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# GEOLOGY AND WATER RESOURCES

OF A PORTION OF THE

# MISSOURI RIVER VALLEY IN NORTH-EASTERN NEBRASKA

BY

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# GEOLOGY AND WATER RESOURCES OF A PORTION OF THE MISSOURI RIVER VALLEY IN NORTHEASTERN NEBRASKA.

By G. E. Condra.

## INTRODUCTION.

The region considered in this report lies in northeastern Nebraska, south of Missouri River, and extends about 150 miles east and west and approximately 29 miles north and south. The total area is over 4,100 square miles, comprising Dakota, Cedar, Knox, and Boyd counties and the northern part of Holt County, as shown in Pl. I.

The eastern part of the area was settled long ago, and the western counties are now rapidly filling up. The entire region has a fertile soil, and there is sufficient rainfall to insure crops in most seasons, especially where careful cultivation is practiced. Very little irrigation is needed, and a few short ditches constructed during exceptionally dry years are not used at present. In 1903 no irrigation whatever was employed.

Stock raising is carried on extensively where the land is not farmed. There is an abundance of ground water throughout most of the area, yet at places in Boyd, Knox, and Holt counties there is difficulty in obtaining a sufficient supply of good well water for stock and domestic purposes. On this account considerable space is given in this report to ground water and shallow wells in those counties.

Many springs, some of them of good volume, are found in every county. Artesian wells are obtained on the Missouri bottom and adjacent lowlands from eastern Boyd to the northeastern part of Dixon County.

This report is a result of studies made in the field during the summer of 1903, under the direction of N. H. Darton. There was found to be much local interest in cement rock, coal, and the water conditions. Special trips were made into Dixon and Dakota counties with Prof. J. E. Todd, who has furnished important suggestions as to the geology and has supplied several sections. It was found necessary to determine the broader structural and stratigraphic relations of the Cretaceous formations, and, in order to do this, observations were continued into Iowa and South Dakota.

Only about 250 square miles of the area have been topographically surveyed and these are included in the Elk Point quadrangle, which extends from South Dakota into Dixon and Dakota counties. Outside of that area altitudes were obtained from railroad levels and by the use of an aneroid barometer.

## TOPOGRAPHY.

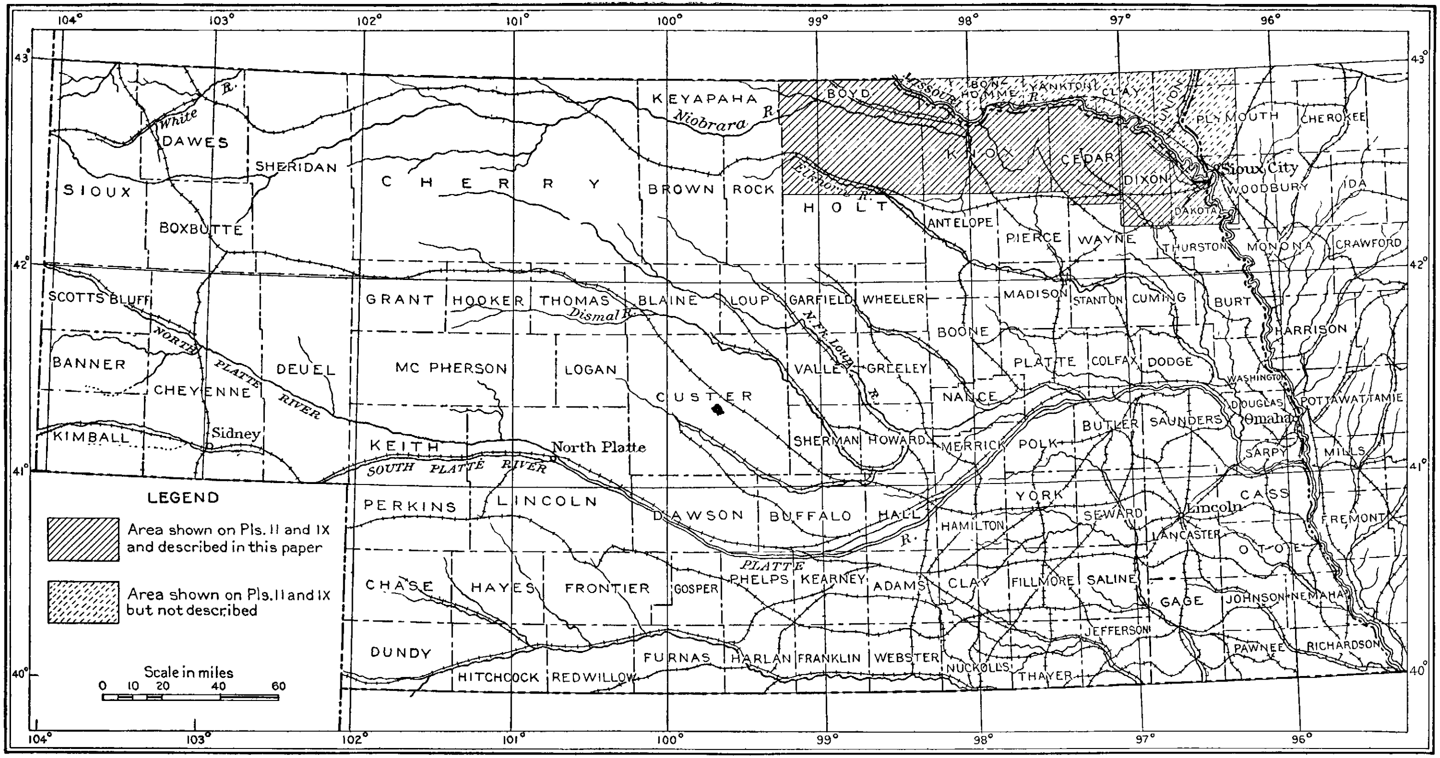
The principal topographic features of the region are the result of the erosive action of streams, but glacial action has modified the surface in some districts by changing the preglacial drainage and adding deposits of gravel, sand, bowlders, and clay, while the wind has modified certain sandy surfaces into small areas of dunes. The altitude varies from over 2,100 feet on the table-lands of western Holt and Boyd counties to about 1,100 feet on the lowlands of Dakota County. The Missouri River, which is the principal stream, has eroded a trough, usually with steep slopes, to an average depth of 500 to 600 feet below the general upland level. The entire area slopes gradually downward from west to east, and more steeply northward from the high divides toward Missouri River. While most of the area slopes and drains northward toward that river, the drainage of small portions of Holt, Knox, Cedar, Dixon, and Dakota counties flows southeastward and reaches the river farther south.

## DESCRIPTIVE GEOLOGY.

### STRATIGRAPHY.

Study of the local geology of a region affords information concerning the soil, aids in drilling artesian wells by indicating the thickness and character of the formations through which the drill must pass, and is a guide to many natural resources which may be advantageously developed.

The formations in this area are all of sedimentary origin and belong to the Cretaceous, Tertiary, and Quaternary systems. The Cretaceous strata, which are the lowest exposed, consist of beds wide in extent and nearly horizontal in position or with a slight dip to the west. They are composed of clay, chalk, limestone, and sandstone, which were for the greater part marine accumulations of mud, minute calcareous shells, and sand. These formations outcrop extensively along Missouri River and other streams, as shown in Pl. II (in pocket), and by well records their relations at other places are known. The total thickness of the Cretaceous beds in the western part of Boyd County is thought to be about 1,400 feet. From records of deep borings at Ponca and Sioux City it is known that the Carboniferous limestones also underlie the region, beginning at a depth of about 545 feet at Ponca, Nebr., and 335 feet at Sioux City, Iowa.




SKETCH MAP OF NEBRASKA.

The following sections represent the succession at certain typical localities:

*Section below the mouth of Aowa Creek, Dixon County, Nebr.*

| | Feet. |
|---|---|
| Loess, extends 98 feet higher in slope; exposed | 7–30 |
| Glacial till | 22 |
| Greenhorn limestone: | |
| Limestone, slabby; with many remains of *Inoceramus labiatus* | 5½ |
| Clay, dark, sandy, with some chalk | 1 |
| Limestone, slabby, containing *Inocerami* | 4 |
| Limestone, bluish, chalky, weathers to a light color resembling Niobrara chalk rock; contains some *Inocerami* | 9 |
| Graneros shale: | |
| Clay, bluish and somewhat chalky above, dark below, contains iron pyrites concretions, and sulphate of iron as a powder | 49½ |
| Clay, dark, at places carbonaceous above, usually sandy, containing concretions of iron pyrites and marcasite and rosettes of selenite | 7 |
| Dakota sandstone: | |
| Sandstone, light to rusty color, porous, and soft; with root marks. Rusty iron concretions occur near the center and base. The beds thicken and dip westward | 7–10 |
| Clay, dark, contains irregular streaks of light-colored sand | 2½ |
| Sandstone, nodular, contains rusty iron, limy at places | ¾ |
| Shale and nodules, dark, very sandy near ravine | 1 |
| Sandstone, with layers of concretionary iron between beds | 4½ |
| Sandstone, rusty and dark, varying from sandstone to shale | 5½–6 |
| Sandstone, rusty, porous at 1,120 feet above sea level | |

The beds show a steeper westward inclination near the mouth of Aowa Creek, beyond which they appear to rise again for a short distance.

*Combined section from Vermilion Ferry to the Dixon-Cedar county line.*

| No. | | Feet. |
|---|---|---|
| 7. | Loess; thick on higher slopes. | |
| 6. | Glacial drift; usually covered by loess | 0–3 |
| 5. | Niobrara chalk rock, light color, soft, rises in hills above, exposed in three banks | 1–5 |
| 4. | Clay, dark, with some selenite crystals, sandy at places | 13 |
| 3. | Sandstone and clay, varies from sandstone to plastic clay. Beds carbonaceous at places | 8 |
| 2. | Clay, bluish or dark, plastic, covered with many selenite crystals. Contains two zones of calcareous concretions, one 63–65 feet and the other 55 feet above the river. In one bank a thin bed of rusty sandstone is found 10 feet above the river | 73 |
| 1. | Shale, dark blue, chalky, containing *Serpula*, large, flat *Inocerami*, *Ostrea congesta*, and *Prionocyclus*. Exposed above water | 3–4 |
| | Altitude of top of No. 1, at ferry | 1,130 |
| | Altitude of base of No. 5 | 1,224 |
| | All below No. 5 are included in the Carlile shale of the Benton group. | |

On the eroded upper surface of the Cretaceous lie sheets of sand and clay of Tertiary age, which are thickest and most typically developed in the western parts of Boyd and Holt counties, and thin out in Knox and Cedar counties. The only portion of the Tertiary thus far identified here is the Arikaree formation and an unnamed formation of Pliocene age. A more careful examination of the western part of the region may possibly show the presence of outliers of the White River formation below the Arikaree.

Lying on the eroded surface of the Cretaceous and Tertiary formations, over wide areas, are the deposits of clay, sand, gravel, bowlders, loess, and alluvium of Quaternary age.

## STRUCTURE.

In outcrops in northeastern Nebraska the rocks usually appear to lie horizontal, but they have a slight general inclination to the west or west-northwest, which becomes very low for some distance above the mouth of Niobrara River. The principal structural features are shown on the cross sections Pl. III (in pocket). The westerly dip is indicated by the differences in altitude of the top of the Dakota sandstone, which slopes from a height of 40 feet above the river level, or altitude of 1,160 feet, at Sioux City to a depth of 500 feet, or altitude of about 720 feet, at Niobrara. This difference of 440 feet in 80 miles indicates an average dip of 5½ feet to the mile. The dip from Sioux City to Ponca, however, is slight, making the average dip from Ponca to Niobrara about 7 feet to the mile. At Lynch, 23 miles west of Niobrara, the altitude of the top of the formation is about 690 feet, which indicates a fall of only about 1 foot to the mile in that direction, while to the northwest, up the Missouri valley, there is a similar low dip.

## DESCRIPTION OF THE ROCKS.

### CRETACEOUS SYSTEM.

#### DAKOTA SANDSTONE.

The Dakota sandstone is of considerable economic importance, furnishing artesian water, brick clay, fair building stone in places, and small amounts of a poor grade of lignite coal.

It outcrops occasionally in bluffs in southeastern Dakota County, Nebr., at Sioux City, Iowa, and along Big Sioux River in Iowa. In Nebraska the formation outcrops at intervals from the high hills southeast of Homer to a point northeast of Ponca, where it passes beneath the river level. It extends far to the northwest and the southwest under later formations and comes to the surface in the Black Hills and the Rocky Mountains. According to well records, its upper surface lies at a depth of 360 feet at Aten, 600 feet at Santee, 500 feet at Niobrara, and 700 feet at Lynch.

The formation is penetrated by wells at Ponca, Nebr., and Sioux City, Iowa, where in each case the thickness is thought to be between

300 and 400 feet. In the Ponca well, 700 feet deep, the base of the formation appears to be at an altitude of about 755 feet, while its upper surface, exposed in bluffs east of the town, rises to 1,135 feet, indicating a thickness of 380 feet; but this estimate probably is somewhat too large.

According to Professor Todd the mouth of the Sioux City well is 38 feet below the outcrops of the sandstone, whose altitude is 1,122 feet, and, as the bottom of this sandstone, according to the well record, is at an altitude of 825 feet, the thickness is 335. It is thought, however, that the beds observed near the mouth of the well are not at the top of the formation and that some higher strata have been removed by erosion.

The Dakota formation is composed largely of thick deposits of coarse friable sandstone, light buff to rusty in color, with interbedded clay beds of different colors, mostly blue, gray, and yellow. One thick bed of clay north of Sioux City overlies the massive cross-bedded sandstone which outcrops along the river banks in that vicinity. Numerous iron-oxide concretions abound in the clay, as do also thin beds of sandstone merging into irregular, sandy iron-oxide deposits of variable thickness. Lignite, in thin irregular beds, occurs in the upper part of the formation, and also at lower levels near Jackson and Homer. Many well-preserved leaves are found which have been studied and described by various paleontologists.

The component beds of the Dakota formation in this region are not sufficiently continuous, extensive, nor distinctive to afford a basis for subdividing the formation into different horizons, yet in the outcrop area the following order has been observed, passing downward: (1) Porous sandstone with root marks, interstratified clays, and shale or lignite beds; (2) clay, thin sandstone, and concretionary ironstone beds; (3) massive, cross-bedded sandstone with thin beds of clay.

As the sandstones weather more slowly than the clay beds they often form bluffs (see Pl. IV, *A*), which extend as a more or less continuous escarpment from southeastern Dakota County to a point near Ponca. At cut banks along the river and near the mouths of a few ravines these bluffs form prominent points and buttresses. The topography varies somewhat, the massive sandstone giving sharp outlines and the clay more gradual slopes. Loess and Graneros clay often slide down over these outcrops, concealing the beds.

*Section of Dakota sandstone 5 miles southeast of Homer, Nebr.*

| | Feet. |
|---|---|
| Thin beds of sandstone and clay, colored by iron | 18 |
| Sandstone, massive, cross-bedded. These beds vary much in texture; within a few feet they may grade from sand into sandstone and even quartzite. The colors are light gray, rusty, and dark | 19 |

*Section of Dakota sandstone and overlying loess at the quarry just northwest of Homer, Nebr.*

| | Feet. |
|---|---|
| Loess at top of bluff | 12 |
| Clay, shaly and oxidized to a yellowish color | 2 |
| Sandstone, light colored, porous, massive, not cross-bedded | 7 |
| Clay, light colored, concretionary | 2 |
| Sandstone, much like No. 6 but with root marks in upper part | 10 |
| Clay, light colored, sandy, oxidized; yellowish at places, with hard layers of concretionary iron 1 to 12 inches thick | 28 |
| Clay, yellowish, with fewer iron concretions than in No. 3 | 5 |
| Sandstone, light colored to rusty, massive, cross-bedded, interstratified with thin layers of clay | 20 |

In the Ashford well just west of Homer, the lowest bed of the above section was not penetrated at a level fully 70 feet lower. This member of the Dakota formation rises high in the bluffs some 6 or 7 miles southeast of Homer.

*Section of Dakota sandstone and glacial clay in the quarry at Jackson, Dakota County, Nebr.*

| | Feet. |
|---|---|
| Glacial clay with some sand | 3 |
| Sandstone, rusty | ½–1 |
| Sandstone, light colored, loosely cemented | 2 |
| Sandstone, rusty to light colored, friable, in beds 2 to 8 inches thick with thin layers of light-colored clay between | 8 |
| Clay, sandy, light colored | ½ |
| Sandstone, light colored, friable | 1½ |
| Sandstone, clay or sand, varying; color rusty to light | 3 |

Parts of the stone in this quarry are used for building purposes. Several good specimens of leaves were found here. According to the report of the well drillers a thin bed of impure coal lies 30 feet below the lowest point in the quarry.

*Record of Mattison's well, N.E. ¼ S.W. ¼ sec. 20, T. 31 N., R. 6 E., southeast of Ionia, Nebr.*

| | Feet. |
|---|---|
| Shaly limestone | 0– 8 |
| Chalk | 8– 12 |
| Dark shale | 12– 45 |
| Blue clay | 45–105 |
| Soft sandstone | 105–277 |
| Sand and gravel | 277–302 |
| Clay or shale | 302–312 |
| Soft sandstone | 312–487 |
| Gravel | 487–517 |

## BENTON GROUP.

The Bentón group lies between the Dakota and Niobrara formations and, as Mr. Darton has shown, is separable in this region into three distinct formations, which represent the Graneros shale, the Green-

*A.* DAKOTA SANDSTONE ON BANK OF MISSOURI RIVER BELOW MOUTH OF AOWA CREEK.

*B.* GREENHORN LIMESTONE ON GRANEROS SHALE NORTHEAST OF PONCA, NEBR.

horn limestone, and the Carlile formation of eastern Colorado and the Black Hills.

