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Water-Bearing Formations of Nebraska

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WATER-BEARING FORMATIONS OF NEBRASKA

By

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This report has been written primarily for the well drillers of Nebraska in the hope of assisting them in their important service. It is to be followed as soon as possible by a bulletin on the groundwater resources of the state.

The Nebraska well drillers are quite conversant with the formations drilled in their respective areas and have some acquaintance with the geology of the state as a whole. This is as it should be, because a knowledge of the materials of the land and their conditions of occurrence is necessary for successful well-making.

There are many water-bearing horizons in our state. Their distribution is far from uniform, there being places with little or no groundwater, and other places with vast quantities of it. In some areas, the water horizons are shallow and in others deep. Their exact occurrence must be known to the drillers, largely from experience.

The well drillers explore the water-bearing formations. The knowledge and experience accumulated by them is a valuable contribution to the state. It results in wells better suited to the needs, and in sanitary well water supplies.

The Geological and Water surveys study the geology and the groundwater resources of the state. They receive valuable data from the water well drillers and try to serve the latter in the solution of problems that arise in the location of wells, the types of wells, and the improvement of water supplies generally. The close cooperation that exists between the surveys and the drillers also results beneficially to the state.

It is not the purpose of this paper to describe the topography, geology, and geography of Nebraska, because the drillers have heard and read much on these subjects in connection with their state conventions and short courses. Rather, it seems more appropriate here to review the water horizons, as such, with only sufficient discussion of the geology and physical features as may be necessary to develop the subject.

Those who are to read this paper know how the rainfall enters the ground, how it passes to underground storage, how it moves in the aquifers, and how it is released through wells or by springs. They know, too, that there are impervious strata such as shales and clays, and pervious beds, as sands, sandstones, and some limestones, and that the quality of water and its rate of delivery in wells depend upon the nature of the formation in which it occurs.

Much of the groundwater of the state occurs in the mantlerock which is the unconsolidated surface deposits, such as alluvium, dunesand, loess, glacial drift, and glacio-fluvial sands and gravels. The areal distribution of these deposits is shown by Plate I.

Beneath the mantlerock are many more or less consolidated beds which are known collectively as the bedrock. In parts of the state where there is little or no mantlerock water, drilling is carried into the bedrock formations, the distribution of which is shown by Plate II.

Explanation of Plate I. This plate shows the surface distribution of the leading kinds of mantlerock in Nebraska, also where the bedrock is exposed. The regions designated by the letters A to F inclusive are the western tablelands and those shown by G, H, and J are the northern tablelands. In addition, there are many small bedrock outcrops in the valley-sides in other parts of the state. The tableland regions are covered with little or no mantlerock.

The surface of the state is occupied by relatively large areas of unconsolidated mantlerock which are shown on Plate I by the figures 1 to 6. Much of the loess-covered area (2), except its extreme southwestern part, is underlain by two thick sand and gravel deposits, known as the *Holdrege* and *Grand Island* sands, which outcrop at places along the borders of the Republican, Little Blue, Big Blue, Platte, and Loup valleys. These deposits, which carry much groundwater, underlie the middle course of the Platte Valley and reach westward for a considerable distance under the sandhills and at places onto the hard lands designated as G, H. I, and J. They thin out south of the Republican in Nuckolls, Webster, Franklin, and Harlan counties.

The sandhill areas, shown by Plate I are occupied at the surface by dunesand and other sandy materials. The alluvial lands vary greatly from silt to sand and gravel. In places along the larger valleys, as the Platte, Loup, and Republican, there are alluvial terraces capped with loess. In general, the alluvial valley-fills vary in texture according to the source of the materials comprising them, whether fine or coarse. The alluvium becomes coarser, as a rule, with increased depth. Our state is noted for its broad alluvial valleys of which the Platte is best known.

The location of the so-called drift lands of the state is shown on Plate I by the figures 4 and 5. The term "drift", as here used, applies to the deposits made by glaciers, either by the ice sheets or by streams emerging from them. The 100 feet or more of drift in Nebraska includes two fairly persistent sand and gravel sheets and two boulder clay deposits which are called *till* sheets. The latter were formed by the glaciers and the associated deposits of sand and gravel were formed by running water.

The mantlerock formations are now discussed briefly.

ORIGIN OF THE MANTLEROCK FORMATIONS

Glaciers, running water, and wind were the agencies that formed the mantlerock. They derived the sediments largely from bedrock locally, and from areas outside Nebraska, and modified them into the present land forms. It has taken many years of study to determine the origin of these deposits, the story of which is about as follows:

First. An ice sheet, called the *Nebraskan,* formed in Canada and moved southward to and across eastern Nebraska and across the states farther east. It eroded the country to the north and northeast of our state, ground the softer rock debris to clay, silt, and sand and deposited these materials and boulders as the *Nebraskan* till sheet 50 to 100 feet thick in the eastern part of Nebraska and to variable thickness in northeastern Kansas, northern Missouri, Iowa, and some other states to the east.

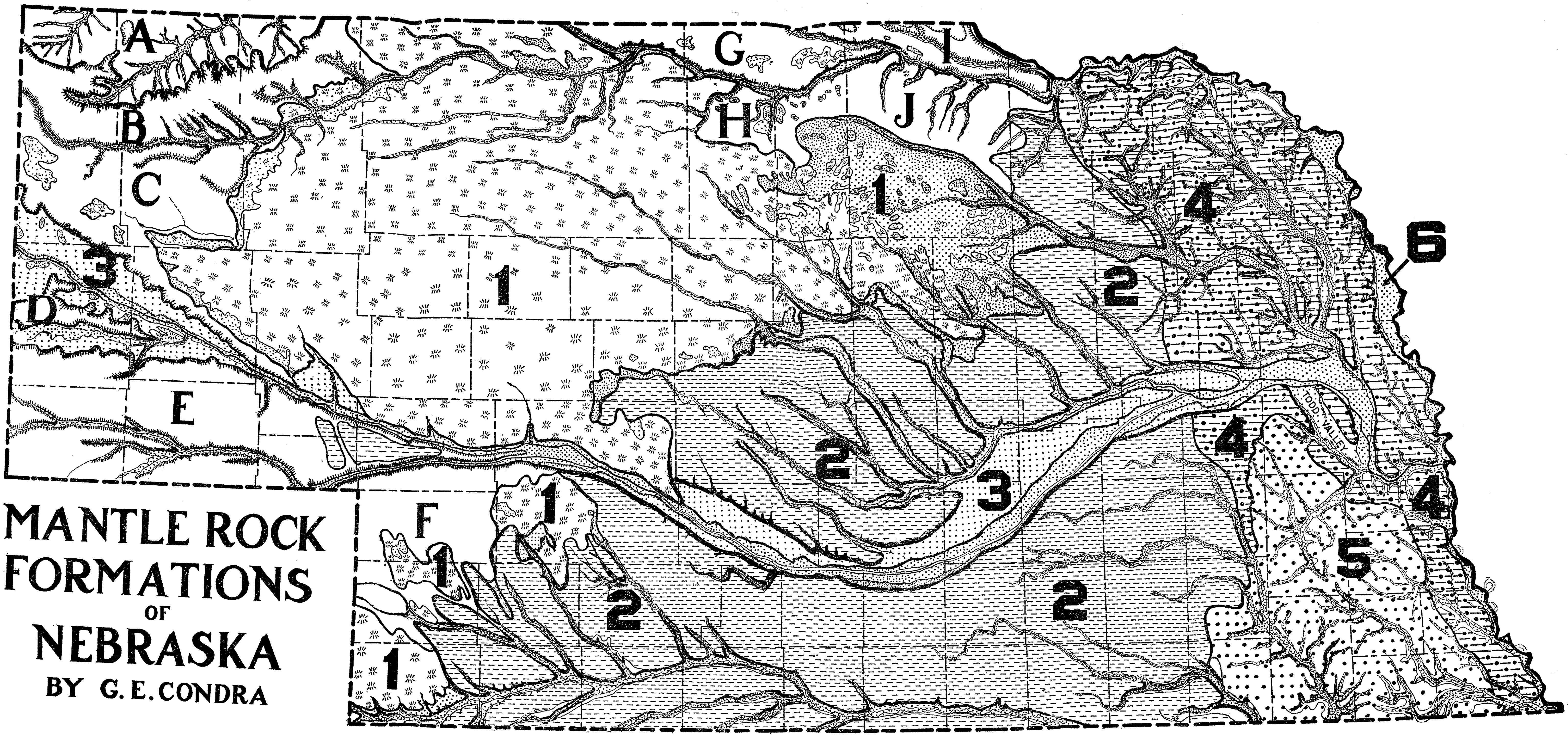
Outwash from the advancing glacier was deposited on the old bedrock surface and this in turn became covered by the till proper. The outwash is now a discontinuous sandy formation under the *Nebraskan* till sheet, and is at times called the subglacial gravel.

