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GEOLOGY AND GROUND-WATER RESOURCES OF WEBSTER COUNTY, IOWA

by

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Prepared Cooperatively by the United States Geological Survey and the Iowa Geological Survey

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The nomenclature and classification of rock units used in this paper are those of the Iowa Geological Survey and do not necessarily coincide with those accepted by the United States Geological Survey.

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FOREWORD

Modern studies of the underground and surface water resources of Iowa have been carried on in recent years by a cooperative effort of the U.S. Geological Survey and the Iowa Geological Survey with the aid and encouragement of other State and Federal departments, institutions, groups, and individuals. Some of the collected data are published in nation-wide Federal reports. It is felt, however, that material pertaining particularly to Iowa assembled in State bulletins would render the data more readily available and useful to interested persons in this State.

This report, Bulletin No. 4, Geology and Ground Water Resources of Webster County, is the first study of ground water to appear in the water resources bulletin series. One reason that Webster County was selected for study is that almost all municipalities, industries, and individuals within the county rely on the underground sources for their water supply. Inasmuch as ground water occurs in rocks and its quality and availability are largely controlled by rocks, the report contains a comprehensive treatment of the geology of the county in order that the ground-water resources may be better understood and utilized. Thus, the report should be useful not only to the users or potential users of ground water but to others who require basic geologic data.

Similar reports on other counties in the State are in preparation and will be published upon completion.

H. Garland Hershey
State Geologist

Iowa City, Iowa
September 1, 1955

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GEOLOGY AND GROUND-WATER RESOURCES OF WEBSTER COUNTY, IOWA

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WILLIAM E. HALE

ABSTRACT

Webster County, comprising an area of 718 square miles just northwest of the center of Iowa, had a population of 44,241 in 1950, with 25,115 in Fort Dodge, the principal city. Some 94.4 percent of the county is in farm land; corn is the principal crop and is used in the raising of hogs and cattle, an important occupation in this part of the country. Mineral products include gypsum, clay, coal, sand, gravel and limestone.

The mean annual precipitation at Fort Dodge is 31.21 inches, of which more than 3 inches normally occurs during each of the months May, June, July, August, and September. The average number of growing days is 150. The warmest month generally is July; during December, January, and February the average temperature normally is below freezing.

The upland area, comprising over 80 percent of the county, is mostly a gently undulating, slightly eroded glacial-drift plain. Morainal hills of low relief occur in the extreme southern and northern parts of the county. The Des Moines River flows through the county from north to south and, together with its tributaries, drains the entire county except the southwestern part, which is tributary to the Raccoon River. The Des Moines River has cut a deep, narrow valley about 90 feet below the upland in the northern part of the county and about 220 feet below the upland in the southern part. The tributary streams commonly have shallow valleys more than a few miles back from the Des Moines River.

Glacial deposits of Pleistocene age, ranging in thickness from 50 feet in the north to 175 feet in the south, mantle the indurated rocks over all the upland area, but indurated rocks ranging in age from Mississippian to Cretaceous are exposed in places along the valleys of the Des Moines River and its tributaries.

Rock cuttings obtained from many wells in Webster and surrounding counties give control on the subsurface geology. Red serpentinized basalt, presumably of pre-Cambrian age, was encountered in a well at a depth of 2,290 feet, or 1,310 feet below

sea level, at Fort Dodge. The stratigraphic sequence includes rocks of late Cambrian, Ordovician, Devonian, Mississippian, Pennsylvanian, Permian, and Cretaceous age. Rocks of Silurian, Triassic, and Jurassic age are not known to occur in the county.

In the northwestern part of the county, a thick section of shale and sandstone of Cretaceous age has been downfaulted in respect to adjacent limestone and sandstones of Paleozoic age. These strata rest on strata of undetermined age and appear to surround a core of igneous rock. Only the easternmost part of the structural basin lies in Webster County, the remainder being in Calhoun, Pocahontas, and Humboldt Counties. The abrupt lateral change in lithology, the contorted and brecciated condition of the strata, the circular outline, and the igneous core suggest a volcanic structure. Faulting has occurred also in the vicinity of Fort Dodge and has created a graben, about one-third of a mile wide at Fort Dodge, which trends in a direction somewhat north of east.

Many shallow wells obtain small quantities of hard water containing considerable iron from sands and gravels in the Pleistocene drift sheets. Two large sand-and-gravel-filled buried channels occur near Duncombe and Gowrie and give promise of yielding much water.

Cretaceous strata generally yield little water to wells in Webster County, even where thick because of downfaulting along the western margin of the county. The Fort Dodge formation of Permian age likewise contains little water, and the shales in the formation probably prevent recharge to underlying limestones from waterbearing beds in the drift.

Sandstones of Pennsylvanian age generally yield little water to wells, but where they occur as channel fills, particularly in the central part of the county, they yield moderate supplies.

Mississippian rocks form aquifers which supply many farm wells, particularly in the northern part of the county, and yield small to moderate supplies of hard water which may have an objectionably high fluoride content. Devonian strata yield little water to wells in Webster County, and unusually hard water can be expected because of the gypsum content in the Cedar Valley and Wapsipinicon limestones.

The St. Peter sandstone and the upper part of Prairie du Chien formation, both of Ordovician age, are relatively good aquifers, and yields of 50 to 200 gallons a minute with moderate drawdowns can be expected from them.

The most consistently high yielding zone of aquifers is formed by the lower part of the Prairie du Chien, the Jordan sandstone, and the St. Lawrence formation. The transmissibility of these beds is between 50,000 and 110,000 gallons a day per foot at Fort Dodge. The water from these aquifers is hard and in places contains objectionable concentrations of iron. The strata below the St. Lawrence formation are not promising as a source of water in Webster County, and the available water is likely to have a high chloride content.

The towns having municipal water-supply systems are Badger, Callendar, Dayton, Duncombe, Gowrie, Harcourt, Lehigh, and Fort Dodge. Yields from wells at Fort Dodge are abnormally high, probably because of the fractured condition of the strata; four wells finish in the Mississippian rocks, one in the Devonian rocks, and one in the Jordan sandstone. Water levels in the well field have declined from a reported elevation of 62 feet above land surface in 1911 to approximately the land surface in 1951. The pumpage from the field had increased to about 3.6 million by 1950. Water levels may be expected to decline between 1 and 2 feet a year if pumpage continues to increase at the same rate as during the past 15 years; but if pumpage is stabilized at 3.6 million gallons a day, the water levels may decline no more than 10 feet within the next 30 years. These postulated declines in water level will be accelerated by drilling any additional private wells that will draw water from the same water-bearing beds.

INTRODUCTION

Purpose and Scope of the Investigation

In order to utilize the ground-water resources of the State of Iowa to greatest advantage and to meet the increased demand for municipal, domestic, stock, and industrial supplies, the collection of detailed data on the occurrence and movement of ground water is necessary. Such studies have been carried on for years by the Iowa Geological Survey, and since 1938 its program of investigation of the ground-water resources has been in cooperation with the United States Geological Survey. As 90 percent of the population of Iowa depends on ground water for its supply, it is desirable to make the collected information available to the public. Reports presenting data on the geology and ground-water conditions within individual counties are therefore prepared. Based on intensive work begun in Cerro Gordo County in 1939 a detailed geologic and ground-water report is being prepared by H. G. Hershey, T. W. Robinson, and R. M. Jeffords. The detailed study of ground water in Webster County, to determine the recharge, movement, discharge, and quality of water available, began in August 1942 and continued intermittently through 1951. The work was started under the general administration of the late O. E. Meinzer, Geologist in charge of the Ground Water Branch of the United States Geological Survey, and was continued under the present Chief of the Branch, A. N. Sayre, and was under the direct supervision of H. Garland Hershey, Director of the Iowa Geological Survey and State Geologist.

In Webster County all the municipal water supplies are developed from wells, and most of the water for farm and industrial use is obtained from ground-water sources. Inasmuch as some rocks comprise the water-bearing beds and others form barriers to the replenishment of aquifers and restrict the movement of water, the occurrence of ground water is related directly to the geology. As the construction of wells is facilitated if the sequence of rocks at the well site is known in detail, this report gives information on the character, thickness, and extent of the several rock units in the county.

Location and Extent of the Area

Webster County is about 45 miles northwest of the center of the State (fig. 1). It extends from the south line of T. 86 N. to the north line of T. 90 N. and from the east line of R. 27 W. to

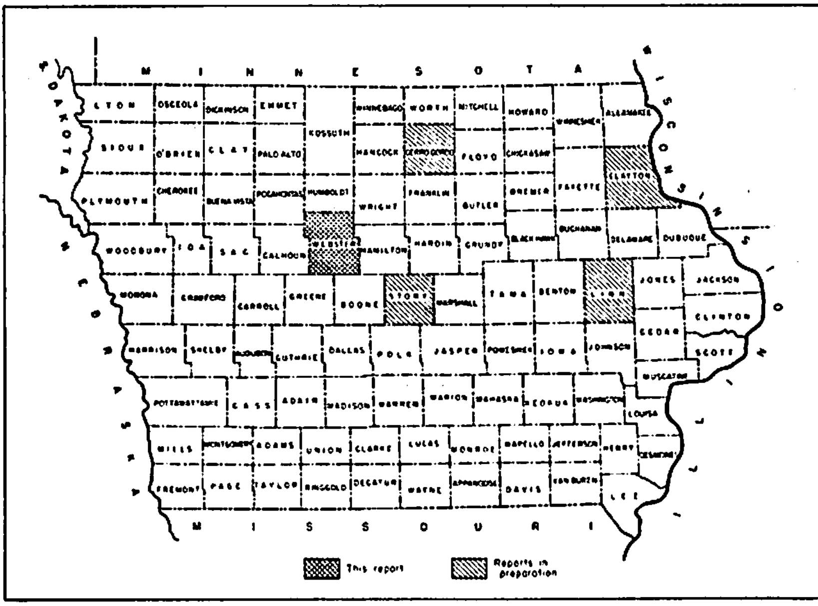


Figure 1.—Index map of Iowa showing Webster County and areas for which cooperative ground-water reports are in preparation. General information on ground-water conditions in each county of Iowa is given by Norton and others (1912). A continuing statewide program for the collection of data on the geology and ground-water conditions also provides basic information for most localities throughout Iowa.

the west line of R. 30 W., and includes an area of 718 square miles. The rectangular outline of the county is broken by the offsetting of the two northern tiers of townships about 2 miles to the west of the southern tiers of townships.

Previous Investigations

The exposures of indurated rocks along the Des Moines River in Webster County were studied during some of the earliest geologic work in the State, when river transportation was one of the easiest means of travel. Studies of the gypsum included those of Owen (1852, p. 125-128), Hall (1858, p. 142), White (1868, p. 135-141), McGee (1884, p. 258), Keyes (1894, p. 197-211; 1895, p. 259-304), Wilder (1923, p. 47-535), and Lees (1924, p. 113-120). Studies of the coal were made by Worthen (1858, p. 173-180), Hall (1858, p. 142), White (1870, p. 254-257, 293-303), and Keyes (1894, p. 197-211). Reports on the general geology and stratigraphy of Webster County were prepared by Wilder (1902, p. 185, 186), Lees and Thomas (1919, p. 599-616), and Van

Tuyl (1925, p. 282-284, 301-303). Reports presenting information on ground water in Webster County were written by Wilder (1902, p. 185, 186), Norton (1912, p. 188, 914-922; 1928, p. 80-90, 193-204, 206-210, 362; 1935, p. 321, 322), and Lees (1935, p. 372-375, 391-396). Analyses showing the mineral character of some ground waters in Webster County, with accompanying well descriptions, are given in a report by the State Planning Board (1938, p. 118).

Fluctuations of water level in observation wells in the county, together with data from other areas, are listed in Water-Supply Papers of the U. S. Geological Survey (1944-51, Iowa section).

Methods of Investigation

The field work for this report consisted of several parts. Data on well construction, geologic formations penetrated, and production and use of water were collected for about 350 wells, most of which obtain water from relatively shallow unconsolidated water-bearing beds. Water samples were collected from 40 representative wells in the county, and chemical analyses were made by the Iowa Geological Survey in the water laboratory of the State Hygienic Laboratory at Iowa City.

Measurements were made of the temperature of the water, depth to water level, depth of well, yield, and drawdown for many of the wells. More extensive tests were made to determine interference effects between the wells in the Fort Dodge city well field. Water levels were measured in a selected group of wells at 3-month intervals beginning in 1942, and an automatic recorder was installed in a shallow well near Harcourt to obtain detailed information on the fluctuations of water level. The elevations of many of the wells were determined, largely by differential barometric leveling, so as to determine the configuration of the surface of several geologic units.

Topographic maps published by the U. S. Geological Survey aided in establishing horizontal and vertical control; the Lehigh and Fort Dodge quadrangles cover approximately the eastern two-thirds of the county. The general highway and transportation map of Webster County of the Iowa State Highway Commission was modified to produce base maps for the investigation.

The consolidated rocks, where exposed by stream erosion of glacial materials, were studied principally during October and November 1949 and at infrequent intervals during 1950 and 1951. The geology of the consolidated rocks in most of Webster County, however, had to be worked out from the study of drill cuttings and drillers' logs. All well cuttings obtainable in Iowa are examined and plotted graphically to scale in the office as a routine phase of the statewide subsurface geologic studies.

Wells have been assigned numbers based on the public-land-survey divisions so that in referring to a well it generally is unnecessary to give a description of its location. The number is in three units separated by hyphens. The first unit represents the township number; the second unit represents the range number; the third unit represents the section and the location of the well in a 40-acre tract within the section. The subdivision of the section is represented by letters to indicate the 40-acre tract in which the well is located, as shown in figure 2. If there

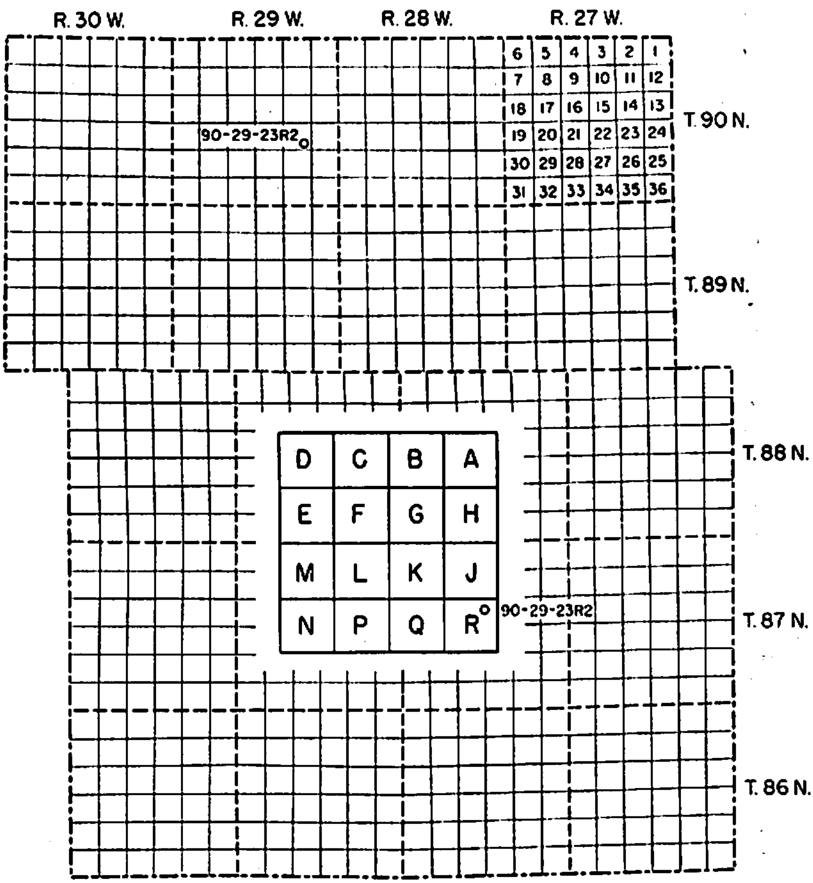


Figure 2.—Map of Webster County illustrating the well-numbering system used in this report. The inset shows the method used in subdividing the section into quarter-quarter sections for indicating location of wells.

is more than one well in a 40-acre tract, a number is added after the letter symbol. For example, well 90-29-23R2 represents the second well located in the SE¼SE¼ sec. 23, T. 90 N., R. 29 W.

Acknowledgments

The residents of Webster County cooperated in supplying information on their water supply and in permitting measurements at their wells. Drilling firms operating in the county were particularly cooperative in saving samples of well cuttings and supplying data on well construction and yield. Information on the municipal water supplies was generously given by the water superintendents. In particular, J. W. Pray, Manager of the Department of Municipal Utilities, Fort Dodge, devoted considerable time supplying data on the city well field.

Several present and past members of the Geological Surveys have supplied information which has aided in preparing the report. They have examined and correlated many sets of drill cuttings and have made subsurface studies that permit increasingly reliable correlation of the well records. Assistance was given by them also in measuring water levels and pump yields, collecting water samples, and interpreting certain phases of the geology.

Figures and plates were prepared by or under the supervision of George J. Degenfelder of the Iowa Geological Survey.

The theory expressed as to the origin of the structural features of the Manson area was developed by C. R. Murray of the U. S. Geological Survey and the description of it in this report is based on discussions with him.

GEOGRAPHY

History

The history of Webster County is reviewed comprehensively by Pratt (1913) and only a brief summary is included here. Prior to 1850 there were only a few widely scattered farms in this part of Iowa. The few settlers, fearing trouble with the Indians, requested protection of the United States Army. As a result, a military post, named Fort Clarke, was established in 1850 on high ground east of the Des Moines River and south of Soldier Creek. The name of the post was changed to Fort Dodge in the following year. The Fort was abandoned in 1853, but it formed the nucleus for the city of Fort Dodge.

By 1852 the population of the area was reported to be 243, and need was increasing for local governmental organization. The General Assembly of Iowa provided for the organization of Webster County on January 22, 1853, and the first official action by the county was taken in May 1853. A dispute arose over the selection of a county seat, but Fort Dodge was selected in 1856. A year later the county was reduced to its present size when the eastern townships were separated from it to form Hamilton County.

Topography and Drainage

Webster County is in the western lake section of the Central Lowland physiographic province of the Interior Plains division (Fenneman, 1928), which is composed of young glacial plains, moraines, lakes, and lacustrine plains. Most of the county exhibits the constructional topography developed by the deposits left by the last ice sheet that invaded the area. The land surface is very gently undulating over large areas (pl. 5A) ; the greatest relief occurs in the vicinity of the Des Moines River and the mouths of tributary streams.

