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## BULLETIN 19

# THE GEOLOGY OF NESS AND HODGEMAN COUNTIES, KANSAS

**By RYCROFT G. MOSS**

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By Rycroft G. Moss.

## INTRODUCTION.

Purpose of Report. The geologic investigations in Ness and Hodgeman counties were undertaken for the purpose of adding to the geologic knowledge of the state and assisting in the development of local mineral products. The Kansas Geological Survey is preparing a large-scale geologic map of the state, and the areal geologic maps in this report will form a part of that map. Data on the stratigraphy of the rocks outcropping in Ness and Hodgeman counties add to the knowledge of the rocks of Kansas and assist in the correlation of these rocks with those of other states. A knowledge of the stratigraphy and geologic structure is indispensible in searching for petroleum and is a great aid in developing other natural resources.

Previous Geologic Work. No detailed geologic reports on Ness and Hodgeman counties have been published previously, but some data have been published that apply to the area in a general way. N. H. Darton,[1] in describing the geology and underground water resources of the Central Great Plains, discusses the general geology and stratigraphy of western Kansas. Records of water wells in Ness and Hodgeman counties are included in this report. Darton and others,[2] in a geologic guidebook of the area along the route of the Santa Fe railway, include a geologic cross-section which crosses Ford county just south of the south line of Hodgeman county. Rubey and Bass,[3] in 1925, made the first detailed report on an area in western Kansas in a bulletin on the geology of Russell county. This publication contains detailed descriptions and correlations of the Cretaceous strata and names a chalk member of the Greenhorn limestone after the town of Jetmore in Hodgeman county. Bass,[4] in 1926, published a report on geologic investigations in western

1. Darton, N. H.: The geology and underground water resources of the Central Great Plains. U. S. Geol. Survey Prof. Paper 32, 1905.

2. Darton, N. H. and others: Guidebook to the Western United States. U. S. Geol. Survey Bull. 613, 1915.

3. Rubey, W. W., and Bass, N. W.: The geology of Russell county, Kansas. Kansas Geol. Survey Bull. 10, 1925.

4. Bass, N. W.: Geologic investigations in western Kansas. Kansas Geol. Survey Bull. 11, 1926.

Kansas in which the geology of Ellis and Hamilton counties and the regional structure of the rocks of western Kansas are discussed. The authors of the Russell and Ellis county bulletins originated the classifications of structure and surface rocks used in the present report.

During the last few years oil companies have done a vast amount of geologic work in western Kansas. Most of the data collected by them are, for commercial reasons, not available to the public, but the records of wells drilled are generally available. These give considerable knowledge of the buried rocks and furnish a guide to future prospecting. Millions of dollars have been expended in western Kansas in prospecting for oil. Several oil pools have been discovered, but, taken as a whole, the production to date has not paid for the drilling that has been done. Many areal geologic data in this area have been kindly furnished the Kansas Geological Survey by oil companies.

Field Work and Acknowledgments. The field work upon which this report is based was done in the summers of 1929 and 1930. Most of the data on Ness county were obtained in 1929, and those for Hodgeman county in 1930. A field conference with J. B. Reeside, Jr., Kenneth K. Landes, and A. L. Morrow was held in July, 1930, to study the invertebrate paleontology of the Cretaceous strata. The valuable assistance given by Doctor Reeside is greatly appreciated. The writer wishes to express appreciation of helpful supervision and criticism in the field work and in preparation of the manuscript by Kenneth K. Landes; and also to acknowledge help given by Thos. H. Allan and others of the Midwest Refining Company for areal geologic data and well elevations. The Phillips Petroleum Company furnished areal geologic data in Hodgeman county which were very useful. The writer also wishes to acknowledge assistance by Robert McNeely, of the Independent Oil Company, in checking stratigraphic intervals in the Niobrara formation, and by William F. Howell, of the Phillips Petroleum Company, who furnished core-drill information on the thickness of the Carlile shale. Subsurface data on the Coleman well were kindly furnished by Charles Ryniker and Roy Hall, of the Gypsy Oil Company. The writer is indebted to many local citizens for data on water wells, sand and gravel deposits, and other geologic information, particularly L. L. Hunt and P. G. Roth, of Ness City, William Benge, of Jetmore; and Humphrey Owens, of Utica.

## GEOGRAPHY AND TOPOGRAPHY.

LOCATION AND CULTURE. Ness and Hodgeman counties are located in central-western Kansas (Fig. 1). Ness county includes townships 16 to 20 south, and ranges 21 to 26 west, an area of approximately 1,080 square miles, or 691,200 acres. Hodgeman county is directly south of Ness county and includes townships 21 to 24 south, and ranges 21 to 26 west, an area of approximately 864 square miles, or 552,960 acres.

Ness county is served by two railroads, the Missouri Pacific and the Scott City branch of the Atchison, Topeka and Santa Fe. The Missouri Pacific crosses the northern end of the county, following

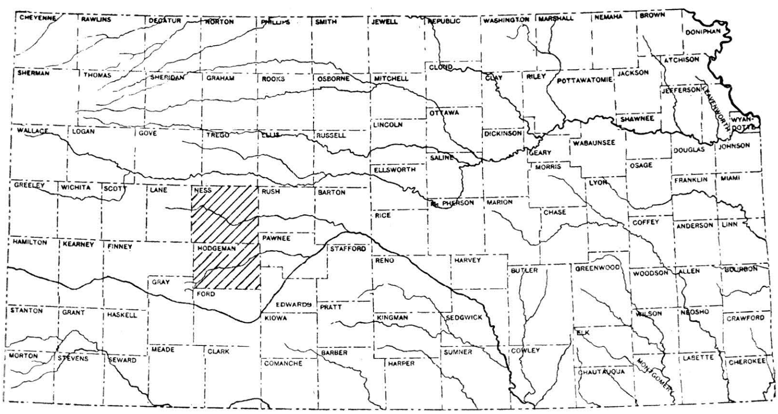



FIG. 1.—Index map of Kansas, showing the location of Ness and Hodgeman counties.

the divide between Smoky Hill river and Walnut creek. It runs through Brownell, Ransom, Arnold and Utica. The Scott City branch of the Atchison, Topeka and Santa Fe follows Walnut creek in a westerly direction across the middle of the county, going through Bazine, Ness City and Beeler.

Hodgeman county is served by a spur line of the Atchison, Topeka and Santa Fe railroad, which leaves the main line at Larned and follows Pawnee river to the east line of Hodgeman county and then follows Buckner creek, passing through Hanston and terminating at Jetmore.

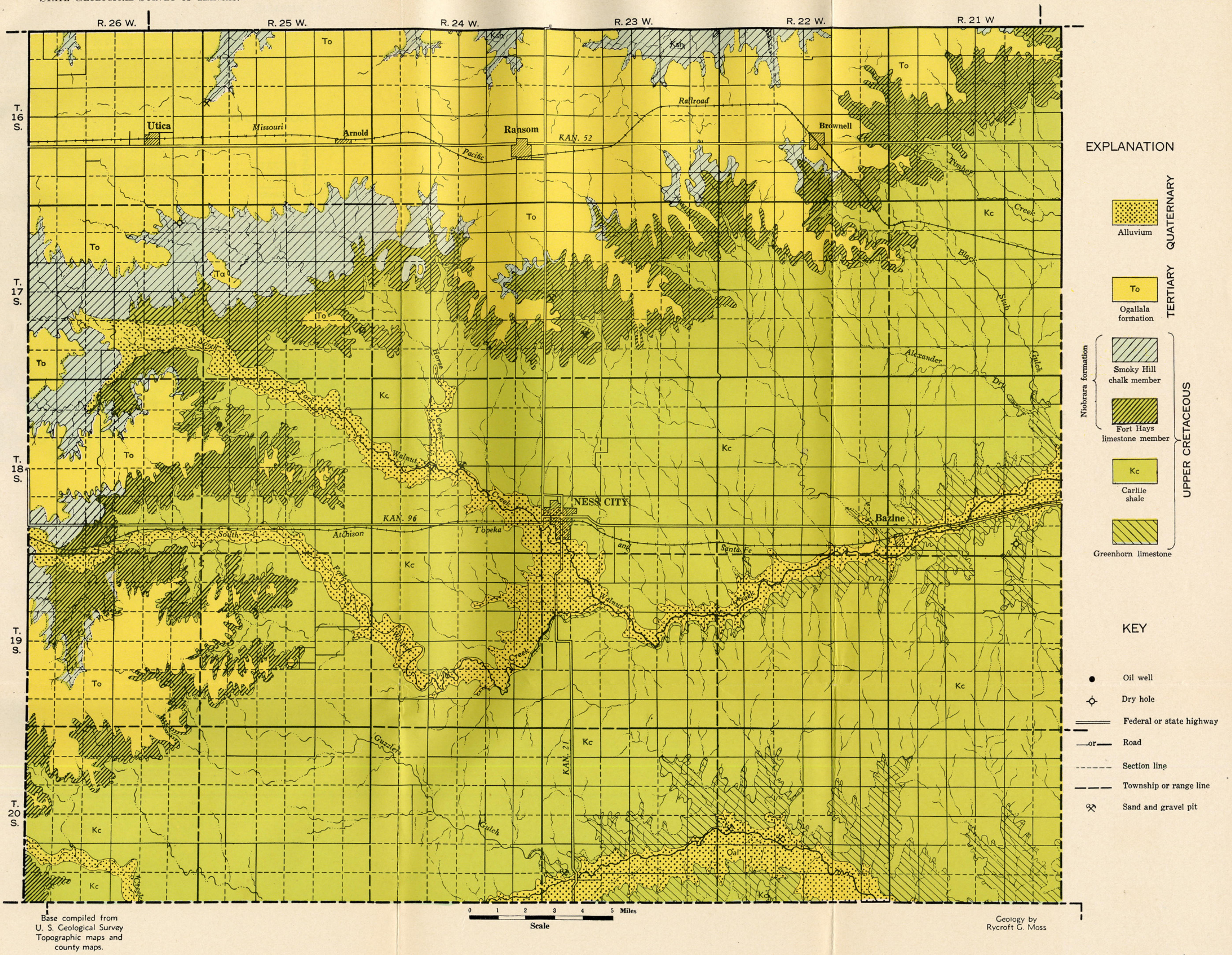
U. S. Highway 50 North crosses Hodgeman county in an east-west line following Buckner creek. A north-south state highway crosses the two counties, passing through Ness City and Jetmore, and two east-west state highways cross Ness county following the two railroads. Practically all of the area of the two counties is accessible by graded county and township roads.

Ness county has a population of 8,358, and Hodgeman county has a population of 4,157 (1930 census figures). Ness City, the county seat of Ness county, has a population of 1,509, and Jetmore, the county seat of Hodgeman county, has a population of 914. Ransom and Bazine have a population of 431 and 423 respectively, and Utica has a population of 382. Hanston has a population of 254, Brownell 207, Beeler 110, and Arnold 90.

Most of the area of Ness and Hodgeman counties is in the Arkansas river drainage basin. Only a narrow strip, four to eight miles wide, along the north edge of Ness county drains into Smoky Hill river. All of Ness county, except the strip on the north edge and another along the south edge, drains into Walnut creek, which rises in Lane county and flows eastward to join Arkansas river at Great Bend. All of Hodgeman county (except a small area in the southeast corner), and the southern end of Ness county, drain into Pawnee river, which rises in Finney county and joins Arkansas river at Larned about 25 miles east of the east line of Hodgeman county. Pawnee river flows through the northern part of Hodgeman county. Its largest tributary, Buckner creek, rises in the northeast part of Gray county and flows northeastward, joining Pawnee river at a point about five miles south of the northeast corner of Hodgeman county. The largest tributary of Buckner creek is Sawlog creek, which rises in the northwest corner of Ford county and joins Buckner creek at Hanston, in eastern Hodgeman county.

TOPOGRAPHY. The total relief of the area is approximately 600 feet. The highest point, west of Utica on the divide between Smoky Hill river and Walnut creek, has an elevation of about 2,650 feet, and the lowest point, where Walnut creek leaves Ness county, has an elevation of 2,050 feet. Locally, however, the relief nowhere exceeds 300 feet. Physiographically, Ness and Hodgeman counties lie on the eastern edge of the High Plains and in the south part of the Blue Hills upland.[5] The Ogallala capped divides (see Plates I and II) between the larger streams form the eastern margin of the High Plains, and the uplands formed by the Greenhorn limestone and the lower Carlile shale in eastern Ness county and northeast Hodgeman county compose the southern part of the Blue Hills upland. In southern Hodgeman county the Ogallala has overlapped the Niobrara, Carlile and part of the Greenhorn formations, so that the Blue Hills upland terminates to the south against a gently slop-

5. Moore, R. C.: The surface features of Kansas. Kansas Geol. Survey, 1930.


R. 26 W.
R. 25 W.
R. 24 W.
R. 23 W.
R. 22 W.
R. 21 W
T. 16 S.
T. 17 S.
T. 18 S.
T. 19 S.
T. 20 S.
Utica
Missouri
Arnold
Ransom
Pacific
KAN. 52
Railroad
Brownell
Timber
Creek
Black
Hub
Alexander
Dry
Gulch
Horse
Creek
North
Fork
Walnut
Creek
NESS CITY
KAN. 96
Atchison
Topeka
and
Santa Fe
Bazine
South
Fork
Walnut
Creek
Guzzler
Gulch
KAN. 21
Qal
To
Ksh
Kc
EXPLANATION
Alluvium
QUATERNARY
Ogallala formation
TERTIARY
Niobrara formation
Smoky Hill chalk member
Fort Hays limestone member
Carlile shale
Greenhorn limestone
UPPER CRETACEOUS
KEY
Oil well
Dry hole
Federal or state highway
Road
Section line
Township or range line
Sand and gravel pit
Base compiled from U. S. Geological Survey Topographic maps and county maps.
Scale
0 1 2 3 4 5 Miles
Geology by Rycroft G. Moss

