

Spring 1939

The Lime Content of Rocks of The Upper Cretaceous System of Osborne County, Kansas

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DOI: 10.58809/OZXP2482

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THE LIME CONTENT OF ROCKS
OF THE UPPER CRETACEOUS SYSTEM
OF OSBORNE COUNTY, KANSAS

being

A thesis presented to the Graduate Faculty of
the Fort Hays Kansas State College in partial
fulfillment of the requirement for the degree
of Master of Science

by

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Date Jan. 14, 1939.

ACKNOWLEDGMENT

I desire to acknowledge my indebtedness to Professor Roy Rankin, Head of the Chemistry Department, his colleague, Dr. Wilbert Chappel, and to my wife, Ila, for their assistance and inspiration given me throughout the investigation of this problem.

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I. INTRODUCTION

This report is the result of several weeks of intensive study and investigation in the field and in the laboratory. In making this study of the rocks of Osborne County, Kansas, the writer is concerned chiefly with the chemistry of the rocks rather than with their geological formation. He has not attempted to make a complete analysis of the rocks, but has limited his investigation in order to determine certain facts concerning their lime content. He has attempted to determine the consistency of the percentage of lime in a given member in various parts of the county and also of different beds of a given member in the same locality. He has also investigated the possibility of the existence of limestone of a percentage sufficiently high to be used for cattle feeding and for the manufacture of lime. As far as the writer has been able to determine, there has been no such analysis made for this particular locality previous to this time.

II. GEOGRAPHY OF OSBORNE COUNTY

Osborne County is located in northern Kansas in the second row of counties south of the Nebraska line and slightly west of center. It is a square, being five townships in length and the same number in breadth, with a total area of approximately 573,000 acres. There are two towns with a population of over 1000: Osborne, the county seat with a population slightly under 2000; and Downs, twelve miles northeast of Osborne, with a population of approximately 1500. Smaller towns of the county include Portis, Alton, Covert, and Natoma.

The county is served by three railroads. The Missouri Pacific enters the county near the northeast corner. At Downs it divides, one branch going up the north fork of the Solomon River through Portis to its terminus at Lenora in Norton county, while the other branch cuts across to the south fork of the Solomon at Osborne and continues up that fork through Alton to its terminus at Stockton in Rooks County. A branch of the Union Pacific cuts across the extreme southwest corner of the county, serving Natoma. A branch of the Santa Fe extends from Salina in a northwesterly direction through Hunter and Tipton in Mitchell County and through east-central Osborne County to its terminus at Osborne.

The county is served by U. S. Highway No. 24, which crosses it in a general east-west direction, and by Kansas State Highway No. 8, which runs in a north-south direction. Osborne County also maintains

83 miles of roads surfaced with a limestone gravel.

Osborne County is strictly an agricultural region. Approximately 53% of the county is cultivated, the principal crop being wheat. The remaining area is used as grazing land for cattle and sheep.

Almost all of Osborne County is drained by the Solomon River and its tributaries. These tributaries are small; they have narrow valleys, and in few cases drain more than two townships. The western row of townships, however, is drained by tributaries of the Nelius River, which flows eastward across Russell County and eventually enters the Smoky Hill River a few miles west of the point where the Solomon River also joins the Smoky Hill.

Elevations range between 1300 feet in the Solomon valley in the eastern part of the county to 2125 feet on the tops of bluffs in the southwestern part. The High Hills in the southeastern part of the county stand considerably higher than the adjacent stream valleys. Relief ranging from 500 to 800 feet in a mile may be noted in this locality.

The local physiographic features of the county are the flood plains, which were formed by the deposition of stream-carried material. The flood plain of the Solomon River ranges in width from one to four miles. Terraces may be observed at a number of places along the Solomon and in a few localities are very prominent. Two terraces are noticeable in the vicinity of Osborne, one about 7 feet above the present flood plain and the other one about 15 feet above. A terrace having an average height of about 15 feet above the present flood plain occurs between Alton and the western edge of the county. West

III. TOPOGRAPHY

Almost all of Osborne County is drained by the Solomon River and its tributaries. These tributaries are small; they have narrow valleys, and in few cases drain more than two townships. The southern row of townships, however, is drained by tributaries of the Saline River, which flows eastward across Russell County and eventually enters the Smoky Hill River a few miles west of the point where the Solomon River also joins the Smoky Hill.

Elevations range between 1300 feet in the Solomon valley in the eastern part of the county to 2100 feet on the tops of divides in the southwestern part. The Blue Hills in the southeastern part of the county stand considerably higher than the adjacent stream valleys. Relief ranging from 200 to 300 feet in a mile may be noted in this locality.

The lowest physiographic features of the county are the flood plains, which were formed by the deposition of stream-carried material. The flood plain of the Solomon River ranges in width from one to four miles. Terraces may be observed at a number of places along the Solomon and in a few localities are very prominent. Two terraces are noticeable in the vicinity of Osborne, one about 7 feet above the present flood plain and the higher one about 18 feet above. A terrace having an average height of about 15 feet above the present flood plain occurs between Alton and the western edge of the county. West

of Downs on the north fork of the Solomon are three distinct benches, 2 feet, 5 feet, and 25 feet above the valley floor. Both the flood plains and the terraces are composed of a silty loam which makes a very fertile soil and on which prosperous farms are located.¹

The greater part of Osborne County is covered by rocks of the Upper Cretaceous age. Only a relatively small part of it is covered by Tertiary and Quaternary sediments. Due to the gradual increase in elevation from the eastern side of the county to the western side and the nearly horizontal rock structure, the older formations occur to the east and the younger to the west. The youngest formation of the Upper Cretaceous System, the Shaly Hill shale, occurs in the higher parts of central and western Osborne County. The Tertiary rocks which cover the Great Plains extend into the north-western part of the county and form the youngest bench in that particular area. The flood plains of the Solomon and its tributaries are covered with alluvium of the Quaternary period.

A better understanding of the outstanding features of the exposed rock formations of Osborne County may be obtained from the following table.

1. Landes, Kenneth K. The Geology of Mitchell and Osborne Counties, Kansas, p. 9-11.

IV. STRATIGRAPHY

The greater part of Osborne County is covered by rocks of the Upper Cretaceous age. Only a relatively small part of it is covered by Tertiary and Quaternary sediments. Due to the gradual increase in elevation from the eastern edge of the county to the western edge and the nearly horizontal rock structure, the older formations occur to the east and the younger to the west. The uppermost formation of the Upper Cretaceous System, the Smoky Hill chalk, appears in the higher parts of central and western Osborne County. The Tertiary rocks which cover the Great Plains extend into the southwestern part of the county and form the uppermost bench in that particular area. The flood plains of the Solomon and its tributaries are covered with alluvium of the Quaternary System.

A better understanding of the outstanding features of the exposed rock formations of Osborne County may be obtained from the following table.