The *Nebraskan* glacier became a great dam across the valleys of the Dakotas and Nebraska, causing lakes to form in their lower courses, and turning the drainage southward along its western border. The drainage from between Canada on the north and the Black Hills was diverted through central Nebraska by the thick ice sheet. The river sediments, together with outwash from the glacier, then filled the old preglacial valleys and spread a broad sand and gravel deposit (*Holdrege* formation) 40 to 100 feet thick in central Nebraska west of the glacial dam.

Second. The climate, becoming warmer, caused the *Nebraskan* ice sheet to melt and retreat northward. This left a nearly level till plain in eastern Nebraska and a broad sand plain extending westward to the tablelands. During this inter-glacial stage, the surface of the till plain became weathered, forming on its surface a dense claypan-like layer called *gumbotil,* and the *Holdrege* sand plain to the west became covered with a thin, light-gray, loess-like formation which is known as the *Fullerton* formation. Then, the region was eroded in places, making small valleys.

Third. The climate becoming colder and more humid, a second glacier, known as the *Kansan,* formed in the northland and advanced over about the same area that had been covered by the *Nebraskan.* During the advance of the Kansan ice, outwash from it mantled the *Nebraskan* till sheet unevenly, and this deposit, called the *Aftonian* sand and gravel, was over-ridden in turn by the glacier which caused a second sand and gravel formation, called the *Grand Island,* to be deposited to the west, on the *Fullerton* and *Holdrege* formations, and made a thick till sheet (*Kansan*) on the *Aftonian* sand.

Fourth. A warmer climate caused the retreat of the *Kansan* glacier northward and left central and eastern Nebraska as a broad sand plain to the west and as a till plain to the east. During this inter-glacial stage, the surface of the *Kansan* till plain was weathered and leached to a considerable depth forming soil and *gumbotil,* and the *Grand Island* sand



MANTLE ROCK FORMATIONS OF NEBRASKA

BY G. E. CONDRA

LEGEND:

A-J -- AREAS OF LITTLE MANTLE ROCK: A-WHITE RIVER & HAT CREEK BASINS, B-PINE RIDGE TABLE, C-BOX BUTTE TABLE, D-WILDCAT RIDGE, E-CHEYENNE TABLE, F-PERKINS TABLE, G-CROOKSTON-SPRINGVIEW TABLE, H-AINSWORTH TABLE, I-BOYD PLAIN, J-HOLT TABL

1-6 -- MANTLE ROCK AREAS: 1-DUNESAND & SAND, 2-LOESS, 3-ALLUVIUM AND LOESS-CAPPED TERRACES OF PLATTE VALLEY, 4-LOESS ON DRIFT, 5-DRIFT, 6-MISSOURI BOTTOMLAND ALLUVIUM.

PLATE I

plain to the west became thinly mantled at places with a grayish, silty, loess-like deposit, which is called the *Upland* formation. Central and eastern Nebraska were, at that time, a nearly flat plain.

Fifth. The third glacier (*Illinoian*) advanced into Illinois and Iowa, but not into Nebraska. However, the rainfall increased here and caused heavier run-off. The Missouri, Elkhorn, Loup, Republican, and other rivers came into existence in about their present positions. They carved large valleys and tributaries, reducing considerable areas of eastern and southern Nebraska to bold hills, and left the less eroded areas as upland plains. Erosion through the *Nebraskan* and *Kansan* till sheets, and at places through the sand plain on the west, uncovered the bedrock formations along some of the principal valleys.

Sixth. With the change to a warmer and less humid climate, the *Illinoian* ice sheet retreated northward. During this inter-glacial stage the valleys of eastern Nebraska and western Iowa became filled to considerable depths with gravel, sand, and silt washed in from the eroding uplands.

With yet lower rainfall and more erosion by the wind much of the state was mantled with dust (*Loveland* loess) to depths of 5 to 50 feet or more. This reddish loess was brought by wind, from the dry areas of adjacent states, mainly to the west and northwest and probably also from the south, and in part from our tablelands, and from the sandhills which were forming. The *Loveland* loess is now generally covered by later deposits, but it has been exposed in many highway cuts and by erosion in small valleys.

Seventh. The fourth glacier (*Iowan*) invaded northern Iowa and the rainfall became heavier in the areas bordering it, as in Nebraska. This increased rainfall resulted in considerable erosion, deepening of valleys, terrace development, and the formation of a deep soil on the *Loveland* loess where the topography was comparatively level. This old soil is now buried as a dark layer beneath a later loess. It is exposed in many highway cuts and valleys of eastern and southern Nebraska.

Eighth. The *Iowan* glacier retreated northward to Minnesota and Wisconsin, due to a warmer, dryer period, and a heavy deposit of dust (*Peorian* loess) was spread over the land from Illinois to Colorado. This loess is the buff-colored, fine-textured, silty deposit that mantles most of the uplands and high terraces of the southeastern half of Nebraska to depths of 20 to 50 feet or more. It was derived in about the same manner as the *Loveland* loess, part of its material coming from the sandhills, where wind erosion was again active.

Ninth. With the readvance of the *Iowan* glacier, now known as the *Wisconsin* ice invasion, and with the recurrence of more rainfall, the valleys of the state were deepened, forming the lower alluvial terraces of eastern Nebraska. The colluvial slopes began to develop and our deep, fertile soil began to form on the *Peorian* loess of the uplands and terraces.

Tenth. Since the retreat of the *Wisconsin* glacier, some of the valleys have deepened a few feet, the alluvial slopes have continued to develop, some loess has accumulated, sandhills have formed locally, soil development has continued, especially on the smoother lands, and wash from the uplands has accumulated on the flood plains in places.

The rivers are now removing much soil and soil-forming material from the hilly lands of the state due to the destruction of the prairie and the cultivation of the land. The soils of the hilly lands are being depleted by sheet erosion and the slope lands are being gullied.

OUR RELATION TO GLACIATION

Glaciation changed Nebraska directly and indirectly to a marked degree. It brought materials in from the north, ground them up on the way, and mantled the eroded bedrock of shale, limestone, chalk, and sandstone with these materials to an average depth of about 100 feet and, as noted before, caused the deposition of two sand and gravel formations in the central part of the State with a combined thickness of 100 to 200 feet.

The later glaciations that reached Iowa and other states to the east, influenced Nebraska through climatic changes, which caused severe land erosion here during the humid periods and valley-fillings and extensive loess accumulation during the dryer periods. Soil was formed on the smoother lands when the climate was humid and sandhills were developed on the sandy land when the climate was dry.

The loess was derived from large areas west, northwest, and southwest of Nebraska and deposited thickest where there was protective vegetation, as along the borders of the large valleys. In places it drifted like snow, accumulating to greatest thickness on the leeward sides of hills. In general, the glaciers, streams, and the winds brought much land debris to our state from the north and west during the Glacial period and deposited it as the mantlerock formations which now contain much of our groundwater.

Glaciation gave to the State rich soil forming materials at the surface and water-bearing beds beneath. Had the State not been glaciated, much of central and eastern Nebraska would be occupied at the surface by the Pierre shale, Niobrara chalk, Carlile shale, the Greenhorn limestone, a large roughland on the Dakota sandstones, and by belts of shaly land and stony land on the Permo-Pennsylvanian formations. Conditions would be about like they are in parts of Kansas and Oklahoma where there are acute groundwater problems. Figure 1 shows how the drift deposits lie in northeastern Nebraska in relation to the bed rock.

