DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 12

UNDERGROUND WATERS OF A PORTION OF SOUTHEASTERN NEBRASKA.—DARTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1898

IRRIGATION REPORTS.

The following list contains titles and brief descriptions of the principal reports relating to water supply and irrigation prepared by the United States Geological Survey since 1890:

1890.

First Annual Report of the United States Irrigation Survey, 1890; octavo, 123 pp.

Printed as Part II, Irrigation, of the Tenth Annual Report of the United States Geological Survey, 1888–89. Contains a statement of the origin of the Irrigation Survey, a preliminary report on the organization and prosecution of the survey of the arid lands for purposes of irrigation, and report of work done during 1890.

1891.

Second Annual Report of the United States Irrigation Survey, 1891; octavo, 395 pp.

Published as Part II, Irrigation, of the Eleventh Annual Report of the United States Geological Survey, 1889–90. Contains a description of the hydrography of the arid region and of the engineering operations carried on by the Irrigation Survey during 1890; also the statement of the Director of the Survey to the House Committee on Irrigation, and other papers, including a bibliography of irrigation literature. Illustrated by 29 plates and 4 figures.

Third Annual Report of the United States Irrigation Survey, 1891; octavo, 576 pp.

Printed as Part II of the Twelfth Annual Report of the United States Geological Survey, 1890–91. Contains "Report upon the location and survey of reservoir sites during the fiscal year ended June 30, 1891," by A. H. Thompson; "Hydrography of the arid regions," by F. H. Newell; "Irrigation in India," by Herbert M. Wilson. Illustrated by 93 plates and 190 figures.

Bulletins of the Eleventh Census of the United States upon irrigation, prepared by F. H. Newell; quarto.

No. 35, Irrigation in Arizona; No. 60, Irrigation in New Mexico; No. 85, Irrigation in Utah; No. 107, Irrigation in Wyoming; No. 153, Irrigation in Montana; No. 157, Irrigation in Idaho; No. 163, Irrigation in Nevada; No. 178, Irrigation in Oregon; No. 193, Artesian wells for irrigation; No. 198, Irrigation in Washington.

1892.

Irrigation of western United States, by F. H. Newell; extra census bulletin No. 23, September 9, 1892; quarto, 22 pp.

Contains tabulations showing the total number, average size, etc., of irrigated holdings, the total area and average size of irrigated farms in the subhumid regions, the percentage of number of farms irrigated, character of crops, value of irrigated lands, the average cost of irrigation, the investment and profits, together with a résumé of the water supply and a description of irrigation by artesian wells. Illustrated by colored maps showing the location and relative extent of the irrigated areas.

1893.

Thirteenth Annual Report of the United States Geological Survey, 1891–92, Part III, Irrigation, 1893; octavo, 486 pp.

Consists of three papers: "Water supply for irrigation," by F. H. Newell; "American irrigation engineering" and "Engineering results of the Irrigation Survey," by Herbert M. Wilson; "Construction of topographic maps and selection and survey of reservoir sites," by A. H Thompson. Illustrated by 77 plates and 119 figures.

A geological reconnoissance in central Washington, by Israel Cook Russell, 1893; octavo, 108 pp., 15 plates. Bulletin No. 108 of the United States Geological Survey; price, 15 cents.

Contains a description of the examination of the geologic structure in and adjacent to the drainage basin of Yakima River and the great plains of the Columbia to the east of this area, with special reference to the occurrence of artesian waters.

1894.

Report on agriculture by irrigation in the western part of the United States at the Eleventh Census, 1890, by F. H. Newell, 1894; quarto, 283 pp.

Consists of a general description of the condition of irrigation in the United States, the area irrigated, cost of works, their value and profits; also describes the water supply, the value of water, of artesian wells, reservoirs, and other details; then takes up each State and Territory in order, giving a general description of the condition of agriculture by irrigation, and discusses the physical conditions and local peculiarities in each county.

Fourteenth Annual Report of the United States Geological Survey, 1892–93, in two parts; Part II, Accompanying papers, 1894; octavo, 597 pp.

Contains papers on "Potable waters of the eastern United States," by W. J. McGee; "Natural mineral waters of the United States," by A. C. Peale; "Results of stream measurements," by F. H. Newell. Illustrated by maps and diagrams.

(Continued on third page of cover.)

DEPARTMENT OF THE INTERIOR

WATER-SUPPLY

AND

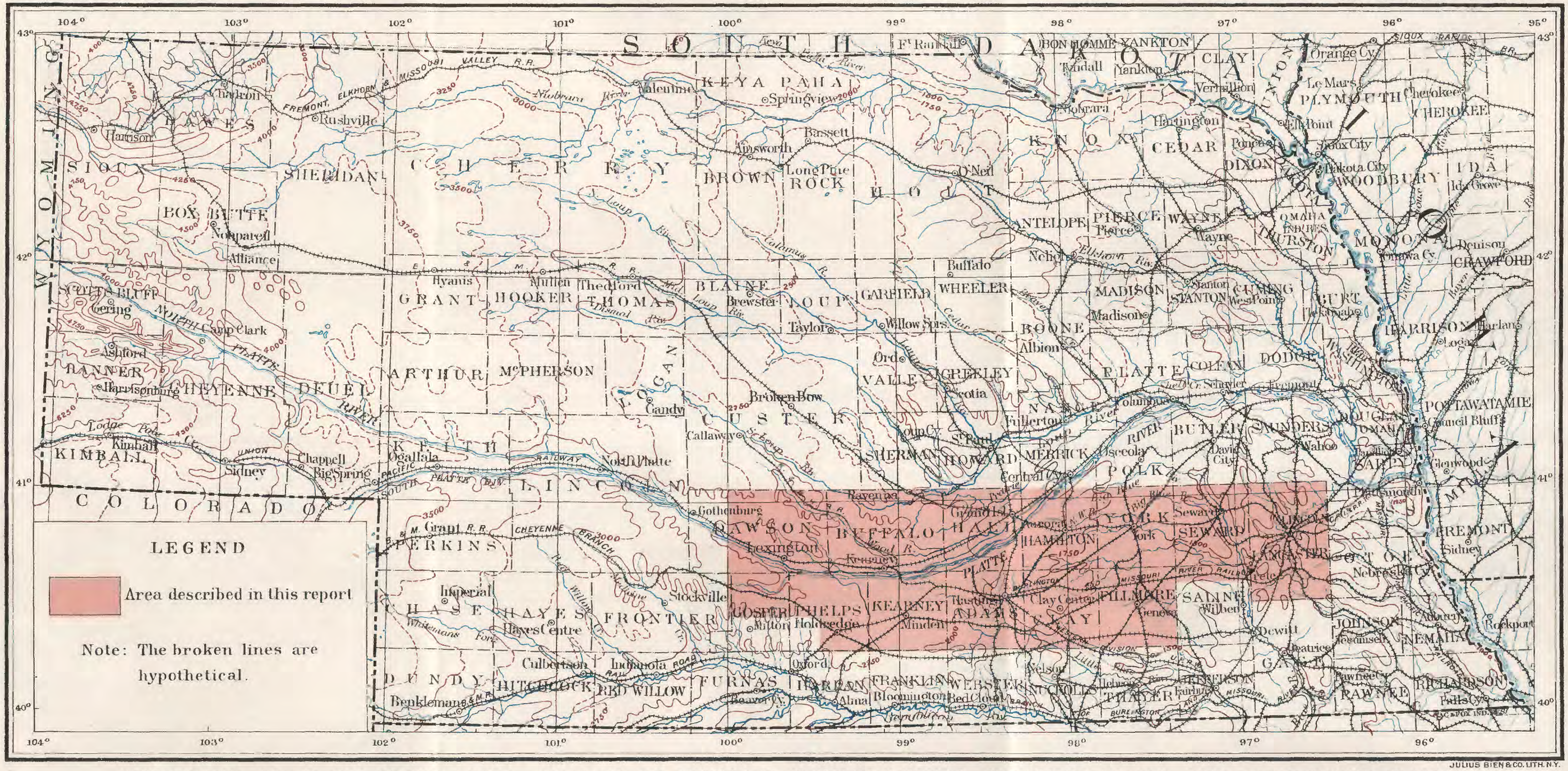
IRRIGATION PAPERS

OF THE

UNITED STATES GEOLOGICAL SURVEY

No. 12

WASHINGTON
GOVERNMENT PRINTING OFFICE
1898



CONTOUR MAP OF NEBRASKA, COMPILED FROM U. S. GEOLOGICAL SURVEY MAPS AND RAILROAD DATA

BY N. H. DARTON 1897.

Scale

40 20 0 40 80 120 MILES

Contour Interval 250 feet.

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

UNDERGROUND WATERS

OF

A PORTION OF SOUTHEASTERN NEBRASKA

BY

NELSON HORATIO DARTON

WASHINGTON

GOVERNMENT PRINTING OFFICE

1898

CONTENTS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF HYDROGRAPHY,
Washington, June 14, 1897.

SIR: I have the honor to transmit herewith a manuscript prepared by Mr. N. H. Darton, assistant geologist of this Survey, relating to the underground or well waters of a portion of the State of Nebraska. The facts given are the results of field work in this State during the season of 1896. Beginning in the vicinity of Lincoln, Nebraska, Mr. Darton not only made a detailed examination of the surface geology, but carried on a careful search for all wells, both shallow and deep. As far as possible, information was obtained concerning the depth of the wells, the character of the strata penetrated, and the volume and quality of the water supply. This work was conducted westward to the vicinity of Lexington. In this work Mr. Darton was assisted by Mr. Joseph E. Macfarland, a young man whose untimely death at the end of the field season deprived the Survey of the services of one of its most promising and energetic junior geologists.

To a discussion of the geologic formations and their water contents Mr. Darton has appended a statement as to the possibility of obtaining artesian water, adding such facts as were procurable concerning the utilization of the available water supply in irrigation. In this particular area agriculture is not regarded as dependent, to any considerable extent, upon the artificial application of water, but the examples cited show that in many localities irrigation on a small scale can be employed with profit. It is proposed during the coming field season to extend this investigation westward into the areas where the necessity for irrigation has long been recognized and where water supplies have a still greater value. The field work is confined largely to the areas of which topographic maps have been prepared, as without such maps studies of underground waters are necessarily vague and inconclusive.

Very respectfully,

F. H. NEWELL,
Hydrographer in Charge.

Hon. CHARLES D. WALCOTT,
Director United States Geological Survey.

PLATTE RIVER NEAR ASHLAND, NEBRASKA, SHOWING STREAM DEPOSITS.

UNDERGROUND WATERS OF A PORTION OF SOUTHEASTERN NEBRASKA.

By NELSON HORATIO DARTON.

INTRODUCTION.

This report relates to underground waters in Lancaster, Seward, northern Saline, York, Fillmore, Hamilton, Clay, Hall, Adams, Buffalo, Kearney, Phelps, northern Gosper, and eastern and central Dawson counties, an area of about 6,700 square miles.[1] It is the result of observations made with the assistance of Messrs. J. E. Macfarland and C. A. Fisher in the summer and autumn of 1896. It deals mainly with waters occurring at moderate depths, but also briefly reviews the probabilities of obtaining water supplies from deeper-seated sources.

The region is one in which the average annual rainfall is not sufficient to insure full crops every season, even in the eastern part of the area, where the rainfall is considerably greater than in the western counties. Fortunately, very nearly all of this region is underlain by water-bearing deposits, which in most districts yield good supplies of water to pump wells. The depth to this water varies from less than 10 feet in the valley of Platte River to somewhat over 300 feet in the higher plateau areas of Dawson and Gosper counties and in a few instances in the high drift hills of Lancaster County. The supply is also variable in amount, but in most cases the average windmill does not lower its level. The waters have been used to some extent for irrigation, and the results have been entirely satisfactory, so far as the crops are concerned. In most cases a single windmill has not proved adequate to supply water for the irrigation of over 15 acres, under the most favorable conditions, and in the deeper wells, or where the water is more scanty in supply, the limitations are greater. This acreage is, however, sufficient for the cultivation of a profitable diversified crop, large enough at least to carry a family over a dry season. It is not the purpose of this report to discuss the efficacy of

[1] The greater part of this area is covered by topographic atlas sheets of the Survey, as follows: *Lincoln*, York, *Grand Island*, *Wood River*, *Kearney*, and *Lexington*, of which those in italics are now ready for sale at 5 cents each.

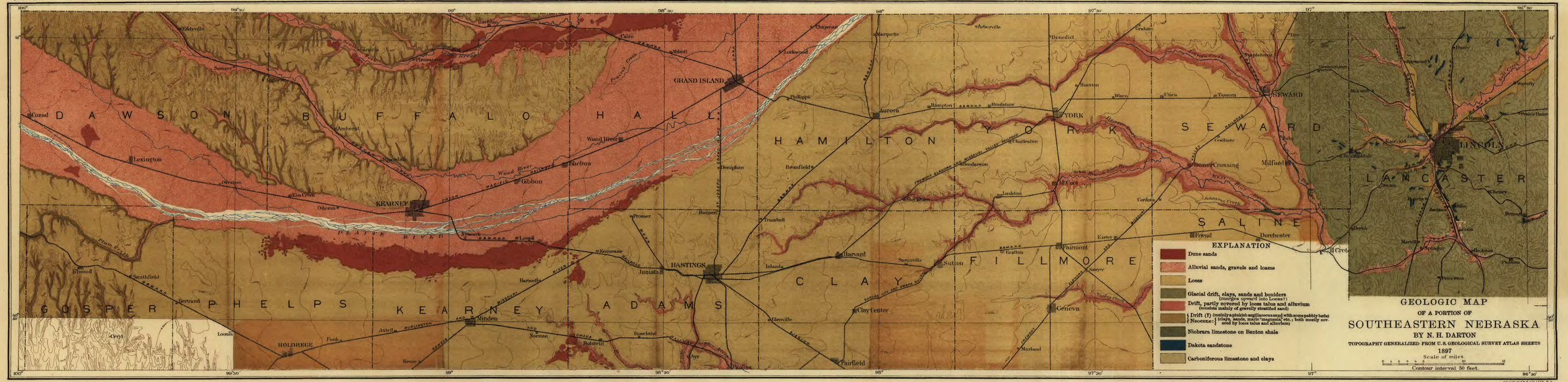
windmills, which it is believed can be greatly increased, nor the prospects for irrigation in the district. The location and extent of the underground water will be set forth mainly by maps, which will also give information in regard to the conditions of its occurrence.

TOPOGRAPHY OF THE DISTRICT.

The region to which this report relates lies on the eastern slope of the Great Plains which extend from the Rocky Mountains toward the Mississippi River. It comprises several types of land forms. The greater part of the area is a smooth plain, sloping gently eastward from an altitude of 2,700 feet near the one hundredth meridian to about 1,400 feet in the vicinity of the ninety-seventh meridian—a slope of about 7 feet to the mile. Westward this plain is widely trenched by the broad valley of Platte River, which lies from 80 to 160 feet below the plains surface. There are also other valleys of moderate width, of which the largest are those of the Big and Little Blue rivers and their branches, South Fork of Loup River, Wood River, and Plum Creek. To the east, in eastern Seward and Lancaster counties, the smooth plains give place to a region of high drift hills, deeply intersected by wide valleys. Another characteristic feature of the region is the sand-dune areas, mainly along the south side of the valleys of Platte and Loup rivers.

The valley of Platte River is 20 miles wide in Hall County, but it narrows considerably toward the west. East of Kearney, where it is also occupied by Wood River, a branch of Platte River, the valley is 12 miles wide. At Kearney the width rapidly diminishes to 8 miles, and this width continues some miles westward. In Dawson County the valley widens to 15 miles. The floor of the valley of Platte River is a very smooth plain, sloping gently toward the east. The river flows in channels but slightly depressed below the valley floor, and in dry seasons the water meanders through these channels in small ramifying rivulets, with intervening sand banks of various sizes. The character of these sand banks is shown in Pl. II.

There are some islands which are submerged only in times of high water; the principal one, known as Grand Island, has a length of 42 miles and owes its isolation to a narrow channel which passes around its northwestern side. The river usually does not occupy the center of the valley, but has a general disposition to hug its south side. In Hamilton County the principal channel is at the bottom of the slope which rises to the higher plain. East of longitude 99° 30′ the valley of Platte River is depressed from 80 to 100 feet below the surface of the adjoining plains, but the depth gradually increases in Dawson County to over 150 feet. Wood River has a level-floored valley, which merges into that of the Platte just north of Kearney. The South Fork of Loup River flows in a valley which averages about a mile in width in the northern part of Buffalo County.



JULIUS BIEN & CO. LITH. N.Y.

In Seward, Saline, York, Fillmore, Hamilton, Clay, Adams, Kearney, and eastern Phelps counties the plains present very broad areas of smooth surface, and often extend uninterruptedly for many miles. They are, however, more or less deeply trenched by the branches of Big and Little Blue rivers, and toward the west, where the land rises higher above the adjoining valleys, the plains are very much cut up by small branch brooklets, so that much of the higher region of Buffalo, Dawson, and Gosper counties consists of narrow ridges, usually with steep slopes, separated by numerous narrow valleys. In Gosper County these valleys assume a canyon type, particularly along the steep slope on the south side of the Platte Valley and in the slopes extending southward toward the Republican Valley.

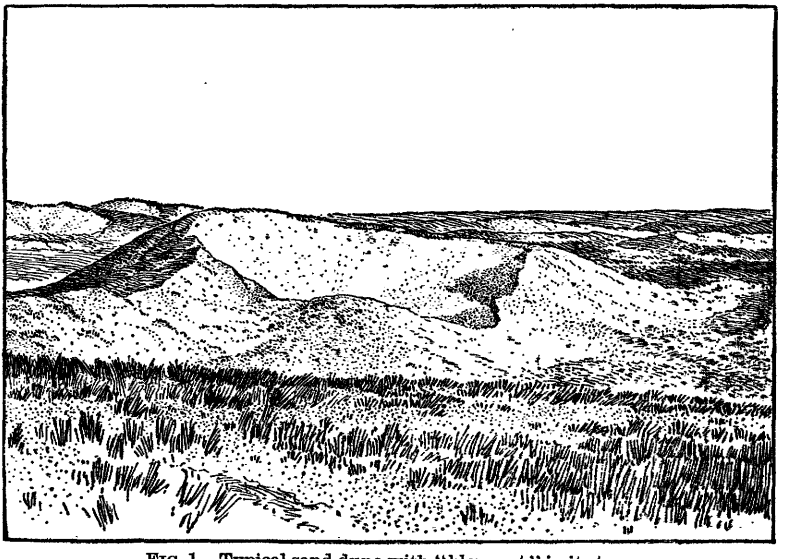


FIG. 1.—Typical sand dune with "blow-out" in its top.

In the drift-hill region of Lancaster and adjoining counties another type of topography is presented. There are high, rolling hills in long, irregular ridges separated by wide, level-floored valleys, of which the Salt Creek Valley with its branches is the most extensive. Lincoln is built at a confluence of a number of branches of Salt Creek and along the adjoining slopes of the drift hills. The drift surface rises to an altitude of about 1,550 feet in the eastern portion of Seward County, but the altitude to which the higher summits rise eastward gradually diminishes to from 1,300 to 1,400 feet in the eastern portion of Lancaster County. The bottom of the valley in which Lincoln is situated has an altitude of about 1,150 feet.

Areas of sand dunes are very frequent in the Platte and Loup valleys in Hall, Buffalo, Adams, Kearney, and Phelps counties. Some smaller areas also occur in Dawson County and on the high plains

and slopes about the head waters of Little Blue River in western Adams and eastern Kearney counties. The areas are characterized by their irregular, hummocky contour and loose sand surfaces. Some of the higher mounds rise 100 feet above the adjacent lowlands and are conspicuous features in the landscape. There are many basins among the hills and meandering valleys which have no outlets. The largest bodies of the sand extend for 50 miles along the south side of the Platte Valley south of Kearney, lying mainly against the slope which rises to the higher plains. There are also extensive deposits south of the South Fork of Loup River in northern Buffalo and Hall counties. The width of the wider portions of these sand-dune belts is about 3 miles. A "blow-out," a characteristic feature in some of the sand-dune areas, is shown in fig. 1 (p. 13.)

GEOLOGY.