A slightly eroded upland area includes at least 80 percent of the area of the county and, in general, ranges between 1,100 and 1,200 feet in altitude. The land surface is somewhat higher in the western, northern, and extreme southern parts of the county than in the central and eastern parts. Small morainal hills of low relief (pl. 5C) extend across the county along the southern border and through the northern two-thirds of the county. The hills in the latter area, somewhat higher than the hills to the south, increase in relief toward the north. Numerous shallow depressions which formerly contained water or mud flats which greatly

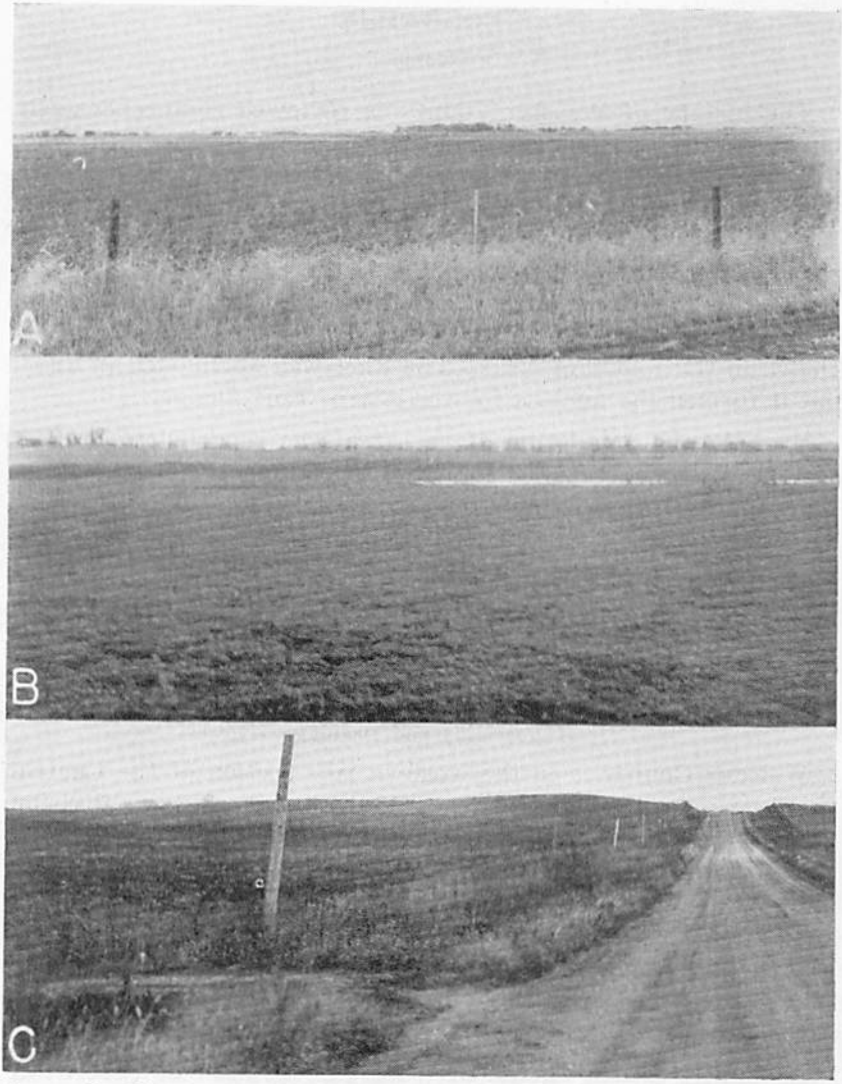


PLATE 5.—VIEWS OF UPLAND TOPOGRAPHY IN WEBSTER COUNTY. *A*, VERY GENTLY UNDULATING SURFACE OF THE MANKATO DRIFT IN SEC. 1, T. 87 N., R. 29 W.; *B*, POND IN DEPRESSION ON THE MANKATO DRIFT SURFACE IN THE SE¼ SEC. 5, T. 90 N., R. 30 W.; *C*, MORAINAL HILLS IN SEC. 26, T. 90 N., R. 29 W.

restricted farming and hampered travel occur on the upland area. Drainage works were well established by 1912 (Pratt, 1913, p. 253, 254), and only a few swampy areas now remain (pl. 5B).

The Des Moines River, which is the principal stream, has cut a deep, narrow valley from where it enters the county near the center of the northern boundary to where it leaves the county near the eastern end of the southern boundary. The valley is generally less than three-fourths of a mile in width, but locally, as near the junction with the Boone River in the southern part of the county and also about 2 miles north of Fort Dodge, it is more than a mile wide. In places, consolidated rocks form cliffs 50 feet high, and the relief between the river and the upland area is about 90 feet in the northern part of the county and about 220 feet in the southern part (pl. 6A). The sandstone bluffs extending about 8 miles along the river north of Lehigh, and now partly included in Dolliver State Park, were noted especially by several geologists; Lees (1916, p. 516) states:

"Below Kalo massive, yellow, cross-bedded sandstone forms the walls as far as Lehigh, though covered along much of this distance with a veneer of drift. The bare rocky walls of the master gorge, presenting occasional vertical cliffs forty to fifty feet in height, are exceedingly picturesque and make delightfully attractive spots when framed in the verdant mantle which clothes much of the floor and slopes of the valley. With the increasing depth of the gorge the picture becomes more charming and where, as at Lehigh, the bluff rises at one sweep 190 feet from the water's edge to the upland levels it is one which will be excelled with difficulty in the landscape of central Iowa."

Terraces, representing remnants of the flood plain of the Des Moines River when it flowed at higher levels, occur along

PLATE 6.—VIEW OF THE DES MOINES RIVER VALLEY IN THE SOUTHWESTERN PART OF THE COUNTY LOOKING NORTHEAST FROM THE NW¼ SEC. 21, T. 86 N., R. 27 W.

the sides of the valley, and a relatively large one, approximately 50 feet above river level, is preserved along the right bank about 2 miles south of the Humboldt County line. Additional terraces were noted in secs. 14, 23, and 26, T. 88 N., R. 28 W., and along the right valley wall near the junction with Boone River.

The largest tributary of the Des Moines River in the county is Lizard Creek, which has a general southeasterly trend and after making a series of right-angle turns flows eastward into the river at Fort Dodge. South Lizard Creek trends roughly parallel to Lizard Creek but swings northeastward to join Lizard Creek before the latter joins the River. Both creeks have cut deep, narrow valleys over much of their course in the county, but in the exteme western part South Lizard Creek meanders on the surface of the drift plain. Extensive high-level terraces about 1,100 feet above sea level and about 25 feet below the upland level just west of Fort Dodge are preserved along much of Lizard Creek and along the lower part of South Lizard Creek (pl. 9A).

Other tributaries to the Des Moines River are Bass, Deer, and Badger Creeks in the northern part of the county; Soldier, Gypsum, and Holiday Creeks in the central part; and Prairie, Crooked, Brushy, and Skillet Creeks in the southern part. These smaller streams are deeply incised near their mouths, but within 5 to 10 miles from the Des Moines River they become sluggish streams, which, for the most part, have been straightened and deepened artificially to carry off water from tile drains on the adjacent farm lands and to minimize flood damage. The Boone River joins the Des Moines River near the southern end of the eastern boundary of the county, but its valley does not comprise an appreciable area in Webster County.

The Des Moines River and its immediate tributaries drain the entire area except the southwestern part, which is drained by the southward-flowing West and East Buttrick Creeks, tributaries of the Raccoon River. These streams have developed only very shallow valleys in the drift.

The discharge of the Des Moines River was measured at Kalo, about 7 miles downstream from Fort Dodge, from October 1913 to September 1929. The mean daily discharge at the gaging station at Kalo (Crawford, 1942, p. 70) is given in table 1.

Records of the flow of the Des Moines River and its tributaries are given by the Iowa State Planning Board (1935), Crawford (1942 and 1944), and the U. S. Geological Survey (1952). These records include discharge measurements on the East Des Moines

TABLE 1. MEAN DISCHARGE, IN CUBIC FEET PER SECOND (cfs), OF DES MOINES RIVER AT KALO

A discharge of 1 cfs is equivalent to 448.8 gallons per minute (gpm).

Calendar year	Discharge (cfs)	Calendar year	Discharge (cfs)
1914	958	1921	1,290
1915	3,870	1922	796
1916	1,890	1923	465
1917	1,560	1924	764
1918	1,200	1925	456
1919	2,220	1926	554
1920	2,160		

River near Hardy, the West Des Moines River at Humboldt, both in Humboldt County, the Des Moines River near Boone in Boone County, the Boone River at Webster City in Hamilton County, and Lizard Creek near Clare in Webster County. A recording gage was installed at the gaging station at Fort Dodge below the mouth of Lizard Creek in December 1949.

Climate

The following brief summary of climatic conditions in Webster County is based on data published by the Weather Bureau, U. S. Department of Commerce. The climate is subhumid, the average annual precipitation at Fort Dodge being 31.13 inches (fig. 3), which is 0.34 inch below the average for the State. The greatest precipitation falls during the months of May through September (fig. 4) averaging about 4 inches in each of these 5 months.

There is a large annual range in temperature (fig. 4), the hottest days occurring in July (monthly average 74° F.) and the coldest during December, January, and February, when the average monthly temperatures are below freezing.

The length of the growing season (fig. 4) averages about 150 days; the last killing frost in the spring occurs in April or May and the first in September or October.

Natural Resources and Related Industries

The principal natural resources of Webster County are surface and ground water, soil, gypsum, shale, coal, sand and gravel, and limestone. Surface water and ground water are generally

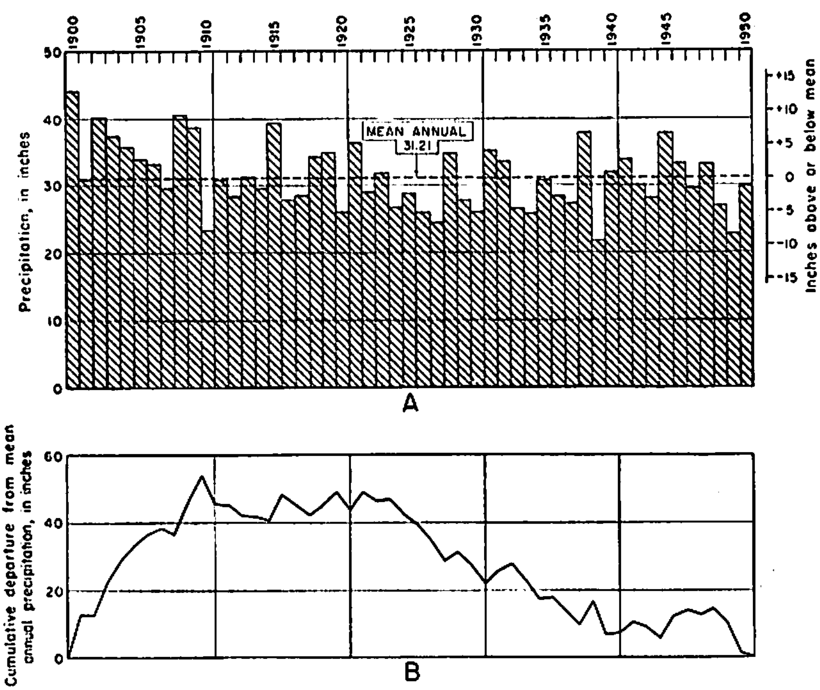


Figure 3.—Graphs showing (A) annual precipitation and (B) cumulative departure from mean annual precipitation at Fort Dodge, Iowa. (Basic data from records of the U. S. Weather Bureau.)

so abundantly available, at relatively little cost, that their value as a resource is often underestimated. Surface water has been discussed briefly under the heading of drainage, and ground water will be discussed at length in other parts of the report.

The soils of the county are very fertile and together with proper drainage and the favorable climate make the county a part of one of the most productive farming areas in the United States. For a comprehensive discussion of the soils the county the reader is referred to Stevenson (1918). The products relating to the soil are discussed under the heading of agriculture.

The production and processing of gypsum in Iowa is confined now to a small area southeast of Fort Dodge (pl. 7). The gypsum occurs primarily as a single bed, which has a maximum thickness of 30 feet and crops out along the walls of the Des Moines Valley and a few of its tributary valleys in and south of Fort Dodge. Under the upland area the gypsum is overlain by 50

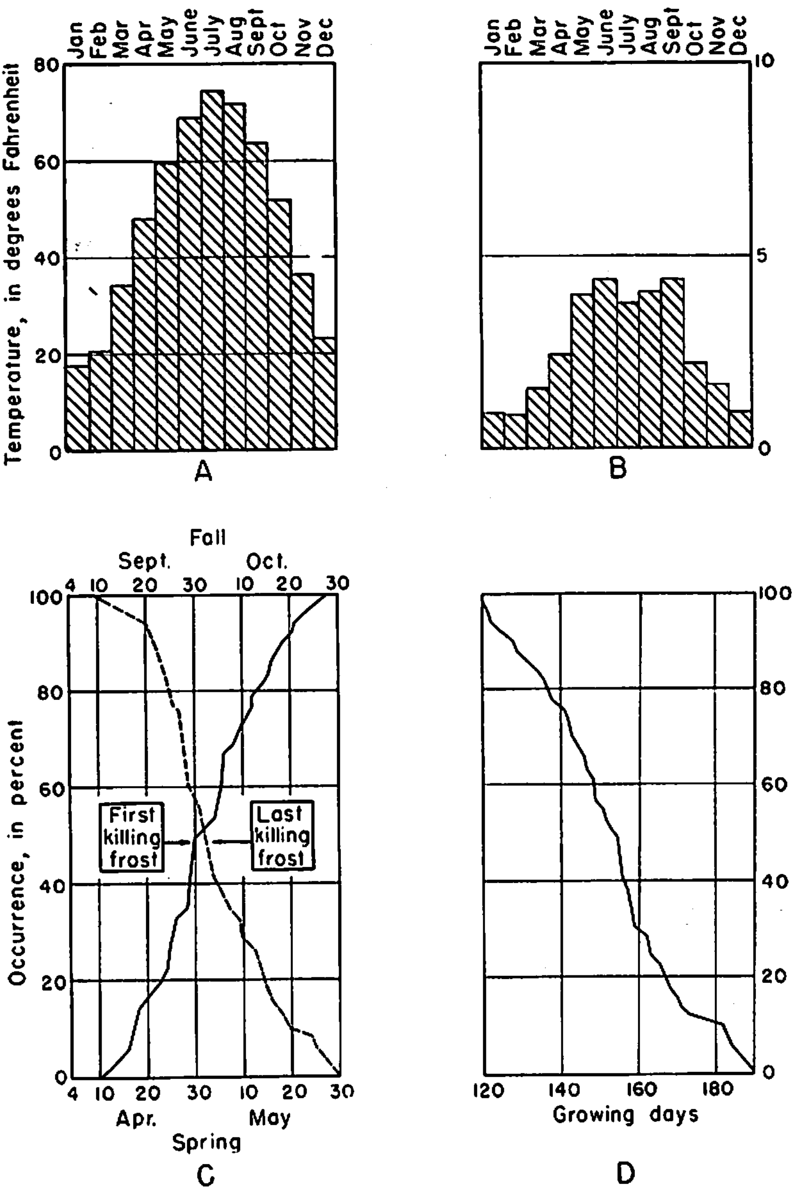


Figure 4.—Graphs showing (A) average temperature by months, (B) average precipitation by months, (C) occurrence of first and last killing frosts, and (D) length of growing season at Fort Dodge, Iowa. (Basic data from records of the U. S. Weather Bureau.)

to 70 feet of shale and drift. The areal distribution of the gypsum as indicated by Wilder (1923, pl. 1) is shown in figure 5.