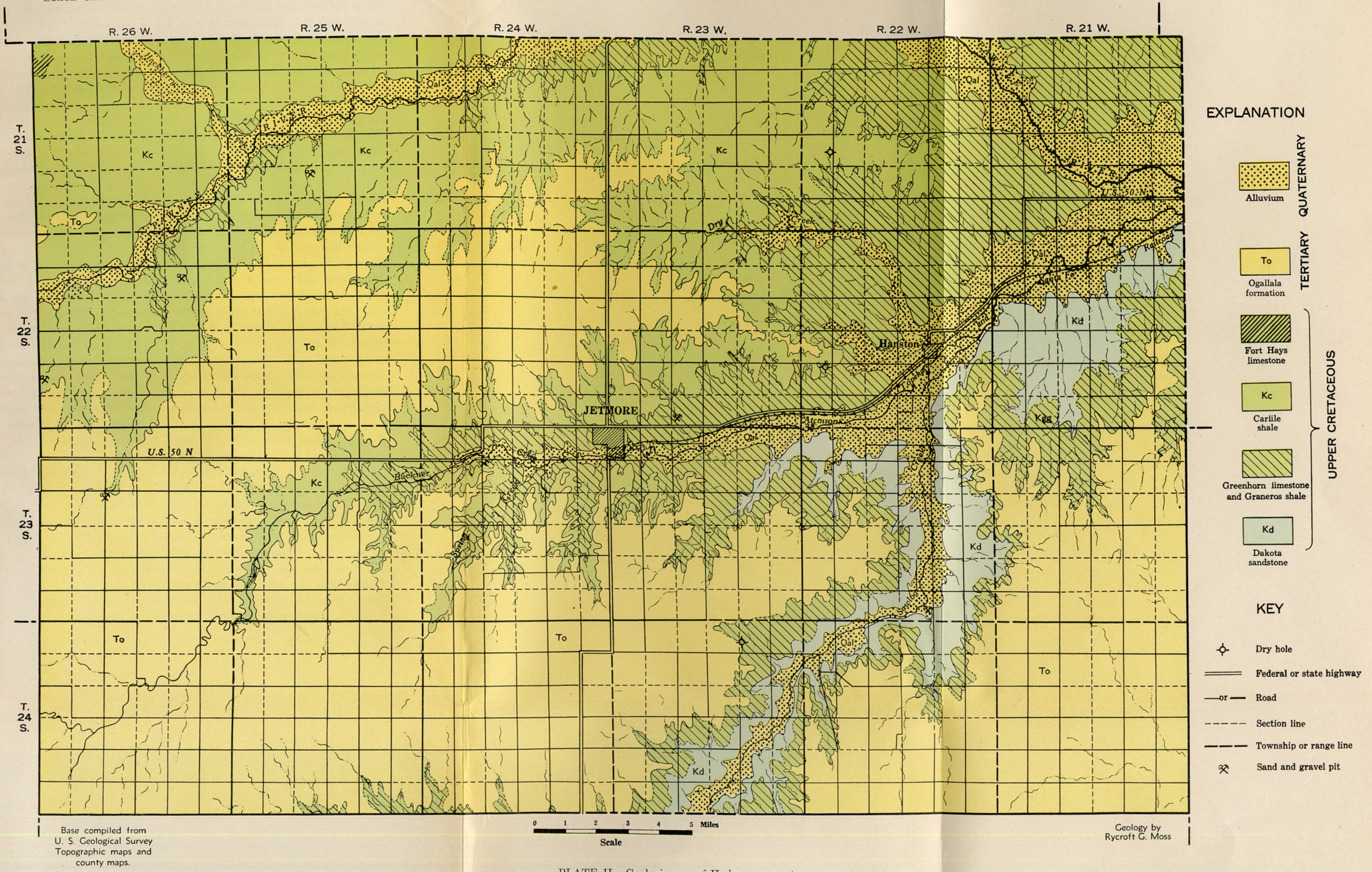



PLATE II.—Geologic map of Hodgeman county.

ing Ogallala-covered plain which joins the Great Bend prairie to the east. This termination is due to the truncation and covering of northward-dipping Cretaceous strata by the eastward-dipping Ogallala, so that the Greenhorn and Ogallala escarpments converge in central Hodgeman county. A recent physiographic classification by Fenneman[6] places this area in the plains border section of the Great Plains province.

The central parts of the divides between the major streams are flat and undissected and are sometimes poorly drained. An example of this is "Dutch Flats," a few miles northwest of Jetmore, where several small, intermittent lakes occur on the divide between Pawnee river and Buckner creek.

Since the major drainage of the area is to the east, the divides trend and slope eastward. The south flanks of the divides slope rather gently to the streams, but the north flanks have short, steep slopes. This asymmetrical cross section of the divides and valleys has been explained by Bass[7] as being due to the greater effect of the erosive processes on the southward-facing slopes. The southward-facing slopes are usually covered by soil, and outcrops of bedrock are rare. Resistant beds make only a slight bench, if they have any expression at all. Contrasted with these gentle and smooth slopes the northward-facing slopes are usually terraced, due to differential erosion of alternating hard and soft strata, with large areas where there is not enough soil to support vegetation. The valleys that trend northward or southward have nearly symmetrical cross sections. When any difference can be noted, the westward-facing slope is usually the more gentle.

All of the major streams have developed flood plains, some of which are over two miles in width. Along their north sides the flood plains grade gently into the south-facing slopes, but on the south side there is usually a sharp break where they join the steep north-facing slopes. The streams usually flow along the south side of the flood plains, and for considerable distance they may mark the areal contact between the alluvium and bedrock. Exposures of bedrock are very rare on the north side of the flood plains.

The flood plains, the southward-facing slopes, and the flat divides are utilized chiefly for cultivating wheat and corn, the chief agricultural products of the two counties. The "breaks" along the south side of the streams are mostly used for grazing purposes.

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6. Fenneman, N. M.: Physiography of the Western United States. John Wiley and Sons, 1930.

7. Bass, N. W.: The geology of Cowley county, Kansas. Kansas Geol. Survey Bull. 12. p. 17, 1929.

## STRATIGRAPHY: ROCKS EXPOSED.

The surface rocks of Ness and Hodgeman counties are of Quaternary, Tertiary and Cretaceous age. The soils and alluvium are the most recent, the Ogallala (Tertiary) is the next oldest, and the Cretaceous strata, including the Dakota, Benton and Niobrara formations, are the oldest rocks exposed in the area. These rocks are underlain by still older rocks that have been penetrated by deep wells and will be taken up in a later section of this report. The table on the opposite page outlines the rocks exposed in stratigraphic order with the oldest at the bottom.

### Quaternary System.

#### Recent Deposits.

The soil covering of most of the area and the alluvium deposited by the streams are of Recent age. These deposits are, for the most part, silty clays and sandy loams with some loess. The thickness of the soil varies from a few inches to several feet. The stream alluvium is 20 to 50 feet thick in some places. Besides the loams and clays there are some deposits of talus and sand and gravel in the Recent deposits.

A mantle of soil obscures the bedrock over most of the area of Ness and Hodgeman counties. The southward-facing slopes are gently graded and covered by a rather thick, fertile soil, except where some resistant stratum is near the surface. Areas where the Jetmore member of the Greenhorn limestone and the Fort Hays limestone crop out have only a thin mantle of soil. The southward-facing slopes are generally tillable. On the other hand, the northward-facing slopes usually have scant soil covering and the steeper bedrock slopes contain accumulations of talus. Examples of talus slopes are the slopes immediately south of Jetmore and the slopes on the south side of Walnut creek, near Beeler.

The plateau-like uplands of the high plains are covered by a sandy loam that is usually several feet thick and is considered the best wheat land. The soil does not contain as much moisture as the bottom land, but it seems to have the property of giving up its moisture for plant growth better, so that the crops raised here are nearly as good as on the bottom lands. This property of the soil and the undissected character of the uplands make them the best areas for wheat raising.

*Table of rock formations in Ness and Hodgeman counties, Kansas.*

| System | Series | Formation | Member | Lithologic character. | Thickness in feet. |
|---|---|---|---|---|---|
| Quarternary. | Recent. | | | Soil. Stream alluvium. Sand and gravel. Talus. | 0–40 |
| Quarternary. | Pleistocene (?). | | | Upper terrace deposits of sand and gravel. Volcanic ash. | 0–15 |
| Tertiary. | Pliocene. | Ogallala. | | Both consolidated and unconsolidated silt, grit, sand and gravel on the High Plains. | 0–100 |
| | | Unconformity | | | |
| CRETACEOUS. | Upper Cretaceous | Niobrara formation. | Smoky Hill chalk member. | Alternating beds of soft chalk and chalky shale. Some thin bentonite beds. | 0–225 |
| | | Niobrara formation. | Fort Hays limestone member. | Massive chalk beds up to six feet thick alternating with thin, soft chalky shales. | 80 |
| | | Unconformity | | | |
| | | Carlile shale. | Blue Hill shale member. | Bluish-gray, fissile clay shale with sandy zone at top and septarian concretions in upper part. | *a*260 |
| | | Carlile shale. | Fairport shale member. | Chalky shale with thin chalky limestone beds and small, discoidal concretions at base. | |
| | | Greenhorn limestone. | Pfeifer shale member. | Chalky shale with thin chalky limestones, discoidal concretions and thin bentonite beds. "Post rock" limestone at top. | 19–21 |
| | | Greenhorn limestone. | Jetmore chalk member. | Alternating beds of chalky shale and chalky limestone. "Shell" limestone at top. | 23 |
| | | Greenhorn limestone. | Hartland shale member. | Chalky shale with few thin beds of chalky and granular limestone and thin beds of bentonite. | 80 |
| | | Greenhorn limestone. | Lincoln limestone member. | Chalky shale with thin beds of crystalline limestone and thin bentonite beds. | |
| | | Graneros shale. | | Bluish-gray clay shale, sandy shale and sand lenses. | 21–36 |
| | | Dakota sandstone. | | White to brown lenticular sandstone with gray and variegated sandy shale. Only top of formation exposed. | 50 |

*a*. Phillips Petroleum Company core hole.

Soils derived from the upper 200 feet of the Carlile shale are not very fertile. This part of the Carlile is a noncalcareous clay-shale which weathers into a sticky gumbo soil that is difficult to till and does not produce good crops.

The flood plains of the larger streams have a good soil and are used for raising corn, wheat and some hay and feed. Those of Pawnee river, in the eastern two-thirds of Hodgeman County, and Walnut creek, east of Ness City, are the widest and contain large and prosperous farms.

SAND AND GRAVEL. The stream beds contain deposits of sand and gravel that have been derived from the Ogallala formation, the Pleistocene (?) sands and gravels, and the Cretaceous chalky limestones. The pebbles of chalk in these deposits are an objectionable constituent for structural work because they weaken a concrete aggregate.

### PLEISTOCENE (?) DEPOSITS.

Beds of unconsolidated sand and gravel that occur along the slopes south of Pawnee river in the western half of Hodgeman county may belong to the Pleistocene. They lie in most places from 100 to 150 feet above the present level of Pawnee river. The position of this sand and gravel indicates that it is a remnant of a former terrace of Pawnee river. Similar deposits along Smoky Hill river in Ellis and Russell counties have been referred to the Pleistocene by Bass.[8] The beds are made up chiefly of granitic sands and pebbles but contain, also, some chert and limestone pebbles. This material was derived from areas of Ogallala and other rocks to the west. The Pleistocene (?) gravel and sand are exposed on the ridges between the small ravines and in the cut-banks of the ravines. On the ridges the presence of sand and gravel may be recognized by pebble-strewn areas which are almost barren of vegetation. The "soap weed" (Yucca) grows on the deposits and on the wash derived from them.

VOLCANIC ASH. Two deposits of volcanic ash were noted in the area: one at Ness City[9] and the other southwest of Beeler, a quarter of a mile east of the southwest corner of sec. 6, T. 19 S., R. 26 W. This latter deposit is exposed for 400 feet along the edge of a small, northward-facing hill. The ash is six feet thick where exposed by animal burrows. At the point of exposure there is about three feet of overburden. The area of the deposit probably does not exceed an acre. The ash lies on lower Smoky Hill chalk and is about 50 feet below the Ogallala.

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8. Rubey, W. W., and Bass, N. W.: The Geology of Russell county, Kansas. Kansas Geol. Survey Bull. 10, p. 19, 1925.

9. Landes, K. K.: The volcanic ash resources of Kansas. Kansas Geol. Survey Bull. 14, p. 36, 1928.

## Tertiary System.

### Ogallala Formation.

The Ogallala formation is made up of sand, grit, gravel and silty clays that are cemented by calcium carbonate in some places. The mortar-like appearance of the gritty beds that have been cemented has caused them to be called "mortar beds." The "mortar beds" are the most conspicuous part of the formation, since they are resistant to erosion and form benches and, in some cases, vertical bluffs. The materials composing the Ogallala deposits were derived from the erosion of pre-Ogallala rocks to the west, chiefly from the Rocky Mountain uplift. The material was carried eastward and deposited by streams in the form of a gigantic piedmont plain. The gritty, unsorted character of the deposits suggest that they were deposited under arid conditions by sporadic floods of the streams. The material is chiefly granitic sands and pebbles with a few pebbles of chert, limestone and basic igneous rocks.

The Ogallala formation caps the plateau-like uplands that make up about a third of the area of Ness and Hodgeman counties. These uplands are the eastern fringe of the high plains which rise gently westward to the Rocky Mountains. Since the Ogallala formation is more resistant than most of the underlying Cretaceous strata there is a distinct topographic break in most places at the contact. On the north-facing slopes the Ogallala beds form a steep slope, and along the northward-flowing streams they have been eroded into steep-walled valleys. Many of the northward-flowing tributaries of Buckner and Sawlog creeks are locally known as "canyons." On the south-facing slopes the topographic break is usually not pronounced and in places may not be evident, so that there is a gentle, unbroken slope from the top of the Ogallala down across lower strata to the bottom of the valleys. Thus, the contact between the Ogallala formation and the underlying Smoky Hill chalk on the north side of Walnut creek south of Ransom and Utica cannot be distinguished by the topography. Also, where the Ogallala is in contact with the Fort Hays limestone or the Jetmore chalk member of the Greenhorn limestone there is little or no topographic distinction, because each is about equally resistant to erosion.