TABLE I

Rock formations exposed
in Osborne County, Kansas²

System and series		Formation and member	Lithologic character	Thickness in feet
QUATERNARY	Recent		Modern stream deposits Terrace deposits Soil and talus Spring deposits	
	Pleistocene (?)		Intermediate sand and gravel deposits Loess	0-50
U. C. Tertiary		Ogallala	Unconsolidated sediments on divides "Mortar" beds	

2. Ibid., p. 13.

TABLE I (cont.)

System and series		Formation and member	Lithologic character	Thickness in feet	
CRETACEOUS	Upper Cretaceous	Niobrara formation	Smoky Hill chalk member	Chalk and chalky shale	0-115
			Fort Hays limestone member	Massive chalk alternating with thin chalky shale beds.	60
		Carlisle shale	Blue Hill shale member	Gray, fissile clay shale with sandstone at top and concretions in upper part	200
			Fairport shale member	Chalky shale with thin limestone beds in lower part	103
		Greenhorn limestone	Pfeiffer member	Chalky limestone and shale	18
			Jetmore member	"Shell" limestones and chalky shale	17
			Hartland shale member	Bluish-gray chalky shale with a few thin limestone and bentonite beds.	22-27
			Lincoln member	Chalky shale and thin, hard crystalline limestone beds	25

V. GEOLOGY OF THE UPPER CRETACEOUS SYSTEM³

A. Niobrara Formation

The Niobrara formation, which is the highest and youngest part of the Cretaceous exposed in Osborne County, is subdivided in Kansas into an upper member, the Smoky Hill chalk, and a lower, the Fort Hays limestone.

1. Smoky Hill Chalk Member

The Smoky Hill chalk member is 700 to 800 feet thick in the western end of the state, but only the lower part is present in Osborne County as a thin veneer overlying the more resistant Fort Hays limestone. The maximum thickness of Smoky Hill chalk known to be present in Osborne County is 115 feet. The member is composed of alternating thin-bedded chalk and tan weathering chalky shale. The Smoky Hill chalk is usually eroded away except where it is protected by a cap of "mortar beds", and even there the slopes are so gentle that the chalk is exposed only in ravines and road cuts. A characteristic feature of the Smoky Hill member is the presence of discoidal concretions, often circularly furrowed, which are composed of pyrite and limonite.

3. Ibid., p. 16-30.

2. Fort Hays Limestone Member

The Fort Hays limestone is much the more prominent member of the Niobrara formation in Osborne County. It extends into the county from Rooks County in two long points, one north and the other south of the south fork of the Solomon River. These points are intricately dissected by tributaries of the Solomon. Because of the greater hardness of this limestone, it forms steep slopes and cliffs. Where no Smoky Hill chalk veneer is present above the Fort Hays member, the rock makes a fairly smooth plateau surface which is generally covered by an abundance of white residual limestone fragments. Superficial faults caused by landsliding are common in the outcrop area of this member.

The Fort Hays limestone differs from the overlying Smoky Hill chalk largely in its proportion of massive chalk to chalky shale. This proportion in the Smoky Hill member runs about one to one, but the Fort Hays member contains at least six times as much massive chalk as chalky shale. The Fort Hays member appears to be slightly coarser in texture and somewhat harder than the chalk of the Smoky Hill member. The individual beds of Fort Hays limestone vary in thickness, but many of the beds are from 2 to 3 feet thick. These beds are separated by thin layers of light gray chalky shale, usually 1 to 6 inches thick. The color of the beds ranges from creamy white through yellow to light brown.

As a general rule the soil of the Fort Hays plateau and on the Smoky Hill chalk slopes and buttes is very thin and stony. Larger areas underlain by these two members are unsuitable for cultivation and are used for grazing.

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B. Carlile Shale

The Carlile Shale is divided into two members, the Blue Hill shale above and the Fairport shale below. The essential difference between the two is the absence of calcareous material in the former, whereas the Fairport is highly calcareous. Since both members are shaly, there is no distinct break between them, and the contact is hard to find. However, where fresh exposures occur the distinction can readily be made between the two, for the Blue Hill is black while the Fairport is gray to light yellow.

1. Blue Hill Shale Member.

The Blue Hill shale covers a large area in Osborne County, occupying the steep slopes beneath the Fort Hays escarpment. The elevation of the Fairport-Blue Hill contact in southwestern Osborne County is about 1800 feet. The Blue Hill member is about 200 feet thick. A gray argillaceous sandstone varying in thickness from a few inches to a few feet, lies at the top of the member directly beneath a thick scarp-making Fort Hays limestone bed. The greater part of the Blue Hill member consists of a very fissile blue-gray noncalcareous shale with several zones of septaria concretions. The concretions in the sandy zone near the top of the Blue Hill member may have diameters as great as 8 feet. The shale concretions range in diameter from a few inches to 4 feet. They are spherical, discoidal or lemon-shaped in form and contain cross-cutting veins of calcite.

2. Fairport Chalky Shale Member.

About 100 feet of chalky shale occupies the lower third of the Carlile formation. The contact with the overlying Blue Hill shale is generally obscured by soil or talus covering. The Fairport in Osborne County occupies a narrow belt along the south boundary in the drainage of Wolf Creek and short wedges extend up the two forks of the Solomon River. Outcroppings of this member are few in Osborne County. There is no lithologic difference between the lowermost Fairport and the uppermost Greenhorn, but the line is drawn at the top of the "post rock" largely because of a distinct faunal break at that point. The shale in Fairport is coarsely laminated and gray when fresh, weathering to cream or tan. Minute crystals of calcite are scattered through the shale, giving it a speckled appearance.

C. Greenhorn Limestone

The Greenhorn formation is unimportant in Osborne County, appearing only in the river bottoms at the eastern and southern edges of the county. It is divided into four members, named in downward order the Pfeiffer, Jetmore, Hartland, and Lincoln. Although all are composed of limestone and limy shale, massive limestones are much more prominent in the upper two members than in the Hartland and Lincoln.

1. Pfeiffer Member.

The Pfeiffer is the top member of the Greenhorn, and outcrops immediately beneath the upland surface. It is composed of beds of massive white limestone and shale that is blue when fresh, but is

generally buff in color on the outcrop. The "post rock" is the most prominent bed in the Pfeiffer member. It ranges in thickness from 8 to 10 inches, and invariably has an iron seam (limonite-stained chalk) at or near the center. This rock has been extensively quarried and the abandoned quarries can be recognized by the presence of a shallow trench and mounds of the stripped-off over-burden.

2. Jetmore Member.

The Jetmore member is composed of two very prominent limestone beds, a number of thinner chalky limestone beds, and zones of limy shale. The shale generally weathers to a white or tan color, which aids in distinguishing this member from the underlying Hartland, in which the shale is predominantly blue, even when weathered. The limestone beds are more highly fossiliferous than those in the overlying Pfeiffer. The separation of the Jetmore member is easy, for from 3 to 5 feet of shale immediately overlies and underlies it. The top of the member makes a distinct bench, while the slope beneath is generally steep and rocky. The "shell bed" of this member is quarried in southeastern Mitchell County and in Cloud County for fence posts and buildings.