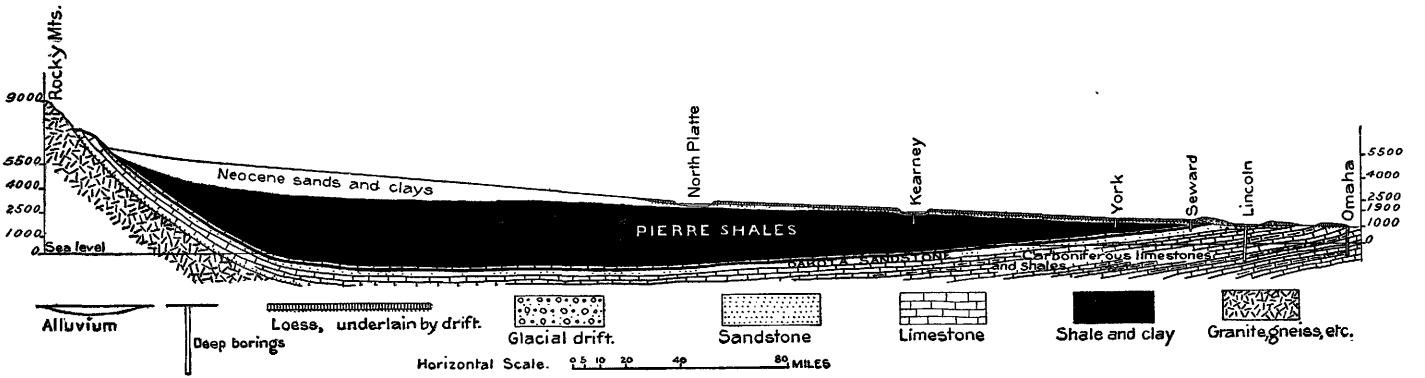
GENERAL STRUCTURE.

Southeastern Nebraska is underlain by Carboniferous and Cretaceous formations bearing a superficial mantle of Pleistocene deposits. The older formations have a gentle slope toward the west, and the overlying deposits are in general conformable to the eastward slope of the land. In Pl. IV is given a cross section from the Rocky Mountains to the Missouri River at Omaha, showing the general structural relations.

East of the longitude of Lincoln the limestone and associated rocks of the Carboniferous formation reach the surface, and they are frequently exposed in the valleys in the southeastern corner of the State. Toward the west their gentle dip and the rapid rise of the land carry them far beneath the surface, so that in the vicinity of the ninety-ninth meridian they appear to lie at a depth greater than 3,000 feet. Farther westward they may or may not increase in depth, but they rise in approaching the Rocky Mountains and outcrop high on the slopes of these mountains in Colorado and Wyoming.

The series of Cretaceous formations which lie on the Carboniferous beds comprises the Dakota sandstone, the Benton shales, the Niobrara limestone, and the Pierre shales. The lowest member, the Dakota sandstone, reaches the surface, to the eastward, in a zone which passes near Lincoln.

In the slopes of the Rocky Mountains the Dakota sandstone is separated from the Carboniferous beds by the Juratrias red sandstones, sands, and clay, which probably extend for some distance eastward, no doubt under the western portion of Nebraska, but they do not reach the surface in the eastern portion of the State. A characteristic exposure of these beds on the eastern slope of the Rocky Mountains is given in Pl. V. Near the ninety-seventh meridian the Dakota sandstone passes under the thin series of Benton shales and Niobrara limestones, and these in turn soon disappear beneath a mass



SECTION FROM THE ROCKY MOUNTAINS ACROSS WYOMING AND NEBRASKA.

of Pierre shales, which attain a thickness of over 3,500 feet under the central and western portion of the State. The Carboniferous and Cretaceous formations in the eastern part of the State are heavily overlain by Pleistocene deposits, comprising a large mass of glacial drift and a thick mantling of loess. West of longitude 98° 30′ there intervenes between the Pleistocene deposits and the Cretaceous formations a series of Neocene deposits, which gradually thicken toward the west, and finally, rising above the slope on which the loess lies, become the dominant surface formations in the western portion of the State. The glacial drift is a thick mass in Lancaster County. It thins rapidly toward Missouri River and westward, its attenuated margin passing under a thick sheet of loess in both directions. Toward the west the larger mass of glacial drift presents an obscure morainal front along the eastern side of Seward County, from which a continuous thick mantle of loess extends far westward. Under this loess mantle there is a thin sheet of drift materials extending out from the front of glacial drift. West of latitude 98° 30′ a thin wedge of calcareous

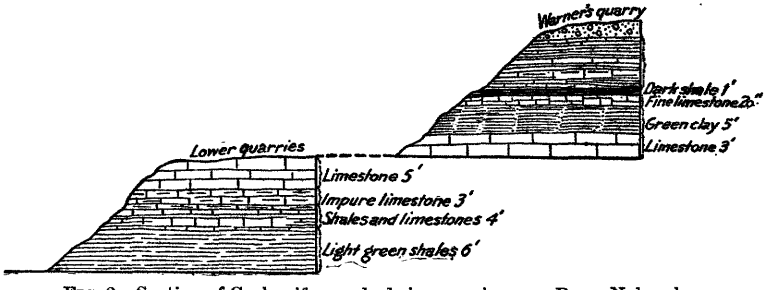


FIG. 2.—Section of Carboniferous beds in quarries near Roca, Nebraska.

and siliceous sediments, of Neocene age, comes in between the loess and drift and the Pierre shale surface, gradually thickening toward the west. The loess mantle is widely trenched by the valley of Platte River and more or less deeply excavated by the other valleys, which are often cut through to the underlying Pleistocene and Neocene formations.

The loess has a thickness of from 60 to 90 feet in greater part. Flooring the large depressions that traverse the region are deposits of alluvial formations, which are of great width along Platte River. In some portions of the area there are accumulations of dune sands of greater or less extent, and these, aside from sand banks in the rivers, are the most recent formations of the region.

THE FORMATIONS.

Carboniferous.—Carboniferous limestones reach the surface in southern, central, and eastern Lancaster County. They consist of a variety of limestone beds with intercalated shales and clays. The principal exposures are in the vicinity of Roca, near Hickman, and

about Bennett. At these localities the rocks have been quarried, notably about Roca, where they have furnished large amounts of fine building stone. A columnar section of the rocks at Roca is given in fig. 2 (p. 15), which comprises all the members exposed in the quarry just north of Roca station and in the Warner quarries and depressions a mile north of the village.

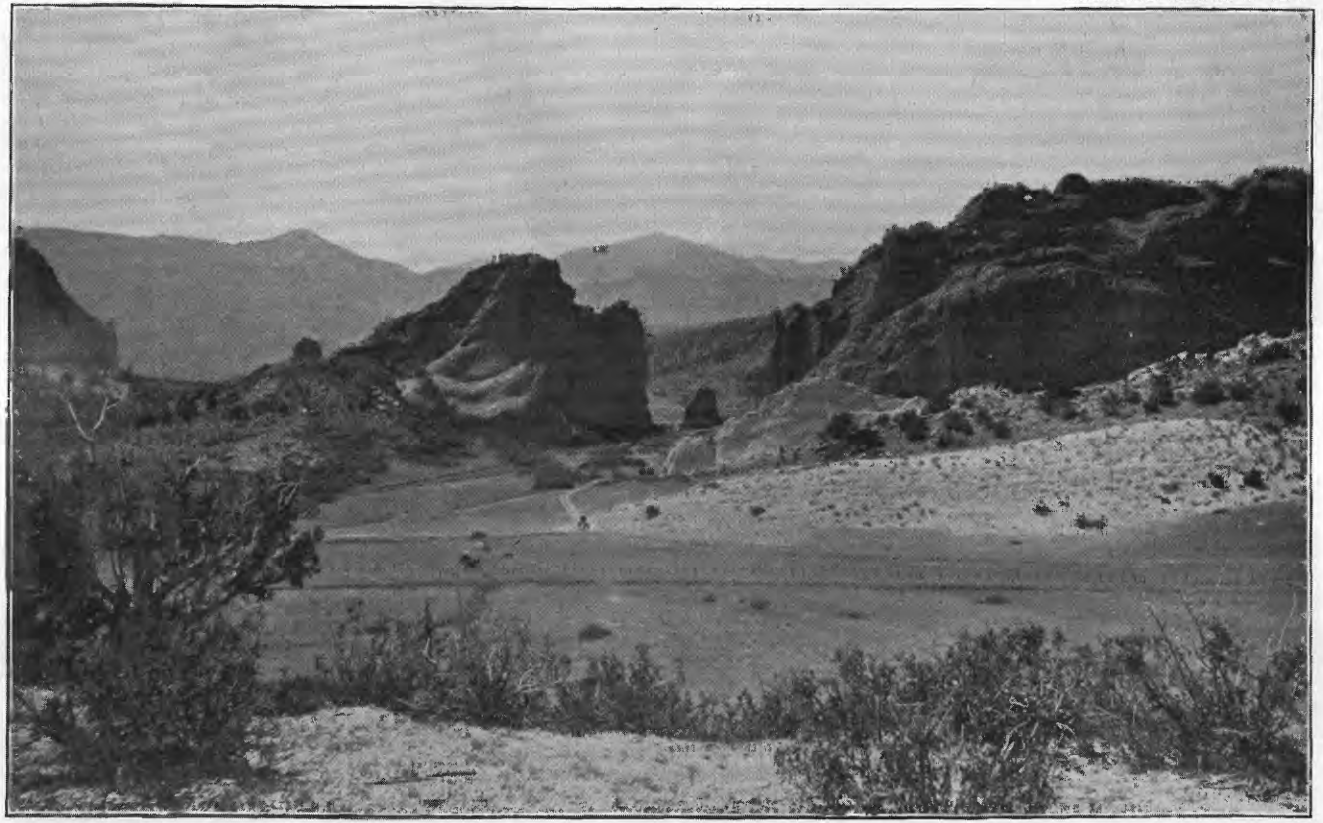
From the beds in Warner's quarry Mr. Macfarland collected the following fossils:

Euomphalus rugosus.	P. cora.
Setopora biserialis?	P. nebrascensis.
Marginifera splendens.	Chonetes flemingi.
Spirifer cameratus.	C. granulifera.
Meekella striatocostata.	Fusilina cylindrica.
Seminula subtilita.	Ambocœlia planoconvexa.
Derbya crassa.	Orthis (Rhipidomella) carbonaria.
Rhombopora lepidodendroides.	Pugnax uta.
Productus semireticularis.	Orbiculoida sp.

At Bennett some different members of the formation are exposed, and so far it has not been possible to ascertain the relative positions of the rocks of the two areas. Probably in the region between Roca and Bennett and toward the south the Carboniferous beds are not far beneath the surface in the deeper hollows, but they are covered by the general heavy drift mantling. In the deep borings at Lincoln the Carboniferous beds were penetrated to a depth of over 1,000 feet. They appear to begin at a depth of about 269 feet. The section given in fig. 7, page 29, illustrates the general succession of deposits.[1]

Dakota sandstone.—In eastern Nebraska the Carboniferous formations are overlain directly by the Dakota sandstone, without trace of the Juratrias deposits intervening. At a point a mile and a half due north of Roca station the contact may be seen; at Bennett the two formations are in immediate proximity; and in the wells at Lincoln the contact lies about 269 feet beneath the surface. A finely exposed contact is shown in Pl. VI. The contact line between the Dakota sandstone and the Carboniferous beds in eastern Nebraska presents many steep slopes, indicating an irregular shore line against which Dakota sediments were deposited. The materials of the Dakota formation are mainly gray and brown sandstone, but there are also intercalated clays of various colors. Portions of the sandstone are highly ferruginous, so much so as to be frequently mistaken for iron ore. The sandy character of the formation is, however, prominent throughout. Where the amount of iron is large the rock is very apt to have a highly concretionary structure. The coarser sandy members are usually cross bedded. A characteristic outcrop is shown in Pl. VII. The texture of the sandstone varies irregularly from

[1] A more detailed description of the beds is given by Mr. B. P. Russell in the Sixth Biennial Report of the Commissioner of Public Lands and Buildings to the Governor of Nebraska, 1888, pp. 57–84. Lincoln, 1888.



JURATRIAS RED SANDSTONES, SANDS, ETC., AT ENTRANCE TO GARDEN OF THE GODS, NEAR MANITOU, COLORADO.

rock which is quite firm to sand which is hardly consolidated. In most cases the material is a soft sandstone which can be easily excavated with the pick. Some of the firmer beds contain fossil leaves in considerable abundance.

In the region covered by this report the exposures of Dakota sandstone are confined to Lancaster County and the vicinity of Pleasantdale in eastern Seward County. They occur at intervals along the sides of depressions of branches of Salt Creek, and at Bennett at the head of the Little Nemaha River. They are mainly very small and quite widely scattered, and are due chiefly to the excavation of depressions which have been cut through the glacial drift. Their location is shown in Pl. III (p. 12). In some cases belts of exposures mark the presence of a ridge of Dakota sandstone under the drift. The most extensive outcrops occur at intervals along and near the Burlington and Missouri River Railroad from Lincoln nearly to Roca, on the western slope of the ridge on the east side of Southeast Salt Creek. There are quite extensive exposures about the penitentiary and in the vicinity of the Chicago, Rock Island and Pacific Railroad crossing. Just east of Saltillo gray sandstones appear halfway up the slope, and they are again exposed on the point of the next ridge 2 miles farther south, lying against the Carboniferous limestone. The brown sandstones appear on Antelope Creek in the southeastern corner of Lincoln, as shown in Pl. VIII, at the "cave" in the southern margin of the city, and at the crossing of the Chicago, Rock Island and Pacific Railroad and Burlington and Missouri River Railroad, Nebraska City branch. Between Emerald and Pleasantdale the Dakota sandstone rises as a moderately high ridge under the drift and is exposed in a number of railroad and stream cuts. The beds are extensively cross bedded, and in some of the exposures consist of a highly ferruginous sandstone with complex concretionary structure. There are several exposures on both slopes of Haines Branch Valley and along the hollow beginning 2 miles southwest of Rokeby. They are of the usual brown sandstone. At the brick and tile works a mile southwest of the insane asylum the formation is represented by clays mainly of mottled pink, brown, and gray colors, with streaks of sand and sandstone and a bed of dark-gray clay containing a large amount of organic material. The clays have been mined extensively at this place for brick and tile, for which they appear well suited. They are overlain by a small amount of drift and a considerable mass of fossiliferous loess. Some of the features of this exposure are shown in Pls. XIV and XV.

There is another excavation in a similar mass of clay in the southern edge of West Lincoln, just east of the lake. The exposures of Dakota sandstone north of Lincoln are along Little Salt Creek and some of its branches south and southwest of Davey, along Rock Creek north of Waverly, and in depressions along the head branches of Rock

Creek northeast of Davey. In all of these exposures there is seen brown sandstone, excepting in the railroad cut northeast of Davey, where a mottled clay is exposed. The only exposures discovered east of Lincoln are in a small branch of Stevens Creek 6½ miles east of the Lincoln post-office, at an old quarry in the north side of Stevens Creek a mile and half above its mouth, and in the hollow just north of the railroad a mile west of Prairie Home. The exposure of the Dakota sandstone just south of Bennett, at the head of the Little Nemaha River, is very interesting. The formation consists of quite regular beds, from 1 foot to 2 feet in thickness, of beautifully cross-bedded sands hardly sufficiently cemented together to be classed as sandstone. The exposure is across a depression from limestone, as shown in fig. 3. The relations indicate that probably there was here a steep shore of the limestone during the deposition of the Dakota sandstone, although possibly the two formations are separated by a fault. In Pls. IX and X there are reproduced photographs of portions of the exposure, showing the cross bedding very clearly. In Pl. IX the overlying glacial drift is also shown.

FIG. 3.—Cross section at Bennett, Nebraska; looking north.

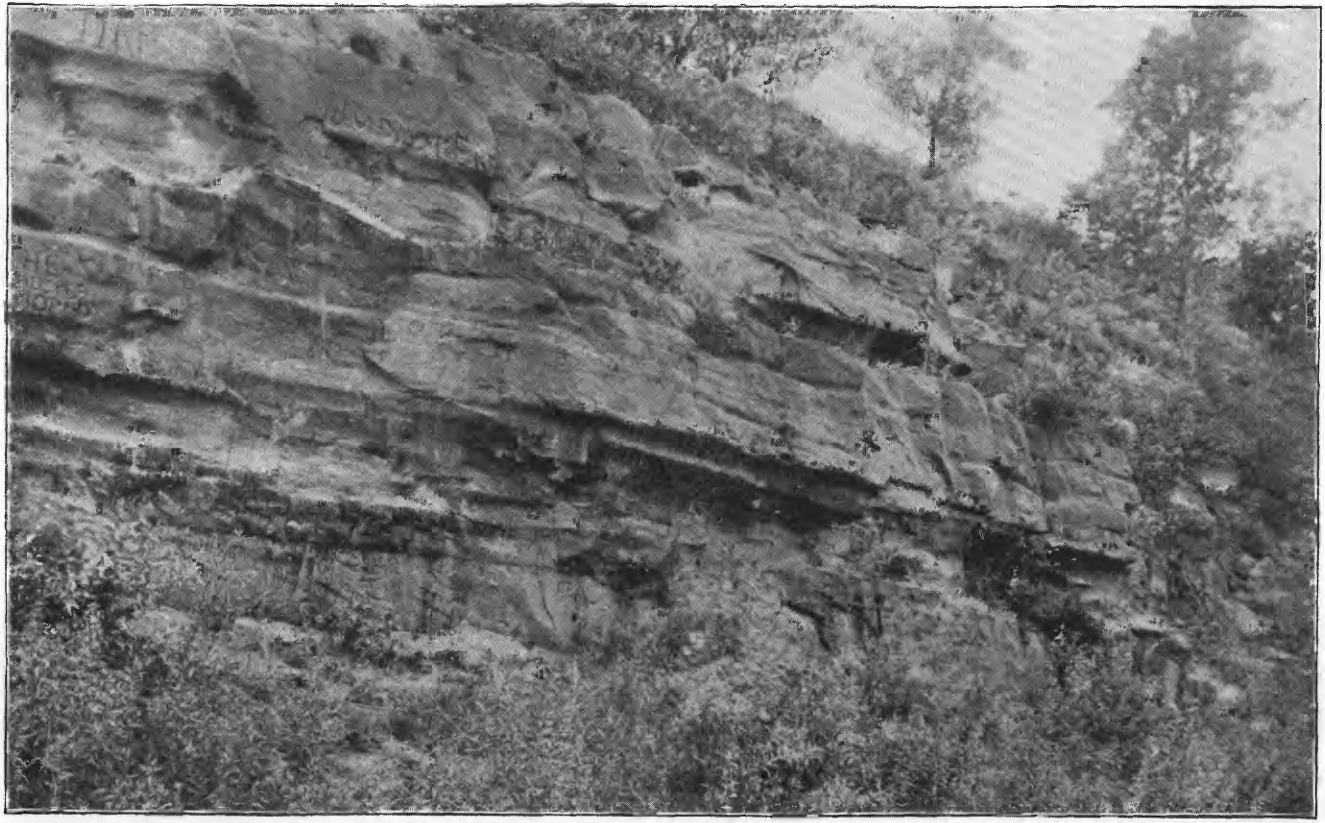
The Dakota sandstone has been reported in many of the wells in Lancaster County, and in fact it is one of the principal sources of water supply in the deeper wells.

In the boring made by the State near Lincoln in 1886 the lower portion of the Dakota formation was penetrated. According to Mr. B. P. Russell,[1] the materials covering the Carboniferous limestone were as follows:

Feet.	
0 – 4	Sandy loam.
4 – 20	Angular greenish sand.
20 – 24⅜	Coarser whitish sand.
24⅜ – 48¼	Coarse gravel.
48¼ – 52	Sand, whitish, even grained, in part rounded.
52 – 57	Coarse gravel.
57 – 74	Fine yellow sand.
74 –100	Lighter sand.
100 –112½	Coarser, dark-yellow sand; gravel and iron pebbles.
112½ –133¾	White sand and gravel, with brine at 119 feet.
133¾ –135	Yellowish-white sand.
135 –147⅜	Yellow sand; small pebbles.

[1] Sixth Biennial Report of the Commissioner of Public Lands and Buildings, December 1, 1888, pp. 65-68. A slightly different record is given in the Fifth Report, 1886, p. 19.

DAKOTA SANDSTONE LYING ON CARBONIFEROUS LIMESTONE, WEST BANK OF MISSOURI RIVER, AT MOUTH OF PLATTE RIVER.
(The arrows indicate the plane of contact.)



DAKOTA SANDSTONE ON WEST BANK OF MISSOURI RIVER, AT MOUTH OF PLATTE RIVER.

Shows cross bedding and beds of coarse materials.

Feet.			
147⅜	–164¼	Coarse yellow sand and gravel.	
164¼	–179⅜	Yellow sand.	
179⅜	–195	White sand; gravel.	
195	–202	Very coarse gravel.	Containing brine 35°; strong flow.
202	–205	Coarse gravel and conglomerates.	
205	–206⅛	Coarse conglomerate with chalky, flinty pebbles.	
206⅛	–208⅘	Soft gray sandstone.	
208⅘	–209⅛	Reddish clay.	
209⅛	–214⅕	Light-drab clay.	
214⅕	–244½	Fine-grained, gray, very soft sandstone.	
244½	–247¼	Greenish-drab clay.	
247¼	–267 1/12	Fine-grained, reddish, very soft sandstone.	
267 1/12	–269 1/12	Arenaceous gray clay lying on chert, shale, and limestone.	