*Graneros shale.*—The best exposures of the Graneros shale are in river bluffs below the mouth of the Aowa Creek, above Ponca Landing, and at the Bigley Ravine, near Ponca. The shale lies on the Dakota sandstone and is overlain by the Greenhorn limestone. It occurs high in the slopes in Dakota County, and dips gradually to the northwest, its base reaching the level of the river about 3 miles north of Ponca. The thickness in Dixon County is from 50 to 60 feet, while in the Black Hills it varies from 800 to 900 feet. According to Mr. Burchard [a] it appears to thin out and disappear southeast of Homer, where the Greenhorn limestone lies very close to if not directly on the Dakota sandstone. It is composed principally of very dark gray to bluish-gray clay or soft shale which grades above and below into harder shale. The section at the mouth of Aowa Creek (p. 7) shows the usual relations.

*Greenhorn limestone.*—This medial member of the Benton group lies from 50 to 60 feet above the Dakota sandstone and is 18 to 20 feet thick, not including a few feet of shaly transition beds above and below. The principal rock is fossiliferous limestone with an admixture of clay and some sand. The upper beds are slabby, highly fossiliferous, and stained with iron, while the lower beds are more massive and chalky and contain a smaller number of large fossils. The formation is characterized by very numerous casts of *Inoceramus labiatus* (see Pl. VI). This limestone was traced from high in the hills of southeastern Dakota County to the river level in the Ionia section northeast of Newcastle.

Pl. IV, *B* shows a characteristic outcrop of this limestone. These beds weather out like chalk and were formerly mistaken for the Niobrara chalk rock, which, however, occurs at a higher level farther west.

*Section of Greenhorn limestone and associated beds in cut bank and slide three-fourths mile northwest of Ponca Landing, Nebr.*

| | Feet. |
|---|---|
| Loess and till | 80 |
| Greenhorn limestone: | |
| Limestone, weathered, sandy; contains many casts of *Inoceramus labiatus* | 8–9 |
| Limestone, bluish gray, massive, chalky | 10 |
| Graneros shale: | |
| Clay, bluish, stratified | 20 |
| Clay, dark or bluish, at places rusty | 25–30 |
| Shale, dark, quite hard | 2 |

[a] Geology of Dakota County, Nebr.: Proc. Acad. Sci. of Sioux City, Iowa, 1903–4, vol. 1, p. 150.

*Carlile shale.*—This uppermost division of the Benton group begins to appear above the Greenhorn limestone in eastern Dixon County and thickens westward to 170 feet in northwestern Dixon County to over 200 feet at Niobrara, and to 500 to 700 feet in the Black Hills. In the eastern part of its outcrop area it erodes rapidly, forming slopes over which loess and Glacial drift slide from above, concealing it at many points in the bluffs of Dixon County. The base of the formation reaches the level of the river just west of the so-called Ionia Volcano, northwest of Newcastle. The upper surface is about 140 feet above the river level in sec. 28, T. 32, R. 4 E., 97 feet above at Vermilion Ferry, 71 feet above northeast of St. James, 30 feet above north of St. Helena, and reaches the level of the river about 4 miles beyond the last-named town. Recent slides northeast of Ponca expose 8 to 12 feet of Carlile above Greenhorn limestone in the vicinity of the ferry. A well-marked line of contact with the Niobrara chalk above is shown in Pl. V, *A*.

The formation is composed principally of dark-gray and bluish-gray stratified clays, with two zones of fossiliferous chalky shale. Sandstone beds of variable extent and character generally occur at different levels, but usually near the top, as just west of Vermilion Ferry. Large concretions of carbonate of lime are found above the middle of the formation. Drillers in penetrating this formation experience difficulty with the hard concretions and sandstone and with the thin layers of iron pyrites which also often occur in it. Many fish-scales, a large, flat form of *Inoceramus*, *Prionocyclus*, *Serpula*, and *Ostrea congesta* are common fossils.

A locality in northern Dixon County, in sec. 10, T. 31, R. 5 E., has received the name Ionia Volcano. It is simply a bluff of shale in which the oxidation of a large amount of iron pyrites often produces considerable heat, at times sufficient to give rise to steam and sulphur fumes, and even to cause slight baking of the shale.

Two zones of concretions of carbonate of lime occur in the Carlile shale. The lower zone is a continuous one, and its concretions are large, lens-shaped forms, 2 to 8 feet long and 1 foot or more thick (Pl. V, *B*). This horizon continues at about 50 feet from the top of the formation from high in the slope in sec. 32, T. 32, R. 5 E., to a point between St. James and St. Helena, where the dip takes it down to the level of the Missouri. The upper zone consists of smaller concretions at a less continuous horizon 8 to 10 feet above the first. These concretions weather out and fall to the base of a slope, where they crack into irregular pieces. In many of them calcite and selenite crystals occur.

While selenite crystals may be observed throughout the Graneros, Carlile, Niobrara, and Pierre, they are most abundant on slopes of the Carlile formation, especially at the Ionia Volcano or on other

*A.* CARLILE SHALE OVERLAIN BY NIOBRARA NORTHEAST OF JAMES, NEBR.

*B.* CALCAREOUS CONCRETIONS IN CARLILE FORMATION WEST OF VERMILION FERRY, NEBR.

bluffs in that region, where they are commonly mistaken for mica. They vary in size from minute needles to 2 to 3 inches across. They originate near the surface from the weathering of the iron pyrites scattered through the clay, some of the products of which react with lime in solution in percolating waters, forming calcium sulphate which crystallizes as selenite. The usual belief that they were formed when the strata were deposited and that they occur in large numbers throughout the beds is therefore erroneous.

*Section of Carlile shale and associated formations at the Ionia Volcano, in northern Dixon County, Nebr.*

| | Feet. |
|---|---|
| Loess and till | 15-35 |
| Clay (Carlile), dark, plastic. Contains sulphate of iron, epsom salts, selenite crystals, etc., over the surface. Sulphur dioxide fumes rise from the clay at one point | 112 |
| Shale, bluish | 15 |
| Limestone, slabby, with fish scales and *Inoceramus labiatus* | 1½ |

Altitude of river, 1,118 feet; of top of hill, 1,265 feet.

The lowest bed is a part of the Greenhorn, while the overlying bluish shale is a transition to the base of the Carlile. It is prominently represented in a ravine below the old landing about 1 mile away.

Professor Todd has noted the existence of a thin but very persistent layer of clay closely resembling bentonite near the middle of the Carlile formation. It varies from 1½ to 3 inches thick. At Vermilion Ferry it is about 10 feet above the river. At the Ionia Volcano it is about 100 feet above the top of the Greenhorn beds, and it is at same horizon in ravines in the SW. ¼ sec. 26, T. 31 N., R. 5 E., and in a shaft in the SW. ¼ sec. 24 of the same township. It is suggested that it may originally have been a thin stratum of volcanic ash.

### NIOBRARA FORMATION.

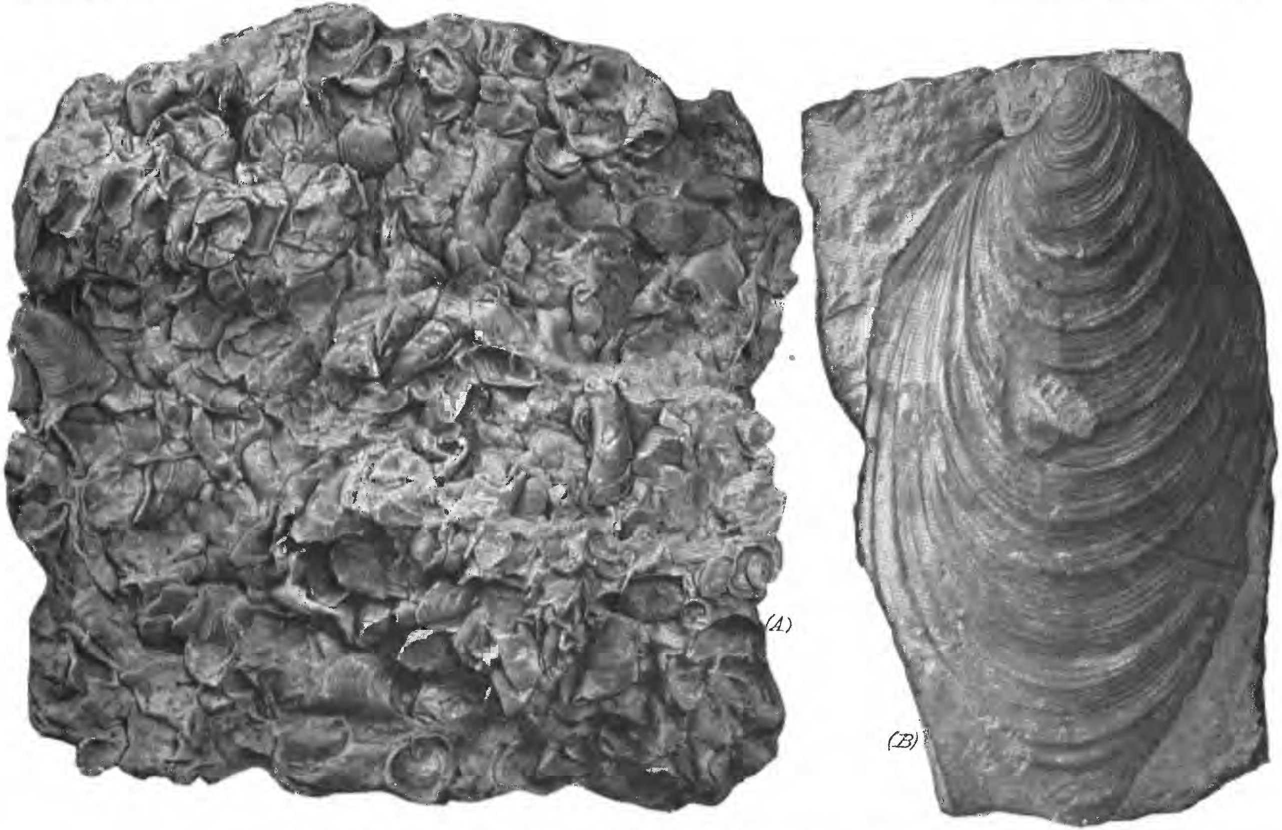
The Niobrara formation lies between the Carlile and the Pierre shales and is a conspicuous and characteristic feature of the region. It outcrops in the creek slopes of northwestern Dixon County, high in the river bluffs just west of Vermilion Ferry, and thence westward and northward along Missouri River and its tributaries to the great bend of that river in South Dakota. A thickness of about 130 feet remains in the hills northeast of St. James, Nebr., while westward at the margin of the Pierre shale the total thickness is over 200 feet. The easternmost points at which the formation is exposed or found in wells are in the SE. ¼ SW. ¼ sec. 32, T. 32 N., R. 5 E., and the W. ½ sec. 6, T. 29 N., R. 5 E. The dip, which is westerly, is low from St. James to Niobrara, beyond which the upper surface seems to be nearly level with perhaps a slight rise in the direction of Chamberlain, S. Dak. The base of the formation is 97 feet above the river near Vermilion Ferry, 71 feet northeast of St. James, and 30 feet at St. Helena, a few miles beyond which it passes below the level of the river. At the cement works west of Yankton, S. Dak., the upper surface is fully 140 feet above the river surface, while the base lies a few feet below it.

The formation is composed of lead-gray chalk rock, which weathers yellowish, with a variable admixture of clay and sand. Thin limestone beds composed of small *Ostrea congesta*, found principally in the upper portion, are a characteristic feature (see Pl. VI). In Cedar County and apparently at Niobrara, Knox County, the base of the formation is a sandy, hard limestone. The purer chalk beds vary from less than 1 inch to as much as 6 feet in thickness and merge into mixtures of chalk and clay in variable proportions. The upper surface is usually weathered, leaving a relatively larger percentage of clay, iron, and sand than is found in the more massive beds below. In the latter there are nearly vertical joint planes intersecting each other at angles of about 90 degrees. Deeply decayed surfaces have gypsum plates in the joint and bedding planes, and at places selenite crystals are scattered over the surface. The purer massive chalk is of fine grain, porous texture, low specific gravity, and gives a characteristic dead or hollow sound when struck with a hammer. Its economic value lies in its use for the manufacture of cement and for building stone.

The chalk bluffs of the Missouri present a strikingly barren appearance and are usually of a conspicuous yellow color. The bluffs have a uniform height above the river for a distance of over 200 miles in Nebraska and South Dakota, but are notched by many small draws. The upper surface of the formation falls to within 8 or 10 feet of the river at Wheeler and Nieveen, S. Dak. For most of the distance, from a point 5 miles below Greenwood to Yankton, the Niobrara bluffs are prominent on one side of the river or the other. At a number of places slight faults and flexures were observed; most of the latter occur at the mouths of small ravines and appear to be caused by the swelling of beds. The steeper slopes are often covered with splinters of chalk rock broken from the cliffs above.

*Section of Niobrara limestone and associated formations northeast of St. James, Nebr.*

| | Feet. |
|---|---|
| Loess. Rises in hills to an altitude of over 1,400 feet | 40–50 |
| Niobrara chalk, massive, somewhat sandy, and harder in lower beds. Base at 1,205 feet above sea level. Rises in hills to an altitude of 1,335 feet, or a thickness of 130 feet exposed | 40–50 |
| Carlile clay, dark and bluish, with some sand and sandstone. Large calcareous concretions 50 to 55 feet below top. Exposed in slope to river | 71 |




CHARACTERISTIC FOSSILS OF NIOBRARA FORMATION AND GREENHORN LIMESTONE.

*A*, Ostrea congesta; *B*, Inoceramus labiatus.

*Section of Niobrara limestone and Pierre shale on Bazile Creek at bend in road 1 mile south of Bazile Point, Nebr.*

| | Feet. |
|---|---|
| Pierre shale: | |
| Carbonaceous clay, dark in bank, lighter on weathered surface, which is strewn with selenite crystals and small yellowish concretions of irregular form | 6 |
| Niobrara: | |
| Weathered chalk, yellowish, with 3 or 4 light-colored streaks 2 inches thick and about 1 foot apart, *O. congesta* present | 7 |
| Chalk, beds irregular, sandy, and at places concretionary; gypsum plates occur in bedding and irregular joint planes. Lower beds 6 to 8 inches thick. *O. congesta* is the common fossil | 8½ |
| Blue chalk, lower 4 feet in 2 beds; large *Inocerami* and *O. congesta* present | 8 |

*Analysis of Niobrara chalk rock.*

[Howison Crouch, analyst.]

| | Unweathered specimen. | Weathered specimen. |
|---|---|---|
| Moisture | 0.70 | 1.11 |
| $SiO_2$ | 4.52 | 6.02 |
| Organic matter | 3.14 | 1.03 |
| $SO_3$ | 2.14 | .85 |
| $CO_2$ | 37.80 | 37.11 |
| CaO | 49.66 | 47.98 |
| $FerO_3$ and $Al_2O_3$ | 1.87 | 5.92 |
| Mg | Trace. | Trace. |
| | 99.86 | 100.02 |

PIERRE SHALE.

The Pierre shale is the thickest member of the Cretaceous in Nebraska, varying in thickness from a few feet in northwestern Cedar County to over 500 feet in western Boyd County. The base, lying on the Niobrara, slopes down slowly from western Cedar County to central Knox County, beyond which it is either horizontal or has a slight rise westward. The eroded top reaches an altitude of over 1,900 feet in western Boyd County. At the cement works, 4 miles west of Yankton, S. Dak., the Pierre clay just above the Niobrara chalk is distinctly crumpled, a feature which may have been caused by the ice sheet.

During Eocene and early Miocene times this region was a land area eroded into hills and valleys. The Pierre clay was entirely removed in the eastern part, and on the rough upper surface later Tertiary and Quaternary deposits were laid down, to be themselves in turn partly removed by weathering and erosion.

The Pierre shale is commonly called "gumbo" and "soapstone," and consists principally of dark and bluish, plastic, and finely stratified clays. It carries lenses of limestone, and beds of shale, impure chalk, and thin layers of concretionary ironstone. At its base there is a dark carbonaceous clay, resembling coal, which is exposed along the Missouri, beginning in irregular lenses near Chamberlain, S. Dak., and extending as a continuous, well-marked horizon from a few miles farther down the river to eastern Knox County. At the latter place it contains, near the middle, an admixture of whitish clay, resembling fuller's earth and varying in thickness from 10 to 30 feet or more. The next horizon above is made up of dark and bluish plastic clays with thin seams of iron ore. Above this are alternating beds of shaly chalk and clay, the former weathering reddish; these chalky beds are often mistaken for Niobrara chalk. The highest beds of the Pierre, as observed in Boyd County, are bluish clay with some concretions of iron ore. The sections on page 17 give the strata more in detail.

The Pierre shale in this region is not rich in fossils. A few *Inocerami*, shark's teeth, and mososaur remains were observed by the writer. Mr. R. F. Stout, Center, Nebr., has collected from Pierre chalky beds about 72 vertebræ, the paddle bones, and pieces of ribs of a very large mososaur. He also secured crocodile bones and a number of *Belemnitella*.

The beds do not rise steeply in bluffs but, weathering rapidly, form rolling hills and long slopes. A typical hilly country of Pierre shale lies between Santee and Herrick in what is called the Devil's Nest. The hills, though usually either grass-covered or farmed where not too rough, show light to dark bands at different levels. This appearance is due to the alternation of beds, the chalky deposits causing light bands, the chalk stained with iron giving rise to yellowish soil, and the dark clays and iron-bearing beds giving brownish and dark streaks.

In the high ridge just north of Niobrara River and southeast of Spencer, certain hard beds at different levels cause flat summits or a series of irregular steps rising from east to west. The topography of the different zones of the Pierre is well shown along Bazile Creek, which has a grade of about 400 feet in 24 miles. Gradual clay slopes extend from altitude 1,560 to about 1,500 feet; steeper, chalky slopes with a narrower valley extend from altitude 1,500 to 1,400 feet; while the clays below give more gentle slopes and a wider valley down to about 1,280 feet, at which altitude the Niobrara chalk begins and bluffs prevail.