The gypsum has been obtained from hillside quarries, one drift and several shaft mines, and open pits. The trend has been

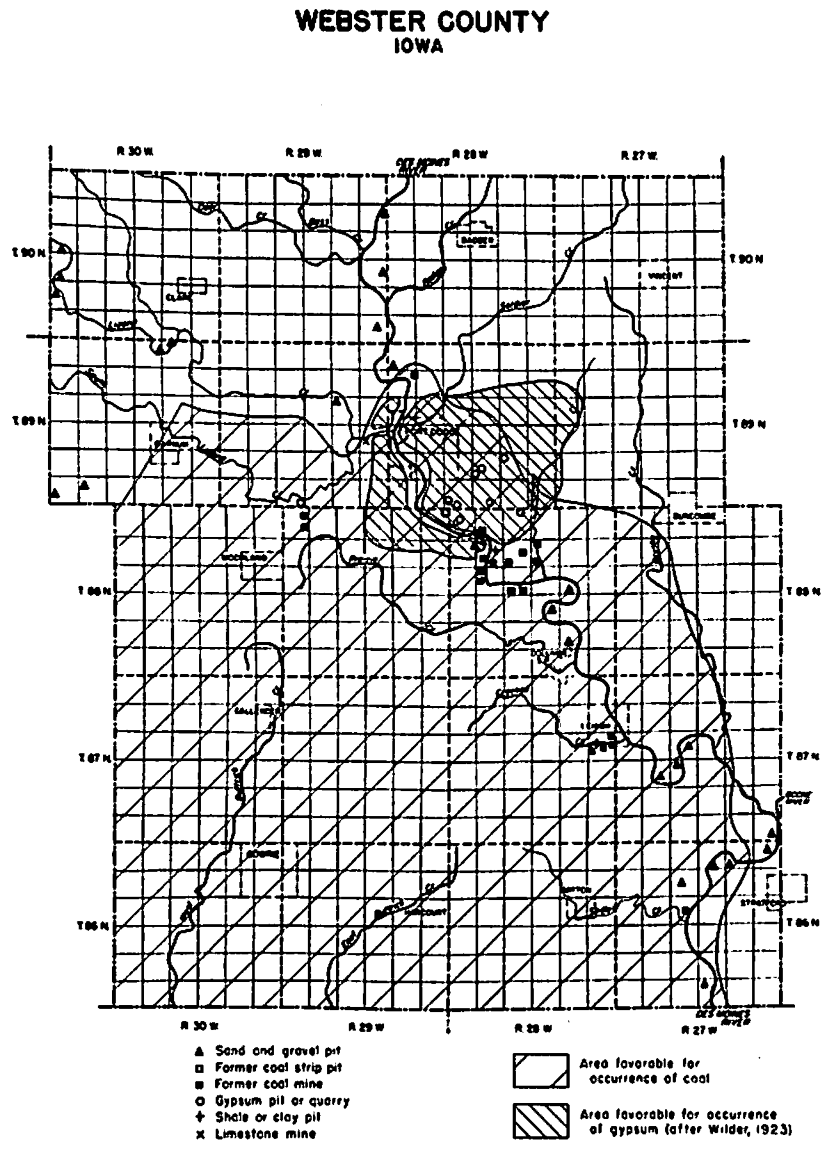


Figure 5.—Map of Webster County showing location of gypsum quarries, shale pits, sand-and-gravel pits, limestone mines, and former coal mines; also areas favorable for occurrence of coal and gypsum.

toward the development of open pits, as machinery capable of removing the overburden economically became available (pl. 7). More gypsum can thus be obtained from an acre by stripping than from mines, because in mines a considerable amount must be left as pillars. No accurate estimate of the reserves of gypsum

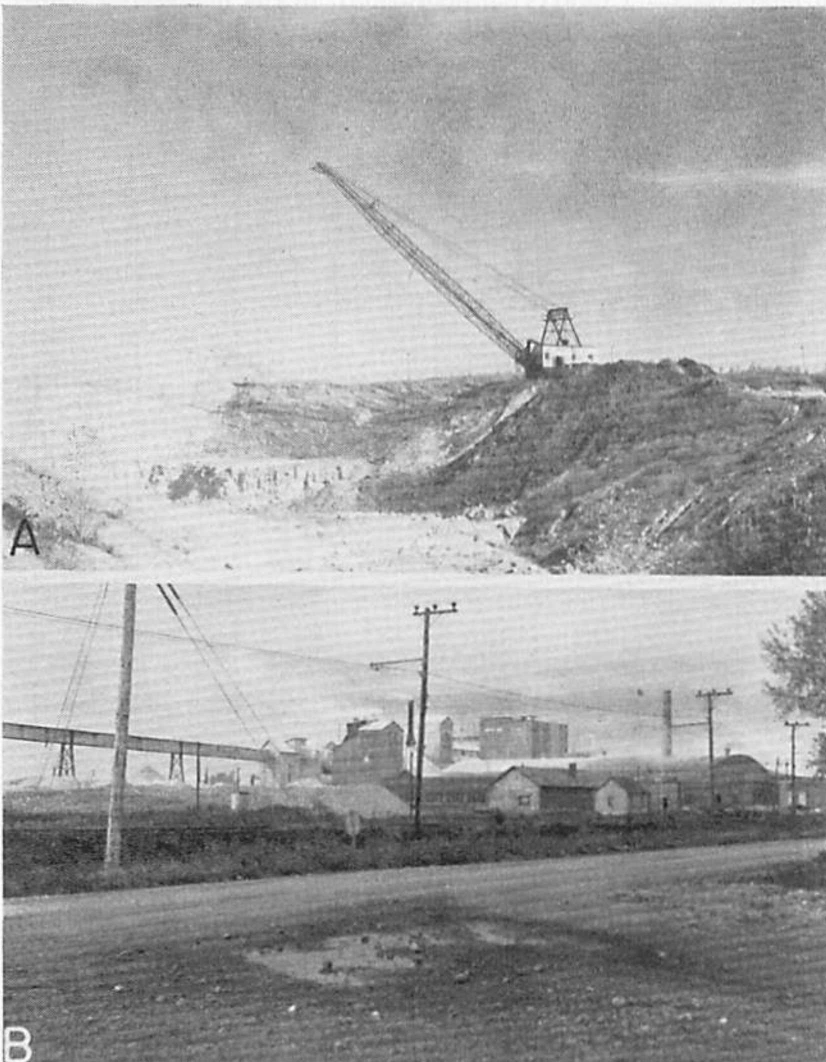


PLATE 7.—*A*, GYPSUM QUARRY IN THE NW¼ SEC. 26, T. 89 N., R. 28 W., SHOWING THE THICK BED OF GYPSUM AND THE SHALE AND DRIFT OVERBURDEN; *B*, PLANT FOR MANUFACTURING GYPSUM PRODUCTS, LOCATED NEAR FORT DODGE, IOWA.

is available, but Wilder (1923, p. 181) estimated that the Fort Dodge field could sustain an output of 2 million tons a year for 75 years. This estimate probably should be increased now because of the improved methods of recovery.

Five companies now mine and process gypsum near Fort Dodge, and two concerns sell crude gypsum, obtained as a by-product of other quarrying operations, to the processing plants. Gypsum products include principally plaster, plasterboard, wallboard, and construction blocks. The production of crude gypsum from 1895 to 1949 is shown in figure 6.

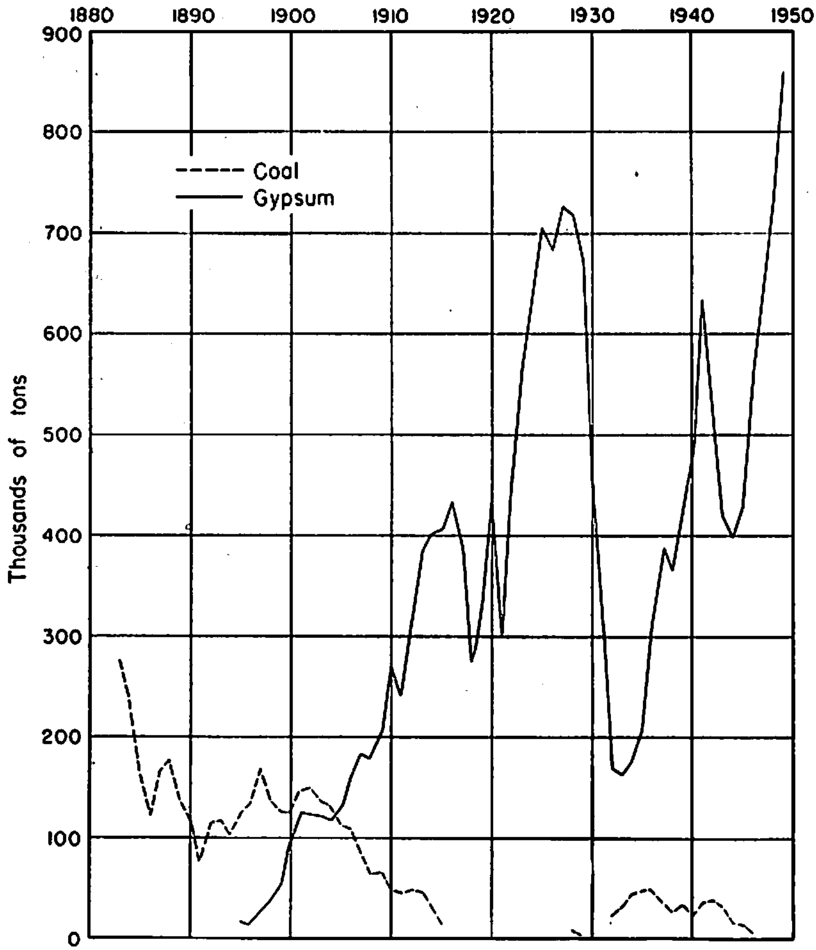


Figure 6.—Graphs showing production of coal and crude gypsum in Webster County.

Some shales of Pennsylvanian age are satisfactory for the manufacture of brick and tile, and several shale pits have been developed along the valley walls of the Des Moines River (pl. 8). Formerly, several brick and tile plants were located in Fort

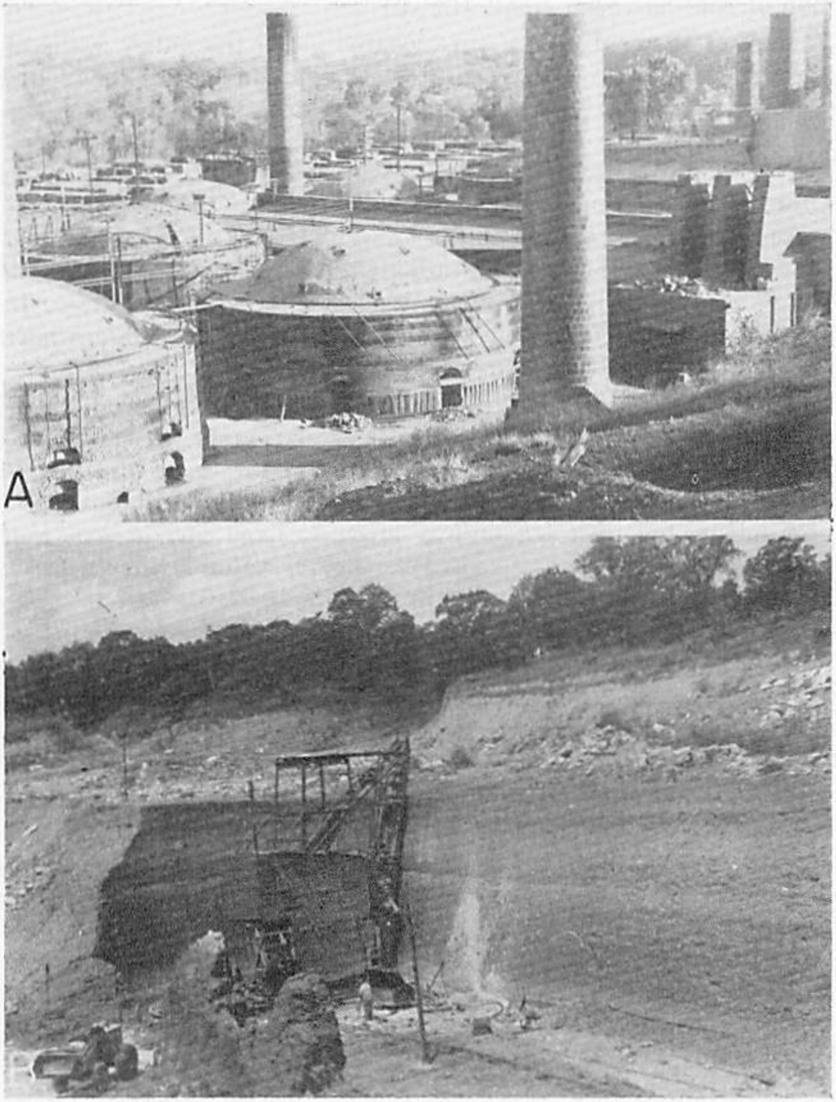


PLATE 8.—*A*, BRICK AND TILE PLANT IN THE DES MOINES VALLEY SOUTH OF FORT DODGE SHOWING FIRING KILNS; *B*, SHALE PIT WITH OPERATING PLANER BY WHICH RAW MATERIAL IS OBTAINED FOR MANUFACTURE OF CLAY PRODUCTS. (Photograph by R. M. Jeffords.)

Dodge, but the four plants now in operation are in the Des Moines valley south of Fort Dodge (fig. 5).

Webster County contains some of the most northerly workable coal beds in the State, and it formerly ranked high among the coal-producing counties; however, in recent years the production of coal has been small (fig. 6).

Most of the coal mines were located along the valley walls of the Des Moines River between Fort Dodge and a point just south of Lehigh. Hinds (1909, p. 34-54) divides the area into seven mining districts as follows: Fort Dodge, Kalo, Coalville, Holiday Creek (comprising the Coalville Basin of Wilder, 1902, p. 90), Otho, Linnburg, and Tara districts. The most productive areas were the Coalville basin and the Lehigh district. Workable thicknesses of coal probably occur outside the areas already developed, but extensive exploration work is needed to define localities. In general, the more favorable areas are south of Fort Dodge, where coal-bearing Pennsylvanian rocks are thickest.

Analyses of coals in Webster County are given in table 2. This table shows that coals from Webster County are similar to other Iowa coals and, compared with other low-rank bituminous coals, are high in moisture, volatile matter, total combustibles, and sulfur; but they are slightly lower in fixed carbon, ash, and calorific value. On the basis of the calorific value determined for the coal from the Corey mine at Lehigh, the coals fall into the high-volatile C bituminous-coal class.

Sand and gravel are obtained principally from terraces along the Des Moines River and Lizard Creek (pl. 9A) in Webster County, although some has been taken from the scattered kames and eskers in the more hilly areas of the county. The material is used for road surfacing and for concrete aggregate, but the content of shale pebbles is reported to be too high for use in some types of concrete. The location of gravel pits that are operating and those known to have been operated is shown in figure 5.

The St. Louis limestone and sandstones of Pennsylvanian age have been quarried in places along the Des Moines River and its tributary, Soldier Creek. The rock was used locally for foundations and retaining walls. One of the more important sandstone quarries was located in the NW¼NE¼ sec. 14, T. 88 N., R. 28 W. (Beyer and Williams, 1907, p. 479, 480), where about 15 feet of sandstone was worked; at one time this was the most extensive sandstone quarry in the State. At present,

TABLE 2. PROXIMATE ANALYSES OF COALS FROM WEBSTER COUNTY (after Lees and Hixon)

Locality and sample	Moisture	Total combus-tibles	Ash	Volatile combus-tible matter	Fixed carbon	Coke—(fixed carbon plus ash)	Sulfur			Calorim-etry B.T.U.	Authority
							In sulfides	In sulfates	Total		
Collins mine No. 6, Coalville	7.48	84.06	8.44	39.52	44.54	52.99	4.98	0.26	5.24	....	G. E. Patrick
Collins mine No. 4, Coalville	7.80	82.88	9.32	37.74	45.14	54.46	3.97	0.12	4.09	....	do
Old Reese mine, Fort Dodge	9.92	48.77	41.31	29.69	22.08	63.39	....	....	....	....	do
Carlson mine, Kalo	10.10	76.53	13.36	32.83	43.69	57.06	1.68	0.18	1.86	....	do
Craig Cannel mine, Kalo, cannel coal	5.87	78.26	15.87	39.04	39.22	55.09	6.87	0.25	7.12	....	do
Craig, slope, Kalo, bituminous	8.46	81.37	10.17	37.97	43.40	53.57	5.19	0.10	5.29	....	do
Crooked Creek mine, Lehigh, top of seam	7.74	78.94	13.32	34.47	44.47	57.79	4.83	0.81	5.64	....	do
Crooked Creek mine, middle of seam	8.52	82.65	8.83	38.64	44.01	52.84	3.71	0.48	4.19	....	do
Crooked Creek mine, bottom of seam	8.57	81.86	9.57	37.57	44.29	53.86	3.47	0.18	3.65	....	do
Crooked Creek mine shaft, Lehigh	6.99	76.66	16.34	34.40	42.26	58.60	5.67	0.37	6.04	....	do
Corey mine, Lehigh	7.77	81.27	11.00	38.05	43.21	54.21	7.02	0.68	7.70	....	do
Corey mine, Lehigh	....	85.96	14.04	37.98	47.98	....	....	....	5.90	12,431	Iowa State College
Colburn mine, Fort Dodge	13.02	80.60	6.38	37.54	43.06	49.44	....	....	....	....	J. D. Whitney
Colburn mine, calculated on dried coal	....	92.66	7.34	43.16	49.50	56.84	....	....	....	....	do
Sec. 18, T. 88 N., R. 28 W	14.95	77.87	7.18	34.98	42.89	50.07	....	....	0.81	....	do
Same, calculated on dried coal	....	91.56	8.44	41.13	50.43	58.87	....	....	....	....	do
Sec. 13, T. 88 N., R. 28 W.	9.46	73.35	17.10	33.69	39.66	56.85	....	....	2.52	....	do
Same, calculated on dried coal	....	81.01	18.99	37.21	43.80	62.70	....	....	....	....	do
Rees mine, Fort Dodge	14.05	77.61	8.34	36.42	41.19	49.53	....	....	....	....	Rush Emery
Same, calculated on dried coal	....	90.32	9.68	42.38	47.94	57.62	....	....	....	....	do
Cannel Coal, Sec. 17, T. 88 N., R. 29 W	10.46	74.37	15.17	37.44	36.93	52.10	....	....	....	....	do
Same, calculated on dried coal	....	83.06	16.94	41.80	41.26	58.20	....	....	....	....	do
Sec. 17, T. 88 N., R. 28 W	10.13	73.33	16.54	37.25	36.08	52.62	....	....	....	....	do
Same, calculated on dried coal	....	81.59	18.41	41.44	40.15	58.56	....	....	....	....	do
Collins mine, Coalville	13.91	78.83	7.26	37.00	41.83	49.09	....	....	....	....	do
Same, calculated on dried coal	....	91.57	8.43	42.98	48.59	57.02	....	....	....	....	do
Cannel Coal, Rees mine, Fort Dodge	9.92	48.77	41.31	26.69	22.08	63.39	....	....	....	....	do
Same, calculated on dried coal	....	54.14	45.86	29.63	24.51	70.37	....	....	....	....	do
Average of county, 4 samples	12.14	76.04	11.82	37.03	39.01	50.83	....	....	....	....	do
Same, calculated on dried coal	....	86.64	13.36	42.15	44.49	57.85	....	....	....	....	do
Tyson seam, near Lehigh	12.70	77.03	10.27	44.12	32.91	....	....	....	5.33	....	Iowa State College
Lehigh	17.47	70.94	11.59	31.35	39.59	....	....	....	4.87	....	do
Average of 10	7.83	80.65	11.52	37.23	43.42	....	....	....	5.08	....	do

no sandstone or limestone quarries are in operation, but limestone for agricultural purposes, road surfacing, and concrete aggregate is being produced from a mine west of Fort Dodge (pl. 9B). Beds below the St. Louis limestone and above the Gilmore City limestone are worked.