It is thought that the top of the Dakota formation was entered at a depth of 48¼ feet, but the evidence is by no means conclusive.

From the data of wells and outcrops in the Lincoln region it has been possible to prepare a map (Pl. XX) with contour lines showing the altitude of the surface of the Dakota sandstone under a portion of Lancaster County and adjoining area. These lines are intended to indicate the contour of the sandstone surface on which the drift deposits lie. An endeavor has also been made to differentiate the valleys cut into the sandstone in areas from which the drift has been removed, as, for instance, along the center of the Salt Creek and Southeast Salt Creek valleys. A further explanation of the relations is shown by cross sections in Pl. XXI. The irregularities of contour are probably mainly due to preglacial erosion, but there is some evidence that the elevated area about Pleasantdale is due in part to an upward arching of the beds.

In Pl. XVII the depth of the Dakota sandstone below the surface is shown for each 50 feet, as a guide to the contained water supply.

Benton and Niobrara formations.—The Benton formation, in its typical development, consists of dark shale lying conformably on the surface of the Dakota sandstone. Owing to the heavy drift and loess covers in the region in which the Benton formation should be expected to reach the surface, only one exposure of that formation has been found. This is in the bed of Big Blue River just below Milford, where a few inches of black shales of supposed Benton age are to be seen under the Niobrara beds. As it was not possible to obtain evidence as to the depth at which the Dakota sandstone lies in this vicinity, no definite statement can be made of the thickness of the Benton deposits, but it is thought they will prove to be less than 100 feet thick. The boring at Seward, of which a record is shown in fig. 8, page 31, found 100 feet of dark clay lying between "sand and gravel" and the top of the supposed Dakota beds. If the "sand and gravel" are drillings from Niobrara beds, which is probable, the underlying clay would be Benton. The probable location of the eastern margin of the formation is shown in Pl. XX.

The Niobrara formation is represented by impure siliceous limestones, which outcrop at a number of points in the eastern and southern part of Seward and Saline counties. The beds are usually thin, but owing to their hardness and the ease with which they can be quarried, they have been employed to some extent for foundation and other rough work. There are some quarries near Pleasant Hill, along the west side of the North Fork of Turkey Creek, on the east bank of Big Blue River 4 miles north of Crete, and in the upper portion of the valley of Middle Oak Creek, northeast of Germantown. The formation is also exposed for some distance along Beaver Creek near the southern margin of Seward County, and along Big Blue River just below Milford, notably in a small branch just south of the Soldiers' Home at Milford, as shown in Pl. XI; and it is said to appear in the bed of Big Blue River in the vicinity of Camden.

The rock is characterized by impressions of the fossil oyster known as *Inoceramus labiatus* and possibly some other species. In some of the beds, also, we may expect to find the characteristic fossil *Ostrea congesta*. The general aspect of these fossils is shown in the two figures on Pl. XII. These fossils are here figured because it is very important to be able to distinguish them from the Carboniferous fossils in the limestone which underlies the Dakota sandstone. Their occurrence is a guide to the progress of a deep boring west of longitude 97°, for the water-bearing Dakota beds may be expected in regular order below. The thickness of the Niobrara formation can not be definitely stated, as none of the exposures were complete, and we have no well records which are sufficiently definite to afford a basis for precise estimation. It is believed, however, that the formation will not prove to be over 40 or 50 feet in thickness, and probably it is considerably less.

Pierre shales.—This formation consists of a great mass of shales, predominantly dark gray in color, which thicken rapidly westward under central and western Nebraska. Owing to the heavy mantle of loess and drift, and, to the west, of Neocene deposits, there are no exposures of these shales at the surface. They have, however, been deeply penetrated by a number of well borings. At Kearney it is claimed that they are over 2,500 feet thick; at Hastings they extend from 224 feet to 1,346½ feet; at Dannebrog they extend from 135 feet to 1,011 feet, and at York they were penetrated for several hundred feet. It is probable that the thickness is 4,000 feet under the western portion of the State, as shown in Pl. IV, but the actual amount is not known. The shales contain occasional thin beds of sand, iron pyrites, and heavy dark clay.

Neocene formations.—The representatives of the Neocene formations which are so prominent in the western portions of Nebraska are found underlying the Pleistocene deposits in the central portion of the State, where their thickness gradually decreases until finally they thin out entirely.

EXPOSURE OF DAKOTA SANDSTONE ON ANTELOPE CREEK, IN SOUTHEASTERN PORTION OF LINCOLN, NEBRASKA.
Also shows glacial drift.

The materials consist of siliceous and calcareous sediments, mainly of a sandy texture and chalky aspect. They are often called "magnesia." Portions of the beds are light-colored, very sandy clays containing chalk-like nodules. The eastern margin of these deposits has not been definitely located in the area to which this report relates. South of the South Fork of Loup River there is no evidence of their existence east of longitude 98° 30′, but north of that river they may extend somewhat farther east. They are exposed in depressions northeast of Kearney, and from thence westward in Buffalo, Dawson, Phelps, and Gosper counties, where many of the deeper canyons cut into them. Owing to the manner in which the loess rolls down or caves along the slopes of the wider depressions, exposures are relatively rare, and so far it has not proved practicable to map the Neocene formations very satisfactorily, owing to their being thus concealed for long intervals in depressions in which they might otherwise be expected to outcrop. To the west the exposures increase in abundance and a greater thickness of the formation is exposed. The most extensive exposures in the area to which this report relates are along the upper portions of Plum Creek.

Earlier Pleistocene deposits.—These deposits comprise a mass of glacial drift in Lancaster and eastern Seward counties, and a thin sheet of gravelly sand, which extends far westward under the loess mantle of the plains region, and appears to be contemporaneous with the glacial drift. The glacial drift constitutes a very irregular mass of bowlder clays, sands, gravels, and bowlder beds, covering the greater part of Lancaster County. It constitutes high hills, which are traversed by the deep, wide valleys of Salt Creek and its branches in the region about Lincoln. The glacial drift ends toward the west in the slope which descends quite steeply to Big Blue River from Seward southward. Its precise western limit could not be definitely determined owing to the overlapping of loess and the frequent lack of distinctive outcrops. The greater portion of the glacial drift consists of blue and gray bowlder clays. There are also beds of blue and gray clay nearly pure or containing a little mixture of fine sand, but scattered bowlders of pebbles occur almost everywhere through it. There are included sand beds, ordinarily containing bowlders, but locally quite free from them, and numerous lenses of bowlder beds, consisting mainly of bowlders. The pink Sioux quartzite, often in very large masses, is a conspicuous feature of the drift, but there are many other rocks associated. Wide areas of clay surface with only a few scattered bowlders occur, and other areas of light-colored sandy clays, particularly on the higher, level lands, which appear to be loess merging into the glacial drift. A characteristic bowldery surface is shown in Pl. XIII.

No order of succession has yet been determined for the glacial deposits. Instructive exposures are very rare, and well records have

thrown but little light on the relations. In fig. 4 is given a sketch of some features exposed on the Chicago, Rock Island and Pacific Railroad cut near Prairie Home, in Lancaster County.

The central mass is an oxidized, ferruginous clay of brownish-buff color, with scattered pebbles and soft calcareous concretions. The overlying sheet of bowlders contains many masses of pink Sioux quartzite, mainly angular, with some fragments of other crystalline rocks. This is overlain by pinkish sandy clay, with a few pebbles, mostly of small size. On the top is a mantle of pale-buff loam, with ferruginous and calcareous concretions somewhat like loess in aspect, but more argillaceous and lacking the typical texture.

The thin drift sheet which extends far westward from the glacial-drift margin, under the loess, underlies a wide area of central Nebraska. It is usually a thin sheet of sandy clay, commonly of pinkish color. Eastward it becomes more sandy, thickens, and is often represented by coarse sand. Pebbles of a great variety of rocks of Rocky Mountain origin occur, both in the pink sandy clays and in the more sandy portions to the east. These pebbles are characteristic of the deposit as far westward as I have traced it, which is in the vicinity of Ogal-

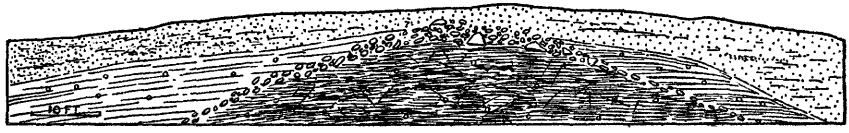
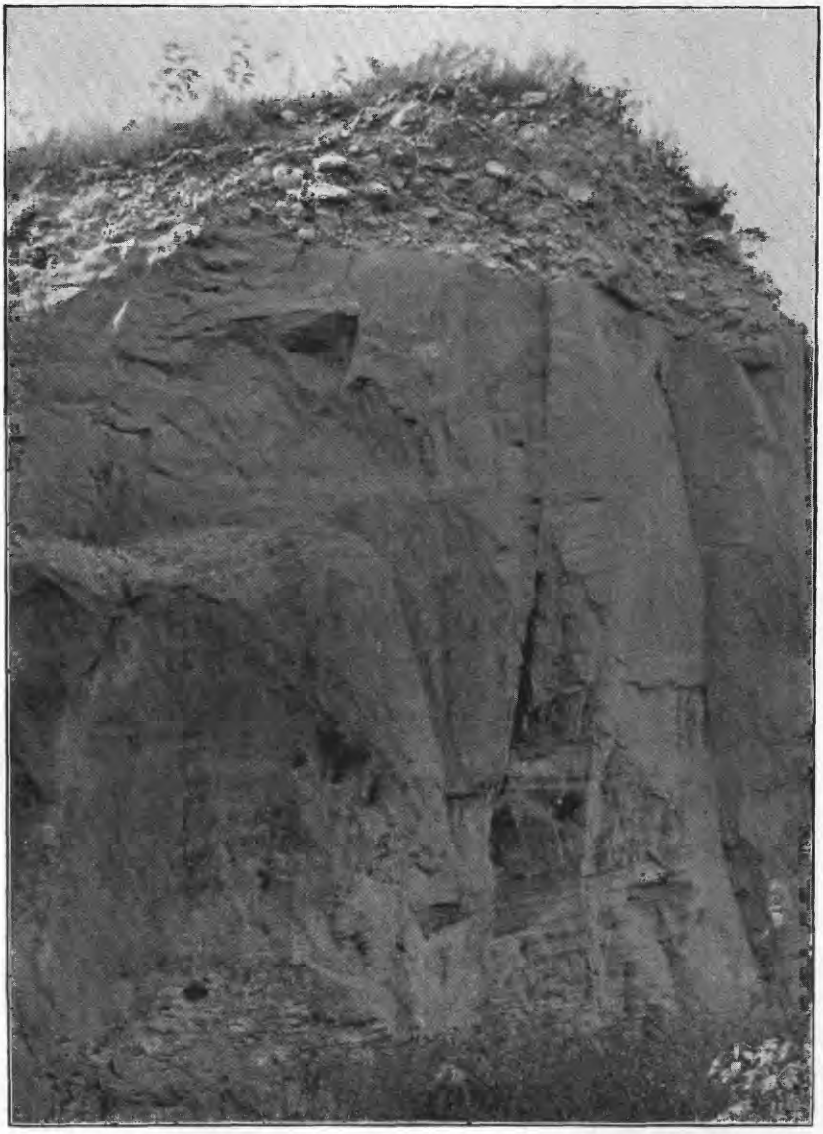


FIG. 4.—Glacial formations in cut one-quarter mile west of Prairie Home station; looking north.

lala. The precise relation of this formation to the glacial drift can not be ascertained in the area examined, but it appears to merge into glacial-drift deposits in eastern Seward County.

The loess.—The loess is a great mantle of light buff-colored loam, which constitutes the surface of the plains of south-central Nebraska over thousands of square miles. It abuts against and overlaps the thick mass of glacial drift to the east in eastern Seward County, but extends westward in a vast tabular surface. From the eastward there is a lower-level phase which extends up the depressions of Salt Creek and Little Nemaha River, but does not reach an altitude much above 1,250 feet in the Lincoln region. The most extensive development of the formation is in the wide plains west of Big Blue River, where it covers all of the surface between the large drainage depressions. A wide trench is cut through the formation by the valley of Platte River, and many smaller streams have cut through or deeply into it.

In the upland portions of Buffalo, Dawson, and Gosper counties the surface is deeply invaded by numerous small valleys, which become steep-sided canyons as the land rises to the west, particularly in Gosper County.



DAKOTA SANDSTONE OVERLAIN BY GLACIAL DRIFT, NEAR BENNETT, NEBRASKA.
(LOOKING WEST.)

Shows cross bedding.

DAKOTA SAND IN QUARRY JUST SOUTHEAST OF BENNETT, NEBRASKA.
Shows regular and cross bedding.

The materials of the loess consist of fine sandy loam, somewhat calcareous, and chiefly of a pale brownish-yellow color. Occasionally a streak of sand is found, and some portions are slightly more argillaceous than usual. The material is of remarkably uniform texture, compact, but perfectly soft. Water falling upon its surface is absorbed in some measure, but on steep slopes the material is rapidly excavated wherever a rivulet gets a fair start.

In the lower part of the formation, possibly underlying it and entirely separate, are deposits of volcanic ash, usually mixed with more or less fine sand, but often so pure as to be of brilliant white color, and consisting almost entirely of fine shreds of volcanic glass. The purer material is very serviceable as a polishing powder. The occurrence of this volcanic-ash deposit has been reported at two localities within the area, but owing to lack of knowledge as to the conditions under which it occurs, no description of it will here be offered.

The loess is generally fossiliferous, containing scattered fossils of quite a variety of species, often represented by numerous individuals. These fossils were found throughout the area represented as loess in Pl. III. It also contains calcareous concretions, especially toward the east. An outcrop of loess in Salt Creek Valley is shown in Pl. XV.

Alluvium.—The wider, deeper valleys are floored with alluvial deposits which have been brought from greater or less distances by the streams now occupying these valleys. Along the smaller drainage ways the materials are of such local origin that it has not always been possible to differentiate them satisfactorily, but in the larger valleys they are well-defined alluvial accumulations of considerable thickness. The most notable deposits are those in the wide valley of Platte River, which has a width of 20 miles at Grand Island, 12 miles at Kearney, and 15 miles at Lexington, and is floored to a considerable depth with alluvial deposits.

Along the South Fork of Loup River and Wood River there are also narrower alluvial deposits, which are confluent with those of the Platte Valley. There are deposits also along Little Blue River, Big Blue River and its branches, and in the depression of Salt Creek and its branches.

A large amount of the alluvial deposits consists of loess-like material containing streaks of clay and gravel, but usually lacking the loess texture and fossils. In the immediate vicinity of Platte River, along its channel and islands, the deposits are mainly coarse sands with more or less gravel, but there are extensive admixtures of loam and some clay. In the valley of Salt Creek the material is largely loess-like, but there is also a great deal of dark mud, and this is in greater part the characteristic which is presented along Big Blue River and its larger branches.

Dune sands.—The area to which this report relates lies southeast of the great sand-hill region of Nebraska, but it includes a number of

small local sand-dune areas. The largest of these extends along the south side of the Platte Valley from opposite Elm Creek to opposite Wood River. There are several small dune areas along the south side of the valley of the South Fork of Loup River near Sartoria and Pleasanton, and the southern extremity of an extensive area is found just west of Cairo. There are some small detached areas of dune sands southwest of Kenesaw, in Adams County, and south and southwest of Holstein, in the same county, and in the eastern part of Kearney County. These dune sands are wind blown and derived mainly from alluvial deposits of the river bottom, which have traveled along the valley and accumulated where changes in the trend of the valley were favorable for stopping them, or where some minor obstructions arrested their progress. The belt south of Kearney has a width of about 5 miles where it is widest.

The sands lie on the pebbly or sandy floor of the river bottom, but are usually banked up against the edge of the loess upland, and in some places extend up onto the plains surfaces. The dunes present great varieties of form, cones, ridges, mounds, and basins being the most general. Over much of the area there is no movement of the sand, and the surface is covered with sod. There are, however, many bare places from which the sand is traveling. In windy weather more or less sand is blown all over the region, and loose sand is mixed with the soil of the loess plain adjoining, usually for some distance from the margin of the sand-dune area. A characteristic sand dune is portrayed in fig. 1, on page 13.

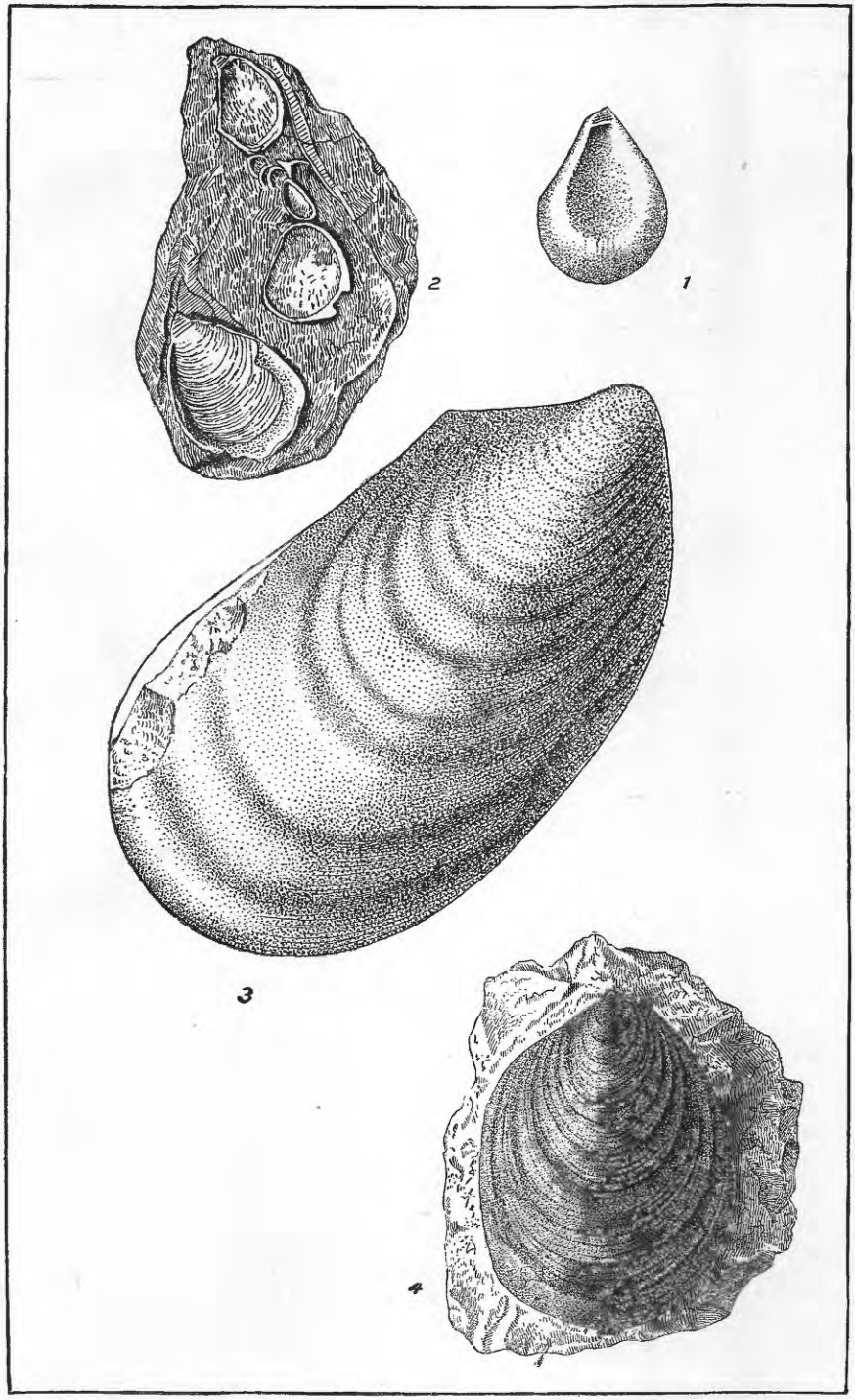
THE WATER HORIZONS.

The underground waters of southern-central Nebraska occur in several geologic horizons. In the region west of Big Blue River the various beds of coarse material lying between the loess and the Pierre shales afford a general water supply which is of large volume at nearly all localities. The eastern edge of the Neocene deposits and the drift sands which lie just below loess are the principal reservoirs of these waters.

In the wide valley of Platte River nearly all of the coarser materials, especially the basal beds of the alluvium and the coarser portions of the alluvium near the stream, are filled with water, which is obtainable from shallow wells. Although in dry weather the Platte River shows very little water at the surface, just below the dry sand and shingle in its bed there is a sheet of water which extends widely under the alluvial flat on either side. These permeable alluvial materials and more or less underlying coarse material of Neocene and Pleistocene age contain a large aggregate supply of water.

