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**STATE GEOLOGICAL SURVEY *of* KANSAS**

**RAYMOND C. MOORE, State Geologist**
**KENNETH K. LANDES, Assistant State Geologist**

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## BULLETIN 16

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# THE GEOLOGY OF MITCHELL AND OSBORNE COUNTIES, KANSAS


**By KENNETH K. LANDES**

**With a Chapter on "ROCKS NOT EXPOSED," by**
**J. W. OCKERMAN**


*Printed by authority of the State of Kansas*

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## STATE GEOLOGICAL SURVEY

RAYMOND C. MOORE, Ph. D.,
State Geologist.

KENNETH K. LANDES, Ph. D.,
Assistant State Geologist.

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# The Geology of Mitchell and Osborne Counties, Kansas.

## INTRODUCTION.

Purpose of the Report. The investigation of the geology of Mitchell and Osborne counties had three primary objectives. The first was the reconnaissance mapping of the outcropping geological formations. The greater part of the time in which the writer was in the field was spent on this work, and the resulting map not only illustrates the report but also constitutes a part of the geological map of Kansas now in preparation by the State Geological Survey. The existence of a detailed geological map, whether of a county or of a state, is of great value. Many of our mineral products, such as coal, salt, gypsum and even oil and gas, are confined in their occurrence to certain series of geological formations, and on a geological map the location of the outcrops of these rocks is indicated. Consequently intelligent prospecting for new mineral deposits is dependent upon a detailed geological map. Complete state maps have already been made of Colorado, Oklahoma, Missouri, and many other states.

A second objective was to add to the scientific knowledge of the rock strata of this region, both those that crop out and those that lie beneath the surface. Many sections of exposed rock beds were measured and described, indicating in some detail the nature of the geologic formations in Mitchell and Osborne counties. In addition, the formations which do not outcrop at the surface were studied by J. W. Ockerman by means of well cuttings, and his descriptions and discussion are included in this report. Stratigraphic studies are necessary both in the preparation of the geological maps and in the search for mineral deposits located beneath the surface. By means of a geological map and stratigraphic data supplied by the geological survey the prospector can determine the depth at any given locality to possible oil, coal, or other mineral-bearing formations.

The third purpose of this report is to aid in the exploitation of the natural resources of Mitchell and Osborne counties. Practical assistance is given to those who wish to find new deposits of oil and gas, road materials, underground water or other mineral products in these counties. The farmers and landowners in the area covered by the geologic map are benefited because soil is essentially dependent on the nature of the rock formations from which it is derived. A first step in scientific agriculture is an accurate geological and soil survey which supplies information on the characteristics and a guide to the most advantageous use of the soils.

PREVIOUS GEOLOGICAL WORK. No detailed reports dealing specifically with the geology of Mitchell and Osborne counties have been published. However, this area has been visited by several geologists and some data collected by them have appeared in print. In 1890 Robert Hay[1] made a section across the salt marsh in southeastern Mitchell county and discussed the origin of the salt in its relation to local stratigraphy. In 1897 the Kansas University Geological Survey published its "Report on the Stratigraphy and General Geology of Western Kansas."[2] In this volume there appears a general discussion of the physiography of western Kansas by Erasmus Haworth and the first detailed description of the Kansas Cretaceous, written by W. N. Logan. In addition the latter author describes geological sections made by him from Clifton, in Cloud county, to the Colorado line, across both Mitchell and Osborne counties, and another section from Beloit to Tipton, in Mitchell county. There also appeared in this report a reconnaissance geological map of the state which shows in an approximate manner the distribution of the Niobrara, Benton, and Dakota outcrops in Osborne and Mitchell counties. Prof. E. H. S. Bailey, in his report on the Mineral Waters of Kansas,[3] includes a description of Great Spirit or Waconda Springs in Mitchell county, and analyses of the water. N. H. Darton's "Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains"[4] (1905) includes a discussion of the stratigraphy of western Kansas and of the deep-water wells in the various counties.

Between 1905 and 1925 no publications were issued describing results of field investigation in this part of Kansas. In 1925 a detailed report by Rubey and Bass[5] on the "Geology of Russell County" presented observations that are applicable to Osborne county, adjoining on the north, and to Mitchell county, farther east. The following year N. W. Bass described the geology of Ellis

1. Notes on Some Kansas Salt Marshes: Kan. Acad. of Sci. Trans., vol. 12, pp. 97-100; 1890.
2. Volume II.
3. Kansas Univ. Geol. Survey, vol. 7, pp. 197-206; 1902.
4. U. S. Geol. Survey, Prof. Paper 32.
5. Kan. Geol. Survey, Bull. 10, 104 pp.; 1925.

county,[6] which lies west of Russell county. In another part of the report by Bass[7] the regional structure of the top of the Dakota sandstone of western Kansas is described, with a map extending in northern Kansas as far east as Cloud county. Simultaneously with the field work in preparation for the present report, a party in charge of Monta E. Wing was engaged in mapping the geology of Cloud and Republic counties, which lie to the east and northeast of Mitchell county.[8]

FIELD WORK AND ACKNOWLEDGMENTS. The field work on which this report is based was carried on during the summer of 1929. Mitchell county was mapped by the writer, assisted by Lyndon Morrow, while the geological work in Osborne county was done by R. G. Moss. The writer is indebted to these men both for their able assistance in the field and for their helpful coöperation in the preparation of the manuscript. Field conferences with Monta E. Wing, engaged in mapping Cloud county to the east, and with H. D. Miser and J. B. Reeside, Jr., of the United States Geological Survey, were of valuable assistance in securing a better understanding of the local stratigraphy. The writer also wishes to acknowledge aid given him by local citizens, especially J. P. Boesche, William Drinkern, and Dr. W. H. Cook, all of Beloit.

The geological mapping was of a reconnaissance nature and the formation boundaries were sketched on quadrangle topographic sheets of the U. S. Geological Survey. Many vertical sections of the formations were measured, chiefly by hand level but in some instances by stadia. Most of the rock descriptions were made in the field, although some specimens were collected and subsequently examined in the laboratories of the State Geological Survey. Studies of the well logs and well cuttings were made by J. W. Ockerman, of the Survey staff, and the results obtained constitute a part of this report.

## GEOGRAPHY.

LOCATION AND CULTURE. Mitchell and Osborne counties are located in northern Kansas in the second row of counties south of the Nebraska line and slightly west of center (Fig. 1). The former county contains five townships east and west and four north and south, with a total area of nearly 459,000 acres, while Osborne county is likewise five townships wide but has an added row of

6. Kan. Geol. Survey Bull. 11, pp. 11-52; 1926.
7. Ibid., pp. 84-89.
8. Report in press.

townships on its southern border, with a total area of approximately 573,000 acres. There are three cities in these two counties with a population greater than 1,000: Beloit, the county seat of Mitchell county, with a population slightly over 3,000; Osborne, the county seat of Osborne county, with a population a little less than 2,000; and Downs, in northeastern Osborne county, with a few hundred less than Osborne. There are a number of smaller towns, mainly in the Solomon river valley.

Three railroads serve this area. The Missouri Pacific enters Mitchell county near the northeast corner and follows the valley

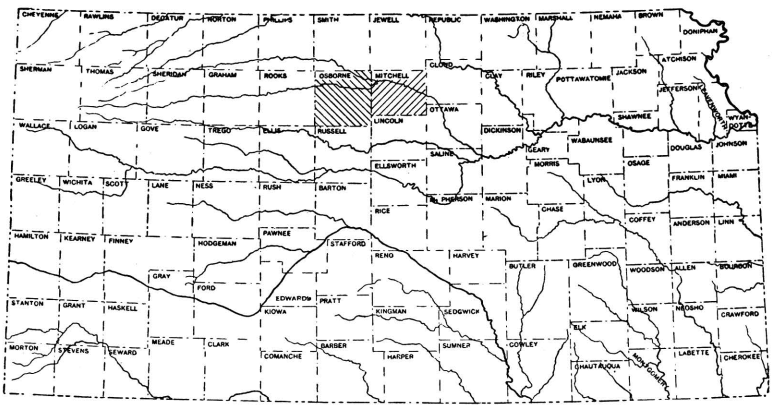


FIG. 1.—Index map of Kansas showing location of Osborne and Mitchell counties.

of the Solomon river from Beloit through Glen Elder and Cawker to Downs, where it divides, one branch going up the north fork of the Solomon through Portis, at the north boundary of Osborne county, to its terminus at Lenora, while the other branch cuts across to the south fork of the Solomon at Osborne and continues up that fork through Bloomington and Alton to its terminus at Stockton in Rooks county. A branch of the Union Pacific extends up the Solomon river valley from the main line at Solomon to Beloit. A branch of the Santa Fe extends from Salina in a northwesterly direction through Hunter and Tipton in southwestern Mitchell county and through east-central Osborne county to its terminus at Osborne.

U. S. Highway 40 North, in large part either paved or graveled, crosses the two counties in a general east-west direction following the course of Solomon river to Downs on the north fork and from there going west and south to Osborne and then out of the county along the valley of the south fork of the Solomon. State highways extend north and south through both county seats and, in addition, a state-maintained road connects Beloit with Concordia. Still another state highway crosses the southwestern corner of Osborne county, passing through the town of Natoma. Mitchell county maintains 167 miles of county roads and Osborne 78 miles. Section-line roads are present except where the topography is too rough.

TOPOGRAPHY. Almost all of Mitchell and Osborne counties are drained by Solomon river and its tributaries. Salt and Rock creeks, which drain southern Mitchell county, enter Solomon river beyond the east border of the county. The southwestern corner of Mitchell county and the southern row of townships in Osborne county are drained by tributaries of Saline river, which flows eastward across Russell and Lincoln counties and eventually joins Smoky Hill river in Saline county a few miles west of the point where Solomon river also joins the Smoky Hill. Solomon river forks near the Mitchell-Osborne county line, the south branch coming from the west across Osborne county and the north fork flowing southeastward across the northeast corner of the same county. The valley of the Solomon has had a decided effect upon the culture of the two counties because of the fertility of its flood plain, its availability for water power, and the easy route it affords for railroads and highways. For these reasons the large centers of population are all located adjacent to the river. With the exception of the two major forks the tributaries of the Solomon are small; they have narrow valleys, and in few cases drain more than two townships.

Elevations range between 1,300 feet in the Salt creek and Solomon valleys in the eastern part of the area to 2,100 feet on the top of divides in southwestern Osborne county. The Blue Hills in southwestern Mitchell county and similar hills in Osborne county stand considerably higher than the adjacent stream valleys. Relief ranging from 200 to 300 feet in a mile may be noted.

A succession of slopes and benches lies above river level. The lowest physiographic features are the flood plains, which were formed by the deposition of stream-carried material. The flood plain of Solomon river ranges in width from one to four miles and extends across Mitchell county and up both forks. The flood plains of the tributaries are very much narrower. Terraces, which are remnants of older and higher flood plains, may be observed at a number of places along the Solomon and in a few localities are very prominent. They were noted in Mitchell county between Beloit and

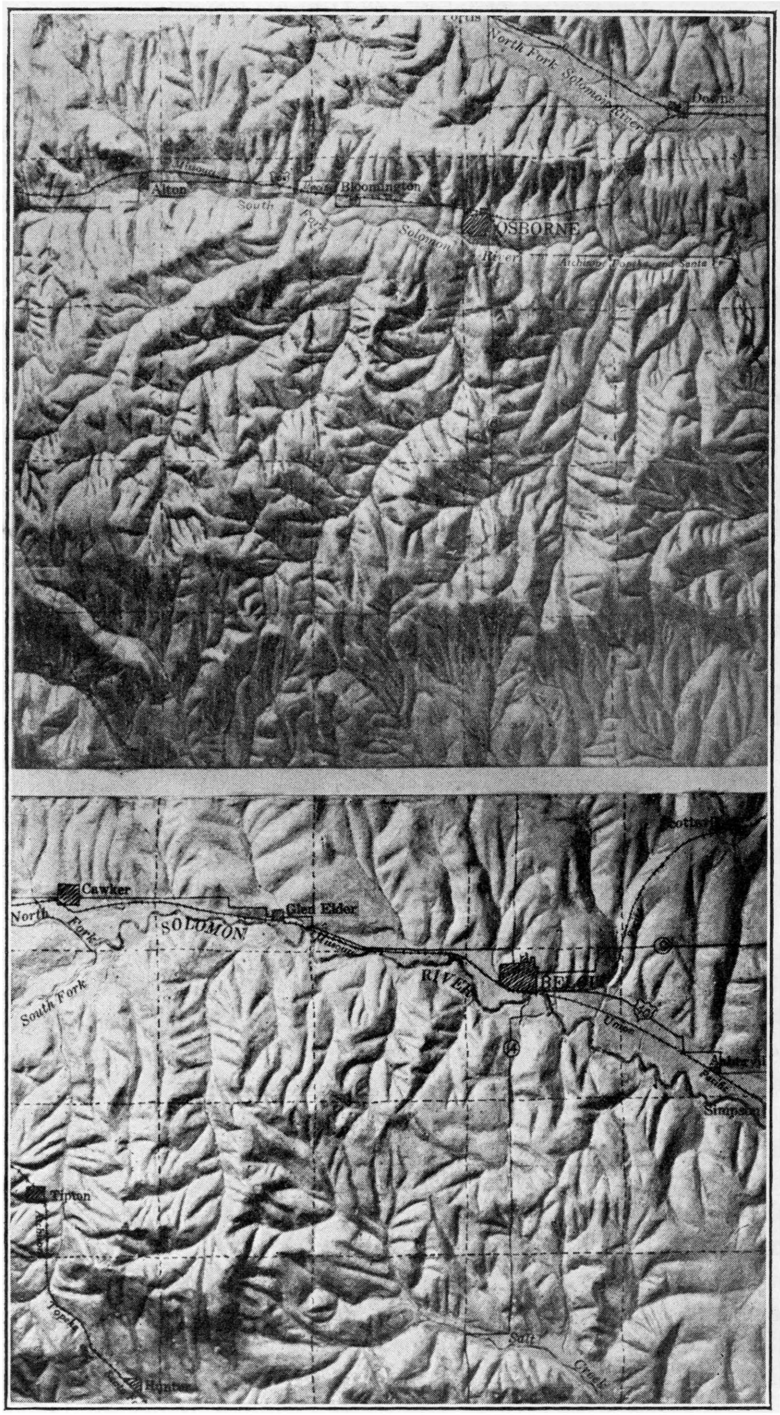


PLATE I.—Upper: Relief model of Osborne county.
Lower: Relief model of Mitchell county.

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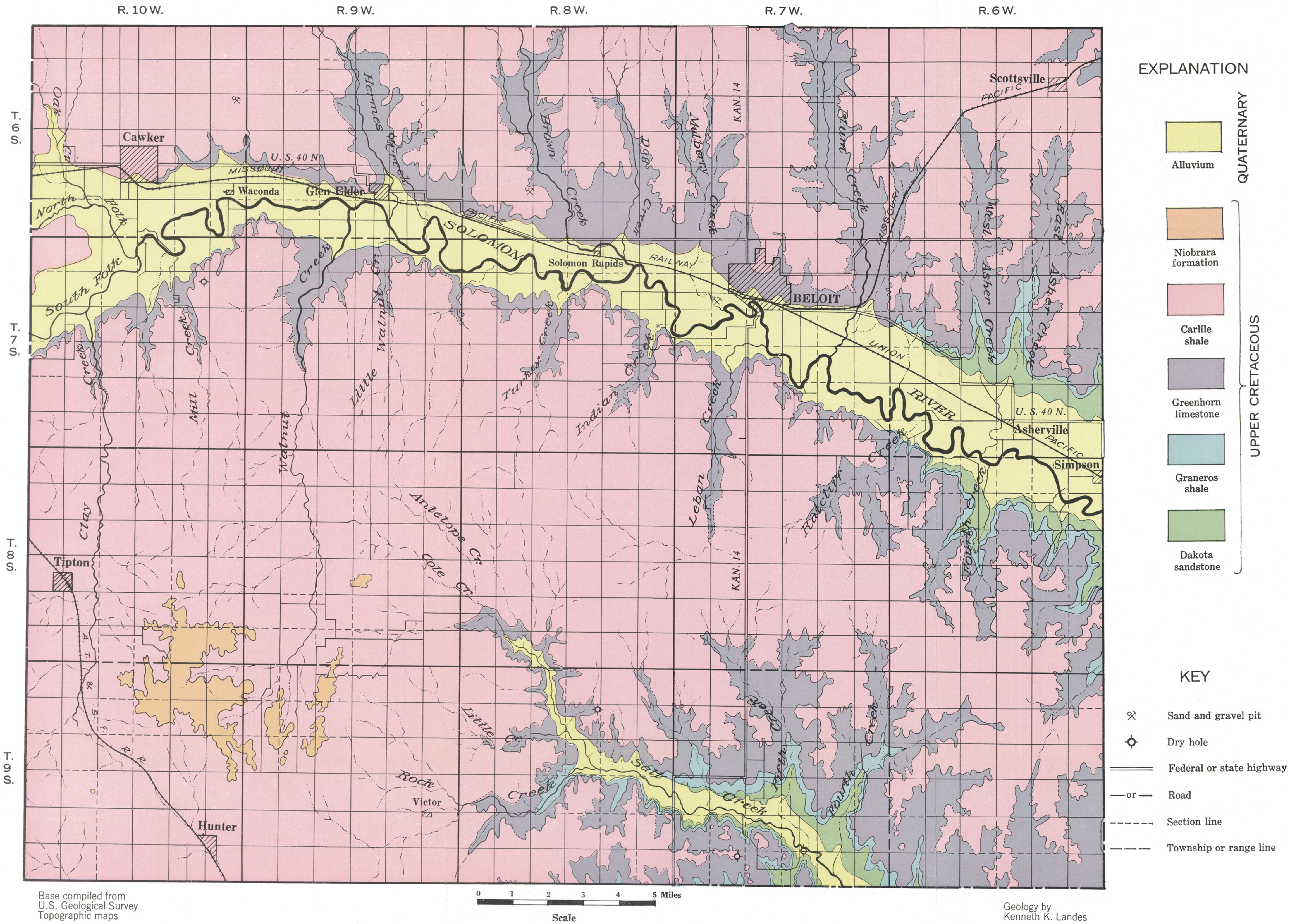
# GEOLOGIC MAP OF MITCHELL COUNTY, KANSAS