3. Hartland Member.

The Hartland member of the Greenhorn limestone consists largely of shale, with a few thin beds of crystalline limestone. The shale ranges in color from light bluish gray to tan. The shale is soft and limy. Because of the soft character of the rocks in the Hartland, exposures are rare. This member outcrops near the bottom of a few

valleys in southern Osborne County.

4. Lincoln Member.

The Lincoln limestone and shale lies immediately beneath the Hartland, but due to the soft nature of most of the rock and its usual position near the bottom of the valleys, actual exposures are few. However, the limestone bed lying at the top of the member is fairly resistant and may form a bench. The limestone beds of the Lincoln are either finely or coarsely crystalline and contain numerous shells and shell fragments. The color is generally some shade of brown. The shale, which composes most of the member, is in part chalky but most yellow.

VI. METHOD OF COLLECTING SAMPLES

All rock samples used in this investigation were obtained through personal visitations from surface outcroppings of the strata in various localities. Whenever layers of different rock formations were noticed in the same stratum, a sample of each was taken. A geological map of Osborne County, published by the State Geological Survey, was used as a guide in determining the location of the various strata. The writer would drive his car along a section line until he observed an outcropping of a desired stratum. By carefully checking his speedometer, he was able to get the exact location of the sample. The sample was taken from the outcropping by use of a hard steel chisel and hammer, care being taken to cut away the weathered surface of each rock so that a clean, fresh, unaltered sample was obtained. Each sample was placed in a glass jar, properly labeled, and taken to the laboratory.

VII. LABORATORY PROCEDURE⁴

A. Preparation of Samples for Analysis

One or two small fragments of the rock were placed in an iron mortar. Grinding was avoided as much as possible, the rock being reduced to a fine powder by a forceful, vertical pounding with an iron pestle. After each portion had been crushed, the powder was poured out on a large sheet of glazed paper. This procedure was continued until about 200 grams of the sample had been crushed and transferred to the paper, where it was thoroughly mixed. Approximately 20 grams of the powder were then placed in a weighing bottle and allowed to heat for one hour at 110° C. in an electric oven.

B. Removal of Insoluble Matter and Silica

Two portions of the dried sample, of about 0.3 gram each, were weighed out and placed in 250 cc. beakers. Each beaker was covered with a watch glass and the rock treated with 25 cc. of water and then 50 cc. of dilute hydrochloric acid (sp. gr. 1.12) in small portions. The solution was warmed gently until nothing further appeared to dissolve and then evaporated to dryness on the electric hot-plate. A mixture of 5 cc. of water and 5 cc. of concentrated hydrochloric acid

4. Talbot, Henry P. Quantitative Chemical Analysis, p. 184-198.

(sp. gr. 1.20) was poured over the residue and again evaporated to dryness. The residue was finally heated in the electric oven for an hour at a temperature of 110° C. The residue was then treated with 50 cc. of dilute hydrochloric acid (one volume acid sp. gr. 1.12 to five volumes of water) and boiled for about five minutes. The solution was filtered and the filter washed with hot water until free of chlorides.

C. Removal of Iron Oxide and Aluminum Oxide

To the filtrate from the insoluble residue was added ammonium hydroxide (sp. gr. 0.96) until the solution just smelled distinctly of ammonia. To this was added 5 cc. of saturated bromine water. After the solution had boiled for five minutes, 10 cc. of ammonium chloride solution was added, and the solution was kept warm until it barely smelled of ammonia. It was filtered immediately and the precipitate was washed free from chlorides with hot water. After replacing the receiving beaker by the original beaker, the precipitate was dissolved by pouring through the funnel 25 cc. of hot, dilute hydrochloric acid (one volume dilute HCl sp. gr. 1.12 to five volumes of water). The filter paper was washed several times with hot water and the combined oxides reprecipitated by ammonium hydroxide and bromine water as described above. The precipitate was collected on the filter paper already used and it was washed free from chlorides with hot water.

D. Precipitation of Calcium as Calcium Oxalate

The combined filtrates and washings from the double precipitation of the combined oxides were evaporated to about 300 cc. and then made alkaline with ammonium hydroxide (sp. gr. 0.96). Three drops of methyl orange were used as an indicator. The solution was made acidic with dilute hydrochloric acid, 2 cc. in excess being added. The liquid was heated nearly to boiling and 40 cc. of ammonium oxalate solution (40 g. of $(\text{NH}_4)_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ dissolved in 1 liter of water) was added very slowly. The solution was allowed to boil for two minutes and then ammonium hydroxide added dropwise from a pipette until the solution turned yellow. A small excess of ammonium hydroxide was added and the solution heated for a few minutes. It was set aside for one-half hour and then decanted through a filter. The filtrate was tested for complete precipitation. The precipitate was redissolved by pouring 25 cc. of warm dilute hydrochloric acid through the filter. The filter was washed several times with hot water, and finally with a few cc. of dilute ammonium hydroxide.

The solution was diluted to 250 cc., heated to boiling, and 1 cc. of ammonium oxalate was added. The calcium was reprecipitated as calcium oxalate by the addition of ammonium hydroxide in slight excess. The solution was boiled for two minutes, allowed to stand for one-half hour, and then filtered through the filter previously used. The precipitate was washed free from chlorides.

E. The Preparation and Standardization of the Potassium Permanganate Solution

The lime content of the sample being analyzed was determined by subjecting the precipitated calcium oxalate to volumetric analysis. The titrating solution used for this purpose was an approximately tenth-normal standardized solution of potassium permanganate.

This solution was prepared by dissolving 3.25 g. of potassium permanganate in 1 liter of distilled water and boiling it for fifteen minutes. The solution was then allowed to stand for at least twenty-four hours, after which it was filtered through a layer of asbestos to remove the precipitate of hydrated manganese dioxide.

