than a quarter mile south of the cut. No other large invertebrates were noted though search was made for them. One vertebra showing the double cups characteristic of a fish of reptile was found.

CHALK IN THE CHAMBERLAIN-OACOMA AREA

Chalk outcrops in the bluffs of the Missouri where it forms cliffs, both north and south of the city of Chamberlain. It is also exposed in cliffs on the west bluffs of the Missouri Valley where the railroad and highway cross the river. Evidences of chalk can also be seen in the bluffs of American Creek at the eastern side of Chamberlain and in the valleys in the vicinity of Oacoma.

The top of the formation lies about 50 to 70 ft. above the level of the river and about 100 ft. below the black zone of manganese and iron nodules which can be readily seen along the bluffs of the valleys of that region. The chalk cliffs are usually to be found under the shoulders which project from the sides of the valleys, and from which much of the overlying burden of shale has been eroded. Any quarries will have to be in the bottoms of the valleys, as the valleys, are cut into the top of the formation which extends to a depth of about 100 ft. below them.

Typical sections were taken north and south of Chamberlain, and gave the following results:

Sections North of Town:

Location: One and a half miles up the river from Chamberlain.

	Drift
111 ft.	Contact covered. Shale
58 ft.	Manganese zone
110 ft.	Black shale
85 ft.	Chalk, light grey, thin bedded, almost shaly. Weathers to a grey and on longer exposure a bright buff. Looks like a very dirty chalk. (Chalk Sample 27 from upper half of outcrop and Chalk Sample 26 from lower half.)

Location: Along road northeast of Chamberlain pump house.

67 ft.	Drift
	Good contact
73 ft.	Shale
	Contact covered
31 ft.	Manganese zone
122 ft.	Shale
	Contact covered
76 ft.	Covered chalk zone