STATE GEOLOGICAL SURVEY
RAYMOND C. MOORE, STATE GEOLOGIST
K. K. LANDES, ASST. STATE GEOLOGIST




BULLETIN 16, PLATE II

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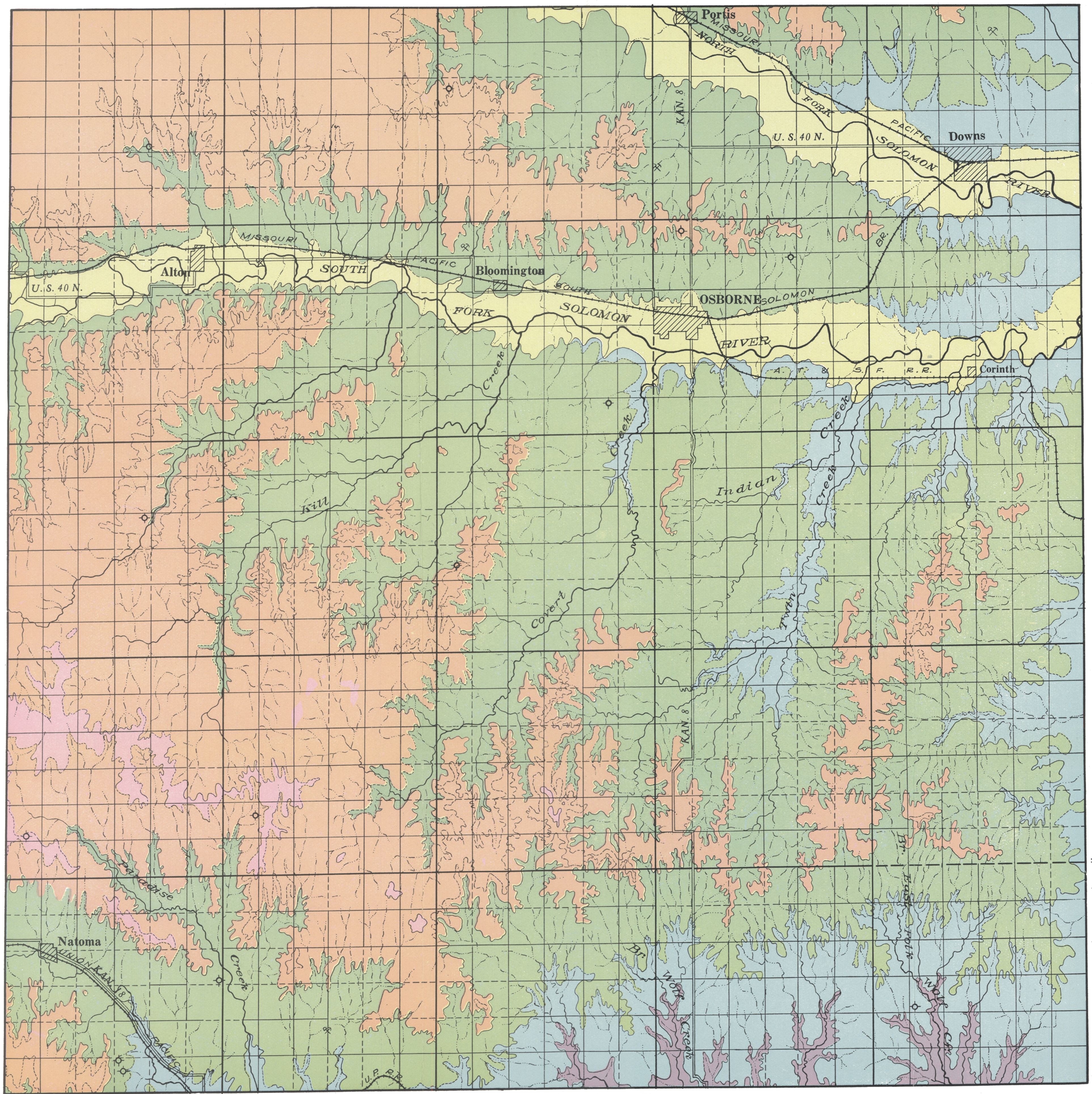
# GEOLOGIC MAP OF OSBORNE COUNTY, KANSAS

STATE GEOLOGICAL SURVEY
RAYMOND C. MOORE, STATE GEOLOGIST
K. K. LANDES, ASST. STATE GEOLOGIST




## EXPLANATION

QUATERNARY
- Alluvium

TERTIARY
- Ogalalla formation

UPPER CRETACEOUS
- Niobrara formation (Contact between Fort Hays and Smoky Hill members shown by black line where recognizable.)
- Carlile shale
  - Blue Hill shale member
  - Fairport chalky shale member
- Greenhorn limestone

## KEY

- Sand and gravel pit
- Dry hole
- Federal or state highway
- Road
- Section line
- Township or range line

Base compiled from U.S. Geological Survey Topographic maps

Geology by Rycroft G. Moss

BULLETIN 16, PLATE III

Asherville and in the western part, where they stand about 12 feet above the present flood plain. Two terraces have been noted in the vicinity of Osborne, one about 7 feet above the present flood plain and the higher one 18 feet above. A terrace occurs between Alton and the western edge of Osborne county which has an average height of about 15 feet above the present flood plain. West of Downs on the north fork of the Solomon are three distinct benches, 2 feet, 5 feet, and 25 feet above the valley floor. Both the present flood plains and the terraces are composed of a silty loam which makes a very fertile soil and on which prosperous farms are located. The upper part of the Salt creek flood plain in southern Mitchell county contains a salt marsh, so conditions there are not favorable for cultivation, but farther down stream the flood plain is very successfully cultivated.

With the exception of a small thickness of Dakota sandstone and Graneros shale in the extreme eastern and southeastern parts of Mitchell county, the first formation encountered above flood-plain level in this county is the Greenhorn limestone. The Greenhorn is composed of alternating beds of hard limestone and shale, and its erosion produces a rocky slope. Consequently the outcrop area of this formation is not tillable except where the slope angle is a very low one, as in places north of the Solomon flood plain. A gentle slope permits deep soil formation. The top member of the Greenhorn is the "fence post" limestone, which is fairly resistant to erosion and which usually makes a shoulder between the valley slopes and the nearly flat upland. The plateaulike upland is a very prominent feature in central Mitchell county. A veneer of Fairport shale, measuring up to about 40 feet in thickness, covers the "fence post" limestone and is eroded to a rolling topography with very slight relief. Because of the limy character of the Fairport shale and the absence within it of any hard rocks it makes a good soil. The major wheat-producing area of Mitchell county is in Fairport shale. Unfortunately the rising surface to the west causes this shale to disappear under younger formations, so Osborne county does not have the agricultural advantage afforded by a "Fairport plateau." As the younger formations yield a less fertile soil, Osborne county produces on an average about a million dollars less wheat annually than does Mitchell county in spite of its greater area. Where the Fairport shale is very thin, as in southeastern Mitchell county, the soil is stony, due to the underlying limestones, and the land is used for grazing.

The Fairport shale forms the lower part of the Carlile formation. The upper part is the Blue Hill shale which is noncalcareous and more easily eroded than the Fairport. The Blue Hill shale is preserved only where a protective capping of Niobrara limestone is present. The generally steeper slopes in this shale and its low fertility due to lack of lime make it of little value for cultivation. A considerable part of the Blue Hill outcrop is given over to stock raising.

The Blue Hill shale is capped by Fort Hays limestone, the basal member of the Niobrara formation. This rock is very resistant to erosion and causes the formation of flat-topped buttes such as the Blue Hills and high plateaus. The upper member of the Niobrara, the Smoky Hill chalk, appears in the higher parts of central and western Osborne county. It is generally eroded to form rocky slopes, but the presence of hard layers may cause the formation of buttes and small mesas. As a general rule the soil on the Fort Hays plateau and on the Smoky Hill chalk slopes and butte tops is very thin and stony. Large areas underlain by Niobrara rocks are unsuitable for cultivation and are used for grazing.

The Tertiary rocks which cover the Great Plains extend into western Osborne county. These remnants of the high plains form the uppermost bench in the area under discussion. The Tertiary rocks have been eroded to a rolling surface which is successfully cultivated.

## STRATIGRAPHY.

All the bedrock formations in Mitchell and Osborne counties are Upper Cretaceous in age. Due to the gradual increase in elevation from the eastern edge of Mitchell county to the western edge of Osborne county and the nearly horizontal rock structure the older formations occur to the east and the younger to the west. The surface rocks in Mitchell county are largely members of the Greenhorn and Carlile formations, while the greater part of Osborne county is covered by rocks of Niobrara age. Only a relatively small part of the two counties is covered by Tertiary and Quaternary sediments.

### Quaternary System.

Recent Deposits. The stream valleys, especially Solomon river and its forks and Salt creek, are floored with alluvium of Recent age. This material is a sandy loam which may also contain locally derived chalk pebbles. The terraces are of similar composition and

*Table of rock formations exposed in Mitchell and Osborne counties, Kansas.*

| System and series. | | Formation and member. | | Lithologic character. | Thickness in feet. |
|---|---|---|---|---|---|
| QUATERNARY. | Recent. | | | Modern stream deposits. Terrace deposits. Soil and talus. Spring deposits. | 0–50 |
| | Pleistocene (?). | | | Intermediate sand and gravel deposits. Loess. | |
| U. C. Tertiary. | | Ogallala. | | Unconsolidated sediments on divides. "Mortar" beds. | |
| CRETACEOUS. | Upper Cretaceous. | Niobrara formation. | Smoky Hill chalk member. | Chalk and chalky shale. | 0–115 |
| | | | Fort Hays limestone member. | Massive chalk alternating with thin chalky shale beds. | 60 |
| | | Carlile shale. | Blue Hill shale member. | Gray, fissile clay shale with sandstone at top and concretions in upper part. | 200 |
| | | | Fairport shale member. | Chalky shale with thin limestone beds in lower part. | 103 |
| | | Greenhorn limestone. | Pfeiffer member. | Chalky limestone and shale. | 18 |
| | | | Jetmore member. | "Shell" limestones and chalky shale. | 17 |
| | | | Hartland shale member. | Bluish-gray chalky shale with a few thin limestone and bentonite beds. | 22–27 |
| | | | Lincoln member. | Chalky shale and thin, hard crystalline limestone beds. | 25 |
| | | Graneros shale. | | Dark bluish gray shale with sandy streaks. | 26 |
| | | Dakota sandstone. | | Sandstone with variegated shale. | 30+ |

only slightly greater age. The soil at the surface of both the flood plain and the terraces yields prolific crops.

Of very recent age is the deposit of calcareous tufa composing the low cone or mound built by the waters of Great Spirit spring at Waconda, about two and one-half miles southeast of Cawker City. As the water, under slight artesian pressure, overflows from the orifice of the spring it evaporates to such an extent that some of the mineral matter in solution, especially calcium carbonate, is precipitated. The same method of cone-building is observed in the hot springs and geysers of Yellowstone Park. The cones are not built by volcanic eruption. The rock deposited at Great Spirit springs varies in color from white or gray to yellowish brown, and is layered because of periodic rather than steady overflow. There are quite noticeable open spaces between some of the layers which give the rock a high porosity and allow escape of most of the water through the sides of the cone. As is generally the case in spring deposits of this type, the precipitated material tends to form countless small spheroids, called pisolites.

PLEISTOCENE (?) DEPOSITS. Sand and gravel deposits which occur at a position intermediate between the river terraces and the high Tertiary gravel beds are tentatively placed in the Pleistocene. They were formed by streams which have either disappeared or have shifted and deepened their channels so as to leave isolated sand and gravel deposits on the flanks of the present valleys. Erosion by tributary creeks has destroyed most of these abandoned channel deposits, so that now there is but a patch of them here and there to furnish a clue to the drainage pattern of the past. Solomon river at one time followed a course through Mitchell county about two miles north of its present channel and along this belt is a row of sand and gravel deposits. Other Pleistocene (?) deposits occur in southwestern Mitchell county and in northeastern, northern, western, and southwestern Osborne county. These isolated deposits and those formed by the ancestral Solomon river are described more fully under the heading "Sand and Gravel."

Also of probable Pleistocene age is the conglomerate on Salt creek, which is well exposed in the southeast quarter of sec. 14, T. 9 S., R. 8 W., on the north bank of Salt creek. It consists of cement and gravel similar in appearance to the "mortar beds" belonging to the Ogallala formation. However, this exposure is over twenty miles east of the nearest known Ogallala outcrop and is different in composition. Most of its pebbles have been derived from the slightly higher limestones belonging to the Lincoln "marble" of the lower Greenhorn formation. The gravel toward the top of the crop is not cemented and forms a flat terrace which lies 18 to 20 feet above the present Salt creek flood plain. It is probable that this gravel was washed into the valley from the surrounding bedrock terrain in Pleistocene times, and since then it has become partially consolidated through cementation.

Deposits of loess, a fine sandy loam of probable wind origin, are not as abundant in Mitchell and Osborne counties as in some of the adjacent counties, such as Cloud county. A few relatively thin loess deposits have been noted in southwestern Osborne and northeastern Mitchell counties.

## Tertiary System.

OGALLALA FORMATION. No deposits of undoubted Tertiary age occur in Mitchell county or in eastern Osborne county. Two narrow fingers of Tertiary rocks extend from the less dissected high plains of southern Rooks county into southwestern Osborne county. Out beyond the two fingers are a few small outliers, the easternmost one of which lies in sec. 27, T. 9 S., R. 13 W., in the south-central part of the county. These fingers and outliers are found only along the tops of the highest hills and ridges, the elevation of the bottom of the Tertiary deposits ranging between 2,060 feet along the Graham county line and 2,020 feet feet at the easternmost outlier.

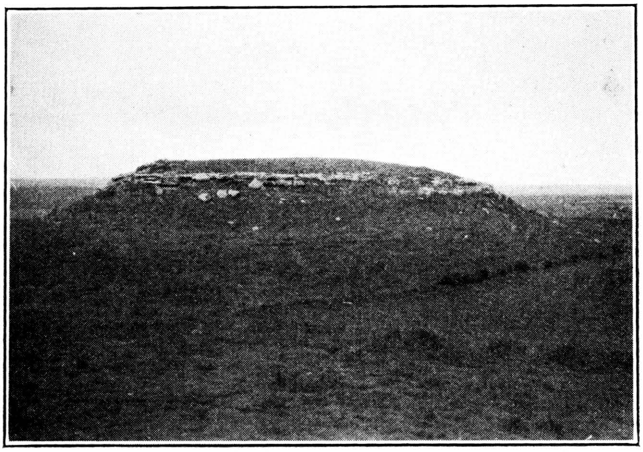


PLATE IV.—Hill capped by "mortar beds" of the Ogallala formation, sec. 22, T. 9 S., R. 13 W., Osborne county.

Because of studies made elsewhere in western Kansas[9] these Tertiary rocks are assigned to the Ogallala formation of late Miocene-Pliocene age. The Ogallala was deposited by ancient and relatively swift streams which flowed eastward from the Rocky Mountains to the ancestral Mississippi. The formation is composed of clay, sand and gravel, and calcium carbonate. Secondary precipitation of calcium carbonate by ground water in the otherwise unconsolidated Tertiary material has caused some of it to be cemented into hard rocks, which due to their appearance are locally called "mortar beds."

9. N. W. Bass: Geological Investigations in Western Kansas; Kan. Geol. Survey, Bull. 11, pp. 16-18; 1926.

*Section of the Tertiary rocks occurring near the SW corner of sec. 22, T. 9 S., R. 13 W.*[10]

| | Feet. |
|---|---|
| Ogallala formation: | |
| Hard mortar bed | 10 |
| Friable, soft silty sandstone. This bed has been quarried for building sand and fragments of large vertebrate fossils are reported to have been found within it | 8 |
| Hard mortar beds; alternating hard and soft layers; some of the harder layers have been finely silicified | 10 |
| Soft sand and mortar beds; lower part made up chiefly of recemented Smoky Hill chalk pebbles. Rests on eroded surface of Smoky Hill chalk | 16 |
| Total exposed thickness | 44 |

## Cretaceous System.

With the exception of the "mortar beds" all of the consolidated rocks in Mitchell and Osborne counties are of Upper Cretaceous age. Furthermore, all of the Upper Cretaceous formations of Kansas are represented in these two counties with the exception of the Pierre shale, which overlies the Niobrara formation in the western end of the state.

### Niobrara Limestone.

The Niobrara formation, which is the highest and youngest part of the Cretaceous exposed in Mitchell or Osborne counties, is subdivided in Kansas into an upper member, the Smoky Hill chalk, and a lower, the Fort Hays limestone. The Smoky Hill chalk member is 700 to 800 feet thick in the western end of the state, but only the lower part is present in Osborne county as a thin veneer overlying the more resistant Fort Hays limestone, and in Mitchell county it has been eroded altogether. The maximum thickness of Smoky Hill chalk known to be present in Osborne county is 115 feet, measured in sec. 7, T. 9 S., R. 15 W. The member is composed of alternating thin-bedded chalk and tan weathering chalky shale. Because of its soft character, the Smoky Hill chalk is generally eroded away except where it is protected by a cap of "mortar beds," and even there the slopes are so gentle that the chalk is exposed only in ravines and road cuts. A characteristic feature of the Smoky Hill member is the presence of discoidal concretions, often circularly furrowed, which are composed of pyrite and limonite. Large fossil shells of *Inoceramus* (*Haploscapha*) *grandis* are common. These shells are usually covered by the relatively small shells of the *Ostrea congesta.*

10. Section measured by R. G. Moss.

The Fort Hays limestone is much the more prominent member of the Niobrara formation in Mitchell and Osborne counties. It extends into the latter county from Rooks county in two long points, one north and the other south of the south fork of Solomon river. These points are intricately dissected by tributaries of the Solomon. The valley end of the tributary divides is generally marked by outliers, and other outliers occur to the east beyond the tip of the Fort Hays points. The only Fort Hays Limestone in Mitchell county

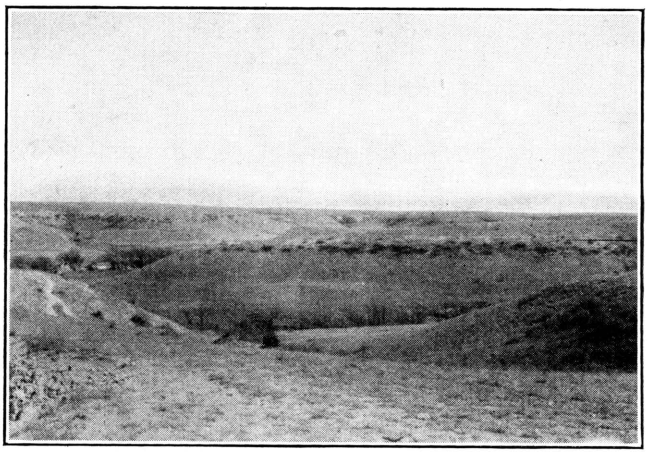


PLATE V.—Fort Hays capped hills in sec. 13, T. 7 S., R. 15 W., Osborne county. Bushes are about at contact between Fort Hays limestone and Blue Hill shale.

occurs as outliers capping the Blue Hills and near-by buttes. Because of the greater hardness of this limestone, it forms steep slopes and cliffs. Where no Smoky Hill chalk veneer is present above the Fort Hays the rock makes a fairly smooth plateau surface which is generally covered by an abundance of white residual limestone fragments. Superficial faults caused by landsliding are common in the outcrop area of this member, especially where a long point extends out along the top of a ridge. Large jointed blocks tend to slide over or perhaps even squeeze out some of the underlying shale so that the lower surface of the Fort Hays limestone may be considerably lower in elevation than is normal, or the blocks may be tilted to give abnormal and, of course, entirely superficial dips.