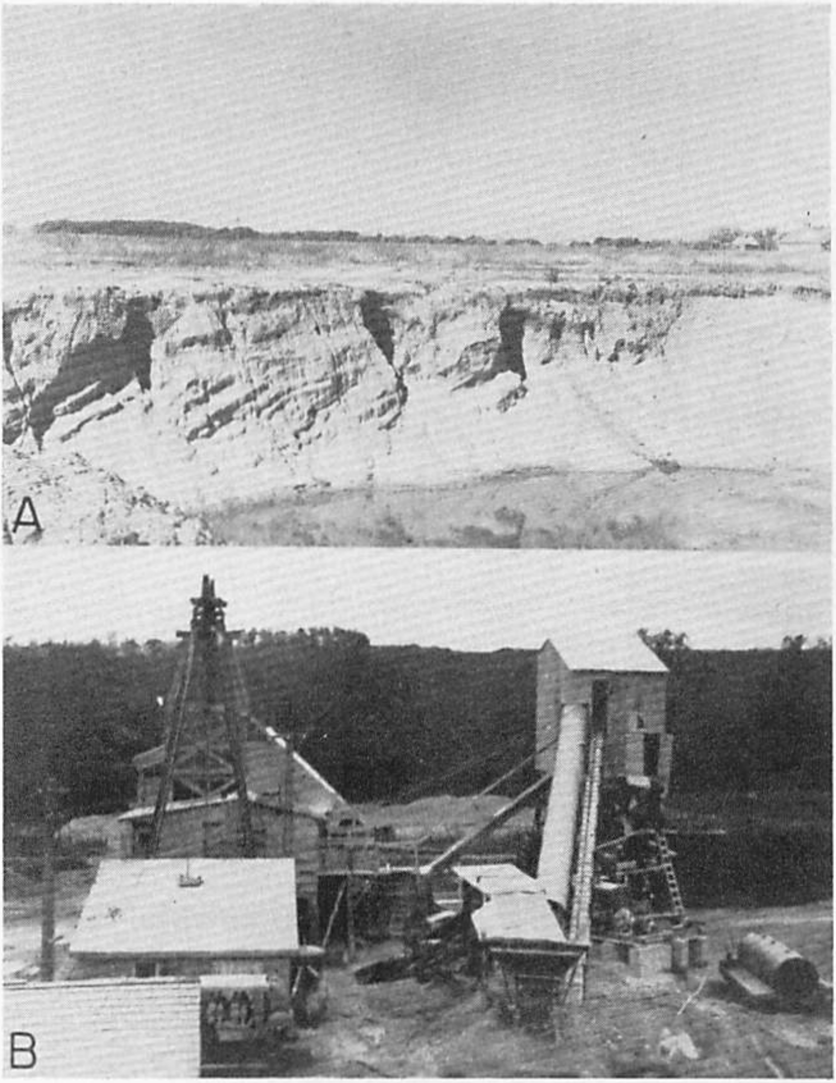


PLATE 9.—*A*, SAND AND GRAVEL PIT ON THE HIGH TERRACE IN THE VALLEY OF LIZARD CREEK NEAR THE CENTER, SEC. 14, T. 89 N., R. 29 W., SHOWING THE FLAT SURFACE OF THE TERRACE AND INDICATING THE EXTENSIVE NATURE OF THE DEPOSIT; *B*, TIPPLE OF LIMESTONE MINE AND CRUSHING PLANT LOCATED IN THE NW¼SW¼ SEC. 24, T. 89 N., R. 29 W.

Beyer and Wright (1914, p. 601) predict that quarrying is not likely to become an important industry in the county because of the poor quality of rocks and their limited availability.

Agriculture and Related Industries

About 94.4 percent of the land area in Webster County is in farms (U. S. Census, 1940), although not all the area is cultivated. The principal crops are corn, oats, and soybeans (table 3), and a small amount of wheat, barley and rye are grown. The feeding and marketing of cattle and hogs is an important occupation, and considerable milk is produced and sold to creameries in the area. A large meat-processing and packing plant is located at Fort Dodge, and a few concerns in the locality manufacture farm equipment and animal serums.

Table 3.—Crops of Webster County, 1949.
(Data from Iowa Year Book of Agriculture, Iowa State Department of Agriculture, 1950.)

CROP	ACREAGE
Corn	180,568
Oats	105,519
Soybeans	38,988
Hay, all kinds	18,557
Flaxseed	1,600

Population

Only a few settlers were in Webster County before 1850, but the population increased to 2,504 by 1860. To about 1900 the population increased at a relatively uniform rate of about 750 a year,

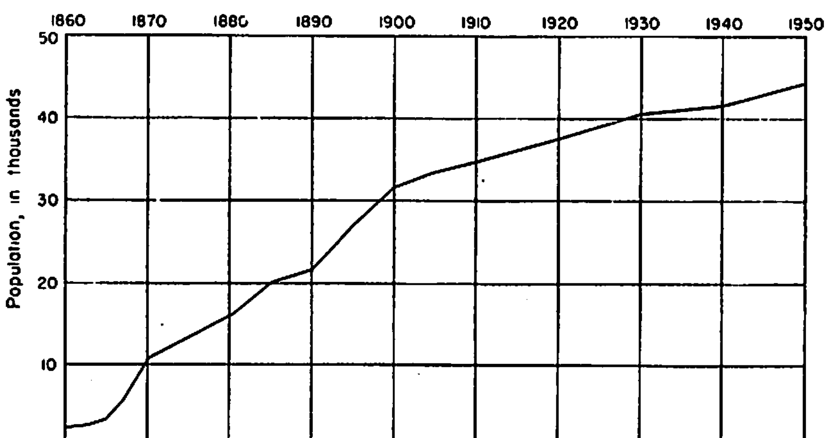


Figure 7.—Graph showing trend in population of Webster County (data from Pratt, 1913, and U. S. Bureau of the Census reports).

TABLE 4. POPULATION OF CITIES AND TOWNS IN WEBSTER COUNTY

	Population			
	1920	1930	1940	1950
Webster County	37,611	40,425	41,521	44,241
Cities and towns	24,336	26,097	27,770	30,053
Badger	244	254	251	301
Barnum	137	148	184	193
Callender	376	349	377	387
Clare	259	254	232	179
Dayton	836	713	732	793
Duncombe	442	354	341	378
Fort Dodge	19,347	21,895	22,904	25,115
Gowrie	895	1,050	1,028	1,052
Harcourt	307	204	282	303
Lehigh	1,090	996	1,004	881
Moorland	181	179	215	248
Stratford (part in Webster County)	39	38	34	a30
(total)	694	699	712	673
Vincent	182	194	192	193

to a total of 31,775. Since 1900 the increase has continued, but at a slower rate (fig. 7); by 1950 the population was 44,241. (See table 4.)

For the past 30 years the increase in population has been mainly in the cities, the towns of the county showing no appreciable change (table 4). The population of Fort Dodge has continued to increase, and in 1950 the city ranked thirteenth in the State, with a population of 25,115. The population of the farms and small unincorporated communities has changed only slightly, from about 13,300 in 1920 to about 14,200 in 1950.

Transportation

The county is served by six railroads connecting with larger cities to the north, east, south and west (pl. 1). A line of the Illinois Central Railroad extends east-west across the county through Duncombe, Fort Dodge, and Barnum. The Chicago Great Western Railway crosses the county in a northeast-southeast direction through Vincent, Fort Dodge, and Moorland. A line of the Chicago & Northwestern Railway extends through Stratford, Dayton, Harcourt, and Gowrie in the southern part of the county. The Fort Dodge, Des Moines & Southern Railway begins at Fort Dodge and extends through Lehigh, Harcourt, and Gowrie. The Minneapolis & St. Louis Railway has two lines in the county, one extending from the north county line southward through Badger to Fort Dodge, and the other crossing the western part of the county through Clare, Moorland, Callender, and Gowrie. The Chicago, Rock Island, & Pacific Railroad crosses the southwestern part of the county through Gowrie.

U. S. Highway 20 extends in a general east-west direction through Duncombe, Fort Dodge, and Moorland, and U. S. Highway 169 is a north-south highway extending through Harcourt and Fort Dodge. State Highway 5 starts at Fort Dodge and extends westward near Barnum. State highways also link the towns of the county with the two Federal highways. Nearly all the county is traversed by section-line roads, many of which are graveled.

Fort Dodge has regular airline service from an airport located north of the city.

A pipeline carrying natural gas has been laid through the eastern part of the county, and a branch line serves Fort Dodge.

GENERAL GEOLOGY

Rocks are defined as the aggregates of minerals forming the crust of the earth. Under this broad definition there are three main classes of rocks, subdivided according to differences in origin, composition and texture. Igneous rocks have their origin in molten masses that rise and solidify near or at the surface in various forms. Sedimentary rocks are formed by the physical accumulation of particles transported and deposited by various means, by precipitation from solution, or from organic remains. Metamorphic rocks are formed from the alteration of sedimentary and igneous rocks by pressure and heat.

Although sedimentary rocks quantitatively constitute only a small fraction of the rocks in the earth's crust, they form a thin, interrupted mantle over the more abundant igneous and metamorphic rocks. Because of their easily accessible position and chemical and physical properties they have great economic importance. The composition and texture of sediments depend upon the conditions under which they were deposited; thus they may be very heterogeneous even within small areas or uniform over large areas.

As sediments continue to be deposited, later layers are superimposed on earlier formed ones. This superposition combined with the preservation of remains of plants and animals showing different stages of evolution forms the basis of the geologic time table.

Once deposited, the sediments are subjected to other geologic processes, time again being a factor in the amount of change they undergo. They are frequently compacted and consolidated; folded and faulted; uplifted, weathered, and eroded; and submerged and covered by new sediments. The sum total of these processes is the stratigraphic column of today. Differences in the rate and duration of deposition and erosion at various places account for the marked differences in the geologic section from place to place. Study of the results produced and the processes involved constitutes an important part of the science of geology.

Summary of Stratigraphy and Geologic History

Pre-Cambrian igneous and metamorphic rocks comprising the basement complex underlie Webster County at depths probably less than 3,000 feet. The basement complex is overlain by a succession of stratified sedimentary rocks that range in age from pre-Cambrian to Cretaceous. The lithologic details of these strata are known from well cuttings and outcrops and are given in table 5. The areal distribution of these rocks on a pre-Pleistocene erosion or bedrock surface is shown on plate 1.

Unconsolidated Pleistocene deposits, largely of glacial origin, occur at the surface over most of Webster County and lie unconformably on the older indurated, stratified rocks. The unconformable relationship and the general thicknesses of all the formations are shown by means of cross sections through Webster County (pls. 3 and 4).

The stratigraphic nomenclature used in this report is that used by the Iowa Geological Survey and does not necessarily agree with the nomenclature used by the U. S. Geological Survey.

TABLE 5. GENERALIZED SECTION OF THE GEOLOGIC FORMATIONS IN WEBSTER COUNTY, IOWA

System	Series	Subdivision	Thickness (feet)	Physical character	Water supply
Quaternary	Pleistocene	Recent	0-30	Thin alluvial sand and gravel deposits in the Des Moines River valley. Peat and sand in depressions on till.	No large supplies are developed at present. Yield water to a few farm and domestic wells in valley.
		Wisconsin stage	0-125	Till and some sand and gravel, generally in narrow meandering channels. Extensive terrace sand and gravel.	Small supplies are developed for farm supply on the upland over most of county. Large yields possibly can be developed in larger channel deposits. Terrace gravels contain water.
		Sangamon stage Illinoian stage Yarmouth stage	0-10	Loess, leached, probably occurs as scattered masses.	Yields negligible quantities.
		Kansan stage	0-50	Till, sand and gravel.	Sand and gravel yield small supplies.
		Aftonian stage	0-20	Gravel, leached, as isolated remnants.	Restricted extent precludes major development.
		Nebraskan stage	0-40	Brown till, partly leached, some sand and gravel, partly leached.	Sand and gravel yield some water; larger amounts in larger channels.
Cretaceous		Undifferentiated beds	0-400	Shale and some limestone and sandstone in northwestern part of county.	Thin beds of sandstone may yield some water, but no wells known to be finished in these rocks.
		Dakota sandstone	0-30	Sandstone, sand and gravel in west-central part of county; thick sandstones, shales and some lignite in northwestern part.	Yields moderate quantities of water to wells in west central and northwestern part of county.
Permian(?)		Fort Dodge formation	0-70	Red, gray and green calcareous silty shales and fine-grained sandstone; gypsum; thin basal conglomerate of limestone pebbles.	Unimportant source of water. Known only to yield water to one well in western part of county.
Pennsylvanian	Desmoinesian	Undifferentiated beds	0-230	Predominantly shale containing some sandstone.	Farm supplies are obtained from sandstone in southern part of county and from channel sandstone in eastern part of county.
	Meramecian	Ste. Genevieve	0-70	Green and red calcareous clayey shales.	Yields little water to wells. Shales are cased to prevent caving.
		St. Louis limestone	0-60	Buff and beige sandy limestone and dolomite; sandstone, calcareous medium-grained, frosted grains; some gray shale. Unevenly bedded.	Yields small to moderate supplies.
	Osagian	Undifferentiated beds	40-100	Dark-brown dolomite; gray shale; gray argillaceous limestone and dolomite in lower part; some glauconite and chert.	Yields small to moderate supplies locally. Shale generally must be cased off.

TABLE 5. GENERALIZED SECTION OF THE GEOLOGIC FORMATIONS IN WEBSTER COUNTY, IOWA—Continued

Mississippian	Kinderhookian	Gilmore City limestone	85–125	Cream sublithographic and oölitic limestone.	Yields small to moderate supplies locally.
		Hampton formation	130–210	Buff to brown dolomite (Iowa Falls member), cream limestone (Eagle City member), and brown dolomite containing grayish to white chert (Maynes Creek member).	Yields small to moderate supplies generally.
		Undifferentiated beds	20–45	Siltstone and gray shale.	Yields no water.
		Aplington dolomite	0–15	Buff to brown dolomite containing some chert.	Yields little water.
Devonian	Upper Devonian	Sheffield shale	0–20	Green and gray dolomitic shale.	Yields no water.
		Lime Creek shale Shellrock limestone Cedar Valley limestone	350–550	Predominantly cream dolomite containing limestone and shale beds near top and base; Cedar Valley limestone may contain some gypsum in southeastern part of county.	Lime Creek and Shellrock may yield small amounts of water. Cedar Valley limestone may yield moderate supply. Water probably very hard and mineralized in southeastern part of county.
	Middle Devonian	Wapsipinicon limestone	80–125	Buff to brown dolomite, locally argillaceous; near base may contain shale and brown to black detrital chert; probably contains some gypsum in southeastern part of county.	Yields moderate amount of water to deeper wells. Water may be very hard.
Ordovician	Cincinnatian	Maquoketa shale	50–150	Cherty, argillaceous dolomite; small amount of calcareous shale.	Probably yields small amount of water to deep wells.
	Mohawkian	Galena dolomite	125–200	Buff to brown dolomite (Dubuque and Stewartville members) containing dull white chert in lower part (Prosser member).	Probably would not yield substantial amount of water.
		Decorah shale	125	Calcareous gray shale and gray and black mottled limestone (Ion dolomite member); gray to brown limestone and dolomite (Guttenberg limestone member); green shale with black fossil fragments (Spechts Ferry shale member).	Probably yields little water. Shales generally must be cased off.
		Platteville limestone		Light-brown sublithographic limestone (McGregor limestone member); green and brown slabby shale (Glenwood shale member).	Probably yields little water. Shales generally must be cased off.
	Chazyan	St. Peter sandstone	55–65	Medium-grained sandstone.	Generally yields moderate amount of water.
	Beekmantownian	Prairie du Chien formation	275–350	Sandy dolomite in upper part (Shakopee dolomite member); sandstone and sandy dolomite in middle part (Root Valley sandstone member); cherty dolomite in lower part (Oneota dolomite member).	This formation together with underlying Jordan sandstone yields large quantities of water at Fort Dodge and could be developed elsewhere in the county by means of deep wells.

TABLE 5. GENERALIZED SECTION OF THE GEOLOGIC FORMATIONS IN WEBSTER COUNTY, IOWA—Continued

System	Series	Subdivision	Thickness (feet)	Physical character	Water supply
Cambrian	St. Croixan	Jordan sandstone	40–65	White, fine- to medium-grained frosted sandstone; dolomite in part but generally very loosely cemented.	Yields large supplies of water. Yields commonly are increased by shooting.
		St. Lawrence formation	80–90	Fine-grained, sandy dolomite; trace of silt; glauconitic in lower part.	Yields small amounts of water in county, but large supplies in central and eastern Iowa.
		Franconia sandstone	230–260	Gray glauconitic dolomitic siltstone and gray glauconitic and buff limestone; some dark-green shales and glauconitic beds.	Probably yields little water.
		Dresbach formation	130–160	Very silty glauconitic limestone, some green shale (Eau Claire member); lower beds are fine- to coarse-grained frosted sandstone (Mt. Simon sandstone member).	Lower sandstone yields small quantities; water seems to contain objectionable concentration of chloride.
pre-Cambrian		Undifferentiated red beds	20+	Dark-red dolomitic soft flaky shale.	Probably do not yield water. Shales cave and require casing.
		Undifferentiated igneous or metamorphic rock		Hard crystalline rocks.	Probably will yield no water.

Proterozoic Era

Few wells in Webster County have penetrated rocks older than those of Cambrian age, and therefore little is known about pre-Cambrian geology in the county. Red sandstones and shales, commonly referred to as the "red clastics," have been encountered in deep wells in Iowa and provisionally have been assigned to the pre-Cambrian. They are commonly arkosic and probably were derived from erosion of granitic pre-Cambrian rocks. The stratified deposits are probably thin and discontinuous in most of northwestern Iowa. Basic igneous or metamorphic rocks, possibly of pre-Cambrian age, are believed to underlie some areas in northwest Iowa.

Paleozoic Era

Sediments of Early or Middle Cambrian age probably never were deposited in Iowa or were removed by erosion before Late Cambrian time. During Late Cambrian time the land had subsided and most, if not all, of Iowa was invaded by a sea. Extensive deposits of sand and silt representing the St. Croixan series accumulated in eastern Iowa, but in Webster County the series is thinner and includes mostly silt, shale, and limestone. Deposition continued without a conspicuous interruption into the Ordovician period, when the sediments that were later consolidated into the limestone, dolomite, and sandstone of the Prairie du Chien group were laid down. Uplift and partial erosion of these sediments occurred prior to the marine invasion in Early Ordovician time in which the sands composing the St. Peter sandstone were deposited. After periods of nondeposition and possible uplift and erosion, the seas covered the area again in Middle Ordovician time and deposited shales and limestones comprising the Plattville limestone and Decorah shale and the Galena dolomite. The Maquoketa shale, which is represented by argillaceous limestone and dolomite in Webster County, was deposited during the Late Ordovician.

Rocks laid down during the Silurian period and preserved in southwestern, central, and northeastern Iowa are absent in Webster County. If deposited here, they were removed by erosion during the early part of the Devonian period.

The land was next inundated probably during the Middle Devonian, and with several interruptions in deposition, limestone was deposited during Middle and Late Devonian time. These deposits comprise the Wapsipinicon, Cedar Valley, Shell Rock, and Lime Creek formations. Near the close of the Devonian period argillaceous sediment (Sheffield formation) was being deposited in the seas in Iowa, and similar sediments (Maple Mill shale) continued to accumulate also during the Early Mississippian. Lime became the dominant sediment deposited in the seas during the remainder of the lower and middle Mississippian, although there were many transgressions and regressions of the sea. These limestone sediments now make up the Kinderhookian, Osagian, and Meramecian series in most of Iowa. No evidence remains of deposition during late Mississippian time.