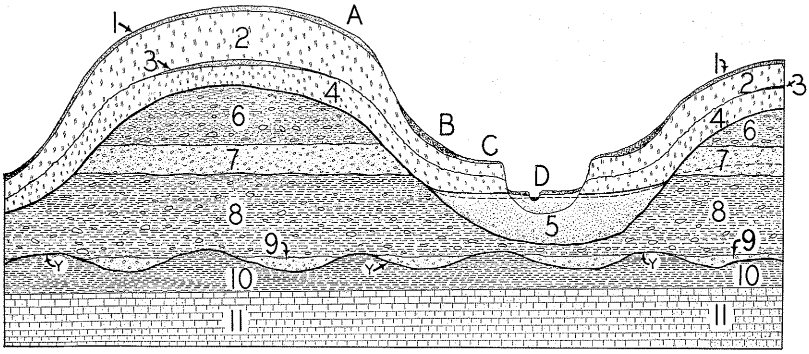


FIGURE 1.—A generalized cross-section of the Loess Hill Region of northeastern Nebraska: 1, soil on the *Peorian* loess; 2, *Peorian* loess; 3, old soil on the *Loveland* loess; 4, *Loveland* loess; 5, alluvium, old and recent; 6, *Kansan* till; 7, *Aftonian* sand and gravel; 8, *Nebraskan* till; 9, subglacial sand and gravel; 10, *Graneros* shale; 11, *Dakota* sandstone.

The land forms are: A, Loess Hill; B, colluvial slope; C, terrace; D, flood plain or bottomland proper.

MANTLEROCK WATER HORIZONS

The open-textured mantlerock absorbs much of the rainfall and passes it to groundwater storage whereas the more closely textured deposits shed much of the rainfall to surface drainage. The outcrop areas of shale land along the valleys shed the rainfall and have no water horizons. Summarized, the groundwater horizons of the mantlerock regions of the state are located formationally as follows:

1. At the base of the loess where it rests on one of the *till* sheets or on the Upland clay. This horizon gives weak wells.
2. In the alluvial sands and gravels, which are extensive and a main source of well water in Nebraska.
3. In the dunesand and subjacent sandy deposits of the sandhills. At places here the water storage stands high, i.e., in the dunesand proper.
4. In the *Aftonian* sand lying between the *Kansan* and *Nebraskan* till sheets. Locally, there is some water in the *Kansan* and *Nebraskan* till sheets proper.
5. In the *Grand Island* and *Holdrege* sands and gravels. These carry much water.
6. In subglacial gravels, i.e., in gravel-filled channels beneath the *Nebraskan* till sheet.

THE BEDROCK FORMATIONS

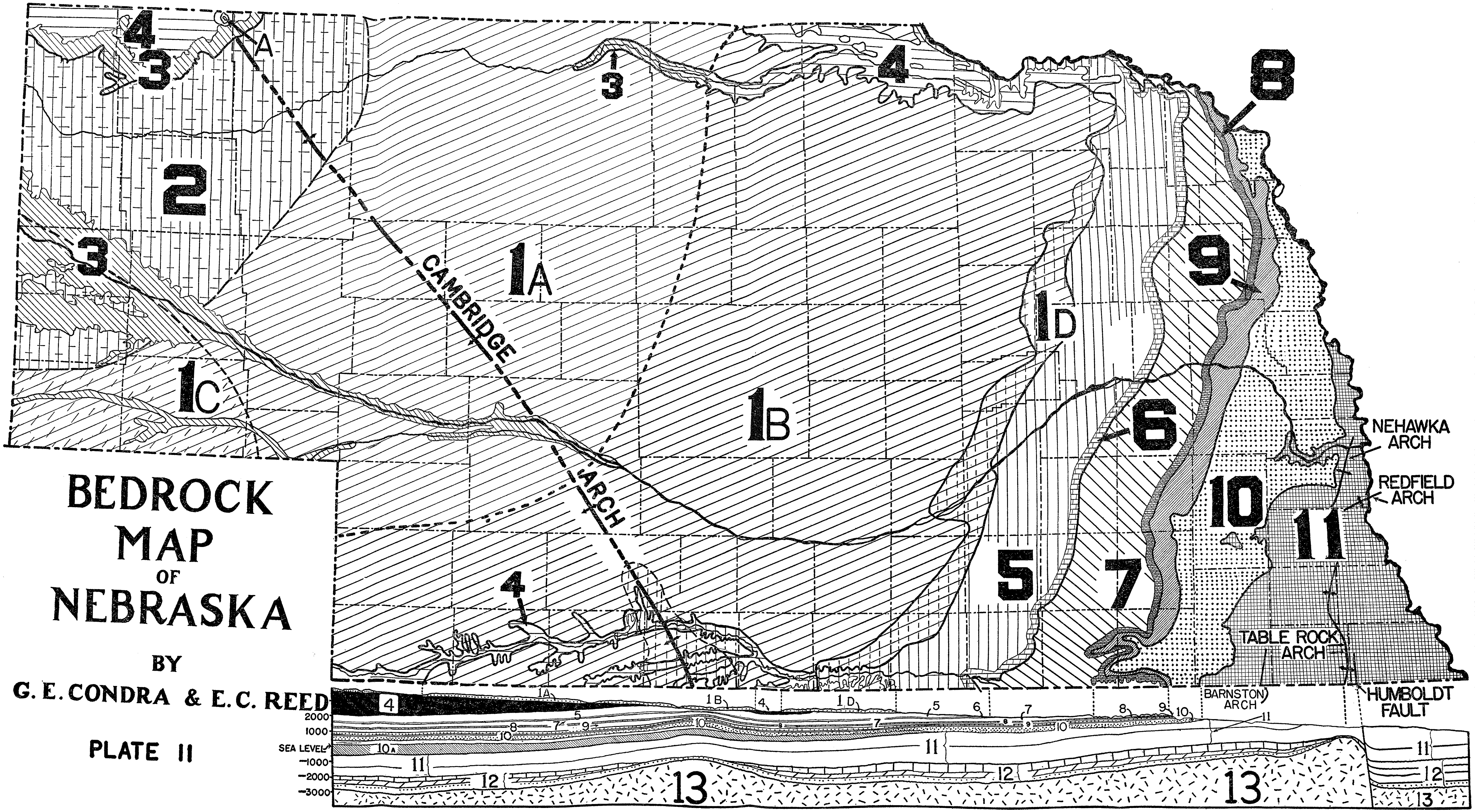
Everywhere below the mantlerock in our State and extending downward to granite are more or less consolidated strata. Plate II shows the occurrence of the main divisions of the bedrock exposed in Nebraska and the generalized cross-section on it shows how these divisions and older rocks occur beneath the surface.

The bedrock formations, up to and including the Pierre and Fox Hills, were largely formed in the sea, from sediments washed in from the land, and by the accumulation of calcareous shells of animals that lived in the sea. The Brule clay, Arikaree, and Ogalalla formations were deposited on the land after the sea floor had been elevated and roughened by erosion. The story of the origin of bedrock formations, though interesting, is described in many geological reports and need not be reviewed here, because the drillers are more interested in the occurrence and water-relations of these formations than in the story of their origin.

The combined thickness of the stratified bedrock varies greatly, being thinnest on the arches or anticlines of the state and thickest in the basins between these arches. The range in thickness is between 558 feet on the Table Rock arch southeast of Dubois and 9,000 feet or more in Banner County. Wells have been drilled through the stratified rocks to granite, as near DuBois, Table Rock, and Holdrege, and several have been drilled to rocks just above the granite, as at or near Omaha, Fremont, Lincoln, Nebraska City, Nehawka, Dawson, Cambridge, Bassett, and Chadron.

The oldest rocks outcropping in the state are in the Platte Valley west of Oreapolis, Cass County. They are limestones and shales of the Pennsylvanian System. Our knowledge of the nature and the occurrence of the formations lying between the Pennsylvanian beds and the granite has been obtained by a study of the cuttings, cores, and logs of wells and by a study of the outcrops of these formations in the bordering states. Information regarding the older bedrock formations can be found in Bulletin No. 4, *Deep Wells of Nebraska,* by the State Geological Survey.