The Fort Hays limestone differs from the overlying Smoky Hill chalk largely in its proportion of massive chalk to chalky shale. This proportion in the Smoky Hill member runs about one to one, but the Fort Hays member contains at least six times as much massive chalk as chalky shale. Also, the Fort Hays is not as thin-bedded as the Smoky Hill, for in the former many of the beds are from 2 to 3 feet thick. The color ranges from creamy white through yellow to light brown. Mud cracks were observed in a bed lying about 25 feet above the base in sec. 13, T. 7 S., R. 15 W. The thickness of the Fort Hays limestone is about 60 feet.

*Section of the lower 40 feet of the Fort Hays limestone member of the Niobrara chalk in sec. 13, T. 7 S., R. 15 W.*[11]

| | Ft. | In. |
|---|---|---|
| Broken chalk (top of bluff) | 8 | 0 |
| Shale | .. | 2 |
| Chalk | 1 | 3 |
| Shale | .. | 2 |
| Chalk | .. | 10 |
| Shale | .. | 1 |
| Chalk | 2 | 8 |
| Shale | .. | 1 |
| Chalk | .. | 7 |
| Shale | .. | 2 |
| Chalk | 2 | 8 |
| Shale | .. | 1 |
| Chalk | 2 | 11 |
| Shale | .. | 1 |
| Chalk | 1 | 9 |
| Shale, containing mud cracks and weathering orange-tan | .. | 6 |
| Chalk partings | 1 | 6 |
| Chalk | 2 | 0 |
| Shale | .. | 2 |
| Chalk | .. | 4 |
| Shale | .. | 1 |
| Chalk | 2 | 0 |
| Shale | .. | 3 |
| Chalk with partings 4 inches below top | 1 | 6 |
| Shale | .. | 1 |
| Chalk | 2 | 9 |
| Shale | .. | 2 |
| Chalk | 4 | 5 |
| Shale | .. | 1 |
| Chalk | 3 | 0 |
| Sandy gray shale (Blue Hill) | .. | .. |
| Total | 40 | 4 |

11. All of the chalk is light yellow to white; the shale is light gray to yellow. Section measured by R. G. Moss.

## Carlile Shale.

The Carlile shale is divided into two members, the Blue Hill shale above and the Fairport shale below. The essential difference between the two is the absence of calcareous material in the former, whereas the Fairport is highly calcareous. Because of this difference in chemical constitution, the Blue Hill soils are very much less fertile than those produced by the weathering of the Fairport. Inasmuch as both members of the Carlile are shaly, there is no distinct break between them, and the contact is hard to find. Testing for calcium carbonate is not reliable because leaching by surface waters tends to remove this compound from the exposed rocks, or fragments of Niobrara limestone which have been washed or let down from their original position may be present so that calcium carbonate is added to the surface and near-surface rocks. However, where fresh exposures occur the distinction can be readily made between the two Carlile members, for the Blue Hill is black while the Fairport is gray to light yellow. Exposures of Carlile shale are too rare in Mitchell county to permit separate mapping of the two members, but it was possible in Osborne county, due to the more rugged topography, to map the contact between the Blue Hill and Fairport.

Blue Hill Shale Member. The Blue Hill shale crops out around the Blue Hills and other Fort Hays outliers in southwestern Mitchell county. It covers a very large area in Osborne county, occupying the steep slopes beneath the Fort Hays escarpment. The elevation of the Fairport-Blue Hill contact in southwestern Osborne county is about 1,800 feet, while in the Blue Hills region it is approximately 1,600 feet. The Blue Hill member is about 200 feet thick. A variable sandstone or sandy shale zone lies at the top and was named the Codell sandstone by Bass.[12] At the north end of the Blue Hills this unit consists of 42 inches of gray, friable sandstone which weathers to a mottled yellow and which lies directly beneath a thick scarp-making Fort Hays limestone bed. On the other hand, in sec. 24, T. 8 S., R. 13 W., Osborne county, it consists solely of a gray argillaceous sandstone only two inches thick which is limy at the top and weathers to an orange tan or buff color. Farther southwest the sandstone thickens again, as may be seen in the accompanying section.

12. Kan. Geol. Survey, Bull. 11, p. 28; 1926.

*Section of Codell sandstone exposed in the southwest corner of sec. 6, T. 10 S., R. 14 W., Osborne county, Kansas.*

Niobrara chalk:
  Fort Hays limestone member.
Carlile shale:
  Blue Hill shale member:
    Codell sandstone:

| | Ft. | In. |
|---|---|---|
| Argillaceous sandstone, weathering brown | 1 | 0 |
| Soft, fissile, blue-green shale | 3 | 0 |
| Soft, massive cream-colored argillaceous sandstone. Contains calcareous sandstone concretions up to 8 feet in diameter, | 25 | 6 |
| Total thickness of Codell sandstone | 29 | 6 |

  Blue-gray fissile shale.

The remainder of the Blue Hill member consists of very fissile blue-gray noncalcareous shale with several zones of septaria concretions. The cleavage fragments of this shale may be paper thin.

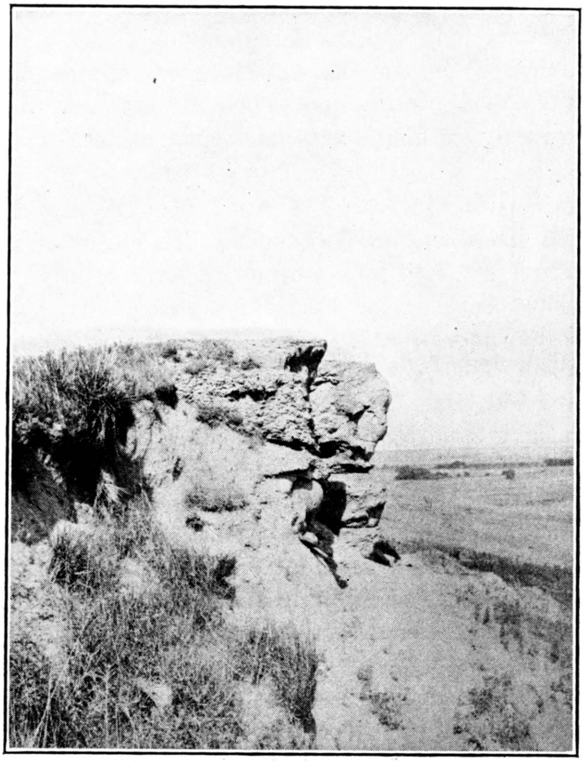


PLATE VI.—Sandstone concretions in upper Blue Hill shale capping hill in sec. 11, T. 10 S., R. 13 W., Osborne county.

Gypsum (locally but erroneously called mica) in characteristic diamond-shaped crystals is abundant at several horizons. The concretions in the sandy zone near the top of the Blue Hill member may have diameters as great as 8 feet. The shale concretions range in diameter from a few inches to 4 feet, with a great many between 12 and 18 inches. They are spherical, discoidal, or lemon-shaped in form and contain cross-cutting veins of calcite. The concretions occur in zones which may be persistent for a considerable distance laterally, in which case they may be utilized for structural mapping. The concretions are sufficiently abundant in some places to make a resistant layer which caps buttes, as in eastern Osborne county.

FAIRPORT CHALKY SHALE MEMBER. About 100 feet of chalky shale occupies the lower third of the Carlile formation. The contact with the overlying Blue Hill shale is generally obscured by soil or talus covering, but the lower contact with the Greenhorn limestone is often visible. The Fairport in Osborne county occupies a narrow belt along the south boundary in the drainage of Wolf creek, and short wedges extend up the two forks of Solomon river. The calcium carbonate content of this member is high and in the basal 20 feet there are a number of thin but persistent limestones. In fact there is no great lithologic difference between the lowermost Fairport and the uppermost Greenhorn, but the line is drawn at the top of the "post rock" largely because of a distinct faunal break at that point. The shale in the Fairport is coarsely laminated and gray when fresh, weathering to cream or tan. Minute white crystals of calcite are scattered through the shale, giving it a speckled appearance. Gypsum crystals ranging from ¼ inch to ½ inch in length were observed at one locality, but these were probably deposited by ground waters that had dissolved the calcium sulphate from the Blue Hill shale before that member was removed by erosion. The limestones of the lower Fairport range in color from a chalky white to a pink or pale red.

*Complete section of the Fairport member of the Carlile shale measured in eastern Osborne county, Kansas.*[13]

*Near east quarter-corner sec. 14, T. 8 S., R. 12 W.*

| | Ft. | In. |
|---|---|---|
| Blue Hill shale. | | |
| Fairport shale member: | | |
| 40. Gray, limy, fossiliferous shale | 7 | 0 |
| 39. Gray, silty, fossiliferous chalk bed; somewhat discontinuous | .. | 6 |
| 38. Gray, fossiliferous chalky shale. Contains ¼-inch bentonitic clay bed 12 feet 4 inches above base | 14 | 6 |
| 37. Gray, silty, fossiliferous chalk bed | .. | 5 |

13. Measured by R. G. Moss.

*Near south quarter-corner, sec. 3, T. 9 S., R. 12 W.*

| | | Ft. | In. |
|---|---|---|---|
| 36. | Gray, limy, fossiliferous shale. Contains white bentonitic clay bed 5 feet above base | 6 | 0 |
| 35. | Gray, fossiliferous chalk bed | .. | 5 |
| 34. | Gray, limy, fossiliferous shale. Contains a one inch bed of white bentonitic clay 3 feet above base and a pyritic, concretionary zone 2 feet above base. Pyrite concretions oxidize to limonite, leaving casts of pyrite crystals. Shale contains *Ostrea congesta* and *Serpula* sp. | 4 | 9 |
| 33. | Gray, silty, fossiliferous chalk bed, lenticular | .. | 3 |
| | *Near northwest corner, sec. 31, T. 7 S., R. 11 W.* | | |
| 32. | Gray, fissile, limy shale containing abundant *Ostrea congesta*. Contains lenticular chalk bed up to 6 inches thick 1 foot above base | 6 | 6 |
| 31. | Yellow-tan to white bentonitic clay bed containing numerous discoidal pyritic and limonitic concretions | .. | 1 |
| 30. | Gray, argillaceous chalk bed | .. | 3 |
| 29. | Fissile, dark gray, limy shale containing a thin bed of limonitic clay | 4 | 3 |
| 28. | Gray pyritic and limonitic shale containing selenite | .. | 2 |
| 27. | Gray, fossiliferous limy shale | 3 | 4 |
| 26. | Gray, argillaceous chalk | .. | 7 |
| 25. | Gray, fossiliferous, limy shale | 1 | 4 |
| 24. | Gray, fossiliferous, argillaceous chalk | .. | 5 |
| | *Sec. 1, T. 8 S., R. 12 W.* | | |
| 23. | Gray, fissile, limy shale containing limonitic concretions | 7 | 2 |
| 22. | Zone of two bentonitic clay beds separated by 2 inches of gray shale | .. | 4 |
| 21. | Gray, fissile, limy, fossiliferous shale | 4 | 2 |
| 20. | Gray, argillaceous, fossiliferous chalk | .. | 4 |
| | *Secs. 25 and 26, T. 7 S., R. 11 W.* | | |
| 19. | Gray, limy shale | 1 | 10 |
| 18. | Soft, gray, argillaceous chalk | .. | 4 |
| 17. | Gray, limy shale | 4 | 5 |
| 16. | Sulphur-yellow bentonitic clay containing limonitic concretions, | .. | 3 |
| 15. | Gray, fossiliferous, limy shale | 2 | 2 |
| 14. | White, bentonitic clay. Weathers to orange-tan color | .. | 1 |
| 13. | Gray, fossiliferous, limy shale | 3 | 2 |
| 12. | White, bentonitic clay | .. | 1 |
| 11. | Gray, limy shale | 3 | 5 |
| 10. | Soft, gray, silty chalk | .. | 5 |
| 9. | Gray, limy shale | 2 | 4 |
| 8. | Gray, argillaceous, soft chalk, weathers to light reddish brown, | .. | 4 |
| 7. | Gray, limy shale containing *Ostrea congesta* | 2 | 4 |
| 6. | Gray, silty chalk bed, with parting in middle. Weathers to light reddish brown. "Pink lime" | .. | 4 |
| 5. | Gray, limy shale containing *Ostrea congesta* | 5 | 7 |
| 4. | Gray chalk. Weathers to light tan color | .. | 3 |
| 3. | Gray, limy shale containing abundant *Ostrea congesta* near top, | 7 | 6 |
| 2. | Soft gray chalk | .. | 6 |

| | | Ft. | In. |
|---|---|---|---|
| 1. | Fissile, limy shale with 3-inch bentonitic clay at top and containing three zones of hard limestone concretions; 1 foot above base, 2½ feet above base and 3½ feet above base | 4 | 9 |
| | Total thickness of Fairport shale member | 102 | 10 |

Greenhorn limestone.

"Fence post" limestone.

The three zones of concretions in the botton 5 feet of the Fairport are the only ones in the member. The chalky limestone (bed 2), 4 feet, 9 inches above the "post rock" in this section, is remarkably persistent, but the interval between it and the "post rock" varies from 3½ to 5½ feet, the latter extreme being the more common. Also this bed is usually much harder than indicated in this section. Another unusually persistent layer is the bentonitic seam at the top of bed 1, although in some places it contains a high percentage of granular calcite and looks like the so-called "sugar sand" which lies at about an equal distance below the "post rock." Other limestones that are sufficiently persistent to be used in structure mapping occur at approximately 13, 19, and 21 feet above the "post rock." These all weather to a reddish brown or pink color, especially the 19-foot limestone (bed 6), which is called the "pink lime" by oil geologists. The 13-foot limestone (bed 4) is more brick-colored, cleaves in the middle like the "post rock," and has a dense ground mass which is speckled with minute white calcite grains. The small fossil oyster, *Ostrea congesta,* so common in the Niobrara, is likewise abundant in the Fairport except in the basal portion, which in all probability was deposited before this fossil species developed.

## Greenhorn Limestone.

The Greenhorn formation is unimportant in Osborne county, appearing only in the river bottoms at the eastern and southern edges of the county, but it is of considerable importance in Mitchell county, where it occupies most of the valley slopes. It is divided into four members, named in downward order the Pfeiffer, Jetmore, Hartland, and Lincoln. Although all are composed of limestone and limy shale, massive limestones are much more prominent in the upper two members than in the Hartland and Lincoln. The total thickness of the Greenhorn in Mitchell county is about 82 feet.

Pfeiffer Member. The Pfeiffer is the top member of the Greenhorn and outcrops immediately beneath the upland surface. It is composed of beds of massive white limestone and shale that is blue when fresh, but is generally buff in color on the outcrop. The limestones contain scattered *Inoceramus* shells. The shale zones are thicker than the limestone beds, especially in the lower part of the section, so that part of the member below the topmost limestone (the "post rock") is poorly exposed as a rule.

*Typical section of the Pfeiffer member of the Greenhorn limestone exposed in road cut in the east center of sec. 20, T. 7 S., R. 7 W., Mitchell county, Kansas.*

Fairport chalk.
Greenhorn limestone:

| | Ft. | In. |
|---|---|---|
| Pfeiffer member: | | |
| 8. "Post rock" or "fence post" limestone. Dense, hard chalk containing a few shell fragments and an ever-present iron-stained band at center. Cleaves along this band. Makes slight shoulder | .. | 10 |
| 7. Chalky gray to buff fissile shale. Contains ¾-inch dark gray to black soapy shale 3 inches below top and zones of discoidal limestone concretions at distances of 1 and 2½ feet below top. Some thin limestones occur between lower concretion zone and bottom of shale | 5 | .. |
| 6. Densely crystalline limestone | .. | 3 |
| 5. White, chalky shale, locally stained yellow. Contains three persistant concretionary zones | 6 | .. |
| 4. Hard, fine crystalline limestone | .. | 2½ |
| 3. Chalky shale containing five thin concretionary zones | 2 | 6 |
| 2. Fine crystalline cream-colored limestone | .. | 2 |
| 1. Chalky shale containing two zones of limestone concretions, | 3 | .. |
| Total thickness of Pfeiffer member | 17 | 11½ |

Jetmore member: "Shell" limestone.