During much of Pennsylvanian time deposition occurred in shallow seas or swamps. Conditions were favorable for the accumulation of thick deposits of vegetation which were preserved and gradually altered to coal when covered by younger sediments. Northern Webster County now represents the northernmost limit of continuous beds of the "Coal Measures" in Iowa. Deposition during the Pennsylvanian was not continuous, but there appear to have been cyclic movements of the land with relation to the sea of relatively small magnitude. These sediments in Webster County are a part of the Desmoinesian series of early Pennsylvanian age. Fusulinids of Virgilian age occurring as detrital fragments in the Fort Dodge formation (Moore and others, 1944, p. 692) suggest that younger Pennsylvanian sediments were deposited in the area but were removed by erosion.

The seas are inferred to have covered a part of Iowa during the Permian period. The Fort Dodge formation represents the only known outlier of these sediments in Iowa (Wilder, 1923, p. 171-173).

Mesozoic Era

After the withdrawal of the Permian seas, the land seems to have been uplifted and the existing sediments were subject to erosion until the Cretaceous period, when seas probably invaded Iowa from the west. The older sediments of this period seem to be near-shore deposits, but as the sea advanced farther into Iowa, sandstone, shale, and limestone were deposited. With the recession of the seas, erosion again occurred, and the deposits of the Cretaceous period were removed in part from the county. In the northwestern part of Webster and adjacent counties an abnormally thick sequence of strata, probably Cretaceous in age, was deposited in a small area referred to as the Manson area.

Cenozoic Era

Erosion dominated over deposition in the area during the time between the Late Cretaceous and the Pleistocene, and erosion drainage patterns became well defined. With the encroachment of Pleistocene continental glaciers from the north, these drainage channels were filled with sand and gravel and finally were overridden by the ice. Melting of the ice left till over the surface, and nearly all the smaller and many of the larger pre-Pleistocene valleys were obliterated. Six separate ice sheets invaded Webster County and the area to the north, and each successive continental glacier partly overrode the earlier formed deposits or incorporated them as a part of its sediment load to form the next succeeding till. Melt water also tended to remove the earlier deposits. It is not surprising, therefore, that the relationship of older tills and interglacial deposits are not often clearly shown where they occur beneath a younger till. Wind-blown silts from larger valley areas probably accumulated locally on the till surface in Webster County.

The present valleys have been developed largely by erosion during the Recent stage of the Pleistocene. On the uplands sand, clay, and organic matter tended to fill in the shallow depressions. Some of these now are represented by deposits of peat or peaty soils.

General Structure

Movement of the land or change in sea level results in elevation of land above sea or lowering it farther, but it does not necessarily affect each locality to the same degree. It results in thicker accumulation of sediments in low places and more rapid erosion of the higher areas. In addition, stresses in the earth's crust result in local folding and shearing. Thus, the present configuration of a single formation may reflect movement that occurred many times after the bed was deposited, the effects of erosion, and the environment under which it was deposited.

The Paleozoic rocks of Webster County are folded into a very broad and gently sloping trough, plunging generally southward but with slight flexures and other structural modifications.

One of the most peculiar structural problems in Iowa involves a small area (the Manson area) in Calhoun, Pocahontas, Humboldt, and Webster Counties where predominantly shale deposits extend to an unknown depth below the adjacent limestone and dolomite strata, which are in normal structural and stratigraphic positions.

The Fort Dodge Fault

Keyes (1916, p. 106-112) presents evidence gathered from exposures along Soldier Creek and the Des Moines River valley which suggests faulting in the vicinity of Fort Dodge. He infers that the fault extends southwestward from the vicinity of Clarion in Wright County to Wall Lake in Sac County, a distance of about 80 miles, and he attributes the preservation of the Fort Dodge formation to the faulting in the area. Lees (1924, p. 113-120) suggests, however, that the strata were deposited in an erosional basin unaffected by any faulting in lower beds.

Additional data now available confirm the faulting in the Fort Dodge area and indicate that a small graben trending ENE extends through part of the Fort Dodge well field (fig. 8).

The north fault which forms the north side of the graben is defined approximately for about 2 miles by exposures between South Lizard and Soldier Creeks. On South Lizard Creek in the center of SE¼SW¼ sec. 23, T. 89 N., R. 29 W., the St. Louis limestone is exposed for more than 20 feet above the stream in a bluff along the left bank of the creek and dips downstream to the north. The formation terminates abruptly on the south, how-

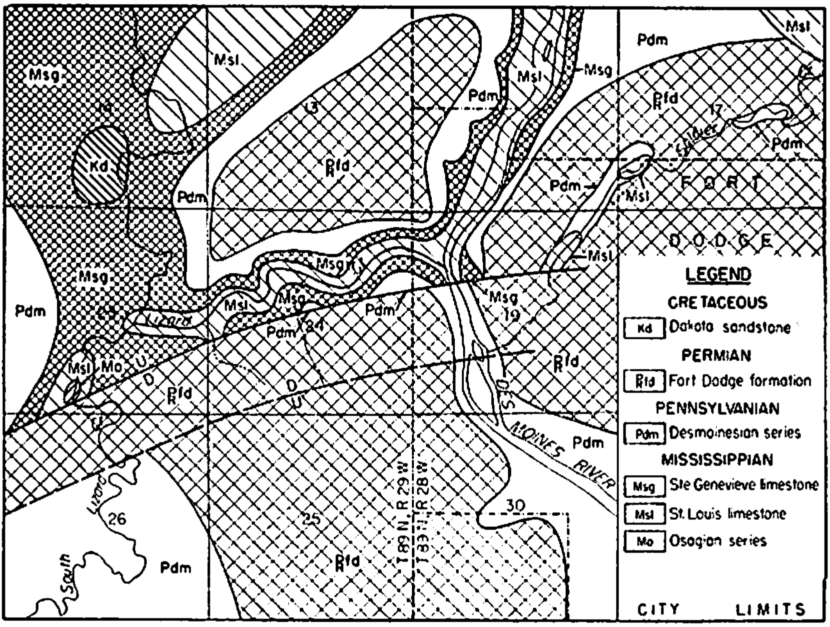


Figure 8.—Bedrock geologic map showing the distribution of consolidated rocks at Fort Dodge and the location of the Fort Dodge fault.

ever, and is in fault contact with the Fort Dodge formation, the shales and sandstones of which are exposed at about the same altitude. Farther east, in the S½ sec. 24, T. 89 N., R. 29 W., shales of the Ste. Genevieve limestone are exposed near the heads of two small ravines leading south from Lizard Creek. Farther headward, shale and sandstone of the Fort Dodge formation are exposed at only slightly higher altitudes.

The north fault plane, which strikes N. 66° E. and dips 66° S., is exposed in the mine workings of the Fort Dodge Limestone Co., where mineable limestone in the undifferentiated beds of the Osagian series is brought into contact with the shale of the Ste. Genevieve limestone. The fault extends eastward beneath State Highway 5, where its occurrence is indicated by the relative positions of outcrops of shale of the Ste. Genevieve limestone and clay and sandstone of the Fort Dodge formation in the NW¼ sec. 19, T. 89 N., R. 28 W. Still farther east, in the valley of Soldier Creek, is additional evidence for the position of the north fault as described by Keyes (1916, p. 110).

The south fault which forms the south side of the graben is known definitely only in the Fort Dodge city well field. The fault plane, which dips northward, was intersected by city well 15.

The two faults, which extend to known depths in excess of 1,000 feet, and probably well into the basement complex, define a wedge-shaped graben with maximum stratigraphic displacements, as indicated by the Mississippian strata, ranging from 175 feet on the south to 250 feet on the north. Pennsylvanian rocks in the graben may not have been displaced an amount equal to that of the underlying Mississippian rocks as the overlying Fort Dodge formation has been displaced less than 50 to 75 feet.

The position of the fault system, which is downthrown on the south about 75 feet, is known definitely only in the immediate vicinity of Fort Dodge, but it may continue for many miles as suggested by Keyes. The graben seems to pinch out within a short distance of Fort Dodge.

The very large yields obtained from wells drilled near the faults in the Fort Dodge city well field suggest that the permeability of the limestone and dolomite adjacent to the graben has been increased greatly by brecciation or solution resulting from the faulting.

The Manson Volcanic Basin

An elliptical area about 25 miles long and 18 miles wide, possibly a cryptovolcanic structure of the type discussed by Branca and Fraas (1905), exists in the Pocahontas-Calhoun-Humboldt-Webster County area (fig. 26). It contains an igneous or metamorphic-rock core, as does the Decaturville structure in Missouri (Bucher, 1936, p. 1071; comment by Tarr, p. 1084). Details of the structure have not been worked out because the area is covered by glacial drift, and only a small number of wells have been drilled to date. However, the well cuttings indicate that the regional structure is abruptly broken by faulting, which has produced a roughly circular structural basin. Outside the basin, the section penetrated by wells generally consists of Pleistocene drift and Paleozoic strata. (See log of well 89-30-11R1.) Within the basin, wells penetrate the Pleistocene drift and then apparently continue in Cretaceous strata to about 600 feet. (See log of well 89-30-2Q1, p. 236.) Below this the deeper wells penetrate about 900 feet of red arkosic sandstone, siltstone, shale, and an occasional dolomite of undetermined age. (See log of well 90-30-4E1.) However, near the center of the structure (western tier of sections of T. 90 N., R. 31 W.) wells encounter igneous rock consisting largely of microcline feldspar or basic tuffaceous rock at a depth of a few hundred feet and in places less than 100 feet. That the crystalline rock continues to considerable depth is shown by a well in the NW¼ sec. 35, T. 90 N., R. 32 W., which entered it at 389 feet and finished in it at 874 feet.

The Cretaceous strata in the outer depressed part of the structure crop out only in the NE¼NE¼SE¼ sec. 11, T. 89 N., R. 30 W. Here along the right bank of Lizard Creek immediately upstream from the bridge over the stream, a few feet of gray micaceous shale, representing the upper part of the strata, is exposed at low-water level. The shale contains fish scales and poorly preserved cephalopods.

Whether a normal sequence of Paleozoic strata underlies the structural basin is unknown, as is the total thickness of the crystalline rock. However, a 1,532-foot well in the NW¼ sec. 35, T. 89 N., R. 31 W., in Calhoun County, located outside the central core, did not penetrate the Paleozoic rocks around the faulted area. A core was obtained from portions of the section penetrated by this well. The rocks show a great deal of contortion and brecciation and indicate that thicknesses of strata in the disturbed area probably do not represent true thickness of the strata where undisturbed.

Bucher (1936, p. 1080, 1081) noted that cryptovolcanic structures in America lie on the flanks of large swells. The Manson structure occurs near the area where the Paleozoic strata rise abruptly to the northwest from the synclinal basin which forms the principal structural feature in the Paleozoic strata of Iowa.

The age of the structure has not been determined; however, some of the movement must have been as recent as Cretaceous time as rocks of this age are involved. The age of the igneous material also is unknown; it could be Cretaceous or younger, or it might represent an upthrust area of the pre-Cambrian basement complex. No contact metamorphism has been observed in the well cuttings of the sedimentary rocks near the igneous material. Bucher (1936, p. 1079, 1080) believes that differentiation of basic or possibly alkaline, magmas, such as has given rise to the basic dikes in the central plateau region of the United States, would form purely feldspathic or even pure quartz rocks. He also states that the ascent of basic magmas has taken place during periods of orogenic rest—of "anorogenic" times. This factor should be considered in assigning an age to the Manson structure.

Core drilling and airborne-magnetometer surveying in progress in September 1953 may help to clarify the structural and stratigraphic details of the Manson volcanic basin.

GROUND WATER

Principles of Occurrence

Water that occurs below the earth's surface is called subsurface water. This discussion of the principles governing the occurrence of ground water, which is the water in the zone of saturation, considers the conditions in Webster County in particular but also presents general data on the occurrence of ground water. For greater detail the reader is referred to the authoritative treatments of the subject by Meinzer (1923, a and b) and Norton and others (1912).

Nearly all rocks within practical drilling depths contain openings or voids which may vary in size from microscopic to cavernous, depending on the composition, compaction and cementation, texture, and structure of the rock. Clastic sediments usually have openings between the grains of material making up the rock (fig. 9). This rock characteristic of containing voids is referred to as porosity and is reported as the percentage of void volume to the total volume of rock.

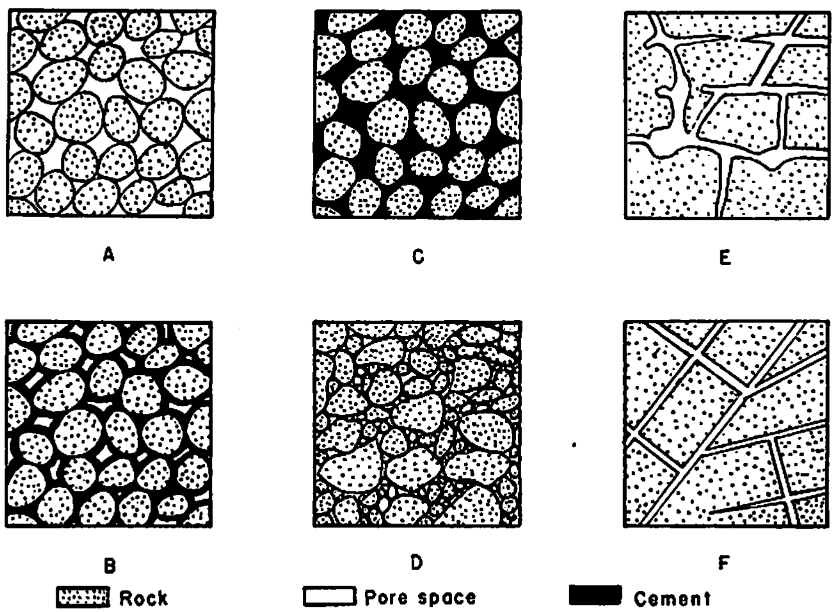


Figure 9.—Diagram showing the nature of interstices in several types of rocks. A, Well-sorted sand having open pores; B, Well-sorted sand having pore spaces partially filled with cement; C, Well-sorted sand having pore spaces closed by cement; D, Very poorly sorted material (till); E, Calcareous rock having well-developed solution opening; F, Hard rock having porosity caused by jointing. (From Hershey, Robinson, and Jeffords, ms. in preparation, after Meinzer, 1923a.)

Limestones may have interstitial openings or be dense. They may also contain openings up to cavern size which have resulted from solution, commonly along fractures. Igneous and metamorphic rocks generally contain few openings; however, some porosity results from weathering, vesicles caused by gas bubbles in lavas, and jointing due to contraction on cooling or other types of fracturing.

The openings in rocks generally are filled with water from a short distance below the land surface to various depths. This zone is called the zone of saturation, the upper surface of which is called the water table. Water in the zone of saturation generally is not static but moves from places of higher hydrostatic head to places of lower hydrostatic head. The points of lowest head are in areas where ground water is being discharged either artificially through wells or naturally by springs or evaporation. In the zone of aeration, which lies between the zone of saturation and the land surface, the openings in the rocks usually contain air and water. This zone consists typically of three parts, the belt of soil water, the intermediate belt, and the capillary fringe (fig. 10).

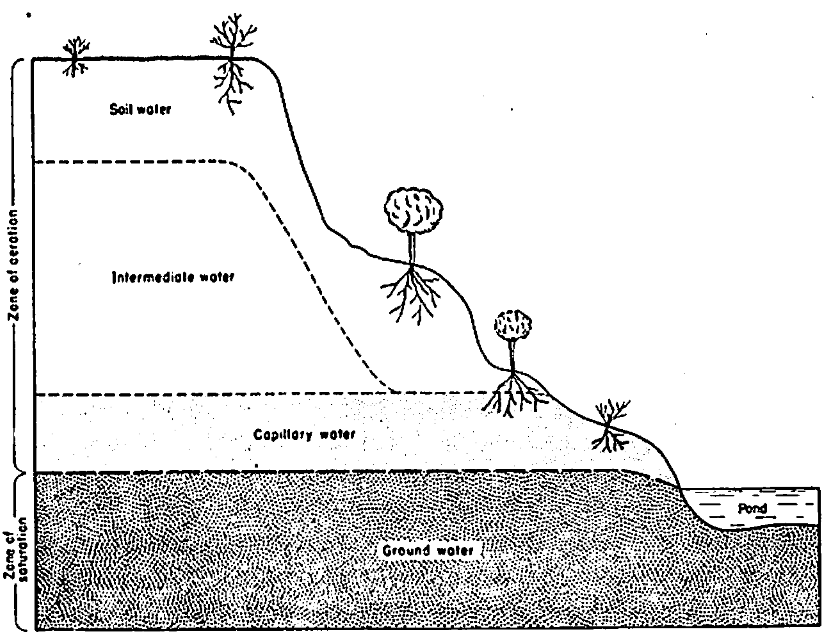


Figure 10.—Diagram showing divisions of subsurface water. (From Hershey, Robinson, and Jeffords, ms. in preparation, after Meinzer, 1923b.)

The belt of soil water is the part of the lithosphere, immediately below the land surface, from which water is discharged into the atmosphere in large quantities by the action of plants or by soil evaporation, and when the quantity received is too great to be held by cohesion and adhesion a part seeps downward.

Water in the intermediate belt is partly in transit downward into the zone of saturation and is partly drawn by molecular attraction into the capillary interstices. Water in the capillary fringe is continuous with water in the zone of saturation but is held above the water table by capillarity acting against gravity. The height to which the capillary fringe extends above the water table depends on the diameter of the capillary openings in the material overlying the water table, being greater in fine material and less in coarse material where the openings are large.

Locally, the soil water, intermediate water, and fringe water may be absent where the zone of saturation extends to the surface.

If there is to be movement of fluids in rocks under differential pressures, the voids or openings must be interconnected. The ability of a rock to transmit fluids is called its permeability, which depends upon the size, number and interconnection of the openings. The larger and more numerous the openings in a given unit the greater is the permeability of the rock. Sand and gravel generally have relatively high permeabilities. Cavernous limestone may have an immeasurably high permeability locally, but within a short distance it can be practically impermeable. This wide range in permeability in limestone and dolomite is shown in Webster County where a few farm wells obtain yields of 10 gallons a minute with small drawdowns from the St. Louis limestone, whereas a supply of only 11 gallons a minute with a drawdown of 225 feet was obtained from the town well at Callender after it had penetrated all the limestone and dolomite of Mississippian age. Although shale and clay may be very porous and contain water, the openings in them are generally so small that they are practically impermeable and yield little or no water to wells.