The Ogallala formation is 100 feet thick in the western part of the area. Farther west it is over 200 feet thick. This thinning to the east is probably due to a lesser amount of original deposition here, as the area is still in the first cycle of erosion since the close of the

Tertiary period. There are, in some places, as many as three "mortar beds," but these cannot be traced very far and are irregular and probably discontinuous. The cemented beds are the most resistant to erosion. Since these "mortar beds" are due to cementation at successive stands of the ground-water table, it is not expected that they would be continuous or uniform, for a water table does not have a plane surface, and the porosity of the beds varies greatly. There is usually a "mortar bed" at the base of the formation where the base is of porous material. In the northeast corner of Ness county a small area was noted where the cement was of silica. This

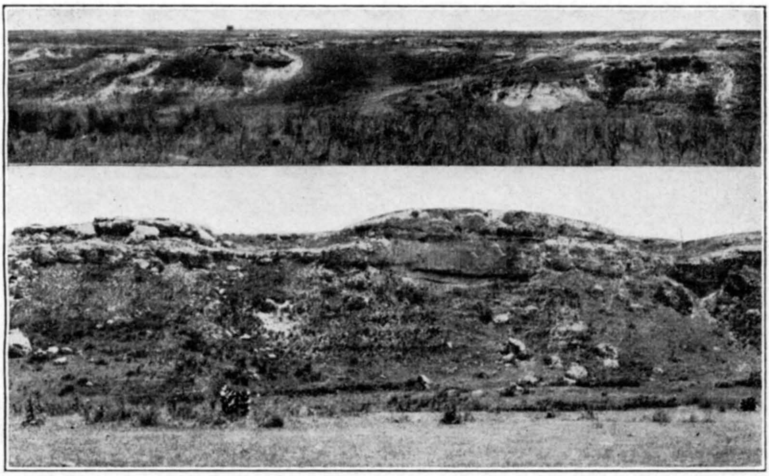

PLATE III. *Upper:* "Mortar beds" of the Ogallala formation in sec. 23, T. 23 S., R. 25 W., Hodgeman county. *Lower:* "Mortar beds" capping the lower beds of the Fairport chalky shale in sec. 14, T. 23 S., R. 25 W., Hodgeman county.

forms a hard quartzitic conglomerate. In general, however, the cement is calcium carbonate. The silty phases are poorly consolidated.

The pre-Ogallala erosion surface in this area did not have much relief, for the contact of the Ogallala with the underlying beds is generally uniform. In places there was a relief of 20 to 40 feet, as indicated by the conclusion that present major drainage lines seem to have been resurrected, the Ogallala beds showing a dip down north-south ridges toward the present major drainage lines.

Since the Ogallala formation has a rather uniform eastward dip of about 10 feet to the mile and the Cretaceous strata a dip of about

10 feet per mile slightly east of north, the Ogallala overlaps successively older Cretaceous strata to the south and east. At the northwest corner of Ness county, where the Ogallala overlies the thickest Cretaceous section in the area, there is about 330 feet of the Niobrara formation. The Ogallala beds overlie 30 feet of the Niobrara in the northeast corner of Ness county. In the extreme northwest corner of Hodgeman county the Ogallala formation overlies 50 feet of Niobrara and the overlap increases from this point south so that the Ogallala overlaps both Carlile shale and the upper 25 feet of the Greenhorn limestone and lies upon the upper part of the Jetmore member at the southwest corner of the county. The Ogallala is probably in contact with the Dakota sandstone at the southeast corner of Hodgeman county.

## Cretaceous System.

### Niobrara Formation.

The Niobrara formation consists of beds of chalk and chalky shale, the latter predominating. The beds weather to a white, tan, buff, or yellowish-pink color, but unweathered exposures are in most cases bluish-gray. The formation is divided into two members, the Smoky Hill chalk above and the Fort Hays limestone below. The Niobrara formation has a thickness of approximately 800 feet in Logan county, Kansas, where it is overlain conformably by the Pierre shale, but it has been truncated to the east by pre-Ogallala erosion. Only the lower 368 feet of the chalk beds remain in Ness county and 50 feet in Hodgeman county.

Smoky Hill Chalk Member. The Smoky Hill chalk consists of soft beds of alternating chalky shale and chalk. On unweathered exposures the beds have a bluish-gray color, and all have the same general appearance and nearly the same hardness. On weathered exposures, however, the slight differences in the composition of different beds is brought out through differential erosion. Even the thinnest beds are differentiated by erosion. This delicate etching of the soft, chalky beds would probably not occur in a humid climate. Induration, or "casehardening," of chalk beds that have been exposed for a long time has taken place making them harder than their unweathered equivalents.

Numerous thin bentonite beds occur in the member. In the lower part there are few of these beds that exceed one-half inch in thickness, but in spite of their thinness they are the key to stratigraphic work within the Smoky Hill member. The bentonites are very persistent laterally, and the intervals between them are constant for short distances and change uniformly over great distances. The bentonite beds weather to a rusty-brown color.

Pyrite concretions are scattered throughout the member. They weather to limonite, and exposures of the chalk beds are strewn with brownish-yellow concretions which are discoidal and reach one foot in diameter. Besides the concretions, the beds contain large pelecypods (*Inoceramus grandis*) which, in the lower part, reach two feet in diameter and weather out to such an extent that some of the exposures are almost covered with pelecypod fragments and concretions.

Since the Smoky Hill chalk is soft, it commonly forms a gentle, soil-covered slope between the overlying Ogallala formation and the underlying Fort Hays limestone. Where exposures do occur the chalk has a bad-land topography that is characteristic of the member. These areas are small, and they are scattered along the southward trending valleys. Along the northward-trending valleys, however, they may cover several square miles. The thickness of the strata exposed in any of the smaller areas rarely exceeds 40 feet.

Only the lower part of the Smoky Hill chalk is present in this area. The greatest thickness is in the northwest corner of Ness county, where it is about 225 feet. Pre-Ogallala erosion truncated the member to the south and east, so it has been completely removed at the northeast and southwest corners of the county.

The following detailed section is a composite of many carefully measured exposures. These sections were measured a few miles north of Ness county and along Smoky Hill river in Trego and Gove counties, because the best exposures occur there. The beds were traced up the small tributaries of Smoky Hill river into Ness county to establish the correlation there. The section of the Smoky Hill chalk member is divided into zones, designated by letters starting at the bottom and lettered consecutively upward. These zones are not the same as those used by Bass[10] and Russell.[11] Their "groups" do not form a continuous series but designate beds that are separated by undetailed intervals. A zone, as here used, consists of 20 to 35 feet of chalky shale capped by a resistant chalk bed. In one case a thick shale (zone C) is set apart, because there is no convenient break in the chalk above. All of the zones contain thin beds

10. Bass, N. W.: Geologic investigations in western Kansas. Kansas Geol. Survey Bull. 11, p. 20, 1926.

11. Russell, W. L.: Stratigraphy and structure of the Smoky Hill chalk in western Kansas. Am. Assoc. Petroleum Geologists, Bull., vol. 13, pp. 595-604, 1929.

of bentonite, which are very important because the intervals between them can be definitely recognized in correlation between exposures. Since there is rarely more than 40 feet of strata represented in any one area, and most of the exposures are capped by a resistant bed, these zones form a convenient lithologic unit.

*Partial Section of Smoky Hill Chalk Member of Niobrara Formation, Trego and Gove counties, Kansas.*

ZONE F.

NE. ¼ sec. 20, T. 15 S., R. 26 W.

| | Ft. | In. |
|---|---|---|
| 47. Massive chalk | 1 | 0 |
| 46. Chalk and chalky shale with a thin bentonite at the top and one five inches below the top | 9 | 1 |
| 45. Alternating beds of chalk and pinkish chalky shale | 13 | 1 |
| 44. Bentonite | 0 | ¼ |
| 43. Chalky shale and chalk | 5 | 7 |
| 42. Soft chalky shale with thin bentonite at top | 0 | 11 |
| 41. Chalky shale and chalk with thin bentonite at top | 5 | 3 |

ZONE E.

Sec. 25, T. 15 S., R. 26 W.

| | Ft. | In. |
|---|---|---|
| 40. Massive chalk bed with a thin bentonite parting at the top | 0 | 11 |
| 39. Chalky shale, tan | 1 | 5 |
| 38. Chalky shale with a thin bentonite parting at the top | 0 | 10 |
| 37. Chalky shale with a thin bentonite parting at the top | 1 | 1 |
| 36. Thin chalk beds and pinkish chalky shale with a thin bentonitic parting at the top | 8 | 5 |
| 35. Bentonite | 0 | ¼ |
| 34. Soft chalk and pinkish chalky shale | 9 | 10 |

ZONE D.

Sec. 13, T. 15 S., R. 26 W.

| | Ft. | In. |
|---|---|---|
| 33. Resistant chalk bed. Forms good bench | 8 | 8 |
| 32. Soft chalky shale. Pinkish-brown color | 7 | 6 |
| 31. Chalk, forming a shoulder | 1 | 8 |
| 30. Chalk and chalky shale with a thin bentonite at top. A thin bentonite parting occurs three feet and nine inches below the top | 6 | 5 |
| 29. Massive buff chalk | 2 | 6 |
| 28. Chalky shale with thin beds of chalk. A thin bentonite parting is one foot and two inches above the base | 12 | 2 |
| 27. Massive chalk beds separated by thin, soft, chalky shales with a thin bentonite parting at the top | 12 | 0 |

ZONE C.

NE. ¼ sec. 13, T. 14 S., R. 25 W.

| | Ft. | In. |
|---|---|---|
| 26. Chalky shale and soft chalk with a thin bentonite at base | 2 | 0 |
| 25. Chalk | 0 | 7 |
| 24. Chalky shale alternating with soft chalk beds | 11 | 4 |

| | | Ft. | In. |
|---|---|---|---|
| 23. | Soft chalk | 5 | 0 |
| 22. | Soft, tan chalky shale | 11 | 0 |
| | **ZONE B.** | | |
| | Sec. 29, T. 14 S., R. 25 W. | | |
| 21. | Massive chalk with thin shale parting at base | 3 | 5 |
| 20. | Massive chalk with parting eight inches below top | 2 | 2 |
| 19. | Soft chalky shale with a dark-brown bentonitic clay 17 inches below top. Contains much pyrite | 2 | 11 |
| 18. | Massive chalk | 0 | 11 |
| 17. | Tan chalky shale | 0 | 7 |
| 16. | Bentonite | 0 | 1 |
| 15. | Chalk | 0 | 6 |
| 14. | Chalk | 0 | 8 |
| 13. | Chalky shale | 0 | 5 |
| 12. | Chalk | 0 | 10 |
| 11. | Chalky shale with thin bentonitic seams | 2 | 7 |
| 10. | Chalky shale, lower part fissile; upper part chalky. Contains small pyrite concretions | 12 | 2 |
| 9. | Bentonite | 0 | 1 |
| 8. | Chalky shale | 2 | 3 |
| 7. | Bentonite | 0 | 2 |
| 6. | Soft chalky shale | 7 | 4 |
| | **ZONE A.** | | |
| 5. | Prominent chalk, hard at top and bottom | 3 | 2 |
| 4. | Chalky shale and thin chalk beds | 15 | 0 |
| 3. | Bentonite | 0 | ¼ |
| 2. | Chalky shale | 0 | 6 |
| 1. | Bentonite | 0 | ½ |
| | Top of Fort Hays limestone. | | |

The above sections, zones A to F, have a thickness of 188 feet. Approximately 40 feet of the next highest zone (G) also occurs in Ness county, but it is not included here because it is not well exposed in the area. It is composed of very soft shale and exposures are rare.

Correlation and measurement in the Smoky Hill chalk is almost entirely dependent on the bentonite beds. This has been noted by Bass,[12] Pinkley and Roth,[13] and Russell.[14] Some of the beds are only a paper-thin parting in which the bentonitic material has been replaced by pyrite which has subsequently been altered to limonite. The thickness of some of the bentonites may vary from place to

12. Bass, N. W.: Geologic investigations in western Kansas. Kansas Geol. Survey Bull. 11, 1926.

13. Pinkley, G. R., and Roth, Robert: An altered volcanic ash from the Cretaceous of western Kansas. Am. Assoc. Petroleum Geologists, Bull., vol. 12, p. 1015, 1928.

14. Russell, W. L.: Stratigraphy and structure of the Smoky Hill chalk in western Kansas. Am. Assoc. Petroleum Geologists, Bull., vol. 13, pp. 595-604, 1929.

place, but there is almost always some trace of them. The interval between horizons increases to the southwest. Comparison of sections measured at different localities indicates that for the lower beds in this area the rate of southwestward thickening is from two and one-half to three per cent per mile.

The Smoky Hill chalk member crops out in the north and west part of Ness county. It is absent in Hodgeman county, having been removed by pre-Ogallala erosion. The best exposures are at the north side of Ness county, along the small tributaries of Smoky Hill river. A few small exposures occur along the north and south forks of Walnut creek at the west side of the county and along the north tributaries of the north fork of Walnut creek as far east as Brownell. Parts of zones A and B occur north and south of Beeler. Only the lower few feet is exposed northeast of Beeler.

Marine invertebrate and both marine and nonmarine vertebrate fossils occur in the Smoky Hill chalk. The area of Niobrara outcrop in Kansas has long been famous for collecting and studying Cretaceous vertebrates, and most of the larger museums of the world have collections from here. Birds, dinosaurs, crocodiles, mosasaurs, turtles, and fish have been found in the member. Many species and genera of these vertebrates were first described from these beds.