A very noticeable feature, especially in northern Holt County, is the presence along Niobrara River and its tributary creeks of many landslides, caused by the infiltration of ground water through joints in the clays, rendering them plastic. Fully 50 slides may be seen along Eagle Creek, between Turner and Ray, where Pierre clay rises from 60 to 100 feet in the slopes. At John Dolin's place, in sec. 26, T. 32, R. 11, a slide formed in 1893 has a length of 20 rods and vertical displacement of from 50 to 100 feet. It completely dammed Eagle Creek, causing the channel to shift several rods southward.

*Section of Pierre shale along Bazile Creek ¼ mile southeast of Mackeyville, Nebr.*

| | Feet. |
|---|---|
| Bluish clay with flakes of iron oxide on surface | 79 |
| Dark, carbonaceous clay which, at places, is chalky, extending below the water in the creek | 12 |

*Section of Pierre shale and Niobrara limestone south of the Missouri River and 3 miles west of Fort Randall, S. Dak.*

| | Feet. |
|---|---|
| Pierre shale: | |
| Clay with ironstone over surface; some selenite above | 13 |
| Clay, yellowish, chalky, varies in character from massive, impure chalk to large concretions of chalk and clay. Dark, flat concretions occur at base | 11 |
| Clay, very dark; carbonaceous with thin, light-colored seams at base; definitely jointed, standing as buttresses, between which it weathers into amphitheater-like recesses; surface lighter where weathered; gypsum flour and selenite in joint and bedding plains. Lemon-yellow concretions occur near top of beds | 28 |
| Niobrara: | |
| Chalk, weathered above, darker below; with few fossils | 40 |

*Section of Pierre shale and overlying deposits, one-half mile northeast of Center, Nebr.*

| | Feet. |
|---|---|
| Loess | 4 |
| Sandy slope | 9 |
| Pebbles and gravel, then fine sand and glacial pebbles at base | 30 |
| Pierre shale: | |
| Dark clay, somewhat chalky when dry | 1½ |
| Light buff-colored clay, bedding not plain, showing gypsum flour and small selenite crystals in joint and bedding plains | 4½ |
| Clay, light, blue, or dark at places; chalky and hard. Rosettes of selenite common over upper 2 feet. Gypsum flour in cracks; crystals in joint and bedding plains | 19 |
| Clay, dark gray | 2 |
| Clay, dark, plastic, with 3 to 6 inch zone of oxidized iron concretions 32 feet below top. This clay seems to extend below the creek. Exposed | 45 |

*Section of Pierre shale above the Whiting Bridge, 7 miles southeast of Spencer, Nebr.*

| | Feet. |
|---|---|
| Clay, dark, plastic, with thin seams of iron | 170 |
| Yellowish clay, darker where not weathered, with some portions bluish | 40 |
| Chalky beds, at places hard enough for building purposes | 2 |
| Alternating dark shale and clay; the shaly beds stand out as buttresses | 36 |

Altitude of river, 1,502 feet; top of slope, 1,750 feet.

### TERTIARY SYSTEM.

Two formations of later Tertiary age occur in this region: one is the Arikaree, which has a wide range over western Nebraska and adjacent States; the other, which has no name, consists of certain stratified sands and clays found in Holt, Knox, and Cedar counties.

#### ARIKAREE FORMATION.

The Arikaree formation is composed of grayish sand and sandy clays, with local beds of sandstone, quartzite, conglomerate, and fresh-water limestone, which, in the table-lands of Boyd, Holt, and Knox counties, are 100 feet or more thick. From these nearly level areas the formation thins on the slopes and ridges toward and between the streams. Certain outliers in the eroded areas give rise to buttes of more or less prominence. Originally the formation extended over all of the western part of the region to which this report relates and well into Cedar County and perhaps farther east, but by subsequent erosion it has been widely removed, leaving only a few remnants, capping buttes on some of the northwest-southeast trending ridges to the east.

The sandy portion of the formation is in part unconsolidated, the grains usually being feebly cemented by a small amount of calcium carbonate. Where there is more complete cementation there are local beds of sandstone which generally show cross-bedding. In several cases the rock contains pebbles. In most of the buttes there occurs a hard, greenish sandstone or quartzite with a silicious cement, identical with that found in the Bijou Hills of South Dakota and at Woodruff, Kans. These hard beds do not occur at definite levels, the nature and kind of the rock often changing within a few feet.

Not many fossils are found in the Arikaree formation. Silicified wood is abundant on the place of Andrew Lukup, southwest of Verdigre. Several mammalian bones have been found about the buttes, but the writer saw only one bone of that class embedded in the rock. The most conspicuous outcrops are in the well-known Twin Buttes, 10 miles west of Butte, Boyd County (Pl. VII, *A*), and Stony Butte, 2 miles southwest of Verdel, Knox County. Twin Buttes, 2,060 feet in altitude, are so prominent that they can be seen for many miles, even from points in South Dakota beyond Missouri River. From the top of the southeast butte, which rises over 100 feet above the plain, a good idea can be gained of the former extension of the Arikaree table-land north in Dakota, west in Keyapaha County, and south in Holt County. The altitude of Stony Butte is about 1,700 feet; in it the Pierre clay is capped by 25 feet of Arikaree formation, the latter being composed of cross-bedded sandstone and quartzite, with a small amount of sand at the base. As

*A*. ONE OF THE TWIN BUTTES, BOYD COUNTY, NEBR.

*B*. KNOLLKEMPER DAM, TURNER, HOLT COUNTY, NEBR.

this sand crumbles out or washes away, the hard beds above are undermined and break into large pieces or bowlders which scatter over the Pierre slope below.

*Section of Tertiary deposits in bluffs northeast of Badger Bridge, Boyd County, Nebr.*

| | Feet. |
|---|---|
| Sand and gravel in slope | 38 |
| Sandstone, quartzitic, greenish to light, cross-bedded, weathers to light color | 2 |
| Sandy loam, grayish, light on surface, darker in bank; not plainly stratified; contains in upper part hard concretions 6 to 8 inches in diameter. These break into irregular pieces showing dendritic structure | 7 |
| Loam, grayish, sandy, weathers to a yellowish or buff color, resembling loess; lies on Pierre shale at an altitude of 1,800 feet | 62 |

*Section of Tertiary deposits at the southeast Twin Butte, Boyd County, Nebr.*

| | Feet. |
|---|---|
| Sandstone; 3 feet top of grayish to greenish and quartzitic, the rest friable, cross-bedded, and showing plant-like tubes | 10–15 |
| Gray sand | 5–10 |
| Porous rock consisting of sand and pebbles in a limy matrix | 6–10 |
| Clayey sand, greenish in beds, grayish on surface | 90? |

In a field just north, and at the top of the bluffs along Keyapaha River, this lower sand is underlain by a bed of greenish quartzite, beneath which is a bed of loam lying on Pierre clay.

## PLIOCENE DEPOSITS.

At the close of Arikaree time the region was extensively eroded by drainage, which for a while at least flowed from northwest to southeast. A few remnants of the deposits of these old, high-level streams may be seen extending southeast across Gregory County, S. Dak., and at other points farther west. The longer axes of the buttes of Arikaree formation in Boyd County extend in the same direction. Parts of northeastern Nebraska were considerably eroded at this time, but finally received the sand and gravel deposits which are thickest to the east and south. The old channels extending across Knox and Cedar counties and described by Prof. J. E. Todd [a] may have been outlined at that time, for they appear to be related to the old channels farther northwest. Old valleys connect Ponca Creek and Niobrara River in secs. 25, 26, and 36, T. 34 R. 14, and south of the buttes near Butte. Sandy gravel-capped ridges trending northwest-southeast, with intervening dry valleys, occur at various places, notably southwest of Butte.

The so-called Pliocene deposits consist principally of stratified sand with some gravel and clay, which comes to the surface in southeastern

[a] Todd, J. E., Moraines of southeastern South Dakota: Bull. U. S. Geol. Survey No. 158, 1899, pp. 6061.

Holt and southwestern Knox counties and lies beneath loess and glacial drift in much of Knox and Cedar counties. The best typical exposures occur in the Devils Nest region between Santee and Herrick, where a thickness of 50 to 100 feet has been observed. The relations of these beds to the Arikaree drift and loess has not been fully ascertained; while they are usually described under the name Pliocene it seems highly probable that the accumulation of much of the formation so characterized extended well into Quaternary time.

### QUATERNARY SYSTEM.

Deposits belonging to this system consist of glacial drift, loess, alluvium, and dune sand.

#### GLACIAL DRIFT.

The drift is composed of irregular masses of bowlder clay and of sand and gravel beds with an admixture of bowlders at places, these materials having been carried to the region by the glacial ice sheet and streams. The bowlder clay is exposed lying on the Cretaceous and Tertiary deposits at various points along the deeper valleys, and is reached in wells at a number of places; it frequently contains northern pebbles and bowlders. Gravel and sand beds are of wide extent under the loess; they rise to an altitude of over 1,600 feet in northwestern Knox County, where they mix with somewhat similar materials of western origin. Along some of the principal streams the gravel beds appear as a terracelike cap. Bowlders occurring in connection with the gravel are found along the streams and on hill slopes in Knox and Cedar counties, where, as a result of undermining, they fall or roll to lower levels; one of the most conspicuous deposits extends from 1 to 3 miles north of Hartington. In Dixon and Dakota counties they seem to be buried beneath the loess and to be in small numbers, as well drillers rarely find them. The western limit of northern drift extends from near Verdel southward along Verdigris Creek.

#### LOESS.

This important surface formation, often called the Bluff deposit, extends over most of Nebraska east and south of the sand hills, and into Iowa, Missouri, Kansas, and other States. It is composed of fine sand and clay particles and contains a small amount of calcium carbonate which holds the grains together loosely. The nearly universal buff color is due to the presence of a small amount of yellow oxide of iron. The thickness varies from a few feet to over 100 feet. Its most noticeable feature is the uniformity of porous texture and massive structure throughout, with only occasional traces of stratification. In western Knox County the loess becomes sandy or changes to a loesslike silt. A close examination of a loess bluff shows faint vertical cleavage and usually the presence of small, light-colored, irregular concretions. Very small shells, usually of land forms, occur at many localities.

The origin of the loess is still a disputed question, some geologists holding that it is a wind deposit, while others claim that it has been deposited in water. From its character and relations in this region, it seems probable that the principal agency has been wind, but the deposits were locally modified by water.

The eastern part of the area described in this report has a hilly loess topography. Near Ponca many vertical slips due to the vertical jointing were observed in the hills, where they are locally called "cat steps." The vertical displacement causes the formation to slide over and cover banks in which older formations occur. Where the talus is removed from below by a stream or other agent, nearly vertical loess bluffs result.

Near Cook Creek, close to the east side of the Santee Indian Reservation, a loess escarpment begins as a bluff rising from 100 to 200 feet above the Cretaceous clays in the Devils Nest below. This high ridge extends southeastward and then curves northeastward to a high hill 4 or 5 miles southwest of St. Helena. The noticeable feature is that the slope is southward from the brink of this escarpment. The loess similarly slopes away from the brink of the Missouri Valley just south of Vermilion Landing, Cedar County.

## ALLUVIUM.

Alluvial deposits composed of sand, clay, and some gravel, floor the principal valleys. These deposits have also been called valley wash and bottom land, while their upper surface is referred to as a flood plain. Level areas of the same nature but somewhat higher, are called benches or alluvial terraces. The alluvial flats along Missouri River vary in width from about 2 to over 10 miles, being widest along Dixon and Dakota counties; between Jackson and Homer they form the extensive bottom lands.

Alluvial materials comprise flood-plain and alluvial-fan deposits. The former have been deposited principally by the Missouri, while the latter, which are well shown between Ionia and Ponca, have been carried from adjacent slopes by weak tributaries, and scattered over the flood plain at the mouths of ravines. The thickness of the alluvium averages much greater than the depth of the river channel; a thickness of 185 feet is reported in the Joseph Holtzbauer well near Aten.

The bottom lands along the Niobrara average from one-half to three-fourths mile wide and are very sandy. Nearly all of the smaller streams flow on narrow beds of alluvium.

#### DUNE SAND.

In certain areas the wind has blown Arikaree, Pliocene, and alluvial sands into small dunes or sand hills. The principal area lies south of Niobrara River, and is from 5 to 8 miles wide, extending from the western part of Holt County to near Bazile Creek. A few small "blow-outs" occur on the highland west of the town of Verdigre. Low sandy ridges, extending in a northwest-southeast direction, occur at several points in Knox and Cedar counties; they were formed earlier than the dunes on the alluvial flats. At a number of places the loess is completely covered by drifting sands. A few small dunes are found on the Logan Creek bottom, near Laurel.

## ECONOMIC GEOLOGY.

### MINERAL RESOURCES.

#### BRICK CLAY.

Cretaceous clays and the loess are used successfully in the manufacture of brick. Twelve brickyards were operating in the region in 1903.

#### SAND AND GRAVEL.

Building sand in unlimited amounts is found along Niobrara and Missouri rivers, and is plentiful in the Tertiary and Quaternary formations. The principal loading station is at Stewart, Holt County, where the sand is scooped onto cars and sent out by trainloads. Gravel suitable for ballast occurs in terraces and in the glacial deposits at many places. Glacial bowlders have been used as foundation materials.

#### BUILDING STONE.

No very attractive and durable stone is found in northeastern Nebraska, and that available occurs under unfavorable conditions. The stone most used is the greenish Arikaree quartzite described on page 18. It is hard and fairly durable, but works in poor form, as the deposits are of very irregular character. It is quarried in most of the stony buttes and at a few lower levels, and is used principally for foundations and milldams. Most of this material is obtained (1) from many places in northern Holt County, as at Ray and Turner, where it is found in residual bowlders; (2) at John Vicknish's quarry, near Ray; (3) northeast of Badger Bridge; (4) in the vicinity of Twin Buttes; (5) just south of the town of Butte; (6) 3 miles north and one-half mile west of Spencer; (7) at the Stumbo quarry, in sec. 20, T. 33, R. 10 W., between Lynch and Gross; (8) on the divide south of Monowi; (9) on Stony Butte, 2 miles south of Verdel; (10) 6 miles southwest of Verdigre; (11) on the divide between Verdigre and Center, and (12) 2 miles southwest of Aten. The quartzite is excellent for concrete work and it would make very fair ballast if crushed.

The Greenhorn limestone is used somewhat for foundations, and the Niobrara chalk, though soft, serves fairly well as a building material where it can be placed above ground water. In some houses it has stood over twenty years with little sign of decay. The Menominee Church, in northern Cedar County, and the house of C. D. Buhro, sec. 20, T. 32, R. 2 W., Knox County, are good examples of this.

The lens of limestone in the Pierre formation 7 miles northwest of Verdigre has been used to some extent as a source of building stone, but there is only a limited supply of it and considerable stripping is necessary.

At Jackson, Homer, and a point 5 miles southeast of Homer, a fair grade of sandstone is found in the Dakota, but the conditions for quarrying are not favorable.

## CEMENT ROCK.

A large portion of the chalk rock of the Niobrara formation is suitable for cement manufacture and, with the growing demand for Portland cement, the production of this material may prove profitable in northeastern Nebraska. It is now manufactured extensively across the river in South Dakota, in mills located 4 miles west of Yankton and 1½ miles north of the river. The plant has been running thirteen years, supplying cement to South Dakota, Iowa, Nebraska, and other States; the output is 300 barrels a day, with 60 men working. The materials used average about 4 parts of Niobrara chalk to 1 part of Pierre clay. The top of the chalk here is weathered and has to be stripped to a depth of about 15 feet. The chalk and clay are mined or quarried, crushed together, thoroughly mixed, and then carried by water slushes to drying vats, where the mixture is dried by solar heat, and separated into blocks. Then come kiln burning, final grinding, and preparation for shipment. A view of the works is shown in Pl. VIII, *A*.

The formations worked at Yankton are exposed in Nebraska along Missouri River from Dixon County to northern Boyd County and afford a vast supply of the raw materials. The principal factors to be considered in the establishment of a plant, besides the presence of suitable cement materials, are the condition in which they are found so as to avoid waste in quarry strippings, the water supply, fuel, and a suitable location, especially in relation to transportation facilities. All of these conditions except cheap fuel exist at many places on the Nebraska side of the river. At Niobrara the chalk rock is of good quality and in large supply, and this place is favorably situated for railroads and river transportation; artesian water and a suitable location for a plant can also be had. A view of an outcrop at this place is shown in Pl. VIII, *B*.

## COAL.[a]

For nearly fifty years there has been more or less prospecting for coal in northeastern Nebraska, but the results have been most unsatisfactory. Near Ponca Landing, from 10 to 18 inches of an inferior grade of lignite is found in the basal portion of the Graneros shale, and it has been worked in a limited way. Near Jackson two holes were recently sunk, which found two thin beds of lignite in the Dakota. In a high bank southeast of Homer a thin bed of lignite rises 85 feet above the river. Paying quantities of coal are not to be expected in this region. The following analyses of Dakota County lignite, by Mr. E. F. Burchard, may be of interest in this connection:

*Analysis of air-dried lignite from near Jackson, Nebr., at a depth of 65 feet.*

[E. F. Burchard, analyst.]

| | |
|---|---|
| Water | 4.03 |
| Volatile matter | 51.40 |
| Fixed carbon | 33.66 |
| Ash | 10.91 |
| | 100.00 |

Sulphur undetermined.

*Analysis of air-dried lignite from shaft near Jackson, Nebr., depth 82 feet.*

[E. F. Burchard, analyst.]

| | |
|---|---|
| Water | 6.47 |
| Volatile matter | 27.24 |
| Fixed carbon | 49.27 |
| Ash | 16.23 |
| Sulphur | .86 |
| | 100.07 |

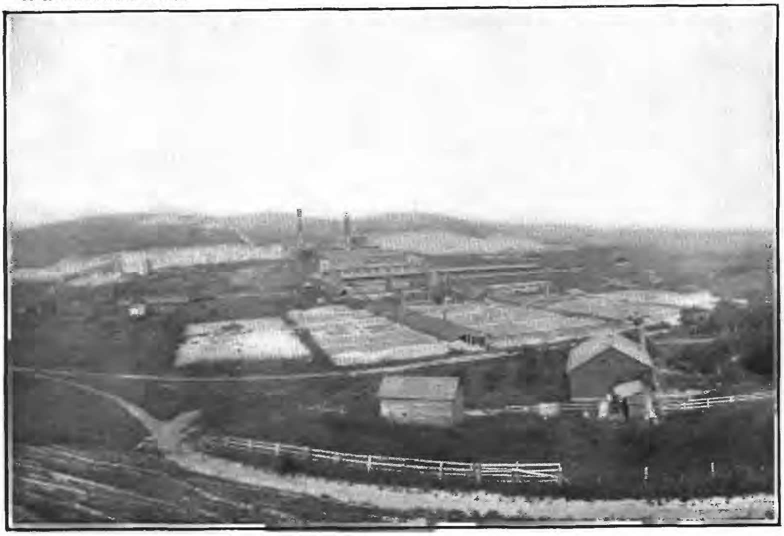
## PEAT.