A formation, group of formations, or part of a formation that is saturated with water and is permeable is called a water-bearing bed or aquifer. It is from aquifers that wells obtain their water. Impermeable beds may have an important effect on the circulation of water in aquifers, depending on their position with respect to the aquifer. They may prevent water from entering water-bearing beds or may confine water within an aquifer, allowing artesian pressures to develop. Although generally considered as impermeable, studies have shown that beds such as shale, where of great extent, transmit appreciable quantities of water and hence must be taken into account in some quantitative studies. As recharge, movement, storage, and discharge of ground water are dependent on the lithology and structure of rocks of the earth's crust, a knowledge of the geology in any region is basic to an understanding of the hydrology.

The upper limit of the zone of saturation is often within permeable materials and the water is in contact with the air in the zone of aeration. The upper surface of the zone of saturation as defined by water levels in wells finished in these permeable materials is called the water table, and the wells are called water-table wells. In such wells the water does not rise above the point at which it first flows into the well. However, just above the water table the strata may become very moist because of the presence of capillary water.

If the water-bearing bed has an upper confining bed and the hydrostatic head of the water in the aquifer is above the top of the confined bed, it is said to be under artesian conditions. Any number of artesian aquifers may occur in depth, depending upon the number of extensive impermeable confining beds in the geologic section, and the head may be different in each of them. In wells penetrating an artesian aquifer, the water level rises above the level at which the water is encountered and represents a point on a pressure surface referred to as a piezometric surface.

A well finished in such an aquifer is called an artesian well, and if the piezometric surface is above the land surface a flowing artesian well results. In the lower levels of the Des Moines valley in Webster County, the piezometric surface is above the land surface in many of the aquifers below the St. Louis limestone, and flowing wells have been developed from them at these localities.

An aquifer may be under artesian conditions in one place and under water-table conditions at another locality, and aquifers that are under artesian conditions where deeply buried are commonly under water-table conditions in their recharge areas.

Water-table aquifers function chiefly as reservoirs. They are generally recharged locally from precipitation or streamflow, and their discharge areas are frequently in the immediate vicinity. Artesian aquifers, on the other hand, serve also as conduits for transmitting water, and the areas of recharge and discharge may be at great distances from the place of use. Bcause of these different conditions, the water-table and artesian aquifers in Webster County are discussed separately.

Water-Table Aquifers

The clay till mantling the upland over a large part of Webster County seriously limits the quantity of shallow water available. In much of this material there is no unconfined ground water and no water table; however, where a local sandy zone is near the upland surface, or where there are sand and gravel-filled valleys, a water table does exist. Most of the wells utilizing water from the shallow water-bearing beds are bored wells ranging from 25 to 60 feet in depth. The general practice is to complete bored wells so that water can enter through the bottom and the joints of the tile casings. Because of the small quantity of water in storage in the till, shallow wells frequently go dry during droughts.

Water-level measurements made in these shallow wells indicate that the water table conforms closely to the general land surface, but it is less rugged. In general the water level in these shallow wells was less than 15 feet below land surface in the fall of 1942, and in many wells it was less than 10 feet. The yield from shallow wells is usually small, and the slope of the water table near the Des Moines River is precipitous, thus indicating aquifers of low permeability. It appears that ground water moves very slowly toward points of discharge in the small depressions on the upland and the major stream valleys. A part of the water probably moves downward into aquifers having lower heads.

Recharge to these shallow aquifers results from local precipitation under favorable geologic conditions. However, recharge is retarded during much of the winter by the frozen ground and during much of the summer by depletion of the soil water by growing vegetation and evaporation. Recharge occurs chiefly, therefore, after the spring thaw and before the appreciable growth of vegetation, and again after the first killing frost and before the ground becomes frozen.

Natural discharge from the shallow aquifers takes place by evaporation and transpiration and by drainage into surface depressions and streams, thus contributing to the base flow of the latter. Artificial discharge is through wells and the extensive tile drainage systems which may be below the water table when it is at a high stage, usually in the spring of the year. For instance, the discharge of North Lizard Creek is measured near Clare in the northwestern part of the county. At this point and for some distance to the west, the stream is more than 50 feet below the upland level and probably more than 30 feet below the general level of the water table or piezometric surface in the shallow aquifers on the upland. For much of the year the flow of the stream is less than a cubic foot per second (448.8 gpm), yet with a water-level rise of only a few feet usually in the spring, the discharge of the stream from indirect and direct ground-water sources is between 30 and 50 cfs. It is inferred from the distribution of the flow that much of it is derived from the tile drainage systems; whether an equal amount would flow naturally is not known.

Before the land was tiled, ponds were common in the numerous depressions on the upland surface. These ponds undoubtedly received discharge from the shallow aquifers at times and evaporation disposed of some shallow water. As water levels in the shallow aquifers declined, the circulation was reversed and water flowed from the ponds into the aquifers. The tile drains remove water that might later reach the water table and thus prevent the water levels from attaining the heights which they formerly reached. Tiling controls the high water levels and thus permits farming of certain areas that would otherwise be useless for this purpose. As the drains are usually laid no more than 4 to 6 feet below the surface, they can lower the water table to this depth only.

Changes in the rate of recharge and discharge cause changes in the amount of water in storage, and these are reflected by the rise and decline of the water table or artesian pressure. Periodic measurements and continuous records of the water level in wells show whether a gain or loss in storage has occurred in these aquifers and how an aquifer reacts to changing conditions of recharge, withdrawal, and discharge. Figure 11 shows the fluctuation of the water level in well 87-28-29N1, a shallow well near Harcourt, for the year 1948 and the relation of the gain in storage to the periods favorable for recharge in excess of discharge. Figure 12 shows the general fluctuations of the water levels in shallow wells and the monthly precipitation for the period of record from 1942 through 1950.

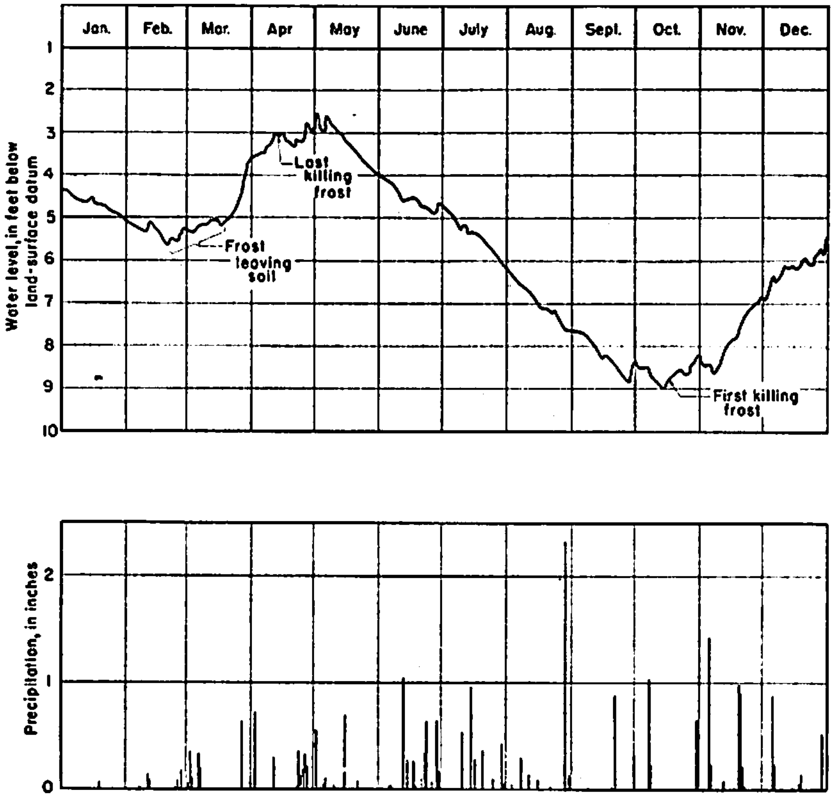


Figure 11.—Hydrograph of a shallow well (87-28-29N1) near Harcourt, Iowa, showing seasonal changes in ground-water storage, and daily precipitation at Fort Dodge, 1948. (From Hershey, Robinson, and Jeffords, in preparation.)

As can be seen (fig. 12), water levels in the shallow wells have not declined progressively during the short period of record, and recharge has been at a rate sufficient to maintain a nearly uniform volume of storage.

Artesian Aquifers

The aquifers below the Osagian rocks probably receive most of their recharge in areas outside Webster County, the recharge areas of the deeper aquifers being more remote than those of the shallower aquifers. From the general configuration of the piezometric surfaces in these deeper aquifers over a large part of Iowa, the recharge areas seem to be north of the county, and the water moves through the lower aquifers in a general southward

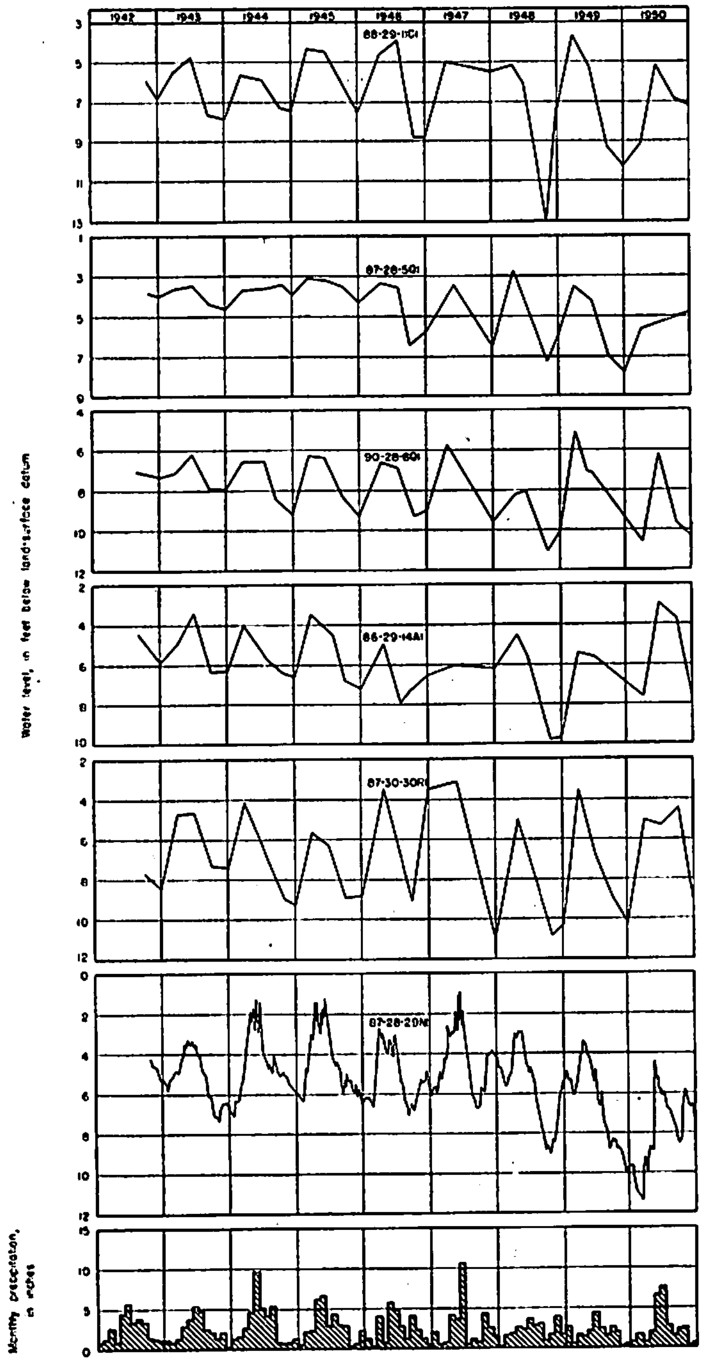


Figure 12.—Hydrographs of six shallow wells in Webster County showing general fluctuations in water levels and monthly precipitation at Fort Dodge, Iowa.

direction. The natural discharge areas also are unknown and surely remote.

These deeper aquifers are essentially unaffected by periods of drought. Before their utilization by wells, the piezometric surface or artesian pressure was probably stable; that is, the discharge from the aquifer was equal to the recharge and there was little change in gradients or storage. With the discharge increased artificially by wells in the county, the water now comes from storage and, as a consequence, the artesian pressures decline in the aquifers developed, the decline being greatest at the well locations. If pumping continues at a uniform rate, the artesian pressures continue to decline but at a decreasing rate with time as water comes from storage over increasingly larger areas. The rate of decline increases, however, if water is withdrawn at increasing rates. These declines are not eliminated until after the cone of depression reaches the area of recharge or discharge, but even with water coming wholly from storage the rate of decline may become so small with time as to be scarcely noticeable.

The initial water level in the 1,240-foot Dayton town well (86-28-14H1) is reported as 62 feet below land surface in 1931. By 1942 the water level had declined to 70 feet, and in 1948 it was about 80 feet below land surface. The increased rate of decline between 1942 and 1948, as shown in figure 13, was caused by the continued increase in the rate of withdrawal from the well. At Gowrie the water level in the deepest town well (86-30-1P2) declined from a reported level of 81 feet in 1926 to about 111 feet in 1942. The rate of decline is not known, but it probably increased from time to time as progressively more water was used by the town. Water levels have declined seemingly since 1911 at a nearly uniform rate in the city wells at Fort Dodge. In 1911 they are reported to have been about 60 feet above land surface in the valley of the Des Moines River. In October 1944 the static water levels were about 11 feet above land surface. Here again the rate of decline of water levels has been increased periodically by the increase in pumpage of water from the well field. More details on the decline of water levels in the well field are given in the section on the Fort Dodge municipal supply.

The moderately deep artesian aquifers may receive much of their recharge within the county through seepage from the overlying sand and gravel aquifers in the drift. The St. Louis limestone, in particular, is recharged probably in this way in the

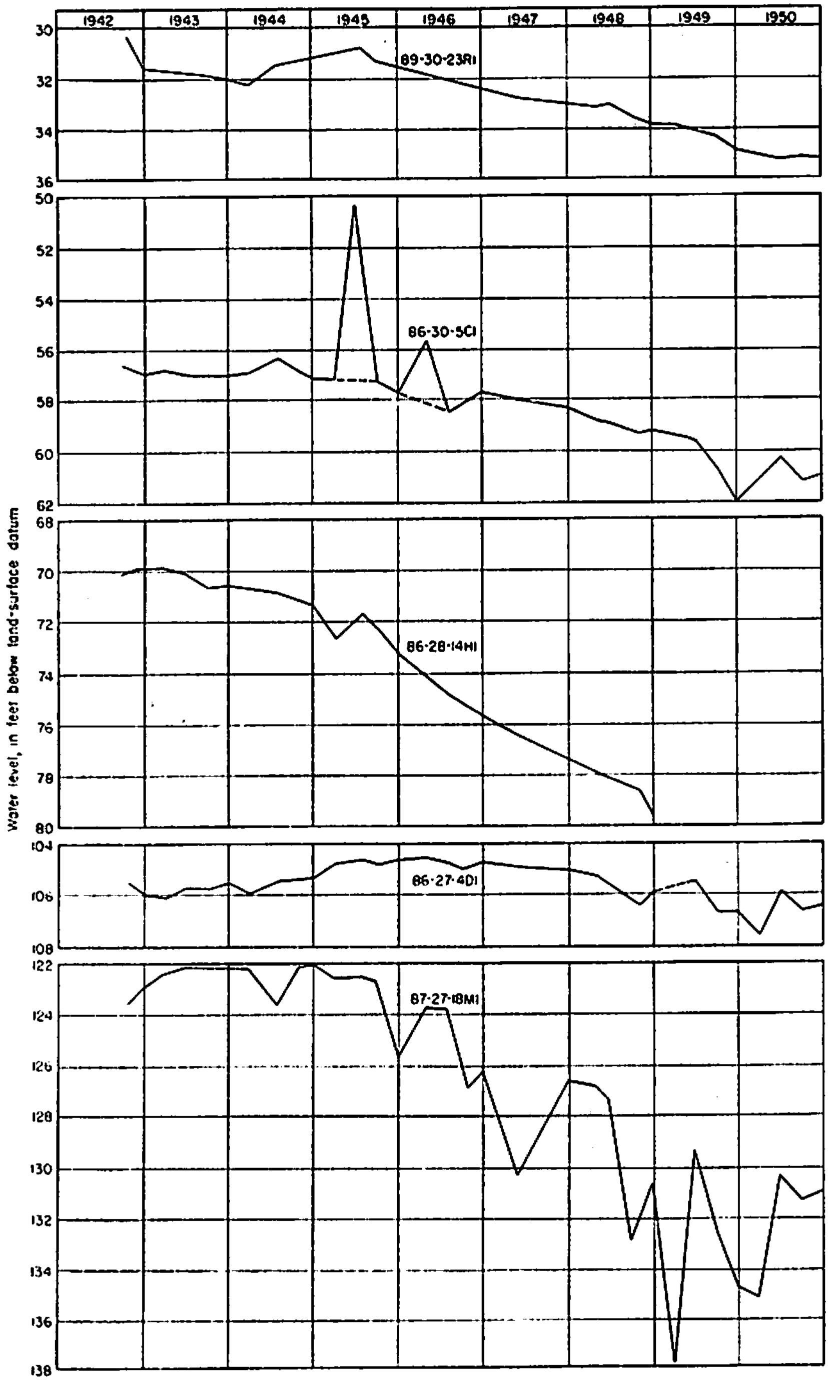


Figure 13.—Hydrographs of five artesian wells in Webster County showing, in general, a gradual decline in pressures. The abnormal rises in water level in well 86-30-5C1 are caused by inflow of shallow water at the mouth of the well.

northern part of the county. The aquifers in the sandstones of Pennsylvanian age also probably receive water under similar conditions in the central part of the county. The lower sand and gravel aquifers in the Pleistocene deposits in turn probably receive water through the overlying sandy zones. Water is discharged from the St. Louis limestone and rocks of Pennsylvanian age through springs and seeps located mostly along the Des Moines River. One of the largest springs in the area, having a reported flow of about 45 gallons a minute from the St. Louis limestone, is located in the SE¼SE¼ sec. 14, T. 90 N., R. 29 W. A few springs having flows of 10 to 20 gallons a minute issue from the sandstones of Pennsylvanian age along the Des Moines River north of Lehigh. Seepage areas occur commonly in these rocks along the river banks.

