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

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THE LIME CONTENT

OF ROCKS OF THE UPPER CRETACEOUS SYSTEM

OF ELLIS COUNTY, KANSAS

being

A Thesis presented to the Graduate Faculty
in partial fulfillment of the requirements
for the Degree of Master of Science

by

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I. INTRODUCTION

The report which is being submitted here is the result
of several weeks of field and laboratory work investigating the
rocks of the Upper Cretaceous System of Ellis County, Kansas. The
writer has attempted to consider the subject primarily from a chem-
ical viewpoint although much of the background for the work has been
of a geological nature. There has been no attempt to give a complete
chemical analysis of the rocks of the Upper Cretaceous System, but
rather a more or less thorough analysis in regard to the percentage
of lime that the rocks of the various formations and members in re-
spective parts of the county may contain. Also the attempt has been
made 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. The possibility of the existence
of limestone of a percentage sufficiently high to be used for cattle
feeding and for the manufacturing of lime has also been investigated.
So far as the writer has been able to learn, there has been no work
done on the chemical composition of the rocks of the Upper Cretaceous
System of Ellis County, other than at Yocemento. Undoubtedly analytic-
al work was done there during the time the cement factory was operat-
ing. However, the plant has been closed for a good many years and no
printed materials are available regarding the nature of the enterprise.

Much of the work has been based upon the geological report of N. W.
Bass, entitled "Geologic Investigations in Western Kansas."

II. GEOGRAPHY AND LOCATION

Ellis County lies only a short distance north and west of the center of Kansas. It is approximately 30 miles square and contains about 576,000 acres. The main line of the Union Pacific railroad between Kansas City and Denver passes through the county in an east-west direction. Hays is the largest town in the county with a population of 5,000; it also is the county seat. The Fort Hays Kansas State College and a large experiment station indicate that Hays is the leading educational town of Ellis County. Ellis, the next largest town, has a population of about 2,000, and is a division point of the Union Pacific railroad. There are nine other small towns in the county, many of which are inland villages. Federal Highway No. 40S passes through the county paralleling the railroad and across the county from north to south we find State Highway No. 1. Well graded roads are kept in good repair giving access to all parts of the county with the exception of the extremely rough northwest section.

The county as a whole is quite level and practically treeless, except for narrow lines of trees along the principal streams and for small groves surrounding farm homes.

Wheat raising is the chief industry, although there is an increasing tendency toward diversified farming. The rougher portions of the county, bordering the Smoky Hill and Saline rivers, are largely given over to cattle raising with a sheep ranch located here and there.

III. TOPOGRAPHY

Topographically Ellis County is located at the eastern margin of the High Plains. Its characteristic topographic features are broad, relatively flat, upland benches, deeply cut by the main drainage channels. These main streams flow east, and their valleys are markedly steeper on the south sides than on the north sides. The broad benches rising gently westward, margined by cliffs that have eastward fronts, are controlled by the harder rocks that crop out at the surface. The highest bench which occupies the high divides in the west half of the county is made up of the resistant Tertiary "mortar beds" of the Ogallalla formation. The next bench is supported by the Fort Hays limestone of the Niobrara formation, and the lowest bench, located in the southern and eastern portion of the county, by the Greenhorn limestone.

[1.]The altitude of the surface above sea level ranges from 2,400 feet near the southwest corner of the county to 1700 feet in the northeastern part. The maximum relief in the southwestern part of the county is 360 feet in 4 miles, and at places along the Saline and Smoky Hill rivers has an average fall in a straight line across the county of approximately 10 feet to the mile.

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1. Bass, N. W. Geologic Investigations in Western Kansas. (In Kansas State Geological Survey. Bulletin 11, Lawrence, Kansas.)

IV. STRATIGRAPHY

The rocks exposed in Ellis County are of Quaternary, Tertiary and Cretaceous age. The lowest rocks exposed appear along the Smoky Hill river in the southeastern part of the county. The thick shale members of the Cretaceous system make gently graded, soil-mantled slopes over a large part of the county, but are well exposed in the extreme southwestern part and along the Saline river in the northern part. The top beds of the Cretaceous section represented here are best exposed in the northwestern part of the county, and the tertiary rocks in the western part. The flood plains of the streams are occupied by the Quaternary deposits.

The following table gives the outstanding features of the formations exposed.

Recent		Gravel deposits along the Saline.	
Pliocene and late Miocene	Ogalalla forma-tion	Gravel, sand, silt. Forms level uplands in western county.	0-75
Upper Creta-ceous	Niobrara Forma-tion, Smoky Hill chalk member.	Chalky shale, in-terbedded with brittle chalk. Weath-ers pure white, yel-low orange. Forms badlands. Top not exposed.	100
	Fort Hays lime-stone member.	Massively bedded cream-colored shaley limestone. Forms prominent bluffs bordering main streams.	80

Ibid.

TABLE I[2].

Stratigraphic Section of Outcropping Rocks in Ellis County,
Kansas.

AGE	FORMATION AND MEMBER	LITHOLOGICAL CHARACTER	THICKNESS
Recent		Alluvium in stream flood plains.	0-40 feet
Pleistocene	McPherson (?) Formation	Gravel terraces along Smoky Hill and Saline rivers.	0-20
Pliocene and late Miocene	Ogalalla Formation	Gravel, sand, clay, and "mortar beds" upon high divides throughout county.	0-75
Upper Cretaceous	Niobrara Formation. Smoky Hill chalk member.	Chalky shale, interbedded with buttle chalk. Weathers pure white, yellow orange. Forms badlands. Top not exposed.	100
	Fort Hays limestone member.	Massively bedded cream-colored chalky limestone. Makes prominent bluffs bordering main streams.	55

2.Ibid.

TABLE I (cont.)