As the valley of Platte River is somewhat higher than the adjoining valleys of the branches of Blue, Republican, and Loup rivers, the waters that lie in its bottom flow out laterally through the coarse mate-

NIOBRARA LIMESTONE ON COON CREEK, IN SOUTHERN PORTION OF MILFORD, NEBRASKA. (LOOKING NORTH.)



TYPICAL FOSSILS OF NIOBRARA LIMESTONE.

Ostrea congesta Conrad. { Fig. 1. Interior view of the upper valve, slightly enlarged (after Meek).
Fig. 2. Three small lower valves attached to the shell of a large Inoceramus (after Meek).

Inoceramus labiatus Schloth. { Fig 3. Right valve of an elongated specimen (after Meek).
Fig 4. Small right valve with unusually strong concentric ridges.

rial underlying the loess and issue as springs or underground seepage in these deeper depressions. In the vicinity of Grand Island the evidence is very clear that the Platte waters pass under the loess-covered divide and emerge in the deep valleys of the head waters of branches of Big Blue River, which are considerably lower in altitude than the bottom of the Platte Valley. There is also underground leakage to the north into the depression containing the South Fork of Loup River. This is very clearly shown at Kearney, where, in a series of gage wells sunk for the Division of Hydrography, the water level is shown to gradually decline to the northwest a very appreciable amount within the city limits of Kearney, as shown by fig. 12, on page 40. The wells in the valleys and high lands northward show a continued diminution in altitude of the water surface, which indicates an underground flow to the north. There is excellent evidence that under Phelps and Kearney counties there is underflow from Platte River toward the Republican Valley. This underflow is rendered possible by the pervious nature of the great sheet of materials which lies between the loess and the top of the impervious Pierre shales. These conditions are illustrated in fig. 5.

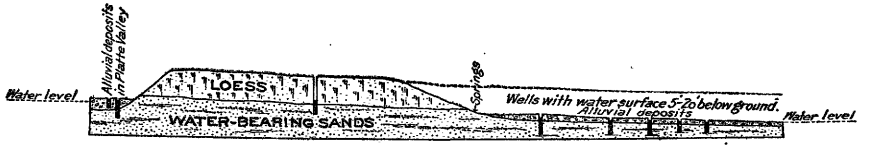


FIG. 5.—Ideal section showing the usual relations of underground waters in the central plains region of Nebraska.

The valley on the left is that of Platte River, and the depression on the right is similar to the depressions of the branches of Big and Little Blue, Republican, and Loup rivers. The rate of this underflow is exceedingly slow, for careful experiments have shown that underground water moving through sands, even if the sands are relatively coarse, does not progress over a mile or two a year.

As the water-bearing beds under the loess thicken westward, their upper portions rise higher above the bottom of the Platte Valley in western Dawson and Gosper counties, and it is usually found necessary to go to considerable depth in them to find sufficient water supply.

Some of the exceptional relations which are often found locally in the region west of the ninety-eighth meridian are illustrated in the cross sections in Pl. XVIII. In section *A* there is shown a condition which is quite frequent in Buffalo and Dawson counties. A well at B has to go to the general underflow in the water-bearing bed A A; but at C, at much less depth, a local water supply of greater or less volume is found in a shallow basin underlain by clay. In section *B* a condition is illustrated which is found in some of the shallower valleys on the high loess plains. Here the underflow conditions are continued

under a valley without interruption, and the beds yield water to wells at G G. They are also reached by wells at E and F, but at E a water supply may be obtained from the gravels flooring the valley bottom. In section *C* are shown the relations of two water-bearing sands separated by a bed of clay. In some areas both horizons are drawn on for water, and either one may contain the greater amount. Ordinarily the deepest wells obtain the largest supplies of water, but in other cases the largest volumes are in the upper bed of sand containing the underflow from the river valleys. A well at H would find abundant supplies of water in the gravels and sands flooring the valley.

Section *D* illustrates a relation which may account for some observed inequalities in the volume of water in the same bed of sand on either side of a river valley. A well at J would yield a good supply of water, but one at K would yield less because the water escapes into the river bottom on the one side and a local deposit of clay seals off the entrance of a continued underflow on the other side of the valley toward K.

Section *E* illustrates a change of material from coarse to fine—pervious to impervious—in the same bed. Thus, a well at L would

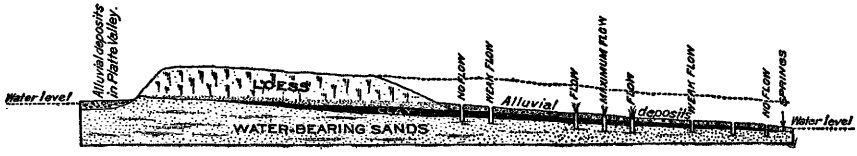
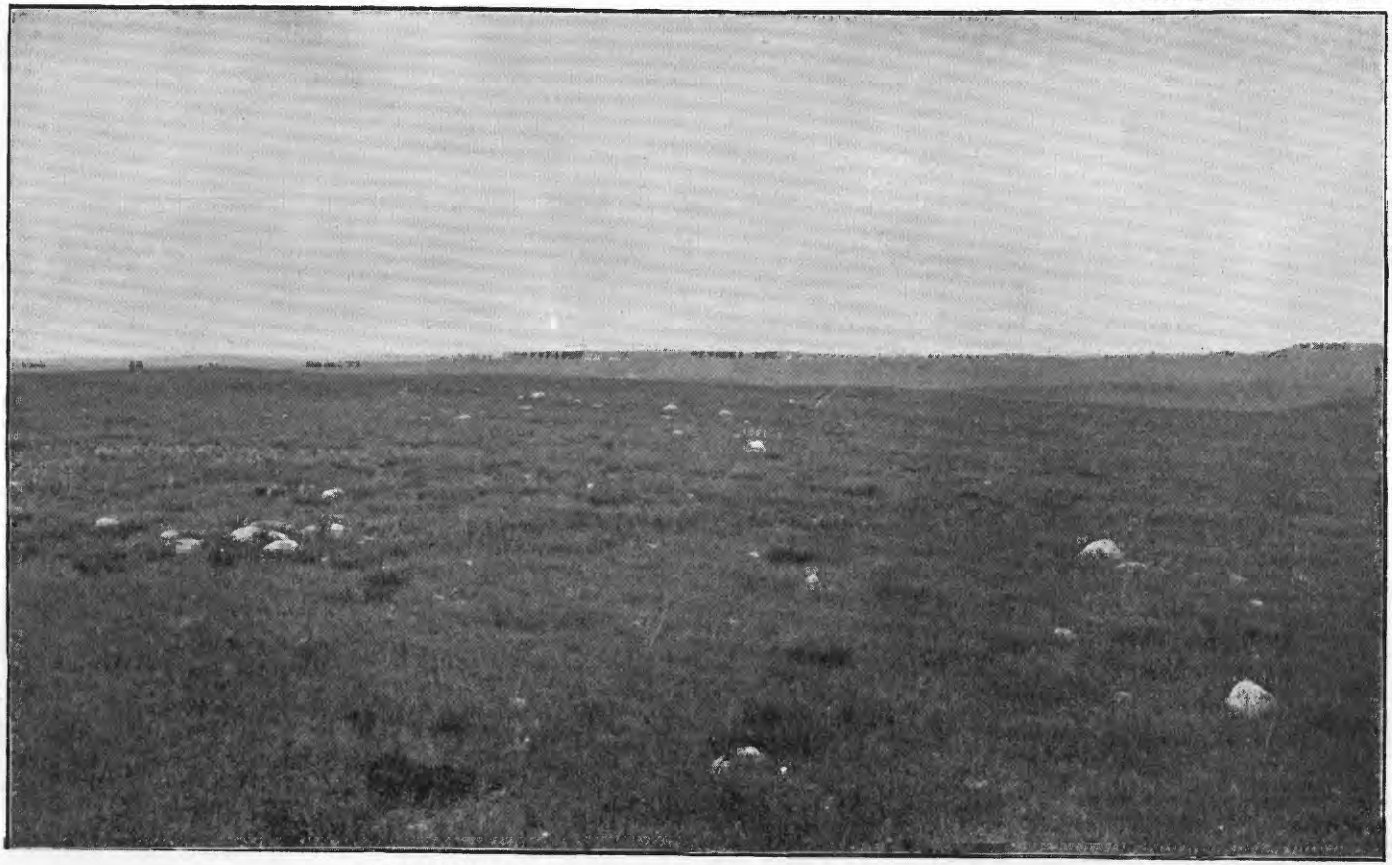


FIG. 6.—Ideal section from the Platte Valley to and down the valley of West Blue River, to show the probable cause of the flow.

obtain a water supply from sands which merge into clay toward M, where the clay would have to be penetrated to underlying sands at greater depth.

The geologic relations of the water-bearing stratum in the Beaver Crossing region are not as yet fully ascertained. The waters lie in sands which are overlain by a heavy bed of tough, impervious clay, but the depths are so moderate that it can hardly be thought that these sands are of the Dakota formation. It is much more probable they are in the western extension of the drift deposits. The head is due to the elevation of the intake area of the waters westward, and it is sustained locally through the protection afforded by a wide extent of the overlying mantle of tough, impervious clay. In fig. 6 is given an ideal section to show the probable relation. This should be compared with the section in fig. 5 (p. 25), which shows the usual conditions in other areas where there is no flow.

In Lancaster and eastern Seward counties the principal supplies of underground waters occur in the Dakota sandstone and sands. In the drift deposits waters are often abundant in supply and satisfactory in quality, but their occurrence is so exceedingly irregular that



TYPICAL STONY DRIFT SURFACE, NORTHERN LANCASTER COUNTY, NEBRASKA.

no definite idea could be formed as to their relations. A large number of wells have been sunk to the Dakota sandstone, which is usually so porous as to yield an excellent water supply. In the lower lands it lies at very moderate depths, but in the higher lands a deep boring is often required to reach it. On account of the definiteness of this water horizon it has been made the basis of water prediction in the Lancaster County area, as shown on Pl. XVII.

The waters of the Carboniferous limestone have been tested at Lincoln, and found to be highly saline. In a portion of this area the waters in the Dakota sandstone, also, are quite saline, owing, it is thought, to impregnation from springs or seepage from the underlying Carboniferous limestone. It is probable that these springs existed during the deposition of the Dakota formation, and have continued in greater or less volume since, for the present superficial deposits of the valley are highly impregnated with salt.

In the sand hills, especially those in northern Kearney and northeastern Phelps counties, more or less water is often found in the base of the sand accumulations, especially where the sand lies on a less permeable portion of the alluvial deposits. Quite a number of shallow wells in the sand-hill region find a satisfactory domestic supply of water without having to sink to the underlying alluvium or loess.

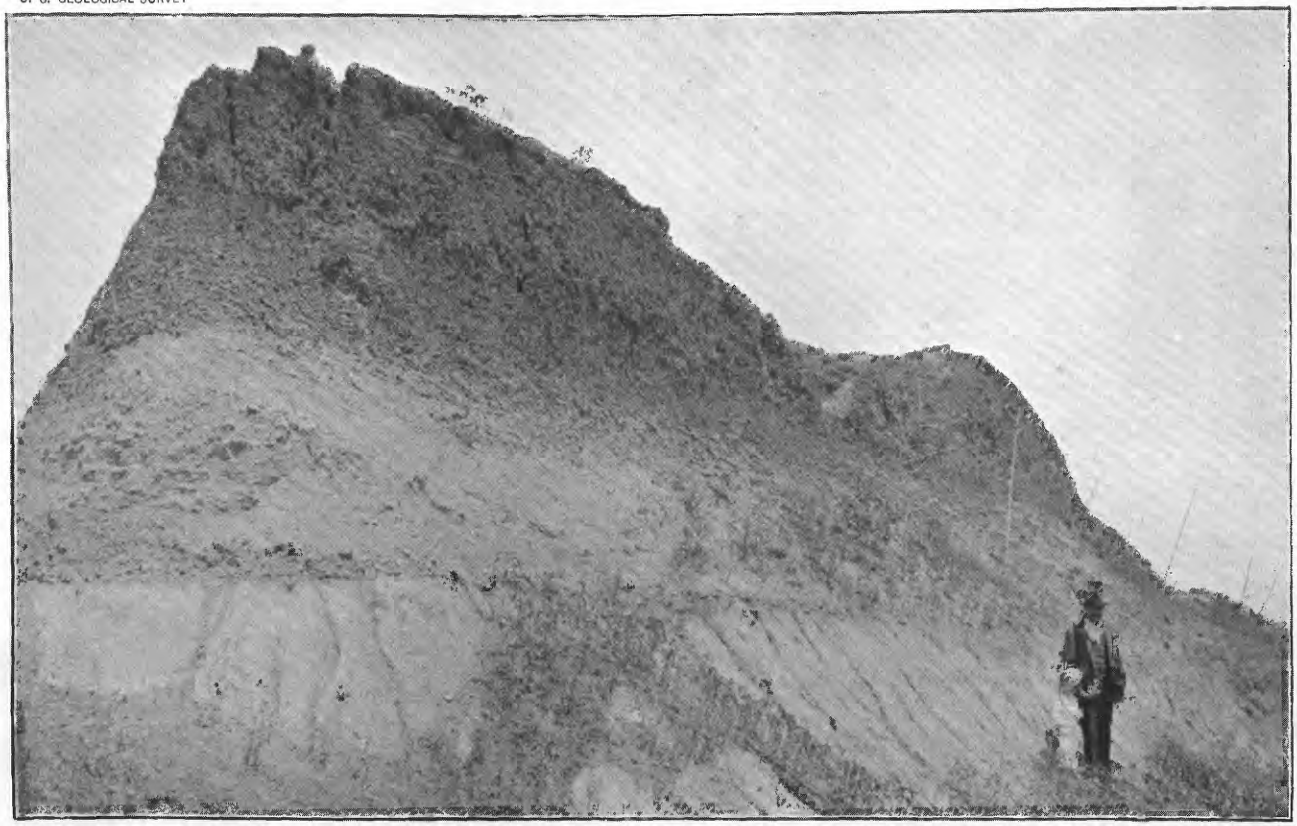
LANCASTER COUNTY.

Lancaster County lies within the area of glacial drift, which is underlain mainly by the Dakota sandstone. There are also wide valleys, mainly those of Salt Creek and its branches, filled with loess and alluvium. The principal water-bearing formation is the Dakota sandstone, but waters also occur among the drift deposits. The waters in the drift are of very irregular occurrence, but they furnish supplies for many scattered wells. As their distribution is governed by laws at present not well understood, it is almost impossible to make a general statement regarding them which would be of any value. In some cases, also, waters supposed to be derived from the drift may possibly accumulate through leakage from the underlying Dakota sandstone. This sandstone appears to carry water supplies throughout the area of Lancaster County, excepting about Roca and along the Little Nemaha River, where the limestones come to the surface, and at a few local points where the rock is less permeable than usual. The surface of the Dakota sandstone slopes, as a rule, gently eastward, although the general dip of the beds of the formation is toward the west. The contour of its surface under the heavy drift mantle is by no means regular, for it presents numerous ridges and mounds of various sizes, separated by irregular depressions, as shown in Pls. XX and XXI. The larger depressions of the county have been excavated through the drift, and in places more or less deeply into the Dakota formation, which gives further complexity to the contour of its surface.

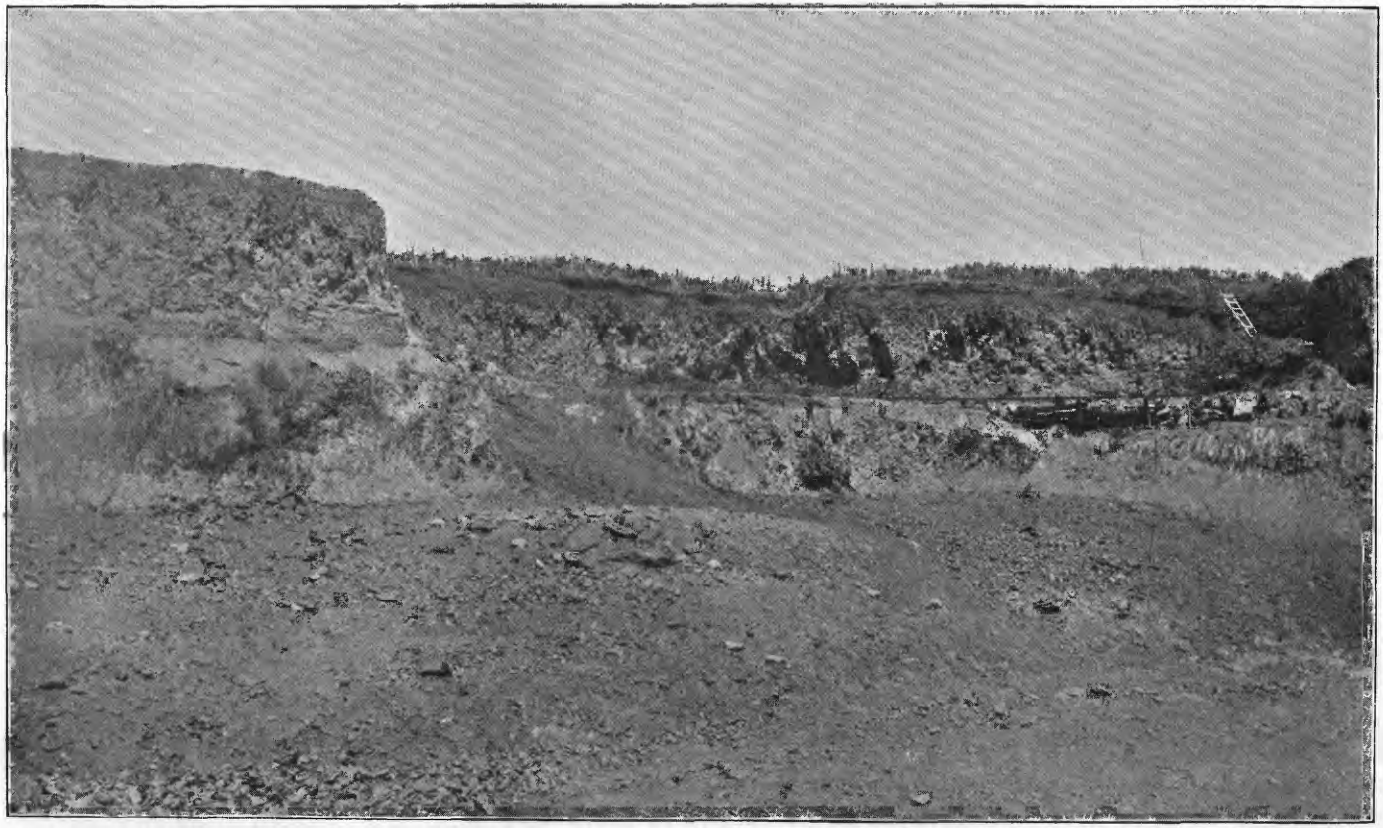
As the Lancaster County region is one of high hills and ridges, the irregular surface of the Dakota sandstone lies at depths which vary greatly. These variations, however, are not too irregular for representation on a map, and in Pl. XVII there is shown the depth to the surface of the sandstone for each 50 feet from 50 to 250 feet. This representation is based on observations of the outcrops, which give a fairly good idea as to the surface configuration of the formation, and on the records of numerous wells which draw their waters from it. It will be seen that the depths are quite closely related to the altitude of the land above the principal valleys, and that there is also a somewhat general increase of depth to the north and northwest. In the area in which waters are shown to be obtainable at less than 50 feet below the surface the supplies are derived mainly from the Dakota sandstone, into which the depressions are excavated. In many portions of these depressions waters are available at considerably less than 50 feet below ground, but there is great irregularity in this regard.

The water supplies for the city of Lincoln are obtained from three pumping stations within the city limits. The Rice well, at Twenty-fourth and N streets, has a main well 50 feet deep and 40 feet in diameter. In its bottom there are seven wells 6 inches in diameter and 140 feet deep, from which the water flows up into the large well to within 15 feet of the ground when the pumps are not in operation. The water is almost perfectly fresh. The supply is augmented by six 6-inch gang wells, 140 feet deep, situated 150 feet south of the main well. The total product is stated to be 200,000 gallons a day. At the Park well, on F street near Sixth, there is a 50-foot well 75 feet in diameter. It contains three 6-inch tubular wells 40 feet deep. The water, which is somewhat salty, rises to within 10 feet of the ground, and the supply is 200,000 gallons a day. At South and Seventh streets there is a supplemental plant, from which the water is quite salty. It consists of a gang of 24 points, 55 to 58 feet deep, 4 inches in diameter, and yielding 150,000 to 200,000 gallons a day. The salinity of the waters used by the city of Lincoln from these three plants increases gradually from east to west toward the center of the salt-marsh area which lies along the western margin of the city. As the Dakota sandstone contains abundance of fresh water to the east and north of Lincoln it seems quite unnecessary that the city supplies should be in part drawn from the salt-basin area. Several deep borings made in Lincoln and vicinity obtained only salt waters. They passed through the Dakota sandstone, which furnishes the waters for the shallower wells, far into the Carboniferous limestones and underlying formations. The record of the well sunk by the State at the southern edge of the Salt Lake, now Burlington Beach, is given in fig. 7. This record was drawn mainly from the statements published by Mr. B. P. Russell,[1] the geologist who was placed in charge of the well.