While there has been no development of peat as a source of fuel in any part of the area, it seems probable that it may be found in considerable quantities in some of the boggy basins. One of the localities that should be investigated is the basin of Perrin Creek, in Cedar County.

## VOLCANIC ASH.

Volcanic ash beds which may yet prove of some importance occur in Holt, Knox, and Dixon counties.

[a] Extended accounts of the lignites of Dakota County are given by E. F. Burchard in Contributions to economic geology for 1903: Bull. U. S. Geol. Survey No. 225, 1904, pp. 276–288; and in Geology of Dakota County, Nebr.: Proc. Acad. Sci. and Letters of Sioux City, 1903–4, vol. 1, p. 150.



*A*. CEMENT PLANT NEAR YANKTON, S. DAK.

*B*. NIOBRARA FORMATION JUST WEST OF NIOBRARA, NEBR.

## WATER RESOURCES.

### GENERAL STATEMENT.

Of the water which falls upon the land, part runs off into surface streams, part evaporates, and part is absorbed by the land and by plant growth. The proportions vary with the rainfall, soil texture, geologic structure, and topography, the volume of rainfall being the most important factor. In northeastern Nebraska the rainfall varies considerably in the different counties, with a general diminution from east to west, the normal annual precipitation ranging from 27 to 28 inches in Dakota, Dixon, and Cedar counties to less than 23 inches in parts of Boyd and northern Holt counties. Mr. George A. Loveland, meteorologist at the University of Nebraska, gives the following data:

Normal annual precipitation at Agee, Holt County, 23.87 inches; Lynch, Boyd County, 23.33 inches; Santee, Knox County, 22.78 inches; Hartington, Cedar County, 27.53 inches; Elk Point, South Dakota, 27.61 inches. The maximum amount of rainfall is in May and June, or during the growing season. Nothing definite is known concerning the amount of evaporation from different soil surfaces in this section. The maximum evaporation is during June, July, and August.

The absorbent power of the soil is greatest in the loess and sandy areas which occupy much of the area. On certain clayey soils on steep slopes the run-off is large, notably on some of the Pierre lands. Water absorbed and collected in the soil is called ground water; it moves slowly downward until it reaches some impervious layer, above which it accumulates in varying amounts, in many areas completely filling or saturating thick beds of sand. The ground water moves slowly from higher to lower regions, at a rate which is greatest in coarse or porous beds. Heavy rains raise the upper surface of the ground water, while long dry spells, when evaporation is greatest, lower it.

A few lakes in the sand hills north of Turner show well this rise and fall of the water table, filling up during wet weather and disappearing at dry times. During the dry years 1893 to 1895 the water table lowered very perceptibly, while during 1903 it rose and numerous new springs appeared at the surface. The ground water also is the source of the shallow wells' supply.

### SURFACE WATERS.

#### STREAMS.

The Missouri River carries a large volume of water, and although its grade is less than 1 foot to the mile it flows rapidly. It is important as a source of water for drinking, domestic purposes, and stock. Many persons drink the turbid water as it comes from the river, but in most cases it is settled in vats before using. While it affords a good supply of stock water, many cattle and a few horses are lost each year by falling into the river at caving banks. These unfortunate animals rarely escape, for, although they gain a footing at some sloping bank, they usually can not climb out, and finally die from exhaustion. The Missouri is also an important avenue for transportation by means of steamers of small size, which carry grain, stock, lumber, and passengers.

Niobrara River receives most of its water from springs at the base of the Arikaree formation. The following discharge measurements were made near the village of Niobrara:

*Discharge, in second-feet, of Niobrara River near Niobrara, Nebr.*

| Date. | Hydrographer. | Discharge. |
|---|---|---|
| April 6, 1901 | O. V. P. Stout | 1,591 |
| April 7, 1901 | do | 2,115 |
| May 11, 1902 | J. C. Stevens | 1,637 |
| July 6, 1902 | do | 2,021 |
| July 25, 1902 | do | 1,401 |
| August 21, 1902 | do | 1,106 |

The stream is shallow and relatively swift, flowing among many sand bars. The water is not deep enough for boating. In this section the south slopes are usually sandy, while those on the north are clayey and very steep. Except for stock and locally for domestic purposes the water is not extensively utilized.

Ponca Creek is a weak stream in a large basin. It heads in south-central South Dakota, in many broad, shallow valleys which carry but little water.

Many water powers available in this region could be utilized to advantage. While power sites are found in each county, the most favorable conditions prevail in Knox and in the northern part of Holt County, where the powers are mostly on the smaller or spring-fed streams, which are not much affected either by floods or dry weather; these have steep grades and keep open most of the winter. As the country becomes more populous there will be increasing demand for water power, which is little used now except to run a few flouring and grist mills.

## SPRINGS.

Springs are an important water resource in all the counties, affording most of the local water supply. The principal horizons from which they flow are (1) between the Tertiary sands and the Pierre clay, (2) between Glacial drift and the Pierre, and (3) from the Dakota sandstone.

The porous Arikaree formation contains a large supply of ground water which sinks to the impervious Pierre clay, along the top of which it flows until it reaches the surface on the hill slopes. This condition is shown by the existence of frequent springs at the base of the Arikaree sands, whence the water flows out over the clay slopes below. This horizon lies high on the slopes in the western parts of Holt and Boyd counties and somewhat lower in Knox. In all cases the same general conditions prevail—an impervious bed checking the downward motion of water accumulating in a porous formation, and a lateral flow to the surface. The water from a series of springs often collects into a flowing stream, but, on the other hand, soil often chokes or checks the flow, especially in pasture lands where cattle and horses assist the process by tramping. During exceptionally humid years, ground water reaches the surface at additional places, producing transient springs. These are often called wet-weather springs, and are evidence of extensive seepage not far back in the slope which, by suitable trenching, can often be opened so as to furnish a permanent flow. Sometimes a short horizontal well or tunnel will reach a permanent supply. Where the formation is not too sandy the same result can be accomplished by boring and drilling.

Boggy places, where the ground water seeps to the surface, occur along certain streams in each county. The springs coming from the Dakota sandstone are, in part at least, seepage from the artesian waters, a portion of which reaches the surface in the eastern part of the area to which this report relates.

## UNDERGROUND WATERS.

### SHALLOW WELLS.

Shallow wells, like most springs, draw their supply from the ground water. The amount of water which a well will afford within a given time depends on a number of conditions, the principal one of which is the nature of the pervious bed. Thoroughly saturated gravels and coarse sands deliver water faster than fine sand. As water is pumped from the well the surface of the water lowers, but this is slow and hardly perceptible in cases where the materials are coarse and there is an abundance of water. It is desirable, therefore, to find water-bearing beds of coarse sand or gravel, and material of this sort prevails at most localities in this region. The water from the Cretaceous formations is generally bad, except that from the Dakota sandstone, and even this is often charged with mineral matter. The Tertiary and Quaternary deposits generally yield a suitable supply of water of good quality. Wells, except the deeper tubulars, vary in depth from a few feet to between 200 and 300 feet, and in diameter from 2 inches to several feet. They are cased with wood, brick, tile, cement, stone, and iron pipe, the first named being mostly used, and the last named being used in driven wells. Wells are dug, drilled, bored, and driven. The water level in most shallow wells is affected somewhat by weather changes. Those on the Missouri bottom, when near the river, seem to fluctuate somewhat with the flood and low-water stages of the river.

### ARTESIAN WELLS.

*Artesian conditions.*—The entire area treated in this report is underlain by the water-bearing Dakota sandstone, which yields artesian wells in many districts. Part of this water comes to the surface in numerous springs in Dixon and Dakota counties, but to the west it lies at depths gradually increasing to 1,500 feet or more. The source of this water is in the Black Hills and the Rocky Mountains, where the Dakota and associated sandstones are extensively exposed. Thence this sandstone dips eastward beneath later Cretaceous clays, but it comes to the surface along Big Sioux River, in Iowa, and also along Missouri River below Ponca, Nebr. The sandstone is porous, and also thick enough to receive and carry large amounts of water. The supply is gathered in the mountain areas and flows very slowly through the sandstone to the lower regions east, where (as, for instance, along the valleys and lower lands of Nebraska and South Dakota) part of it comes to the surface through springs and artesian wells. An important factor is the thick mass of impervious clay and shale overlying the water horizon and preventing its escape in the wide area of plains between the mountains and the Missouri. Such beds overlie the Dakota sandstone as far east as Ionia, Nebr., in the river valley and somewhat farther on the highlands. Talus slopes, glacial clays, and fine sands aid greatly in checking the free escape of water in the eastern outcropping area. Owing to the high altitude of the gathering grounds on the mountain slopes, 4,000 to 5,000 feet, and the low altitude of the region east, the water is under such pressure or head that it flows slowly eastward through the porous sandstone.

The Carboniferous beds which underlie northeastern Nebraska carry artesian water, but at a considerable depth. This horizon was reached in wells at Sioux City, Iowa, and at Ponca, Nebr.

The sandstone of the Carlile formation carries artesian water and yields the weak " pencil " flow or " straw " flow of Knox and Cedar counties. Some of the artesian springs farther up the river may issue from this horizon.

*Chemical composition of artesian water.*—The chemical composition of artesian water seems to vary somewhat with the different flows and localities. The most common mineral compounds present are sulphates of soda, lime, and magnesia, chloride of sodium, and iron, all usually in small amount. There is only a trace of organic impurity.

The following analysis of water from the small school well, Santee, Nebr., was made by Prof. Robert O. Riggs:

*Analysis of water of small school well, Santee, Nebr.*

| | Parts per million. |
|---|---|
| Silica ($SiO_2$) | 9 |
| Aluminum (Al) | 2.1 |
| Calcium (Ca) | 242 |
| Magnesium (Mg) | 48 |
| Sodium (Na) | 87 |
| Potassium (K) | 29 |
| Sulphate radicle ($SO_4$) | 733 |
| Carbonate radicle ($CO_3$) | 84 |
| Bicarbonate radicle ($HCO_3$) | 68 |
| Chlorine (Cl) | 55 |
| | 1,357 |
| Total solids | 1,360 |

The iron was not determined but there is more of it in the water of this well than in that of the large school well.

*Pressure.*—Owing to the elevated source of waters in the Dakota sandstone, these would be under great pressure under the lowlands east were it not for the leakage in the outcrop area which causes the "head" to gradually decrease from west to east. The pressure or head is of great practical importance, for it determines the height to which the water will rise, and consequently the area within which artesian flows are to be expected. This area, deduced from observed pressures, is shown in Pl. IX (in pocket). As the Dakota is composed of alternating beds of sandstone and clay which often are distinct, there are different flows, called "first," "second," "third," etc., which have different pressures or heads, usually greatest in the lowest. This is because there is freer leakage from the upper than from the lower sandstone horizon.

In northeastern Dixon County there is no pressure in the upper sandstone beds of the Dakota formation and only enough in the lower beds to raise water a few feet above the level of Missouri River. Farther west, in northwestern Dixon County and northern Cedar County, the pressure is so small in the upper beds that the flow is not strong, but at lower levels a greater pressure is found.

At Niobrara the pressure is strong enough to force water about 210 feet above the mouth of the Mill well, or to an altitude of 1,450 feet. As above explained, the pressure and head increase from east to west, and if it were not for the fact that the rise of the country is usually more rapid in that direction than the general increase gradient of the water head, artesian water could be obtained over a much greater area. As it is flowing wells are obtainable only in the valleys. At Lynch, at an altitude of about 1,392 feet, there is a closed pressure of 85 pounds to the square inch. Allowing a head per pound of 2⅓ feet (the height of a 1-inch column of water weighing one pound), the water would rise in a pipe 198 feet above the mouth of the well, or to an altitude of over 1,590 feet. As the well is 923 feet deep there is sufficient pressure to raise water in all 1,121 feet. Dividing 1,121 by $2\frac{1}{3}$ we find that the pressure at the bottom of the well is $480\frac{1}{2}$ pounds per square inch.

In the Rosebud Agency well farther northwest, in South Dakota, the artesian water raises to an altitude of 2,000 feet. Different wells in a given locality may show different pressures. The variations may be due to one or more of the following conditions: (1) Difference in the horizon of the flow, the pressure being greater with deeper flows; (2) escape of water outside of the casing; (3) leaks in the casing due to rust; (4) difference in altitude of mouths of wells; (5) choking of flows by sand or clay; (6) proximity of wells causing local interference and decrease below the average pressure; (7) short, loose, or broken casing permitting leakage from a lower sandstone into an upper one.

*Temperature of artesian water.*—In a given locality the temperature is highest in the deeper wells. There is a gradual decrease eastward from over 80° F. in the deep well at Lynch to 54° in one of the Ryan wells in the northern part of Dixon County. It has been observed that the shallow artesian wells with weak pressure have about the same temperature as springs.

*Construction and care of wells.*—It was noted that in many cases but little care had been taken in the selection of proper sites and in the construction of wells in northeastern Nebraska. Some wells have been drilled on land too high for a flow, even when a lower position would have been just as convenient to the owner. Some wells on moderately high lands, which did obtain feeble flows, have since ceased flowing. Wells should be carefully cased, and the casing should fit tightly into cap rock and permit no leakage. Below the cap rock perforated pipe should be used for a part of the distance at least to prevent sand choking the end of the casing. In too many instances there is not enough casing, and it is often so loose that water flows outside of it to the surface. It is best to use double casing. Water standing about the mouth of the well causes the pipe to rust badly, but this can easily be prevented by carefully piping and grading. One of the largest and most expensive wells in the area was lost by the rusting of pipes near the surface; in this case there was a pond of water about the well. In wells with double casing the old inner pipe can be drawn and replaced by a new one.

Large and expensive wells to be used for power should be put down by experienced well drillers who understand how to cut off the upper and weaker flows and produce a well with the greatest possible pressure. It has been found best to keep such wells closed when not in use. If properly cased and not running sand there is no danger of injuring the well by shutting off the flow, but it should be shut off gradually.

*Diminution in pressure and supply.*—It is believed that in some portions of the artesian area the pressure and volume of flow is diminishing, but reliable data bearing on this point are difficult to obtain. Many wells decrease in volume after flowing some time, but the change is often due to breaks in the pipe, leakage, and clogging by sand or iron rust. Sometimes the diminution is local and due to the large number of wells. It is claimed that the pressure in the first and second flows in the Dakota sandstone is decreasing in Cedar County; the first flow at present runs a 2-inch pipe half full, while formerly it ran a full pipe; the second flow, about 80 feet deeper than the first and having more pressure, shows but little change; the third flow, from 30 to 40 feet below the second, has changed very little, if any.

## BLOWING WELLS.

Blowing wells are found at a number of places in Nebraska, especially in Jefferson County. They are also known as "breathing," "howling," and "weather" wells. They occur at several localities in southeastern Knox County and about Mineola, Holt County. The wells have a depth of from 125 to about 200 feet, passing through loess, sand, dry gravel, and sand into water gravel. In some cases there is only a slight movement of air into and out of the well, called "sucking" or inhalation and "blowing" or exhalation. Where the casing is tight above and the opening small a very audible noise may be produced. The movement of air, up or down, seems to depend on the barometric pressure. When the air is heavy during a high barometer the movement is inward, while when the air is light during a low barometer it is outward. Since the well and weather phenomena correlate so closely the wells are called weather wells, and the changes in atmospheric pressure are supposed to cause the "blowing." The dry gravel below forms a reservoir into and out of which air readily passes. While there is more or less air in all formations, that in the porous beds moves most freely. Naturally this reservoir of air is affected by pressure, and the well is an artificial connection between the atmosphere and the air in the porous beds below. Inhalation during very cold weather causes the pipes to freeze sometimes as far down as the water. As soon as a reverse movement begins the pipes thaw out rapidly.

Mr. Charles C. Cleveland, of Creighton, Nebr., furnishes the following description of his well:

My well is 3 feet in diameter and 165 feet deep, dug through loess, 80 feet; sand and gravel, 65 feet; clay, 20 feet. From this clay a 2-inch hole was bored down to water gravel from which the water flowed 15 feet deep in the 3-foot hole. In this well there is at times a current of air moving in or out, although during much of the time it is entirely still. When the weather moderates in winter or is getting warmer at any time the well blows, and the air hissing through the platform can be heard rods away. When the weather turns cold, the air is sucked in. This air must have come out of the dry gravel below the loess. The pump platform has to be made air-tight in winter to prevent pipes freezing to the bottom of the well. All deep wells in this vicinity are blowing wells.

### POLLUTION OF WELL WATERS.

Water is rendered impure by the presence of mineral and organic matter. Some kinds of these may be present without affecting the desirableness of the water for drinking and domestic purposes, but most impurities either are, or are likely to become, injurious to the health. The water supply which comes principally from shallow wells and springs often become contaminated from the surface and is then a source of contagion. Many cases of typhoid fever have come from this cause. The site for a dug well should be selected with great care and should be as far as possible from barnyards, back-houses, etc. All surface drainage should be kept away. Placing a well on higher ground than the house and outbuildings is not always a safeguard, for the water level in a well is so low that in some cases there may be a direct underground seepage from a dangerous source of contamination. Wood curbing often fouls the water by rotting. Spring water may also become polluted if it flows from sands not well protected from surface contamination.