AGE	FORMATION AND MEMBER	LITHOLOGICAL CHARACTER	THICKNESS
Upper Cretaceous (cont.)	Carlile Shale Blue Hill shale member.	Gray-black fissile clay shale; with Codell sandstone bed at top, and several layers of calcareous septarian concretions. Thins southwestward.	175-215 ft.
	Fairport chalky shale member.	Chalky shale interbedded with thin layers of chalky limestone, which increases in number toward the base.	85-115
	Greenhorn limestone Pfeifer shale member.	Chalky shale interbedded with thin layers of soft chalky limestone. Top bed known as "fencepost limestone"... Makes low bench.	20
	Jetmore chalk member.	Alternating thin beds of chalky limestone and chalky shale. Limestone in upper half abundantly fossiliferous... makes pronounced bed.	20
	Greenhorn limestone Hartland shale.	Chalky shale with few thin beds of chalky limestone... makes gentle slope.	35

TABLE I (cont.)

AGE	FORMATION AND MEMBER	LITHOLOGICAL CHARACTER	THICKNESS
Upper Cretaceous (cont.)	Lincoln limestone member.	Yellowish, tan-weathering chalky shale with hard thin-bedded, finely laminated crystalline limestone at top and base... Makes low bench.	20 feet
	Graneros Shale	Dark bluish-black shale with bed of sandy ironstone near base and a few sandy calcareous lenses above.	32-40
	Dakota Sandstone	Fine-grained white sandstone, irregularly bedded, and red, white, and mottled clay and sandy shale. Base not exposed.	20 +

and scarps of fantastic shapes that range in color from white through
yellow to orange and orange-red.

V. GEOLOGY OF UPPER CRETACEOUS SYSTEM[3].

A. Niobrara Formation.

In Kansas the Niobrara Formation has been divided into
two members--the Smoky Hill chalk member above and the Fort Hays
limestone below. In the western and northwestern part of the coun-
ty approximately 150 feet of the basal part of the Niobrara forma-
tion is in places exposed in bare bluffs and badlands.

1. Smoky Hill Chalk Member.

About 100 feet of the basal part of the Smoky Hill chalk
member is exposed below the overlapping Ogallala formation in Ellis
County. It consists of marl beds alternating with chalk and thin
beds of clay. The member occupies a relatively broad area in the
western part of the county, forming the gently rolling table-lands
above the Fort Hays limestone and below the Ogallala formation. The
chalky shale and soft chalk beds break down into smooth, gently graded
slopes through most of its area of outcrop, but in some localities,
particularly in the northward-facing slopes, it makes bare, intricate-
ly dissected badlands. The differential weathering results in buttes

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[3].Ibid.

and scarps of fantastic shapes that range in color from white through
yellow to orange and orange-red.

2. Fort Hays Limestone Member.

The Fort Hays limestone member of the Niobrara formation
in Ellis County is a massively bedded cream-colored chalk or very
chalky limestone. The individual beds of chalky limestone range in
thickness from 6 inches to 6 feet and average about $2\frac{1}{4}$ to 3 feet.
These beds are separated by thin layers, 1 to 4 inches thick, of
light gray chalky clay shale. The bedding is thinner toward the
top of the member, and the upper beds commonly weather almost pure
white. The Fort Hays member appears to be slightly coarser in tex-
ture and somewhat harder than the chalk of the overlying Smoky Hill.
The individual beds are much thicker than those of the Smoky Hill,
the Smoky Hill having much the greater shale content. The individ-
ual beds and series of beds are persistent, with only a slight
change in thickness over large areas.

Because the Fort Hays limestone is considerably harder
than the underlying Carlile shale, it commonly stands in vertical
bluffs that cap a steep, barren shale slope. In Ellis County the
valley of the Saline river is bordered with such bluffs throughout
the area of outcrop of the Fort Hays member.

The Fort Hays member of the Niobrara is quite persistent
and regular in its thickness and general character throughout western
Kansas.

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B.   The Carlile Shale.

The Carlile shale is a chalky and clay shale, about
300 feet thick. The upper two-thirds is composed predominantly of
gray-black fissile clay shale, and the lower third of chalky shale
and thin beds of chalky limestone. In Ellis County it is separated
into the Blue Hill shale member above and the Fairport chalky shale
member below.

1. Blue Hill Shale Member.

The Blue Hill shale member occupies a broad belt of
gently graded, grassed slopes in southern and eastern Ellis County
and a narrow band of bare, steep slopes along the Saline river in
the northern part. Its thickness ranges between 215 feet near the
northeast corner of the county and 175 feet near the southwest cor-
ner. The member is made up of gray-black noncalcareous clay shale,
which at several horizons contains large calcareous concretions,
and in the uppermost 25 feet of gritty shale or sandstone. At the
top of the Blue Hill shale member is a very fine grained sandstone,
including a few layers of sandy shale. Below this sandy shale is
an indurated sandstone bed 5 to 6 feet thick that weathers to a
bright tan color and forms a curved cliff face. The basal sandy ma-
terial grades into the shale below and in most of its outcrops forms
gentle slopes. Gray-black fissile noncalcareous clay shale contain-

ing several layers of calcareous concretions makes up the remainder of the Blue Hill Shale member. Gypsum crystals are not uncommon to this member.

2. Fairport Chalky Shale Member.

The Fairport chalky shale member of the Carlile shale occupies a broad area of low relief in the southern and eastern parts of the county. It has a range of thickness from 85 feet in the northeastern part of Ellis County to 115 feet near the southwest corner. The Fairport chalk is composed throughout of calcareous shale, including thin beds of chalky limestone, which occur in greatest abundance toward the base of the member. On fresh exposures it is bluish, but its weathered surface is a light orange-tan color. The lower half has, in addition, a pink tinge, which gives it a fresh color. This member, particularly the lower half, is lithologically not unlike the underlying Greenhorn limestone, but the fossils contained in it furnish the basis for separation. The upper boundary of the Fairport member is not so sharply defined throughout the county as the base. In good exposures it can readily be determined by the calcareous character of the Fairport shales and their weathered orange-tan color, in contrast with the noncalcareous character and gray-black color of the overlying shales and their stickiness when wet.

The lower member of the Carlile shale continues to increase in thickness westward beyond the boundaries of Ellis County. The boundary between the Fairport member and the Greenhorn limestone is placed at the top of the "fence-post limestone" bed.

C. Greenhorn Limestone.

The entire formation of the Greenhorn Limestone occupies approximately only 15 percent of the surface of Ellis County. The formation has a thickness of nearly 100 feet. We find that the Greenhorn formation is extensively exposed in the southern and southeastern parts of the county and extends a few miles up the Saline river in the northeastern part.