The "post rock" is the most prominent bed in the Pfeiffer member. It crops out at the tops of the bluffs facing Solomon river and Salt and Rock creeks and continues for long distances up the tributary valleys. It ranges in thickness from 8 to 10 inches and invariably has an iron seam (limonite-stained chalk) at or near the center. Because of this feature and the fact that it has been extensively quarried it is an easy bed to follow and is ideal for detailing structure. The abandoned quarries can be recognized by the presence of a shallow trench and mounds of the stripped-off over-burden. In the southeastern part of Mitchell county and in Cloud county[14] the "post rock" becomes thinner and softer and consequently less prominent. The concretions in the shale immediately beneath the "post rock" may locally thicken into massive bench-making limestones. Four feet below the "post rock" a hard dense yellow-cream limestone 3 to 4 inches in thickness and banded with thin iron-stained streaks was observed in a number of sections. Immediately beneath the 3-inch limestone 5 feet below the "post rock" there may be an incoherent granular limestone known as the "sugar sand" bed

14. M. E. Wing. Informal communication.

by drillers in counties to the southwest. Midway between the "post rock" and the "shell bed" of the Jetmore a limestone is seen in many places, which contains more *Inoceramus* shells than the usual Pfeiffer limestone and which either makes a bench or a prominent line of float. This limestone in the section given is concretionary (bed 5), but in other localities it appears as a massive limestone and could be used for detailing structure.

JETMORE MEMBER. The Jetmore member of the Greenhorn limestone is composed of two very prominent limestone beds, a number of thinner chalky limestone beds, and zones of limy shale. The shale generally weathers to a white or tan color, which aids in distinguishing this member from the underlying Hartland, in which the shale is predominantly blue, even when weathered. The limestone beds are highly fossiliferous, more so than those in the overlying Pfeiffer, and are most prominent at and near the top of the member. They become thinner and softer toward the base and cease abruptly at the contact with the Hartland. The separation of the Jetmore member is easy, for from 3 to 5 feet of shale immediately overlie and underlie it. The top of the member makes a distinct bench, while the slope beneath is generally steep and rocky. The Jetmore crops out along the sides of the valleys in central and eastern Mitchell county and in southern Osborne county.

*Section of the Jetmore member of the Greenhorn limestone measured along bluff on south side of Solomon river, south of Solomon Rapids, Kansas.*

| | Ft. | In. |
|---|---|---|
| Greenhorn limestone: | | |
| Jetmore member: | | |
| "Shell bed" | 1 | .. |
| Tan-colored shale | 1 | .. |
| Concretionary zone | .. | 2 |
| Shale with concretionary zone midway | 1 | 3 |
| Hard gray fossiliferous limestone ("subshell") | .. | 4 |
| Shale | .. | 11 |
| Hard gray limestone | .. | 5 |
| Shale with ¼-inch bentonite at base | .. | 11 |
| Hard, gray, crystalline limestone | .. | 5 |
| Thick-bedded blue shale | .. | 9 |
| Soft, shaly chalk | .. | 2 |
| Light tan shale | .. | 6 |
| Chalky limestone | .. | 4 |
| Light tan chalky shale | .. | 8 |
| Cream-colored limestone | .. | 3 |
| Limy shale | 1 | 6 |
| Hard, dense limestone | .. | 6 |
| Shale | .. | 8 |

| | Ft. | In. |
|---|---|---|
| Soft limestone | .. | 3 |
| Fine-bedded blue shale | 1 | 8 |
| Soft, white limestone | .. | 4 |
| Blue shale | .. | 9 |
| Soft limestone | .. | 2 |
| Shale | .. | 8 |
| Soft, shaly limestone | .. | 3 |
| Total thickness of Jetmore member exposed | 15 | 10 |

*Section of the Jetmore member of the Greenhorn limestone measured in the NW cor. sec. 35, T. 10 S., R. 12 W. southeastern Osborne county, Kansas.*[15]

| | Ft. | In. |
|---|---|---|
| Greenhorn limestone: | | |
| Jetmore member: | | |
| "Shell bed." Lower 9 inches hard, fossiliferous, chalky limestone; upper 6 inches concretionary | 1 | 3 |
| Shale | 1 | 1 |
| Chalky limestone | .. | 4 |
| Shale | .. | 11 |
| Chalky limestone | .. | 5 |
| Shale | .. | 8 |
| Chalky limestone | .. | 2 |
| Shale | 1 | 1 |
| Chalky limestone | .. | 2 |
| Shale | .. | 11 |
| Chalky limestone | .. | 4 |
| Shale | 2 | 1 |
| Chalky limestone | .. | 5 |
| Shale | 1 | .. |
| Chalky limestone | .. | 3 |
| Shale | .. | 11 |
| Chalky limestone | .. | 3 |
| Shale | .. | 10 |
| Chalky limestone | .. | 4 |
| Shale | 1 | 2 |
| Chalky limestone | .. | 2 |
| Shale | 1 | 3 |
| Crystalline limestone | .. | 2 |
| Shale, weathers light tan | .. | 5 |
| Chalky limestone | .. | 5 |
| Total thickness of the Jetmore member exposed | 17 | .. |

The so-called "shell bed" consists of two parts. The upper is concretionary in Osborne and Russell counties, but in Mitchell county it is a consistent dense limestone ranging from white to yellowish cream in color. It contains a very few flat *Inoceramus* shells. The lower and thicker portion of the "shell bed" contains a mass of

15. Section measured by R. G. Moss.

oyster shells (*Inoceramus labiatus*) with the individual valves from 4 to 8 inches in length. Coiled ammonite shells, 2 to 8 inches in diameter, may also be present. The two slabs of the "shell bed" are generally eroded unevenly so that the outcrop is terraced. This limestone is quarried in southeastern Mitchell county and in Cloud county for fence posts and buildings. The only other distinctive limestone in the Jetmore is the "subshell bed," the top of which lies

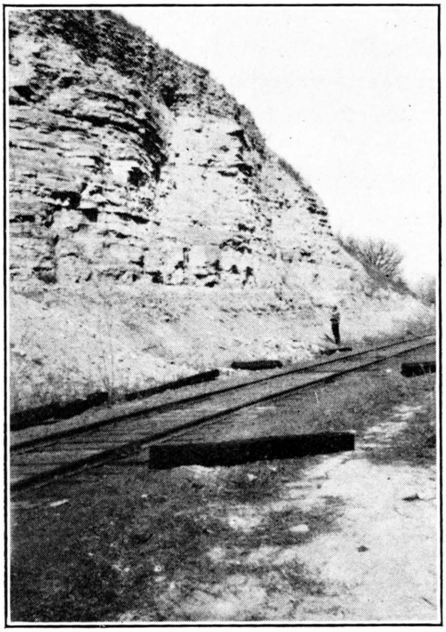


PLATE VII.—Jetmore and upper Hartland (members of the Greenhorn formation) exposed in railroad cut, Glen Elder.

about 2½ feet below the base of the "shell." Although only 4 to 5 inches in thickness, this limestone is very resistant to erosion, and generally makes a separate bench. It is fully as fossiliferous as the "shell bed," but it is darker in color.

HARTLAND MEMBER. The Hartland member of the Greenhorn limestone consists largely of shale, with a few thin beds of crystalline limestone and a number of bentonite seams. The thickness ranges from 22 feet in north central Mitchell county to 27 feet in the southeastern corner of the county. The shale ranges in color from light bluish gray to tan, whereas in the underlying Lincoln the shale is predominately yellow. The shale is soft and limy and is reported to contain abundant *Globigerina*.[16] Three thin beds of crystalline limestone appear in the lower half of the Hartland, which may give a petroleum odor on fresh fracture, just as do the beds of so-called "marble" at the top and bottom of the Lincoln member. The highest of these at the eastern edge of Mitchell county is 8 inches thick, has a slabby fracture, and is very similar in appearance to the top bed of the Lincoln, but differs from that limestone in having thin, chalky stringers. Farther west this bed disappears and is replaced in the Solomon Rapids section by a 3½ inch very dense gray limestone which contains a few small pelecypods and scattered shell fragments. The Hartland bentonite seams are typically yellow at the surface and range in thickness from 1 to 6 inches. Because of the soft character of the rocks in the Hartland, exposures are rare. The member outcrops in the Solomon and Salt creek valleys in Mitchell county and near the bottom of a few valleys in southern Osborne county.

*Section of the Hartland member of the Greenhorn limestone near Solomon Rapids, Kansas.*

| | Ft. | In. |
|---|---|---|
| Greenhorn limestone. | | |
| Jetmore member (section given above). | | |
| Hartland member: | | |
| Bentonite | .. | 1 |
| Blue shale | 4 | 6 |
| Soft cream limestone | .. | 4 |
| Shale, ¼-inch iron seam at base | .. | 10 |
| Blue shale | 2 | 0 |
| Bentonite | .. | 6 |
| Slabby limestone | .. | 4 |
| Blue shale. Lower 6 inches strongly iron-stained | 2 | 10 |
| Resistant gray limestone | .. | 3½ |
| Shale, iron-stained at top | .. | 10 |
| Bentonite | .. | 2 |
| Blue shale, with hard zones | .. | 5½ |
| Petroliferous limestone zone | 1 | 4 |
| Shale | 1 | 3 |
| Petroliferous limestone | .. | 1 |
| Shale | 2 | 0 |
| Bentonite | .. | 1½ |
| Shale | 1 | 0 |
| Bentonite | .. | 1½ |
| Shale | 3 | 0 |
| Total thickness of Hartland member exposed | 22 | 1 |

16. Reeside, J. B., Jr.: Informal communication.

LINCOLN MEMBER. The Lincoln limestone and shale lies immediately beneath the Hartland, but due to the soft nature of most of the rock and its usual position near the bottom of the valleys actual exposures are few. However, the limestone bed lying at the top of the member is fairly resistant and may form a bench, the position of which is midway between benches made by the sandstone at the top of the Dakota and the "shell bed" at the top of the Jetmore. The Lincoln member contains another prominent limestone at the base, while the 22 to 24 feet of intervening space is occupied by shale, with a very few thin limestones and three or four bentonite seams. The limestone beds of the Lincoln are either finely or coarsely crystalline (hence are often called "marble") and contain numerous shells and shell fragments. The color is generally some shade of brown. A freshly exposed surface invariably gives off a petroleum odor, and oil was proven to be present in small amounts by the chloroform test. The limestone at the top of the member is 9 to 12 inches thick and weathers into a series of slabs ½ to 2 inches thick. The basal Lincoln limestone is very coarsely crystalline and dark brown in color, with red or lavender streaks often present. The shale, which composes most of the member, is in part chalky but mostly yellow, so that roads constructed across the outcrop have a distinctive tan color. In common with the other Greenhorn shale beds the calcium carbonate content is high. The bentonites in the Lincoln are no different from those in the Hartland. A complete Lincoln section was not measured in Mitchell county.

*Section of the upper part of the Lincoln member of the Greenhorn limestone, exposed near Solomon Rapids, Kansas.*

| | Ft. | In. |
|---|---|---|
| Greenhorn limestone: | | |
| Hartland member (section given). | | |
| Lincoln member: | | |
| Limestone with partings, petroliferous. Half-inch bentonite at base | 1 | .. |
| Shale | .. | 5 |
| Bentonite | .. | 3 |
| Shale. Lower 2 inches may be bentonitic | .. | 6 |
| Limestone, petroliferous | .. | 2 |
| Shale | 2 | 9 |
| Bentonite | .. | 5 |
| Shale | 9+ | .. |
| Total thickness of the Lincoln member exposed | 14 | 6 |

From observations made in south-central Republic county, northeast of Mitchell county, the remaining 11 feet of Lincoln section is composed of alternating beds of shale and thin crystalline limestones with a 14-inch bentonite bed lying just above the basal "marble."

### Graneros Shale.

The Graneros shale crops out only in the valley of the Solomon at the eastern end of Mitchell county and adjacent to Salt creek near the southern boundary. It is soft and consequently but rarely exposed. The formation is composed largely of dark-colored shale which differs from that in the overlying Greenhorn by being noncalcareous. This shale weathers to a gumbo clay soil which caps the low Dakota hills north of Asherville. Thin ferruginous sandstone layers may be present. The thickness of the Graneros is 26 feet at a point south of Simpson. This is 14 feet less than has been recorded in Russell county,[17] so evidently the formation thins to the northeast.

### Dakota Sandstone.

Only the top 30 feet of the Dakota, including a sandstone and a few feet of underlying shale, crop out in Mitchell county, and the formation is entirely buried in Osborne county. The top member is sufficiently resistant to form a bench which extends up both sides of Solomon river valley to a point between Asherville and Beloit, where it disappears beneath the flood plain. It also extends up the tributary valleys at the east end of the county, especially those to the south. The Dakota bench extends upstream in Salt creek valley as far as the forks with Rock creek and is unusually prominent on the south side of the valley. The top sandstone is buff or red and is cross-bedded. It exhibits a highly porous texture on weathered surfaces. The underlying shale was exposed at only one place and there it was buff and arenaceous.

## Rocks Not Exposed.

By J. W. Ockerman.

### Introduction.

The following discussion of the subsurface formations in Mitchell and Osborne counties is based largely on information derived from drillers' logs. Samples from a few of the wells were secured and studied and the writer is indebted to the Midwest Exploration Company and the Phillips Petroleum Company for the use of their

17. Rubey, W. W., and Bass, N. W.: Kan. Geol. Survey, Bull. 10, p. 51; 1925.

samples. He is especially grateful to Mr. Robert Roth, of the Indian Territory Illuminating Oil Company, for aid rendered in the correlation of the lower Pennsylvanian formations.

## Cretaceous System.

The Cretaceous rocks, as shown by well cuttings, are variable lithologically, being clayey and sandy shale of different colors, sandstone and chalky limestone. The Cretaceous cannot be subdivided into small units as at the outcrop, and in this part of the report only the Colorado group and the "Dakota" sandstone will be recognized.

The Colorado group consists of chalky limestone beds which appear to belong to the Fort Hays, and dark gray to black, in part chalky, shale which is very probably Benton. The shale series is characteristically uniform in color and lithology, and can be recognized in logs without difficulty.

The "Dakota" sandstone includes the sandstone, red, gray, and white shale, and limestone in the lower part of the Cretaceous. At the present time it seems inadvisable to attempt to separate the Comanchean from the Cretaceous, although detailed work should give some results on this problem. The sandstone beds in this series are usually friable; the grains are very poorly sorted and range from coarse and rounded to fine and angular. The sands are usually light gray to white in color, but red sands are not uncommon in the section. Abundant pyrite in zones in the "Dakota" sandstone is characteristic, and "iron" or "pyrite" is found in many of the drillers' logs in this part of the section. Red shale zones are found interbedded with the sandstone along with gray and white shale. Thin beds of limestone are logged by the drillers in the lower part of the section. The "Dakota" series ranges in thickness from 320 feet in Mitchell county to 450 feet in western Osborne county. It rests unconformably on the Permian red beds. Sandstones of the "Dakota" are not safe to use as datum planes for subsurface structure because, though they follow the contour of the Permian red beds fairly well, they vary too much locally for accurate detailed work.

## Permian System.

The Permian ranges from approximately 1,500 feet in thickness in western Osborne county to 1,000 feet in Gish No. 1 well of the Wilcox Oil and Gas Company in sec. 23, T. 6 S., R. 9 W., in eastern Mitchell county, which shows rapid thinning to the north and east. Two distinct lithologic divisions are represented in the Permian, an upper red-bed series known as the Cimarron group, which is composed of nonmarine red shale and sandstone with minor amounts of gypsum and anhydrite, and a lower series, known as the Big Blue group which includes the Sumner, Chase and Council Grove formations. The Big Blue group is made up of salt, gray shale, anhydrite, and gypsum with a few thin dolomitic limestones and thin red beds. Definition of the lower boundary of the Permian presents a problem because of the lithologic similarity that exists between the lower Permian beds and those of the upper Pennsylvanian and also because of the lack of a break or unconformity between the Permian and Pennsylvanian formations. The writer believes that a detailed study of the microfossils will help materially in the solution of this boundary question. Fragments of what appears to be *Fusulina* sp., probably *F. longissimoidea* Beede, were found in cuttings from the well, Vickers No. 1 Luhman, in sec. 11, T. 9 S., R. 16 W., Rooks county, at a depth of 2,350 to 2,358 feet. *Fusulina longissimoidea* is reported to be confined to the upper part of the Wabaunsee formation and should be an excellent fossil for determination of the top of the Pennsylvanian. This particular determination puts the base of the Permian at the base of the lowest fairly thick red beds, which accords with current practice.

The Cimarron group, which lies unconformably below the Cretaceous, is a thick series of red shale and sandstone beds that are usually logged as red rock. A bed of gypsum averaging about 40 feet in thickness is found below the top red bed in the more westerly wells (see sections) and is an excellent marker where found. It is probably equivalent to the Medicine Lodge gypsum, but is usually logged as a limestone, as is most of the gypsum and anhydrite in the Permian section. Below the gypsum layer is another thick red bed and some gray shale containing small amounts of gypsum. The thinning that takes place in the Permian is due to the truncation of the Cimarron beds as they rise eastward. The thickness of this group varies from 600 feet in the Stearns-Streeter Matheson No. 1 test, in sec. 28, T. 10 S., R. 16 W., eastern Rooks county, to 100 feet in the Royal Union Gurley No. 1 well, in sec. 27, T. 9 S., R. 7 W., in eastern Mitchell county. The manner of this thinning may be seen in Plate — by noting the anhydrite bed as it approaches the top of the Cimarron and is cut off in the Alcorn Oil Company well, Beeler No. 1, in sec. 19, T. 9 S., R. 8 W., Mitchell county. The bottom of the Cimarron is placed at the base of the red bed above the salt or the gray shale, occupying the approximate position of the salt if it is absent. This is usually the third major red bed.