Among invertebrates, *Inoceramus* (*Haploscapha*) *grandis* is the most abundant. Fragments of this pelecypod almost cover some of the exposures of the chalk beds. They are always thickly coated with *Ostrea congesta,* a small oyster which rarely occurs unattached. *Inoceramus* (*Haploscapha*) *grandis* attains a diameter of two feet or less in the beds exposed in Ness county, but in the beds above some reach a diameter of three to five feet. The rudistid *Radiolites maximus* occurs sparingly at the base of the member.[15] Besides the larger invertebrates, multitudes of foraminifera, chiefly *Globigerina* and *Gümbelina,* occur in the chalky beds. These minute tests probably make up over half of the calcareous material of the chalk.

FORT HAYS LIMESTONE MEMBER. The Fort Hays limestone lies conformably below the Smoky Hill chalk member. It is composed of thick, massive beds of chalk separated by thin beds of chalky shale. Some of the chalk beds are six feet thick, but the average is less than three feet. The shale partings rarely exceed four inches in thickness. The color of weathered exposures is tan, buff or cream, but in the unweathered state the beds are a light- or dark-gray color.

15. Logan, W. N.: The invertebrates of the Benton, Niobrara, and Fort Pierre Cretaceous. The Univ. Geol. Survey of Kansas, vol. 4, p. 480, 1898.

Since the Fort Hays limestone overlies the soft Carlile shale formation and is overlain by soft, chalky shale beds, it forms a well-defined escarpment in most places. The escarpment is especially prominent where the Ogallala formation rests on the Fort Hays member. Vertical bluffs are developed, especially on north-facing slopes, but on the south-facing slopes shoulders only appear. Gently sloping exposures are in all cases covered with chalk pebbles, and the base of steep bluffs is obscured by talus containing large blocks of

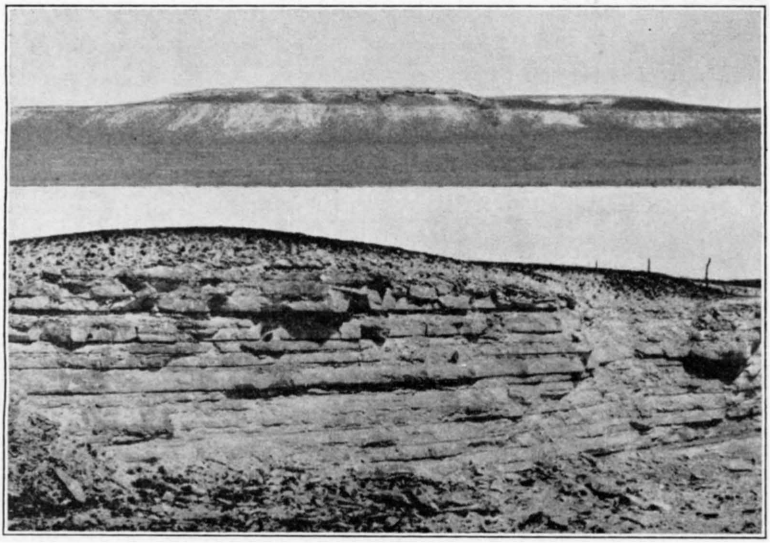

PLATE IV. *Upper:* "Mortar beds" resting on the Jetmore chalk member of the Greenhorn limestone three miles southeast of Jetmore. *Lower:* Upper beds of the Fort Hays limestone in sec. 3, T. 17 S., R. 26 W., Ness county.

chalk. Slumping is common on the steep slopes where, in some places, huge blocks have slipped down the Carlile slope 20 feet or more. Some of these slumped blocks have been mistaken for down-faulted blocks.

The contact between the Fort Hays limestone and the Smoky Hill chalk is transitional from predominating chalk beds to predominating chalky shale. The dividing point here used is the thin bentonite bed at the base of zone A of the Smoky Hill chalk. Although this is a few feet above any massive chalk beds, it is the only convenient and recognizable horizon at which to make a division. The use of this bentonite as the base of the Smoky Hill chalk makes the Fort

Hays limestone 80 feet thick in Ness county. No detailed section of the Fort Hays member is given here, because none could be measured in the area, and as the individual beds are not persistent a section measured elsewhere could not be accurately correlated here.

The Fort Hays limestone crops out in a band extending diagonally across Ness county from the northeast to the southwest corner, making deep reëntrants to the west in the valleys of Walnut creek and Hackberry creek. Except locally the band of outcrop does not exceed a mile in width, and in many places it is very narrow. The only Fort Hays limestone in Hodgeman county occurs in an area of less than half a square mile in the extreme northwest corner of the county.

The only fossils visible, without using a microscope, in the Fort Hays limestone are *Inoceramus deformis* and *Ostrea congesta.* The member also contains abundant foraminifera.

### Carlile Formation.

The Carlile formation lies unconformably below the Fort Hays limestone. It is composed of two members, the upper two-thirds constituting the Blue Hill shale member, and the lower third the Fairport chalky shale member.

Blue Hill Shale Member. This member is a bluish-black, noncalcareous clay shale. It contains zones of large septarian concretions in the upper part and a sandy zone at the top. The sandy zone has been called the Codell sandstone bed by Bass.[16]

The Blue Hill and the upper part of the Fairport form a slope between the Fort Hays limestone and the underlying lower Fairport and upper Greenhorn limestones. The upper part of the Blue Hill member forms a steep slope on the northward-facing hills, where it is overlain by the Fort Hays limestone. These slopes are devoid of vegetation in many cases and are strewn with large septarian concretions. The combination of a steep slope in the upper part of the Blue Hill shale and water seepage from the Codell sandstone bed has caused small landslides at numerous places. The landslides form hummocky areas in which small trees grow. The top of the Blue Hill member is commonly marked by a row of bushes that grow here because of the water in the Codell sandstone bed. The lower part of the member forms gentle slopes, and where exposures occur they are partially covered with selenite (gypsum) crystals.

16. Bass, N. W.: Geologic investigations in western Kansas. Kansas Geol. Survey Bull. 11, p. 28, 1926.

The Blue Hill shale member is 175 feet thick in the southwest corner of Ellis county.[17]. No measurement of the thickness could be made in Ness or Hodgeman counties as there are no complete exposures in this area. The following section shows the character of the upper part of the member.

*Section of Upper Part of Blue Hill Shale Member, measured in sec. 19, T. 17 S., R. 22 W., Ness County.*

| | Ft. | In. |
|---|---|---|
| Fort Hays limestone member. | | |
| 5. Gritty, bluish-gray shale with thin sand beds. The top six inches is a gray, limy sand that weathers to brownish-yellow | 21 | 0 |
| 4. Hard, gray concretionary sandstone bed | 0 | 4 |
| 3. Bluish-gray shale. Contains a few two-inch sandstone beds | 18 | 0 |
| 2. Bluish-gray shale with a zone of large, reddish-brown septarian concretions at the top. The concretions reach five feet in diameter, | 21 | 0 |
| 1. Fissile, bluish-gray shale with a zone of large gray septarian concretions at the top | 10 | 0 |
| Lower beds concealed. | | |

From other exposures it was found that the top of the upper concretionary zone varies from 39 to 41 feet below the top of the member. Sandy beds or sandy shale occur from this horizon up, but the sand is usually confined to the upper 15 to 20 feet, and the individual sand beds are thin. No cross-bedding was observed. The thin, sandy bed at the top of the member weathers to brownish-yellow. Johnson[18] has pointed out that the irregular character and thickness of the Codell sandstone and the phosphatic and conglomeratic character of this zone in eastern Colorado, together with the faunal break between the Carlile and Niobrara formations, indicate an unconformity. However, the strata above and below the contact are structurally conformable.

Microscopic examination of the Codell sandstone shows it to be composed of uniformly fine (average 0.4 mm. diameter), angular quartz grains with a few fragments of altered feldspar and some small fish teeth and bones. Most of the sand grains are slightly frosted and pitted, and since the sand is fine this is probably due to eolian transportation. "Heavy mineral" analyses were made of a number of samples taken from the outcrop between Mitchell and Ness counties. The average of these gave the following: Zircon 68 per cent, tourmaline 12 per cent, garnet (grossularite) 12 per cent, rutile 5 per cent, staurolite 1 per cent, and traces of anatase, chlorite,

17. Bass, N. W.: Geologic investigations in western Kansas. Kansas Geol. Survey Bull. 11, p. 26, 1926.

18. Johnson, J. H.: Unconformity in the Colorado group in eastern Colorado. Am. Assoc. Petroleum Geologists, Bull., vol. 14, p. 789, 1930.

muscovite, corundum and topaz. All of the zircon and the majority of the other minerals are in euhedral crystals or angular fragments. The zircon percentage rises from 58 per cent in Mitchell county to 87 per cent in Ness county. Since zircon is the most resistant mineral, this indicates that Ness county is farther from the source of the sand than Mitchell county. A mineral suite of this type denotes derivation from an area of predominant granitic rocks in which there are small exposures of basic igneous rocks and schist. Staurolite and rutile are not common in granites, but the rest of the minerals are. Staurolite characteristically occurs in schist.

The Blue Hill shale member crops out in a band two to five miles wide east of the Fort Hays limestone. This band is continuous from the northeast to the southwest corner of Ness county and crosses the northwest corner of Hodgeman county, covering an area west of Hackberry creek and north of Pawnee river. The exact area over which the Blue Hill shale member crops out could not be determined, due to the gentle slopes and soil cover. For this reason the members of the Carlile formation are not differentiated on the geologic maps (Plates I and II).

Fossils are found in the septarian concretions of the Blue Hill shale member, but none were found in this area. *Prionotropis woolgari, Inoceramus fragilis,* and species of *Scaphites* are commonly found.

Fairport Chalky Shale Member. The contact between the Blue Hill shale and the Fairport chalky shale is not exposed in Ness or Hodgeman counties, but where observed in other areas it is marked by an abrupt change from underlying chalky shale to overlying noncalcareous clay shale.

The Fairport chalky shale member consists of thick beds of chalky shale alternating with thin beds of chalk or chalky limestone. Many thin, flat concretions occur in the lower part of the member. The chalk beds in the lower part of the member are the hardest and most numerous. A few bentonite beds occur in the shales. The shale and chalk beds are a dull-gray color when unweathered, but weathering changes the color to tan, orange-tan, buff or light-gray. The bentonites are white when fresh but weather to rusty-brown.

Only the lowermost beds of the member are resistant enough to have any topographic expression. The lower 25 feet of the member is commonly terraced. The upper part of the member forms a continuation of the gentle, soil-covered slope of the lower Blue Hill shale member. The Fairport as a whole forms a gentle rolling topography above the Greenhorn limestone escarpment. The soil produced by the weathering of the Fairport rocks is highly fertile. The combination of the gently rolling topography and fertile soil makes the area of outcrop of this member very valuable for farming.

No measurement of the thickness of the Fairport chalky shale member could be made in Ness and Hodgeman counties, as there are no exposures of the upper part. The thickness in the southwest corner of Ellis county as given by Bass[19] is 115 feet. The thickness of the Carlile formation north of Ransom in Trego county was found to be 261 feet in a core hole drilled by the Phillips Petroleum Company. Since there is an unconformity at the top of the formation it is probable that the thinning is in the upper part of the Blue Hill shale member. The following sections show the character of the lower part of the Fairport chalky shale member in Ness and Hodgeman counties.

*Lower Beds of the Fairport Chalky Shale in Hodgeman County, in sec. 1, T. 22 S., R. 26 W.*

| | | Ft. | In. |
|---|---|---|---|
| | Higher beds concealed. | | |
| 13. | Soft, brownish-tan fossiliferous chalk | 0 | 5 |
| 12. | Soft, tan fossiliferous chalky shale with a three-inch bentonite 20 inches above the base and a thin bentonite 28 inches above the base | 5 | 6 |
| 11. | Soft, very fossiliferous chalky limestone | 0 | 3 |
| 10. | Orange-tan chalky shale | 4 | 3 |
| 9. | Soft silty chalk | 0 | 6 |
| 8. | Soft, gray fossiliferous chalky shale with a one-half inch bentonite 10 inches below top | 7 | 6 |
| 7. | Soft gray chalky limestone | 0 | 4 |
| 6. | Gray chalky shale with bentonites 11 and 15 inches above base | 7 | 8 |
| 5. | Soft, gray chalky limestone | 0 | 5 |
| 4. | Tan chalky shale with concretionary zones two, four and six and one-half feet above the base | 8 | 7 |
| 3. | Soft chalky limestone | 0 | 6 |
| 2. | Bentonite and granular calcite | 0 | 5 |
| 1. | Light gray shale with concretions | 5 | 8 |
| | "Fencepost" limestone. Top of Greenhorn limestone. | | |

*Lower Beds of the Fairport Chalky Shale in Ness County in sec. 26, T. 19 S., R. 24 W.*

| | | Ft. | In. |
|---|---|---|---|
| | Higher beds concealed. | | |
| 23. | Tan, fossiliferous silty chalk | 0 | 3 |
| 22. | Tan, gritty, fossiliferous chalky shale | 2 | 7 |
| 21. | Fossiliferous shaly chalk | 0 | 5 |
| 20. | Fissile, tan chalky shale with a thin bentonite bed 28 inches above the base | 4 | 2 |
| 19. | Silty, fossiliferous chalk | 0 | 4 |

19. Bass, N. W.: Geologic investigations in western Kansas. Kansas Geol. Survey Bull. 11, p. 30, 1926.

| | | |
|---|---|---|
| 18. Orange-tan, fissile chalky shale with one-half inch bentonite bed at top | 9 | 6 |
| 17. Shaly fossiliferous chalk | 0 | 6 |
| 16. Orange-tan, fissile chalky shale with a two-inch zone of bentonite and pyrite concretions at the top and a thin bentonite six inches below the top | 5 | 9 |
| 15. Gray silty chalk | 0 | 5 |
| 14. Bluish-gray, fissile chalky shale | 2 | 0 |
| *W. ½ sec. 22, T. 19 S., R. 23 W.* | | |
| 13. Bentonite and granular calcite | 0 | 2 |
| 12. Tan, fossiliferous chalky shale with thin bentonite bed nine inches above the base | 6 | 1 |
| 11. Tan, fossiliferous chalk | 0 | 3 |
| 10. Light-tan, fossiliferous chalky shale with a three-inch zone of bentonite and granular calcite 52 inches above the base | 8 | 1 |
| 9. Rusty-brown fossiliferous chalk | 0 | 6 |
| 8. Light gray and tan, fissile chalky shale | 5 | 5 |
| 7. Reddish-brown fossiliferous chalk | 0 | 6 |
| 6. Fissile, gray limy shale with a one-inch bentonite bed one foot above the base | 6 | 6 |
| 5. Rusty-brown fossiliferous chalk | 0 | 4 |
| *SW. ¼ sec. 18, T. 19 S., R. 23 W.* | | |
| 4. Light-tan to gray fissile shale with concretionary zones 18, 49, 61 and 85 inches above the base | 8 | 6 |
| *Sec. 22, T. 19 S., R. 23 W.* | | |
| 3. Thin-bedded chalky limestone | 0 | 7 |
| 2. Bentonite and granular calcite | 0 | 5 |
| 1. Gray, fissile chalky shale with three zones of concretions 21, 36 and 53 inches above the base | 5 | 8 |
| "Fencepost" limestone. Top of Greenhorn limestone. | | |

In the above sections beds 1 to 9 are the same, but above these it is not possible to make accurate correlations. Beds 3, 5, and 7 can be correlated with sections in Russell and Osborne counties, but the intervals between them are greater in Ness and Hodgeman counties, There are very few exposures of beds above 5.