1. Pfeifer Shale Member.

The Pfeifer shale member exposed near Pfeifer, Ellis County, is capped by the "fence-post limestone" bed, so-called because it is extensively quarried and used for fence posts throughout the region of its outcrop. The Pfeifer member is 19 to 21 feet thick and consists of alternating layers of chalky shale and chalky limestone. On fresh exposure the entire mass exhibits a blue color, but on weathering it becomes a light tan or cream. In general, the member produces gently graded slopes. Its outcrop throughout this region is often marked by white mounds of the overburden removed in quarrying the "fence-post limestone" bed.

2. Jetmore Chalk Member.

The Jetmore chalk member underlying the Pfeifer shale mem-

ber is 20 feet of interbedded chalky shale and chalky limestone.
The chalky limestone beds of this member are harder than those of
the overlying Pfeifer member, and the uppermost bed, which is almost
a foot in thickness, is hard, and characteristically forms a bench
with its blocks scattered along the edge. The chalky limestone beds
become thinner and less numerous in the lower part of the Jetmore
member and grade into the calcareous shale of the underlying Hart-
land member.

Because of the predominance of beds of hard, white, chalky
limestone, the member weathers in steep, almost bare, light-colored
slopes.

3. Hartland Shale Member.

The Hartland shale member lies just below the Jetmore
chalk member. It has a thickness of about 35 feet and contains a few
thin beds of soft chalky limestone and a few thin layers of clay. The
Hartland shale member grades into the overlying Jetmore member with-
out much change in lithology, so it is difficult to determine a dis-
tinct dividing line between the two members.

4. Lincoln Limestone Member.

The Lincoln limestone member, the basal member of the Green-

horn limestone, consists of about 20 feet of chalky shales and thin
beds of light-gray, chalky limestone and of hard, finely banded, dark-
colored, crystalline limestone. The beds of crystalline limestone
are most abundant at the base and top of the member, and emit a strong
bituminous odor when broken. As a whole, this member has a much yel-
lower color than other members of the Greenhorn limestone.

D. Graneros Shale Formation.

The Granerous shale occupies only a narrow strip in the
southeastern part of Ellis County along the Smoky Hill river.   It
is made up predominantly of blue-black fissile noncalcareous clay
shale.   Numerous thin lenses of sandy shale, sandstone, sandy lime-
stone, and ironstone concretions are interbedded with the shale.
Selenite crystals are commonly strewn over the surface, and the shale
has a bitter taste.

E. Dakota Sandstone Formation.

Only the uppermost 18 to 20 feet of the Dakota sand-
stone is exposed in Ellis County and that in an area of only a few
acres. The Dakota sandstone consists, from the top down, of 5 feet
of heavily bedded, fine grained, light gray sandstone, containing
an abundance of carbonized plant fragments; a zone 1 foot thick of
pyrite concretions embedded in sandstone; and 8 feet of massive,
fine grained sandstone. The rocks between the base of the sandstone
and the river are concealed by alluvium.

VI. METHOD OF COLLECTING ROCK SAMPLES

All of the rock samples under consideration for this problem were obtained through personal visitations from surface outcroppings of the strata in various localities. Whenever possible the samples were taken from the large outcroppings. Representative samples were secured from a given stratum and whenever there appeared to be a difference in rock structure in the same outcropping, samples were taken from each type of rock structure. The samples were taken from a wide range covering the greater part of the county, including the various formations and members of the Upper Cretaceous system. A geological map of Ellis County published by the State Geological Survey was used as a guide in helping to locate and to distinguish the various strata. However, the obtaining of the rock samples themselves was done more or less by trial and error, since the geological map showed only which stratum was nearest the surface and gave no definite indication as to where an outcropping might occur. Therefore it was necessary to drive in a car on section lines until an outcropping of a rock formation was observed. By taking careful observation of the speedometer reading of the car, as to miles covered, the exact position of the outcropping rock formation could be located, thereby confirming the formation and member from

which the sample was obtained. A cold chisel and hammer were used
in dislodging the rock sample from the main stratum. Care was taken
that enough of the stratum was chiseled away to be assured that the
sample obtained had not been exposed to weathering. Each sample was
placed in a wide mouth jar. These in turn were labeled as to the
formation, with the exact section, township, and range from which the
sample had been obtained.

VII. LABORATORY PROCEDURE[4].

A. Preparation of Samples for the Analysis.

Each sample when brought into the laboratory from the field trip consisted of rather large rough rock fragments. It was, of course, necessary that these rocks be in a finely powdered form. The samples were ground to a fine powder in an iron mortar. The powdered rock was then dried in an oven at 110° C. for two hours.

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4. Talbot, Henry P.---Quantitative Chemical Analysis, p. 184-200.
    Engelender, Carl J.---Elementary Quantitative Analysis.

B. Removal of Insoluble Matter and Silica.

        Two portions of the same dried sample were weighed into
a 250 c.c. beaker, 50 c.c. of hydrochloric acid (Sp. Gr. of 1.12)
were added and the beaker was covered with a watch glass, and placed
upon the electric hot plate to evaporate to dryness. About three-
tenths of a gram of the sample were used in each trial. When evap-
orated to dryness a few cubic centimeters of water and 5 c.c. of con-
centrated hydrochloric acid were added and again taken down to dryness
on the hot plate. After the residue was allowed to cool, water was
added and also a few cubic centimeters of dilute hydrochloric acid.
The whole was then boiled and the insoluble silicates filtered off.

C. Removal of Iron and Aluminum Oxides.

In the separation of iron and aluminum oxide, dilute
ammonium hydroxide (Sp. Gr. 0.95) was added to the above filtrates,
until just ammoniacal; 5 c.c. of saturated bromine water were added.
The solution was heated to boiling and a few crystals of ammonium
chloride added and more ammonium hydroxide, if the odor of ammonia
was not noticeable. The solution was filtered while hot. When the
precipitate of the iron and aluminum hydroxides was large the pre-
cipitates were redissolved in dilute hydrochloric acid and repre-
cipitated as described above. When the precipitate of the hydroxides
was small this reprecipitation was omitted. The filtrate contained
the calcium in solution.