Movement of water in the St. Louis limestone and sandstones of Pennsylvanian age seems to be toward the Des Moines River but with a general southward component. The trend in water levels in four wells finished in the sandstone of Pennsylvanian age is shown in figure 13. These wells supply water for domestic and stock use, but the amount of water pumped is small, The abnormal peaks on the hydrograph of well 86-30-5C1 (fig. 13) are due to occasional inflow of water from shallow aquifers, penetrated by the dug portion of the well, into the lower drilled part. Considerable water must accumulate in the pit before it can overflow into the casing.

Hydraulic Properties of Aquifers

Two fundamental physical properties of an aquifer are chiefly responsible for determining the rate of movement of water in the aquifer and the quantity of water extractable from it. The areal extent and thickness of the aquifer also are important.

The permeability of a material is its capacity to transmit fluid under a pressure gradient and is dependent on the shape, size, number, and interconnection of voids in the material. Several units of permeability have been proposed by hydrologists, but the coefficient of permeability commonly used by ground-water hydrologists is defined as the flow of water in gallons a day through a cross-sectional area of 1 square foot under a pressure differential of 1 foot of water per foot of material measured in the direction of flow of the water, at a temperature of 60° F. A very useful term, introduced by Theis (1935), is the coefficient of transmissibility, which is the product of the thickness of the saturated portion of the aquifer and the field coefficient of permeability. The coefficient of transmissibility also can be defined as the flow of water in gallons a day through a mile-wide cross section of the saturated part of the aquifer under a gradient of 1 foot per mile at the prevailing ground-water temperature.

The coefficient of storage is defined as the amount of water, expressed as a fraction of a cubic foot, released from a prism of the aquifer having a base of 1 square foot when the pressure or head is reduced by 1 foot of water. In water-table aquifers the coefficient of storage approximates the specific yield, which is the ratio of the volume of water that will drain from a unit volume of material, acted upon by the force of gravity, to the unit volume of the material. In artesian aquifers the coefficient of storage is small compared with that in water-table aquifers because the aquifer remains saturated, the water being released from storage by compaction of the aquifer and squeezed out of intercalated or adjacent fine-grained materials.

Permeability can be determined in the laboratory from samples of water-bearing material, but the results may not be representative because of the difficulty in rearranging disturbed samples of unconsolidated sediments as they were in nature and because of the difficulty of obtaining an undisturbed sample. Field methods, involving pumping tests, may be expected to yield more reliable information on the permeability and storage coefficients. With these data important conclusions can be reached in regard to the quantity of water that an aquifer will yield perennially and the position of the water levels under any given pumping regimen. These data are essential for the proper spacing of wells that will draw from the same aquifer.

To obtain the coefficient of storage it is generally necessary to have an observation well that penetrates the same aquifer as the pumped well in which measurements of water levels can be made during a pumping test. The transmissibility of an aquifer can be determined by measuring water levels and the discharge rate of a single well. The tests, however, must be made under a controlled pumping schedule to make them susceptible to mathematical treatment.

A formula developed by Theis (1935) relates the drawdown at any time and at any place in the vicinity of a discharging well to the discharge of the well and to the coefficients of transmissibility and storage. Theis' equation is usually expressed in the following form: $s=(Q/4\pi T)\,W(u)$, where the term *s* is drawdown produced by a continuous and uniform withdrawal of water from an aquifer of wide extent and uniform thickness and permeability, Q is the discharge rate of the well, and T is the transmissibility. $W(u)$ is the negative exponential integral of $-u$. The value of u is equal to $r^2S/4Tt$ where r is the distance from the well where the drawdown is observed or to be predicted, S is the coefficient of storage, and t is the time since pumping started.

As the ratio r^2/t becomes small as compared with 4T/s, all but the first two terms of the expanded exponential equation forming an exact solution for Theis' formula may be neglected (Cooper and Jacob, 1946, p. 527), giving rise to the approximation $s = (Q/4\pi T) \log_e(2.25Tt/r^2S)$. Converting to common logarithms and units, the equation becomes $s = (264Q/T) \log_{10} (0.3Tt/r^2S)$ in which s is the drawdown in feet at any point in the vicinity of a well discharging at a uniform rate, Q is the discharge rate in gallons a minute, T is the transmissibility in gallons a day per foot, t is the time in days since pumping started, r is the distance from the pumped well, in feet, to the point at which drawdown is measured or determined, and S is the coefficient of storage, as a decimal fraction.

When the approximation is valid as explained above, the variation of s with t (the drawdown curve) plots as a straight line on semilogarithmic paper with t on the logarithmic scale if Q, T, r, and S remain constant. The transmissibility is determined from this straight-line plot by taking the difference in drawdown Δs at two points on the line one log cycle apart, which simplifies computations, and the equation becomes $T = 264Q/\Delta s$.

The rate at which the water level recovers in a well after a period of pumping also can be used to determine the transmissibility of an aquifer. The equation derived and simplified by Theis (1935, p. 522) for ordinary conditions of application is $T = (264Q/\Delta s^1) \log_{10} t/t_1$ where s^1 is the residual drawdown of any instant and t is the time since pumping started and t_1 is the time since pumping stopped. When residual drawdown (or water level) is plotted on the linear scale of semilogarithmic paper against the ratio t/t_1 to logarithmic scale, a straight line should result.

The recovery method was used on the Dayton town well (86-28-14H1), which was pumped for 85 minutes on November 17, 1942, at an average rate of 132 gallons a minute. The recovery curve is shown on figure 14 as the depth to water plotted

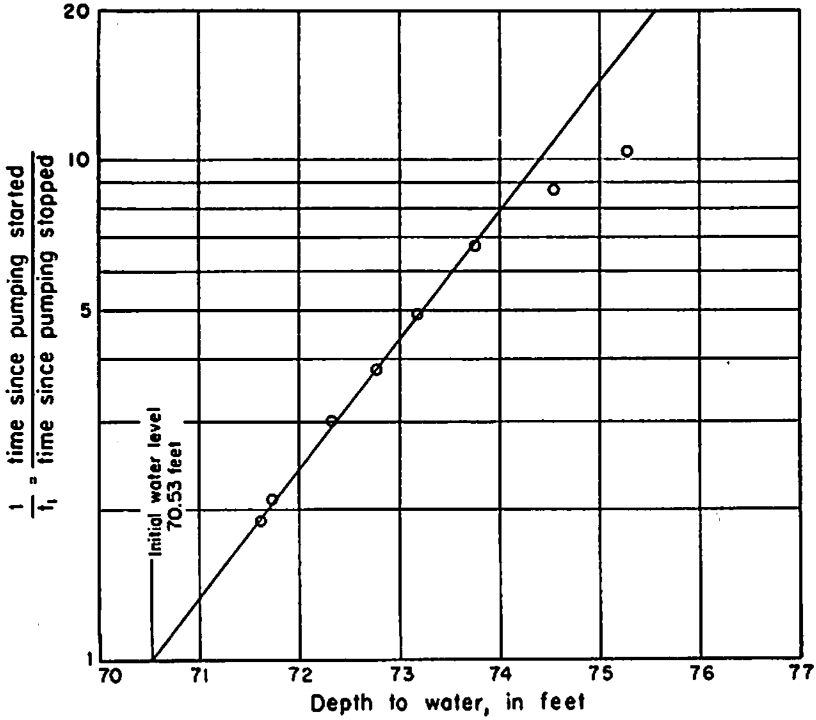


Figure 14.—Recovery of water level in well 86-28-14H1 after pumping well for 85 minutes at the rate of 132 gallons a minute. The depth to water is plotted against the ratio $\frac{t}{t_1}$ on a logarithmic scale.

against the logarithm of the ratio of the time since pumping started to the time since pumping stopped. From this plot, the difference between the water levels, Δs^1, on the recovery curve one log cycle apart, is found by inspection to be 3.87 feet. This value (Δs^1) is submitted in the equation $T=264Q/s^1$ and T is found to be about 9,000 gallons a day per foot. No observation wells were available for measuring drawdowns away from the principal well, so the coefficient of storage for the aquifer or aquifers encountered in the Dayton town well could not be computed.

As the foregoing equations apply rigidly only to aquifers of infinite areal extent, those having boundaries which affect the drawdown produced must be subjected to more elaborate analysis. Thus it is found that drawdown curves for the Pleistocene channel sand-and-gravel deposits depart from a straight line on a semilogarithmic plot by successive changes in slope because of the effect of the impermeable boundaries. The usual method of dealing with impermeable boundaries is by recourse to image wells, which are considered to start pumping at the same time and at the same rate as the real well. The effect of a single impermeable boundary can be simulated by the pumping effect that would be produced by a well located on the other side of the boundary at the same distance as the pumping well and considering the aquifer to be infinite in extent. In a channel, both the boundaries produce image wells which are in turn influenced by the boundaries so that if the boundaries are parallel to each other, the number of image wells become infinite, similar to the number of image reflections in two mirrors facing each other; however the image wells have a decreasing effect with distance from the pumped well, and effects of the more remote ones may not be perceptible. On the other hand, image-well effects may be so numerous that they defy interpretation.

A pumping test made on the Gowrie town well (86-30-1Q1), which is finished in approximately 18 feet of sand and gravel at a depth of 248 feet, illustrates the effect that boundaries have on water levels in pumped wells. A test was made on the well at the time of its completion on July 24, 1950, when the static water level was 45.8 feet below the top of the casing, which is 1.5 feet above land surface. The well was pumped at 180 gallons a minute, and the water-level measurements, made by J. B. Cooper, were plotted against the time since pumping started on the logarithmic scale (fig. 15). The dashed line extending the first straight segment of the drawdown curve represents the curve that probably would have been obtained were the aquifer of uniform thickness and permeability and extensive over a large area in every direction from the well. The break in the curve after the well had been pumped 10 minutes, when the rate of drawdown became twice the original rate, indicates a boundary. Doubling the discharge from the aquifer by assuming an image discharging well perpendicularly across the boundary and at the same distance from the boundary is a solution to the problem. Were this the only boundary, the drawdown would have continued following the second straight-line segment of the drawdown curve. However, a second break in the curve at about 30 minutes probably indicates the presence of a secondary boundary and that the town well is finished in a channel. A third break in the curve occurs about 70 minutes after pumping started and may be the effect of a second set of image wells.

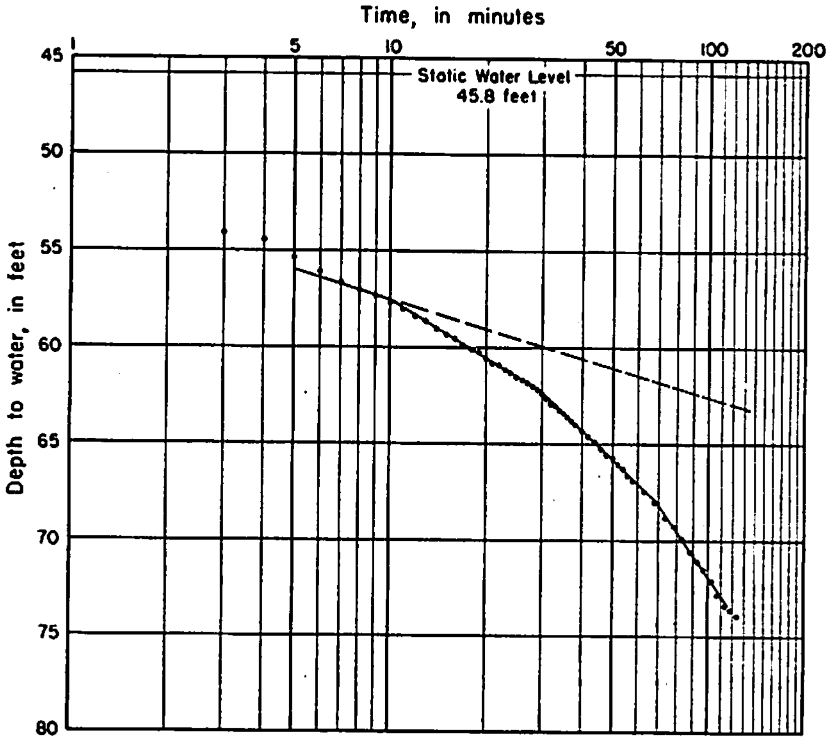


Figure 15.—Drawdown curve for well 86-30-1Q1 being pumped at the rate of 180 gallons a minute. The depth to water is plotted against the logarithm of the time since pumping started.

If the trend in water levels could have been observed during the pumping of well 86-30-1Q1 in additional wells finished in this sand and gravel, the coefficient of storage, the effective width of the channel, and the position or direction of the channel could have been determined. As noted from the drawdown curve, the rate of decline of the water level in this pumped well is greatly increased because of the apparently narrow sand-and-gravel channel in which the well is finished. Unless recharge occurs to the aquifer nearby, pumping levels may be expected to decline materially within a short time. Periodic measurements are desirable to determine more precisely the trend in water level when the well is put into production.

Construction of Wells

Several types of wells have been used in Webster County, including dug, bored, driven, and drilled wells. Dug wells were more common in earlier days, but the principal types now in use are bored and drilled wells. Their general features are discussed briefly here, but for a more comprehensive discussion on well construction the reader is referred to Bowman (1911) and the War Department Technical Manual 5-297.

Dug wells have been constructed principally on the upland in Webster County. An excavation 4 to 6 feet in diameter is usually made in the clays, and where the material is loose, temporary curbing is used to prevent cave-ins until the water is reached. Such excavations may encounter clay extending below the water table, and when a sand or other water-bearing bed is encountered below the clay, the water rises in the well pit. The first water-bearing bed generally prevents further excavation, and brick or rock curbing is installed commonly at the point where the clays become very moist just about the water-bearing bed. This type of well is generally limited to unconsolidated deposits, although a few are finished in rock by blasting.

Bored wells are constructed only in unconsolidated sediments and generally terminate at the first water-bearing bed of consequence. The machine used is an auger, generally motor driven, which can cut a hole as large as 36 inches in diameter, although the more common size is 12 to 24 inches. When a water-bearing sand is penetrated, tile is inserted in the bore to the bottom of the well. Water may enter the well through the bottom and the joints of the tile, but it is desirable to cement around the upper part of the tile to prevent entry of surface and near-surface water. Boring beyond the first water-bearing bed is accomplished at times by reducing the size of the auger to fit inside the first string of tile.

Drive-point wells are satisfactory where water-bearing sand and gravel occur at shallow depth, and the water level is within 25 feet of the land surface. The drive point generally consists of perforated tubing covered by a screen attached to a sharp sturdy point for penetrating the unconsolidated material. Additional lengths of pipe are attached as the point is driven into the ground. This type of well is generally fitted with a suction pump; the working cylinder and piston may be at the top as in a pitcher pump, or the cylinder may be placed below ground in a pit to permit drawing water from a greater depth. Construction of drive-point wells is often facilitated by augering to as great a depth as feasible to minimize the distance the point must be driven through the dense clay that overlies the sand and gravel.

The size of the slots or openings in the drive point should be governed by the size of the sand in the water-bearing bed; it is desirable to have the slots or openings large enough to pass at least the finer 50 percent of the sand initially in order that coarser sand or gravel will collect around the point.

Drilled wells are commonly used to develop water from the deeper Pleistocene sand and gravel and from the consolidated rocks, such as sandstone and limestone. Several types of machines are used in drilling wells, but the equipment used most often in Webster County has been the cable-tool, churn, or percussion-drill rig. With this machine a heavy steel bit attached to a stem is raised and let fall by means of a cable passing over a raising mechanism. The hole is made by breaking up the rock into small chips or wads. Water must be used to hold the cuttings in suspension so that they can be removed by a bailer. Casing may need to be inserted as drilling proceeds through clay or shale to prevent its caving into the well. Sandstone and limestone are generally not cased unless they are thin and occur in a predominantly shale section or unless the water they contain is of undesirable quality. Water may be obtained from thin water-bearing beds by perforating the casing opposite these rocks. In fine sand, a screen may be used to prevent the sand from flowing into the well with the water; however, where the sand and gravel are sufficiently coarse, wells are frequently finished without a screen, the water entering through the open end of the casing.

The diameter of cable-tool wells is governed by the quantity of water to be pumped, by the number of shale beds that will require casing during drilling, and by provision for future repairs. Farm wells commonly are about 6 inches in diameter, and municipal and industrial wells, which generally are equipped with large pumps, are mostly between 8 and 24 inches in diameter at the surface.

A few wells in Webster County have been drilled by rotary equipment. This method of drilling involves circulation of mud-laden drilling fluid downward through the drill pipe and upward in the well bore to remove the cuttings made as the turning bit chips the rock. Drilling is continuous and the size of the hole is not reduced with depth. Unconsolidated strata are prevented from caving by the caking of mud on the walls and the fact that the hole is kept full of water, so that hydrostatic pressure is exerted on the strata. Casing is usually inserted when the drilling is completed or when all the caving materials have been penetrated. This method of drilling is particularly rapid in unconsolidated sediments.

Development of Wells

The yield of wells generally can be increased by development of the water-bearing material around them. Wells finished in sandstone may be made to yield more water by setting off explosives opposite the sandstone to enlarge the bore of the well and develop fractures to give easier access for the water entering the well. A danger in this type of development, particularly in a loosely cemented and fine-grained sandstone, is that sand grains may be pumped with the water, or the charge may not be placed properly and may ruin the well.

Yields of wells finished in limestone and dolomite aquifers may often be increased by acidizing the limestone and dolomite to enlarge the openings through which the water is entering the well. The acid most commonly used is hydrochloric (muriatic), sometimes "diluted" by other chemicals in order that it will dissolve limestone without attacking steel casing unduly.

Wells in fine sand frequently need to be developed in such a way as to remove the finer materials and allow the coarser particles to accumulate around the screen, thus increasing the yield and decreasing the drawdown in the well. Turbine pumps, which can handle considerable sand, are sometimes used for this purpose, and a surging action is produced by alternately starting and stopping the pump and by varying the rate of pumping. Surge plungers or blocks can be operated by drilling rigs to draw the fine material into the well by suction, after which it is removed by the bailer. Gravel is sometimes placed around the well screen to decrease the velocity of approach of the water entering the well, thereby decreasing the quantity of fine sand reaching the well. Although gravel packing is sometimes accomplished by introducing gravel through side holes (small wells drilled around and close to the pumped well) during the development of the well, it is generally more effective if carried on during the drilling phase.

Another method of backwashing wells is to introduce water under pressure into the well and then remove it, thus producing rapid alterations of direction of flow in the aquifers. Compressed air is similarly used to alternately pump water from the well and force it back into the aquifers, thus removing fine materials.