The Fairport chalky shale member covers large areas in Ness and Hodgeman counties. It caps the low divide between Alexander Dry creek and Walnut creek east of Ness City, and the divide between Walnut creek and Pawnee river from a few miles west of Ness City to the east line of Ness county. The band of outcrop crosses Pawnee river five miles east of the west line of Hodgeman county and follows the south side of the river east to north of Hanston and then extends up Buckner creek to within four miles of the west line of the county. From here it follows the south side of Buckner creek to a point two miles east of Jetmore, where it is overlapped by the Ogallala formation.

The member is very fossiliferous, but the fossils are poorly preserved. The most common fossils are *Inoceramus fragilis, Prionotropis woolgari, Ostrea congesta, Globigerina, Gümbelina,* and *Serpula plana*. Bed 9 in the above sections contains abundant *Prionotropis woolgari* south of Buckner creek. *Serpula plana* occurs in higher beds. The others are common throughout the section.

### Greenhorn Limestone.

The Greenhorn limestone consists of a series of thin chalky and crystalline limestones separated by thicker beds of chalky shale which contain thin bentonite beds. Limestone concretions are numerous in the shales in the upper part of the formation. Fresh exposures of limestones and shales are dull-gray in color, and the bentonites are light pearly-gray. Weathering changes the color of the limestones to tan, buff or orange-tan. The shales in the upper part weather to tan or light-gray and in the lower part to tan or orange-tan. The bentonites weather to a rusty-brown or orange color.

The Greenhorn formation has been divided into four members which, from top to bottom, are Pfeifer shale, Jetmore chalk, Hartland shale, and Lincoln limestone. The lower two members are not differentiated in this area. The top of the Greenhorn formation is placed at the top of the "Fencepost" limestone, a thin, chalky limestone which is widely quarried for fenceposts and building stone. This bed marks a faunal break with *Inoceramus labiatus* below and *Prionotropis woolgari* in the everlying Carlile shale. The lower chalk beds of the Fairport member of the Carlile shale are very similar lithologically to the limestone beds in the upper Greenhorn, so there is no distinct lithologic break between the formations. The base of the Greenhorn limestone, however, is marked by a distinct lithologic change from the noncalcareous clay shale and sandy beds of the Granerous shale to the chalky shales and thin crystalline limestone beds at the base of the Greenhorn.

Exposures of the Greenhorn limestone are terraced by the differential weathering of hard and soft beds. On very steep or very gentle slopes only the most resistant beds form terraces, but on moderate slopes almost every thin, chalky or crystalline limestone bed forms a terrace.

The thickness of the formation is approximately 125 feet in Hodgeman county. The entire section is not exposed at any one place, and so measurements were made of the beds exposed in various places and correlated to obtain the total thickness. Part of the middle of the formation is not exposed in Ness or Hodgeman counties, so was measured in Ford county, just south of the Hodgeman county line.

Practically all of the beds of the Greenhorn limestone are fossiliferous. The most abundant and characteristic fossil is *Inoceramus labiatus*. Only a few specimens of this pelecypod are found in the

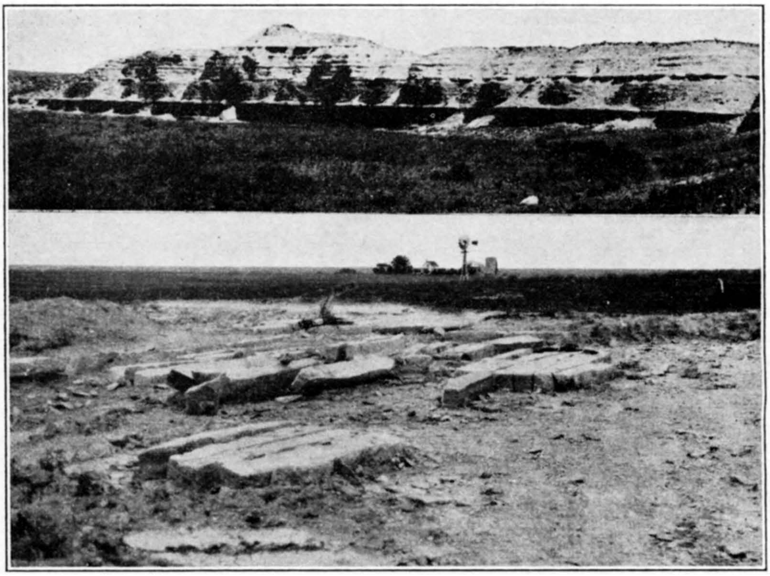

PLATE V. *Upper:* Lower Fairport chalky shale in sec. 29, T. 23 S., R. 24 W., Hodgeman county. *Lower:* "Fencepost" limestone quarry in the NE. ¼ sec. 32, T. 22 S., R. 23 W., Hodgeman county.

lower few feet of the overlying Fairport chalky shale, and none are found below the Greenhorn limestone. Numerous specimens of *Acanthoceras coloradoense* occur in the Jetmore chalk member. Other fossils occuring in the Greenhorn limestone are *Baculites gracilis*, *Mammites* sp., and a few *Inoceramus fragilis*.[20] The most abundant microscopic fossils are *Globigerina* and *Gümbelina*.

PFEIFER SHALE MEMBER. The Pfeifer shale consists primarily of chalky shale, but also contains a chalky limestone at the top ("Fencepost" limestone) and some thin chalk beds and limestone concretions. The "Fencepost" limestone has a brown seam in the

20. Identification by John B. Reeside, Jr.

middle which is not as prominent in this area as it is farther northeast. This limestone forms a terrace, and beds of concretions eight feet below form a shoulder upon weathering. The Pfeifer shale member is never as prominent topographically as the underlying Jetmore chalk member. It weathers to a tan or cream color.

*Section of Pfeifer Shale Member in sec. 19, T. 21 S., R. 25 W., on the Charles Jackson Ranch.*

| | Ft. | In. |
|---|---|---|
| 10. Tan chalky limestone ("Fencepost" limestone) | 0 | 8 |
| 9. Light-gray limy shale with three zones of concretions | 4 | 11 |
| 8. Soft chalky limestone | 0 | 4 |
| 7. Brown granular calcite ("sugar sand") | 0 | 5 |
| 6. Chalky shale | 0 | 6 |
| 5. Chalky limestone | 0 | 2 |
| 4. Bentonite | 0 | 2 |
| 3. Light tan chalky shale with five thin zones of concretions | 5 | 3 |
| 2. Soft chalky limestone | 0 | 3 |
| 1. Gray and light tan chalky shale with four zones of concretions | 6 | 7 |
| Top of Jetmore chalk member. | | |

The member is 19 feet thick in western Hodgeman county and 21 feet thick in eastern Ness county. The beds are remarkably persistent, and can be traced for several hundred miles. The zone of granular calcite (bed 7) is called "sugar sand" by core drillers, because when fresh it has the texture and color of sugar. In core holes the "Fencepost" limestone is identified by its relation to the bentonite and granular calcite bed in the lower Fairport chalky shale (bed 2) and the "sugar sand" in the upper Pfeifer shale member. This makes an excellent marker, and since most of the surface structure mapping is done on the "Fencepost" limestone, the surface and subsurface data fit together readily.

The Pfeifer shale member crops out along Alexander Dry creek in eastern Ness county and along Walnut creek from Ness City east to the east side of the county. The outcrop of the member follows both sides of Pawnee river in both counties as far west as sec. 10, T. 22 S., R. 26 W., near the west side of Hodgeman county. It crosses the divide between Pawnee river and Buckner creek north of Hanston, makes a reëntrant to the west along Dry creek and then follows the north side of Buckner creek from three miles west of Hanston to eight miles west of Jetmore, and then follows the south side of the creek to three miles southeast of Jetmore where it is overlapped by the Ogallala formation. A small inlier of Pfeifer shale occurs in sec. 30, T. 23 S., R. 25 W.

JETMORE CHALK MEMBER. The Jetmore chalk member consists of a series of chalky limestone beds three to six inches thick separated by chalky shales from one to two feet thick. The member is capped by a hard, fossiliferous, chalky limestone one foot thick. This bed is the hardest bed in the Greenhorn limestone in this area and is called "shell rock," because of the abundance of the pelecypod *Inoceramus labiatus* in it. The chalky limestones of this member weather to white or light tan and the shales to tan or orange-tan.

The Jetmore is the most resistant part of the Greenhorn limestone. Everywhere it makes a prominent terrace, and in almost all cases exposures are covered with talus. Valleys are narrow where they cut through this member, widening out above in the Pfeifer shale and below in the Hartland shale. The "shell rock" breaks into large slabs which cover the slopes below. Exposures half a mile south of Jetmore, the type locality, are typical of the member. The Jetmore chalk member is 22 feet thick south of Jetmore.

*Section of the Jetmore Chalk Member One-half Mile South of Jetmore (Type Locality).*

| | Ft. | In. |
|---|---|---|
| 25. Hard, fossiliferous chalky limestone. The upper four inches is concretionary. ("Shell rock") | 1 | 1 |
| 24. Tan, fossiliferous chalky shale with two zones of flat concretions | 3 | 0 |
| 23. Chalky limestone | 0 | 3 |
| 22. Chalky shale | 1 | 2 |
| 21. Chalky limestone | 0 | 5 |
| 20. Tan chalky shale | 1 | 0 |
| 19. Hard chalky limestone | 0 | 5 |
| 18. Tan chalky shale | 1 | 0 |
| 17. Chalky limestone | 0 | 2 |
| 16. Tan chalky shale | 1 | 1 |
| 15. Lenticular chalky limestone | 0 | 3 |
| 14. Tan chalky shale | 1 | 0 |
| 13. Hard chalky limestone | 0 | 4 |
| 12. Tan chalky shale with thin chalk bed one foot above base | 2 | 9 |
| 11. Hard chalky limestone | 0 | 5 |
| 10. Chalky shale | 1 | 0 |
| 9. Chalky limestone | 0 | 6 |
| 8. Tan chalky shale | 1 | 2 |
| 7. Soft chalky limestone | 0 | 4 |
| 6. Tan chalky shale | 1 | 3 |
| 5. Chalky limestone | 0 | 6 |
| 4. Tan chalky shale | 1 | 4 |
| 3. Chalky limestone | 0 | 5 |
| 2. Tan chalky shale | 1 | 4 |
| 1. Chalky limestone | 0 | 4 |
| | 22 | 6 |

The beds are very persistent laterally. A section measured in Russell county has identical beds, but the thickness of the member is less. The same applies to sections in Osborne county,[21] where the thickness is 17 feet, and in Cloud county,[22] where the thickness is 12 feet.

The Jetmore chalk member crops out immediately east of the Pfeifer shale member where the latter is present. The outcrop follows the Pfeifer shale in Ness county and in northern and western Hodgeman county and is present south of Buckner creek east of Hanston, but is overlapped by the Ogallala formation south of this locality in Hodgeman county, although it is present in Ford county just south of the Hodgeman county line.

HARTLAND SHALE AND LINCOLN LIMESTONE MEMBERS. The two lowest members of the Greenhorn limestone cannot be satisfactorily differentiated in Ness and Hodgeman counties. Their upper part consists of calcareous shale with thin, chalky, limestone beds. The lower part is chalky shale with thin crystalline limestone beds. The latter are characteristic of the two members, especially toward the base. Shale predominates in the lower Greenhorn. No lithologic break at which the two members may be separated occurs in the area under discussion. The upper part of the Lincoln-Hartland beds weathers to light tan or gray and the lower part to orange-tan or buff. A few bentonite beds from one to five inches thick are present.

The upper part of the Lincoln-Hartland beds is rarely exposed and forms a gentle soil-covered slope below the Jetmore chalk member. The lower 10 to 15 feet forms a terrace, or shoulder, because the thin crystalline limestones are hard and the underlying Graneros shale is very soft. Exposures of the lower part are usually covered by thin, tan-colored slabs of crystalline limestone that emit a petroliferous odor when freshly broken.

The thickness of the two members is 80 feet in sec. 5, T. 25 S., R. 24 W., northern Ford county. Here there are no limestone beds over five inches thick and the limestones in the lower part are less than three inches thick. About 20 feet below the base of the Jetmore is a five-inch chalky limestone that has been quarried for building stone.