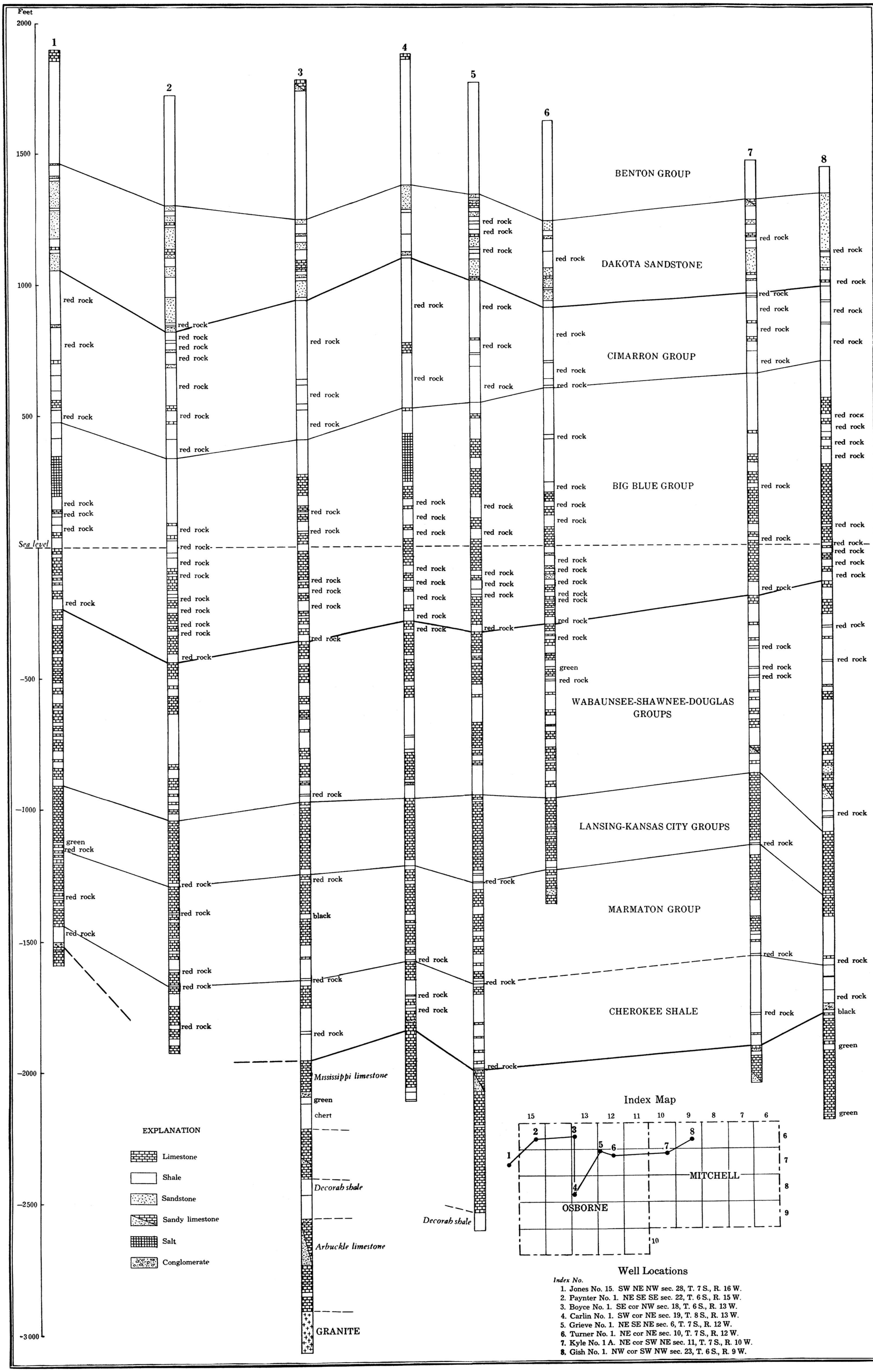



PLATE VIII.—Correlation of well records in northern Osborne and Mitchell counties.

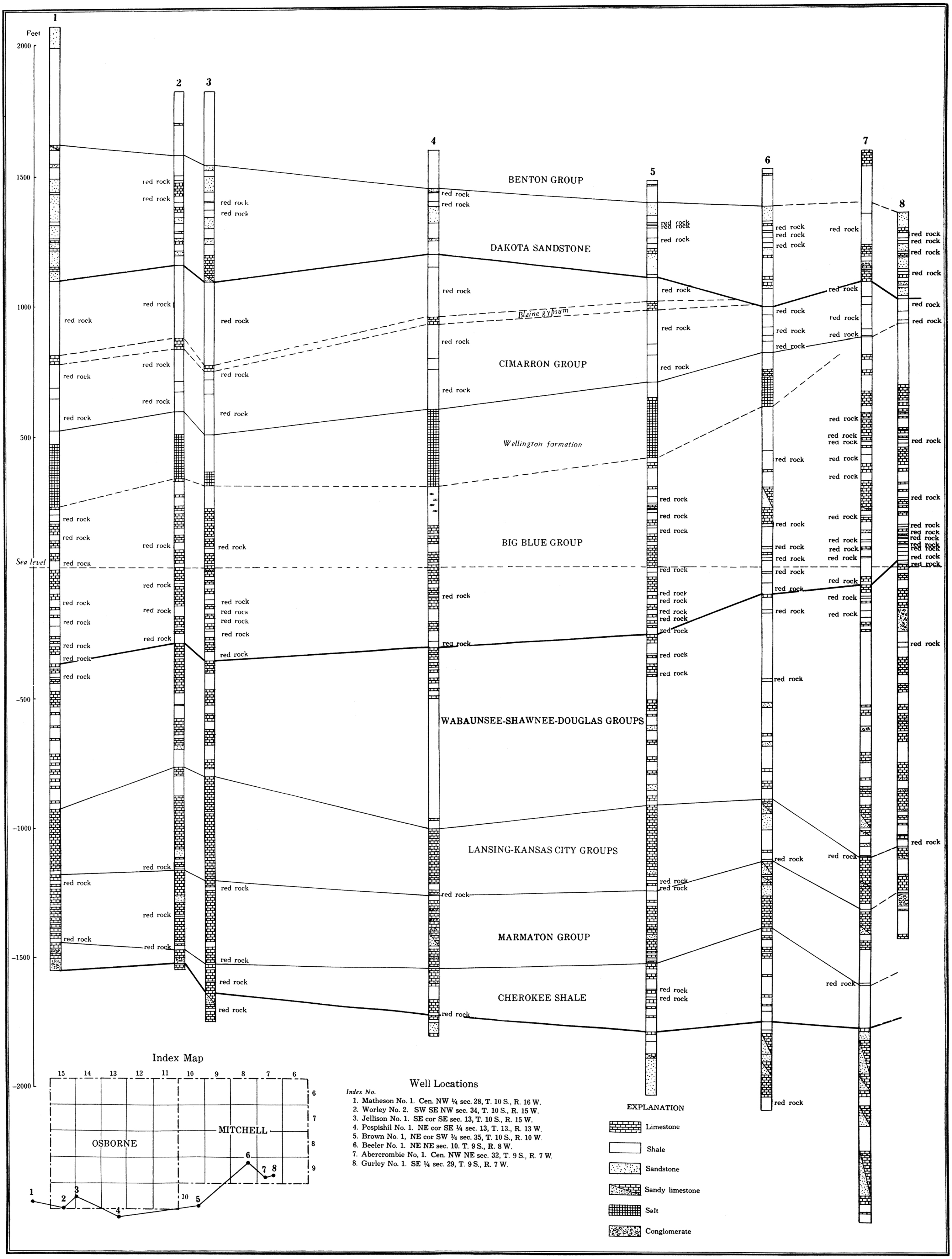



Plate IX.—Correlation of well records in southern Osborne and Mitchell counties.

The Big Blue group, comprising the Sumner, Chase and Council Grove formations, ranges from 800 to 900 feet in thickness in the area studied. The upper part, Wellington, is made up of salt, gray shale and anhydrite. The bed of rock salt varies both in thickness and lithologic character, thinning to the north and east rapidly, as can be seen in Plate —, and changing from a pure salt bed to one made up of interbedded gray shale, gypsum and salt. The purer salt beds are recognized by the drillers, but those in which there is a great deal of shale and gypsum are usually logged as shale or limestone. This uncertainty in recording the salt series makes it inadvisable to use either the top or the bottom of the salt as a basis for structural mapping. Below the salt are thin-bedded deposits of gray shale, red shale, anhydrite, gypsum, and dolomitic limestone. It is important to note that the anhydrite and gypsum beds are logged as limestone, giving the Big Blue group the appearance on the plotted logs of being largely limestone, whereas there is very little true limestone in the section. The base of the Big Blue is placed at the bottom of the lowest fairly thick red bed, until further evidence locates it more definitely.

### Pennsylvanian System.

Conformably below the Permian lies a thick series of Pennsylvanian limestone and shale which ranges from about 1,700 feet in thickness in eastern Mitchell county to about 1,200 feet in western Osborne and eastern Rooks counties. The exact top of the Pennsylvanian is difficult to place because of the lack of a marked lithologic change or an unconformity. In this report it is assumed that red-bed deposits are essentially confined to the Permian and lacking in the Pennsylvanian, and the division of the two groups is based in part on this assumption. The base of the Pennsylvanian is usually distinct, being recognized by the variegated shales, in a large part reddish, and the conglomeratic material, as well as an abrupt, well-marked change in lithology in the pre-Pennsylvanian formations. There is weathered detritus in the basal shales that is indicative of an unconformable condition.

The Pennsylvanian is divided into four parts in this report, the topmost including the Wabaunsee, Shawnee, and Douglas groups, the next the Lansing and Kansas City groups, below this the Marmaton group and at the bottom the Cherokee group. No attempt has been made to separate and identify the Wabaunsee, Shawnee, and Douglas groups. The division of the lower part of the Pennsylvanian into the Lansing-Kansas City, Marmaton, and Cherokee is based on lithologic and paleontologic evidence. The writer is indebted to Robert Roth, of the Indian Territory Illuminating Oil Company, for correlations in the lower Pennsylvanian based upon a careful study of fossil ostracodes and fusulinids. The lower Pennsylvanian section given differs from the usual classification in that it puts the "big lime," which occurs above the Oswald, in the Lansing-Kansas City group instead of correlating it with the Topeka limestone of the Shawnee group. This change, of course, lowers the assigned stratigraphic position of the Oswald lime, placing it in the upper part of the Marmaton formation instead of the Lansing.

The Pennsylvanian series shows a gradual thinning to the west, and all the formations decrease in thickness, especially the Cherokee. For example, in the Marland test, the Kyle No. 1A, sec. 11, T. 7 S., R. 10 W., Mitchell county, the formations in the Pennsylvanian have the following thicknesses: The Wabaunsee-Shawnee-Douglas group, 680 feet; the Lansing-Kansas City, 280 feet; the Marmaton, 420 feet; and the Cherokee, 340 feet; a total of 1,720 feet. In the Midwest-Skelly well, Jones No. 15, in sec. 28, T. 7 S., R. 16 W., Rooks county, the Pennsylvanian is only 1,180 feet thick, the group thicknesses being as follows: Shawnee-Wabaunsee-Douglas group, 560 feet; Lansing-Kansas City, 250 feet; Marmaton, 260 feet; and Cherokee, 110 feet. It can readily be seen that the greatest thinning is in the Cherokee, although the other members show a decrease in thickness also. Lithologically the Pennsylvanian series is made up in a large part of shale, with considerable limestone and but little sandstone. The shale units of the Pennsylvanian are characteristically gray to dark gray in color, and in many parts of the section are quite soft and calcareous. Variegated shale is not uncommon in the Pennsylvanian, especially at the contacts or unconformities between individual groups. This is especially marked in the Oswald producing zone. The limestones are generally soft, compact, and light gray or yellowish in color. Many of the beds are fossiliferous, containing abundant fusulinids and ostracodes which are of value for correlative purposes. A few of the beds are oölitic, and some of the thicker beds are cherty. The sandstones are rather scarce in the section and are usually micaceous and contain fine, angular grains.

WABAUNSEE-SHAWNEE-DOUGLAS GROUPS. The upper division of the Pennsylvanian is a thick series of limestone and shale ranging from 1,020 feet in thickness in the Gurley Abercrombie No. 1 well, in sec. 32, T. 9 S., R. 7 W., Mitchell county, to 560 feet in the Midwest-Skelly well, the Jones No. 15, in sec. 28, T. 7 S., R. 16 W., eastern Rooks county. It comprises the three major groups of the Pennsylvanian of Kansas, namely, the Wabaunsee, Shawnee and Douglas groups. It does not seem advisable on the basis of evidence at hand to attempt to distinguish these groups, but detailed paleontological study will probably make such division possible. The Douglas group is apparently very thin or lacking in this region and there seems to be evidence in many of the wells of an unconformity between the upper division and the Lansing-Kansas City below. Lithologically the group is not markedly different from the Permian above, except in the absence or near absence of red beds. The shale is generally moderately soft and gray, with little or no red shale present in the section. The limestone beds are generally fairly soft, gray to yellow in color, and in a few places are oölitic. They often yield numbers of fusulinids as well as ostracodes and shell fragments.

LANSING-KANSAS CITY GROUPS. This thick limestone series below the Wabaunsee-Shawnee-Douglas group is fairly uniform in thickness but gradually thins toward the west. The series ranges from 250 to 300 feet in average thickness. This group, known as the "big lime," is an excellent marker and is clearly defined in all wells. It has been variously placed in the Pennsylvanian stratigraphically, but the lithologic and paleontologic evidence leads the writed to regard it as belonging in the Lansing-Kansas City group. The series consists predominantly of limestone, which is usually a soft, gray, compact crystalline rock with abundant fusulinids and many ostracodes, as well as shell and bryozoan fragments. In places the limestone contains much chert of a light gray to brown color. Very little shale is found in the section, but at the base there is usually red or variegated shale which marks the contact between the Lansing-Kansas City and the Marmaton. In a few of the wells fine micaceous sandstone is found, but it is neither abundant nor common in this series.

MARMATON GROUP. Unconformably below the Lansing-Kansas City group there is a series of limestone and variously colored shale beds that is assigned to the Marmaton. In the upper part of this lies the Oswald horizon, which is a distinct zone in southwestern Osborne county but becomes indeterminate to the north and east. The Oswald has generally been placed higher in the section, but evidence from fusulinids bears out the correlation in this report.

It may be added here that any controversy arising out of this correlation will be of value if it stimulates greater interest in a careful study of the fossils found in this part of the Pennsylvanian. The Marmaton is not as constant in thickness as the Lansing-Kansas City and ranges from 260 to 400 feet, also gradually thinning to the west. The series is characterized by variegated shale near the top and by the presence in some cases of a porous limestone member which probably coincides with the Oswald porous pay in Russell county and southwestern Osborne county. The series usually has a red or variegated shale at both top and bottom. The limestones are also variable, ranging from soft white and crystalline to brown and porous. Fusulinids and ostracodes are quite abundant and an occasional small brachiopod is also found.

CHEROKEE SHALE. The Cherokee formation below the Marmaton consists predominantly of shale, but there are a few limestone beds. It is variable in thickness, mainly because it rests unconformably upon a pre-Pennsylvanian erosion surface. The formation thins to the west very markedly, being about 300 feet thick in Mitchell county wells and about 100 feet or less in the western Osborne and eastern Rooks county wells. The Cherokee shows a preponderance of reddish and variegated shale, not only at the top and bottom, but also scattered through its section. The limestone beds are generally soft and light gray in color and contain many fusulinids. Shell fragments are not uncommon, but are of little value for identification purposes. The base of the Cherokee often contains beds of conglomerate associated with red and black shale making, wherever present, a definite marker for the base of the Pennsylvanian. There is also a distinct change in the lithology of the pre-Pennsylvanian rocks which aids in identifying the base of the Cherokee.

## PRE-PENNSYLVANIAN ROCKS.

Several of the wells in Mitchell and Osborne counties have penetrated formations older than the Pennsylvanian. Notable among these wells are the Stearns-Streeter Carlin No. 1, in sec. 18, T. 6 S., R. 13 W., the Phillips Grieve No. 1, in sec. 6, T. 7 S., R. 12 W., the Mid-Kansas Boyce No. 1, in sec. 18, T. 6 S., R. 13 W., and the Gurley *et al.* Abercrombie No. 1, in sec. 32, T. 9 S., R. 7 W. The pre-Pennsylvanian formations are Mississippian limestone (?), undetermined Ordovician limestone, Decorah shale, Arbuckle limestone, and pre-Cambrian granite.

Mississippian formations were found in three wells, the Boyce, Abercrombie and Grieve. The thickness ranged from 270 feet in the Abercrombie well to 110 feet in the Grieve well. The Mississippian strata consisted of hard white chert and white to cream-colored dolomite containing a single thin white oölitic limestone bed. Basal Mississippian shale was present in the Abercrombie well. This may be Kinderhook, but as no fossils have as yet been found correlation is uncertain.

The Upper Ordovician limestone studied in the well cuttings was not definitely identified. It was a soft, white to cream-colored dense limestone, with minor amounts of sand present. Edson[18] correlates the Ordovician limestone immediately below the Pennsylvanian in the Carlin well with the Trenton limestone. Other workers in the area report the presence of Viola limestone and the Simpson formation. The Decorah shale, which has been identified in several of the wells, is distinguished by its fauna. It is usually a soft green or greenish gray shale. Bryozoans, especially *Rhinidictya mutabilis* Ulrich, are abundant in the cuttings.

The Arbuckle limestone is characterized by its crystalline dolomite, which ranges from white to brown in color, and an associated coarse subangular sand.

The pre-Cambrian was encountered in the Boyce well at a depth of 3,700 feet, and 160 feet of granite was penetrated. The cuttings were composed chiefly of feldspar and angular quartz, with a minor amount of hornblende and biotite.

The Mid-Kansas Boyce No. 1, in sec. 18, T. 6 S., R. 13 W., had the following lithology in the pre-Pennsylvanian:

Mississippian:

Undetermined formation:

| | |
|---|---|
| **3740-3810.** | Hard white opaque chert, small amount gray crystalline limestone. |
| **3810-3820.** | White oölitic limestone, white chert. |
| **3820-3845.** | Missing. |
| **3845-3860.** | Cream-colored finely crystalline dolomitic limestone, small amount of white chert. |
| **3860-3870.** | Coarse subangular to rounded sand, a little greenish shale. |
| **3870-3885.** | Coarse subangular to rounded sand, white oölitic limestone. |
| **3885-3895.** | Soft white crystalline limestone, coarse sand. |
| **3895-3905.** | Soft greenish gray shale. |
| **3905-3920.** | Soft white finely crystalline limestone. White chert. |
| **3920-3955.** | Hard white chert, coarse sand, white limestone. |
| **3955-3965.** | Missing. |
| **3965-4000.** | Hard white chert, coarse rounded sand. |

18. Edson, F. C.: Pre-Mississippian sediments in central Kansas; Bull. Am. Assn. Petr. Geol., vol. 13, pp. 441-458; 1929.