Pure sodium oxalate was used as the primary standard in the standardization of the permanganate solution. Two portions of the sodium oxalate of about 0.3 g. each were placed in 600 cc. beakers and 400 cc. of boiling water added. To this solution was added 20 cc. of a manganous sulphate solution, which was prepared by dissolving 20 g. of manganese sulphate in 200 cc. of water and adding 40 cc. of concentrated sulphuric acid and 40 cc. of phosphoric acid. The oxalate solution was heated to near its boiling point and the permanganate solution added drop by drop from a burette until an end-point was reached. A blank test was then run with 20 cc. of manganous sulphate solution diluted with 400 cc. of water to determine the volume of the permanganate solution required to produce a very slight pink. This volume was then deducted from the amount of permanganate solution used in the titration. The normality of the permanganate solution was then

calculated by substituting the data obtained in the following equation:

$$\text{Normality of } \text{KMnO}_4 = \frac{\text{wt. of } \text{Na}_2\text{C}_2\text{O}_4 \times 100}{\text{cc. of } \text{KMnO}_4 \times \text{m.e. of } \text{Na}_2\text{C}_2\text{O}_4}$$

F. Volumetric Determination of Calcium Oxide

The precipitated calcium oxalate was washed from the filter paper into a 400 cc. beaker, and 200 cc. of water added. The filter paper was then placed in the beaker and the solution was heated nearly to boiling. After the addition of 5 cc. of concentrated sulphuric acid the solution was titrated at once with the standard permanganate solution. The permanganate solution was added slowly with constant stirring, and finally in single drops until the pink color flashed throughout the solution and persisted for one minute. A ferric ammonium sulphate solution was used for back-titrating when necessary. Care was taken not to use a permanganate solution that had been prepared for more than a week without first standardizing it.

From the data obtained, the percent of calcium oxide was calculated by using the following equation:

$$\% \text{ of CaO} = \frac{\text{cc. of } \text{KMnO}_4 \times \text{N. of } \text{KMnO}_4 \times \text{m.e. of CaO} \times 100}{\text{wt. of sample}}$$

The percentage of lime recorded in Table II is the average of two runs which checked within 0.2 of one percent.

The percentage of calcium was obtained by multiplying the percentage of lime by the gravimetric factor, .7146.

The percentage of calcium carbonate was calculated by multiplying the percentage of lime by the gravimetric factor, 1.7847.

VIII. RECORD OF RESULTS

The results of this investigation are given in the following tables. Table II gives a complete summary of the samples run, their exact locations, and the percentages of lime, of calcium, and of calcium carbonate found in each.

Table III gives the lime content of each sample according to the member from which it was obtained. Tables IV and V are similar to Table III except that they show the percentages of calcium and calcium carbonate, respectively. These tables enable one to see how the percentages of the various samples in the given members or formations compare with one another.

Table VI shows how the lime content of the members and formations in Osborne County compare with that of the respective members and formations in Ellis County.

MAP OF OSBORNE COUNTY

(Location of each sample represented by dot adjacent to sample number as found in Table II.)

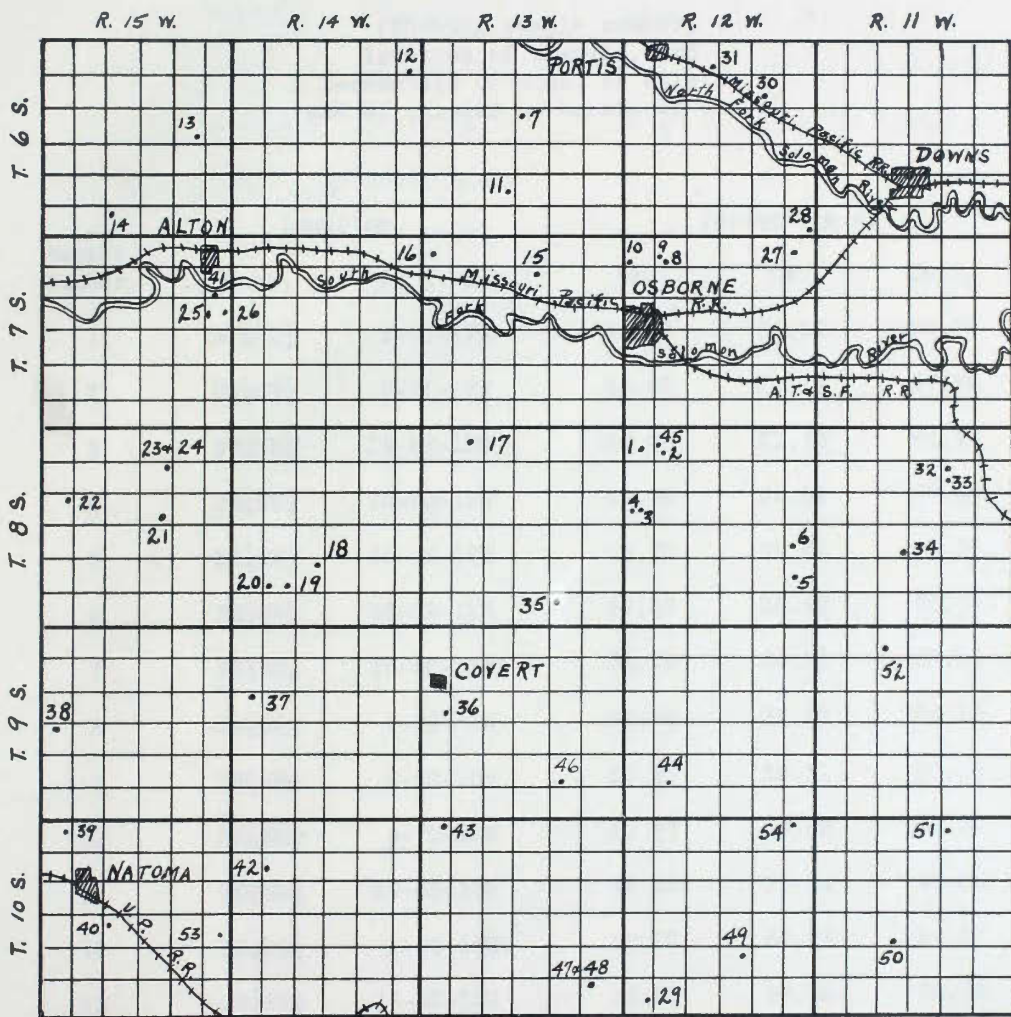


TABLE II

(Showing sample number,
location of samples, and
percentage of lime, of calcium,
and of calcium carbonate in each.)

Sample Number	Location		Percentage of		
	Quar.	S. T. R.	CaO	Ca	CaCO ₃
1	NE $\frac{1}{4}$ SE $\frac{1}{4}$	6-8S-12W	50.82	36.32	90.70
2	SW $\frac{1}{4}$ SW $\frac{1}{4}$	5-8S-12W	38.02	27.17	67.85
3	NW $\frac{1}{4}$ SE $\frac{1}{4}$	18-8S-12W	30.36	21.70	54.18
4	NE $\frac{1}{4}$ SW $\frac{1}{4}$	18-8S-12W	49.04	35.04	87.52
5	SE $\frac{1}{4}$ NW $\frac{1}{4}$	25-8S-12W	53.78	38.43	95.98
6	NE $\frac{1}{4}$ SW $\frac{1}{4}$	24-8S-12W	37.03	26.46	66.09
7	NW $\frac{1}{4}$ NW $\frac{1}{4}$	15-6S-13W	51.70	36.94	92.27
8	SW $\frac{1}{4}$ SW $\frac{1}{4}$	5-7S-12W	52.74	37.69	94.13
9	NW $\frac{1}{4}$ SW $\frac{1}{4}$	5-7S-12W	50.53	36.11	90.18
10	SW $\frac{1}{4}$ SW $\frac{1}{4}$	6-7S-12W	51.77	36.99	92.39
11	SE $\frac{1}{4}$ NE $\frac{1}{4}$	28-6S-13W	46.26	33.06	82.56
12	SW $\frac{1}{4}$ SE $\frac{1}{4}$	1-6S-14W	52.82	37.75	94.27
13	SE $\frac{1}{4}$ SE $\frac{1}{4}$	14-6S-15W	52.97	37.85	94.54
14	NW $\frac{1}{4}$ NW $\frac{1}{4}$	33-6S-15W	46.70	33.37	83.35
15	NW $\frac{1}{4}$ NE $\frac{1}{4}$	10-7S-13W	53.37	38.14	95.25
16	SW $\frac{1}{4}$ NW $\frac{1}{4}$	6-7S-13W	51.49	36.79	91.89

TABLE II (cont.)