The Hartland and Lincoln members are not exposed in Ness

21. Landes, K. K.: The geology of Mitchell and Osborne counties, Kansas. Kansas Geol. Survey Bull. 16, p. 13, 1930.

22. Wing, M. E.: The geology of Cloud and Republic counties, Kansas. Kansas Geol. Survey Bull. 15, p. 27, 1930.

county. However, the Hartland shale, at least, must be present where Pawnee river leaves the county, but is covered by alluvium. Exposures occur in Hodgeman county along Dry creek and along Buckner creek from Jetmore eastward. The best exposures of the lower part are along Sawlog creek, from Hanston to the south line of the county.

### Graneros Shale.

The Graneros formation consists of bluish-gray, noncalcareous clay shale with a few beds of sandstone and sandy shale. The lithology is variable. In some places the formation is all shale, but in others it may be half sandstone and sandy shale. The formation is marked at the top by a sharp lithologic break due to the abrupt change to the calcareous beds of the Greenhorn limestone. At the base of the formation, however, there is usually a transitional zone overlying the Dakota sandstone.

The Graneros shale usually forms a slope between the Greenhorn limestone and the Dakota sandstone. If the slope is covered by a thin layer of soil the vegetation is poor, as the shale does not produce a good soil. Exposures are best where resistant beds in the overlying Lincoln member of the Greenhorn limestone have formed a terrace. The outcrop is strewn with selenite crystals in many cases.

*Detailed Section of the Graneros Shale in sec 24, T. 22 S., R. 22 W.*

| | Ft. | In. |
|---|---|---|
| 5. Bluish-gray, fissile, slightly gritty clay shale containing a few brownish sandy streaks and thin gray sandstone lenses containing *Callista tenuis* | 13 | 8 |
| 4. Rusty, thin-bedded shaly sandstone | 1 | 2 |
| 3. Fissile gray shale containing abundant selenite and sulphur-yellow sandy streaks | 8 | 0 |
| 2. Fissile, bluish-gray gritty shale containing some selenite | 5 | 6 |
| 1. Sand and shale with abundant selenite at top. The lower part is gray and contains sandstone lenses. The upper part is a brownish sandy shale | 8 | 0 |
| | 36 | 4 |

The thickness of the Graneros is variable, ranging from 21 to 36 feet in this area. The above section shows typical lithology but is thicker than the average.

The only fossils found in the Graneros shale in this area were *Callista tenuis* and *Exogyra columbella.* More may occur here, however, as there are many other pelecypods and gastropods and ammonites found at other localities.

The variable thickness of the Graneros shale is probably due to its having been deposited on a slightly irregular surface. The underlying Dakota sandstone is mostly a nonmarine or littoral deposit, so the Graneros sea advanced over a sand-covered area which had a slightly irregular surface. This irregular surface may have been due to uneven deposition, or erosion of the top of the sandstone, or to compaction of shale within the Dakota around or over sand lenses. The sea floor was covered with muds of the Graneros formation which contained sands derived from the underlying Dakota sandstone.

### Dakota Sandstone.

The oldest formation outcropping in the area is the Dakota sandstone. Only the upper 50 or 60 feet of the formation is exposed and this occurs in the south and east part of Hodgeman county. The formation is composed of lenticular sandstone beds and variegated shales. The sandstones are usually cross-bedded. No regular or persistent beds were noted. The sandstone may be cemented with calcium carbonate or with iron oxide. The beds that are cemented by iron oxide are usually harder than the others. Such a bed occurs at the top of the formation in the northwest part of T. 24 S., R. 22 W., where it forms a terrace about a quarter of a mile wide south of Sawlog creek.

Most of the area where the Dakota formation crops out is in gentle soil-covered slopes. Only the hardest beds, which are in the minority, are exposed. Since the parts of the Dakota sandstone that are exposed in most places are the hard sandstone beds, the formation is usually thought to be almost entirely composed of sandstone. However, well logs show that the formation is only about one-fourth sandstone.

Well logs in this area show the Dakota formation to be 350 to 450 feet thick. This thickness includes beds from the base of the Graneros shale to the top of the Permian red beds and may include, in the lower part, beds of Lower Cretaceous age which correlate with the Kiowa shale and Cheyenne sandstone exposed in the southern part of Kansas.

The Dakota sandstone crops out from Rock creek, east of Jetmore, to the south line of Hodgeman county, along Sawlog creek, and along the south side of Buckner creek east of Hanston to the east line of the county. Small exposures occur on the north side of Buckner creek in the vicinity of Hanston. The valley of Pawnee river is cut into the Dakota sandstone near the east line of Hodge-

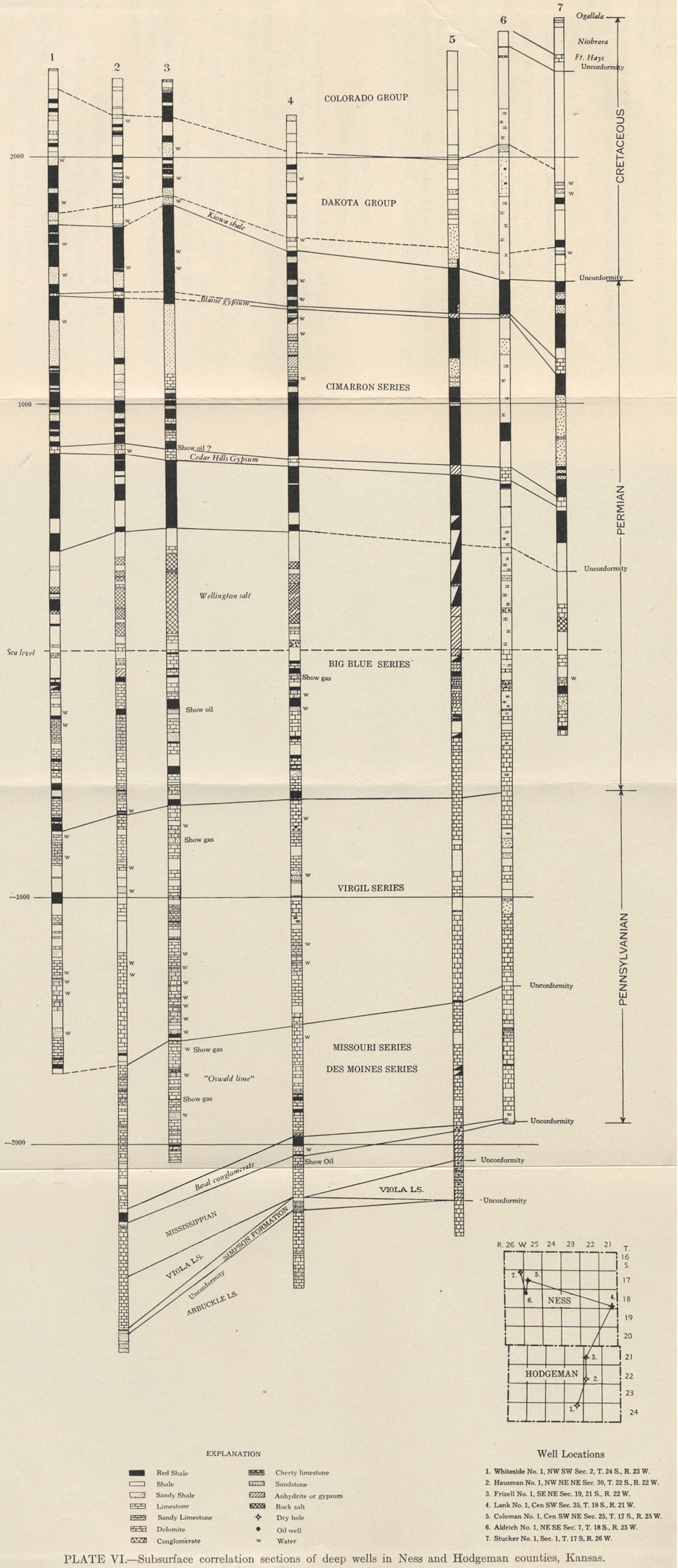


PLATE VI.—Subsurface correlation sections of deep wells in Ness and Hodgeman counties, Kansas.

man county, but there are no exposures as the alluvium covers all of the bedrock.

No fossils were found in the formation in Hodgeman county, but plant fossils and brackish water pelecypods and gastropods occur in it elsewhere.

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## STRATIGRAPHY: BURIED ROCKS.

Seven deep wells have been drilled in Ness and Hodgeman counties. They range in depth from 2,910 feet to 5,120 feet and penetrate rocks of Cambrian, Ordovician, Mississippian, Pennsylvanian, Permian, Lower and Upper Cretaceous and Tertiary ages (Plate VI). The rocks of Upper Cretaceous and Tertiary ages have already been described from surface exposures in the area. Following are descriptions of the older rocks, which are not exposed in the area, but which have been traced by means of logs and well cuttings from areas where they crop out.

### Cretaceous System.

#### Upper Cretaceous.

Dakota Formation. The Dakota formation has already been discussed, but as only the upper part is exposed in Ness and Hodgeman counties it is included here also. The Dakota consists of gray and variegated shales and gray sandstone. The sand is usually fine and angular and frequently contains pyrite concretions. The sands do not seem to form continuous beds, but some of them carry water and it is necessary to run a string of casing to prevent caving if standard tools are used. A string of 15-inch casing is usually run in the Dakota and underreamed to the top of the Permian red beds. The Dakota formation is always recognizable by its lithology, water content, and position below the calcareous beds of the Greenhorn limestone.

#### Lower Cretaceous.

Kiowa Shale. In the Phillips-Hausman well, in sec. 30, T. 22 S., R. 22 W., a bluish-gray shale containing fragments of fossils was penetrated at a depth of 515 feet. No fossils could be identified, but the lithology and position of the shale, together with the occurrence of fossils, suggests correlation with the Kiowa shale of southern Kansas. The sandstone between this shale and the top of the

Permian red beds may be equivalent to the Cheyenne sandstone, but is more probably also of Kiowa age, as are similar sandstones in McPherson county.[23] The Lower Cretaceous rocks become progressively younger to the north, due to overlap.

A definite correlation of the beds in the Phillips-Hausman well cannot be made without a detailed paleontologic study of cores. The correlation of the Kiowa shale in the other wells in Ness and Hodgeman counties is only tentative, as no samples from the other wells were available from that horizon.

## Permian System.

Next below the Cretaceous beds lie about 2,300 feet of continental and marine Permian strata. The upper part, which is chiefly of nonmarine origin, is composed of red beds, anhydrite, and gypsum and is called the Cimarron group. The lower, or Big Blue group, is composed of rock salt, anhydrite, gray and red shales, limestone and dolomite. Some of the limestones are cherty.

The regional dip of the Permian strata in this area is to the southwest. Consequently older beds underlie the unconformity at the base of the Cretaceous to the northeast. Pre-Cretaceous erosion completely removed the Cimarron group in Dickinson county, so that the Dakota sandstone rests on beds of the Big Blue group. The Cimarron group becomes considerably thicker to the south and is over 3,000 feet thick in the Anadarko Basin in the northern part of the Texas Panhandle.

### Cimarron Series.

The beds of the Cimarron series are red and maroon sandy shales containing beds of red and gray sandstone, anhydrite, and gypsum. The thickness of the group ranges from 1,150 to 1,320 feet. The anhydrite and gypsum beds are usually logged as "lime" by the drillers.

Two of the anhydrite beds are persistent over the area. The upper one, which lies 130 to 300 feet below the top of the Cimarron group, is 15 to 50 feet thick and is tentatively correlated with the Medicine Lodge gypsum. This bed is not present to the north and east, as it was removed by pre-Cretaceous erosion. The lower anhydrite bed is about 600 feet below the Medicine Lodge. It is 20 to 60 feet thick and, in most places, consists of a single bed of laminated

23. Twenhofel, W. H.: Geology and invertebrate paleontology of the Comanchean and "Dakota" formations of Kansas. Kansas Geol. Survey Bull. 9, 1924.

anhydrite, but locally it also contains gypsum and dolomite. This bed is tentatively correlated with the gypsum beds of the Cedar Hills formation. It has been traced over about fifteen counties in central-western Kansas and makes an excellent subsurface marker and casing seat.

The lower limit of the Cimarron series is the base of the red beds. In Ness and Hodgeman counties this is 150 to 350 feet below the Cedar Hills anhydrite. The irregularity of the base of the Cimarron series is probably due to an unconformity. An unconformity at this position has been noted in Sumner county, Kansas, by Baker.[24]

### Big Blue Series.

This series may be considered as a transition from the typical marine sediments of the Upper Pennsylvanian of this area to the dominantly nonmarine beds of the Cimarron series. The wells in Ness and Hodgeman counties show the Big Blue series to be 1,000 to 1,125 feet thick. The upper 125 to 200 feet is bluish-gray shale containing thin beds of anhydrite. Below this is 250 to 350 feet of rock salt containing thin beds of anhydrite and gray shale. These upper two members comprise the Wellington group.

Below the Wellington group is a series of gray anhydrite and gray and red-shale beds having a thickness of about 200 feet that is correlated with the Marion group. Next below these anhydrite beds is about 150 feet of cherty limestone, gray shale, and dolomite that is correlated with the Chase group, the cherty beds probably corresponding to the Florence flint and Wreford limestone. The remaining 300 feet of the Big Blue series is made up of limestones and gray and red shales. This lower division contains fusulinids, such as *Pseudofusulina* and *Triticites* and is correlated with the Council Grove group, including the Eskridge shale, Neva limestone, Elmdale shale and the Americus (Foraker) limestone which were formerly included in the underlying Wabaunsee group.

## Pennsylvanian System.

Strata belonging to the Pennsylvanian system in Ness and Hodgeman counties comprise a series of marine beds 1,350 to 1,650 feet thick. These strata are predominantly limestone, with interbedded gray, black and red shales. The Pennsylvanian system has recently

24. Baker, Charles Lawrence: Depositional history of the Red Beds and Saline residues of the Texas Permian. Univ. of Texas Bull. 2901, p. 19, 1929.

been reclassified by Moore.[25] This classification places the top of the Pennsylvanian lower in the stratigraphic section than it was formerly. The Pennsylvanian rocks underlying Ness and Hodgeman counties include strata correlated with the Virgil, Missouri and Des Moines series. A more detailed correlation is not attempted, as these rocks crop out 200 to 250 miles to the east, and the lithology is considerably different here than it is at the outcrop.