[1] Sixth Biennial Report of the Commissioner of Public Lands and Buildings to the Governor of Nebraska, December 1, 1888, pp. 57–84.



GLACIAL DRIFT ON DAKOTA CLAY IN PITS SOUTHWEST OF INSANE ASYLUM NEAR LINCOLN, NEBRASKA.



LOESS ON GLACIAL DRIFT AND DAKOTA CLAY IN CLAY PITS SOUTHWEST OF INSANE ASYLUM NEAR LINCOLN, NEBRASKA.

Loess extends to level of tramway, which is on the thin layer of glacial gravel.

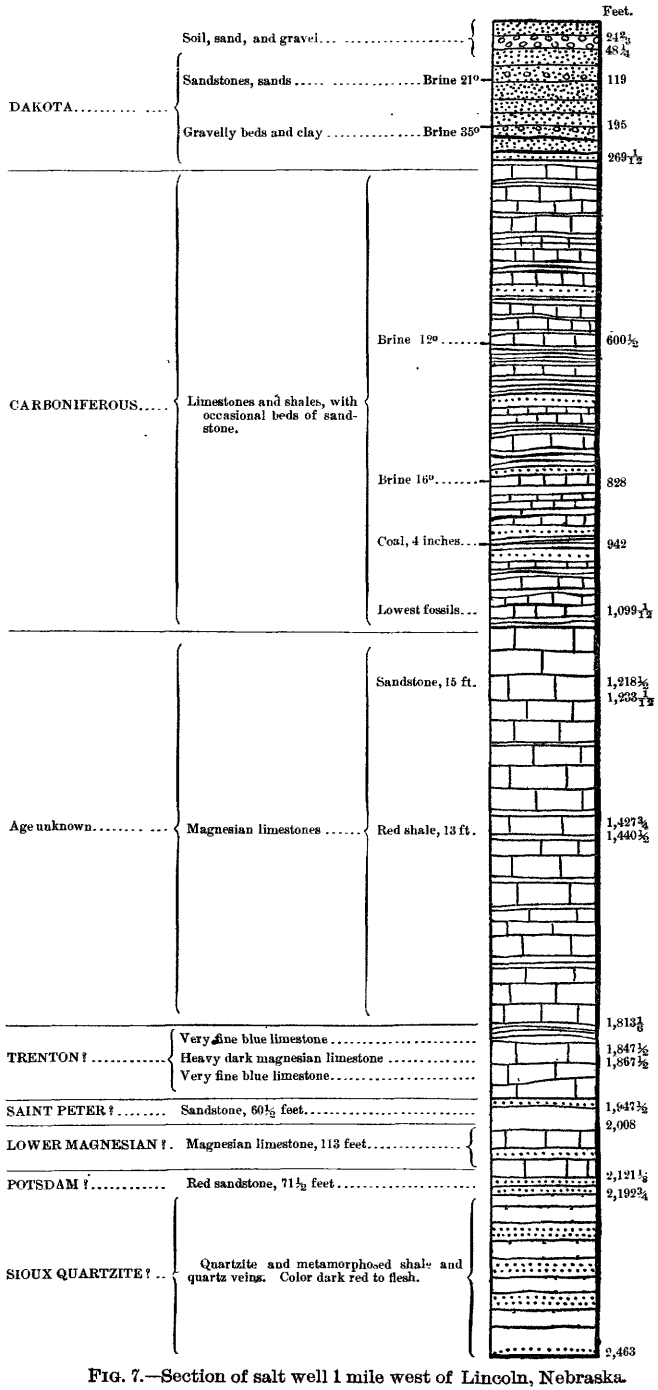


FIG. 7.—Section of salt well 1 mile west of Lincoln, Nebraska.

The borings were deposited in the museum at the State University, in Lincoln. So far as can be judged, the Dakota sandstone began at a depth of about 48 feet and extended to a depth of 269 feet 1 inch.

The clays at 208–214 feet, and the sandstone at 214–244 feet and 248–267 feet appear to be typical Dakota beds. The principal flow of water is from a reddish sandstone in the Carboniferous limestone at 600 feet. It is very saline. A similar flow is obtained at a depth of 570 feet at the sanitarium in Lincoln, and at 560 feet in the 1,050-foot well in the Post-office Square. In the State well another saline flow was found at 828 feet. The head of the water at the sanitarium is about 1,210 feet above sea level, its pressure being 15 pounds to the square inch.

SEWARD COUNTY.

The wells of Seward County draw their supplies from several sources. In the valley of West Blue River, in the vicinity of Beaver Crossing, there is a considerable area in which artesian flows are obtained. In the adjoining plains region the water is in gravels and sands underlying the loess. In the drift hills east of Blue River, waters are found in sands among the drift deposits and also in the underlying Dakota sandstone; and in the valleys of Big Blue River and some of its branches there are waters in the basal portions of the alluvial beds and in the underlying sands and gravels in which the valleys have been excavated. In most areas the supply of water found is very abundant, but at some points in the drift hills and about Seward the volume is small, so far as now developed.

The artesian area in West Blue Valley has been extensively explored by many wells. It begins about 6 miles below Beaver Crossing and extends to the western margin of the county on Beaver Creek and some distance into York County, up the South Branch Valley. Laterally the area of flow is limited by the lower slopes in the valley. About Beaver Crossing the head is sufficient to afford a flow to from 18 to 23 feet above the bottom lands. The head gradually diminishes up and down the valley as the ends of the artesian area are approached. The wells vary in depth from 90 to 140 feet, the shallower ones drawing from an upper stratum of water-bearing beds known as the "first flow." In Beaver Crossing the wells are mainly from 102 to 110 feet deep. The water is obtained from a bed of sand which lies under a sheet of clay extending from 40 to 90 feet. The wells in this artesian area are of various sizes, from 1 inch to 4 inches in diameter. The flows vary from 10 to 150 gallons a minute. The supposed geologic relations in this artesian area are shown in fig. 6, page 26.

It is said that flowing wells have been obtained at Ruby, and in one of the attempts to find deep-seated waters near Seward. The water at Seward was found at a depth of 336 feet, and, it is claimed, flowed out of a pipe 12 feet above ground, but only in small volume. This boring was four blocks east and four blocks south of the court-

RECENT VALLEY DEPOSITS ALONG SALT CREEK, IN EASTERN PORTION OF LANCASTER COUNTY, NEBRASKA.

house. In a boring reported to have attained a depth of 365 feet, a half-mile northeast of the court-house, a supply of water was found which is said to have come within 10 feet of the top (within 40 feet according to another authority). In another attempt to find deep water at Seward a boring was sunk to a depth of 610 feet, where it was abandoned in a mass of "red ocher" without obtaining a flow. From a partial record furnished of this boring the diagram, fig. 8, has been drawn. The red ocher reported in this boring is probably a highly ferruginous phase of the Dakota sandstone. If this is the case, it indicates that at Seward the upper portion of the Dakota formation is too fine grained to yield a water supply. It is unfortunate that the boring was not continued to lower beds of the formation, for, as they are usually coarser, they would no doubt have furnished a water supply.

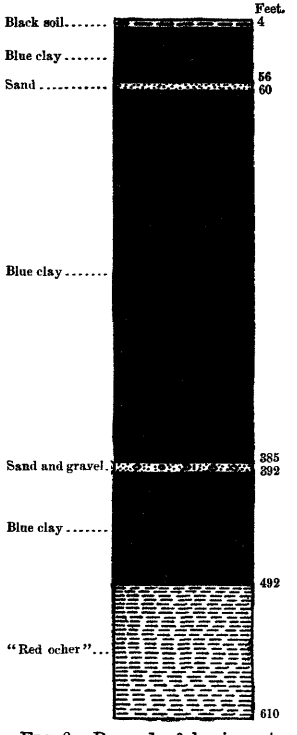


FIG. 8.—Record of boring at Seward, Nebraska.

The principal wells about Seward have a depth of about 60 feet and obtain a fair supply of water in gravels and sands. At Tamora wells average 70 feet in depth and contain about 7 feet of water; at Utica the average depth of wells is 80 feet and the water rises from 1 foot to 2 feet in them. Similar conditions prevail over the greater part of the plains region in the central and western portions of Seward County. At Goehner wells are from 82 to 100 feet deep and contain 15 feet of water. At Cordova they are 105 feet deep and contain 10 feet of water. In the valley of Big Blue River, in the central and northern portion of the county, the water level is usually somewhat less than 50 feet below the ground; at Staplehurst it is 10 to 12 feet; at Bee wells average about 50 feet deep; at Germantown, far up among the drift hills, the wells are from 30 to 50 feet deep and contain from 10 to 15 feet of water.

Through much of the drift-covered country in the eastern portion of Seward County waters are obtainable within 50 feet of the surface in beds of sand and gravel in the drift. In some cases, however, the supplies are scanty and it is necessary to sink deeper wells. The experience with these deeper wells is exceedingly variable. A few in the vicinity of Pleasantdale have been sunk to the Dakota sandstone, which usually yields a satisfactory water supply at depths of 50 to 250 feet, depending upon the altitude of the land. One boring just south of the railroad, halfway between Pleasantdale and Milford,

penetrated the Dakota sandstone for 40 feet, but found it exceedingly hard and almost dry. This, however, appears to be a very exceptional condition.

NORTHERN SALINE COUNTY.

Only the northern half of this county was included in the area examined in 1896. It is a region in greater part of plains, traversed by the North Fork of Turkey Creek, and, near its eastern margin, by Big Blue River. East of the wide alluvium and loess plain in the valley of this river rise the slopes of the hills of glacial drift which are so prominent in the adjoining county of Lancaster. The underground waters which supply the plains region are found in a sheet of sand and gravel which underlies the loess. This water-bearing stratum lies between 60 and 90 feet below ground over the greater part of the plains portion of the county, and yields water to a large number of wells. At Friend the water level is 90 feet below ground. At Dorchester the town well is 110 feet deep, and the water rises to within 98 feet of the surface of the ground.

Along the valley of Turkey Creek and Big Blue River water supplies of greater or less amount are obtained at depths mainly of 30 to 40 feet. The shallower wells at Crete have a depth of about 40 feet, with a water surface 15 feet below ground. In deep wells, sunk for larger supplies for the city, a depth of 155 feet is attained, probably to the top of the Dakota sands. The wells contain 139 feet of water, the water level being 16 feet below ground. On the slopes of the drift hills east of Blue River the waters occur in a very irregular manner. Many of the wells are between 40 and 80 feet in depth, and obtain satisfactory water supplies. Other wells have been sunk to depths of from 120 to 180 feet, notably in an area at the head of Salt Creek, 4 miles southeast of Crete.

The Dakota sandstone underlies this county at no great depth, and might be expected to furnish water supplies, but few attempts have yet been made to reach the formation, as usually sufficient water for local use has been obtained in overlying deposits.

YORK COUNTY.

The greater part of York County is underlain by formations containing large supplies of water, which are in greater part available for wells less than 100 feet in depth. In two small districts on the higher plains the depths to the waters are slightly over 100 feet. These are south of McCool and on the north side of Lincoln Creek north of Bradshaw, where the wells are from 110 to 140 feet in depth, and contain from 10 to 30 feet of water, bringing the water level not much more than 100 feet below ground.

In the depressions of Blue River and its branches and of Beaver and Lincoln creeks it is only necessary to sink from 20 to 40 or 50 feet for abundant water supplies, which come from the same water-

bearing beds as those which lie at greater depth beneath the higher lands. The greater number of wells in York have a depth of about 35 feet and contain 12 feet of water. In the higher land in the northern part of the town the waters lie about 30 feet deeper.

The following are a few representative wells of York County:

Wells in York County.

Locality.	Depth.	Depth of water in wells.
	Feet.	*Feet.*
McCool	15–25	2–5
Lushton	110	20
Charleston	80	
Henderson	94	7
Bradshaw	90–106	4
Benedict	100	15–20
Graham		
Waco town wells	120	30
Waco	102	8–10

In the wide plain between McCool and York the water surface averages about 80 feet below ground, but it presents some slight variations. The greater number of the wells are from 80 to 100 feet deep. At Lushton another bed of water-bearing material also occurs, at a depth of 65 feet. On the plains between Beaver Creek and Turkey Creek the wells are 85 feet deep, and contain 15 feet of water. At Houston the water does not rise above the gravel in which it is contained.

North of Lincoln Creek the conditions are somewhat more variable, but the greater number of wells obtain abundant supplies of water, which rises to within 80 feet of the surface of the ground. In Arborville, which is on relatively low land, the town wells are 35 to 50 feet in depth, and the water rises to within 30 feet of the surface of the ground. In the adjacent higher lands the wells are from 50 to 100 feet in depth. At Waco the water rises 4 to 5 feet above the point where first reached.

The western extremity of the Beaver Crossing artesian area extends up the lowlands in the valley of South Branch of Blue River, in the extreme eastern part of this county. There are only a few flowing wells, but they obtain a fair supply of water from depths varying from 110 to 134 feet. Ascending the river, one finds the head gradually decreasing until no flow is obtainable; descending, an increased head is found, which at its greatest is sufficient to give a flow at 10 feet above the level of the bottom land.

Some years ago an attempt was made to obtain an artesian flow just south of York, at the Russian mill, where a depth of 590 feet

was attained. It is stated that a flow was found at a depth of 530 feet, which spouted 2 feet above the top of a tube extending 14 feet above ground; but this statement could not be authenticated satisfactorily. A small flow was reported at 290 (or 390?) feet. There also appears to be uncertainty in regard to the record of the boring, but according to the most consistent statement, there was fine-grained material to 93 feet, sand and gravel from 93 to 100 feet, shale from 199 feet for a considerable depth, and sandstone at the bottom, in which the drill stuck at a depth of 590 feet. The sandstone may possibly be the Dakota formation.

A deep boring was started at McCool, but it was abandoned at a depth of 150 feet. The following record was furnished by Mr. D. C. Kims, the borer:

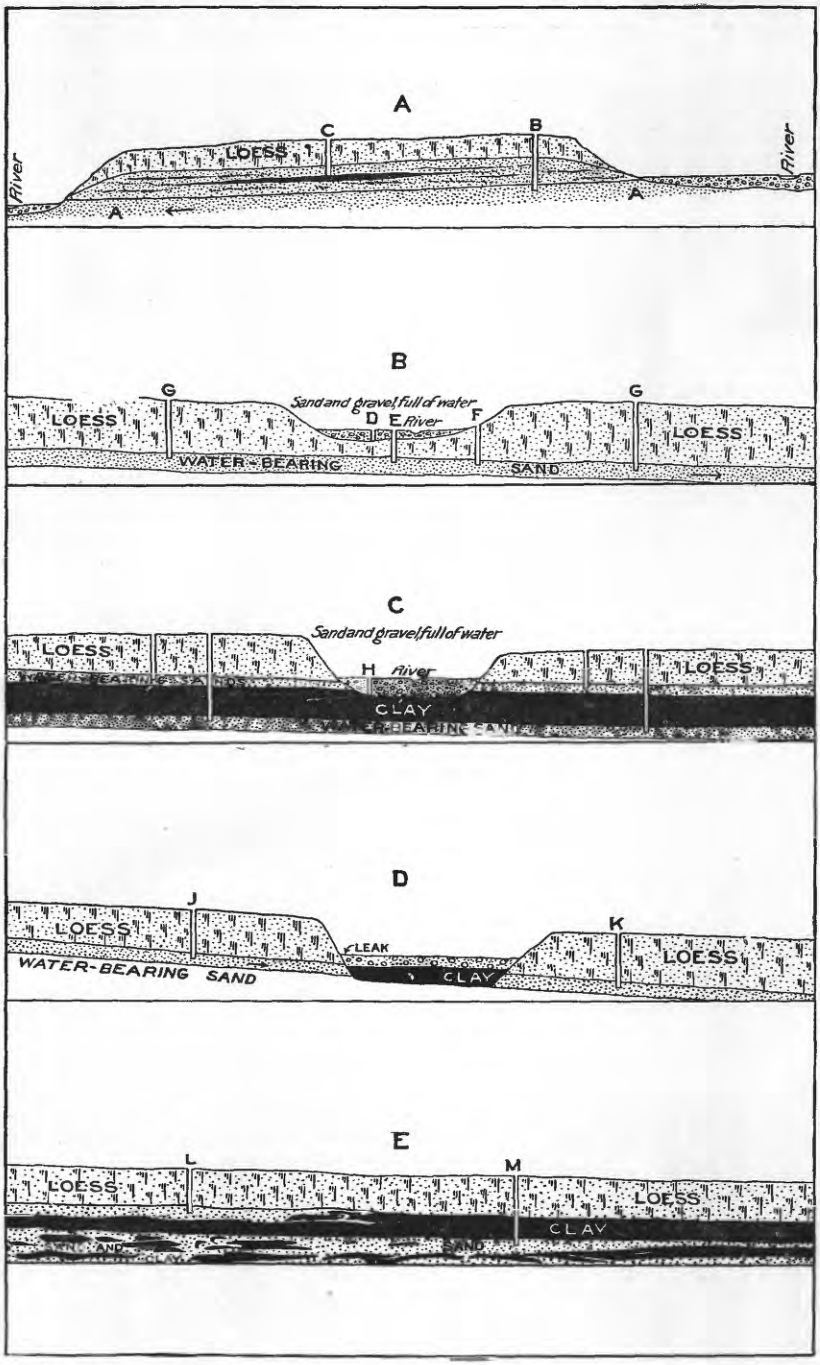
Feet.	
0– 30	Loam.
30	Water.
30– 70	Sand.
70–100	Yellow clay.
100–107	Soft white rock.
107–118	Blue sand and water.
118–150	Tough blue clay, with a 2-foot rock layer.

FILLMORE COUNTY.

In this county the conditions are very similar to those of York County. There are fewer deep valleys, and over the wide, level plains area the wells find abundant water supplies, which usually rise to within from 60 to 90 feet of the surface of the ground. Some of the wells have gone deeper to secure larger volumes of water, but the level to which the water rises is nearly constant over the area. Some representative wells are as follows:

Wells in Fillmore County.

Locality.	Depth.	Depth of water in wells.
	Feet.	*Feet.*
Fairmont	60–70	15–20
Railroad station	237	157
Geneva	120	35
Sawyer	65–75	12–20
Sutton, city supply	140	60
Saronville, town wells	80	15
Strang	80–100	15–30
Exeter	40	15
Martland	96	5
Shickley	85–100	5–10



SECTIONS ILLUSTRATING SOME SPECIAL CONDITIONS AFFECTING UNDERGROUND WATERS IN SOUTH-CENTRAL NEBRASKA.

A record of the well at the railroad station at Fairmont is given in fig. 9.

Some tubular wells in the neighborhood of Saronville are from 140 to 150 feet deep, with large volume of water. At Exeter the water-bearing beds are exceptionally near the surface of the ground.

HAMILTCN COUNTY.

This county comprises a wide area of plains, its northwest corner extending, however, part way across Platte Valley.. It is underlain by a sheet of water-bearing gravels and sands that are exposed in the deep valleys of several branches of Blue River which traverse the central and eastern portions of the county. On the plains surface lying between these valleys the water-bearing stratum is covered with loess to depths of from 50 to 80 feet. In the valley of Platte River the principal water supplies are in the alluvial gravels and sands at depths less than 25 feet.

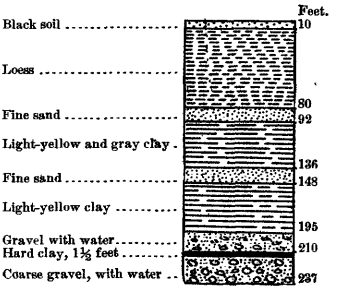


FIG. 9.—Record of deep well at Fairmont, Nebraska.