Description of Plate II. The principal subdivisions of the bedrock are numbered from the youngest to the oldest on this map and cross-section, representing as follows: 1a, 1b, 1c, the Ogalalla formations; 1a, Ogalalla lying on Brule clay; 1b, Ogalalla on Pierre shale; 1c, Ogalalla on Brule clay and that on Laramie and Fox Hills shales and sands, which overlie the Pierre shale; 1d, Ogalalla on Niobrara chalk; 2, Arikaree-Gering and associated beds, on the Brule clay; 3, the Brule-Chadron beds on the Pierre shale north and on the Laramie-Fox Hills south. 4, Pierre shale on the Niobrara; 5, Niobrara chalk, with the Fort Hays limestone (6) at its base on the Carlile shale; 7, Carlile shale on the Greenhorn limestone; 8, Greenhorn limestone on Graneros shale; 9, Graneros shale on the Dakota group of sandstones and shales; 10, Dakota group



BEDROCK MAP OF NEBRASKA

BY

G. E. CONDRA & E. C. REED

PLATE II

on the Permo-Pennsylvanian beds east and on the Sundance-Morrison sands west; 10 a, the "Red Beds" on Permo-Pennsylvanian; 11, Permo-Pennsylvanian on division 12 which includes the limestones, dolomites, shales, and sandstones of the Missippian, Devonian, Silurian, Ordovicion, and Cambrian systems; 12, Ordovician on Pre-Cambrian rocks including granite (13).

NOTE: Plates I and II are drawn to the same scale. By placing Plate I above Plate II one can see what regional relations the mantlerock formations hold to the kind of bedrock lying below. Then, by knowing the thickness of each bedrock formation in the succession downward in the section it is possible to determine the depth of a bedrock water horizon at a given place.

Again, it should be noted that the bedrock formations overlie each other in succession westward. That is, the Permo-Pennsylvanian beds pass under the Dakota beds which extend westward under the Graneros and so with each succeeding higher formation up to and including the Fox Hills-Laramie shales and sands. The Tertiary formations lie on an eroded surface of the older rocks, overlapping them eastward as shown by the cross-section in Plate II.

THICKNESS OF THE BEDROCK FORMATIONS

Enumerated from the youngest to the oldest, the content, succession, and thickness of these formations is as follows:

1. Ogalalla (1a-1d), dark gray to light gray, part reddish; composed of sand, gravel, some clay and limy sandstone which is commonly known as "magnesia rock"; overlaps westward against the Arikaree; thickness, 50 to about 400 feet.

2. Arikaree sandstone and associated beds including the Gering, Monroe, and other divisions (2), grayish, largely sandy; loosely cemented to quite firm sandstone and limy sandstone; combined maximum thickness, 700 to 800 feet.

3. Brule-Chadron beds (3), the Brule being silty, weathering buff; the Chadron composed of clay, silt, sand, and gravel, color largely bluish-gray; maximum thickness of the Brule, about 700 to 800 feet; thickness of Chadron, 50 to 125 feet.

4. Laramie-Fox Hills sands and shales, under the western part of the state in area 1c; color dark gray to brownish; thickness not certain, probably 300 feet to 400 feet or more.

5. Pierre shale (4), smoky-colored, black at base; very sticky and plastic when wet; thickness increasing rapidly westward from the eastern outcrops, from 100 feet or more to 1,000 feet and then to about 3,000 feet in Banner County.

6. Niobrara chalk (5 and 6), bluish-gray, weathers buff; largely shaly chalk; basal 20 to 30 feet or more limy and known as the Fort Hays limestone; combined thickness, 225 feet or more in Cedar and Knox counties; about 100 feet in Dawes County and 400 to 600 feet along the Republican.

7. Carlile shale (7), dark to gray, largely plastic, contains some large concretions; thickness 150 feet northeast, 200 feet or more near Superior, 230 feet at McCook.

8. Greenhorn limestone (8), layers of dark gray shales and gray limestones, contains many oyster-like fossils; thickness 25 to 40 feet.

9. Graneros shale (9), dark gray, with some sand and coaly material near base; thickness 70 to 80 feet northeast, increasing westward, about 150 feet at McCook and 900 feet or more in northern Dawes County.

10. Dakota group (10), consists of two or more sandstone members and about two shale members of which the lower one is gray to mottled grayish-red; texture variable at places; combined thickness 315 feet to about 500 feet. The Sundance-Morrison beds underlie the Dakota in the western counties of the state.

11. "Red Beds" (10a), under the western counties, age not certain, largely shale, contain sandy shale and some gypsum; thickness as shown by the cross-section on Plate II.

12. Permo-Pennsylvanian (11), shales, limestones, and some sandstone and thin coals; well exposed along the valleys of the southeastern counties; combined thickness, except on the anticlines, 1,000 to 2,800 feet in the southeastern counties; quite thin in Dakota County; probably 1,500 feet or more under most of central and western counties but thinner on Cambridge arch.

13. Division 12, shown by cross-section on Plate II; includes the dolomites, limestones, shales, and sandstones in the Mississippian, Devonian, Silurian, Ordovician, and Cambrian systems, also the Sioux sandstone of Pre-Cambrian age; combined thickness represented in the cross-section on Plate II.

14. Granite, extending to unknown depths.

THE BEDROCK WATER HORIZONS

In Nebraska, more than in most states, it is not generally necessary to tap the bedrock waters. However, there are places where comparatively deep wells must be made in order to obtain domestic water supplies and to secure water for special purposes, as at Omaha. The water horizons in the bedrock of the state, though not all of much significance, are as follows:

1. Ogalalla formation, age Pliocene Tertiary.
2. Arikaree-Gering and associated beds (Miocene Tertiary).

3. Brule clay, some water, in thin local sands (Oligocene Tertiary).
4. Chadron formation, in sands and gravels (basal Oligocene Tertiary).
5. Laramie-Fox Hills, in thin sands in shale (late Cretaceous).
6. Niobrara formation, in the basal zone known as the Fort Hays limestone (Cretaceous).
7. Greenhorn limestone (Cretaceous).
8. Dakota group, in two or more sandstone horizons (Cretaceous).
9. Permo-Pennsylvanian, in some of the limestones and sandstones (Carboniferous).
10. Burlington and Keokuk limestones (Mississippian, known as lower Carboniferous).
11. Niagaran dolomite (Silurian).
12. Galena dolomite (Ordovician).
13. St. Peter sandstone and associated sandstones (Ordovician).
14. Jordan sandstone (Cambrian).
15. Dresbach sandstone (Cambrian).
16. Sioux sandstone (Pre-Cambrian).

Numbers 1, 2, 4, and 8 of the above supply most water. The storage in numbers 6 and 7 is scant. Divisions 10 to 15 inclusive have been drilled at Fremont, Lincoln, Omaha, Nehawka, and probably at Nebraska City. They, and division 16, supply some well water at Omaha.

SALT WATER HORIZONS

Although too little reliable information is available from which to definitely outline the salt water horizons it appears from the data at hand that the main zones in the state occur about as follows:

1. In the Dakota group, in a sandy zone above the so-called Fuson shale which lies between the Lakota sandstone at the base of the group and the Dakota sandstone proper which is at or near the top of the group.

2. In two or more zones of the upper part of the Pennsylvalian system, as at Lincoln, and near Union and Unadilla.

3. In beds a few feet below the St. Peter sandstone, as in the Morgan well south of Dawson.

ARTESIAN WATER

Much of the state is underlain by formations carrying water under more or less pressure. The head is developed in the broad basins from which the aquifers rise locally against the limbs of the anticlines, against the Sioux Falls high, or in the Black Hills and the Rocky Mountains.

The chemical qualities of the artesian water seems to vary with the distance it has moved from the point of intake to the place where it is tapped by wells. The leading artesian aquifers are the subglacial gravels, the

Holdrege sand, Ogalalla formation, Chadron formation, Dakota group sandstones, Mississippian limestones, Niagaran dolomite, Galena dolomite, St. Peter sandstone, Jordan sandstone, and the Dresbach sandstone. In most of the wells that have been drilled to the deeper artesian horizons, too little attention has been paid to casing-off the various water horizons, hence the water of most of these wells comes from more than one aquifer and is chemically and physically a mixture of them all.

The 1935 Legislature assigned to the State Geological Survey the duty of conserving the artesian waters of the state against wastage. This service calls for cooperation with the well drillers who understand why these waters should be conserved, especially in those areas where they are the dependable source for domestic use.