The Pennsylvanian in this area contains no sand except in the conglomerate that is usually present at the base of the system. Oil and gas production from the Pennsylvanian in the counties to the northeast comes from porous limestones in the Missouri and Des Moines series or in the basal conglomerate.

### Virgil Series.

This series is 800 to 1,000 feet thick and is composed of limestone and shale. The upper part is composed chiefly of limestone, the middle part chiefly of shale, and the lower 300 to 400 feet almost entirely of limestone. The limestones are gray to cream-colored, and some contain light-colored chert. Some of the beds are porous and carry water. The shales are usually light-gray, but some are nearly black. The middle shaly portion of the Virgil series is usually difficult to drill with standard tools, as the shales tend to cave and frequently must be cemented.

Microfossils, such as ostracodes, bryozoans and fusulinids, can usually be picked from the drill cuttings. Of the fusulinids *Triticites ventricosus* was found in the upper part, and *T. beedei, T. cullomensis* and *T. secalicus* in the lower part.

The base of the Virgil series is marked by an unconformity and the lower 25 feet usually contains thin beds of maroon and green shale.

### Missouri and Des Moines Series.

The lower part of the Pennsylvanian section in this area is correlated with the lower part of the Missouri series and the upper part of the Des Moines series. These rocks have a thickness of 550 to 640 feet in Ness and Hodgeman counties and are chiefly composed of limestone. The upper part is locally known as the "Oswald lime" and the lower 20 to 80 feet as the "Gorham sand," or basal conglomerate. The "Oswald lime" is composed of cream to gray-colored limestone containing some beds of gray shale. One or two

25. Moore, R. C.: Fifth and Sixth Annual Field Conferences, Kansas Geol. Society, Guidebooks, 1931, 1932.

thin, red shales occur in most places about 300 feet below the top of the formation. The limestones contain cherty and oölitic beds that in general are porous. These porous beds carry oil at Fairport, Gorham and elsewhere, but in this area only water and a small amount of gas have been found.

The basal conglomerate varies both in thickness and composition. It is usually thin in the areas which are structurally high. It characteristically consists of beds of weathered chert pebbles, derived from the underlying rocks, and of variegated shales and sandstone, but in the Continental-Aldrich well, in sec. 7, T. 18 S., R. 25 W., it was represented by only a few feet of sand.

Microfossils are found in several zones. No identifiable fossils were found in the upper 100 feet of the "Oswald lime" in this area, but *Triticities* was found at the same horizon in cuttings of wells in Russell and Rush counties. In the Continental-Aldrich well *Fusulina* was found at depths of 4,155, 4,185 and 4,230 feet, and *Chaetetes milleporaceous* was found at a depth of 4,185 feet.

The upper part of the Missouri series is not present in this area. It either was not deposited or was eroded away before the deposition of the Virgil series. This unconformity has been demonstrated by correlation of closely spaced wells, from Russell county to the central eastern part of the state, by Roy Hall.[26] The great porosity of the "Oswald lime" at some places may be due to subaerial erosion. No conglomerate has been found at this horizon, to the writer's knowledge, except in the eastern part of the state. However, if such a conglomerate was present in the Ness-Hodgeman area, it would probably be composed of limestone pebbles and would, therefore, be difficult to determine from drill-bit cuttings.

Since *Triticites* has been found in the upper 30 to 50 feet of the "Oswald lime" in Russell and Rush counties and that genus has not been reported lower than the Missouri series, the upper part of the "Oswald lime" is correlated with the lower part of the Missouri beds,

The lower part of the "Oswald lime" and the basal conglomerate are correlated with the upper part of the Des Moines series and belong to the Marmaton and, possibly, Cherokee groups.[27] The lowermost beds of the Pennsylvanian probably vary in age from place to place, as the surface upon which the early Pennsylvanian sediments were deposited was not a smooth, level one. Therefore,

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26. Kansas Geol. Soc. Meeting, Lawrence, Kan., April, 1931.

27. Roth, Robert: Regional extent of the Marmaton and Cherokee Mid-Continent Pennsylvanian. Am. Assoc. Petroleum Geologists Bull., vol. 14, p. 1258, 1930.

the basal conglomerate of different areas was not deposited at the same time and so is only lithologically equivalent.

## Pre-Pennsylvanian Rocks.

The rocks in Ness and Hodgeman counties lying below the Pennsylvanian are chiefly cherty limestones and dolomites with some sand and greenish shale. Correlation of some of these strata is rather difficult because of their lithologic similarities.

These rocks are important oil and gas producers. Some of the members of the Simpson formation are the most prolific oil and gas producers in the Midcontinent area, and any of the limestones or dolomites lying immediately below the unconformity at the base of the Pennsylvanian are potential oil and gas reservoirs.

Four wells in this area have penetrated rocks older than Pennsylvanian age. These are the Continental-Aldrich and Gypsy-Coleman wells on the Beeler anticline, and the Phillips-Hausman and Barnsdall-Lank wells on the Bazine anticline.

### Mississippian System.

The Mississippian rocks underlying Ness and Hodgeman counties are gray to white, cherty and dolomitic limestones which contain thin beds of greenish-gray shale. The Phillips-Hausman well, in sec. 30, T. 22 S., R. 22 W., penetrated 270 feet of cherty dolomitic limestone, between depths of 4,620 and 4,890 feet, which is probably of Mississippian age. Mississippian cherty and dolomitic limestone is also present in the Gypsy-Coleman well, sec. 25, T. 17 S., R. 25 W.,[28] between depths of 4,384 and 4,493 feet. In the Barnsdall-Lank well, in sec. 35, T. 18 S., R. 21 W., Mississippian strata are present between depths of 4,320 and 4,390 feet.[29] The producing horizon of the Continental-Aldrich well, in sec. 7, T. 18 S., R. 25 W., is probably in the porous, weathered surface of the same limestone.

To the south and east the Mississippian strata are of considerable thickness. In Clark county, Kansas, McClellan[30] has reported 1,600 feet of Mississippian strata. These strata are entirely lacking to the northeast on the Barton Arch, where they were probably removed by pre-Pennsylvanian erosion.

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28. Ryniker, Charles: Letter of April 24, 1931.

29. McClellan, Hugh: Areal distribution of pre-Mississippian rocks in Kansas and Oklahoma. Oil and Gas Journal, October 23, map, p. 33, 1930.

30. McClellan, Hugh: Op. cit., p. 108.

### ORDOVICIAN SYSTEM.

URSCHEL (VIOLA) LIMESTONE. In the Phillips-Hausman and Gypsy-Coleman wells a gray, cherty, dolomitic limestone was penetrated below the Mississippian. This limestone is correlated with the Urschel (Viola) limestone. The Urschel limestone is not present in the Barnsdall-Lank well, where it was probably removed by pre-Mississippian erosion.[31]

SIMPSON GROUP. The Simpson group is composed of green shale and white quartz sand and, where present, is 20 to 50 feet thick. In the Barnsdall-Lank well it was found immediately below the Mississippian limestone, and in the Phillips-Hausman well it was found below the Urschel limestone. It carried only water in those two places. It was not present in the Gypsy-Coleman well. The Simpson beds lie between two unconformities and are consequently quite irregular.

### CAMBRO-ORDOVICIAN.

ARBUCKLE LIMESTONE ("SILICEOUS LIME"). The Arbuckle limestone is composed of sandy cherty dolomite. It lies unconformably below later rocks and may be overlapped by any of them. It has not been drilled through in any of the wells in this area. The Phillips-Hausman well entered it 75 feet and the Gypsy-Coleman well 140 feet. It is probably over 300 feet thick over most of the area of Ness and Hodgeman counties but may be thin or entirely missing in places, as it is in the Fairport and Gorham oil fields and the Bison gas field.

## GEOLOGIC STRUCTURE.

### Structure of Surface Rocks.

The key beds most commonly used for mapping surface structure in this area are the "Fencepost" limestone (top of the Greenhorn limestone) and the base of the Fort Hays limestone. Both of these horizons are easy to identify on the surface and in well cores. In drilling for the base of the Fort Hays limestone it is usually not necessary to take a core, due to the pronounced lithologic change at the contact, but it is necessary to take cores in drilling for the top of the Greenhorn limestone, as there is no lithologic break at that horizon, and identification depends upon the relationships and in-

31. McClellan, Hugh: Op. cit., p. 33.

tervals between the "Fencepost limestone" and thin bentonite and granular calcite beds.

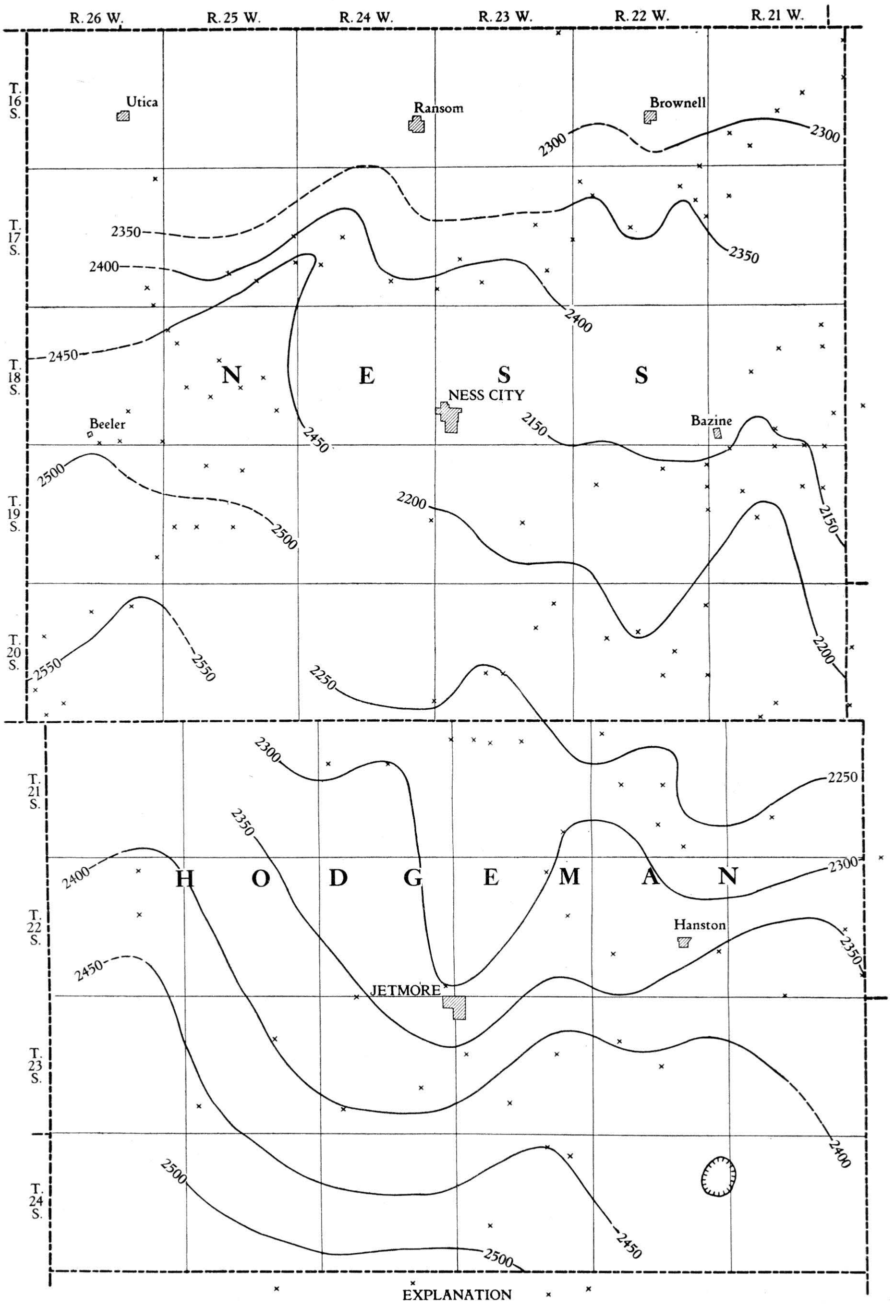
Mapping exposed beds of the Greenhorn limestone necessitates a thorough knowledge of the local stratigraphy, as exposures are frequently poor, and often only one or two thin beds are exposed. Since the intervals between the beds are very constant, it is possible to take elevations on many of the beds in the Greenhorn and lower Fairport and compute the elevations to the top of the Greenhorn.

The bentonite beds in the Smoky Hill chalk member are used for structure mapping and are corrected to the base of the Niobrara formation. In the middle and upper parts of the member it would probably be more convenient to employ a higher key bed, but since the surface mapping must be supplemented by core-drill information, it is necessary to map on the base of the formation, as there is no easily identifiable horizon above this.

The reconnaissance structure map (Plate VII) shows the attitude of the Upper Cretaceous rocks in Ness and Hodgeman counties. The contours in Hodgeman county and in the southeast part of Ness county are on the top of the Greenhorn limestone, and those in north and west Ness county are on the base of the Niobrara formation. The elevations upon which the contours are based were determined from the United States Geological Survey topographic maps and by aneroid barometer. The topographic sheets cover only the eastern part of the two counties.

The regional dip of the Cretaceous strata in this general area is about 10 feet per mile slightly east of north. This structural slope has two northeastward-trending anticlines superimposed upon it in Ness and Hodgeman counties. One of these, here named the Beeler anticline, follows the west side of the two counties, and the other, here named the Bazine anticline, is in the eastern part of the two counties. The prominence of these anticlines is increased by the presence of a deep syncline in the vicinity of Jetmore. The anticlines are not high above the regional slope, but the syncline is considerably below.