D. Precipitation of Calcium as Calcium Oxalate.

In the determination of calcium, the filtrate from the above separation was neutralized with dilute ammonium hydroxide, and then made distinctly acid with hydrochloric acid. Two drops of methyl orange were used as an indicator. The calculated volume of ammonium oxalate solution (40 gr. of $(NH_4)_2 \cdot C_2O_4 \cdot H_2O$ per liter) required to precipitate all the calcium in the sample was then added, assuming the sample to be pure calcium carbonate. Two cubic centimeters in excess of the calculated volume were measured out.

The acidified filtrates were warmed and the precipitating agent added drop by drop, from a pipette, with constant stirring of the solution. Whenever a precipitate formed during the addition of the ammonium oxalate solution, enough hydrochloric acid was added to redissolve it. After the addition of the ammonium oxalate, dilute ammonium hydroxide (Sp. Gr. 0.95) was added from a pipette until the indicator turned yellow. The precipitated calcium oxalate was allowed to settle for at least a half-hour and then decanted through a filter. The filtrate was then tested for completed precipitation by adding a few cubic centimeters of ammonium oxalate solution. The calcium oxalate was redissolved in the beaker with warm dilute hydrochlor-

ic acid, the acid being poured through the filter. The filter was washed several times with hot water and then ammonium hydroxide was poured through it. This solution was diluted to 250 cubic centimeters and brought to boiling; 5 cubic centimeters of ammonium oxalate solution were added, and ammonia in slight excess. This was boiled for two minutes and set aside for a half-hour. The reprecipitated calcium oxalate was filtered off upon the filter first used, and washed free from chlorides.

The precipitated calcium oxalate could then be converted directly into calcium oxide by ignition, but when several analyses are to be made this is considered a longer method than the determination made volumetrically, due to the time required for ignition and weighing. Therefore, the method of volumetric determination of calcium was used.

E. Standardization of $KMnO_4$.

The volumetric determination of calcium requires that
a standard solution of a suitable oxidizing agent be used in titrat-
ing the liberated oxalic acid. Potassium permanganate was chosen
as the oxidizing agent. Only a liter of the potassium permanganate
solution was made up at a time, and it was used no longer than over
a period of two weeks. This gave the assurance that the standard
would not change in composition. Great care was also taken to ex-
clude any organic matters in making up the standard solution.

In preparing the standard solution, about 3.25 grams of
$KMnO_4$ were dissolved in a liter of water and boiled for several min-
utes. The solution was poured into a liter bottle and set aside for
several days. The impurities were then filtered out by means of a
sintered glass filter connected to a suction pump. The solution was
then poured into a glass-stoppered liter bottle made of dark glass.

For the standardization of the potassium permanganate so-
lution, sodium oxalate was used. The sodium oxalate used was a pri-
mary standard meeting the specifications of the American Chemical So-
ciety and assaying 99.95% pure sodium oxalate.

Two portions of the dried sodium oxalate, approximately
.25 gram each, were used. Each portion was dissolved in about 200 c.c.

of water and heated almost to boiling. While still hot 5 c.c. of
concentrated sulfuric acid were added by means of a pipette to the
oxalate solution. The solutions were then ready to be titrated
with the potassium permanganate; care was taken not to allow the
temperature to drop below 70° C. during the titration.   The end
point was a faint permanent pink, indicating the complete oxidation
of the free oxalic acid.

By being careful, it was possible to reach the exact end
point in the titration, saving not only the time of having to back
titrate with oxalic acid, but also the need of obtaining the compar-
ison of the strengths of the permanganate solution with oxalic acid.

The normality of the potassium permanganate was found
by dividing the weight of the sodium oxalate by the product of the
number of cubic centimeters of permanganate used and the gram-milli-
equivalent weight of sodium oxalate.

$$\text{Normality of KMnO}_4 = \frac{\text{Wt. of Na}_2\text{C}_2\text{O}_4}{\text{c.c. KMnO}_4 \text{ x m.e. of Na}_2\text{C}_2\text{O}_4}$$

F. Volumetric Determination of Calcium.

With the potassium permanganate standardized the volumetric determination of calcium could be made. The calcium oxalate was washed from the filter paper into a 400 c.c. beaker, and about 200 c.c. of water added. The filter paper which had held the precipitate was also added to make certain of no loss of calcium oxalate. After heating the solution almost to the boiling point 5 c.c. of concentrated sulfuric acid were carefully added by means of a pipette. The titration of the liberated oxalate ions with standard potassium permanganate was conducted in the same manner as standardization process described above.

To insure accurate results check runs were made on every sample. If the runs did not check to less than two-tenths of a percent calcium per sample, the samples were run again until check results were obtained. The percentages used in this problem, and found in the tables which follow, are the average of the initial and check runs.

The percentage of lime in the sample was determined by multiplying together the number of cubic centimeters of potassium permanganate used, the normality of the potassium permanganate, the gram-milliequivalent weight of calcium oxide and 100; the resulting product was then divided by the weight of the sample.

$$\text{Percent Calcium Oxide} = \frac{\text{c.c. x Normality x m.e. CaO x 100}}{\text{Wt. of Sample}}$$

VIII. RESULTS

The sample containing the highest percentage of lime was taken from the Fort Hays limestone member of the Niobrara formation, Sec. 33, T. 12 S., R. 16 W. The percentage of lime was 54.26. The sample containing the lowest percentage of lime ran but .31 percent. This sample was taken from Sec. 22, T. 13 S., R. 19 W. from the Blue Hill shale member of the Carlile shale formation.

Table II is simply a condensed record of the samples analyzed. It shows the township, range, and section from which the samples were obtained. Also, the percentage of lime, calcium, and calcium carbonate for each sample is given.

Table III gives the lime content of each sample according to the member from which it was obtained. This enables one to see how the percentages of the various samples in a given member or formation compare with each other. Tables IV and V are quite similar to Table II. The only difference is that the comparison is made in Table IV on a basis of percentage of calcium and in Table V on a basis of percentage of calcium carbonate.

The average lime content for each member was then determined. The Fort Hays limestone member ran the highest average percentage of lime--52.06%. The Greenhorn limestone formation ran next highest with

an average of 50.02 percent of lime, with the others lower as is
shown at the bottom of Table III.