In the greater part of the plains area the water-bearing beds lie from 60 to 90 feet below ground. In a few small areas about Aurora and northwestward the water level lies deeper than 100 feet, but, so far as ascertained, good supplies are always obtainable within 125 feet of the surface, the water usually rising to within 100 to 110 feet of the surface of the ground. At Aurora the principal wells have a depth of 110 to 125 feet, with the water level 100 feet below ground. About Bromfield (Giltner post-office) the wells average from 75 to 95 feet in depth and generally contain from 6 to 15 feet of water. About Phillips the water level averages about 90 feet below ground. At Marquette the wells vary in depth from 100 to 130 feet. The town well is 130 feet deep, and the water rises to within 97 feet of the surface of the ground. In another well, 105 feet deep, the water level stands within 99 feet of the surface. At Hampton wells average from 85 to 105 feet in depth, with the water level at about 80 feet below ground. In the valley of Platte River the water level lies from 5 to 8 feet below ground in the vicinity of the river and for a mile and a half westward, beyond which for a wide area the water level seldom exceeds a depth of 15 or 20 feet below ground. In the depressions along the branches of Blue River which traverse the central and eastern portions of this county there are usually excellent water supplies to be had within 30 or 40 feet of the surface, and there is considerable running water in the stream, derived partly from the outcrops of water-bearing beds which furnish supplies of water for the moderately deep wells on the higher lands.

CLAY COUNTY.

This county lies altogether on the high plains, and wide areas of its surface have only a gentle, uniform slope toward the east. In the northern portion of the county there are broad troughs cut by branches of the South Branch of Blue River, and the southwestern corner of the county is crossed by the valley of Little Blue River. The relations of the underground waters are very simple, the water-bearing stratum consisting of gravels and sand lying beneath the loess and dipping gently eastward at a rate very little less than the slope of the plains surface. The water level is about 60 or 70 feet below ground over wide areas, and it is rarely necessary to sink a well to a depth of more than 120 feet to obtain an abundant supply. A large number of wells have a depth slightly less than 100 feet and contain from 10 to 15 feet of water. In the vicinity of Inland and Trumbull there are a few wells in which the waters lie a little deeper than 100 feet.

In the depressions of Little Blue and the branches of Big Blue rivers, waters are obtainable at depths of 20 to 40 feet in greater part. At Fairfield the wells vary from 80 to 100 feet in depth and contain large supplies of water, which rises about 10 feet above the bottom.

At Harvard the wells are generally slightly less than 100 feet deep, but a few have gone somewhat deeper to obtain larger volumes of water. At Clay Center the wells average 100 feet in depth, with the water level at about 85 feet below ground; at Inland, 120 feet, with the water level 110 feet; at Trumbull, 115 to 120 feet, with the water level 110 feet; at Glenville, 103 feet, with the water level 97 feet; at Saronville, 80 feet, with the water level 65 feet; at Sutton, 140 feet, with the water level 80 feet. At Deweese the wells average from 40 to 50 feet in depth and contain from 10 to 15 feet of water. At Edgar the wells are 88 feet deep, with 8 feet of water. At Ong the wells average 80 feet deep, with from 1 to 3 feet of water.

HALL COUNTY.

The greater part of this county lies in the valley of Platte River. In its southwestern corner there is a level area of plains country 60 to 80 feet higher, and in the northwestern corner an area of plains ridges and sand dunes, with the valley of the South Fork of Loup River beyond.

In the wide valley of Platte River the relations of the underground waters are very uniform. The supplies are large and the depth to the water surface is very slight. In the immediate vicinity of the river there is a narrow belt of country in which the water level is less than 10 feet below ground. About Grand Island and westward it lies from 15 to 20 feet deep in greater part, but in some of the lower areas it is nearer the surface of the ground. In the plains region about Doniphan and southwestward the waters lie between 60 and 100 feet

SPRING FROM DAKOTA SANDSTONE ALONG MISSOURI RIVER NEAR MOUTH OF PLATTE RIVER, SARPY COUNTY, NEBRASKA.

below ground, the depth increasing somewhat in the higher land west of Hansen. The tubular wells in this vicinity are usually sunk to a depth of 130 feet, but have the same water level as the shallower borings. In the higher ridges southwest of Cairo the wells ordinarily obtain satisfactory water supplies, but have to be sunk to a depth of 120 to 140 feet. At the waterworks in Grand Island there are thirty-six 2-inch driven wells, 54 feet deep, in which water rises to within 16 feet of the surface of the ground. There are pumped from these wells 1,000,000 gallons per day. Moderate supplies of water are found within 20 feet of the surface, but it was necessary to go considerably deeper to obtain the town supply.

About Abbott the wells are from 25 to 40 feet deep, with the water level at about 18 feet below ground. At Cairo the wells on the higher land are 60 feet deep and contain 35 feet of water.

In the Loup Valley the conditions are similar to those in the Platte Valley eastward.

ADAMS COUNTY.

The underflow from Platte River passes southeastward under Adams County through sands and gravels which present everywhere relatively uniform relations. The waters are more or less free to escape into the valley of Little Blue River, which quite deeply trenches the plains region in the southern portion of this county. The depth to the waters varies closely in relation to the altitude of the land, making due allowance, however, for the uniform slope of both the land and the water-bearing beds to the east and southeast.

In the higher portion of the plains separating the valley of Platte River from that of Little Blue River the water level lies between 100 and 125 feet beneath the surface over considerable areas, as shown in Pl. XVII. On the less elevated areas adjacent, the depths are considerably less—usually from 60 to 80 feet; while in the valley of Platte River, in the extreme northwestern corner of the county, and in the depressions of Little Blue River and its branches to the south, the waters are very near the surface of the ground. At Hastings a large supply of water for city use is obtained from seven wells sunk to a depth averaging 140 feet and containing about 20 feet of water. An attempt was made to obtain water from a deeper source (300 feet), but the 120-foot horizon was found to be the most serviceable.

Some years ago a deep boring was made at Hastings for oil or gas, which has thrown some light on the deeper underground geology of the region. A record published by W. W. Follett[1] is here reproduced in graphic form in fig. 10 (p. 38).

From another authority it was learned that the total depth was 1,346½ feet, the lower 370 feet being reported as "soft shale limestone,

[1] Report on Irrigation, 52d Cong., 1st sess., Senate, Ex. Doc. 41, Part II, Washington, 1893, Pl. XXV.

sand, and gravel, with seashells at 1,300 feet." Hard limestone 1½ feet thick was reported at 775 to 776 feet, soft limestone and shale from 776 to 801½ feet, and light shale and lime rock from 930½ to 976½ feet. The shale was stated to be hard from 250 to 500 feet and soft from 500 to 775 feet.

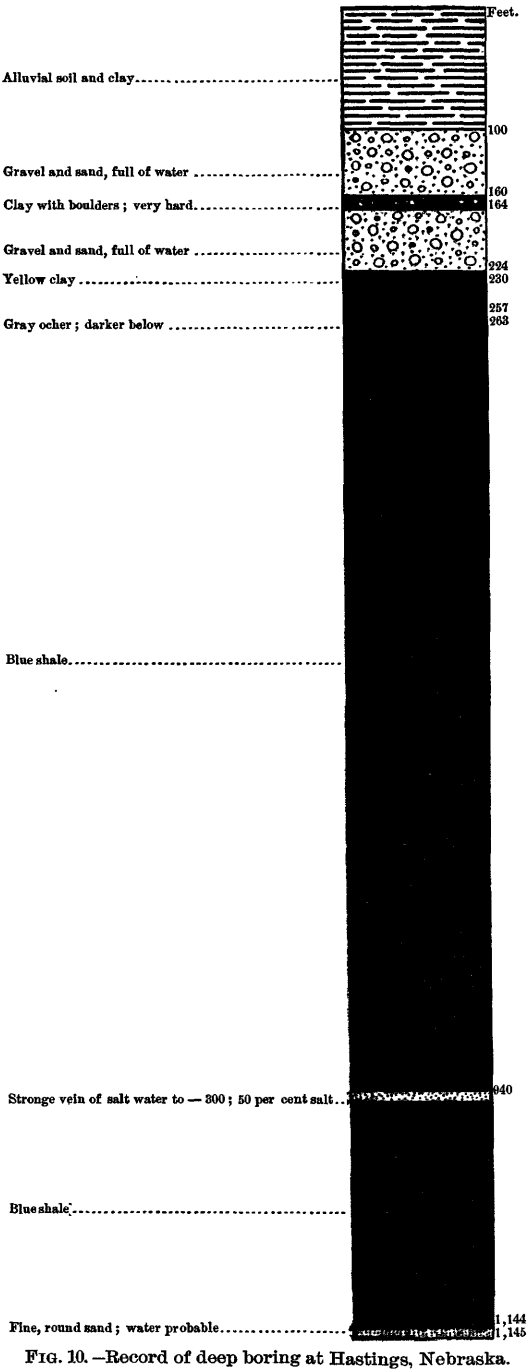
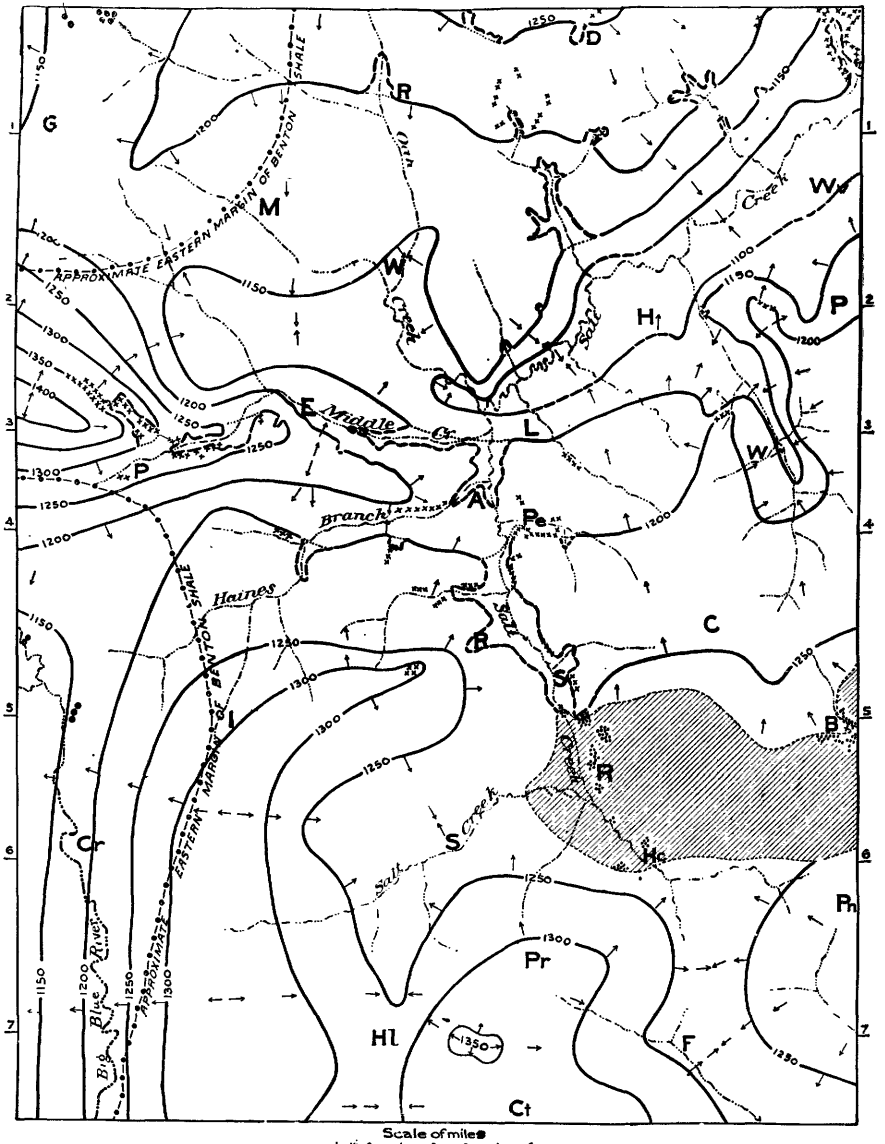


FIG. 10.—Record of deep boring at Hastings, Nebraska.

At Juniata wells are of somewhat variable depth, but they average slightly less than 100 feet and contain about 10 feet of water. At Kenesaw, wells from 90 to 115 feet deep have their water level at about 80 feet below ground. At Prosser the town well has a depth of 115 feet, with the water level 112 feet below ground, slightly deeper than in the adjoining region to the north. At Hansen the water level lies about 70 feet deep. At Roseland the wells average from 80 to 105 feet in depth, with the water level about 80 feet below ground. At Holstein the wells are 130 feet deep, and contain 25 feet of water. At Pauline wells vary from 85 to 105 feet, with the water level at from 80 to 90 feet, depending upon the proximity to Little Blue River. At Ayr a fairly satisfactory supply of water is found at a depth of 30 feet, which rises but little above the bottom of the boring, and the supply varies with the weather.



MAP SHOWING CONTOUR AND RELATIONS OF SURFACE OF DAKOTA SANDSTONE IN THE VICINITY OF LINCOLN, NEBRASKA.

The heavy black lines indicate altitudes above sea level of the surface of the Dakota sandstone. The broken lines indicate depressions cut in this surface since the Glacial period, the dotted lines showing the original configuration. The arrows point to the direction of slope. Present drainage shown by broken-and-dotted lines.

L	Lincoln.	W.	Woodlawn.	B.	Bennett	Hc.	Hickman.
E.	Emerald.	xxP.	Pleasantdale.	Pn.	Panama	A.	Asylum.
Sx.	Saltillo	Cr.	Crete.	G.	Germantown	Pe.	Penitentiary.
Wv.	Waverly.	M.	Malcomb.	Hl.	Hallam.	H.	Havelock.
Pr.	Princeton.	D.	Davey.	R.	Rokeby	P.	Prairie Home.
Ct	Cortland.	R.	Raymond.	S.	Sprague.	W.	Walton.
F	Firth.	C	Cheney.				

BUFFALO COUNTY.

Buffalo County comprises portions of the Platte and Wood River and South Fork of Loup River valleys, with wide areas of intervening high plains. The depths of the underground waters are closely related to the altitude of the land above Platte River, the water-bearing strata sloping eastward at about the same degree of inclination as the slope of the general surface. As the valley of South Fork of Loup River is somewhat lower than the bed of Platte River, and there are beds of permeable material extending under the high plains from one to the other, there is a sheet of water under Buffalo County which is probably moving toward the northeast. This sheet of water furnishes a large volume to many wells in all parts of the county. Immediately along Platte River the wells are very shallow, the water rising to within from 5 to 9 feet of the surface of the ground. This area of shallow wells widens considerably in the vicinity of Gibbon, and extends for some miles, nearly to the Union Pacific Railroad. At Gibbon the water level is within 10 feet of the surface and furnishes large supplies to wells from 25 to 35 feet in depth.

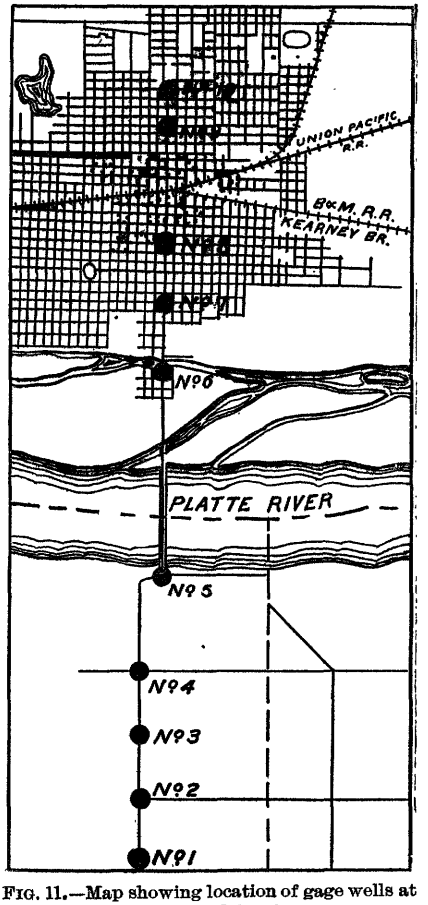


FIG. 11.—Map showing location of gage wells at Kearney, Nebraska.

Next north of this zone and occupying the remainder of the wide valley of Platte River, with an extension up the valley of Wood River, there is a wide area in which the water surface lies between 15 and 40 feet below ground, and similar conditions exist along the valley of the South Fork of Loup River. At Kearney the principal supplies of water are obtained 20 feet below ground in wells from 25 to 35 feet deep in greater part, the depth increasing somewhat and the altitude of the water surface decreasing notably from south to north across the city.

At Odessa wells are 20 feet deep; at Elm Creek 14 feet. At Riverdale, in Wood River Valley, wells 102 feet deep contain 77 feet of water, but other shallower wells in the vicinity have water at the

same level. At Amherst the water level is 25 feet below ground. At Watertown the wells are 85 feet deep. At Miller the town wells are 73½ feet deep and contain 40 feet of water. At Sartoria wells are 22 feet deep and contain 12 feet of water. At Pleasanton they are 15 feet deep. At Ravenna it is found necessary to go to a depth of 60 feet for a good flow, but the water rises to within 20 feet of the surface. Surface waters of relatively poor quality are found at a depth of 30 feet, which rise to the same level.

Over the greater part of the ridge south of the South Fork of the Loup River the water surface is generally from 100 to 150 feet below ground toward the valleys. Along the central ridge north of Amherst is a tract in which it is found necessary to go somewhat deeper, the wells having a depth of 170 to 250 feet, with the water level about 150 feet below ground. In the ridge extending northwest of Kearney between the Platte Valley and the valley of Wood River the conditions are similar to those in the land north of Wood River, and they are the same along the northern edge of the county, north of the South Fork of Loup River.

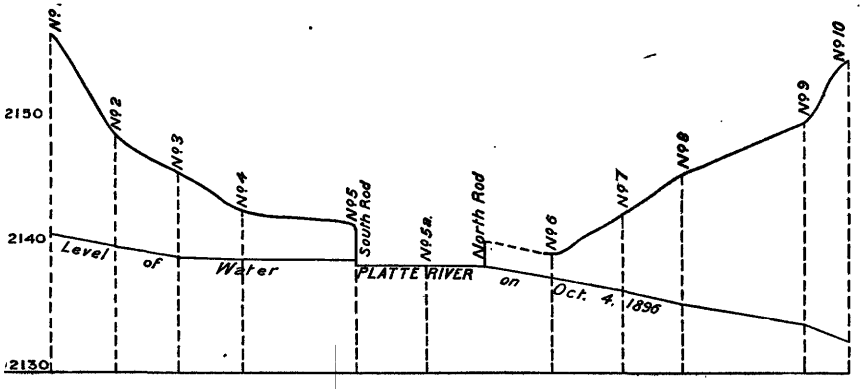
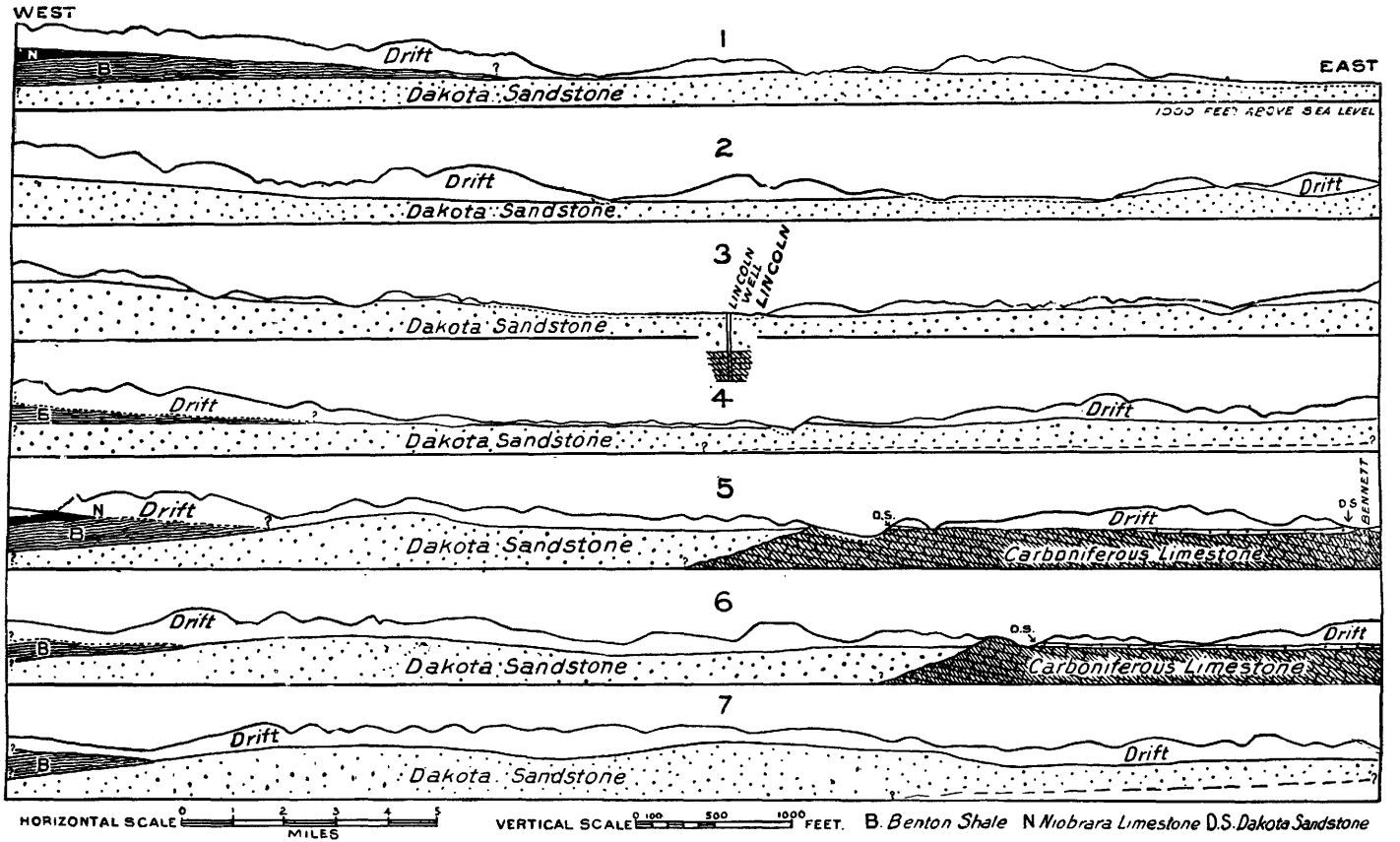


FIG. 12.—Profile of line of wells along Central avenue, Kearney, Nebraska.