Beeler Anticline. This anticline is the most prominent structural feature in the area. From available data the structure apparently trends due north along the west side of Hodgeman county and into Ness county as far as Beeler. Here it bends to the northeast and trends toward Ransom. The only place where data on the west flank are available is northeast of Beeler, in the south part of T. 17




EXPLANATION

× Outcrop of Cretaceous rocks from which elevations were taken    Contour interval 50 feet

Datum in northwestern Ness County is Carlile-Niobrara contact    Datum in rest of area is Greenhorn-Carlile contact

PLATE VII.—Structural contour map of Ness and Hodgeman counties.

S., R. 25 W., and in the southeast part of T. 17 S., R. 26 W., where there is a strong northwest dip.

BAZINE ANTICLINE. This anticline enters Hodgeman county from Ford county a little east of the Jetmore meridian and trends slightly east of north, passing between Jetmore and Hanston. North of here it makes a slight eastward swing and then trends nearly due north, passing just east of Bazine. The most prominent part of this structure is southeast of Bazine, in the central part of T. 19 S., R. 21 W., and in the west part of T. 20 S., R. 21 W.

OTHER STRUCTURES. The two anticlines described are the most outstanding in the area, but there are several anticlinal noses with some prominence. Two of these occur in the northwest part of Ness county, between Ness City and Brownell. Another occurs in T. 21 S., R. 24 W. and T. 20 S., R. 23 W.

RELATION TO OTHER STRUCTURES. The trend of these anticlines parallels the general anticlinal trend of the Upper Cretaceous rocks of western Kansas. The Beeler anticline lies about half way between the Cambridge anticline and the Stockton anticline.[32] The Bazine anticline is apparently a southward extension of the Stockton anticline.

## ECONOMIC GEOLOGY.

### Oil and Gas.

Ness county has the westernmost oil well in the state. This is the Continental Oil Company well on the Aldrich farm, in the NE¼ SE¼, sec. 7, T. 18 S., R. 25 W. The well is shut down at present but had an initial production of 210 barrels. It had a settled production test of 170 barrels of 37° Bé. oil December 15, 1929.[33] The well is producing from a depth of 4,430 feet in dolomitic limestone of Mississippian (?) age just below the unconformity at the base of the Pennsylvanian series. Although the well is less than four miles from the Scott City branch of the Atchison, Topeka and Santa Fe railroad, it has never been put on commercial production, as there has been a general curtailment of oil production since the well was drilled in. Some oil from the well has been sold locally as fuel for other drilling operations in Trego and Ness counties. The well is located on a prominent structural nose on the Beeler anticline.

32. Bass, N. W.: Geologic investigations in western Kansas. Kansas Geol. Survey Bull. 11, p. 88, 1926.

33. Oil and Gas Journal, Dec. 15, 1929.

Judging from the size of the structure it is possible that a large field may be developed here.

The Gypsy Oil Company drilled a well on the Coleman farm northeast of the Aldrich well, in the center of the SW¼ NE¼, sec. 25, T. 17 S., R. 25 W. It had a show of oil at a depth of 4,375 feet, which is approximately at the same horizon as the production in the Aldrich well. The well was drilled deeper to test lower beds, but did not encounter any more oil and was abandoned. As it is located at the northeast end of the structural nose, it apparently was beyond the limit of commercial production on this part of the structure. No wells have been drilled on the structure south of the Aldrich well.

The Plateau Oil Corporation drilled a well on the Stucker farm, in sec. 27, T. 15 S., R. 26 W., to a depth of 3,820 feet. The bottom of the well is in marine Permian strata. The location of the well is lower, structurally, than the Aldrich or Coleman wells, and no shows of oil or gas were reported.

The Barnsdall Oil Company drilled a well southeast of Bazine on the Lank farm, in the center of the SW¼, sec. 35, T. 18 S., R. 21 W. This well had a 20-barrel show of oil at a depth of 4,182 feet in the basal conglomerate of the Pennsylvanian series. Considerable water accompanied the oil. The well was deepened to 4,225 feet, where another good showing of oil was encountered, but this, also, occurred with water, and the well was not deemed to be of commercial value so was drilled deeper and finally abandoned at a depth of 4,755 feet. This well was drilled on the northeast flank of a prominent structural nose on the Bazine anticline. It was not located in the most favorable place, structurally, and another test should be put down to the southwest, as shows of oil in the Lank well possibly indicate an oil pool higher on the anticline.

Three wells have been drilled on the Bazine anticline in Hodgeman county. Only one of these, the Frizell well in sec. 19, T. 21 S., R. 22 W. (the northernmost of the three wells), obtained any shows, and they were small shows of gas. The Frizell well was drilled to a depth of 4,391 feet and had shows of gas at depths of 3,080 and 3,930 feet. The well was stopped in the lower part of the Pennsylvanian series, not reaching the horizon of the oil shows in the Lank well. The Phillips Petroleum Company drilled a well on the Hausman farm, in sec. 30, T. 22 S., R. 23 W., to a depth of 5,120 feet. The well went through the Pennsylvanian series and was abandoned in rocks of Cambrian or Ordovician age. No shows of oil or gas were reported. The Shouse Oil Company drilled a well on the Whiteside farm, in sec. 2, T. 24 S., R. 23 W., to a depth of 4,080 feet. The well was abandoned above the "Oswald lime," so did not test the producing horizons of other areas of western Kansas.

To date there have been no encouraging results of drilling in Hodgeman county, but only one well, the Phillips-Hausman, has made a thorough test of the buried rocks. Neither of the other wells were drilled deep enough to test the unconformity at the base of the Pennsylvanian series or the beds of Ordovician and Cambrian age which are the most prolific oil-producing rocks in the Mid-Continent oil province. It is hoped that more prospects will be drilled in Hodgeman county. Three dry holes do not condemn an entire county.

## Ground Water.

Ground water is obtained from the alluvium of the larger streams, from the Ogallala formation, and from the Dakota sandstone in Ness and Hodgeman counties. The Codell sandstone bed at the top of the Blue Hill shale produces water in other areas but is not an important aquifer in this area. Some of the water used in Ness and Hodgeman counties comes from springs, but most of it comes from wells.

Springs. The only springs of importance occur at the base of the Ogallala formation. Water falling on the Ogallala surface (high plains) in these counties and areas farther west percolates through the porous beds of the formation until it reaches the eastward sloping, impervious surface of the underlying Cretaceous strata. Then it flows slowly eastward and issues forth in springs at the eastern margin of the Ogallala formation. The heads of all the perennial streams in the area are at the base of this formation. The valleys continue on up onto the formation but carry water only at times of heavy precipitation. In many of the valleys the base of the Ogallala is marked by a small grove of trees. Many of the farm houses are located here.

Small springs and seeps occur at the base of the Fort Hays limestone, the water coming from the Codell sandstone bed. The water probably enters the bed near the outcrop through joints in the Fort Hays limestone. Springs in the Dakota sandstone are unimportant in this area, as the beds in the upper part of the formation are not persistent enough to be good aquifers.

Wells. Practically all of the water used for domestic purposes in Ness and Hodgeman counties, and most of the stock water, is derived from wells. The depth to water and the character of the water-producing horizon varies with the location.

In all of the larger valleys water is obtained in the alluvium at depths up to 50 feet. The amount of water available depends upon the thickness of the alluvium and the character of the rocks and size of the drainage basin. The municipal water supply for Jetmore comes from the stream alluvium of Buckner creek ("underflow" water). The wells are drilled adjacent to the creek and are about 50 feet deep. The water supplies of Hanston, Beeler and Bazine are from individual wells, in the stream alluvium, which are pumped by windmills.

The Ogallala is drilled for water more extensively than any other formation in the two counties. On all of the Ogallala-capped uplands "sheet water" is obtained at depths not exceeding 100 feet. This water comes from the base of the formation where it overlies impervious Cretaceous strata, as it does in all the area except, possibly, in the southeast corner of Hodgeman county. Only rarely do wells in the Ogallala fail to produce water, except near the margin of the formation where the water has been drained by streams cutting back into the upland. The Ogallala formation fails to produce water in a few places. This is probably due to low porosity of the beds locally. In such cases it is necessary to drill to the Dakota sandstone, which may be found at depths ranging up to 800 feet.

Ransom has a municipal water supply from the Ogallala formation from wells 100 feet deep. The water comes from a gravel bed resting on the Smoky Hill chalk. Arnold and Brownell both obtain water from this horizon, at depths of 80 and 30 feet, but the towns do not have a municipal supply, and the water comes from individual wells operated by windmills.

Utica has a municipal water supply from an 800 foot well in the Dakota sandstone. Some water is also obtained here at a depth of 80 feet from the Ogallala. Ness City recently put in a municipal water supply, obtaining water from the Dakota sandstone. The water comes from two wells 444 and 455 feet deep. The producing stratum lies about 300 feet below the top of the formation. Two higher water horizons were found in the Dakota, but these did not produce enough water to supply the town.

There are some flowing wells from the Dakota sandstone in secs. 13, 14, 23 and 24, T. 24 S., R. 23 W. The wells start near the top of the Dakota and obtain the artesian water at a depth of about 200 feet. These are the only flowing wells in the area. Wells obtaining water in the Dakota sandstone are common in southeastern Ness county and northeastern Hodgeman county on the uplands covered by the Carlile and Greenhorn formations (which do not carry water). Unless water is available from small alluvial deposits it is necessary to drill to the Dakota sandstone.

CHARACTER OF THE WATER. The table below shows the salt content and hardness of typical waters of Ness and Hodgeman counties. The acid and base radicals are given in parts per million present in the water. The analyses were obtained from the State Board of Health, Lawrence, Kan.

| | Ca. | Mg. | Na. | $CO_3$. | $HCO_3$. | $SO_4$. | Cl. | F. | $NO_3$. | Hardness |
|---|---|---|---|---|---|---|---|---|---|---|
| Utica | 10.4 | 3.4 | 370. | 19.2 | 326. | 160. | 266. | .... | 4.4 | 40. |
| Ransom | 60. | 9.6 | 38. | 0. | 261. | 28. | 17. | .... | 6.7 | 189. |
| Jetmore | 119.2 | 18.3 | 23. | 0. | 327. | 100. | 34. | 0.5 | 2. | 372. |
| Ness City | 100.8 | 17.1 | 28. | 0. | 313. | 86. | 25.5 | 1.0 | 0. | 322. |

The Utica water comes from the Dakota formation and that at Ransom from the Ogallala formation. The Jetmore and Ness City supplies are derived from the stream alluvium. The above analyses indicate that there is a marked chemical distinction between the waters from the different formations. The alluvial and Ogallala waters are quite hard while the Dakota water is relatively soft.

The hardness of the former is mostly due to the large amount of calcium present. The calcium is derived from the calcium carbonate present in the Ogallala formation as a cementing material and from the calcium carbonate of the chalky beds of the Cretaceous strata. The softness of the water from the Dakota sandstone is probably due to the absence of this compound in the sands from which the water is derived.

## Sand and Gravel.

Many deposits of sand and gravel occur in Ness and Hodgeman counties. The best deposits are of Pleistocene (?) age (discussed under Quaternary), but the most extensively utilized deposits are of Recent age and occur in the stream alluvium. The chief use of sand and gravel is in road surfacing. Smaller amounts are used in concrete aggregate for paving, buildings, road culverts and bridges.

Most of the sand and gravel used in Ness county is obtained from the stream bed of the north fork of Walnut creek, west of Ness City. Pits in secs. 21 and 22, T. 18 S., R. 24 W. have yielded considerable quantities. Pits a few miles north of Ness City, in secs. 19 and 29, T. 17 S., R. 23 W., have produced some sand and gravel. A quantity of sand has been taken from the stream bed of Pawnee river south of Ness City. This has been used for buildings and road culverts.

Most of the sand and gravel used in Hodgeman county is taken from the alluvium of Buckner creek. The following pit locations were tested and passed on by the State Highway Department for road metal. Each of these deposits was estimated to contain several thousand cubic yards of sand and gravel.

Locations of sand and gravel pits:

NW cor, sec. 17, T. 23 S., R. 26 W.
Cen. N½ sec. 11, T. 22 S., R. 26 W.
Cen. E side sec. 30, T. 22 S., R. 26 W.
NE¼ sec. 10, T. 23 S., R. 24 W.
SW¼ sec. 3, T. 23 S., R. 23 W.
SE sec. 31, T. 22 S., R. 23 W.

The Pleistocene deposits along the south side of Pawnee river are the cleanest and largest in the area, but they are too far from places of use to have been extensively exploited.

## Building Stone.

The most commonly used stone in this area is the "Fencepost" limestone. It is used chiefly for fence posts, but has been used, also, for buildings of all kinds and for other structural work, such as road culverts and bridges. The uniform thickness of this limestone bed and the softness when quarried makes it an excellent building stone. The thickness varies from seven to nine inches. It case-hardens on exposure. As there is practically no timber in Ness or Hodgeman counties, locally obtained fence posts have to be of stone. But the stone posts now cost about one dollar each, so most new posts in the area are of wood and have been shipped in. Only two active quarries were noted in Ness and Hodgeman counties.

Stone fence posts are used in over 3,000 miles of fence in Ness and Hodgeman counties. A very small part of these are posts taken from the "shell rock" at the top of the Jetmore chalk. The value of stone fence posts in use in the two counties is estimated to be about three-quarters of a million dollars. The value of stone used in building would probably bring the total up to over a million dollars. In the areas where the "Fencepost" limestone crops out are many residences and farm building made of the stone. It is sometimes hauled ten miles or more from the outcrop. Many residences and business buildings in Bazine, Hanston, Jetmore and Ness City are built of the same rock. Some buildings are also built of stone taken from the chalky limestones in the lower Fairport chalky shale.

Many structures have been built of Fort Hays limestone and some Smoky Hill chalk in Ransom, Brownell, Arnold and Utica. Also a large percentage of the older buildings on farms near outcrops of these limestones are similarly constructed. The chalk is usually sawed into blocks.

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