It is interesting to note the variation in percent of
lime of samples taken from the same location and same member, but
from different rock beds. Sample 18 taken from Sec. 28, T. 13S.,
R. 20W. ran 51.36% lime, while sample 19 taken from a bed just a
few feet higher ran but 44.60% lime. These samples were taken from
the Smoky Hill chalk member.

Samples 28, 29, and 30 were taken from the same location
but from beds approximately 5 feet apart. These samples were also
taken from the Smoky Hill chalk member, Sec. 33, T. 11 S., R. 20 W.
Sample 28 ran 39.88% lime, sample 29 ran 49.80% and sample 30 con-
tained 48.69% lime. Observations made of these beds indicated in
color form a considerable difference in chemical content.

Samples taken from the same location of the Fairport
chalky shale member, but from different beds, showed the greatest
variation in lime content of any analyzed. Sample 36 contained
26.87% lime, while sample 37 ran 46.17%. The location was Sec. 9,
T. 15 S., R. 20 W.

Map of Ellis County

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

TABLE II

(Indicating sample number, location of samples, and
percentage of lime, percentage of calcium, and per-
centage of calcium carbonate in each.)

Sample Number	Section	Township	Range	Percentage of Lime	Percentage of Calcium	Percentage of CaCo$_3$
1	1	14S.	19W.	48.36	34.55	85.86
2	22	13S.	19W.	.31	.228	.568
3	27	13S.	19W.	46.99	33.63	83.56
4	10	13S.	19W.	52.90	37.84	94.50
5	29	15S.	17W.	52.39	37.40	92.95
6	32	15S.	17W.	52.29	37.38	92.88
7	30	15S.	16W.	51.73	37.02	91.99
8	13	15S.	17W.	51.69	36.93	91.75
9	22	13S.	18W.	53.94	38.55	95.80
10	4	13S.	18W.	52.14	37.31	92.70
11	3	13S.	18W.	53.71	38.39	95.40
12	9	12S.	18W.	46.20	32.95	81.86
13	33	11S.	18W.	52.76	37.68	93.63
14	27	11S.	18W.	.355	.332	.799
15	15	13S.	20W.	52.67	36.76	93.50
16	16	13S.	20W.	49.00	35.02	87.00
17	20	13S.	20W.	47.11	33.77	83.88
18	28	13S.	20W.	51.36	36.56	90.89
19	28	13S.	20W.	44.60	31.76	78.94

TABLE II (cont.)

Sample Number	Section	Township	Range	Percentage of Lime	Percentage of Calcium	Percentage of CaCo$_3$
20	3	11S.	18W.	50.85	36.31	90.22
21	5	14S.	16W.	48.40	36.23	86.01
22	5	14S.	16W.	47.08	33.61	83.56
23	33	12S.	16W.	54.26	38.78	96.37
24	27	12S.	16W.	52.85	37.77	93.85
25	3	12S.	16W.	49.40	35.30	87.50
26	3	12S.	16W.	27.11	19.37	48.16
27	21	12S.	20W.	45.38	32.44	80.60
28	33	11S.	20W.	39.88	24.82	64.60
29	33	11S.	20W.	49.80	35.60	88.40
30	33	11S.	20W.	48.69	34.79	86.46
31	34	11S.	20W.	50.07	35.78	88.93
32	2	12S.	20W.	54.18	38.72	96.20
33	29	15S.	18W.	51.76	36.99	91.93
34	29	15S.	18W.	40.19	28.72	71.37
35	16	15S.	19W.	51.21	36.60	90.95
36	9	15S.	20W.	26.87	19.20	47.71
37	9	15S.	20W.	46.17	32.97	81.96
38	34	15S.	16W.	49.88	35.65	88.59
39	27	15S.	16W.	43.00	30.74	76.37

TABLE III

(Indicating percentage of lime content in
various members.)

Niobrara Formation				Carlile Shale			
Smoky Hill		Fort Hays		Blue Hill shale		Fairport chalk	
sample	percentage	sample	percentage	sample	percentage	sample	percentage
4	52.95	1	48.36	2	.31	21	48.40
10	52.20	3	47.1	14	.355	22	47.08
12	46.20	9	53.95			25	49.40
16	49.00	11	53.68			26	27.11
17	47.11	13	52.76			35	51.21
18	51.36	15	52.67			36	26.87
19	44.60	20	50.85			37	46.17
27	45.38	23	54.26				
28	39.88	24	52.85				
29	49.80	32	54.18				
30	48.69						
31	50.07						

Average of Runs

48.27 %	52.06 %	.332 %	42.32 %

TABLE III (cont.)

Greenhorn		Graneros Shale		Dakota Sandstone	
sample	percent-age	sample	percent-age	sample	percent-age
5	52.35	38	49.88	39	43.00
6	52.33				
7	51.80				
8	51.67				
33	51.76				
34	40.19				

Average of Runs

50.02 %	49.88 %	43.00 %

TABLE IV

(Indicating percentage of Calcium content in various members.)

| Niobrara Formation | | | | Carlile Shale | | | |
| Smoky Hill | | Fort Hays | | Blue Hill | | Fairport chalk | |
sample	percentage	sample	percentage	sample	percentage	sample	percentage
4	37.84	1	34.55	2	.228	21	36.23
10	37.31	3	33.63	14	.332	22	36.61
12	32.95	9	38.55			25	35.30
16	35.02	11	38.39			26	19.37
17	33.77	13	37.68			35	36.60
18	36.56	15	36.76			36	19.20
19	31.76	20	36.31			37	32.97
27	32.44	23	38.78				
28	24.82	24	37.77				
29	35.60	32	38.72				
30	34.79						
31	35.78						

TABLE IV (cont.)

Greenhorn		Graneros shale		Dakota sandstone	
sample	percentage	sample	percentage	sample	percentage
5	37.40	38	35.65	39	30.74
6	37.38				
7	37.02				
8	36.93				
33	36.99				
34	28.72				

TABLE V

(Indicating percentage of Calcium Car-
bonate in various members.)