THE GROUNDWATER REGIONS

On a basis of the geological features and the quantity, quality, movement, and availability of the water, our state has 18 groundwater regions. Their locations are shown by Plate III, as follows: 1 and 1^2, Northwestern Shale Land Region; 2, Northern Shale Land areas which, except on the Boyd Plain, are not a distinct region; 3^1 to 3^4, Western Table Lands, as four groundwater regions; 3^5 to 3^8, Northern Tablelands, as three water regions and small spurs from two others; 4^1 to 4^4, Sandhill Region and Outliers; 5, Central Region; 6, Platte Valley Lowland Region; 7, Southwestern Region; 8, Loess Plain Region; 9, Republican Valley Region; 10, Northern Drift Region; 11^1 to 11^5, Southern Drift Region; and 12, the Missouri River Lowland Region. The letter A on Plate III marks the southeastern boundary of the Dakota sandstone, and B shows the western border of the drift regions.

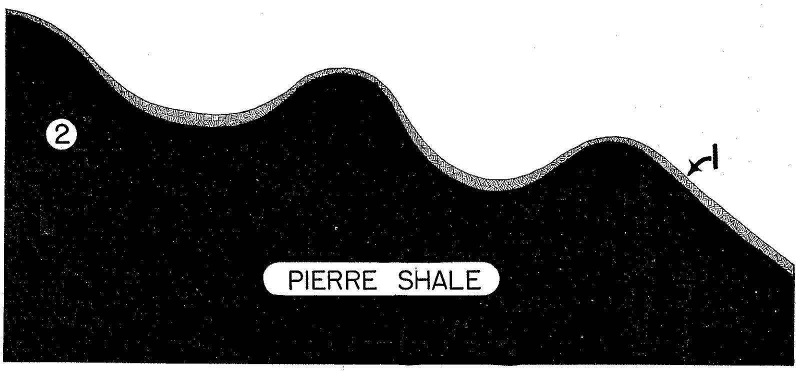
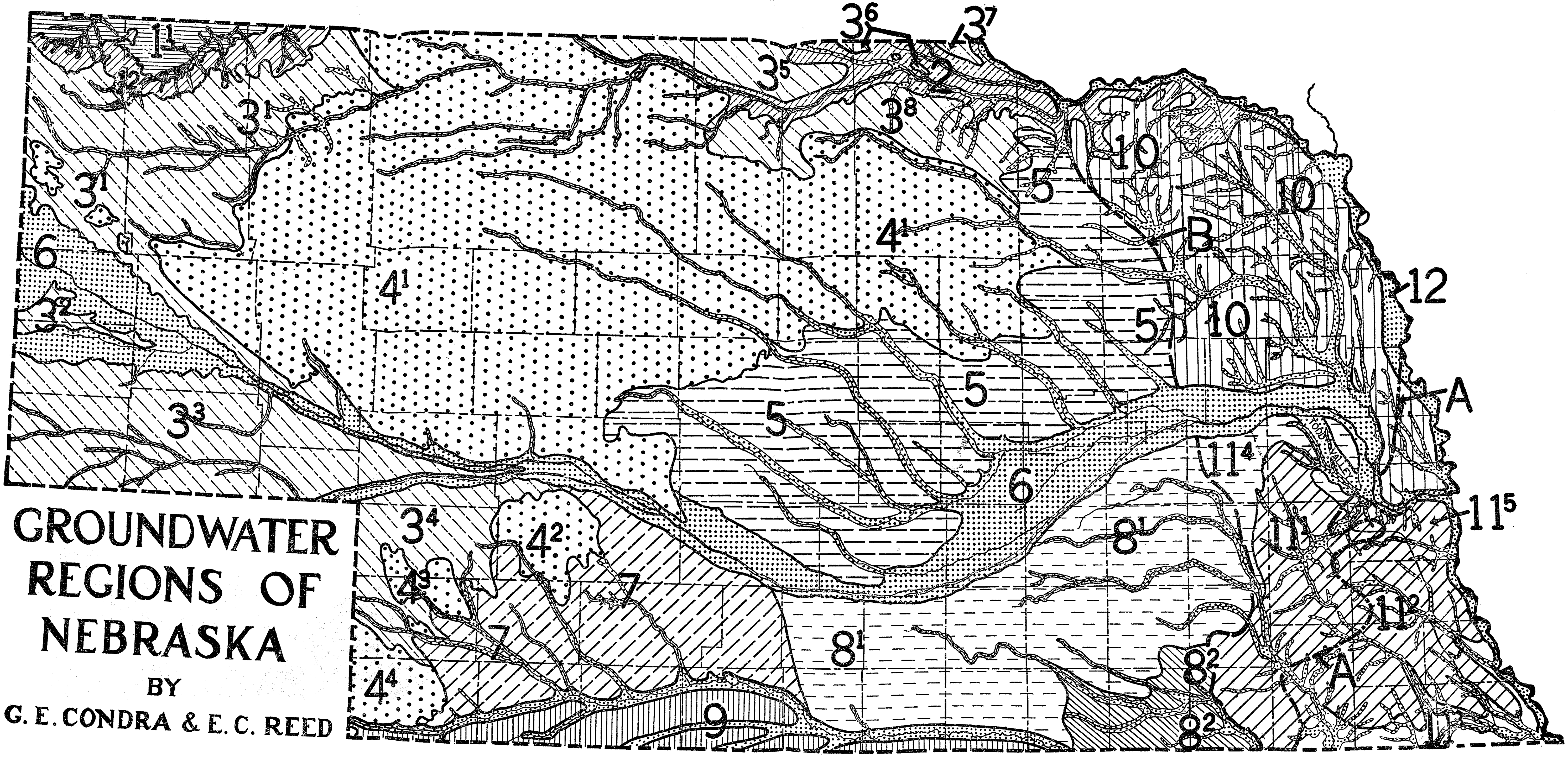


FIGURE 2.—Generalized cross-section in northern Sioux and Dawes counties. A thin accumulation of weathered material and soil on tops and sags of hills (1) is not in condition to store moisture. The Pierre shale (2) extends to great depth and is not water-bearing.

GROUNDWATER REGIONS OF NEBRASKA

BY

G. E. CONDRA & E. C. REED



LEGEND:

1^{1-2}-NORTHWEST SHALE LAND REGION, 2-NORTH SHALE LAND REGION, 3^{1-4}-WESTERN TABLELAND REGIONS, 3^{5-8}-NORTHERN TABLELAND REGIONS, 4^{1-4}-SANDHILL REGION & OUTLIERS, 5-CENTRAL REGION, 6-PLATTE VALLEY LOWLAND, 7-SOUTHWEST REGION, 8-LOESS PLAIN REGION, 9-REPUBLICAN VALLEY REGION, 10-NORTHERN DRIFT REGION, 11^{1-5}-SOUTHERN DRIFT REGION, 12-MISSOURI RIVER LOWLAND, A-SOUTHEAST EDGE DAKOTA SANDSTONE, B-WEST EDGE OF DRIFT

PLATE III

Since the bulletin on the groundwater regions of the state is being written for publication in the near future, only a brief review of the salient features of the water regions is made in this report for use in the forthcoming Well Drillers Short Course and Annual Convention.

Northwestern Shaleland Region (1^1 and 1^2). This well-defined region is occupied by the Pierre shale or dark gumbo lands (1^1) and the Brule and Chadron formations (1^2). It has little groundwater and few wells except on the alluvial lands. However, some wells supply water from the basal Chadron sands in area 1^2. The water conditions in the Pierre shale area are shown by Figure 2.

Fortunately the spring-fed streams that head in the rough lands of Pine Ridge extend through parts of this region affording water supplies for farms and for Chadron and Crawford. The Dakota sandstone underlies the region at depths of 2,000 feet to 3,500 feet, making any production of its water through wells costly and prohibitive.

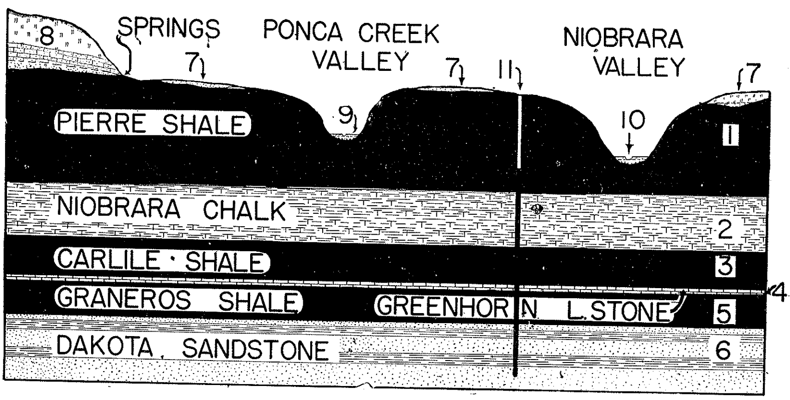


FIGURE 3.—Generalized cross-section of eastern Boyd County and the Niobrara Valley, view eastward, showing the geological formations and the water horizons. The region is underlain by the Pierre shale and other shaly and chalky formations, and quite deeply by the Dakota sandstone. There is no available water in the shales and chalk. The areas where the shale is at the surface carry little or no well water. The sandy, silty surface formations to the north (8) absorb considerable rainfall and store it above the impervious shale. This condition affords well water and springs. The thin surface sand (7) stores small amounts of rainfall from which limited water supplies are obtained during wet years, but the water is depleted by under-drainage, evaporation, and use during dry years. The run-off from the uplands stores water in the alluvial bottom lands (9 and 10), which are the most dependable sources of well water, except where the alluvium is thin and its water is not recharged during drouth. However, the Niobrara alluvium is supplied quite uniformly by water coming from the sandhills.