## WATER RESOURCES BY COUNTIES.

### NORTHERN PART OF HOLT COUNTY.

*Topography.*—The northern part of Holt County drains northeastward to Niobrara River. It is a thinly settled region of over 900 square miles, in which stock raising and dairying are the principal industrial pursuits, especially where the land is rough or sandy. There is considerable farming on the table-land just north of Stewart, Atkinson, and O'Neill. North of this table-land the slope to the Niobrara is quite perceptible, as there is a fall of 400 to 500 feet in from 15 to 25 miles. Tertiary sands form the broad surface slopes. A sand-hill area 5 to 8 miles wide, but with indefinite boundaries, lies just south of Niobrara River and extends across the northern part of the county. The surface sands and gravels here were derived in part from the Tertiary sands and in part from materials brought into the region by Niobrara River when it flowed at a higher level. Beneath the sandy formations the whole region is underlain by Pierre clay, which comes to the surface along the Niobrara and along the lower courses of the principal creeks, forming steep slopes.

The main stream is Niobrara River. Its principal tributaries in this county are the Redbird, Eagle, Big Sandy, and Beaver creeks, all of which head in the table-land and flow northeastward to the river. They are fed principally by springs and flow all the year, the run-off not being much affected by the average rain or by dry weather. The streams vary in length from about 15 to 30 miles, and the grade varies but is generally steep. The valleys are narrow and semicylindrical in form at the edge of the table-land, wider and more mature across the Tertiary slopes, and more deeply trenched in the outcrop zone of Pierre clay. The stream water is used principally for stock and to some extent for domestic purposes.

*Water power.*—None of the creeks have been gaged, but it is evident that they would afford much water power, and the conditions are such that power could be easily and cheaply developed. There are favorable places for inexpensive dams along all of the creeks, while on some of the principal creeks there are numerous power sites. At Turner, Mr. William Knollkemper has a dam (see Pl. VII, *B*, p. 18) 150 feet long and 8 to 10 feet high, constructed of brush, clay, and manure. The power is used to run a well-equipped flouring mill, with a capacity of 60 barrels a day, which has been in operation for twenty-five years. The dam cost but little, for it is simply a crude breakwater which diverts part of the stream into a mill race. For several years a mill was operated on the Big Sandy, near Badger, but it was recently moved to Butte, Boyd County. The dam and race have been somewhat improved and power will be transmitted to the mill at Butte, a distance of 7 miles.

The main drawback to the development of water power for mill purposes in the northern part of Holt County is in the lack of shipping facilities for mill products. However, cheap power could be developed and transmitted to railroad towns both north and south. This plan ought to prove feasible, as fuel for power is high priced.

*Springs.*—Springs from Tertiary and terrace sands and gravels lying on the impervious Pierre clay are numerous along all of the creeks. They afford a large supply of good drinking water, and are used for domestic purposes, stock water, and for irrigation when needed. About Ray they are found on many farms and occur numerously about Saratoga on a small tributary of Eagle Creek. Above Turner on sec. 26, T. 32, R. 11 W. the John Donlin Springs seep out of the sands. Little Sandy Creek heads at a large spring. Near Phoenix some heavy springs are used to irrigate a large orchard, and 5 miles west of Badger some strong springs are used for irrigation during dry years. The Mullehan Springs near Paddock are well known; the water comes out of sand and gravel above the Pierre clay, forming a small fall 35 feet high. In this vicinity there are several very strong springs, most of which are not used. Near the mouth of Eagle Creek springs supply large fish ponds and in dry seasons irrigate from 15 to 20 acres of orchard and garden. At another ranch 2 miles east the spring water, conducted by a ditch three-fourths mile long, is used for irrigation purposes. The springs of this county could be used to greater advantage than they are at present, for in most cases they are high on the slopes and might be piped to and through the houses, which are generally located in the valleys below. Also it seems probable that by boring or by tunneling the ground water at boggy places not far below the table-land could be tapped and caused to flow out as strong springs.

*Shallow wells.*—Since settlements usually begin along the streams or at springs, few wells were put down until the country back from the natural water supply began to be used, first for grazing and later for farming. In much of the higher area of the county sandy formations yield a suitable supply of water, usually soft. At a few places, as north of Middle Branch, the water is in fine sand and is difficult to strain. There are several blowing wells in the vicinity of Mineola.

The following table will serve to show the different well-water conditions:

*Representative wells of northern Holt County, Nebr.*

| Owner. | Location. | Depth. | Diameter. | Depth of water. | Remarks. |
|---|---|---|---|---|---|
| | | *Feet.* | *Inches.* | *Feet.* | |
| O'Neill | O'Neill | 1,400 | ([a]) | 1,360 | Some bad water. Failure. Cost $3,000. |
| J. M. Packard | Sec. 12, T. 29 N., R. 9 W. | 160 | 2 | ........ | Sand all the way down, on high ground. Uses Cook strainer. |
| E. H. Lees | Sec. 28, T. 31, R. 10 W. | 60 | 8 | 10 | On high ground. Through 57 feet of sand into gravel. |
| H. R. Henry | Sec. 22, T. 30, R. 10 W. | 68 | 10 | 9 | Through sand and gravel to coarse gravel. Blowing well. High ground. |
| George Tomlison | Sec. 25, T. 31, R. 10 W. | 76 | 8 | 12 | High ground. |
| A. B. Powell | Sec. 3, T. 31, R. 10 W. | 80 | 8 | 8 or 9 | Do. |
| A. L. Wilcox | Sec. 18, T. 31, R. 12 W. | 16 | 42 | 4 or 5 | In valley. |
| Mr. McGowen | Sec. 24, T. 31, R. 12 W. | 365 | ........ | ........ | Through sand and gravel 15 feet into Pierre clay. On Red Bird divide. |
| Henry Lasher | Sec. 24, T. 31, R. 12 W. | 120 | 8 | 14 | Log: Clay and sand, 25 feet; clay, 20 feet; hard sandy layer, 1 foot; soft decomposed layer; sand. |
| J. J. Schwetzer | Sec. 36, T. 31, R. 12 W. | 8 | 36 | ........ | Dug well. In valley. |
| A. Dobson | Sec. 12, T. 33, R. 12 W. | 20 | ........ | 12 | In valley. |
| J. F. Green | Sec. 9, T. 33, R. 14 W. | 18 | 12 | 8 | Water in pure white sand just above Pierre clay. |
| Frank Sanders | Sec. 12, T. 33, R. 15 W. | 20 | 10 | 10 | Abundant supply. |
| William Dusten | Sec. 22, T. 33, R. 15 W. | 90 | 12 | ........ | |
| Winslow Bros | Sec. 14 T. 33, R. 14 W. | 28 | 5 | 10 | Easily lowered Through soil, sand, gravel. |
| A. W. Sexton | Sec. 33, T. 34, R. 14 W. | 26 | 12 | 13 | Easily lowered. |

[a] Reduced three times; 2 inches at bottom.

*Artesian water.*—There are no deep artesian wells in this county, but many shallow flowing wells are found in the southern townships south of the area treated in this report.

The deep flow reached at a depth of 923 feet in the new well at Lynch, Boyd County, should, if tapped at Whiting bridge, have pressure sufficient to raise the water 75 feet or more above the river. According to barometric readings this would lack about 45 or 50 feet of reaching the river level at the Badger bridge. But since there is a gradual increase in pressure to the west, it is quite probable that a fair flow could be obtained at Badger at a depth of somewhat over 1,100 feet, and on the same basis it appears likely that the water would rise to the river level as far west as the mouth of the Keyapaha River and probably farther.

### BOYD COUNTY.

The water conditions in Boyd County present considerable variety, owing to the diversity of the geologic formations. These comprise surface alluvial deposits, Tertiary sands, Pierre clay, and the Niobrara chalk rock.

*Streams.*—Missouri River receives several unimportant tributaries in the northeastern part of the county, draining an area of approximately 50 square miles of hilly country. The Niobrara flows with steep grade along the southern border of the county, draining a narrow district of approximately 125 square miles and a much larger area in Holt County. This water is used for stock and to some extent for domestic purposes, especially where a suitable supply can not be had from springs and wells. Keyapaha River, a tributary of the Niobrara, flows through a grazing country and is an important source of stock water. The conditions along this stream are favorable for small power sites. Ponca Creek, though having but a weak flow, drains more than half of the county. Its lower course is quickly affected by storm water, owing to extensive slopes of gumbo, or Pierre clay. It heads in broad, shallow sloughs in Gregory County, S. Dak., and in the high lands of Boyd County receives small amounts of ground water and a limited supply from direct run-off. Between Spencer and Butte there are successive terraces at rather regular intervals along the valley, which afford a good supply of spring and well water. Here many of the weak tributaries begin in elliptical holes and ponds in shallow sloughs. Ponca Creek affords good stock water. It has been used successfully as a source of mill power.

*Springs.*—The source of spring water here, as in Holt County, is the ground water in the Tertiary and terrace sands and gravels. Springs occur in large numbers; for example, on the SE. ¼ sec. 8, T. 34, R. 16 W., there are 25 springs, and on sec. 5, adjoining, a shallow cut developed a supply of water that flowed a distance of 120 rods.

The supply of water for Spencer is obtained from springs which come out of terrace sands and gravel three-fourths of a mile northwest of the town. The water is collected in a reservoir at the highest possible level and then pumped to a standpipe. Spring water is piped into a house in Lynch. All along Ponca Creek above Bristow springs issue from sand just above clay, and similar conditions exist along all of the principal streams of the county, especially the Keyapaha in the region of Twin Buttes.

*Shallow wells.*—The well-water supply of Boyd County has been reported as limited and bad, but, while it is true that some farmers have to haul water and that certain small towns have a poor supply, such cases are exceptional. Much alkali water is found in Pierre clay areas, but a large amount of soft water is obtained from Tertiary sand. Many of the gravels yield hard water, and the supply from the chalk rock seldom is satisfactory. Since the central and eastern parts of the county present a variety of surface formations, there are frequent differences in the quality of the underground water. In the area of Pierre shale, where the soil often is satisfactory for crop raising, the water is nearly always bad, but ordinarily it is practicable to locate the farm house on some other formation which will yield good well water. In locating wells it is advisable to prospect in sandy soil with small augers, and in sinking it is best to stop as soon as gumbo is reached, unless a cemented reservoir is to be constructed, for the alkali is dissolved from the clay by the water while it stands in the well. It has been observed that heavy pumping improves the quality of water in wells sunk through sand into the clay. Dry wells are not numerous and probably they occur only where the surface of the impervious clay rises above the ground-water level. Ordinarily such areas are of small extent, and trial borings will indicate their limits.

At Butte good and bad waters occur within a few rods. The water-bearing sands lie in depressions and yield a suitable and an abundant supply. In intervening areas the wells extend into gumbo and yield scanty supplies of poor water. If necessary an abundance of desirable water can be piped from wells near the buttes just south of town. At Monowi the wells are not favorably located, and the result is unsatisfactory. The supply at Gross is usually good.

*Representative shallow wells of Boyd County, Nebr.*

| Owner. | Location. | Depth. | Diameter. | Depth of water. | Quality. | Remarks. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Inches.* | *Feet.* | | |
| Hamilton place | Sec. 36, T. 32, N. R. 9 W | 22 | 20 | 9 | Soft | |
| Chris Johnson | Sec. 24, T. 32, R. 10 | 25 | 18 | 5 | Bad | Limited supply. Soil, sand, gravel, Pierre clay. |
| Charles W. Orr | Sec. 33, T. 34, R. 10 | 15 | 36 | 4 | Hard, good | |
| C. C. Irwin | Sec. 14, T. 33, R. 10 | 24 | 16 | 9 | do | Soil, sand, gravel. |
| J. C. Hoffman | Sec. 14, T. 33, R. 10 | 21 | 36 | 3 | do | Sand and gravel. |
| Hubert Van Pelt | Sec. 14, T. 33, R. 10 | 22 | 12 | 5 | do | Soil, sand, gravel. Limited supply. |
| B. Baker | Sec. 2, T. 32, R. 10 | 12 | 60 | 6 | Hard, fair | Soil, weathered Pierre clay. |
| Albert Gillman | Sec. 2, T. 33, R. 10 | 22 | 36 | 10 | Hard, poor | Soil, sand, weathered Pierre clay. Limited supply. |
| F. P. Mark | Sec. 34, T. 34, R. 10 | 24 | 24 | 16 | Medium hard, good | Sandy loam, clay, sand. |
| John W. Orr | Sec. 21, T. 34, R. 10 | 30 | 24 | 8 | do | Soil, clay, native lime, sand, and gravel. |
| C. A. Dean | Sec. 19, T. 34, R. 10 | 89 | 18 | 10 | do | Soil, sand, clay, sand. |
| F. M. Stumbo | Sec. 20, T. 34, R. 10 | 44 | 28 | 16 | Soft good | Water in 16 feet of gravel under 24 feet of Tertiary marl. |
| P. Carroll | Sec. 29, T. 34, R. 10 | 22 | 12 | 12 | Hard, good | |
| Joseph Crowe | Sec. 22, T. 34, R. 10 | 16 | 36 | 4½ | Soft, fair | |
| I. Jonason | Sec. 25, T. 33, R. 11 | 48 | 36 | 3½ | Soft, good | Water in sand. |
| W. T. Reshaw | Sec. 18, T. 33, R. 11 | 66 | 24 | 7 | Medium hard | Very cold water in thin bed of sand. |
| A. Fulckrod | Sec. 9, T. 33, R. 11 | 11 | 36 | 6 | Poor | |
| Wm. Seeley | Sec. 18, T. 33, R. 11 | 66 | 24 | 6 | Alkaline, bad | Soil, Pierre clay. |
| Martin Laugon | Sec. 19, T. 33, R. 11 | 36 | 4 | 13 | Medium hard, fair | |
| Henry Wagoner | Sec. 28, T. 34, R. 11 | 33 | 36 | 10 | Soft, good | |
| W. J. Everett | Sec. 2, T. 35, R. 11 | 32 | 24 | 6 | Soft | Water in gravel under 21 feet of sand. |
| W. T. Reshaw | Sec. 35, T. 33, R. 12 | 30 | 16 | 15 | Medium hard, bad | Poor water; not used; in Pierre. |
| L. S. Anger | Sec. 34, T. 34, R. 12 | 45 | 12 | 4 | Soft | Soil, sand and gravel. |
| M. Coleman | SE. ¼ sec. 35, T. 33, R. 12 | 24 | 36 | 12 | do | Soil, sand, and thick white chalk. |
| W. E. Kloke | NE. ¼ sec. 35, T. 33, R. 12 | 21 | 12 | 9 | do | Soil, hard-pan soil, putty rock 8-9 inches; gravel, 1 foot; quicksand, 6 feet. |
| I. N. Morrison | NW. ¼ sec. 10, T. 34, R. 12 | 13 | 36 | 8 | Medium | Soil and sand. |
| J. D. Schmidt | Sec. 22, T. 33, R. 12 | 32 | 12 | 8 | Soft | Soil, sand, and gravel. Just to Pierre. |
| S. C. Claucus | Sec. 6, T. 33, R. 12 | 18 | 13 | 10 | do | Soil, sand, and gravel. |
| W. S. Eaton | SE. ¼ sec. 30, T. 34, R. 12 | 41 | 26 | 6 | do | Black soil, 3-4 feet; sand and gravel, 5-6 feet; clear sand, quicksand. |
| John Lampman | NW. ¼ sec. 31, T. 34, R. 12 | 32 | 38 | 8½ | Hard | Soil, sand, white chalky clay. |
| O. R. Carmidrall | SW. ¼ sec. 31, T. 34, R. 13 | 75 | 15 | 15 | do | Clay, rest magnesia. Some gravel in bottom. |
| A. D. Prattyman | NW. ¼ sec. 6, T. 33, R. 13 | 70 | 36 | 12 | Soft | Soil and clay subsoil (light). Did not reach soapstone. |
| J. P. Ross | Sec. 24, T. 33, R. 13 | 36 | 10 | 9 | Hard | Soil, sand, and gravel. Water in gravel. |
| C. E. Whittig | NW. ¼ sec. 15, T. 34, R. 13 | 32 | 16 | 10 | do | Clay, gravel, and quicksand. |
| Elrich Windmyer | SE. ¼ sec. 21, T. 34, R. 13 | 50 | 18 | 25 | Soft | Soil, light-colored, sandy clay. Did not reach soapstone. |
| John Webber | Sec. 36, T. 33, R. 13 | 10 | 48 | 5 | do | Soil and sand. |
| J. D. Garmley | NW. ¼ sec. 29, T. 34, R. 13 | 33 | 36 | 10 | do | Soil, 5 feet; sand, 12 feet; magnesian clay, 20 feet; sand and gravel. |
| J. Gamley | Sec. 25, T. 34, R. 14 | 43 | 48 | 16 | do | Soil and loam, 10 feet; clay, 30 feet; sand and gravel. |
| G. S. Wright | NE. ¼ sec. 21, T. 34, R. 14 | 32 | 22 | 16 | Medium hard | Soil, clay, subsoil, sand. |
| Ed McKemper | Sec. 30, T. 35, R. 16 | 125 | 12 | 15 | Soft | Water in 14 feet; sand and gravel under 110 feet of Tertiary marls and sands. |
| Dwight E. Brown | SE. ¼ sec. 8, T. 34, R. 16 | 33 | 16 | 10 | do | Soil and clay. |
| Jacob Heimerdinger | SW. ¼ sec. 11, T. 34, R. 16 | 15 | 48 | 10 | Hard, good | Clay, 4 feet; balance in a flinty rock. |

*Artesian wells.*—All of Boyd County is underlain by Dakota sandstone containing artesian water, but only a limited area is low enough for surface flows. Strong wells can be obtained along the Missouri bottom and along the Ponca Valley at least as far west as Spencer. The heavy pressure in the deep well recently finished at Lynch demonstrates that there is a deeper and stronger flow there, and probably that artesian wells can be had farther up Ponca Creek and Niobrara River than was formerly supposed. A deep flow was reached at Lynch, which has sufficient pressure to raise water to an altitude of 1,590 feet. This indicates that a surface flow can be obtained in the valley below Spencer, at a depth of about 1,065 feet. If the pressure increases westward across Boyd County a flow may be had in the valley below Anoka at a depth of about 1,170 feet, and as far west along the Niobrara bottom as the Badger Bridge and probably farther. Wells far to the west are more expensive to bore on account of increased depth and will afford little water power.