Ordovician:

Undetermined limestone:

4000-4035. White dense limestone, a little green shale.
4035-4065. White crystalline limestone, small amount green shale.
4065-4085. Soft white dense limestone, a little green shale.
4085-4095. Hard sandy limestone.
4095-4110. Soft white dense limestone, small amount chert.
4110-4155. Hard sandy limestone.
4155-4195. Soft white crystalline limestone, a little green shale.

Decorah shale:

4195-4260. Soft green shale. *Rhinidictya* sp.

Arbuckle limestone:

4260-4350. Brownish crystalline dolomite.
4350-4360. Medium coarse subangular sand.
4360-4480. Yellowish crystalline dolomite. Medium coarse sand.
4480-4500. Medium coarse, subangular to round sand.
4500-4580. Yellowish crystalline dolomite.
4580-4640. White to cream crystalline dolomite.
4640-4700. Yellowish crystalline dolomite.

Pre-Cambrian (Archean?):

4700-4860. Granite.

The Gurley *et al.* Abercrombie No. 1, in sec. 32, T. 9 S., R. 7 W., penetrated several pre-Pennsylvanian formations, as may be seen in the following description of the deeper cuttings:

Mississippian:

Undetermined formation:

3380-3410. Hard crystalline dolomite, coarse sand.
3410-3425. Hard white chert, crystalline dolomite.
3425-3450. Hard crystalline dolomite, white chert.
3450-3533. Hard white chert, white crystalline dolomite.
3533-3570. Medium hard white oölitic limestone, sand.
3570-3580. Hard white finely crystalline limestone, chert.
3580-3650. Gray fissile shale.

Ordovician:

Undetermined formation:

3650-3675. Hard white chert, much sand.
3675-3720. White dense limestone, green shale, sand.
3720-3750. White coarsely crystalline dolomite.

Decorah shale:

3750-3830. Soft green fissile shale.

Arbuckle limestone:

3830-3865. White coarsely crystalline limestone.
3865-3910. Gray coarsely crystalline limestone.
3910-3985. White dense limestone, some dolomite.
3985-4020. Gray crystalline dolomite, white limestone.
4020-4035. White crystalline limestone.
4035-4108. Missing.

## HISTORICAL SUMMARY.*

Pre-Cambrian rocks have been reached by only one well in Mitchell and Osborne counties, but it is possible to reconstruct a picture of the pre-Cambrian landscape from records of wells in adjacent counties. The region at that time was probably a broad undulating plain underlain by granite and other crystalline rocks. Erosion of the pre-Cambrian surface was brought to an end in late Cambrian or early Ordovician times by submergence beneath the sea. Thick limestone beds, subsequently altered to dolomite, and sand were deposited. Shale deposits were laid down next and these in turn were covered by thick limestones. Sedimentation during the Ordovician period was apparently interrupted several times, as some of the Ordovician formations are missing. Deposition continued on into the Devonian period, during which time more limestones were deposited. Then the land rose above the sea and erosion began. In the interval between the recession of the Devonian sea and the advance of the Mississippian sea marked orogenic movements took place. The Nemaha mountains and the Barton arch were pushed up and the Salina basin was formed between them. Mitchell and Osborne counties lie in the western part of Salina basin. Another long period of erosion followed, and a great thickness of Devonian and Ordovician rocks were eroded away. The region was probably reduced to a low plain of moderate relief by the time the Mississippian sea finally covered the area.

Two types of sediments were deposited in the Mississippian sea—a gray to black shale at the base and thick cherty limestone at the top. The silicification of the Mississippian limestone was widespread, for the limestone shows an abundance of chert wherever found.

Uplift and folding occurred again at the end of Mississippian time, and the regions of the Barton arch and Nemaha mountains were warped up as before. The Salina basin remained as a trough between the two uplifted areas. With the emergence of the land, erosional agencies began to remove the Mississippian, and in places it was entirely removed and the older formations eroded in part. Once more the area was reduced to a low plain of moderate relief, which was inundated by the Pennsylvanian sea advancing from the southeast.

The Pennsylvanian was predominantly a period of shale and lime-

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* By J. W. Ockerman and K. K. Landes.

stone deposition. The presence of unconformities between the various Pennsylvanian formations suggests that the sea oscillated back and forth on its western border. Deposition continued apparently undisturbed from Pennsylvanian into Permian, as no unconformity has been found between them. The periods are separated by assuming that no thick red beds were deposited during the Pennsylvanian. The first deposits of the Permian were gray shale, anhydrite, gypsum and salt, with a few limestone beds. The salt series thins to the north and east and is not found in northeastern Osborne county or in the northern part of Mitchell county, either because it was not deposited there or because it has been eroded away. Later in the Permian thick deposits of nonmarine red beds were laid down.

Uplift of the continent caused the withdrawal of the Permian sea. A long period of erosion followed, during which time an unknown thickness of Permian sediments was removed. Just prior to the Cretaceous (Comanchean) submergence, diastrophism elevated the eroded Permian surface in north-central Kansas and caused a rejuvenation of the streams draining the area. The outcropping shales were eroded into hills and valleys of moderate relief. Before erosion could base level this area it was submerged once more and Cretaceous deposition began. Shales and sandstones and a few limestones were deposited over the hills and valleys. The earliest sea was probably marine (Comanchean), but later in the Cretaceous this sea became land-locked and fresh-water sediments of Dakota age were deposited.

Further submergence permitted the marine waters to once more cover the land and the Graneros shales and the limestones and limy shales of the Greenhorn formation were deposited. There followed a time when the sea received large amounts of clay and silt from the streams emptying into it, and the Carlile shale was deposited. By Niobrara time the sea had once more become very limy, so the sediments deposited were highly calcareous. Before the close of the Niobrara the land began to emerge and the sea to withdraw toward the west. A long period followed during which no sedimentation occurred in Mitchell and Osborne counties, but as the area was probably at no great elevation above the sea the amount of material eroded was of small magnitude.

At the close of the Cretaceous earth movements to the west caused the formation of the Rocky Mountains and the complete withdrawal of marine waters. During the succeeding period, the Tertiary, streams running eastward from the Rockies carried a heavy load of sediment which was deposited over thousands of square miles, forming the Great Plains. A veneer of Tertiary sediment probably originally extended across both Osborne and Mitchell counties.

The Tertiary rivers finally diminished in size and deposition ceased. The streams draining Mitchell and Osborne counties began to deepen and widen their valleys so that most of the Tertiary and some of the Cretaceous rocks were removed. Some of the streams shifted their channels, leaving sand and gravel deposits where the old channels once were. The major streams finally reached the downward limit to which they could erode and commenced to deposit alluvium in the form of flood plains in the valley bottoms. Where a stream built a flood plain at a level that was but a temporary limit and then later deepened its valley a terrace was formed. This process of erosion and deposition still continues.

## STRUCTURAL GEOLOGY.

The structural geology of Mitchell and Osborne counties was studied by means of data obtained both in the field and from well logs. During the field investigation elevation readings were made with an altimeter on key horizons such as the top of the "post rock" in Mitchell county and the base of the Niobrara in Osborne county, and by means of these data a structure map of the surface formations was drawn (Plate X). As control points were fairly numerous and frequent temperature and pressure corrections were made for the altimeter readings, the writer believes this map illustrates the regional structure with fair accuracy. By calculating the elevations of different formations encountered in wells drilled in Mitchell and Osborne and surrounding counties J. W. Ockerman was able to draw subsurface contour maps illustrating the regional structure of the top of the Permian (Plate XI), the base of the Permian (Plate XII), and the base of the Pennsylvanian (Plate XIII). The number of wells was insufficient to give complete control in all parts of the two counties, so only a general picture of the subsurface structure is possible. Errors in correlation of the formations from one well to another would cause some errors in the contour maps, but the writer does not believe that these, if present at all, are of sufficient magnitude to change seriously the regional structure.

## Surface Structure.

The surface formations in north-central Kansas have a dip to the north averaging between 10 and 15 feet to the mile, but a remarkable exception occurs in Mitchell county due to the presence there of a structural basin (Plate X). This basin covers a large area in the center of the county, and the formations dip into it from all sides, especially from the southwest and northeast. Two anticlinal noses lie in the southeast part of the county and another one, which probably has some closure, lies in western Cloud county and extends over into northeastern Mitchell county. An exceptionally long, northward-plunging anticline occurs along the western side of Mitchell county and separates the basin to the east from a synclinal area to the west in eastern Osborne county.

The typical north dip in Osborne county is modified by the northern extension of the Fairport anticline which produces oil in northwestern Russell county. This anticline enters Osborne county near the southwestern corner and as it extends northward in bifurcates, one branch trending to the northeast through the town of Osborne and the other continuing only slightly east of north and entering Smith county a short distance west of Portis. As the two branches continue northward the western one increases in magnitude, while the eastern one decreases and dies out just south of the Smith county line. A small basin lies south and west of Bloomington. The southeastern township of Osborne county is structurally high and some closure probably is present there.

Some very pronounced domes lie in northern Lincoln and southern Mitchell counties. These are too local to appear on the regional structural map, but some of them have closures as great as 90 feet and dips up to 4 degrees. The most prominent domes lie east of Salt creek, in the northern part of T. 9 S., R. 8 W., and the southern part of T. 8 S., R. 8 W., and south of Salt creek, in T. 9 S., R. 7 W. Abnormal dips may be observed along most of the Greenhorn outcrop in the Salt and Rock creeks drainage. These frequently cause a stratum to dip beneath a tributary valley and then reappear again for a short distance farther up the valley. Most of the domes are elliptical in outline, but a few were noted which were practically circular. Abnormal dips were also observed northwest of Beloit, in sections 20 and 29, T. 6 S., R. 7 W. Limestones in the Greenhorn formation had a pronounced southward dip in section 29 and a relatively steep westward dip in section 20. Only a few of the domes in Mitchell county have been tested with the drill, but disappointment has so far followed all attempts to find oil in such structures both here and in Lincoln county.

## Subsurface Structure.

The contour map drawn on top of the Permian (Plate XI) is very similar to the one constructed from surface data. Both show a pronounced anticlinal nose trending northeastward from the southwestern corner of Osborne county. No bifurcation of this structure is shown on the subsurface map, but that could be explained by lack of data due to absence of wells drilled along critical parts of the fold. The synclinal area in eastern Osborne county appears on both maps. The Tipton anticline is not apparent on the subsurface map, but this may be due to lack of control points in southwestern Mitchell county. The large structural basin can only be inferred on the subsurface map by the manner in which the contour lines diverge when approaching this area. South-central Mitchell county is high on all three of the subsurface maps.

The base of the Permian (Plate XII) dips westward in Osborne and western Mitchell county at a rate of about 7 feet to the mile. A northward trending anticlinal nose extends into southern Mitchell county from Lincoln county. A similar anticline extends into the southwestern corner of Osborne county. Although control points are scarce in central Mitchell county the dips appear to flatten out there.

The basal Pennsylvanian structure (Plat XIII) is dominated by a northward plunging syncline through central Osborne county and a northward plunging anticline in south-central Mitchell county. The lowest elevations are in the vicinity of Portis in north-central Osborne county while the highest are in the southwestern corner of the same county. The relatively steep rise to the southwest is caused by the presence of the Fairport anticline in northwestern Russell county. The elevation of the base of the Pennsylvanian is 200 feet higher in southwestern Osborne county than it is on the axis of the anticline in southern Mitchell county.

The lack of uniformity between the structure of the base of the Permian and that of the base of the Pennsylvanian is due to thickening of the Pennsylvanian sediments to the east and northeast.

## Origin of Surface Structures.

The well-developed domes occurring in southern Mitchell and northern Lincoln counties appear to be ideal places in which to drill. Yet several of the domes have been tested and no oil has been found

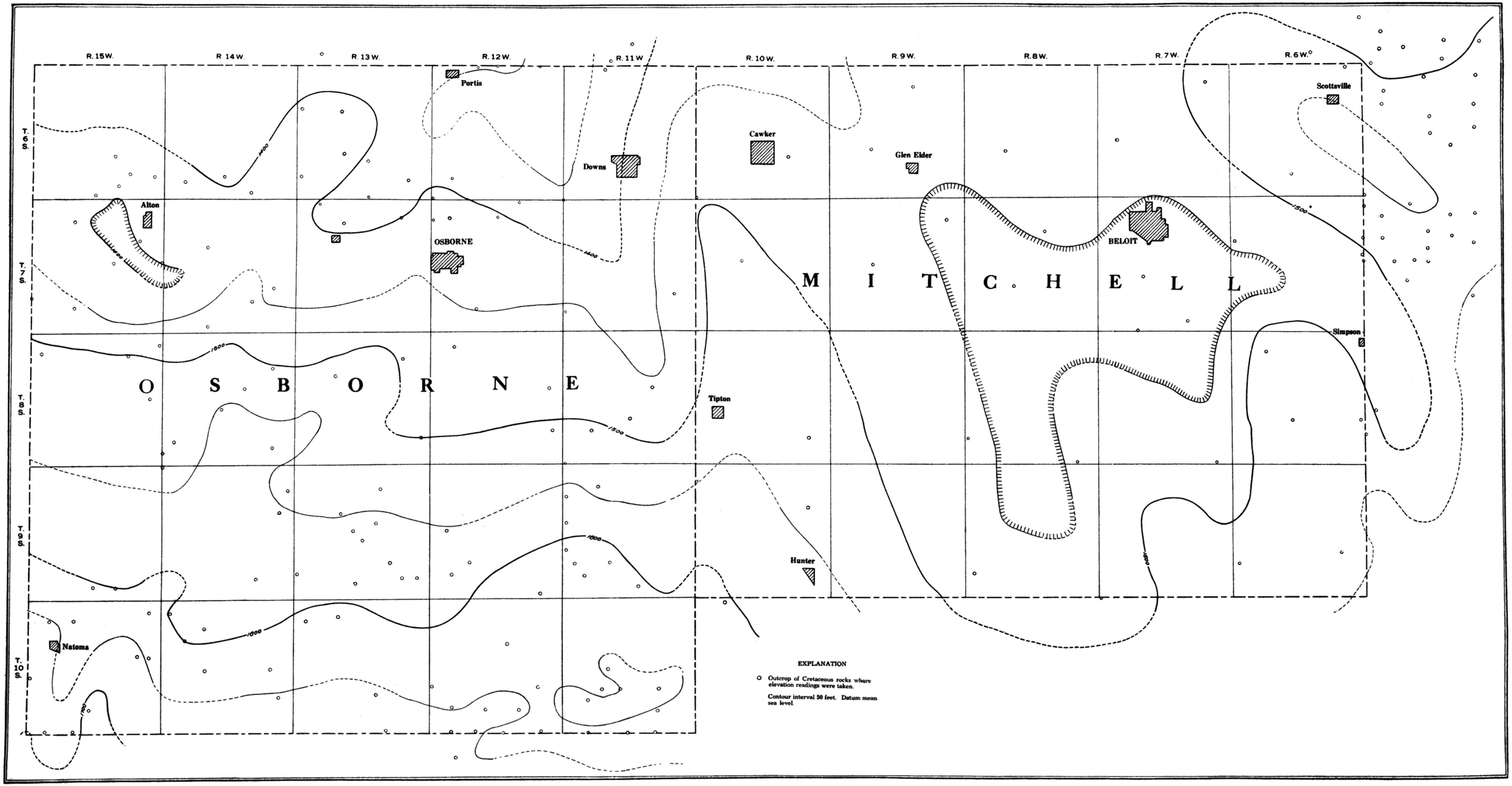


PLATE X.—Structural contour map of top of Greenhorn formation, Osborne and Mitchell counties.

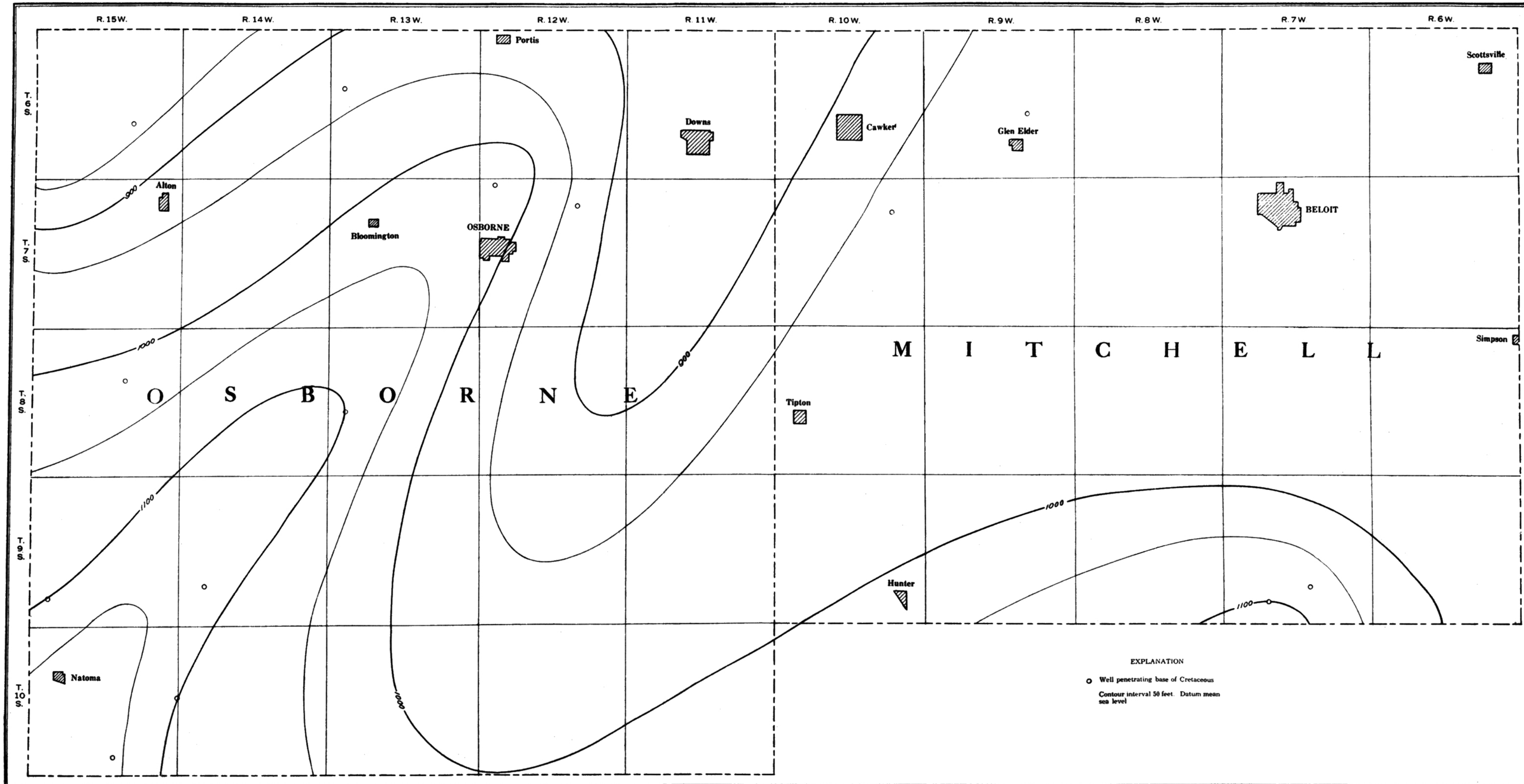


PLATE XI.—Structural contour map of top of Permian, Osborne and Mitchell counties.