Sample Number	Location		Percentage of		
	Quar.	S. T. R.	CaO	Ca	CaCO ₃
17	SW $\frac{1}{4}$ NE $\frac{1}{4}$	5-8S-13W	35.28	25.21	62.96
18	NE $\frac{1}{4}$ NE $\frac{1}{4}$	28-8S-14W	54.56	38.99	97.37
19	SE $\frac{1}{4}$ SE $\frac{1}{4}$	29-8S-14W	53.15	37.98	94.86
20	SW $\frac{1}{4}$ SW $\frac{1}{4}$	29-8S-14W	53.19	38.01	94.93
21	SE $\frac{1}{4}$ SE $\frac{1}{4}$	16-8S-15W	54.10	38.66	96.55
22	NE $\frac{1}{4}$ NE $\frac{1}{4}$	18-8S-15W	54.44	38.90	97.16
23	NE $\frac{1}{4}$ NE $\frac{1}{4}$	10-8S-15W	54.10	38.66	96.55
24	NE $\frac{1}{4}$ NE $\frac{1}{4}$	10-8S-15W	55.49	39.65	99.03
25	SW $\frac{1}{4}$ NW $\frac{1}{4}$	13-7S-15W	53.89	38.51	96.18
26	SE $\frac{1}{4}$ NE $\frac{1}{4}$	13-7S-15W	53.80	38.45	96.02
27	SW $\frac{1}{4}$ NW $\frac{1}{4}$	1-7S-12W	53.45	38.20	95.39
28	SE $\frac{1}{4}$ SE $\frac{1}{4}$	36-6S-12W	53.23	38.04	95.00
29	NE $\frac{1}{4}$ SE $\frac{1}{4}$	31-10S-12W	53.20	38.02	94.95
30	SW $\frac{1}{4}$ SW $\frac{1}{4}$	11-6S-12W	54.45	38.91	97.18
31	SE $\frac{1}{4}$ SE $\frac{1}{4}$	4-6S-12W	52.66	37.63	93.98
32	SW $\frac{1}{4}$ NW $\frac{1}{4}$	11-8S-11W	50.65	36.19	90.40
33	NW $\frac{1}{4}$ SW $\frac{1}{4}$	11-8S-11W	54.32	38.82	96.94
34	SE $\frac{1}{4}$ SE $\frac{1}{4}$	21-8S-11W	52.74	37.69	94.13
35	NW $\frac{1}{4}$ NW $\frac{1}{4}$	35-8S-13W	53.16	37.99	94.87
36	NW $\frac{1}{4}$ SE $\frac{1}{4}$	18-9S-13W	53.48	38.22	95.45
37	NW $\frac{1}{4}$ NE $\frac{1}{4}$	18-9S-14W	49.09	35.08	87.61
38	NE $\frac{1}{4}$ NW $\frac{1}{4}$	19-9S-15W	50.67	36.21	90.43

TABLE II (cont.)

Sample Number	Location		Percentage of		
	Quar.	S. T. R.	CaO	Ca	CaCO ₃
39	SE $\frac{1}{4}$ NE $\frac{1}{4}$	6-10S-15W	51.85	37.05	92.54
40	NW $\frac{1}{4}$ NW $\frac{1}{4}$	21-10S-15W	52.74	37.69	94.13
41	SE $\frac{1}{4}$ SE $\frac{1}{4}$	12- 7S-15W	5.061	3.617	9.032
42	NW $\frac{1}{4}$ SW $\frac{1}{4}$	8-10S-14W	51.78	37.00	92.40
43	NE $\frac{1}{4}$ NE $\frac{1}{4}$	6-10S-13W	54.39	38.87	97.07
44	SE $\frac{1}{4}$ SW $\frac{1}{4}$	29- 9S-12W	53.84	38.47	96.09
45	SW $\frac{1}{4}$ SW $\frac{1}{4}$	5- 8S-12W	.252	.18	.449
46	SE $\frac{1}{4}$ SW $\frac{1}{4}$	26- 9S-13W	53.63	38.32	95.71
47	NW $\frac{1}{4}$ NW $\frac{1}{4}$	36-10S-13W	46.45	33.19	82.90
48	NW $\frac{1}{4}$ NW $\frac{1}{4}$	36-10S-13W	55.08	39.36	98.30
49	NE $\frac{1}{4}$ NE $\frac{1}{4}$	27-10S-12W	54.26	38.77	96.84
50	SW $\frac{1}{4}$ SE $\frac{1}{4}$	21-10S-11W	54.47	38.92	97.21
51	SW $\frac{1}{4}$ NW $\frac{1}{4}$	2-10S-11W	1.016	.726	1.813
52	SW $\frac{1}{4}$ SW $\frac{1}{4}$	4- 9S-11W	38.18	27.28	68.14
53	NW $\frac{1}{4}$ SE $\frac{1}{4}$	24-10S-15W	.298	.213	.532
54	NW $\frac{1}{4}$ NW $\frac{1}{4}$	1-10S-12W	53.05	37.91	94.68

TABLE III

(Showing percentage of lime content in
the various members.)

Niobrara Formation

Smoky Hill		Fort Hays			
Sample	Percentage	Sample	Percentage	Sample	Percentage
1	50.82	5	53.78	25	53.89
4	49.04	7	51.70	26	53.80
10	51.77	8	52.74	28	53.23
11	46.26	9	50.53	30	54.45
14	46.70	12	52.82	31	52.66
15	53.37	13	52.97	33	54.32
27	53.45	16	51.49	34	52.74
32	50.65	18	54.56	36	53.48
35	53.16	19	53.15	39	51.85
37	49.09	20	53.19	40	52.74
38	50.67	21	54.10	42	51.78
44	53.84	22	54.44	43	54.39
52	38.18	23	54.10	46	53.63
		24	55.49		
		Average of Runs			
49.77		53.26			

TABLE III (cont.)