The wells at Lynch throw much light on the underground conditions. In the old well, completed in 1900, it is reported that at the top there were 260 feet, mostly "soapstone," 40 feet of Niobrara chalk rock at the base of the Niobrara formation, 275 feet of "soapstone" with some hard layers, 25 feet of hard rock and "sandstone" (presumably Greenhorn limestone), 20 feet of soapstone and clay, 50 feet of slate with coaly layers, 4 feet of so-called coal, 38 feet of sandstone, 30 feet of hard clay and sandstone, and 18 feet of porous sandstone in which the flow began. Other flows appeared in sandstones below until, at 797 feet, the flow was so strong that work was discontinued. The flow was 465 gallons a minute, pressure 52 pounds, temperature 79½° F., and diameter 6 to 4½ inches. In the new well bored in 1903 a pressure of 85 pounds is reported and a yield of 3,100 gallons a minute. The large flow in the new well is somewhat spasmodic in pressure and it has also thrown out considerable sand. It is to be used for mill power. The first flow was at 740 feet and the third at 875 feet; the temperature is 90°, and the diameter is 10 inches to 350 feet and 8 inches below. This well is shown in Pl. X.

*Section of the new artesian well at Lynch, Boyd County, Nebr.*

| | Feet. |
|---|---|
| Sand and gravel | 0– 18 |
| Pierre clay (called soapstone) | 18–105 |
| Niobrara chalk rock, sandy and hard below | 105–300 |
| Carlile clays, with some beds of pyrites | 300–588 |
| Greenhorn limestone | 588–610 |
| Graneros clays and shales | 610–700 |
| Dakota sandstone and clay, alternating. Four or five different flows reported | 700–923 |

Total depth 923 feet. Altitude of mouth, 1,392 feet.

SECOND ARTESIAN WELL AT LYNCH, NEBR.

*Analyses of waters of artesian wells at Lynch, Nebr.*[a]

[Parts per million.]

| | 8-inch or new well. | 4-inch or old well. |
|---|---|---|
| Combined water and organic matter | 233 | 232 |
| Silica ($SiO_2$) | 56 | 16 |
| Iron and alumina ($Fe_2O_3$ and $Al_2O_3$) | 10 | 2.8 |
| Calcium (Ca) | 251 | 255 |
| Magnesium (Mg) | 39 | 57 |
| Sodium (Na) | 46 | 52 |
| Potassium (K) | 12 | 15 |
| Sulphate radicle ($SO_4$) | 682 | 667 |
| Carbonate radicle ($CO_3$) | 75 | 67 |
| Chlorine (Cl) | 74 | 61 |
| Total solids | 1,474 | 144 |

[a] S. Avery and A. Jacobsen, analysts.

A well is now (1905) being drilled on sec. 33, T. 34, R. 11, near Rosedale, but the drill is fast at a depth of 793 feet. If boring is continued, a good well may be obtained at a depth of 1,100 to 1,200 feet. The first mill well at Lynch was three years in boring. The following altitudes, obtained from the Chicago and Northwestern Railway and by the use of an aneroid barometer, may be of value in considering the depth and head of the artesian waters:

*Altitudes on line of Chicago and Northwestern Railway.*

| | Feet. |
|---|---|
| Monowi [a] | 1,322½ |
| Lynch [a] | 1,400½ |
| Spencer [a] | 1,541½ |
| Anoka [a] | 1,638½ |
| Fairfax, S. Dak.[a] | 1,932½ |
| Niobrara River at Whiting Bridge | 1,502 |
| Niobrara River at Badger Bridge | 1,635 |
| Missouri River at Greenwood | 1,229 |
| Missouri River at Fort Randall | 1,240 |
| Town of Spencer | 1,637 |
| Town of Butte | 1,795 |

## KNOX COUNTY.

Loess, varying in thickness from a few feet to over 100 feet, forms the surface over most of Knox County, its continuity being interrupted by a sandy area west of Verdigris Creek, by a clayey region beyond the Niobrara, by sandy sections near Santee, and by places where deeper valleys cut through to underlying formations. The northern and central parts of the county are somewhat hilly, and lower than the more level regions to the south and southeast. There is considerable bottom land along the Missouri and the Niobrara. The chalk rock so prominently exposed along the Missouri extends southward under the Pierre, Tertiary, Glacial, and loess deposits.

[a] Base of rail at station.

In much of the county the Pierre clay and Niobrara chalk rock, which usually afford an inferior supply of water, are deeply buried by other formations and are not reached in ordinary wells. Except for an area of about 60 square miles draining south to Elkhorn River, the general slope and drainage is northward to the Missouri.

*Streams and water power.*—The Missouri is the most important stream; it flows along the northern margin of the county and is often the source of local water supply. The Niobrara River receives 7 tributaries of some importance from the south, but practically none from the north. Verdigris Creek, with a drainage basin of about 250 square miles, is one of the best water-power streams in northern Nebraska, gaging about 105 second-feet and flowing throughout the year. A mill is successfully run by water power from this stream at the town of Verdigre; the dam is constructed of greenish quartzite obtained 6 or 7 miles southwest. Several other good power sites exist between Verdigre and Niobrara River.

Bazile Creek closely resembles the Verdigris in character, but has a drainage basin in the center of the county, of about 400 square miles in area. Much of the power here is not favorably located with respect to railroads, but it might be transmitted to Creighton, Bloomfield, Winnetoon, and other towns. There are two well-constructed dams along the creek, one at the Bazile mill and the other at the lower Bazile mill (see Pl. XI, *B*). Each dam has a fall of about 12 feet and is made of greenish quartzite and each supplies water for 60-barrel flouring mill. Farther downstream numerous favorable power sites could be located.

Frankforter Creek, frequently called Weigand Creek, in the northeastern part of the county, is too weak for power, especially during the drier months.

*Springs.*—The rainfall accumulates as ground water in the loess and sand and gravel deposits, and from these springs issue, especially at the contact with impervious beds. Many flow from the outcropping edge of the top of the Pierre clay, which extends along the sides of the valley slopes. Talus from later formations often covers the clay more or less in the outcrops and sometimes carries the spring water to lower levels. In some parts of the county the upper surface of the clay is very uneven as a result of erosion.

As in adjacent counties the number of springs is very great, practically every little ravine along the Niobrara, Verdigris, and Bazile valleys being fed by a spring, large or small. Only a few can be noted: Springs just southwest and northwest of Verdigre could be piped to furnish an abundance of water for the town. The La Mont Springs, about 2 miles south of Niobrara, are quite strong. A spring at the place of R. F. Stout, sec. 5, T. 30, R. 5 W., south of Center, is

*A.* OLD WELL AT SANTEE AGENCY, NEBR.

*B.* LOWER DAM ON BAZILE CREEK, KNOX COUNTY, NEBR. BUILT OF QUARTZITE.

piped some 350 yards to a hydrant at the house; the water, temperature $55\frac{1}{2}°$ F., issues from the base of coarse sand at the clay contact, at an altitude of about 1,525 feet, or 35 feet above the hydrant. A notably heavy spring is located $1\frac{1}{2}$ miles southeast of Center. A small spring near the creek at the lower Bazile mill yields a good quality of drinking water; the flow is 7 gallons per minute, and the temperature $54\frac{1}{2}°$. Several springs are found along the Frankforter Creek; one at Weigand affords a good supply of water for a public watering place, stock, and house use.

*Shallow wells.*—North of Niobrara and in the Ponca basin the shallow-water conditions are very variable; the best supplies are obtained from irregular areas of sand and gravel on the divides and from the flood-plain deposits. In the southwestern part of the county water is derived from Tertiary sands in wells from 100 to 200 feet deep. In the central, southern, and eastern portions good water is obtained in gravel, which often lies 175 feet deep on high ridges and table lands, and 20 to 35 feet in the old northwest-southeast valley extending from Verdigris Creek past Winnetoon and Creighton to the southeast. At a few places Tertiary sands rise above the gravel beds and afford a supply at less depths. Many blowing wells are found in Tps. 29 and 30, Rs. 2, 3, and 4.

The Pierre clay has not been reached in wells over 200 feet deep on the high lands south of Bloomfield, which indicates a great thickness of post-Cretaceous formations, many of them water-bearing. Over much of the eastern half of the county two gravel beds, separated by clay and sand, are encountered, except where they have been removed by erosion or where Tertiary sands rise above them.

In this county, as elsewhere, the water derived from wells extending into the Pierre clay and the Niobrara chalk rock usually contains much alkali, unless the beds have lost their soluble matter by leaching. Usually, not far from places underlain by these formations, good water may be obtained from alluvial or other sands.

*Artesian wells.*—Large supplies of artesian waters are available in all of the lower lands of the county, and in many places the conditions are favorable for high-pressure wells. The mill well at Niobrara, used so successfully for power, indicates that such wells might be obtained at many points on the Missouri, Niobrara, and Ponca bottoms. With little doubt one or more stronger flows can be had at a slightly greater depth, and an attempt is now being made at the Niobrara mill to reach one of these; the last report (1905) indicates slow progress in the drilling and a depth of 500 feet.

*Representative shallow wells of Knox County, Nebr.*

| Owner. | Location. | Depth. | Diameter. | Depth of water. | Quality. | Remarks. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Inches.* | *Feet.* | | |
| Charles Cleveland | Sec. 28, T. 29 N., R. 4 W | 186 | 4 | 36 | | Clay, 80 feet; gravel and sand, 65 feet; clay, 40 feet; gravel, 1 foot. |
| Jack L. Burt | Sec. 23, T. 29, R. 4 | 185 | 3 | 4 | Soft | Yellow clay, 80 feet; sand, 60 feet; dry quicksand, 23 feet; dry gravel, 13 feet; hard pan, 4 feet; gravel, 4 feet. |
| D. C. Billeck | Sec. 26, T. 29, R. 4 | 182 | 2 | 10 | | Loess, 120 feet; sand, 18 feet; dry gravel, 24 feet; yellow clay, 8 feet; water gravel, 8 feet. |
| W. H. Wort | Sec. 26, T. 29, R. 5 | 40 | 12 | 10 | Soft | 25 to 28 feet sandy loam; sand, quicksand, gravel. |
| (In town) | Sec. 3, T. 30, R. 3 | 20 | 2 | 4 | | |
| Colin Valentine | Sec. 11, T. 30, R. 3 | 40 | 30 | 32 | Soft | |
| Peter Ward | Sec. 1, T. 30, R. 4 | 126 | | 2 | do | Blue clay—some sand and gravel. |
| John Roberts | Sec. 3, T. 30, R. 4 | 90 | | Dry. | | 15 feet of black soil and rest mostly sand; coarse gravel in bottom. |
| John Tucker | Sec. 3, T. 30, R. 4 | 137 | | | Hard | Black soil and sand with some clay. |
| John Roberts | Sec. 4, T. 30, R. 4 | 169 | | Varies. | do | 50 feet black soil and rest dry sand; water easily lowered, but quite steady supply. |
| Louis Eggert | Sec. 8, T. 30, R. 4 | 102 | | 2 | do | Black soil on top, sand and gravel below. |
| Charles Ward | Sec. 9, T. 30 R. 4 | 140 | | 12 | do | Sand and gravel, little clay; water supply not steady; easily lowered at times. |
| I. Ellingson | Sec. 4, T. 30, R. 5 | 16 | | 9 | | Sand and gravel; well in bottom above creek. |
| W. D. Patton | Sec. 35, T. 31, R. 3 | 14 | 3×4 | 3 | | |
| J. B. Crockett | NE. ¼ sec. 21, T. 31, R. 4 | 57 | | 15 | Hard | Soil, bluish clay, gravel and water. Blowing well. |
| Frank Hajek | Sec. 8, T. 31, R. 5 | 30 | 16 | 6 | Soft | Soil, sand to soapstone. |
| Frank Jelenek | Sec. 5, T. 31, R. 5 (in town) | 17 | 12 | 3 | do | Soil, sand and water in gravel. |
| F. P. Krolop | NW. ¼ sec 12, T. 32, R. 8 | 18 | 18 | 10 | Medium | Soil, sand, 2 feet; gravel, 2 feet; soapstone rest of distance. |
| Chris. Johnson | Sec. 28, T. 32, R. 8 | 8 | 36 | 4 | do | Soil, 4 feet; sand, sand and gravel. |
| J. H. Rothwell | Sec. 25, T. 32, R. 8 | 35 | 1½ | 10 | Hard | Soil; reddish clay, 25 feet; gravel. |
| M. Thompson | Sec. 18, T. 32, R. 6 | 21 | 2 | 10 | Soft | Soil and sand. In Niobrara Valley. |
| J. A. Lindsan | Sec. 16, T. 32, R. 6 | 14 | 2 | 3 | do | Black soil, 5 feet; sand, 9 feet. |
| L. Weigand | Sec. 1, T. 32, R. 3 | 24 | 24 | 10 | do | Soil, clay, then water. |
| C. H. Sawyer | NE. ¼ sec. 7, T. 32, R. 3 | 40 | 36 | 9 | Medium | Soil, loess, 35; sand and gravel with water. |
| Frank Weigand | NE. ¼ sec. 10, T. 32, R. 3 | 42 | 24 | 8 | do | Soil, loess, 6; sand and gravel. |
| Chas. Jancore | Sec. 7, T. 32, R. 3 | 125 | 24 | | | |
| James Renner | W. ½ sec. 23, T. 32, R. 3 | 24 | 36 | 15 | Hard | Soil, sand and gravel. In small valley. |
| School | Sec. 13, T. 33, R. 5 | 80 | | 6 | Alkaline | 6 feet into chalk rock. |
| Charles Jacocks | Sec. 11, T. 32, R. 3 W | 130 | 36 | 5 | Hard | Soil, loess and sand (?). |
| D. C. Cleveland | 5½ miles east of Creighton | | | | | Sandy loess, 75; gravel, 80; fine sand, 10. |

A new well is soon to be put down at the Santee Agency. The old well there, which has been used successfully for mill power, irrigation, fire protection, and general water supply, is now of little use (see Pl. XI, *A*), because the casing has rusted off 2 or 3 feet below ground. The large well at the school afforded clear water for about two weeks when finished, and the volume was at first over 2,000 gallons per minute. After a while it began throwing out sand and shale, and the flow ceased entirely a few times but was started again each time by cleaning. At present the pressure is 26½ pounds at the mouth of the well, which is 105 feet above Missouri River. In this well trouble was experienced with the casing at a depth of about 500 feet. The present water supply is thought to come principally from the first flow. Wells in the northeastern part of the county have decreased in pressure and flow, principally because they were not properly cased.

Attempts to get wells on high lands have failed because of the altitude, the pressure, though strong in the water-bearing beds below, not being sufficient to force the water to the height necessary.

*Record of well at the packing house, Niobrara, on the Missouri bottom, sec. 8, T. 32, R. 6 W.*

| | Feet. |
|---|---|
| Soil and sand | 0– 70 |
| Niobrara chalk rock | 70–200 |
| Clays and shales with thin beds of iron pyrites (Carlile) | 200–410 |
| Limestone (Greenhorn) | 410–442 |
| Clay and shale (Graneros) | 442–520 |
| Dakota sandstone and clay | 520–600 |

*Record of small well at the school, Santee, Nebr., sec. 13, T. 33, R. 5 W.*

[Mouth of well 143 feet above the Missouri River.]

| | Feet. |
|---|---|
| Soil and sand | 0 – 23 |
| Pierre clay | 23 – 35 |
| Niobrara chalk rock | 35 –240 |
| Clay, shale, and thin beds of iron pyrites (Carlile) | 240 –445½ |
| Limestone (Greenhorn) | 445½–502 |
| Clay and shale (Graneros) | 502 –600 |
| Dakota sandstone | 600 –604 |

*Record of John Lytle well, sec. 19, T. 33, R. 2 W., Nebraska.*

[Mouth about 70 feet above the Missouri River.]

| | Feet. |
|---|---|
| Soil | 0– 6 |
| Niobrara chalk rock | 6– 88 |
| Clays and shales with hard beds (Carlile) | 88–380 |
| Limestone (Greenhorn) | 380–400 |
| Clay and some shale (Graneros) | 400–490 |
| Dakota sandstone and clay (second flow) | 490–530 |