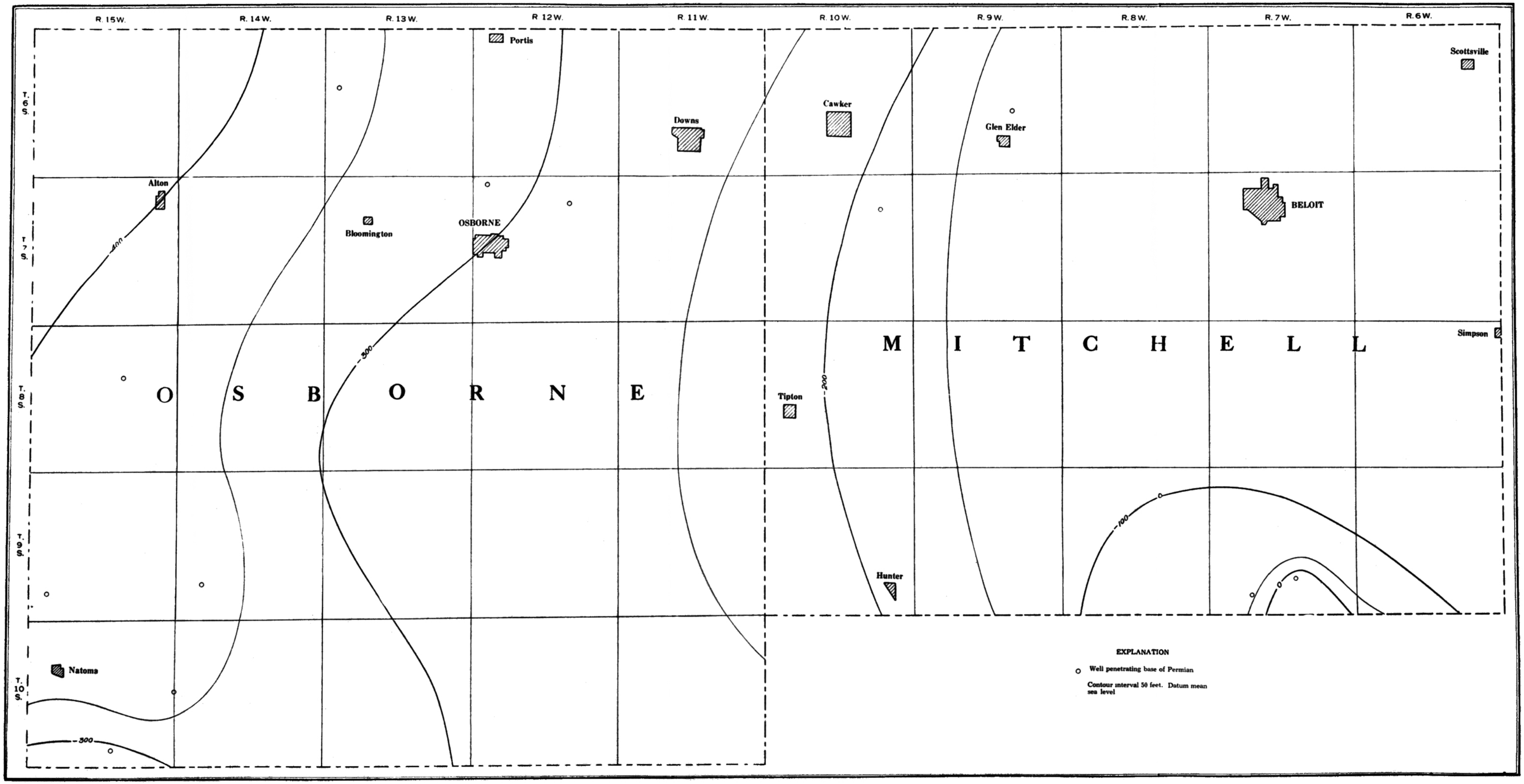


PLATE XII.—Structural contour map of base of Permian, Osborne and Mitchell counties.

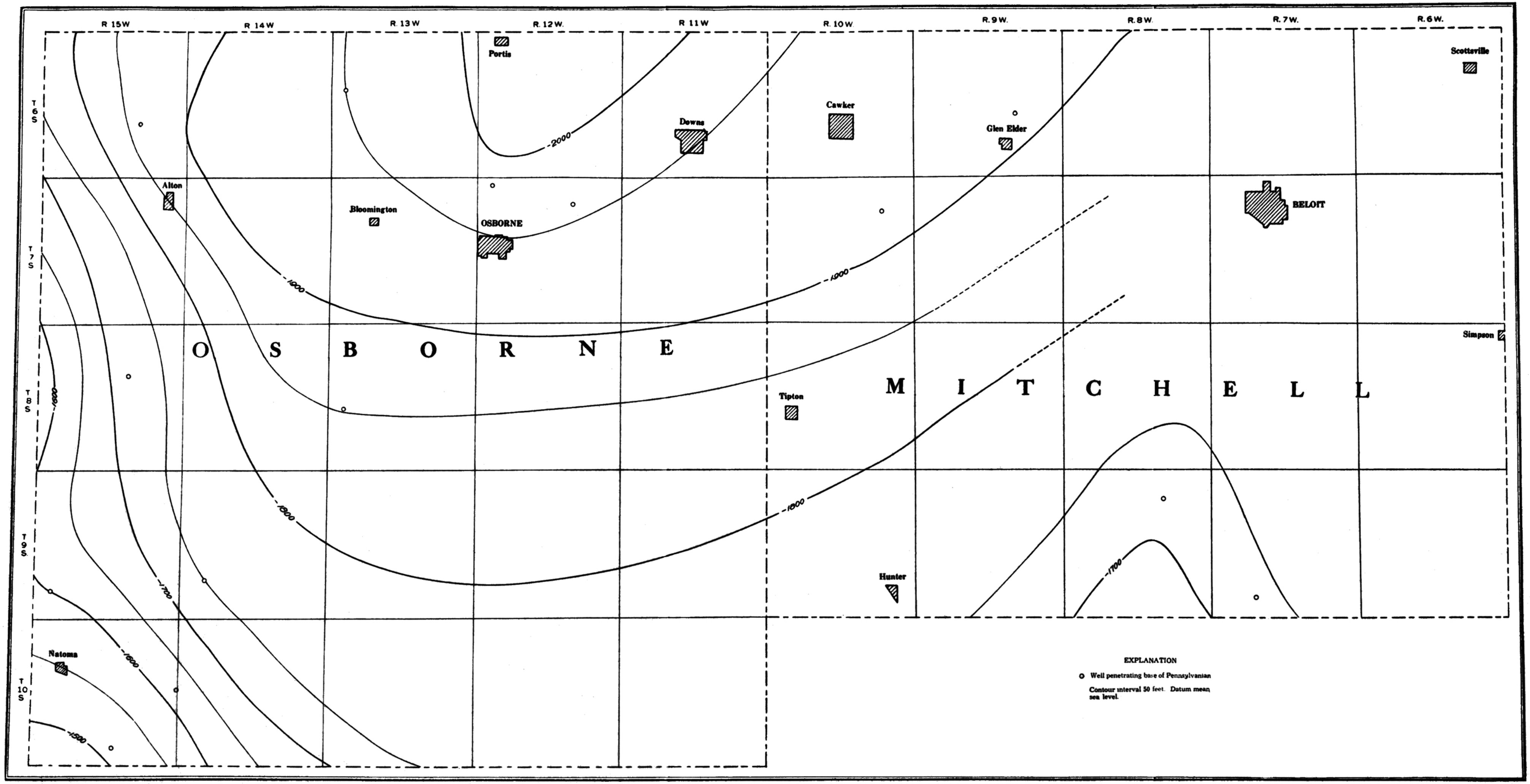


PLATE XIII.—Structural contour map of base of Pennsylvanian, Osborne and Mitchell counties.

in them. Furthermore, it appears that some of the wells which were best located in regard to surface structure actually found the Pennsylvanian formations at lower elevations than near-by wells. Such was the case in the Abercrombie and Gurley wells shown at the right side of the correlation chart (Plate IX). The Abercrombie well entered the Permian about 60 feet higher than the Gurley, but was 80 to 90 feet lower in the Pennsylvanian. The writer believes that the sharp domes so common in this section of Kansas are confined to the Cretaceous rocks and are due to inclined deposition of the Cretaceous sediments on the flanks of Permian hills. A more complete discussion of this problem is in preparation.

## ECONOMIC GEOLOGY.

### Oil and Gas.

Although at the present time (June, 1930) there is no oil or gas production in either Mitchell or Osborne county, there has been a good deal of prospecting. Nineteen wells have been drilled to depths ranging from 2,200 feet to 4,860 feet. Thirteen of these were drilled in Osborne county and the remainder in Mitchell. A list of the wells follows:

| *Company.* | *Farm and location.* | *Depth in feet.* |
|---|---|---|
| Mitchell county: | | |
| Marland | Beeler 1, NE¼ NE¼, sec. 10, T. 9 S., R. 8 W. | 3,605 |
| Gurley *et al.* | Abercrombie 1, center NW¼ NE¼, sec. 32, T. 9 S., R. 7 W, | 4,108 |
| Royal Union | Gurley 1, SE¼, sec. 27, T. 9 S., R. 7 W. | 2,780 |
| Marland | Kyle 1, SW cor. NE¼, sec. 11, T. 7 S., R. 10 W. | 2,588 |
| Marland | Kyle 1A, NE cor. SW¼ NE¼, sec. 11, T. 7 S., R. 10 W. | 3,520 |
| Wilcox Oil & Gas Co. | Gish 1, NW cor. SW¼ NW¼, sec. 23, T. 6 S., R. 9 W. | 3,634 |
| Osborne county: | | |
| Benedum-Trees | Paynter 1, NE¼ SE¼, sec. 22, T. 6 S., R. 15 W. | 3,650 |
| Mid-Kansas | Boyce 1, SE cor. NW¼, sec. 18, T. 6 S., R. 13 W. | 4,860 |
| Mid-Kansas | Towne 1, NE¼ NW¼ NE¼, sec. 35, T. 7 S., R. 13 W. | 2,200 |
| Neiswanger *et al.* | Turner 1, NE cor. NE¼, sec. 10, T. 7 S., R. 12 W. | 2,986 |
| T. C. Johnson | Cooley 1, center NW¼ NE¼, sec. 15, T. 8 S., R. 15 W. | 3,607 |
| Stearns & Streeter | Carlin 1, SW cor. NE¼, sec. 19, T. 8 S., R. 13 W. | 3,990 |
| Davis-Druger *et al.* | Preuter 1, SW¼ SE¼, sec. 30, T. 9 S., R. 15 W. | 3,703 |
| Empire | Crist 1, SE cor NE¼, sec. 30, T. 9 S., R. 14 W. | 3,775 |
| Jarvis *et al.* | Jellison 1, SE cor. SE¼, sec. 13, T. 10 S., R. 15 W. | 3,576 |
| Liggett *et al.* | Worley 2, SW¼ SE¼ NW¼, sec. 34, T. 10 S., R. 15 W. | 3,365 |
| Liggett *et al.* | Worley 1, NW cor NW¼, sec. 34, T. 10 S., R. 15 W. | 3,600 |
| Delhi | Dorman 1, SW ¼ SW¼, sec. 20, T. 10 S., R. 11 W. | 3,478 |
| Phillips | Grieve 1, NW¼ SE¼ NE¼, sec. 6, T. 7 S., R. 12 W. | 4,383 |

Seven of the nineteen wells reported shows of oil or gas. The sole Mitchell county well to give any encouragement was the Beeler No. 1, which reported a show of oil at a depth of 3,335 feet. The Turner No. 1, in northeastern Osborne county, had a show of gas at a depth of 2,777 feet, and the Carlin No. 1, near the center of the county, had an oil show in a thick sand between 2,670 and 2,736 feet. A good show of oil at a depth of 2,840 feet was reported by the Dorman No. 1, in the southeastern corner of Osborne county, but the producing sand was only 3½ feet thick. The Preuter No. 1 and the two Worley wells, in southwestern Osborne county, are the remaining ones to report shows. The Preuter had a show of oil at a depth of 3,515 feet and the Worley No. 1 logged a show of gas at 2,488 feet, oil in limestone between 3,120 and 3,125 feet and good shows of oil and gas between 3,145 and 3,155 feet, and between 3,170 and 3,175 feet. The Worley No. 2 (in the same section) had a gas show in limestone between 2,725 and 2,810 feet, shows of gas and oil between 3,037 and 3,044 feet, and an oil show between 3,058 and 3,068 feet.

The oil-producing areas nearest to Osborne and Mitchell counties are in northwestern Russell county (the Fairport field) and in southeastern Rooks county.[19] There is no production to the north and east, and the closest producing fields to the southeast lie in McPherson and Rice counties.

Most of the tests drilled in Osborne county were located on the northeastward-trending bifurcating anticline shown on the surface-structure map (Plate X). The Mitchell tests were drilled on sharp local domes which do not appear on the regional structure map. Unfortunately the structure of the Cretaceous rocks does not in all cases continue downward into the deeper and older sediments, so it is precarious to try to find oil in the Pennsylvanian and pre-Pennsylvanian formations of Mitchell and Osborne counties on the basis of surface structure. The control points are too few and too scattered on the structure contour map of the base of the Pennsylvanian (Plate XIII) to show up any local anticlines that may be present. The only area that appears to be at all favorable for prospecting on the Pennsylvanian map is the anticlinal nose in southern Mitchell county. It is interesting to note that the only well in Mitchell county to record a show of oil was the Beeler well, which was located near the axis of this anticline but well down on the nose. A well drilled farther south would be higher on the Pennsylvanian structure and would have a better chance of striking oil.

The presence of nineteen dry holes in Mitchell and Osborne counties does not necessarily condemn these two counties as potential producers of oil and gas. It is very doubtful if any of the tests were well located in regard to the rock structure of the Pennsylvanian

19. Kesler, L. W.: Oil and Gas Resources of Kansas in 1927, Kan. Geol. Survey, Mineral Resources Circular No. 1, p. 44; 1928.

and older formations. Before future wells are drilled it is advisable to map the subsurface structure by means of core-drill holes carried down into the Permian, preferably to a point below the salt series.

## Sand and Gravel.

Sand and gravel are in constant demand, mainly for use in surfacing roads and in concrete. The expense of road-surfacing and concrete work can be materially decreased if near-by beds of these materials can be found. The deposits of sand and gravel in Mitchell and Osborne counties are divisible geologically into two types, recent stream deposits and prehistoric stream deposits. The former type is found in the present river flood plains and in the low terraces, which are dissected remnants of slightly older flood plains. The older stream deposits are of Pleistocene (?) age and were formed by streams which existed at a higher elevation and followed an entirely different drainage from those of to-day. Erosion by present streams has in most cases completely destroyed those older deposits, but here and there a remnant is left from which sand and gravel can be quarried. Deposits of this type are much more important commercially in Mitchell and Osborne counties than those formed by the present streams.

The supply of material of Recent age is very great, but unfortunately it is too fine in most places to meet modern requirements for road surfacing and concrete. Sand has been produced from a number of bars along the Solomon river in times past. At least two such bars have been exploited in the vicinity of Beloit. One is the Barger pit west of town, and a sample from it is described by Seaton and Taylor as follows:[20]

A sample from the Barger pit at a bend of the Solomon river near Beloit. It was sent by A. E. Home, county engineer, Beloit, Kan., who considered it a fair sample of the run of the pit. Besides the quartz and feldspar, it contained a very small percentage of softer minerals. The gravel consisted of rounded pebbles and flat stones 3 inches to 4 inches across, the whole making up 8 per cent of the total sample. This sand ranked eleventh in the tests, with a strength 5 per cent greater than the standard. It should be noted that this rating is based on the results from two briquettes only, and therefore should not be considered as entirely conclusive.

Another pit south of town was described by the same authors as follows:[21]

20. Seaton, R. A., and Taylor, I. I.: Tests of Kansas Sands for Use in Mortar and Concrete; Kan. St. Agr. Col., Eng. Exp. Sta., Bull. 3, p. 29; 1916.

21. Op. Cit., p. 41.

A sample from a bar of the Solomon river near Beloit. It was taken from sand delivered for concrete and was sent by A. E. Home, county engineer, Beloit, Kan. It contained a small percentage of the softer minerals and also a small percentage of small soft shells and 1.4 per cent of silt. The gravel made up 6 per cent of the total sample and contained small shells, hard mud, and sand lumps. It ranked forty-sixth in the tests, with a strength 80 per cent of the standard.

J. P. Boesche, county engineer of Mitchell county, reports the recent exploitation of a sand bar in an abandoned channel of Solomon river south of Beloit and states that the sand was used for plaster and concrete, but was pretty fine for the latter use.[22] A similar sand bar two miles east of Alton, in the northwest corner of sec. 8, T. 7 S., R. 14 W., Osborne county, has been recently worked and the coarse sand used for road surfacing.