Niobrara Formation				Carlile Shale			
Smoky Hill		Fort Hays		Blue Hill		Fairport chalk	
sample	percent-age	sample	percent-age	sample	percent-age	sample	percent-age
4	94.50	1	85.86	2	.568	21	86.01
10	92.70	3	83.56	14	.799	22	83.56
12	81.86	9	95.80			25	87.50
16	87.00	11	95.40			26	48.16
17	83.88	13	93.63			35	90.95
18	90.89	15	93.50			36	47.71
19	78.94	20	90.22			37	81.96
27	80.60	23	96.37				
28	64.60	24	93.85				
29	88.40	32	96.20				
30	86.46						
31	88.93						

TABLE V (cont.)

Greenhorn		Graneros shale		Dakota sandstone	
sample	percentage	sample	percentage	sample	percentage
5	92.95	38	88.59	39	76.37
6	92.88				
7	91.99				
8	91.75				
33	91.93				
34	71.37				

Graph comparing percentage of Lime in Smoky Hill
Chalk Member.

Sample No	5	10	15	20	25	30	35	40	45	50	55	60
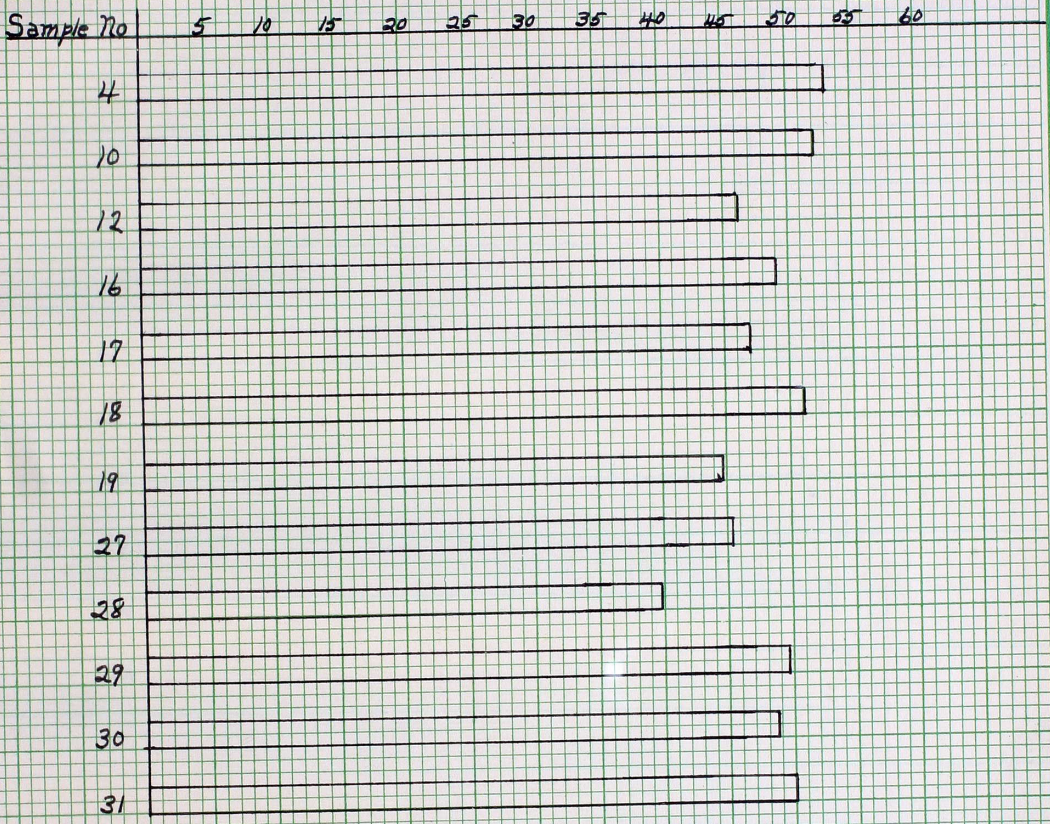
Graph comparing percentage of Lime in Fort Hays Limestone Member.

Sample No	5	10	15	20	25	30	35	40	45	50	55	60

Graph comparing percentage of Lime in Fairport Chalk Member.

Horizontal axis (percentage): Sample No. 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60