*Artesian wells of Knox County, Nebr.*

| Name. | Location. | Diameter. | Depth. | When drilled. | Pressure when drilled. | Yield per minute. | Temperature. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | *Inches.* | *Feet.* | | *Pounds.* | *Gallons.* | *F.°* | |
| Dan's well, Hiles ranch. | 1¼ miles east of Monowi, sec. 18, T. 33, R. 8 W. | 3-2 | 770 | 1895 | | | 70 | Pressure now 11 pounds, with leak. Third flow, 740 feet. Temperature varies. |
| O. Hegen | 7 miles west of Niobrara, sec. 21, T. 32, R. 7 W. | 2 | 500 | 1903 | | | | A surface flow is not expected. Depth given is for Aug. 15, 1903. |
| Mrs. John Havlicek | Near Verdigris, sec. 29, T. 31, R. 6. W. | 2 | 770 | 1896 | Formerly 34, now 11. | 14 now | 74½ | |
| Niobrara mill well | Niobrara | 8 | 656 | 1896 | At first 95 | 1,900 | 68 | Pressure July 14, 1903, 65 pounds when not entirely shut off. Pressure 120 pounds when closed 2 weeks in 1896. |
| Niobrara packing-house well. | do | 2 | 600 | 1895 | Reported 107 | Was 280 | 66 | Pressure weak now with leak; also yields about 35 gallons per minute. |
| Foreman ranch | 4 miles east of Niobrara, sec. 12, T. 32, R. 6 W. | 2 | 548 | 1903 | 82 | 240 | 65 | Principal flow at 520 feet. |
| Large school well | Santee, sec. 13, T. 33, R. 5 W. | 8 | 740 | 1899 | 55 when drilled, 26⅔ now. | 1,699 when drilled, 106.2 cubic feet now. | 64 | Mouth of well 105 feet above Missouri River. |
| Small school well | do | 3 | 604 | 1885 | Very weak | | 64½ | This water is piped through houses. |
| Agency well | do | 6 | 600 | | Weak | | 64 | Not much used now. Leaks at break in pipe. |
| Herrick ranch well | 2 miles west of Herrick, sec. 16, T. 33, R. 3 W. | 2 | 400 | | Was strong, weak now. | 8 | 62 | Pipe badly rusted. On Missouri bottom. |
| Clark well (formerly Brown). | 1½ miles northwest of Herrick, sec. 15, T. 33, R. 3 W. | 2 | 400 | | Weak | | 61 | On bottom land. Cased the second time. |
| T. C. Van Meter | Sec. 13, T. 33, R. 3 W | 2 | 504 | 1892 | Not strong | 2 | 63 | On high ground. |
| John Lytle | Sec. 19, T. 33, R. 2 W | 2 | 550 | 1899 | | 10 | 63½ | About 70 feet above the Missouri River. |
| C. D. Buhrow | Sec. 20, T. 33, R. 2 W | 6 | 650 | 1894 | 64 when drilled, ceased flowing this summer. | 30 with big leak | 62 | Up Frankforter Creek. Diameter below 44 feet is 4½ incnes. |
| Lytle ranch well | Sec. 17, T. 33, R. 2 W | 2,3 | 400 | 1887 | 25½ with big leak | 3 | 62½ | Passed through 10 feet of bowlders at depth of 50 feet. Formerly had high pressure. |
| Mastin Mische | E. ½ sec. 20, T. 33, R. 2 W. | 2 | 600 | | Weak now, was very strong. | 6 | 62 | About 70 feet above the Missouri River. |
| Kate Phelps well | SE. ¼ sec. 16, T. 33, R. 2 W. | 1 | 400 | | 11 | 3 | 62 | On Missouri bottom. |
| John Mische | do | 2 | 395 | | Weak | 9 | 60 | On Missouri bottom, near chalk bluff. |
| Chas. Mische, lot well. | Sec. 15, T. 33, R. 2 W | 2 | 405 | | 14 now, with leak. | | 59½ | Part way up chalk bluff. |
| A. P. Sage | Sec. 13, T. 33, R. 2 W | 2 | 700 | | Does not flow | | | Used as a tubular well; 200 feet above river. |
| Chas. Mische | Sec. 15, T. 33, R. 2 W | 2 | 425 | | 14 now, with leak. | 9 | 61 | Part way up chalk bluff. |

### CEDAR COUNTY.

The most extensive surface deposit in Cedar County is the loess, below which lie Quaternary and Tertiary sands, clay, and gravel. Of the Cretaceous formations only a few detached areas of Pierre clay occur, while Niobrara chalk rock underlies all of the county, either beneath later formations or at the surface. The other members of the Cretaceous exposed along the Missouri lie at lower levels beneath the chalk.

The surface of the county is for the most part gently rolling, with drainage to the northeast and southeast. The principal streams, aside from the Missouri, are Bow and West Bow creeks, which converge north of St. James. The southern and southeastern townships are drained by Logan Creek.

*Springs.*—The big springs near Coleridge were well known in the early history of the county as a watering place for immigrants. Curlew Springs, issuing from banks beneath the drift in a boggy slough, are also well known. The Frank Hochstein Spring on sec. 8, T. 32, R. 2, is perhaps the finest in the county. It is located at the foot of a loess-capped hill and the water boils up from a circular hole the depth of which has not been ascertained. The flow is between 400 and 500 gallons per minute, which, according to the owner, has not changed in thirty-eight years. The water deposits some iron and on that account is usually regarded as coming from the artesian supply. The temperature is only $50\frac{1}{2}°$. The water is used for drinking, domestic and dairy purposes, and stock.

*Shallow wells.*—In this county there is usually an abundance of good water available in shallow wells, from Tertiary and Glacial sands and gravels. In some localities the wells extend into the chalk rock, which gives very hard water but contains less alkali than farther west, the formation appearing to be leached out in this county. Not many shallow wells are found along the Missouri bottom, the water supply there being derived from artesian wells.

The depth of common or shallow wells is controlled to a considerable degree by the topography. In the broad valleys water is obtained at a depth of a few feet, usually from 10 to 40, while on some of the intervening ridges and high lands the depth to it is considerably greater.

About Hartington the depths vary from about 15 to 35 feet and at Coleridge from 20 to 45 feet.

*Representative shallow wells of Cedar County, Nebr.*

| Owner. | Location. | Depth. | Diameter. | Depth of water. | Quality. | Remarks. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Inches.* | *Feet.* | | |
| Chas. Clark | Sec. 21, T. 33 N., R. 1 W. | 60 | 24 | 15 | Hard | Soil, clay 20–30 feet; chalk rock. |
| James Marsh | Sec. 16, T. 33, R. 1 W | 72 | 24 | 20 | do | Good drinking; soil, clay; chalk rock. |
| Town well | Sec. 16, T. 33, R. 1 W | 70 | 60 | 11 | Medium | Soil to 12 feet; sand; soil; gravel with water. |
| H. Wubben | NE¼ sec. 23, T. 33, R. 1 E. | 100 | 36 | | Hard | Soil; loess 30 feet; red chalk rock 20 feet; blue chalk 48 feet. |
| Carl Doeller | Sec. 35, T. 33, R. 1 E | 50 | 48 | 2 | do | Soil; loess 44 feet; chalk. |
| L. P. Lauretzen | Sec. 26, T. 32, R. 2 E | 50 | 48 | 10 | do | |
| Ernest Ferber | Sec. 1, T. 31, R. 2 E | 36 | 2 | | | Black dirt 3 feet; sand 22 feet; balance gravel. |
| W. H. Hight | Sec. 9, T. 29, R. 2 E | 13 | 39 | 9 | Medium. | Soil, gumbo; sand in bottom. |
| Ed Fiscus | Sec. 18, T. 29, R. 3 E | 55 | 2½ | | Hard | Soil, silty; loess 51 feet; sand with water at bottom. |
| R. C. Chase | Sec. 34, T. 30, R. 3 E | | 30 | | do | Loess, sand, and gravel; is 60 feet below highest hills. |

*Artesian wells.*—There are nearly 100 flowing artesian wells in Cedar County, all of which are either along or near the Missouri bottom. Their distribution is shown on Pl. IX (in pocket), and most of their features are given in the table, page 47. In addition to these there are many tubular wells on the highlands to the south, some of which flowed for a short time. The supply in these tubular wells comes from the artesian water in the Dakota sandstone and rises as high in these wells as it would in pipes at artesian wells on the Missouri bottom. Mr. Chamberlain, who drilled most of the wells in Cedar County, states that flowing wells can be had up West Bow Creek for 7 miles and up Bow Creek for 6 miles from the river. Beyond that distance they cease to flow.

This important resource should be protected by more careful casing of wells; all should be cased to the cap rock and kept under control at the surface. As it is there is an enormous loss by underground leakage and the waste of flows on the surface.

*Record of artesian well at St. Helena, Nebr.*

| | Feet. |
|---|---|
| Chalky limestone | 0– 25 |
| Shale | 25– 59 |
| Dark blue clay | 59–329 |
| Shale | 329–369 |
| Black shale with hard layers and lignite 6 inches thick at 399 and 418 feet | 369–418 |
| Sand with flow, underlain by clay | 418–466 |

*Artesian wells of Cedar County, Nebr.*

| Owner. | Location. | Depth. | Diameter. | When drilled. | Pressure. | Yield per minute. | Temperature. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Inches.* | | *Pounds.* | *Gallons.* | *° F.* | |
| Frans Nelson | NW. ¼ sec. 17, T. 33, R. 1 W | 500 | 1¼ | | Weak | | 59 | Soil; chalk to perhaps a little below the river clay, hard beds, and shale to sand rock. |
| Albert Miller | Sec. 18, T. 33, R. 1 W | 648 | 3½ | | None | | | Water raised to within 56 feet of the surface about 200 feet above river. |
| D. Miller | NE. ¼ sec. 17, T. 33, R. 1 W | 365 | 2 | 1898 | 15 | 26 at first | 59½ | Soil; sand 45 feet; no chalk; clay and shale for most of distance; thin cap rock with porous sand rock beneath. Flow at 337 feet. |
| John Nelson | SW. ¼ sec. 16, T. 33, R. 1 W | 400 | 2 | 1883 | Weak | | 59½ | About 10 feet above river. |
| Do | SW. ¼ sec. 16, T. 33, R. 1 W | 400 | 2 | | 14 | 7 now | 60 | On Missouri bottom. |
| John Aten | Sec. 16, T. 33, R. 1 W | 400 | 2 | 1896 | 9 now | 7 | 58½ | Do. |
| Eugene Saunders | SE. ¼ sec. 9, T. 33, R. 1 W | 400 | 2 | 1896 | 8 | 7 | 58½ | On Missouri bottom. Diameter reduced to 1 inch at top. |
| Joseph Holtzbauer | SE. ¼ sec. 10, T. 33, R. 1 W | 400 | 2 | 1895 | Strong | 15 | 59 | Soil and sand, 181 feet; clays, shale, and hard rock to water rock. |
| J. H. Coacher | SW. ¼ sec. 11, T. 33, R. 1 W | 380 | 2 | | | | | Rusted pipe. Used as tubular well. |
| John Nelson | Sec. 12, T. 33 R. 1 W | 400 | 2 | | About 13 | 7 | 59½ | Pressure was stronger. |
| L. Hoesing (Eikhoff well) | Sec. 30, T. 33, R. 1 W | | | | None | Does not flow | | On high ground. Tubular. |
| William Lackman | NE. ¼ sec. 27, T. 33 R. 1 W | | 2 | | do | do | | Flowed for a time. Used as tubular well now. |
| Dave Nelson | Sec. 12, T. 33, R. 1 W | 380 | 2 | 1897 | Strong | 44 | 60 | |
| Albert Lee | Sec. 8, T. 33, R. 1 E | 360 | 2 | 1896 | Weak | 78 when drilled; 52 now. | 59½ | Soil, 4 feet; quicksand, 20 feet; coarse sand and gravel, 30 feet. The rest of the way blue clay, with few layers of hard rock ranging from 3 inches to 3 feet in thickness. |
| C. B. Clark | NW. ¼ sec. 17, T. 33, R. 1 E | 420 | 2 | | Good | | 69 | |
| H. Yager | Sec. 16, T. 33, R. 1 E | 360 | 2 | 1889 | Weak | 5½ | 58 | On Missouri bottom. |
| M. U. Hoyt | SW. ¼ sec. 17, T. 33, R. 1 E | 454 | 1½ | 1893 | Fairly strong | | 58½ | Is used for the house, barn, and three pastures. |
| Dave Nelson | NE. ¼ sec. 15, T. 33, R. 1 E | | 1½ | 1892 | Weak | 40 | | On Missouri bottom. |
| Mrs. Mary Bruns | Sec. 23, T. 33, R. 1 E | 500 | 1½ | | do | | | |
| Joe Baehmer | Sec. 22, T. 33, R. 1 E | 500 | 2 | 1890 | Ceased to flow | | | First flow at 290 feet; second flow at 500 feet. |
| Do | Sec. 22, T. 33, R. 1 E | 500 | 2 | 1896 | Strong | 15 to 20 | 62 | |
| George Housman | Sec. 24, T. 33, R. 1 E | 350 | 2 | | Strong; was 35 | Full pipe | 60 | |
| A. Tielke | Sec. 25, T. 33, R. 1 E | 630 | | | Does not flow | Does not flow | | Temperature warm. |
| H. Brunig | Sec. 25, T. 33, R. 1 E | 602 | 2 | 1894 | | At first 25; does not flow now. | | Clay, 200 feet; limestone, 25 feet; clay, 60 feet; hard rock, 40 feet. |
| John Cooper | Sec 25, T. 33, R. 1 E | 520 | 2 | | Was strong | Does not flow now | | Temperature was warmer than shallow well. |
| Kate Housman | Sec. 30, T. 33, R. 1 E | 530 | 2 | 1901 | 19 | 30 at first | 63 | |
| John Statman | Sec. 30, T. 33, R. 1 E | 600 | 2 | | | | | Flowed for short time only. Now used as tubular well. |
| M. C. Smidt | Sec. 32, T. 33, R. 1 E | | 2 | | None | Ceased to flow | | Soil, etc., 20 to 30 feet; chalk; clay over 100 feet; hard rock; clay and shale, 100 feet; sand and sandstone. Ran out of pipe at 300 feet. Water lifted at 120 feet, but did not flow out. |

*Artesian wells of Cedar County, Nebr.*—Continued.

| Owner. | Location. | Depth. | Diameter. | When drilled. | Pressure. | Yield per minute. | Temperature. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Inches.* | | *Pounds.* | *Gallons.* | °*F.* | |
| T. N. Jones | Sec. 34, T. 33 N., R. 2 E. | 280 | 2 | 1893 | Fairly strong | Pipe nearly full in horizontal position. | 60 | On Missouri bottom lands. |
| W. C. Jones | Sec. 28, T. 33, R. 2 E. | 420 | 2 | 1893 | Strong | | $60\frac{1}{2}$ | |
| Do | Sec. 29, T. 33, R. 2 E. | 200 | 2 | 1896 | do | Pipe nearly full | $60\frac{1}{2}$ | |
| Do | Sec. 28, T. 33, R. 2 E. | 300 | 2 | | | Ceased flowing | | |
| Frank Arens | Sec. 34, T. 32, R. 1 E. | 535 | 3 | 1889 | | 2 | | |
| B. Wubben | SW. $\frac{1}{4}$ sec. 5, T. 32, R. 2 E. | 500 | 2 | | Weak | 4 | 61 | |
| Do | SW. $\frac{1}{4}$ sec. 5, T. 32, R. 2 E. | 600 | 2, reduced to $1\frac{1}{4}$ below. | | At first 4 | Weak at first, ceased flowing. | | Passed through considerable chalk. |
| C. E. Klapping | Sec. 10, T. 32, R. 2 E. | | 2 | | Weak | | $60\frac{1}{2}$ | |
| Frank Wiesler | Sec. 9, T. 32, R. 2 E. | | 2 | | do | 5 | 60 | |
| Peter Hochstein | SW. $\frac{1}{4}$ sec. 8, T. 32, R. 2 E. | 530 | 2 | 1888 | do | 2 | $60\frac{1}{2}$ | |
| Ernest Ferber | NE. $\frac{1}{4}$ sec. 10, T. 32, R. 2 E. | 241 | 2 | 1886 | do | Two $1\frac{1}{4}$-inch pipes full. | 60 | |
| T. N. Jones | NE. $\frac{1}{4}$ sec. 10, T. 32, R. 2 E. | 2 | 400 | 1890 | Was 30, now 17 with leak. | Pipe full | 60 | First flow forced water 56 feet above the bottom, second flow strong, third stronger. |
| Jacob Keizer | SE. $\frac{1}{4}$ sec. 9, T. 32, R. 2 E. | 2 | 500 | 1893 | None now | Flows a little out of ditch 6 feet deep. | | |
| August Hochstein | SW. $\frac{1}{4}$ sec. 10, T. 32, R. 2 E. | 2 | 360 | 1894 | Strong | Horizontal pipe nearly full. | 59 | In Bow Creek Valley. |
| F. Ashbre | NE. $\frac{1}{4}$ sec. 12, T. 32, R. 2 E. | 2 | 300 | | do | 11 | 59 | |
| James Keegan | SE. $\frac{1}{4}$ sec. 14, T. 32, R. 2 E. | 2 | 400 | | Weak | 1 | 60 | |
| John Hochstein | NW. $\frac{1}{4}$ sec. 15, T. 32, R. 2 E. | 2 | 320 | | do | Size of finger flow | 59 | Do. |
| W. D. Schulte | NE. $\frac{1}{4}$ sec. 23, T. 32, R. 2 E. | 2 | 360 | 1887 | 30 | 60 | | |
| A. W. Jones | NE. $\frac{1}{4}$ sec. 11, T. 32, R. 2 E. | 2 | 417 | 1896 | 10 | Flows horizontal pipe (2 inches) half full. | 58 | |
| Do | Sec. 11, T. 32, R. 2 E. | 2 | 300 | 1893 | Could not gage | Flows 2-inch horizontal pipe. | $58\frac{1}{2}$ | |
| Ferd Ashbre | NW. $\frac{1}{4}$ sec. 13, T. 32, R. 2 E. | 2 | 400 | | Weak | | 59 | |
| St. James Well | NW. $\frac{1}{4}$ sec. 24, T. 32, R. 2 E. | 2 | 540 | | None | Does not flow now. | | |
| Bert Thompson | NW. $\frac{1}{4}$ sec. 24, T. 32, R. 2 E. | 2 | 300 | | Weak | $2\frac{1}{2}$ | 59 | |
| F. Leise | SE. $\frac{1}{4}$ sec. 25, T. 32, R. 2 E. | 2 | 340 | | do | 2 | 58 | |
| Do | Sec. 25, T. 32, R. 2 E. | 2 | 400 | | Was weak | Flow ceased | | |
| Peter Kugan, Ashmole Well. | NE. $\frac{1}{4}$ sec. 14, T. 32, R. 2 E. | 2 | 520 | 1894 | Strong | Flows horizontal pipe full. | $62\frac{1}{2}$ | |
| Nels Anderson | Sec. 23, T. 32, R. 2 E. | 2 | 400 | 1888 | Weak | 30 | | 270 feet to water. |
| H. E. McKenzie | Sec. 24, T. 32, R. 2 E. | 2 | 448 | 1894 | | | | At first flowed pipe full. |
| Jones-McKenzie | SE. $\frac{1}{4}$ sec. 7, T. 32, R. 3 E. | 2 | 40 | | 16 | Flows a 2-inch pipe nearly full. | 61 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Richard Brewer | SW. ¼ sec. 8, T. 32, R. 3 E. | 2 | 400 | 1900 | Nearly 4 now | Runs 2-inch horizontal pipe nearly full. | 60½ | Pressure varies with season. Strong when drilled. Decreased six months after. |
| Do. | NE. ¼ sec. 8, T. 32, R. 3 E. | 2 | 300 | 1893 | Weak | 1½ | 58½ | |
| H. Wiseman | SE. ¼ sec. 8, T. 32, R. 3 E. | (a) | 280 | 1883 | Could not determine. | | 58½ | |
| T. W. Whitehouse | Sec. 9, T. 32, R. 3 E. | 2 | | | | | | 15 feet above river. |
| Riley Brewer | Sec. 9, T. 32, R. 3 E. | 2 | 280 | | | Runs ⅓ pipe full | 59 | |
| Mrs. L. Larson | SW. ¼ sec. 11, T. 32, R. 3 E. | 2 | 280 | | None; was fairly strong. | None | | Flow stopped in 1902, owing to rusted pipe. |
| S. Boyles | NE. ¼ sec. 15, T. 32, R. 3 E. | 2 | 365 | | 6 | 7 | 57 | Well not well cared for. Overflows, forming a marshy pond. |
| Theodore Beste | SW. ¼ sec. 15, T. 32, R. 3 E. | 2 | 310 | 1900 | 17 | Good flow | 60 | |
| Do. | NE. ¼ sec. 15, T. 32, R. 3 E. | 2 | 240 | | Weak | 3 | 58 | |
| Do. | NE. ¼ sec. 16, T. 32, R. 3 E. | 2 | 270 | | do | 4 | 58½ | |
| Do. | SW. ¼ sec. 12, T. 32, R. 3 E. | 2 | 310 | 1891 | Weak now; 18 when drilled. | 8 | 59½ | |
| C. B. Larson | NW. ¼ sec. 15, T. 32, R. 3 E. | 2 | —300 | | 1 | 1¼ now | 56 | Overflows into pond or marshy place near house. |
| Nels Anderson | SW. ¼ sec. 21, T. 32, R. 3 E. | 2 | | | Just fair | 3 or 4 | 59½ | |
| Do. | NW. ¼ sec. 21, T. 32, R. 3 E. | 2 | 340 | | Very weak | 1 | 59 | |
| Do. | NE. ¼ sec. 22, T. 32, R. 3 E. | 2 | 400 | | None | No flow now | | |
| Do. | Sec. 23, T. 32, R. 3 E. | 2 | 400 | 1888 | | 1 barrel | | |
| Ferd Ashbre | Sec. 16, T. 32, R. 3 E. | 2 | 40 | | Fair | 5 | 59½ | |
| Do. | Sec. 7, T. 32, R. 3 E. | 2 | 300 | | Not strong | | 59 | 35 feet above river. |
| J. W. Gowery | Sec. 21, T. 32, R. 3 E. | 2 | 327 | 1893 | 2 | | 55½ | |
| Do. | Sec. 21, T. 32, R. 3 E. | 2 | 310 | | Weak | 3 | 55 | Just flows. |
| Herman Koch | NE. ¼ sec. 14, T. 32, R. 3 E. | 2 | 270 | 1893 | Could not gage | 20 | 59¼ | |
| Fred Riefenrath | SE. ¼ sec. 12, T. 32, R. 3 E. | 2 | 250 | | Was 12 | 8 | 57 | Drilled about 12 years ago. |
| Do. | NE. ¼ sec. 23, T. 32, R. 3 E. | 2 | 530 | 1886 | Weak now | 12 | 59 | When first drilled this well was the cause of considerable trouble between its owner and parties owning land over which the water flowed. |
| Frank Reifenrath | SW. ¼ sec. 11, T. 32, R 3 E. | 2 | 245 | 1887 | Could not gage | 11 | 57½ | Owner could not give log. Casing at first 1¼ inches; then 2 inches, and became strong again. Owner is 83 years old. |
| Chris Sartorius | SE. ¼ sec. 13, T. 32, R. 3 E. | 2 | 255 | 1887 | | 7 | | When first drilled volume 40 gallons per minute. |
| Swan Anderson | Sec. 24, T. 32, R. 3 E. | 2 | 280 | | Weak | Enough to form quite a lake northwest of house. | 69 | Is piped to different lots about the barn. Runs in a large tile, 3 feet high, near the house. The pressure is little more than enough to lift the water to this level, as there is only a weak overflow. Temperature given was in the large tile. |
| J. C. Dawson | NE. ¼ sec. 24, T. 32, R. 3 E. | 2 | | | | Horizontal pipe, 1 inch at top, full. | 63½ | |
| Do. | Sec. 24, T. 32, R. 3 E. | 2 | 340 | 1890 | Weak, pipe leaks | 2 | 60 | Much $H_2S$ in water. |
| John Lammers | Sec. 35, T. 32, R. 3 E. | 2 | 600 | 1885 | Ceased flowing | All that 2-inch casing could hold. | | |