The last resort in obtaining water on the shaly land of the area represented by the cross-section, and at similar points farther east, is to make deep wells to the Dakota sandstone, from which, due to artesian pressure, the water lifts to near the surface, as shown by the well at 11.

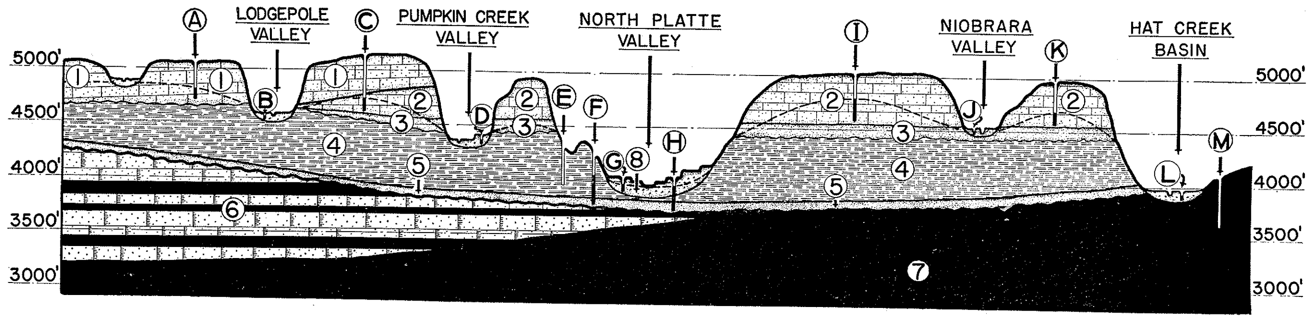


FIGURE 4.—Generalized north-south cross-section of Nebraska near the Wyoming line. Formations: 1, *Ogalalla;* 2, *Arikaree;* 3, *Gering;* 4, *Brule* clay; 5, *Chadron;* 6, *Laramie-Fox Hills* sands and shales; 7, *Pierre* shale.

Well conditions: A, Well extending to basal part of the *Ogalalla;* B, well extending into *Lodge Pole* alluvium; C, well extending into *Arikaree* formation; D, well extending into the basal alluvial sand in Pumpkin Creek Valley; E, dry well in *Brule* clay; F, well extending through *Brule* clay to the *Chadron* formation with water under pressure; G, well extending to base of North Platte Valley alluvium; H, well on low terrace of North Platte Valley extending to the *Chadron* formation; I, well on the *Box Butte* table and extending into the basal part of the *Arikaree* formation; J, shallow well on the alluvial bottom land of Niobrara Valley; K, well on Pine Ridge extending to basal part of the *Arikaree* formation; L, well in Hat Creek Basin, extending into alluvium; M, dry well on a *Pierre* shale hill in Hat Creek Basin.

Note that the *Gering* and *Arikaree* wedge out to the south (left side of section) and that the *Laramie-Fox Hills* thins to the north. The configuration of the water table as indicated by the dashed line shows the combined effect of topography and bedrock porosity. Sea-level elevations are shown by the figures at the ends of the section.

Northern Shaleland Region (2). This so-called region consists of several disconnected small areas. It is essentially like region Number 1, but is occupied locally by thin deposits of sand and gravel in which there is some water storage. The areas are underlain at depths of 400 to 1,000 feet or more by the Dakota sands to which some wells have been drilled to secure bedrock water. Figure 3 shows the groundwater conditions here.

Western Tableland Regions (3^1-3^4). In these regions, (Figure 4) an impervious platform on the Brule and Pierre formations stands quite high above the major drainage ways. Much of the rainfall here is absorbed and passed to ground storage. The watertable is at depths of 100 to 300 feet. Under-drainage generally is southeastward, but locally to the valleys where it gives rise to springs. Most of the wells extend to deep gravels in the Ogalalla or the Arikaree and associated beds. Usually they are quite strong, and of the cased type. The water is medium hard.

Sandhill Region and Outliers (4^1-4^4). The Sandhill Region and its outliers are filled to overflowing with water replenished from rainfall (Figure 5). The impervious platform on Brule clay and the Pierre shale

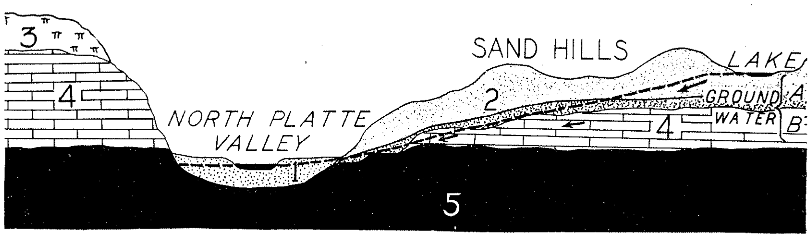


FIGURE 5.—Generalized cross-section from the vicinity of Blue Lake to and across the North Platte Valley, view westward, showing the formations and water conditions. Formations: 1, Alluvium; 2, Dunesand and sands; 3, *Peorian* loess; 4, *Ogalalla* formation; 5, *Pierre* shale. The dashed line indicates the water table level and the arrows show the direction of water migration.

is overlain with open-textured Tertiary sands, Pleistocene sands, and dunesand. The depth of water storage is 700 or 800 feet in places. The general direction of underflow is southeastward, but locally to the Niobrara and other valleys. The water is medium hard, but alkaline in some of the lake basins beneath which, at depths of 50 feet or more, is good water. There are many artesian wells in the eastern part of this region, their depths ranging between 80 feet and 700 feet.

Central Region (5). This lies between the sandhills, Northern Drift Region, and the Platte Valley Lowland. It is smooth to hilly or rough and capped by the loess deposits underlain by the Grand Island and Holdrege sands which locally overlie the Ogallala formation. The impervious floor is on the Pierre and Niobrara formations. Replenishment is from local rainfall and by general underflow and from the surface-drainage ways heading in the sandhills. Underflow is southeastward. Groundwater storage is quite extensive and of good quality. Wells are of the tubular and cased types, extending to sand or gravel at depths of 100 to 200 feet in the uplands and only to shallow depths in the valleys.

Platte Lowland Region (6). This extensive region consists of alluvial bottomland and low to high terrace capped with loess. The central part of it is underlain by the Holdrege and Grand Island gravels which have a combined thickness of 50 to 100 feet or more, resting locally on the Ogalalla beds and more generally on impervious bedrock. The alluvial deposits are thin in Pumpkin Creek Valley and generally quite thick in the lower course of the Platte Valley. Replenishment is from rainfall, from the river, and in the central and western courses by underflow from the sandhills. The water is abundant and medium hard, but becoming alkaline where there is excessive seepage and poor drainage, as near Minatare and Lexington. The wells in this area are usually strong, many of them being used for irrigation. They are largely of the cased type. Underflow is down-valley and locally southeastward from the valley in the stretch from Cozad to east of Grand Island.

Southwestern Region (7). This region is largely covered with thick loess deposits and underlain at a few places by deposits of Pleistocene sand and gravel and more generally underlain by the Ogalalla which lies on the Pierre. There is intake from the surface drainage and the underflow from the small sandhill areas to the northwest which feeds the live streams leading through the region. There is water storage in the alluvial bottomlands and in the Ogallala and Pleistocene sands and gravels lying above the Pierre. This storage is tapped by cased wells, depth 100 to 250 feet. Some of the upland water issues as springs over the Pierre.