The sand and gravel obtained from the older river channels is much coarser and is in demand by road builders. The prehistoric streams evidently moved with more speed than the modern streams, for they could transport fragments of larger size. The sand-and-gravel deposits in northern Mitchell and western Cloud county are so aligned that it is possible to determine roughly the location of one such ancient stream. A sand-and-gravel deposit about two miles northeast of Cawker, in the northeast quarter of sec. 24, T. 6 S., R. 10 W., lies at the upstream end of the known section of this river. The old stream channel can be traced from that point east and southeast roughly parallel to and about two miles north of the present Solomon river through deposits lying in sec. 23, T. 6 S., R. 9 W., sec. 29, T. 6 S., R. 8 W., and a row of closely connected deposits just east of the county line in the southwest corner of T. 7 S., R. 5 W., Cloud county.[23] Unfortunately erosion by the tributaries of Solomon river has removed most of the sand and gravel which at one time occupied this river channel. However, it is undoubtedly true that not all the remnants have been discovered as yet, so favorable results should follow sand-and-gravel prospecting along a line drawn through the known deposits. The most likely places on this line are where it crosses divides between the Solomon tributaries. Furthermore, it is possible that extension of the line to the west would aid in locating new deposits in that direction.

Descriptions of the individual pits follow:

22. Informal communication.

23. For a description of sand and gravel in southwestern Cloud county see Wing, M. E.: Geology of Cloud and Republic Counties, Kan. Geol. Survey, Bull. 15. These deposits have been extensively utilized by Mitchell county in road work between Beloit and the Cloud county line.

*North center of the northeast quarter sec. 24, T. 6 S., R. 10 W. (about 1½ miles north of Waconda Springs).* The material quarried here consists of quartz sand and flat white chalk pebbles. The latter were undoubtedly derived from erosion of the Fort Hays limestone which at one time covered this area. A septarian concretion with a diameter of 2½ to 3 feet and a probable weight of at least 300 pounds was uncovered during the excavation of this pit. As this stone is too heavy to have been transported by the stream which deposited the gravel, it must have rolled down from near-by Blue Hill shale which cropped out along the upper valley slopes at that time, but which has since been entirely removed by erosion. The stream bed lies on a level with the lower Fairport shale, and as the septarian concretions lie at least 200 feet higher the ancient valley must have been relatively deep and steep-sided in this vicinity. The concretion was covered by stream gravel and thus preserved.

*Northwest quarter sec. 23, T. 6 S., R. 9 W. (about 1½ miles north of the eastern edge of Glen Elder).* A circular pit about 8 feet deep and 150 feet across has been excavated into a gravel bed containing flat fragments of Fort Hays limestone, smaller spherical pebbles of the same material, coarse quartz sand with a few pebbles, and silt. The material is loosely cemented and is covered by a soil overburden ranging in thickness from a few inches to 5 feet.

*Northeast quarter of the southeast quarter of sec. 29, T. 6 S., R. 8 W. (about 4 miles due east of Glen Elder).* This is a newly opened pit in which is exposed a highly cross-bedded mixture of quartz sand and limestone gravel. As in the other pits, the gravel is composed mostly of Fort Hays fragments, but in addition there are a number of larger limestone slabs, ranging in thickness from 2 to 3 inches and in length from 8 inches to 1½ feet. These pieces are too large to have been transported any distance and were undoubtedly derived from locally outcropping lower Fairport limestones, which they resemble in appearance very closely.

In addition there are a number of other sand-and-gravel deposits which are so isolated that they cannot be connected up into any ancient drainage system. Perhaps sufficient additional deposits will eventually be discovered so that it will be possible to plot the courses of other Pleistocene (?) streams, and then the search for new deposits can proceed on a more scientific basis. Descriptions of isolated deposits visited by the writer follow:

*Western edge of southwest quarter of sec. 20, T. 9 S., R. 10 W. (about 6 miles south of Tipton).* A road cut here exposes a mixture of quartz sand and Fort Hays fragments very similar to the deposits north of Solomon river. This deposit has not as yet been exploited, but it may later be opened up for the purpose of surfacing roads in this section of the county.

*Secs. 27 and 28, T. 10 S., R. 14 W. (southwestern Osborne county).* This deposit is about 10 feet thick and caps the ridges. It is composed of mixed gravel, sand, and chalk pebbles, and has been used for building.

*Southeast corner sec. 6, T. 7 S., R. 13 W. (1 mile northwest of Bloomington).* Two pits have been excavated with a maximum depth of about 15 feet.

The overburden ranges from 1 to 3 feet. The gravel is obviously waterlaid, but it is composed practically entirely of Fort Hays fragments. The size is also remarkably uniform, with a high percentage of the pebbles between ½ and 1 inch in diameter. A few larger pieces 8 inches to 1 foot in length are also present.

*Center of west edge of sec. 30, T. 6 S., R. 12 W. (4½ miles north of Osborne).* This deposit has been opened up by two large adjoining pits. It is very similar to the one described in the preceding paragraph, except that the material is apparently a little finer and contains streaks of very fine calcareous sand a foot or so in thickness. A fringe of hills capped by Fort Hays limestone lies a short distance to the south and west, and the deposit thins in those directions. Material taken from this quarry was used to surface highway U. S. 40 N. between Osborne and the Solomon river crossing west of Downs. The highway in the vicinity of Downs was surfaced by material taken from a quarry in sec. 3, T. 6 S., R. 11 W., which was not visited by the writer. In addition there are a few other sand-and-gravel deposits in Mitchell and Osborne counties which were not visited during the course of the field work, and hence are not described.

## Ground Water.

Fresh Water Supplies. Water is obtained in Mitchell and Osborne counties from river flood plains, bedrock sandstones, and the thicker alluvial deposits. Wells drilled to a depth of 35 or 40 feet in the flood plain of Solomon river strike the so-called river underflow and produce large supplies of water. This water is hard but potable. To get a large supply of water on the uplands it is necessary to drill to a porous bedrock stratum, such as a sandstone. The Dakota sandstone, reached at an average depth of 140 feet, contains ample water, but with the exception of the region south and east of Beloit and a narrow zone in the northeast corner of Mitchell county, the water is too highly mineralized for domestic use.[24] However, Darton[25] believes that the salt water comes from saliferous shale which occurs at the top of the Dakota, and deeper drilling into the lower sandstones might encounter fresh water. Proper casing off of the salt water would be necessary before this lower water could be obtained in unpolluted condition. It is possible in western Osborne county to drill 100 to 200 feet and encounter the Codell sandstone, which usually carries a good supply of potable water. Where the Tertiary mantle is thick good water may be obtained from porous layers in the Ogallala. Shallow wells dug in soil or alluvium are utilized for small and generally unreliable water supplies in the

24. Data supplied by W. H. Drinkern, well driller, Beloit, Kan.
25. U. S. Geol. Survey, Prof. Paper 32, pp. 307-311.

upland areas where salt water only is encountered in depth. Cisterns are also resorted to in these localities.

WACONDA SPRINGS.[26] Three springs of mineralized water occur in the Solomon river valley in Mitchell county about 2½ miles southeast of Cawker City. The largest one, known as Great Spirit spring, is the only one usually visited. It is situated at the northern edge of the river plain and by precipitation of the less soluble compounds which the waters carry in solution has built up a mound 42 feet high with a diameter at the base of 300 feet and at the top 150 feet. The top is nearly flat, with a craterlike depression in the center 35 feet deep and abount 54 feet across. This depression is filled with water, but overflow is rare, due to escape of the water through openings on the flanks of the mound. The water contains over 1,120 grains of mineral matter per gallon, of which 775 grains are sodium chloride (salt), 206 grains sodium sulphate, 66 grains magnesium sulphate (Epsom salts), 41 grains magnesium carbonate, and 31 grains of calcium carbonate. A second spring lies about ½ mile southeast. It is situated on the flood plain adjacent to the river and has not had opportunity to build a mound due to erosion by high waters. The water of this spring has a similar composition to that of Great Spirit spring. The third spring is located a short distance south in the bed of the river and is accessible only in low water.

Contrary to local belief the Waconda springs are in no way volcanic, and neither do they have any connection with the ocean. They are merely artesian springs and the water is mineralized because it comes from the saliferous shale lying at the top of the Dakota. Drilled wells penetrating this formation produce water of the same type. The water in the Dakota formation is under pressure, as shown by the manner in which it rises in wells. The 100 feet or so of shale and limestone lying between the top of the Dakota formation and the surface at Waconda has been penetrated by an unusually persistent fissure which has permitted the water to escape. Natural channel ways are being used by the ascending water instead of holes drilled by man.

Adjacent to Great Spirit spring is a health resort consisting of a hotel and bathhouses. The water has been bottled and shipped for many years.

26. Description and chemical data from E. H. S. Bailey: Special Report on Mineral Waters, Kan. Univ. Geol. Survey, vol. VII, pp. 197-206; 1902.

## Building Stone.

The most popular building stone in Mitchell and eastern Osborne counties is the topmost limestone of the Greenhorn formation, the well-known "fence post" limestone, or "post rock." Due to its stratigraphic position the areal distribution of this rock can be noted on the geological map by following the contact line between the Greenhorn and Carlile formations. The "post rock" is generally

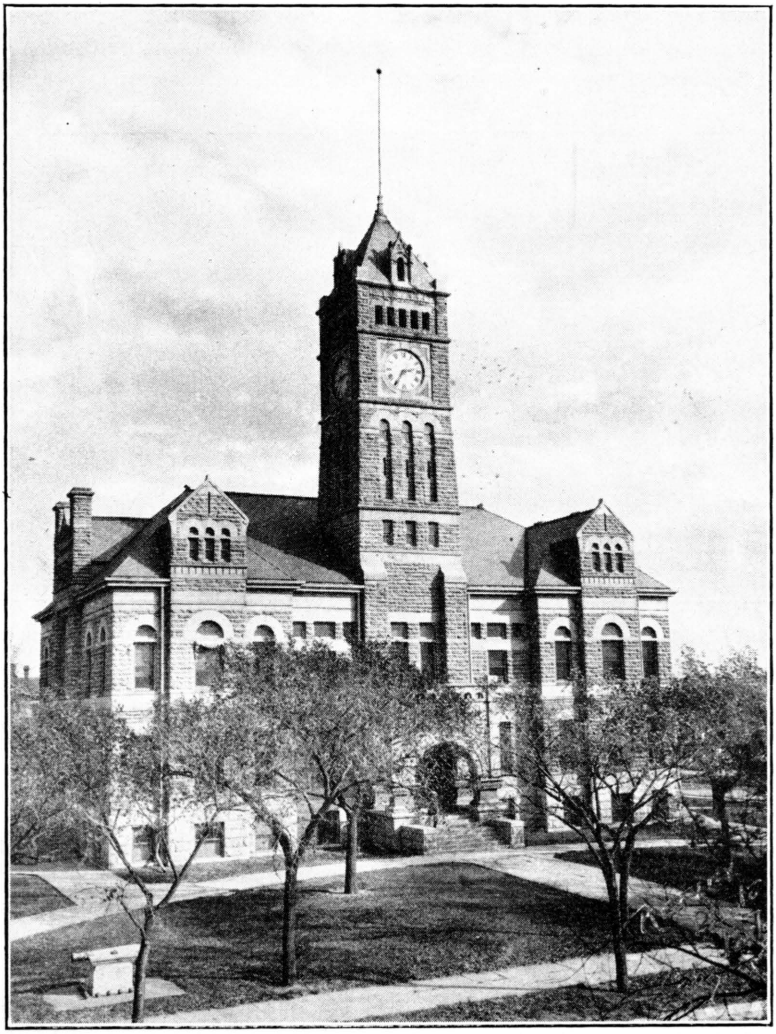

PLATE XIV—Mitchell county courthouse, Beloit, constructed of "post rock."

8 to 9 inches thick, and at or near the middle of the layer a remarkably persistent and characteristic red-colored seam is found. Other limestones above and below the "post rock" may also exhibit an iron-stained seam, but in none of these is the seam as persistent or the rock as hard and thick. The presence of the iron seam gives the "post rock" a pleasing appearance in buildings. The limestone is quarried by stripping off the overburden and then boring rows of holes through the rock, by means of which blocks of desired dimension are wedged off. There are miles of abandoned "post rock" quarries along the south bank of the Solomon river valley and also on the north bank where the slopes are sufficiently steep to prevent

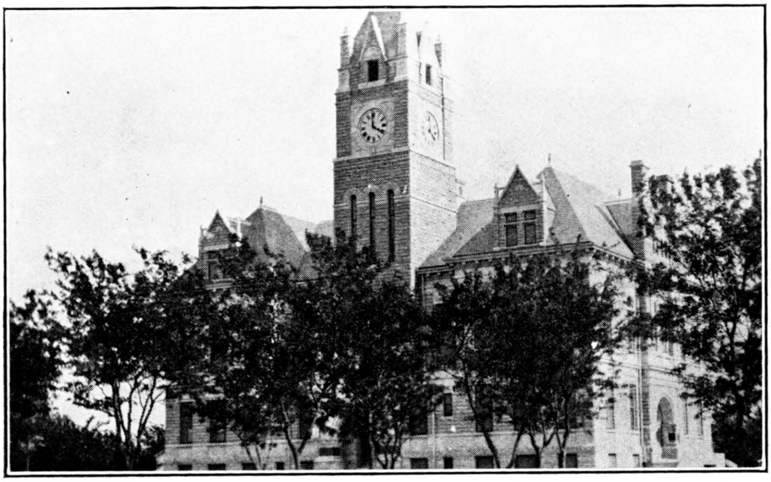

PLATE XV.—Osborne county courthouse, Osborne, constructed of Fort Hays limestone.

deep soil formation. Many of the quarries have been abandoned so many years that they are grass-covered, and the only means of recognition are the dumps of stripped-off overburden. The great linear extent of some of the quarries is due to the fact that it is cheaper to extend the quarry along the outcrop than to strip off a constantly increasing thickness of overburden. Although some of the quarries in Mitchell county are of comparatively recent age, no operations were being carried on in the summer of 1929. The reasons for this are probably that enough of the limestone has been quarried to satisfy the local market for fence posts, that increased labor costs make the rock a rather expensive building stone, and that concrete has come into extensive use for the construction of buildings. Because of the treeless character of the uplands in this section of Kansas stone fence posts are common. A great many dwellings, schoolhouses, business blocks, and public buildings, especially in Mitchell county, have been built with "post rock." It is also used in walls, and large slabs are split along the iron seam and used for sidewalks.

The so-called "shell rock," the uppermost limestone in the Jetmore member of the Greenhorn, is quarried rather extensively along the western border of Mitchell county. A quarry in the "shell" was noted on the north side of the west center of sec. 31, T. 9 S., R. 7 W., from which fence posts have been secured. Similar quarries were observed in the southeastern corner of the county. The "shell rock" in this locality is used entirely for fence posts, but farther east it has been used in buildings.

Hard beds occurring in the Fort Hays member of the Niobrara formation have been utilized for building stone in central and western Osborne county. The stone has a yellowish cream color and a pleasing appearance.

## Coal.

No coal has been mined in Mitchell county for a number of years, and none has ever been mined in Osborne county. A persistent seam of lignite occurs about 30 feet below the top of the Dakota formation, and its outcrop has been traced through Republic, Jewell, Cloud, Mitchell, Lincoln, Russell, and Ellsworth counties. It has not been consistently reported in wells drilled to the west of the outcrop, so it may disappear in that direction. The thickness ranges from 10 to 36 inches. The only possible areas in Mitchell county where it could outcrop or be sufficiently close to the surface to mine are in the Solomon valley below Beloit and in the Salt and Rock creek bottoms. If present in Osborne county its depth would be 100 to 350 feet below the surface.

The Dakota coal of western Kansas does not constitute an economic resource of any immediate importance. But at one time mines in this area were successfully operated. The fifth report of the state inspector of coal mines, for the year 1891, states concerning Mitchell county:

ANALYSIS. Kind of coal, lignite; average thickness of vein, 14 inches; total output, 1890, 23,700 bushels, or .03 per cent of the total output of the state; 1891, 26,000 bushels, or .03 per cent of the total output of the state; estimated value of output, 1890, $1,777; 1891, $1,950; number of employees, 1891, 20.

But little mining is done in this county, except during the winter months.

The openings are all on the drift plan, and the work is performed largely by farmers and their families. The trade is entirely local. Saltville is the post-office address of the men who run the drifts in this county.[27]

Saltville post office, now abandoned, was located in the northeast corner of the southeast quarter of sec. 9, T. 9 S., R. 7 W. The mines were located on Salt and Rock creeks. One of these was reported to the writer as being located in the northwest corner of sec. 22, T. 9 S., R. 8 W. Mines have also been mentioned in the Solomon river valley.[28] The Blue Hill Mining Company is reported to have mined coal in the southeast quarter of sec. 32, T. 8 S., R. 9 W.[29] Inasmuch as this area lies in the outcrop of the Blue Hill shale it is believed that this coal must have come from a local carbonaceous phase.

## Miscellaneous.

SALT. Well records show that salt underlies all but the northern end of Osborne county, and the northern and eastern sides of Mitchell county. The salt occurs in the Permian strata and ranges in thickness from only a few feet to over 150 feet. The depth ranges from 800 feet at the Beeler well, in sec. 10, T. 9 S., R. 8 W., Mitchell county, to 1,625 feet in the Prater well, in sec. 30, T. 9 S., R. 15 W., Osborne county. Salt is obtained commercially from depths lying between 800 and 1,000 feet at several places in Kansas, the nearest plant being at Kanopolis, in Ellsworth county. Present market conditions do not justify the erection of another salt plant in Kansas, but the geological conditions are just as favorable for salt mining in southwestern Mitchell county (for instance at Hunter) as they are at Kanopolis.

HELIUM. Of considerable scientific interest is the presence of helium in gas obtained from a well drilled about 3 miles southwest of Victor, in Mitchell county, by W. H. Drinkern, of Beloit. The depth from which the gas is secured is 136 feet, which would place it in the Dakota formation. An analysis of the gas follows:[30]

| | |
|---|---|
| Carbon dioxide | 18.72 |
| Oxygen | 0.31 |
| Methane | 0.95 |
| Nitrogen | 80.02 |
| Helium | 1.08 |
| Total | 101.08 |

27. Ibid., p. 37.
28. Crane, W. R.: Kan. Univ. Geol. Survey, vol. 3, p. 143; 1898.
29. Jordan, A. E.: Informal communication.
30. Government analyst. Data furnished by W. H. Drinkern.

Although the percentage of helium is unusually high, the total amount present cannot be very great, as the quantity of gas is small. The helium is probably derived from the disintegration of radioactive minerals contained in the Dakota sandstone.

□

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