Carlile Shale			Greenhorn Limestone	
Blue Hill Shale	Concretions of Blue Hill shale	Fairport Chalk		
Sample Percent- age	Sample Percent- age	Sample Percent- age	sample Percent- age	
41 5.061	2 38.02	54 53.05	29 53.20	
45 .252	3 30.36		47 46.45	
51 1.016	6 37.03		48 55.08	
53 .298	17 35.28		49 54.26	
			50 54.47	
Average of Runs				
1.657	35.17	53.05	52.69	

TABLE IV

(Showing percentage of calcium content
in the various members.)

Niobrara Formation

Smoky Hill		Fort Hays			
Sample	Percentage	Sample	Percentage	Sample	Percentage
1	36.32	5	38.43	25	38.51
4	35.04	7	36.94	26	38.45
10	36.99	8	37.69	28	38.04
11	33.06	9	36.11	30	38.91
14	33.37	12	37.75	31	37.63
15	38.14	13	37.85	33	38.82
27	38.20	16	36.79	34	37.69
32	36.19	18	38.99	36	38.22
35	37.99	19	37.98	39	37.05
37	35.08	20	38.01	40	37.69
38	36.21	21	38.66	42	37.00
44	38.47	22	38.90	43	38.87
52	27.28	23	38.66	46	38.32
		24	39.65		
		Average of Runs			
35.56		38.06			

TABLE IV (cont.)

Carlile Shale			Greenhorn Limestone				
Blue Hill Shale	Concretions of Blue Hill Shale	Fairport Chalk					
Sample Percent- age	Sample Percent- age	Sample Percent- age	Sample Percent- age	Sample Percent- age			
41	3.617	2	27.17	54	37.91	29	38.02
45	.180	3	21.70			47	33.19
51	.726	6	26.46			48	39.36
53	.213	17	25.21			49	38.77
						50	38.92
Average of Runs							
1.184		25.13		37.91		37.65	

TABLE V

(Showing percentage of calcium carbonate
in the various members.)

Niobrara Formation

Smoky Hill		Fort Hays			
Sample	Percentage	Sample	Percentage	Sample	Percentage
1	90.70	5	95.98	25	96.18
4	87.52	7	92.27	26	96.02
10	92.39	8	94.13	28	95.00
11	82.56	9	90.18	30	97.18
14	83.35	12	94.27	31	93.98
15	95.25	13	94.54	33	96.94
27	95.39	16	91.89	34	94.13
32	90.40	18	97.37	36	95.45
35	94.87	19	94.86	39	92.54
37	87.61	20	94.93	40	94.13
38	90.43	21	96.55	42	92.40
44	96.09	22	97.16	43	97.07
52	68.14	23	96.55	46	95.71
		24	99.03		
		Average of Runs			
88.82		95.05			

TABLE V (cont.)

Carlile Shale			Greenhorn Limestone	
Blue Hill Shale	Concretions of Blue Hill Shale	Fairport Chalk		
Sample Percent- age	Sample Percent- age	Sample Percent- age	Sample Percent- age	
41 9.032	2 67.85	54 94.68	29	94.95
45 .449	3 54.18		47	82.90
51 1.813	6 66.09		48	98.30
53 .532	17 62.96		49	96.84
			50	97.21
Average of Runs				
2.957	62.77	94.68	94.04	

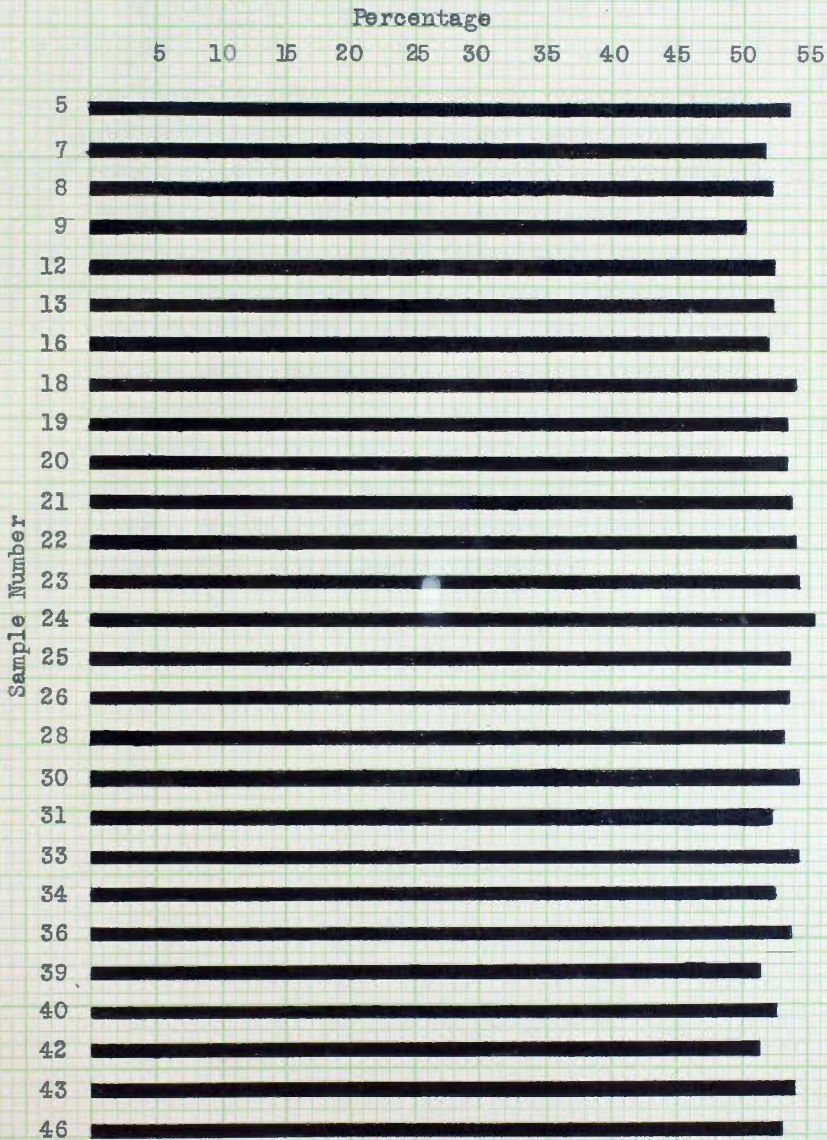
TABLE VI

(Comparing the percentage of lime
in the various members of Osborne County
with that in the same members of Ellis County.)