Loess Plain Region (8^1-8^2). The outstanding feature of this region is the presence of the thick Holdrege and Grand Island sands which lie between the loess cap and the impervious platform on the Pierre shale and the Niobrara chalk. There is extensive intake from the Platte underflow

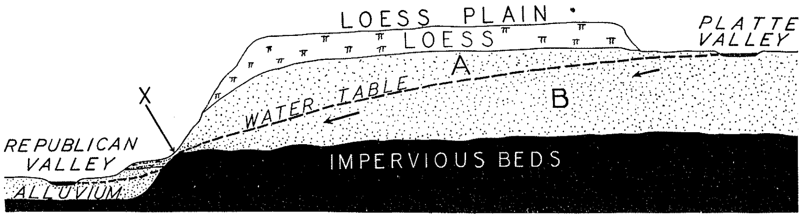


FIGURE 6.—Generalized cross-section across the Loess Plain, view westward, showing how the water passes from the Platte River southeastward to the Republican and Big Blue valleys. The dry portion of the *Grand Island* and *Holdrege* sands and gravels is shown by A, B indicates the water-bearing sands and gravels and X marks the location of springs along the northern edge of the Republican Valley.

(Figure 6) to the lower course of the Republican and to the Blue rivers. Except in the area 8^2, where the impervious platform stands quite high locally and the sands are fine, there is an abundance of medium hard water in this region. In this latter location there are places where it is difficult to find adequate groundwater and the wells are sunk on alluvial lands or they are drilled to the Fort Hays base of the Niobrara or to the Dakota. Wells in the Loess Plain Region are generally from 80 to 150 feet in depth and predominately of the tubular type except those in the cities, which are cased.

Republican Valley Region (9). The groundwater conditions here, though not hard to understand, present some difficult problems (Figure 7). All of the region is underlain by the Pierre shale to the west and

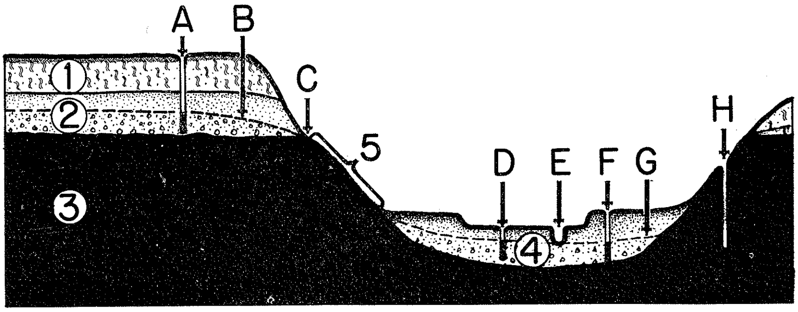


FIGURE 7.—A generalized cross-section of the Republican Valley in Webster County. looking eastward. Note the dry, shaly land belts along the valley-sides (5) on shale (3). Observe the location of the thick, upland sands and gravels (2) in which there is a strong underflow from the Platte Valley with the water table at B. There is water-bearing alluvial land in the Republican Valley (4). The dependable water supplies here during drouth are obtained from the underflow along the Republican and from the sands that are recharged from the Platte Valley. Elsewhere in the area of the cross-section, there is little water except that found in the Dakota sandstone at a depth of 400 feet or more on the valley floor and at greater depths in the uplands. The location of the river is at E; a bottom land well is at D, and a terrace well at F; whereas a dry well is in the shaly land at H. The water table level is shown by G.

the Niobrara to the east. These formations are covered quite generally in the uplands by the Ogalalla and only locally by the Pleistocen sands and gravels and much of the upland is mantled with the loess deposits. There are narrow belts along the valley-sides in which the Pierre and Niobrara have been exposed incident to the erosion of rather deep drainage ways. This presents an unfavorable condition, in that there is no intake on the impervious slopes and much water is drained away from the borders of the upland water-bearing beds. It forms dry borders along the valleys in which only dry wells are obtained, except by deep testing. Fortunately, considerable water is retained in the divides away from the drainage ways and the bottomlands of the Republican and its various tributaries carry considerable alluvial water. The springs issuing from the upland gravels are important sources of water supply in this region.

The depth to water in the Dakota beds is 400 feet or more along the lower course of the Republican in Nebraska and deeper westward being 1,200 feet on the valley floor at Beaver City and somewhat deeper at McCook

Northern Drift Region (10). This region is largely mantled with loess and alluvium resting on the till sheets between and below which are the Aftonian and subglacial gravels. There are dry belts in some of the bluff lands and other valley-sides. Most wells tap the alluvial land or the drift horizons but in case of failure in these locations, drilling is done to the Dakota sandstones at depths depending upon the topographic positions, whether in valleys or on the high upland (Figure 8). The depths range

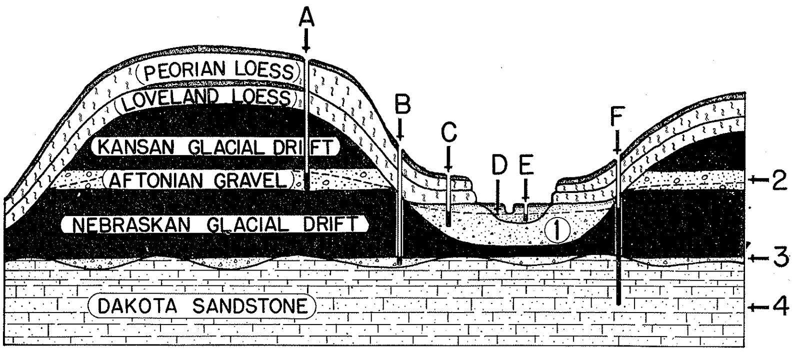


FIGURE 8.—Cross-section of a Loess hill in the northeastern part of Nebraska, showing the geological formations and the water horizons, which are the alluvial sands (1) of the bottom land, the glacial sands (2 and 3) and the Dakota sandstone (4). Unfortunately the water supply in the glacial sands are not now restored very much from the rainfall, due to the thick cover of loess. This water was accumulated in ages past. It can be exhausted by heavy pumping and wastage. When it fails, prospecting for a supply is done on the bottom land in which the groundwater is replenished by the run-off of the hills. Finally, the last chance for a dependable well water supply in much of the Loess Hill Region and in parts of the Drift Hill region is the Dakota sandstone to which many wells were drilled last year.

between about 100 feet or more on the east and 800 at the northwest. Many wells were sunk to the Dakota in this region during the dry year of 1934. In a few places, the Dakota water is too heavily mineralized for domestic use.

Southern Drift Region (11^1-11^5). Though essentially similar to the Northern Drift Region, this region is separated from the latter by the Platte River lowland. Its groundwater conditions are complicated and at places puzzling (Figure 9). Wells tap the alluvial, *Aftonian,* subglacial sands, *Dakota, Pennsylvanian* and older horizons. Where there is no

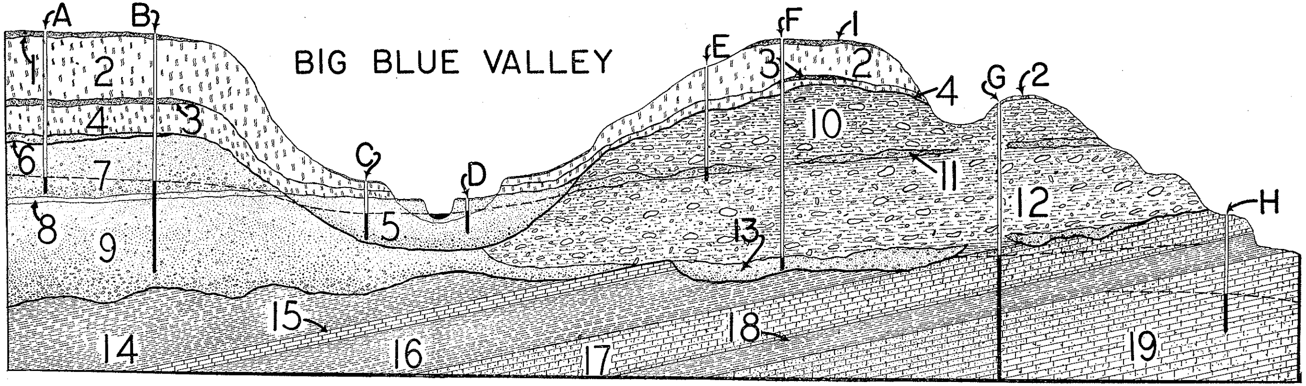


FIGURE 9.—A generalized cross-section in the vicinity of Seward, from the Loess Plain west of the Big Blue Valley to the Drift Hills east of the valley, view northward. The formations shown by this figure are: 1, Soil on the *Peorian* loess; 2, *Peorian* loess; 3, the old soil on *Loveland* loess (4); 5, alluvium in the Big Blue Valley; 6, *Upland* silt; 7, *Grand Island* sand and gravel; 8, *Fullerton* silty clay; 9, *Holdrege* sand and gravel; 10, *Kansan* till sheet; 11, *Aftonian* sand and gravel; 12, *Nebraskan* till sheet; 13, subglacial gravel; 14, *Carlile* shale; 15, *Greenhorn* limestone; 16, *Graneros* shale; 17, *Dakota* sandstone; 18, *Fuson* shale; and 19, *Lakota* sandstone.