GAGE WELLS AT KEARNEY.

A series of wells were sunk under the direction of Prof. O. V. P. Stout during the spring of 1896. These were located in a nearly north-south line, at distances of about one-half mile from each other. The first, or No. 1, is in the sand hills 2½ miles south of the bridge across Platte River at Kearney, on the main road. Nos. 2, 3, and 4 are successively one-half mile apart north from No. 1. No. 5 is on the south bank of the river. There is also near this a gage rod, marked in the table "S. R.," this being the southerly gage, showing the height of open water. About the middle of the bridge is a well, known as "5*a*," sunk in the low island, submerged at high water. At the north end of the bridge is the gage rod marked in the table "N. R.," about one-half mile from well No. 6, on the north side of the river. This well was tampered with and subsequently replaced, readings being begun on August 17. The remaining wells, Nos. 7, 8, 9, and 10, are



CROSS SECTIONS SHOWING RELATIONS OF DAKOTA SANDSTONE IN THE VICINITY OF LINCOLN NEBRASKA.

on Central avenue in Kearney, Nos. 9 and 10 being a short distance north of Midway Hotel. The elevations of the tops of the well casings, as determined by careful leveling, and of the zeros of the two rods, are given in the following list, referred to the Union Pacific datum:

Elevation of top of well casing; wells near Kearney.

Well.	Elevation.	Well.	Elevation.
	Feet.		*Feet.*
No. 1	2,157	No. N. R	2,137.49
No. 2	2,148.96	No. 6	2,139.50
No. 3	2,145.97	No. 7	2,142.66
No. 4	2,143.01	No. 8	2,146.31
No. 5	2,141.88	No. 9	2,149.82
No. S. R	2,137.57	No. 10	2,154.85
No. 5*a*	2,139.99		

The following table gives the reading of distance of the water surface below the top of the well casing:

Distance of water surface below top of well casing; wells near Kearney.

Date.	Day.	1.	2.	3.	4.	5.	S. R.	5*a*.	N. R.	6.	7.	8.	9.	10.
April	19	.....	9.90	7.00	3.30	2.90	.....	.....	.....	1.30	6.70	11.50	17.70	23.10
	26	.....	9.50	6.40	3.80	3.00	.....	.....	.....	.....	6.20	11.00	17.10	22.70
May	3	.....	9.10	6.10	3.10	2.90	.....	.....	.....	.....	6.50	11.40	17.60	23.10
	10	.....	9.40	6.85	3.40	3.00	.....	.....	.....	.....	6.20	11.15	17.35	22.90
	18	.....	9.26	6.45	3.10	2.85	.....	.....	.....	.....	6.55	11.80	17.10	23.50
	25	16.50	9.45	6.62	3.38	3.05	.....	.....	.....	.....	6.80	11.37	17.36	23.65
June	1	16.04	9.05	6.55	2.93	2.82	.....	.....	.....	.....	5.90	10.92	16.95	23.15
	8	16.25	9.28	6.62	3.10	3.02	.....	.....	.....	.....	6.01	11.10	17.10	23.28
	18	16.50	9.56	6.83	3.35	3.40	.....	.....	.....	.....	5.81	10.75	16.98	22.95
	23	16.55	9.60	6.90	3.45	3.50	.....	.....	.....	.....	5.89	10.80	17.10	23.20
	30	16.43	9.61	6.70	3.15	3.12	.....	.....	.....	.....	5.68	10.61	16.76	22.65
July	9	16.40	9.38	6.61	3.18	3.15	.....	.....	.....	.....	5.59	10.35	16.68	22.83
	16	16.80	9.85	7.10	3.61	3.72	.....	.....	.....	.....	6.01	10.98	17.30	23.31
Aug	12	15.39	8.65	6.36	4.09	2.76	1.11	.....	1.20	.....	6.08	10.56	16.05	22.06
	17	15.50	8.78	6.42	4.00	2.81	0.98	1.94	1.26	1.94	6.25	10.59	16.05	22.14
	22	15.43	8.75	5.81	4.02	2.92	0.89	1.70	1.09	2.15	6.11	10.94	16.08	22.13
	29	15.69	8.84	6.53	4.16	3.95	—0.52	2.49	—0.43	2.61	6.25	10.63	16.16	22.15
Sept	5	15.71	8.85	6.56	4.20	3.87	—0.17	2.52	—0.23	2.69	6.30	10.67	16.13	22.12
	12	15.75	8.89	6.60	4.24	3.96	0.84	1.57	—0.07	2.63	6.41	10.73	16.15	22.14
	19	15.80	8.94	6.65	4.18	2.75	1.07	1.39	1.23	1.95	6.27	10.76	16.21	22.22
	28	15.84	8.97	6.68	4.07	2.81	1.03	1.35	1.18	1.96	6.16	10.80	16.25	22.25
Oct	4	15.88	9.01	6.72	4.05	2.84	0.95	1.40	1.16	1.99	6.12	10.75	16.25	22.25
	11	15.91	9.05	6.76	4.05	2.81	1.01	1.49	0.79	2.13	6.15	10.79	16.29	22.29
	18	15.92	9.06	6.77	3.97	2.78	1.03	1.42	1.06	1.89	6.04	.....	16.30	22.30
	26	15.95	9.11	6.70	3.94	2.80	1.03	1.42	0.98	1.75	6.06	.....	16.33	22.33
	31	15.97	9.13	6.79	3.90	2.65	1.15	1.10	1.34	1.39	6.06	.....	16.30	22.30
Nov	8	16.00	9.18	6.74	3.82	2.54	1.82	.....	1.94	1.28	6.08	.....	16.36	22.32
	15	16.02	9.20	6.69	3.76	2.71	1.13	1.25	1.38	1.95	6.11	.....	16.38	22.36
	21	16.05	9.22	6.73	3.76	2.55	.....	.....	.....	2.04	6.08	10.85	16.41	22.39
	30	16.08	9.24	6.76	3.72	2.39	1.39	Frozen	1.58	1.82	6.13	10.76	16.45	22.47
Dec	7	16.11	9.27	6.65	3.65	2.50	1.35	.....	0.86	1.87	6.15	10.98	16.40	22.40
	13	16.13	9.29	6.57	3.59	2.52	1.29	0.98	1.45	1.55	6.06	10.80	16.42	22.39
	19	16.16	9.33	6.52	3.54	2.46	1.52	Frozen	1.51	1.75	6.00	10.82	16.45	22.40
	29	16.14	9.25	6.54	3.55	2.45	1.36	Frozen	1.53	2.00	5.98	10.77	16.41	22.43

KEARNEY COUNTY.

Kearney County extends from Platte River far southward across the divide between the Platte and Republican rivers. The greater part of its area is high, level plains, terminated northward by the Platte Valley along a zone bordered by sand hills. Little Blue River heads in the eastern part of the county and has cut a moderately deep valley north of Norman. The underground waters lie in a sheet of gravels and sand which slopes gently to the east and southeast. Under the higher land in the central and southwestern portion of the county they lie from 100 to 155 feet below ground. To the north and east the depth diminishes gradually, and in the lower lands along Platte Valley they are only a few feet below ground. At Minden the water level is 80 feet below ground, but ordinarily wells are sunk 40 or 50 feet into the water-bearing beds.

As the land rises to the southeast the underground waters lie deeper, but as the water-bearing horizon also rises gradually to the west the increase in depth does not correspond precisely with the increased altitude of the land. At Keene the water level is about 105 feet below ground, and wells are sunk to a depth of 120 to 160 feet. North of Wilcox the water level varies from 110 to 135 feet in a rather irregular manner; and to the south, as the land rises rapidly in the southwestern corner of the county, the water level is found to be considerably over 150 feet below ground. At Axtel the water level closely approximates 100 feet below ground, being a little less to the north and a little more to the south. At Norman the town wells have a depth of 100 to 125 feet, with the water level at about 95 feet below ground. About Hartwell the water level is about 65 feet deep, but is somewhat deeper than this in the village. Along the belt of sand hills the waters are obtained at various depths, but often fair supplies are yielded by moderately shallow wells. On the lower lands in the Platte Valley the waters are rarely over 45 feet below ground, the depth gradually decreasing toward the river. About Lowell the water surface is from 6 to 9 feet below ground; at Newark it averages about 8 feet, but wells ordinarily are sunk 8 or 10 feet into the water-bearing beds.

PHELPS COUNTY.

The configuration and relations in Phelps County are similar to those of Kearney County, but the flat-topped divide between the Platte and Republican valleys is a somewhat more elevated ridge. Along the southern margin of the county the land slopes toward Republican River, and in the southwestern corner of the county, which was not investigated as to its water resources, there are deep canyons which contain head waters of small lateral branches of

Republican River. The underground waters lie in a sheet of gravel and sand, which dips southeastward, but presents some local variations in the regularity of its inclination. The dip of the beds to the southeast is slightly less than the upward slope of the land southwestward, so that to the north and east the waters lie at a less depth than they do farther west. In the highest area of the plains, southwest of Holdrege, the water level lies over 200 feet below ground. The depth decreases regularly northeastward to the edge of the plains south of the valley of Platte River. In the valley of Platte River there is a narrow strip of land along the river in which the water level is less than 10 feet below ground, but southward, through the belt of sand hills to the edge of the valley, the waters lie mainly within 25 feet of the surface of the ground.

At Holdrege the city wells have a depth of 200 feet and contain 60 feet of water. The water level in the vicinity is very uniformly at 140 to 160 feet below ground. At Atlanta it is 180 feet below ground; about Sacramento it varies from 120 to 140 feet; at Funk it is 125 feet; at Axtel, 100 feet; and at Loomis, 180 to 190 feet.

DAWSON COUNTY.

The underground waters of Dawson County present a wide range of variation in their depths, from very near the surface in the immediate vicinity of Platte River to over 300 feet in the high lands in the northwestern portion of the county.

The water level corresponds quite closely in altitude with the bed of Platte River and has a similar gentle inclination to the east and southeast. The exceptional depth of the waters in the northern portion of the county is therefore mainly due to the altitude of the land above the river, but it is in some measure increased by a diminished quantity of water in the upper beds of the water-bearing series. The zone in which the water surface is less than 10 feet below ground is narrow along the south side of Platte River, but extends to and beyond the Union Pacific Railroad at some points east of Lexington, and it is unusually wide in the vicinity of Cozad. In Cozad an excellent supply of water is obtainable at depths of 6 to 8 feet below ground in wells from 20 to 30 feet deep. About Lexington the water surface is from 21 to 22 feet below ground, and wells average from 25 to 35 feet in depth. Similar conditions prevail over a wide belt extending northward to the base of the slopes which rise to the table-land lying between the valleys of Platte and the South Fork of Loup rivers, the depths gradually increasing as the land gains in latitude.

North from Cozad, where the bottom of the valley has a relatively rapid rise, there is a considerable area within the valley where the water surface is over 50 feet below ground and wells are between 100 and 120 feet deep. In the high ground lying between the valleys

of Platte and Wood rivers, and again on the north side of the valley of Wood River, the waters lie at a depth below ground in proportion to the increasing height of the land. Eastward in this region there are wells which obtain water supplies within 200 feet of the surface of the ground, but westward the water surface rises less rapidly than the land surface, and it is necessary to go considerably deeper for water supplies. In this portion of the county the greater number of wells are sunk in depressions, to avoid the necessity for sinking them to the depth necessary on the higher ridges. Wells on the higher lands are over 300 feet deep.

In the valley of Wood River the water surface lies from 25 to 35 feet below ground in greater part, and yields satisfactory supplies to many wells of moderate depth. At Sumner the principal supplies are obtained from wells 93 feet deep, in which the water surface is 25 feet below ground.

In the south-central portion of Dawson County there are abundant water supplies at moderate depth in the valley of Platte River, obtained in wells from 25 to 30 feet deep near the river and from 35 to 45 feet deep back toward the foot of the upland. Southward, on the top of the table-land, the water surface lies from 220 to 250 feet below ground in greater part, but there are a few local exceptions. The wells are mainly tubular and have depths of 222 to 285 feet.

NORTHERN GOSPER COUNTY.

The greater part of this region is an elevated plain, invaded from the south by many canyons at the heads of branches of the Republican River, and traversed northward by the wide, deep valley of Plum Creek. Its northeastern corner extends to Platte River and covers a small area along the south side of the valley of Platte River. The underground waters lie at approximately the same altitude as the bed of Platte River, with a gentle general slope to the east and southeast. The waters are in a great sheet which is probably flowing very slowly to the east, and in some measure to the south into the deep valley of Republican River. The depth to the water surface is closely related to the altitude of the land above Platte River.

Along the central area of plains constituting the divide between Plum Creek and waters draining into the Republican River the water surface lies from 180 to 280 feet below ground, the increase being quite regular to the west. About Smithfield wells have a depth of 240 feet and contain 18 feet of water; at Elwood the depth is 320 feet and the wells contain 20 feet of water. On the high lands between Plum Creek and the Platte Valley the water surface lies 150 feet below ground north of Smithfield, and between 200 and 220 feet north of Elwood and in the extreme northwestern corner of the county. Along Plum Creek, waters are usually obtained within 150 feet of the surface in the western part of the county, and within 50 feet of the surface in

the eastern part of the county, the rate of decrease being fairly regular as the valley is descended. In the valley of Platte River, in the northeastern corner of the county, the water surface lies within 6 feet of the ground surface immediately adjoining the river, and within from 20 to 30 feet toward the foot of the highlands.

PROSPECTS FOR DEEPER-SEATED WATERS.

Although a number of deep borings have been made in the central and western portions of the area to which this report pertains, they appear not to have gone to a depth sufficient to reach the formations in which water supplies might be expected. A boring at Kearney attained a depth stated to be 2,460 feet, where it was discontinued, far down in the Pierre shale. One at Hastings reached a depth of 1,145 feet; one at Dannebrog a depth of 1,000 feet; one at York, 590 feet; and one at Seward was bored to a depth of 610 feet. At the latter place the Dakota sandstone appears to have been penetrated, but it did not yield a flow. In the other borings this formation was not reached.

In South Dakota the Dakota sandstone carries a very large volume of excellent water under high pressure which is available over a wide area in the eastern part of the State and in the depressions of the Missouri and confluent valleys. This water passes into the formations along the foothills of the Black Hills and the Rocky Mountains at altitudes of from 3,000 to 5,000 feet, and has a great pressure and high head in the eastern part of South Dakota. This pressure and head diminishes gradually toward the southeast, and finally in the extreme corner of the State flowing water can not be obtained. This is due to the fact that the formation reaches the surface along Big Sioux River and the Missouri River below Vermilion, so that the waters are free to escape and thus lose their volume and pressure. Precisely the same conditions are found in the northeastern corner of Nebraska, and it is reasonable to believe that they may be found to be essentially the same over a wide area in central Nebraska, especially on the lower plains and along such valleys as the Platte, where the land is not elevated much higher than in the eastern part of South Dakota.

The Dakota sandstones outcrop in Lancaster and adjoining counties, where they are free to lose their water, and this is also the case with the upper members of the Carboniferous formations which outcrop extensively in the counties east and southeast of Lancaster. In this area the Dakota sandstone is seen to be full of water in hundreds of wells which have been sunk in it, and from its outcrops flow innumerable springs, which do much toward filling the small streams of Lancaster County. These waters are in all probability largely derived from an intake zone along the western outcrops, and it is believed that much of the water passes under the entire length of the State of Nebraska, as shown in Pl. IV, to the wells and springs which

extend along a zone of outcrop of Dakota sandstone in Lancaster, Gage, Saunders, Dodge, Burt, Thurston, and Dakota counties. A typical spring in this belt is shown in Pl. XIX. Of course these waters have but very slight head in Lancaster County, but they nearly all rise at least a few feet in the wells which are sunk to them. Westward, however, away from the zone of leakage, we should expect the pressure to gradually increase, as it does to the north and west in South Dakota. Whether the increase would be at a sufficiently rapid rate to give flows at the surface in the central and western portion of the area to which this report relates can not be predicted from our present means of calculation.

In the following diagram I have introduced a sketch of a piece of physical apparatus which illustrates the increase of head away from the leak toward the source of pressure, representing closely the relations which appear in the South Dakota artesian basin, and probably in a measure also those of central and eastern Nebraska. It will be seen that the gradient is a relatively rapid one, but we must bear in

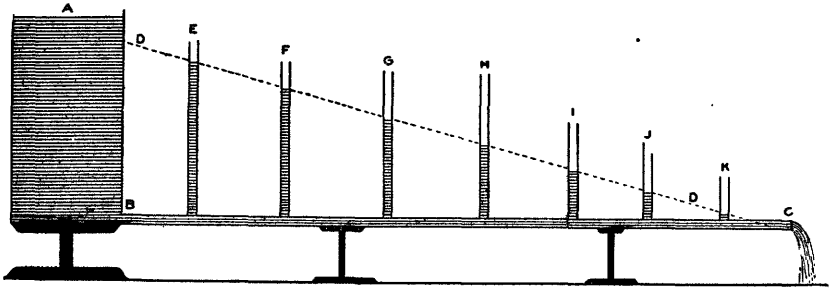


FIG. 13.—Diagram of apparatus for illustrating the declivity of head of liquids flowing from a reservoir.

mind that the distance from eastern Nebraska to the Rocky Mountains is very great and much of the intervening land slopes up to a fairly high altitude. There is another condition which may be adverse. The Dakota sandstone is exceedingly variable in physical character. In Lancaster County and in the belt extending northward to the Missouri River at Dakota City the sandstone is porous, clay is not predominant, and the conditions are favorable for the transmission of large water supplies. It may be that westward the formation becomes finer grained over a greater or less area in such manner as to choke out water. Of this, however, there is no definite evidence. In the outcrops in Jefferson County there is considerable clay admixture, but many of the beds are sufficiently porous to carry the water. The outcrops are found far westward in Kansas, not far south of the Nebraska boundary, and they appear to be coarse and suitable for bearing water.

In the next underlying formation, the Carboniferous limestones, flowing water has been obtained in considerable volume in the wells at

Lincoln, but it is so salty that the wells are more likely to prove useful as sources of salt supply than for anything else. It is probable, however, that this saline water is of relatively local occurrence, occupying a basin under eastern Nebraska, and that farther westward the waters in the Carboniferous formation may be perfectly fresh, or at least only slightly mineralized. It would hardly be safe to offer this as a prediction, but it is worth bearing in mind as as a possibility. At Omaha, northward in Dakota, and eastward in Iowa excellent waters are obtained from Carboniferous limestone. It is therefore desirable to point out the advisability of sinking deep wells in the region west of Seward and Saline counties to test, in the first place, the water resources of the Dakota sandstone, and if these are inadequate, to drill deeper to the underlying formations. The depth to which it would be necessary to go can not be definitely calculated from data now on hand. At Kearney the Pierre shales were reported to extend from a depth of 71 feet to 2,460 feet, the bottom of the boring; but it is believed that the top of the Dakota formation was not far below. Eastward the thickness of Cretaceous shales diminishes gradually as the Dakota and underlying formations rise toward the surface and the land decreases in altitude. Some of these relations are further illustrated in Pl. IV.