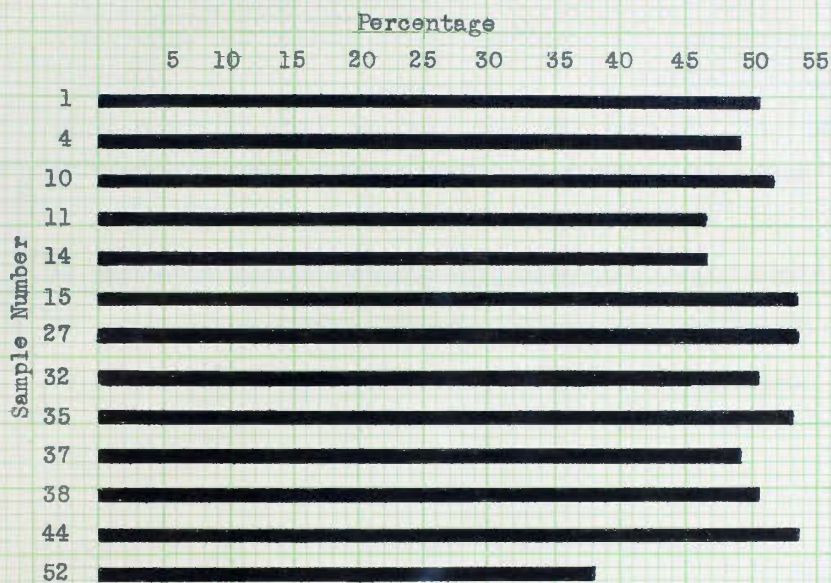
		Osborne	Ellis ⁵
Smoky Hill	High Run	53.84	52.95
	Low Run	38.18	39.88
	Average of Runs	49.77	48.27
Fort Hays	High Run	55.49	54.26
	Low Run	50.53	47.10
	Average of Runs	53.26	52.06
Blue Hill Shale	High Run	5.061	.355
	Low Run	.252	.310
	Average of Runs	1.657	.332
Fairport Chalk	High Run	53.05	51.21
	Low Run	53.05	26.87
	Average of Runs	53.05	42.32
Greenhorn	High Run	55.08	52.35
	Low Run	46.45	40.19
	Average of Runs	52.69	50.02

5. Rarick, Lawrence. The Lime Content of Rocks of the Upper Cretaceous System of Ellis County, Kansas.

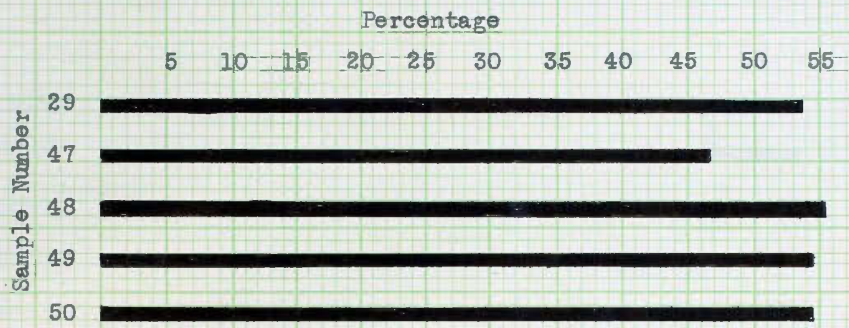
Graph comparing the percentage of lime
in the different samples of
Fort Hays Limestone



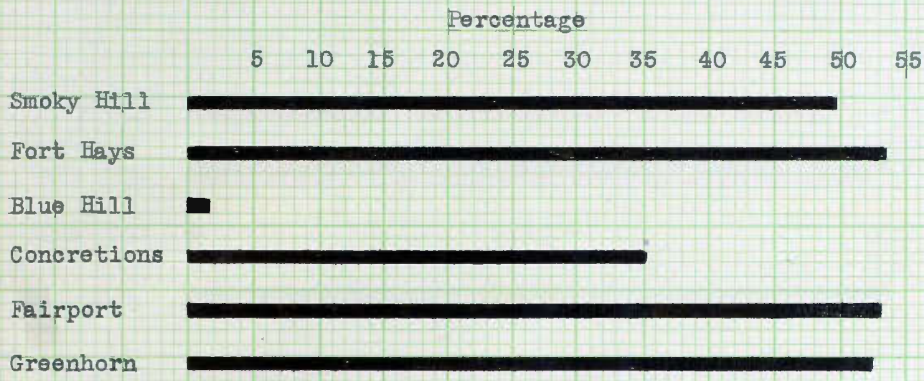
Graph comparing the percentage of lime
in the different samples of
Smoky Hill Chalk



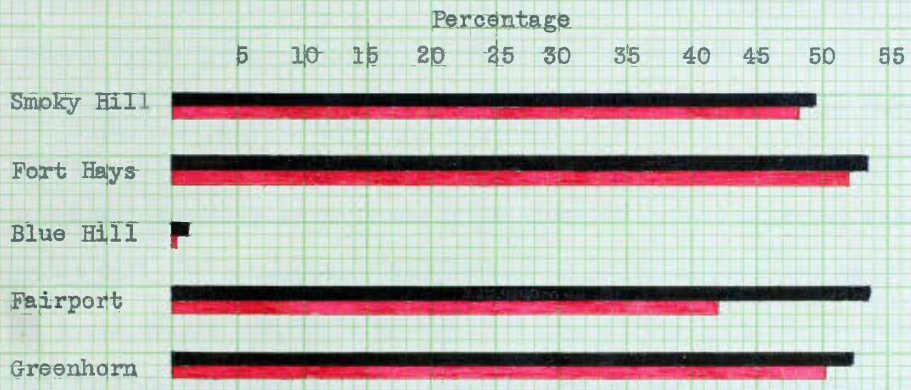
Graph comparing the percentage of lime
in the different samples of
Greenhorn Limestone



Graph comparing the average of
the runs of the percentage of lime
in the various members of Osborne County



Graph comparing the average of
the runs of the percentage of lime
in the various members of Osborne County
with that for the same members of Ellis County



— Osborne County
— Ellis County

IX. SUMMARY AND CONCLUSIONS

The percentage of lime ranges from .252 for the sample of Blue Hill shale taken from sec. 5, T. 8 S., R. 12 W., to 55.49 for the sample of Fort Hays limestone obtained from sec. 10, T. 8 S., R. 15 W.

The range is not nearly so great for the samples of the same member. Table III indicates that the sample from sec. 29, T. 9 S., R. 12 W., contains 53.84 percent lime, which is the high run for the Smoky Hill chalk member. The low run of 38.18 percent for this member is found in the sample taken from sec. 4, T. 9 S., R. 11 W. This member runs fairly high in lime content, ten of the thirteen samples running better than 49 percent lime.

The most prominent member in Osborne County is the Fort Hays limestone of the Niobrara formation. Samples of this member run fairly constant as regards the percentage of lime present, the high run, as stated above, being 55.49 percent while the low run is 50.53 percent, a variation of approximately 5 percent. Samples of this member from the same stratum but in beds a few hundred feet apart show very little difference. For example, samples 8 and 9 from separate outcroppings about 300 feet apart in sec. 5, T. 7 S., R. 12 W., contain 52.74 percent and 50.53 percent of lime respectively. Also sample 23 taken from a road-cut in sec. 10, T. 8 S., R. 15., about three feet below the surface, has a lime content of 54.1 percent, while sample 24 taken from the same stratum but in a bed six feet

below the former sample runs 55.49 percent lime. Each of the twenty-seven samples of this member runs better than 50 percent lime.