a 1½ inches, 1¼ now.

### DIXON COUNTY.

The southwestern part of Dixon County resembles adjacent parts of Cedar County in topography, structure, and water conditions. In most other portions, except on the bottom land and along the bluffs on the Missouri, loess-covered hills predominate. The amount of sand and gravel beneath the loess appears to decrease to the northeast. The northwestern part of the county is underlain by Niobrara chalk rock. Glacial clay appears to be more widely distributed than in Cedar County.

Very little difficulty is experienced in obtaining a good supply of water, the Benton clays being the only beds that yield well water unfit for use. The principal water-power stream, the Aowa, is not strong, but inexpensive dams at Ponca and Martinsburg, constructed of brush, stone, and soil, afford water power for flouring and grist mills.

*Springs.*—Many springs occur in the county, one of the most notable of which is at Waterbury, where the flow has been used for locomotives. The water here rises from a considerable depth into a large circular basin near the station. One-half mile south a similar spring 45 feet across and 20 feet deep, flows between 300 and 400 gallons of water a minute, never freezing over during winter.

The Hurley Springs, about 5 miles west of Martinsburg, come out of sands above bowlder clay at an altitude of 1,425 feet. South of this place there is a general seepage from the slope at an altitude of 1,500 feet.

*Shallow wells.*—Much of the domestic water supply is from very shallow wells, which are affected somewhat by dry weather. In several localities the water table comes so near the surface that flowing wells might be had. One well 45 feet deep, at the stock yards in Allen, overflows. At Allen the water rises to within 12 feet of the surface, from a bed of gravel which lies at a depth of 70 feet. The following representative wells show the prevailing conditions in this county:

*Representative shallow wells of Dixon County, Nebr.*

| Owner. | Location. | Depth. | Diameter. | Depth of water. | Quality. | Remarks. |
|---|---|---|---|---|---|---|
| | | *Feet.* | *Inches.* | *Feet.* | | |
| Town well of Wakefield | Sec. 32, T. 27 N., R. 5 E | 80 | 6 | 60 | Very good, hard | Black loam 10 feet; clay 30 feet; gravel. |
| J. W. Hypse | Sec. 24, T. 27, R. 4 E | 104 | 2 | 80 | Hard | Black loam 4 feet; clay, sand, and gravel 100 feet. |
| Peter Norell | Sec. 25, T. 27, R. 4 E | 67 | 36 | 25 | Bad, hard | Loam 2 or 3 feet; red clay, gravel, blue clay. |
| G. A. Herrick | Sec. 33, T. 29, R. 6 E | 27 | 3½ | 7 | | |
| R. C. Caulk | Sec. 9, T. 28, R. 5 E | 266 | 5 | 56 | Hard | Yellow clay 111 feet; 31 feet to dry sand; dry gravel 18 feet; sand rock 1½ feet; dry sand 30 feet; 30 feet water; clay and sand 2 feet; water gravel 26 feet; light yellow clay 8 inches. |
| Benson Grain Co | Sec. 26, T. 28, R. 6 E | 55 | 1½ | | do | |
| Ioderson | NW. ¼ sec. 11, T. 29, R. 4 E | 155 | | | | Soil and loess 10; sand 6; yellow clay 34; blue clay (granules) 100; sand and water 5 feet. |
| Maggie Hurley | NE. ¼ sec. 10, T. 29, R. 5 E | 71 | 5 | 30 | Hard | Soil, sand, and gravel mixed with clay, 15 feet; soil; blue clay to water. |
| D. Hurley | NE. ¼ sec. 2, T. 29, R. 5 E | 45 | 6 | 18 | do | Reached second water. |
| Lawrence Phillips | Sec. 7, T. 29, R. 5 E | 15 | 36 | 10 | do | |
| Dennis Hurley | Sec. 10, T. 29, R. 5 E | 26 | 3½ | 22 | do | Water in blue clay—affected very little in dry seasons. |
| Do | do | 44 | 6 | 26 | | Can not be pumped dry. |
| J. E. Ekersoth | Sec. 22, T. 30, R. 6 E | 22 | 36 | 18 | Hard | |
| Gilbert Bros | Sec. 28, T. 30, R. 3 E | 60 | 36 | 14 | do | Soil, loess 40 feet; blue glacial clay 22 feet; sand and gravel. |
| A. Wiedenfeld | Sec. 6, T. 30, R. 4 E | 80 | 24 | 15 | | Loess 50 feet; cobblestone and gravel 5 feet; blue clay 25 feet. |
| Sam. Thomas | NW. ¼ sec. 24, T. 30, R. 4 E | 156 | | 36 | | Loess 100 feet; sand 56 feet. |
| Nick Thomas | SW. ¼ sec. 12, T. 30, R. 4 E | 265 | | 65 | | Loess 40, blue clay and sand 60, sand 150, and shaly clay 15 feet. |
| John Rahn | NW. ¼ sec. 34, T. 30, R. 5 E | 301 | | Many. | | Loess 60, blue clay (Benton) 210, sandstone with water (Dakota) 29 feet. |
| O. J. Anderson | NE. ¼ sec. 33, T. 32, R. 4 E | 167 | | 10 | Good | Loess 130, dry sand 11, sandy clay 8, and fine sand with water 18 feet. |

*Artesian wells.*—There are a few artesian wells on the bottom lands in the northern part of the county. If wells were sunk to the lower beds of the Dakota formation and carefully cased, flows could be had several miles farther southeast. There are also a number of deep tubular wells located on high land south of the Missouri bottom. The following wells are now flowing:

*Artesian wells of Dixon County, Nebr.*

| Name. | Location. | Depth. | Diameter. | Length of casing. | When drilled. | Pressure. | Yield per minute. | Temperature. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | | *Feet.* | *Inches.* | *Feet.* | | *Pounds.* | *Gallons.* | *F.°* | |
| Chris Sartorious | Sec. 19, T. 32 N., R. 4 E. | 300 | 2 | 70 | | Weak | 2 | 61 | Pipe leaks. |
| Fred Reifenrath | Sec. 19, T. 32, R. 4 E. | 300 | 1½ | 65 | | do | 2 | 61 | Pipe rusted. |
| J. P. Warnick | Sec. 29, T. 32, R. 4 E. | 280 | 2 | 60 | 1893 | 2 now | 1 | 61 | Pressure 8 pounds when drilled. |
| Do | NE. ¼ sec. 29, T. 32, R. 4 E. | 280 | 2 | 70 | 1898 | Weak (leaks) | | 60½ | Flows pipe half full. |
| C. Weeks | Sec. 28, T. 32, R. 4 E. | 290 | 2 | At first 50; now 1-inch pipe to bottom. | | 5½ | | 60¼ | Flowed at 240 feet. Pressure 9 pounds when drilled. |
| Thomas Warnick | NW. ¼ sec. 28, T. 32, R. 4 E. | 277 | 2 | 60 | 1899 | 6 now; was 8 | | 60¾ | Sand, 70 feet; limestone and clay, 80 feet; sandstone and water, 27 feet. |
| Do | Sec. 28, T. 32, R. 4 E. | 177 | 2 | 60 | 1901 | Weak | | 59 | Shallowest well in this region. |
| Butler Bros | Sec. 34, T. 32, R. 4 E. | 300 | 2 | | | None | 1 | 58 | Pipe rusted off. |
| Dexter Rice | Sec. 28, T. 32, R. 5 E. | 265 | 2 | 40 | 1888 | Nearly 10 | | 61 | Pressure 10 pounds when drilled. First flow at 160 feet. |
| T. J. Ryan | Sec. 32, T. 32, R. 5 E. | 265 | 2 | At top 3 inches in diameter. | 1896 | 2 now | 3 | 55 | Pressure 8 pounds when drilled. |
| Do | Sec. 32, T. 32, R. 5 E. | 400 | 2 | | 1886 | 12½ originally | 3 | 54 | Flowed 50 gallons when drilled. |
| Geo. Mathison | Sec. 20, T. 31, R. 6 E. | 484 | 3 | | 1888 | None | | | Flowed 3 weeks. Rises within 3 feet of top. |

### DAKOTA COUNTY.

Dakota County resembles Dixon in configuration but includes a much wider area of bottom lands along the Missouri. Its uplands are deeply trenched by the small valleys of many watercourses, with the intervening ridges or plateau remnants thickly capped by loess. Cretaceous rocks from Dakota to Greenhorn appear in the slopes and often present extensive outcrops. The Missouri bottom land is thickly floored by alluvial deposits.

The principal stream is Missouri River, which defines the eastern boundary. There are several creeks of moderate size, the most notable of which is Elk Creek, a stream which flows with a remarkably crooked course north from Emerson to Goodwin, then east and southeast to Jackson, and finally southeast and east to the river northeast of Homer. There is much surface water, but the principal water supplies are from the numerous springs and shallow wells.

*Springs.*—Many springs issue from the Dakota sandstone, which outcrops from above Jackson to the southeastern part of the county. These afford an abundance of good cool water for drinking, domestic purposes, and stock. A spring in sec. 24, T. 28 N., R. 8 E., 2 miles northwest of Homer, has been used for forty-eight years for domestic supply and as a public watering place. It flows 6 gallons a minute, with a temperature of 51°.

The Miller Spring, a short distance northwest of Homer, is piped from a tile sunk in the sand; part of the flow fills a 1-inch pipe.

At a ranch a half mile north of Homer the sand rock has been dug into and a reservoir walled up, from which runs enough water to fill a 2-inch pipe. A half mile north of this place there is one of the strongest springs in the vicinity, and about 6 miles southwest of Jackson there are two very strong springs.

*Wells.*—Underground-water conditions are much the same as in Dixon County, except that the Dakota sandstone rises nearer to the surface and is easily reached by tubular wells. There are no artesian wells in the county; the artesian water reached in such wells farther west issues here as springs.

The following is the record of a tubular well on high ground 6 miles southwest of Jackson: Loess, 90 feet; sand and hard spongy clay, 6 feet; dark clay with a bed of limestone near the middle, 156 feet; sand rock with good water, 6 feet.

Wells on or near the bluffs between Jackson and Homer are usually 80 to 100 feet deep, but several in Jackson are deeper. The Ashford well at Homer is 184 feet deep. The supply is usually good, but in the Ashford well the water is poor on account of improper casing through clay beds which carry soluble salts. On the bottom lands the depth to the first water varies from 20 to 25 feet, but at 35 feet the water is usually poor. Formerly most wells were drilled to the greater depth, but now they are driven to the first water. According to reports by well drillers the alluvium southeast of Jackson is from 80 to 100 feet deep. A steady supply of good drinking water is obtained at Homer in a well 40 feet deep. In the southwestern part of the county wells are very shallow, but yield inexhaustible supplies.

## AGRICULTURAL RESOURCES.

### SOILS.

The soils of the region are of several types, having been formed by various agencies acting on rocks of different kinds; most of them are closely related to the underlying formations. Much of the eastern and central parts of the area lies in the fertile loess region, where the soil is deep and easily worked, receives and holds moisture well, and yields heavy crops on both hilly and level lands. The alluvial bottom-land or flood-plain soil is also fertile and easily tilled, but in the lowest areas fields are often damaged by high waters and by shifting of the river channel. The heavy Pierre clay, or gumbo soil, is especially extensive in Boyd County; it contains some alkali and often affords bad water, but usually produces good grass and heavy yields of corn, oats, and wheat, especially where the clay is mixed with sand. The sandy upland soils in Cedar, Knox, Holt, and western Boyd counties stand droughts well and are gradually being utilized.

### CROPS.

The principal crops are hay, corn, wheat, and oats, but alfalfa and sugar beets are also successfully grown. Mixed farming is practiced generally, except at points where the land is too sandy, or the topography is not favorable. Every county has a large acreage of hay land; in Cedar County this crop is grown principally along broad creek basins. While corn grows well throughout most of the region, it does best at certain points on the Missouri bottom. The heaviest yield of oats per acre in 1903 was in Boyd County, southeast of Spencer, and near Gross. Grain elevators are found at every railroad station. The reported acreage of the principal grain crops in 1902, not including Holt County, was as follows: Corn, 279,055; wheat, 105,981; oats, 115,958; rye, 12,680; barley, 4,877.

### STOCK RAISING AND DAIRYING.

One of the most important industries in the region is cattle raising, and in many localities wide areas are used for grazing, especially where the land is too rough or too sandy for farming. The principal pasture lands are in the northern part of the Santee Indian Reservation in Knox County, in southwestern Knox County, in the sandy and rough portions of Holt and western Boyd counties, and on the bluff and ravine lands along Missouri River. Hogs, sheep, and horses are also raised in large numbers.

Dairying has attained an important place in the economy of the region. Cream is shipped from nearly all the railroad stations, Holt County leading in its production in the State of Nebraska.

## TIMBER.

The timber growth is of considerable importance in most of the counties. It occurs mostly along the river and creek bottoms and up many ravines. The principal trees of economic importance are cottonwood, bur oak, elm, and scattering walnut; some of these are as much as 4, 5, or even 6 feet in diameter. The timber is used for posts, firewood, lumber, frames, and bridges. Sawmills operate at a number of points, as north of St. Helena, northwest of St. James, on Brooky bottom, and west of Aten. The sawmills obtain their timber principally from caving banks along the rivers, where the timber would be rapidly destroyed if not removed. The bur-oak growth is thickest in northern Dixon and Cedar counties, where it is cut into posts for which there is much demand. Timber cutting begins about September and lasts during the autumn and winter.

# INDEX.

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