Sample No.	Lime %
21	~48
22	~46
25	~46
26	~27
35	~52
36	~27
37	~43

Sample No | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60

Bar chart with horizontal bars for samples:
- 5
- 6
- 7
- 8
- 33
- 34
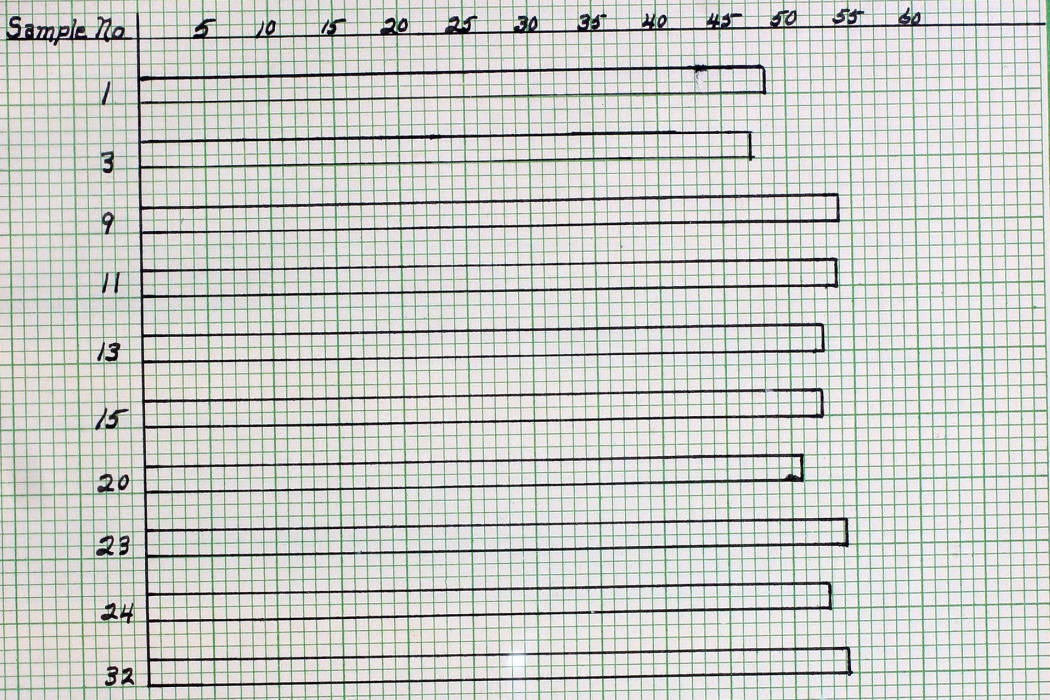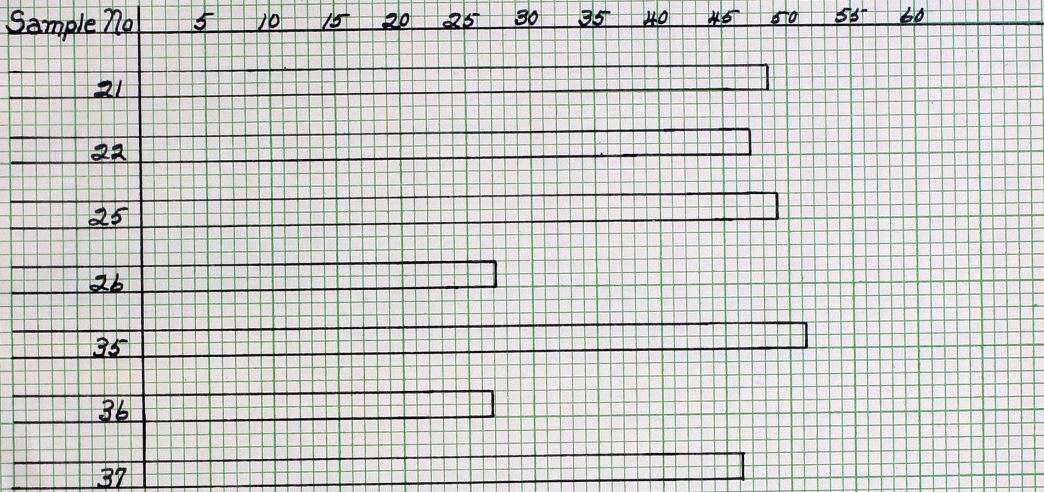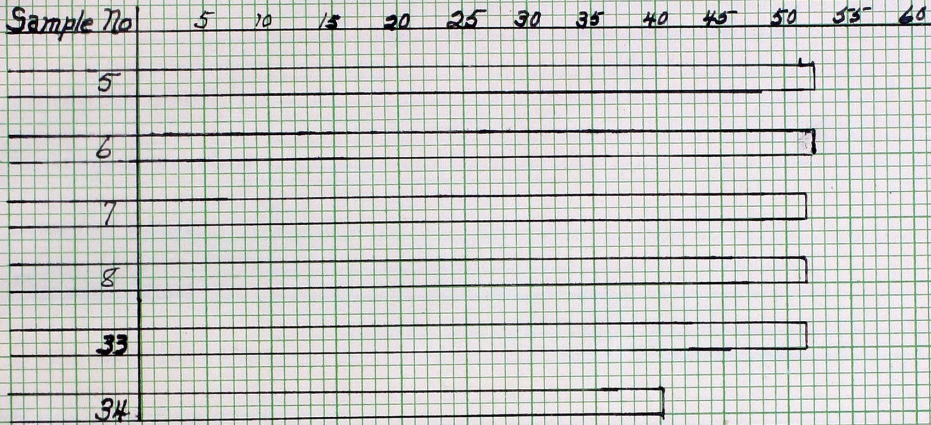
Graph comparing average Lime content of
Formations and Members of Upper Cretaceous System.

43.

Smoky Hill Chalk

Fort Hays Limestone

Blue Hill Shale

Fairport Chalk

Greenhorn Limestone

Graneros Shale

Dakota Sanstone
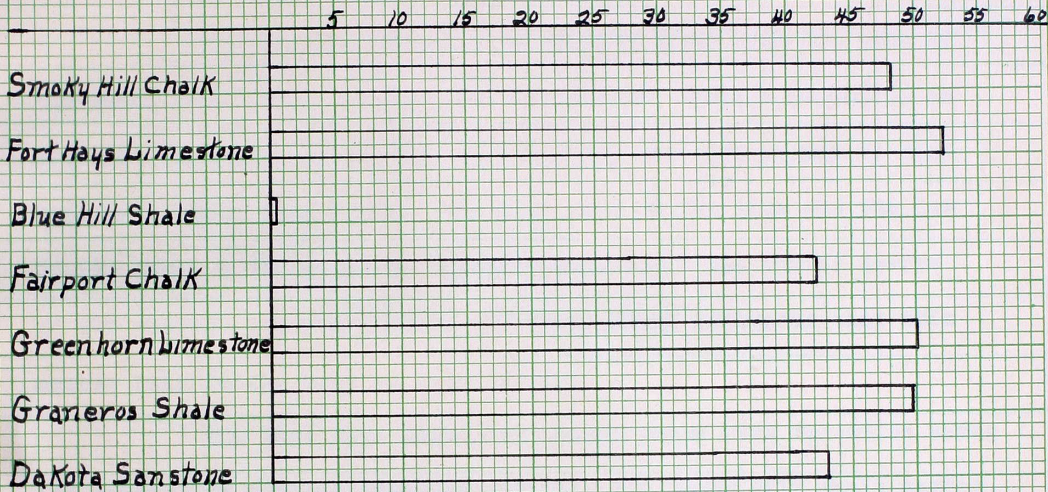
IX. SUMMARY AND CONCLUSION

The lime content of the samples taken from the beds of the Smoky Hill chalk member do not show as great a variation as might be expected considering that many of the beds appear to contain more shale than chalk. The high runs 52.95% lime and the low 39.88% lime, a variation of approximately 13%. Ten out of twelve of the samples run higher than 45% lime, which indicates that this member runs fairly high in lime content.

The Fort Hays limestone member shows less variation among its samples in percent lime content than the Smoky Hill chalk member. The difference between the high and low is but approximately 6% and eight out of ten samples run from 50.85% to 54.26% lime. The Fort Hays limestone member not only averages the highest in lime content, but the percentage of lime in its beds throughout the county is also quite constant.