The Blue Hill shale member shows a comparatively wide variation in lime content among its samples, with a high run of 5.061 percent and a low run of .252 percent. However, two of the four samples are fairly constant. The high run is from sample 41 taken from an outcropping in sec. 12, T. 7 S., R. 15 W., which was interspersed with thin layers of an orange colored argillaceous sandstone. The presence of this sandstone might easily account for the relatively high percentage of lime found.

The concretions of the Blue Hill shale, while not considered to be representative of that or any other stratum, run surprisingly uniform in lime content. There is only a variation of approximately 7.5 percent between the high and the low run.

Outcroppings of Fairport chalk were difficult to locate, which explains the running of only one sample. The sample run contains 53.05 percent lime, which is equivalent to 94.68 percent calcium carbonate. This tends to verify the statement that the Fairport member is highly calcareous.

Four of the five samples taken from the Greenhorn formation run fairly constant in the percentage of lime, the percentages ranging from 53.20 percent to 55.08 percent. Sample 47 from sec. 36, T. 10 S., R. 13 W., however, drops to 46.45 percent. This is probably due to the fact that sample 47 was taken from a bed of shale. Sample 48, taken from a chalk bed two feet below sample 47, runs 55.08 percent. Evidently the Greenhorn of Osborne County runs fairly constant in the percentage of lime.

It is apparent that Osborne County has an abundance of outcropping rock that is high in lime content and which can easily be obtained. Let us now consider some of the present day uses for rock of this type.

The most important economic use for the rock of the Upper Cretaceous System of Osborne County is its local use as a building stone. Many dwellings, schoolhouses, churches, public buildings, and business buildings have been built throughout Osborne County with Fort Hays limestone. However, this use has decreased noticeably in the past few years. This may be due to the fact that labor costs make the rock a rather expensive building stone, and that concrete has come into such an extensive use for the construction of buildings.

The Portland cement industry has been on the increase for the past twenty years, due to extensive road-building programs, the development of reinforced concrete construction, and the adaptability and uniformity of the material produced. Reinforced concrete has been so perfected that it is used in the construction not only of walls, piers, sidewalks, floors, and building foundations, but also tunnels, dams, canal walls, and girders.

In the manufacture of Portland cement it is necessary that great care be exercised in adjusting the proportions of lime, alumina, and silica in order that a good quality of cement be produced. Cement which contains too much lime will be "unsound"--that is, in time concrete made from it will expand and crack. If too little lime is present, the concrete will be low in strength and may "set" too quickly. Cement high in alumina is also likely to be quick setting, while high silica cement is usually very slow hardening. The raw materials from which Portland cement is manufactured may be divided into two

classes: those supplying the lime and those furnishing the silica, iron oxide, and alumina. The first are termed calcareous, and the second argillaceous.⁶

The "cement rock" is an argillaceous limestone containing the necessary constituents in proportions so nearly right that only slight adjustments are necessary. This rock usually contains between 65 and 80 percent calcium carbonate. In order to make a satisfactory mixture for burning, the percentage of calcium carbonate must average about 75 percent. Shale or clay is usually added to cut down the percentage if it is too high, while limestone is used to build it up.⁷ Limestone, marl, and shale of the proper quality for the manufacture of Portland cement are found abundantly in Osborne County.

Good lime is nearly pure calcium oxide, CaO , or a mixture of calcium and magnesium oxides, $\text{CaO} + \text{MgO}$. High calcium limes are stronger than those containing considerable percentages of magnesia.⁸ Lime is obtained by driving out all the carbon dioxide from limestone. Although lime may be obtained from limestone containing as low as 35 percent lime, the better grades of lime are obtained from limestone having at least 50 percent lime. The rock of Osborne County is well suited for the manufacture of this product, as is shown by the fact that thirty-nine of the forty-eight samples of the Niobrara and Greenhorn formations which were run during this investigation contain better than 50 percent lime.

Lime is used not only for building purposes but also in the manufacture of such articles as bleaching powder, paper, sand bricks,

6. Rogers, Allen. Industrial Chemistry, p. 365.

7. Ibid., p. 365.

8. Ibid., p. 353.

ammonia soda, and fertilizers. Much lime is placed on the market and sold as agricultural lime.

Agricultural lime is any material containing either calcium or magnesium which when added to the soil will neutralize or correct its acidity. Substances used as agricultural lime include crushed limestone, marl, burned lime, and hydrated lime. The last two of these are far too expensive for ordinary use. The form most commonly used in eastern Kansas is crushed limestone. The purity of the limestone is an important factor in determining its value as an agricultural lime. A good quality crushed limestone should for this purpose have a calcium carbonate equivalent between 90 and 100 percent.⁹

The use of ground limestone in cattle-fattening rations has been a much discussed topic for the past few years among agriculturists throughout Kansas. The Kansas Agricultural Experiment Station at Manhattan, Kansas, a few years ago conducted experiments in which it was found (1) that alfalfa hay added to silage when fed to fattening cattle improves the ration materially, (2) that only a few legume hays and no nonlegume hays can be substituted with equally as good results as alfalfa hay, and (3) that the constituents for which alfalfa hay is most valuable--protein and calcium--may be secured practically as satisfactorily from an increased amount of cottonseed meal or other protein supplemental feed, and ground limestone.¹⁰ Another series of experiments conducted by the Kansas Agricultural Experiment Station showed an advantage of adding calcium carbonate, either as straight

9. Agricultural Experiment Station Circular 152.

10. Agricultural Experiment Station Circular 185.

calcium carbonate or finely ground high calcium content limestone, to a calf-fattening ration consisting of corn, cottonseed meal, cane silage, and prairie hay.

Limestone for use in cattle-fattening rations should contain a minimum of 95 percent calcium carbonate.¹¹ Osborne County has much available limestone suitable for use both as agricultural lime and for cattle-fattening rations. As is shown by Table V, twenty-one of the forty-five samples taken from the Niobrara and Greenhorn formations run above 95 percent calcium carbonate.

The rock deposits of Osborne County are great and of a lime content suitable for use in the manufacture of articles which utilize limestone as raw material. However, there are three other factors which must be considered in the successful production of such articles, i. e. an abundance of natural fuel, a ready market, and cheap transportation of the finished products to market. Although coal is commonly used as fuel in the manufacture of lime products, it has been found that oil makes an excellent fuel for this purpose.¹² An abundance of fuel oil can be obtained easily from the oil-fields of Russell County approximately forty miles to the south. But Osborne County lacks a near, ready market for lime products, and it is doubtful that the natural resource afforded by its rocks will be used industrially for many years to come.

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 12. Rogers, Allen. Industrial Chemistry, p. 367.

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