Note the extreme contrast between the area west of the Big Blue Valley where the thick *Grand Island* and *Holdrege* sands and gravels are available as aquifers and the area farther to the east where the discontinuous nature of the *Aftonian* and subglacial sands and gravels makes them less reliable as sources of water supplies.

Wells: A, Well extending to the basal sands of the *Grand Island* formation; B, well extending to the *Holdrege* sands and gravels; C, well on terrace and extending to alluvial sands; D, well on flood plain extending to alluvial sand and gravel; E, well extending to *Aftonian* sand and gravel; F, well extending to subglacial sand and gravel; G, well missing the *Aftonian* and subglacial gravels and extending to the *Lakota* sandstone at base of *Dakota* group; H, well starting on the *Dakota* sandstone and extending to the *Lakota* sandstone.

available water in, between, and below the drift sheets, supplies are located on the alluvial lands if they occur near enough to the place where water is needed. Then, in case water is not found in a mantlerock horizon, a well is drilled to the Dakota sands, i.e., where these sands underlie the place. Finally, should the location be to the southeast of the Dakota outcrop (see A of Plate III), prospecting must be done in yet older bedrock formations, which is expensive and hazardous. Here is where the detailed reports of the Geological Survey should be consulted.

Plate III shows the Southern Drift Region as five areas. Areas 11^1 and 11^4 are underlain by the Dakota; areas 11^2 and 11^5 are underlain by the Permo-Pennsylvanian and older beds; area 11^5 is mantled with loess whereas in most of the region drift is at the surface, except where there is alluvium or bedrock exposed. In area 11^3, the valley-sides, and at places, the higher uplands are formed on bedrock (largely shale) in which there is scant groundwater and dry or weak wells are obtained (Figure 10).

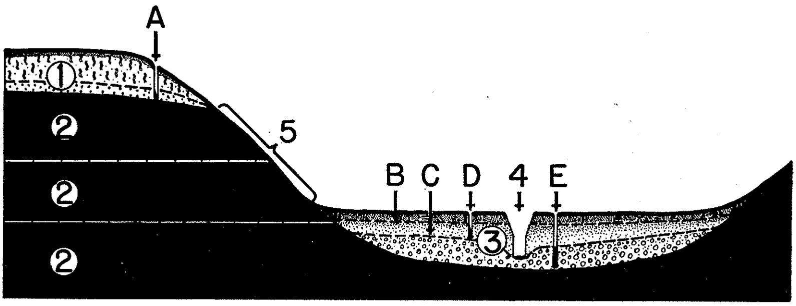


FIGURE 10.—Generalized cross-section of the South Fork of the Big Nemaha Valley about four miles south of Dawson, Richardson County, showing the water-bearing formations and the areas without well water. Note that there is a thin water-bearing sand in the upland (1) in which the well (A) went dry during the drouth. The shaly land (5) carries no well water. The alluvial land (3) is the dependable source of water in this area during dry years. The location of the watertable here before drainage was installed and prior to the drouth is indicated by B, and its position after drainage and during the late drouth is indicated by C. The location of a shallow bottom land well that failed is shown by D and a well that was deepened by E.

Area 11^4 is largely underlain by channels of subglacial gravel resting on shales or on the Dakota. The wells are generally deep. Todd Valley is an old course of the Platte deeply filled with sand and gravel and capped with loess. It has abundant water at depths of 80 to 100 feet. The Dakota sands carry salty water at places in the southern drift region, as north and northwest of Lincoln. Shallow flowing wells, with water from subglacial gravel, are found near Tecumseh, Cook and Valparaiso. Salt water artesian wells occur at Lincoln.

Missouri River Lowlands (12). The alluvial lands of this region, composed of fine sediments, extend to depths of 60 to 100 feet. Along the bluff line are narrow terraces and small alluvial fans capped with loess or reworked loess and underlain by sands resting on Cretaceous (north) and Pennsylvanian (southeast).

The alluvial land of the region is nearly filled with water of only fair quality. Springs in the bluffs bordering the region supply considerable water for farm use along the edges of the bottomland. Artesian wells tapping the Dakota are obtained in the region between Tekamah and Boyd County. At Omaha, some artesian water is obtained from the Mississipian and older formations at depths of from 500 to 2,000 feet. Figure 11 shows the groundwater conditions in the bluff land and on Missouri River bottomland in the vicinity of Blair.

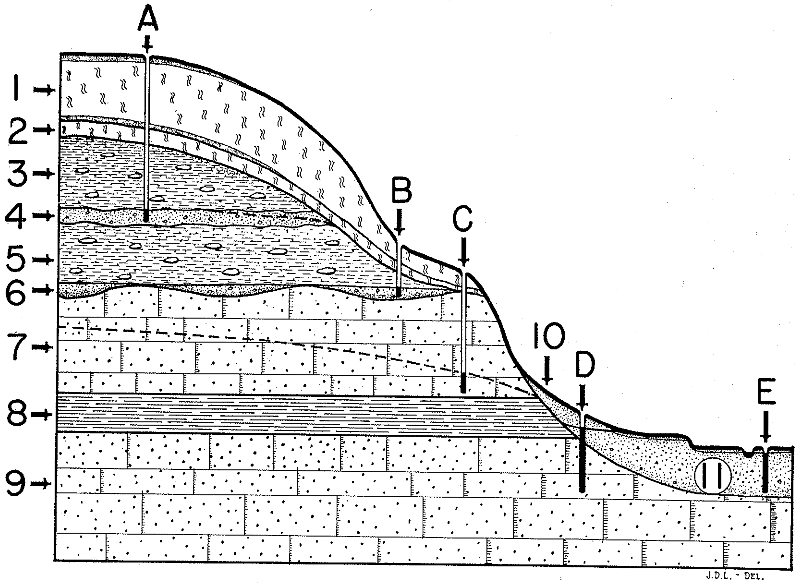


FIGURE 11.—A generalized cross-section in the vicinity of Blair, extending from the bluff lands to the Missouri River bottom land, view northward. Formations: 1, *Peorian* loess; 2, *Loveland* loess overlain by an old soil; 3, *Kansan* till sheet; 4, *Aftonian* sand and gravel; 5, *Nebraskan* till sheet; 6, subglacial sand and gravel; 7, *Dakota* sandstone; 8, *Fuson* shale; 9, *Lakota* sandstone; 10, colluvial silts and sands extending onto terrace; 11, alluvium of the Missouri River bottomland.

Well locations: A, Well extending to the *Aftonian* gravel; B, well extending to subglacial sand and gravel; C, well extending to lower part of the *Dakota* sandstone; D, well extending to the *Lakota* sandstone; E, well extending into the alluvial silt and sand of Missouri River bottomland.

PUBLICATIONS

It is believed that Nebraska well drillers appreciate the value of assistance secured from literature concerning the geology and water supplies of the region in which they are working and should avail themselves of every opportunity to add to their libraries. Publications of the Geological and Water surveys, both national and state, should be acquired when they are available and be preserved for future use. Unfortunately some of the most valuable papers yet published are no longer available by ordinary means and some may be found in only a few libraries. Therefore, it seems that the drillers should secure such literature as soon as possible before the supply is exhausted. Mr. W. R. Johnson of the Nebraska Survey was asked to prepare a list of publications which might be of use to well drillers and this list is included at the end of this paper.

ACKNOWLEDGEMENTS

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