CHALK OUTCROPS IN THE VICINITY

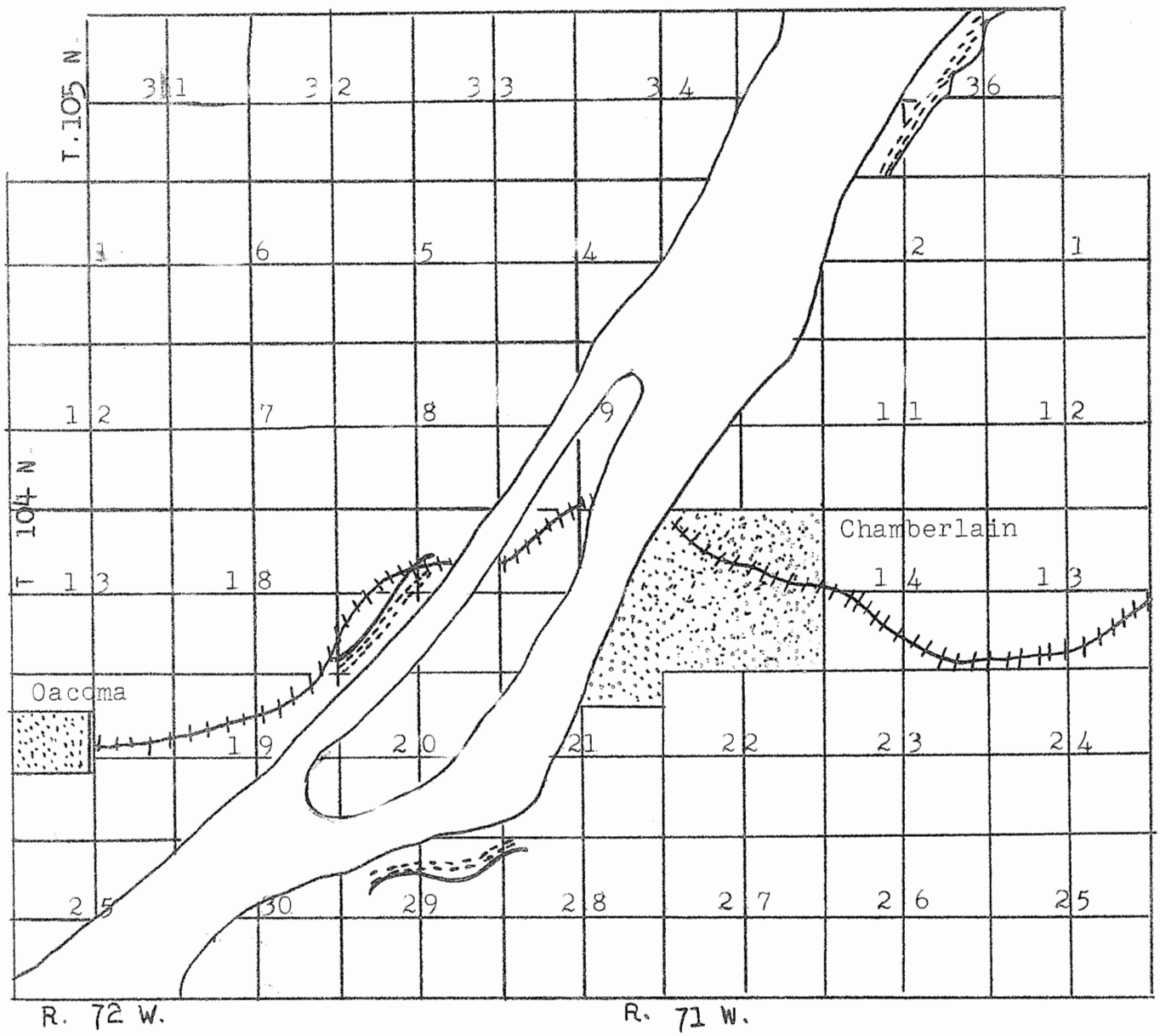
OF

CHAMBERLAIN ** OACOMA

Chalk Outcrops Described

Towns

Railroad; Chicago, Milwaukee, St. Paul and Pacific



Sections South of Chamberlain:

Location: On hill in N. E. $\frac{1}{4}$, Section 29, T. 104 N., R. 71 W. Taken with a barometer.

130 ft.	Till shale
70 ft.	Manganese zone
145 ft.	Shale
55 ft.	Chalk (Sample taken from this--No. 28)

Location: S. W. $\frac{1}{4}$, Section 17, T. 104 N., R. 71 W. From cliffs near first tracks and highway south of bridge.

	Pierre shale. Black, full of gypsum. One bone found; could not identify it as all broken.
10 ft.	Grey chalk, weathers lighter to white. Beds not so thin, averaging two to six inches under talus where Sample N. 29 was taken. This zone seems fairly continuous though some big cliffs do not show it.
60 ft.	Dark colored, chalk weathering a dark grey and in some places a dark buff. Bedding fairly massive, (1-3 ft.) where very fresh but on a little, weathering becomes shaley in appearance. (Chalk Sample No. 30)

Character

The chalk of this region is almost without exception dark in color. Most of it is thin bedded and looks shaley, when but a little weathering has taken place. Instead of the massive blocks characteristic of much of the chalk of the state, these outcrops present a woody appearance as though the material were splintering off. On very fresh faces, however, these minor beds are not so apparent and in places like the railroad and highway cuts near Oacoma it appears blocky in some beds. This shaley appearance and weathering is due to the large amount of clay which the formation contains.

Chemical analyses made in the State Chemical Laboratory of typical samples of this chalk gave the following:

Chalk Sample No. 26:

Location: One and one half miles up the river from Chamberlain.

Calcium Carbonate ($CaCO_3$)	67.01%
Aluminum (Al_2O_3)	.76%
Iron (FeO)	3.69%
Volatile Matter	10.83%
Insoluble Matter	9.35%

Chalk Sample No. 27:

Location: One and one half miles up the river from Chamberlain.

Calcium Carbonate ($CaCO_3$)	74.13%
Aluminum (Al_2O_3)	1.44%
Iron (FeO)	1.37%
Volatile Matter	5.06%
Insoluble Matter	15.46%

Chalk Sample No. 28:

Location: N. E. $\frac{1}{4}$, Section 29, T. 104 N., R. 71 W.

Calcium Carbonate ($CaCO_3$)	74.64%
Aluminum (Al_2O_3)	.66%
Iron (FeO)	3.12%
Volatile Matter	9.65%
Insoluble Matter	6.15%

Chalk Sample No. 29:

Location: S. W. $\frac{1}{4}$, Section 17, T. 104 N., R. 71 W. About 15 ft. above the river level.

Calcium Carbonate ($CaCO_3$)	75.61%
Aluminum (Al_2O_3)	2.13%
Iron (FeO)	2.13%
Volatile Matter	2.34%
Insoluble Matter	15.94%

Chalk Sample No. 30:

Location: S. W. $\frac{1}{4}$, Sec. 17, T. 104 N., R. 71 W. Taken about five ft. above railroad tracks, which is about sixty ft. below the top of formation

Calcium Carbonate ($CaCO_3$)	69.21%
Aluminum (Al_2O_3)	.83%
Iron (FeO)	3.23%
Volatile Matter	11.01%
Insoluble Matter	3.33%

Fossils:

Fossils were not abundant. A few scattered Ostrea congesta were the only large invertebrates noted. Some fish scales were scattered through the rocks.