The Blue Hill shale member seems to be consistent in its lack of lime, running less than half a percent in two runs taken from widely separate localities in the county.

The Fairport chalky shale member of the Carlile shale shows the widest variation in lime content among its samples of all the members, with a high of 51.21% and a low of 26.87%. This variation can possibly be explained by the presence of alternating chalk and shale

beds in greater thickness and number than in the other members. It might be interesting to repeat here the result of the findings in Sec. 9, T. 15 S., R. 20 W. in the Fairport member. From a large out-cropping of shale the sample runs 26.87%; from the same locality but from a chalk bed a few feet lower the sample runs 46.17%, a variation of approximately 20%.

Five of the six samples taken from the Greenhorn lime-stone formation run quite constant in percentage of lime, the differ-ence in range lying between 51.67% and 52.35%. Sample 34, however, drops approximately 11% below the others. This is due to the fact that sample 34 was taken from a thin bed of shale. Sample 33, taken from the same location but from a chalk bed, runs 51.76%. The indi-cations are that the Greenhorn formation runs fairly constant in per-centage of lime excluding the thin beds of shale.

The Graneros Shale formation, which is primarily composed of sandstone beds, runs surprisingly high in lime. The sample taken from the narrow strip of Graneros shale exposed in Ellis County runs 49.88% lime.

The sample taken from the Dakota Sandstone formation con-tains 43% lime, which is a relatively high lime content for sandstone beds.

It might be well to mention to the reader some of the in-teresting economic possibilities that Ellis County offers relative to

this problem. Probably one of the most important economic uses of limestone is its use in the production of Portland cement. The expansion of the Portland cement industry in the last twenty years is due to extensive road-building programs, to the development of reinforced concrete constructions, and to the adaptability and uniformity of the material. Not only walls and piers, but girders of concrete are now freely used. Bridge piers, tunnels, dams, and canal walls are built of concrete as well as sidewalks, steps, garage and factory floors, and building foundations. One reason for the almost universal use of Portland cement is the comparative ease of working; another is its strength which increases with age; a third is its uniformity, which permits calculations of strength as reliable as those made for structural steel. The necessary raw materials for the production of Portland cement are lime in the form of limestone and clay or shale. The latter must contain silica, iron oxide, and alumina.[5] These raw materials, in the form of limestone and shales, are abundantly found in the Upper Cretaceous formation of Ellis County.

Lime, more properly called quicklime, is the oxide of calcium, CaO, and is obtained by driving the carbon dioxide out of limestone. The reaction $CaCO_3 \rightleftharpoons CaO + CO_2$ is reversible; it runs to the right if the carbon dioxide is removed. Limestone suitable for the production of lime should contain no less than 50% lime[6]; as the preceding tables

5. Riegel, Emil Raymond--Industrial Chemistry, pp. 90-98.

6. Willaman, John F.--Vocational Chemistry, pp. 100-101.

show, many limestone beds of this region are suitable for lime produc-
tion.

Lime as quicklime is used for mortar with a mixture of
lime, sand, and water. Mortar has been largely displaced by Portland
cement, but seven-tenths of the lime made is still used for structural
purposes, either as mortar, or mixed with cement or plaster.[7] Lime
is also used in the chemical industries, such as ammonia soda, gas puri-
fication, paper making, and tanning. Hydrated lime is used to make
sand bricks, and as a fertilizer; it is also one of the raw materials
for bleaching powder.

Lately much attention has been given to the possibility
of using ground limestone in cattle fattening rations, especially in
this section of the country in which legume hays are not grown. These
sections do, however, produce silage crops including corn, as well as
the grain sorghums and sweet sorghums, which, however, are inferior
to the legume hays in their calcium content. The Kansas Agricultural
Experiment Station at Manhattan, Kansas, recently conducted a series
of experiments using ground limestone in non-leguminous cattle fatten-
ing rations. The results of these experiments over a three year period
showed an advantage of adding calcium carbonate either as straight
calcium carbonate or finely ground high calcium content limestone to

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[7] Riegel, Emil Raymond--Industrial Chemistry, p. 96.

a calf fattening ration consisting of corn, cottonseed meal, cane silage, and prairie hay. In another experiment the tests showed the possibility of using silage alone as the roughage portion of cattle fattening rations when supplemented with a high calcium content powdered limestone. Limestone for use in cattle fattening rations should contain a minimum of 95 percent calcium carbonate.[8.] Limestone suitable for cattle feeding in Ellis County is found only in the Fort Hays member of the Niobrara formation. Four of the ten samples taken from the Fort Hays member ran above 95 percent calcium carbonate which indicates that a plentiful supply of limestone of cattle feeding quality is available in this county.

At the present time the most important economic use of the rock of the Upper Cretaceous System of this county is that of building stone. Most of the churches of the county and the buildings on the campus of the Fort Hays Kansas State College are built of native stone. The Fort Hays limestone member and the Greenhorn limestone formation yield a grade of stone that has proved very satisfactory for building purposes.

As can readily be seen the natural resources of this county in regard to its rock deposits are great. We may say that the

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8. Dr. C. W. McCampbell, Professor of Animal Husbandry, Kansas State College of Agriculture and Applied Science, in answer to written inquiry.

natural resources in this regard **far** outweigh the present need. Generally speaking, the lime content of the rock of the Upper Cretaceous system in this county is high, but the lack of ready market and the high cost of transportation to industrial centers makes the economic value at present in most instances only a dormant possibility.

2. Engelhardt, Carl ?. Elementary Quantitative Analysis. New York, John Wiley and Sons, 1929, 40-50.

        Contains a good laboratory outline for the volumetric analysis of limestone.

3. Hillebrand, W. F. Analysis of Silicate and Carbonate Rocks. 285 p. (United States Geological Survey. Department of Interior. Bulletin No. 700.)

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4. Pirsson, Louis V., and Schuchert, Charles. A Textbook of Geology. New York, John Wiley and Sons, 1922. 600 p.

        A general reference book on geology.

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       of raw products.

6. Talbot, Henry P. Quantitative Chemical Analysis. 7th. ed., re-
       vised and rewritten by L. F. Hamilton and S. G. Simpson. New
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