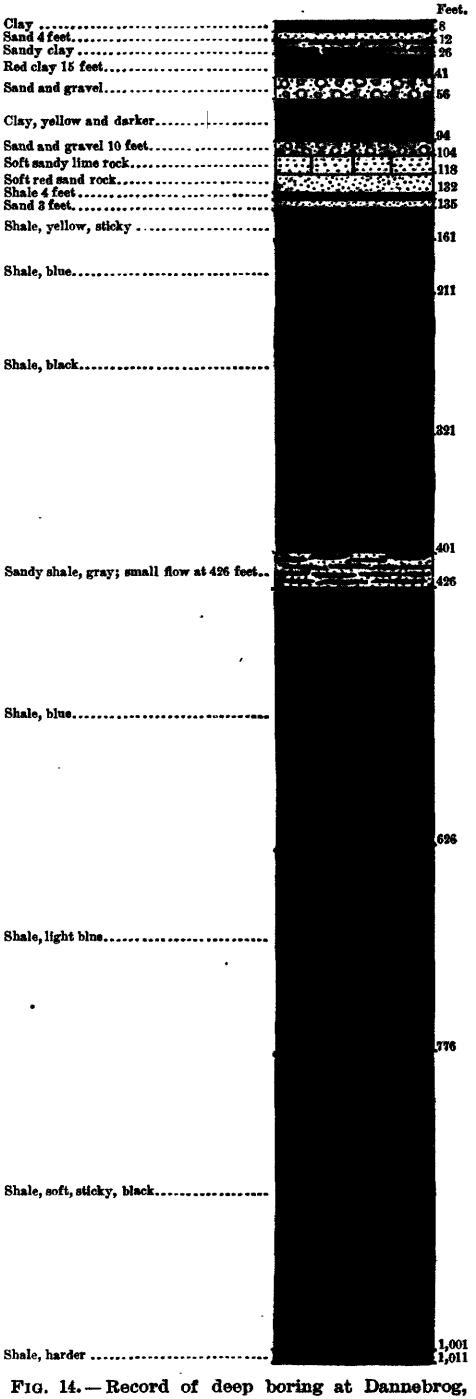


FIG. 14.—Record of deep boring at Dannebrog, Howard County, Nebraska.

Owing to the difficulty of sinking a boring in the overlying clays of the Cretaceous formations, expert well drilling will be necessary, and borings should be very large at the top. The experiments will be expensive, but it is hoped that at some such point as Grand Island, Hastings, Kearney, or North Platte an attempt will eventually be made to ascertain the resources of the Dakota sandstone and, if necessary, the underlying formations.

IRRIGATION BY UNDERGROUND WATERS.

At many points in this region the underground waters have been employed for irrigation. In the Beaver Crossing area the artesian flows have been used, but elsewhere the supply has to be lifted to the surface with windmills. In greater part the irrigated areas have been only a very few acres or a garden. Under most of the region there are ample supplies of water for extensive irrigation, but with windmill pumping it usually has not been found practicable to irrigate properly over 10 to 15 acres from one mill. When the waters lie over 75 or 100 feet below ground the amount available is less, for the efficiency of pumping rapidly decreases beyond a moderate depth. Very few irrigators regard artificial watering as profitable for large field crops of low market value, but for small, diversified crops for family subsistence and local sale, and some special crops, such as potatoes, pump irrigation is certain to be appreciated as a necessity in dry seasons and a useful adjunct even in the more rainy ones.

In traveling over the area to which this report relates an endeavor was made to obtain some data in regard to the methods and results of farm well irrigation in the various counties. Information was also gathered in regard to irrigation in the Beaver Crossing artesian basin. The results of these inquiries are set forth in the following pages.

LANCASTER COUNTY.

In this county there is considerable irrigation in a small way, mainly of garden areas. Some experiences of irrigators are as follows:

Mr. H. G. Weber, gardener, west of Lincoln, irrigates garden truck, including onions, radishes, lettuce, spinach, asparagus, pieplant, eggplant, pepper, cabbage, tomatoes, cucumbers, celery, and other vegetables. His well is 60 feet deep, but the water rises to within 26 feet of the surface. The pump has a 3-by-10 cylinder. The reservoir is on the highest land and has a capacity of 1,000 barrels. In a good wind the pump supplies 10 to 12 barrels per hour. Mr. Weber states that, although his plant is small, the results have been very satisfactory.

Mr. E. H. Cushman, near Lincoln, states that he has been irrigating a market garden for two years. He has a 12-foot aermotor windmill, which runs a pump with 6-inch cylinder and a 12-inch stroke, raising about 2 gallons of water to the stroke. The well is about 32 feet deep, with approximately 14 feet of water, in large supply. The reser-

voir is 50 by 100 feet and 4 feet deep. Can irrigate 10 acres. Has also built a "Jumbo" mill to run two pumps with 3-inch cylinders, 12-inch stroke.

Mr. E. E. Smith, near Lincoln, irrigates 5 acres, mainly of garden truck. He has a well 25 feet deep, containing 12 feet of water. His reservoir is 50 feet square. Water is pumped with a 5-foot aermotor.

SEWARD COUNTY.

In the artesian area along Blue River, in the vicinity of Beaver Crossing, the waters have been used by a number of farmers for irrigation of small areas. The results have been very satisfactory, and the disposition to introduce irrigation in this area is growing in a most encouraging manner. Only a few facts have been obtained in regard to irrigation plants and results.

Mr. J. T. Godding has a well which is 105 feet deep, 3 inches in diameter, and yields 125 gallons per minute, which will rise to 25 feet above the surface. He irrigates, with good results, a field 40 rods square, which is flooded directly from the wells.

M. M. Martson, near Beaver Crossing, irrigates 10 acres with artesian waters in dry seasons. He has a 3-inch well, 100 feet deep, and the water rises 20 feet above ground. The reservoir is 2 rods wide by 40 rods long and 8 feet deep.

Messrs. Horney and Evans have two flowing wells, with water at depths of 90 to 100 feet, which rises 15 feet above ground. They are 3 inches in diameter and flow 100 gallons each per minute. In dry seasons they irrigate potatoes.

Mr. Thomas Wilson, near Beaver Crossing, has a 4-inch flowing well, 125 feet deep. The water rises 5 feet above ground. His reservoir is 40 by 60 feet. Three acres of potatoes irrigated in 1896 yielded twice the product obtained from adjoining fields not irrigated.

Mr. Thomas Trilzman, near Beaver Crossing, irrigates from a flowing well. His reservoir is 100 by 50 feet and 6 feet deep. His corn yielded 85 bushels and prairie grass 2 tons per acre. Sugar beets were found to be greatly benefited by the water.

Mr. F. M. Dimery, near Beaver Crossing, has nine flowing wells on his farm, of which the average depth is 100 feet. Four of them are 3-inch pipe, and flow about 150 gallons per minute. Two of the wells have been used for irrigating 60 acres of land direct from the wells in small ditches made with a plow. Mr. Dimery has also irrigated a 2-acre garden and 6 acres of meadow.

On the Fountain Head Experimental Farm, near Beaver Crossing, Mr. T. C. Ferguson has irrigated extensively by artesian waters.

Mr. J. W. Arasmith has wells near Beaver Crossing, and a half-acre reservoir with 4-foot banks, but has not as yet irrigated.

Mr. M. Powell irrigates a small area of bottom land from his flowing well.

FILLMORE COUNTY.

Mr. J. H. Little, near Fairmont, has irrigated to some extent. He has two bored wells, 70 feet deep. His pumps are 8½ by 16 inch cylinders, and 1½-inch pipe is used. A 12-foot windmill works both pumps, yielding from 10 to 20 barrels per hour. He irrigates 5 acres of orchard in the autumn and winter, and estimates that the yield was about doubled by irrigation. His reservoir is 30 by 150 feet.

YORK COUNTY.

Mr. L. D. Stilson, near York, is irrigating from two small ponds. One is 25 by 40 feet, carrying 30 inches of water, supplied from the overflow of house well, 40 feet deep, pumped by windmill. The overflow is used for lawn and shrubbery. The other pond is 40 by 100 feet and contains 4 feet of water, supplied by a 4-inch pump with windmill from a well 40 feet deep. During January and February he pumped water directly onto a little more than an acre of strawberries, with very satisfactory results. He is planning to put in a third pond, 75 by 200 feet, pumping the water 75 feet, to supply apple, peach, and cherry orchards.

Mr. F. E. Porter, at McCool Junction, has irrigated from a pond 70 feet in diameter, 5 feet deep, and capacity of 4,000 barrels. He employs a 12-foot Eclipse mill, with 5-inch cylinder, which pumps 1,000 barrels in twenty-four hours, in a good, steady wind. He employs hose of 10-ounce oiled ducking for distribution of water. His results in irrigation of garden truck have been most satisfactory. Many other persons irrigate small truck patches with ordinary windmill pump.

HAMILTON COUNTY.

Mr. G. L. Cushman, near Chapman, is irrigating with considerable success. He employs a Dempster vaneless 16-foot mill, with 8-inch cylinder and pipe. It is 32 feet from surface to bottom of screen, and the water level can not be pumped down. The reservoir is 110 feet in diameter, and is located on a portion of the land which is slightly higher than the adjacent fields. His ditches are dug, with banks of the excavated material. Potatoes have been the crop, but the plant as it now stands will hardly supply water enough for 5 acres in dry seasons. Irrigation was found to increase the crop to a very notable degree, but no precise figures are offered.

BUFFALO COUNTY.

Mr. Joseph Buck, near Shelton, irrigated about 1 acre of potatoes in 1895. His well is 25 feet deep, and with his present pumping arrangements yields about 150 gallons per minute in a fair wind. The supply appears to be inexhaustible. His reservoir is one-half acre in size.

Mr. W. K. Wright, near Gibbon, irrigates from a reservoir 1 acre in area, with banks about 5 feet high on the outside. The water supply is from two 12-inch pumps operated by two 16-foot windmills, each pump delivering about 130 gallons per minute in a fair wind. The water level is 10½ feet below the surface. One of the pumps draws the water from eight 3-inch pipes radiating from a chamber which fastens to the bottom of the cylinder. Each of the radiating pipes is 4 feet long, the outer ends connecting with elbows to perpendicular pipes with gauze points driven 12 feet into the water. The other pump is supplied from an open well 54 feet deep, 16 inches in diameter, with 700 three-quarter inch auger holes, covered with gauze, near the bottom. The largest volume of water is in gravel 18 feet thick, beginning 10½ feet below the surface. Below this the water contained too much quicksand. Mr. Wright has found that flooding the land in the autumn and winter is very beneficial to the crops of the ensuing season. In 1895, 20 acres of corn were irrigated once, at earing time, with the gratifying result of doubling the crop over that of adjoining nonirrigated lands. He has raised 150 bushels of potatoes per acre. His main ditches are 2½ to 4 feet wide, according to the slope of the ground. The land does not carry water well for long distances. He thinks he can depend on irrigating 25 acres, with water to spare some seasons for the further irrigation of from 15 to 20 acres more.

Mr. R. M. Jones, near Elm Creek, irrigates with a Dempster mill, 16-foot wheel, pumping from eight 3-inch points driven from the bottom of a hole 8 feet deep, 11 feet in diameter, into water-bearing gravels below. He has been able to wet about 25 to 30 acres by running the water out over the frozen ground. Corn, wheat, barley, and oats yielded very fine crops, which, however, were seriously damaged by hail before harvesting.

DAWSON COUNTY.

Along the valley of the Platte in this county irrigation from shallow wells by windmills has been practiced at several localities. Information could be procured from only a few of the irrigators. The following statements are representative:

Mr. G. Malchow, near Lexington, irrigates from a 20-foot well with pumping outfit and reservoir situated on a low knoll, which is about 8 feet higher than adjoining portions of the farm. The pump consists of an 8-inch pipe, 20 feet long, with two laterals, 2 inches in diameter, driven down 19 feet deep into the water-bearing beds. The first water is 21 feet from the top of the knoll, in a bed of gravel 2 feet thick, underlain by 10 to 12 inches of clay and sand, below which are other water-bearing gravels. The reservoir is 6 feet deep, 150 feet long, and 100 feet wide. In 1895 the wind had sufficient force to keep this reservoir about full from March to the 1st of July. Two acres were planted in potatoes and 1 acre in a variety of garden truck,

including lettuce, onions, beets, carrots, cabbage, etc. The water was turned into these fields about twice a week, and the products were large and fine. Owing to lack of market, however, the operation was not a profitable one. In the middle of June, Mr. Malchow irrigated 2 acres of potatoes, and these yielded, on harvesting, about 100 bushels to the acre. Potatoes in the adjoining fields not irrigated made practically no crop at all. There were also irrigated 2 acres of oats, which made 40 bushels to the acre, while other oats in the vicinity made only 10 bushels. By comparing results with neighbors who apply the water direct from the wells, it was found that storage in reservoirs is very necessary, both to gain sufficient volume for irrigation and to allow the water to acquire the proper temperature.

Mr. G. Ballmer, near Gothenburg, has a Dempster irrigation outfit, consisting of 8-inch pump, 30-foot tower, and 16-foot open wheel. The well is 40 feet deep, 8 feet wide, and has six 2-inch pipes 29 feet long, with sand points which are driven down into the gravel. They connect in the bottom of the well with an 8-inch cylinder. He estimates that by running the pump continuously he could irrigate 20 to 30 acres. His reservoir is 60 by 200 feet, with banks about 4 feet high. At present he is irrigating only in a small way—fruit trees, truck patch, a few acres of potatoes, and 5 acres of corn.

Mr. Alex. I. Johnson, near Lexington, makes the following statement: He has an 8-inch pump with six 2-inch pipes attached. The water level is 14 feet below the surface and the supply is very large. With a 10-inch stroke his mill pumps about 100 gallons per minute. The reservoir is 100 feet long by 60 wide, and holds water sufficient for about 2 acres at a time. From this plant he has irrigated from 10 to 12 acres, which have yielded good crops during seasons when the crops failed completely on nonirrigated land. His potatoes have yielded 110 bushels, corn 40 bushels, while in nonirrigated areas only 15 bushels were obtained last season.

Mr. L. A. Lewis, near Cozad, gives the following particulars in regard to his irrigation operations: His well is 20 feet by 8 feet, with six sand points driven 10 feet below and connected with an 8-inch cylinder. The water level is 22 feet below the surface. His windmill is 16 feet in diameter and has a 10-inch stroke. He believes that with a sufficiently large reservoir, in a moderately windy season, he could irrigate from 50 to 60 acres. He has not, however, built a reservoir. During the last two seasons he has raised potatoes, onions, and other vegetables. In the season of 1896 he raised 250 bushels of onions on 30 square rods. His potatoes yielded 250 bushels per acre in 1895. On adjoining fields not irrigated the potato crop was practically nothing. He realizes the necessity of having a reservoir to furnish the water in sufficient volume and at the proper temperature.

Mr. Oliver Miller, near Cozad, has a plant to irrigate about 5 acres in the Platte Valley. His well is 45 feet deep and contains the usual

large water supply. His windmill raises about 25 gallons per minute under a favorable wind. The reservoir is 5 rods square and holds 4 feet of water. His crops have been potatoes and garden truck, of which the yield is about doubled by irrigation.

Mr. A. F. Velt, near Lexington, irrigates from 10 to 15 acres in dry seasons. His well is 62 feet deep and the windmill a 16-foot Dempster. The reservoir, 60 by 100 feet in area and 4 feet deep, can be filled in about four days with a 6-inch stroke. Mr. Velt reports very satisfactory results with potatoes, onions, cabbage, corn, and miscellaneous garden truck.

INDEX.

1895.

Sixteenth Annual Report of the United States Geological Survey, 1894–95, Part II, Papers of an economic character, 1895, octavo, 598 pp.

Contains a paper on the public lands and their water supply, by F. H. Newell, illustrated by a large map showing the relative extent and location of the vacant public lands; also a report on the water resources of a portion of the Great Plains, by Robert Hay.

A geological reconnoissance of northwestern Wyoming, by George H. Eldridge, 1894; octavo, 72 pp. Bulletin No. 119 of the United States Geological Survey; price, 10 cents.

Contains a description of the geologic structure of portions of the Big Horn Range and Big Horn Basin, especially with reference to the coal fields, and remarks upon the water supply and agricultural possibilities.

Report of progress of the division of hydrography for the calendar year 1893–94, by F. H. Newell, 1895; octavo, 176 pp. Bulletin No. 131 of the United States Geological Survey; price, 15 cents.

Contains results of stream measurements at various points, mainly within the arid region, and records of wells in a number of counties in western Nebraska, western Kansas, and eastern Colorado.

1896.

Seventeenth Annual Report of the United States Geological Survey, 1895–96, Part II, Economic geology and hydrography, 1896; octavo, 864 pp.

Contains papers on "The underground water of the Arkansas Valley in eastern Colorado," by G. K. Gilbert; "The water resources of Illinois," by Frank Leverett; and "Preliminary report on the artesian waters of a portion of the Dakotas," by N. H. Darton.

Artesian-well prospects in the Atlantic Coastal Plain region, by N. H. Darton, 1896; octavo, 230 pp., 19 plates. Bulletin No. 138 of the United States Geological Survey; price, 20 cents.

Gives a description of the geologic conditions of the coastal region from Long Island, N. Y., to Georgia, and contains data relating to many of the deep wells.

Report of progress of the division of hydrography for the calendar year 1895, by F. H. Newell, hydrographer in charge, 1896; octavo, 356 pp. Bulletin No. 140 of the United States Geological Survey; price, 25 cents.

Contains a description of the instruments and methods employed in measuring streams and the results of hydrographic investigations in various parts of the United States.

1897.

Eighteenth Annual Report of the United States Geological Survey, 1896–97, Part IV, Hydrography, 1897; octavo, 756 pp.

Contains a "Report of progress of stream measurements for the calendar year 1896," by Arthur P. Davis; "The water resources of Indiana and Ohio," by Frank Leverett; "New developments in well boring and irrigation in South Dakota," by N. H. Darton; and "Reservoirs for irrigation," by J. D. Schuyler.

Water Supply and Irrigation Papers.

This series of papers is designed to present in pamphlet form the results of stream measurements and of special investigations. A list of these, with other information, is given on the outside (or fourth) page of this cover.

Survey bulletins can be obtained only by prepayment of cost, as noted above. Postage stamps, checks, and drafts can not be accepted. Money should be transmitted by postal money order or express order, made payable to the Director of the United States Geological Survey. Correspondence relating to the publications of the Survey should be addressed to **The Director, United States Geological Survey, Washington, D. C.**

WATER-SUPPLY AND IRRIGATION PAPERS.

1. Pumping water for irrigation, by Herbert M. Wilson, 1896.
2. Irrigation near Phœnix, Arizona, by Arthur P. Davis, 1897.
3. Sewage irrigation, by George W. Rafter, 1897.
4. A reconnoissance in southeastern Washington, by Israel C. Russell, 1897.
5. Irrigation practice on the Great Plains, by E. B. Cowgill, 1897.
6. Underground waters of southwestern Kansas, by Erasmus Haworth, 1897.
7. Seepage waters of northern Utah, by Samuel Fortier, 1897.
8. Windmills for irrigation, by E. C. Murphy, 1897.
9. Irrigation near Greeley, Colorado, by David Boyd, 1897.
10. Irrigation in Mesilla Valley, New Mexico, by F. C. Barker, 1898.
11. River heights for 1896, by Arthur P. Davis, 1897.
12. Water resources of southeastern Nebraska, by Nelson Horatio Darton, 1898.
13. Irrigation systems in Texas by W. F. Hutson, 1898.
15. Operations at river stations, 1897, Part I, 1898.
16. Operations at river stations, 1897, Part II, 1898.

In press:

14. New tests of certain pumps and water lifts used in irrigation, by O. P. Hood, 1898.

In addition to the above, there are in various stages of preparation other papers relating to the measurement of streams, the storage of water, the amount available from underground sources, the efficiency of windmills, the cost of pumping, and other details relating to the methods of utilizing the water resources of the country. Provision has been made for printing these by the following clause in the sundry civil act making appropriations for the year 1896–97:

Provided, That hereafter the reports of the Geological Survey in relation to the gauging of streams and to the methods of utilizing the water resources may be printed in octavo form, not to exceed 100 pages in length and 5,000 copies in number; 1,000 copies of which shall be for the official use of the Geological Survey, 1,500 copies shall be delivered to the Senate, and 2,500 copies shall be delivered to the House of Representatives, for distribution. [Approved June 11, 1896; Stat. L., vol. 29, p. 453.]

The maximum number of copies available for the use of the Geological Survey is 1,000. This quantity falls far short of the demand, so that it is impossible to supply all requests. Attempts are made to send these pamphlets to persons who have rendered assistance in their preparation through replies to schedules, or who have furnished data. Requests made for a certain paper and stating a reason for asking for it are granted whenever practicable, but it is impossible to comply with general demands, such as to have all of the series sent indiscriminately.

Application for these papers should be made either to Members of Congress or to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
Washington, D. C.