Utilization Of Water

Domestic and stock wells on farms in Webster County far outnumber all other types; however, the relatively few municipal wells produce a greater quantity of water. A relatively small volume of water is pumped for industrial use.

Farm Wells

Nearly all the water used for domestic and stock purposes on the farms in Webster County is obtained from wells. Most of them are bored wells less than 70 feet in depth and finished in sand and gravel of Pleistocene age, but several hundred of them are drilled into the sandstone, limestone, and dolomite of Mississippian age. Only a few farm wells, however, are drilled below the Hampton formation, and the water obtained is hard. The fluoride content of the water in the glacial drift and sandstones of Pennsylvanian age is low, but the iron content is generally excessive. Wells finished in the lower indurated rocks commonly obtain water having a high iron content and containing more than 1.5 parts per million of fluoride.

Public Water Supply

Most of the county grade schools and the larger consolidated schools obtain their water supply from wells. Wells for the smaller grade schools are usually finished in Pleistocene sand and gravel, and the consolidated schools at Lanyon and Barnum also obtain water from wells finished in the glacial drift.

The well at the consolidated school at Burnside obtains water from sandstone of Pennsylvanian age, and wells at the Moorland and Otho consolidated schools obtain water from Mississippian rocks. The Dolliver State Park Well is finished in the Hampton formation of Mississippian age.

Ground water is pumped from various aquifers for the public water supplies of the towns of Badger, Callender, Dayton, Duncombe, Gowrie, Harcourt, Lehigh, and Stratford, and the city of Fort Dodge.

Badger. The town of Badger obtains its water supply from two wells. The initial well (90-28-15D1) was drilled in 1931 into the Gilmore City limestone to a reported depth of 280 feet. The well is reported to be cased with 5-inch pipe to a depth of 149 feet and with 4-inch pipe from 150 to 206 feet. The bottom 74 feet of the well is open 3¾-inch hole. Water is obtained from the St. Louis and Gilmore City limestones. The initial water level was reported to be 40 feet, and the temperature of the water measured at the force pump, which has a measured capacity of 23 gallons a minute, is 50°F.

In 1948 a second well (90-28-15D2) was drilled through limestone and dolomite of Mississippian age to a reported depth of 530 feet and cased with 8-inch pipe to a depth of 145 feet and with 6-inch pipe from a depth of 142 to 220 feet. The casing is cemented in the hole. Water is obtained largely from the Gilmore City and Hampton formations. The initial water level was reported to be 95 feet and the pumping level 187 feet at 55 gallons a minute. This well is equipped with a turbine pump powered by an electric motor.

Water is pumped directly into the distribution system, and a small storage tank at the first well maintains a pressure of 25 to 50 pounds per square inch. The water is hard and contains enough iron to cause staining (table 9). The average daily pumpage is estimated as about 7,000 gallons. In addition to this, a few privately owned wells 25 to 55 feet in depth are still used.

Barnum. The town of Barnum has no public water-supply system, and water is obtained from privately owned shallow bored wells. The consolidated school in the south part of town formerly obtained its water from a 202.5-foot drilled well (89-30-23R1), but the yield of the well was small and the water was reported to be of poor quality. The school supply is obtained now from a bored well (89-30-23R2) about 55 feet deep. The town is located near the border of the abnormal sequence of rocks in the Manson area, and it may be difficult to obtain a satisfactory water supply below the Pleistocene sands and gravels.

Callender. Three wells were in operation in 1950 supplying water for the distribution system at Callender. Well 1 (87-30-12E1), located in the south part of the park, was drilled in 1938 to a reported depth of 727 feet and cased with 8-inch pipe to a depth of 440 feet. The casing is perforated from 277 to 297 feet and from 420 to 440 feet and packers were placed outside the casing at depths of 277 and 382 feet. The well is an open 6½-inch hole below 440 feet. Initially, the water level was reported as 94 feet below land surface; a yield of 11 gallons a minute produced a drawdown of 224 feet after the well had been pumped for approximately 23 hours. This small quantity of water was developed from limestones of Mississippian age, and the coefficient of transmissibility of all the water-bearing beds open to the well, as determined from recovery measurements during a pumping test, was less than 50 gallons a day per foot. The well is equipped with a high-lift pump powered by an electric motor that is operated intermittently by a time-control system. The operator estimates that about 6,000 gallons a day is pumped from the well.

A test hole (87-30-12L1) was drilled into sand and gravel at a reported depth of 60 feet about 2 blocks east of the first well, to augment the supply. A yield of 15 gallons a minute was reported to have been obtained after the hole was completed as a well and placed in service.

The third well (87-30-12L2) was drilled to a depth of 185 feet in 1949, finishing in 15 feet of sandstone of Pennsylvanian age. It is cased to a depth of 171 feet with 6¼-inch pipe and is equipped with a force pump which delivers 12 gallons a minute. At this pumping rate, the reported drawdown is 113 feet; the original water level was 35 feet below land surface.

Water from the Callender wells is pumped directly into the distribution system, and the overflow goes into storage in the water tower. The water is hard and contains between 0.6 and 0.9 parts per million iron, an amount sufficient to cause staining. The water from the 727-foot well contains 2.1 parts per million of fluoride.

Clare. The town of Clare had a public water-supply system, but it was abandoned because of continued difficulty with sand in its 180-foot well (90-30-24N2). Water now is obtained by means of privately-owned bored wells. The Catholic school at Clare obtains water from sandstone of probable Cretaceous age at a reported depth of 180 feet (90-30-24N1). The nonpumping level is reported to be 118 feet and the drawdown 12 feet at 14 gallons a minute.

Dayton. Water is supplied to the town distribution system primarily by one well (86-28-14H1), drilled to a depth of 1,240 feet in 1931. The well is drilled into the Wapsipinicon limestone of Devonian age but probably obtains a part of its supply from other Devonian and Mississippian rocks. The well is reported to be cased with 13-inch pipe to a depth of 323 feet, 10-inch pipe from 312 to 505 feet, and 8-inch pipe from 770 to 966 feet. Below 966, the well has 274 feet of 8-inch open hole.

The initial water level was reported to be 62 feet below land surface. On November 17, 1942, the water level was 69.9 feet after the pump had been idle for 22 hours, but later in the day the pumping water level was 146.2 feet after the well had been pumped for 1.3 hours at 132 gallons a minute. The transmissibility of the aquifers open to the well, as determined by recovery measurements made during a pumping test (fig. 14), is about 9,000 gallons a day per foot. The trend in nonpumping levels in this well from 1942 through 1948 is shown in figure 13.

An older well (86-28-14H2), 10 to 6 inches in diameter and reportedly 688 feet in depth, is presently used as a standby well. The well is finished in limestone and dolomite of Mississippian age, and a force pump delivers 20 gallons a minute from the well.

The water from the 1,240-foot well has a temperature of 56° F., is hard, and contains enough iron to cause staining of fixtures; the fluoride content is about 2.8 parts per million. (See analysis, table 9.) Since 1947 the water has been pumped under pressure through iron-removal and softening equipment. The softened water is pumped into a water tower having a storage capacity of 70,000 gallons. The amount of water pumped after 1947 is estimated in part, inasmuch as about 4,000 gallons a day is bypassed around the softener and is not metered. (See table 6.)

Duncombe. The public water supply of Duncombe is derived from one well (88-27-3D1), located in the park in the north part of town, which was completed in 1945 at a depth of 974 feet. Casing in the well is reported to include 10-inch pipe to a depth of 251 feet (cemented in to a depth of 50 feet) and 8-inch pipe from 235 to 290 feet (slotted from 251 to 290 feet). An open 8-inch hole was drilled below 290 feet. The nonpumping water level was 49.2 feet below land surface on January 25, 1945, and the drawdown 36.8 feet after a pumping period of 146 minutes

TABLE 6. WATER PUMPED BY TOWN OF DAYTON
(Thousands of gallons)

	1942	1943	1944	1945	1946	1947	1948	1949
January	....	275	440	522	685	815	770	1,015
February	....	240	365	472	623	700	795	990
March	....	278	441	540	806	770	915	1,160
April	....	350	483	477	798	770	870	1,130
May	....	336	431	539	759	750	940	1,155
June	....	342	445	535	662	750	990	1,425
July	....	492	450	457	757	920	990	1,425
August	....	465	519	694	783	1,000	990	1,260
September	389	459	533	704	812	940	....	1,185
October	356	369	400	725	766	890	....	1,255
November	333	393	451	675	717	770	965	1,065
December	346	429	583	722	....	800	1,015	1,135
Total	a1,424	4,448	5,601	7,062	a8,168	9,935	a9,240	14,200

a Record incomplete.

at 33 gallons a minute. The transmissibility of the aquifers penetrated by the well, as determined by recovery measurements made during a pumping test, was about 1,000 gallons a day per foot. The well is equipped with a turbine pump powered by an electric motor.

An older well (88-27-4A3) formerly supplied the town but was abandoned shortly after completion of the newer well. It was drilled to a reported depth of 417 feet in about 1911 and deepened to 546 feet in 1932. It is cased with 6-inch pipe to a reported depth of 200 feet and with an unknown amount of 5-inch casing. Water is obtained from Mississippian rocks, and the water level is reported to have been about 40 feet below land surface during nonpumping periods. A force pump powered by an electric motor delivered 16.5 gallons a minute.

The water is pumped directly from the present supply well into the distribution system without treatment, a water tower having a capacity of 40,000 gallons handling the excess water supplied temporarily to the system. No record is kept of the amount of water pumped, but it is estimated to be about 12,000 gallons a day. The water is hard and contains an excessive amount of iron, 1.4 parts per million (table 9). The temperature of the water pumped is 50° F.

Fort Dodge. The following discussion of the development of the public water-supply system at Fort Dodge was prepared largely from records and statements of J. W. Pray, Manager of the Department of Municipal Utilities, Fort Dodge.

The city of Fort Dodge constructed a large-diameter well on the bank of the Des Moines River in 1881, and this supplied the city until 1891. At that time a larger collecting gallery was constructed on Island Park in the SW¼ sec. 19, T. 89 N., R. 28 W., a short distance southeast of the present treatment and pumping plant. The gallery was used until 1907, some raw river water being used intermittently during the latter part of the period to meet the needs of the city.

Attempts had been made to increase the quantity of water available by drilling two 100-foot wells, one on Island Park and one on the east bank of the river. However, a flow of 10 gallons a minute was all that was obtained from each of them. A shaft was then sunk in rock on the east bank to a depth of 88 feet, the depth at which the two test wells had encountered water. The yield from this shaft also was inadequate, and a tunnel was driven horizontally through the rock at the bottom for a distance

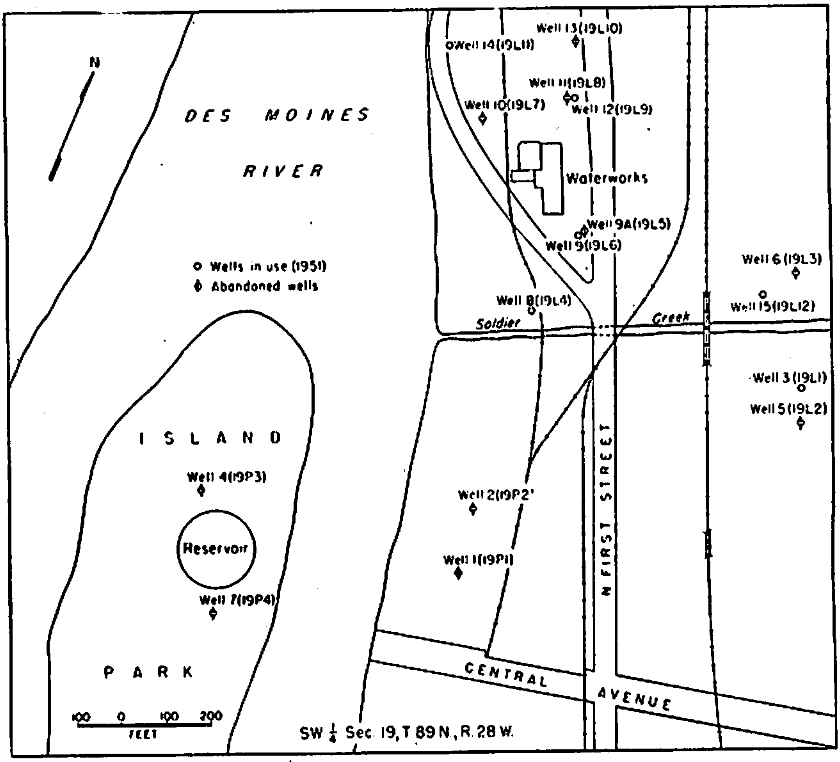


Figure 16.—Map of part of Fort Dodge showing the city well field.

of about 300 feet under the river. Abut 80 gallons a minute was obtained from this installation.

In September 1907, well 1 (89-28-19P1) was completed at a depth of 1,827 feet as a flowing artesian well. It was drilled in the bottom of an 88-foot shaft (fig. 16). Between 1907 and 1949, 15 additional flowing wells were drilled. Of these, wells, 1, 2, 4, 5, 6, 7, 9A, 10, 11, and 13 have been abandoned, and wells 3, 8, 9, 12, 14, and 15 were in service in 1951. The gallery system was abandoned in 1919.

The general procedure in the construction of the wells in this field has been to drive pipe through the shales that overlie the water-bearing limestones, depending on the shales to cave and form a water-tight seal. None of the wells seem to have developed leaks around the casing. Many of the wells have been recased, and, in this operation, cement has been used commonly to obtain a water-tight seal between the new and old casings.

As many as three strings of casing may extend to the surface in some of the wells, but only the inner casing is considered in the following discussion of the individual wells.

Well 1 (89-28-19P1) was drilled into the Jordan sandstone to a reported depth of 1,827 feet in 1907. The well was cased with 10-inch pipe to a depth of 328 feet, 9-inch pipe from 1,036 to 1,056 feet, 6-inch pipe from 1,332 to 1,390 feet, and 5-inch pipe from 1,375 to 1,439 feet. The depths at which the flow of the well increased were not recorded, but the flow was measured by the driller at several depths from time to time during drilling as follows:

Depth (feet)	Total flow (gallons a minute)
328	144
1,390	287
1,497	316
1,536	374
1,578	484
1,827	571

The head or pressure on the aquifers was not measured. The temperature of the water in the finished well was reported to be 55° F.

A turbine pump was installed in 1910 to augment the discharge from the well, but the hole filled with shale and sand so as to damage the pump within a short time. In 1911 the well was cleaned to a depth of 1,400 feet and an unknown amount of casing was added. The flow is reported to have been 500 gallons a minute after the repair work was completed. The natural flow from the well is reported to have been 300 gallons a minute in October 1919, and the yield about 600 gallons a minute with a pumping level of 50 feet below land surface. The head on the aquifers seems to have been slightly less than 40 feet above the surface or about 1,030 feet above sea level. Thereafter the well was pumped intermittently by air lift until it was abandoned and plugged in 1938.

Well 2 (89-28-19P2), located about 150 feet north of well 1, was drilled in 1911 to a reported depth of 670 feet and was cased with 15-inch pipe to a depth of 152 feet (pipe perforated near bottom) and with 10-inch pipe from 480 to 500 feet. The flow of the well is reported to have been initially 150 gallons a minute, and 50 gallons a minute in October 1919. At a discharge rate of 200 gallons a minute, the reported pumping level was 140 feet.

Well 3 (89-28-19L1) was drilled in 1911 to a depth of 215.5 feet and reconstructed in 1921. The well was recased at the latter time with 17-inch wrought-iron pipe to a depth of 205 feet and with a slotted length of 12-inch cast-iron pipe resting on the bottom of the well. The flow is reported to have been 600 gallons a minute initially and 200 gallons a minute in 1919. On completion of the repair work in 1921, the natural flow was 350 gallons a minute, and when pumped at 750 gallons a minute, the drawdown was reported to be 50 feet. An airlift pump was installed in the well in 1921 and used through October 1935. In 1938 it was again necessary to recase the well to the bottom, 12- and 10-inch pipe (slotted in lower 14 inches) being used. The well was connected to the suction line common to all wells in the field in 1951.

Well 4 (89-28-19P3) was drilled in 1913 and was completed in Mississippian rocks at a depth of 400 feet. The well was cased to a depth of 105 feet with 8-inch pipe, the initial flow being 160 gallons a minute. The flow had reduced to about 15 gallons a minute in October 1919, and the well was abandoned.

Well 5 (89-28-19L2), about 75 feet south of well 3, was drilled in 1913 to a reported depth of 624 feet and cased with 8-inch pipe to a depth of 136 feet and with 6-inch pipe from 130 to 292 feet. The initial flow was about 50 gallons a minute, but this flow had diminished to about 10 gallons a minute in October 1919 when the well was abandoned.

Well 6 (89-28-19L3), about 65 feet north of well 3, was drilled in 1914 to a reported depth of 283 feet and cased with 8-inch pipe to a depth of 253 feet. The initial flow was reported to be 190 gallons a minute, but this decreased by 1919 to about 90 gallons a minute. On installing an airlift pump, the discharge was increased to 250 gallons a minute, and the pumping level was reported as 75 feet below land surface. The well was taken out of service in 1938 and sealed with concrete in 1948.

Well 7 (89-28-19P4) on Island Park, was drilled in 1914 to a reported depth of 498 feet and cased to a depth of 138 feet with 8-inch pipe. The flow was reported to be 80 gallons a minute in 1914 and 20 gallons a minute in 1919. At this latter date, the pumping level was 135 feet below land surface at 80 gallons a minute.

Well 8 (89-28-19L4) was drilled in 1923 to the St. Peter sandstone at a depth of 1,436 feet. By 1938 large quantities of sand had entered the well, and it was cleaned out to a depth of at least 504 feet. It was recased with 12-inch casing to a depth of 257 feet, the initial 8-inch liner between 618 and 1,040 feet being left in the well. Inasmuch as the well is filled up to a depth of approximately 500 feet, little water is believed to be obtained from the deeper strata. The initial flow was reported to be 750 gallons a minute and the discharge of the well, when pumped with an airlift installed in 1926, 1,500 gallons a minute. On May 18, 1929, the reported nonpumping level was 41.5 feet above land surface and the natural flow was 514 gallons a minute. The airlift was removed from the well in August 1934, and the well was connected to a common suction line with other wells in the field. A turbine pump, powered by an electric motor, was installed in January 1948, and the well can now be pumped either by means of the turbine pump or by the common suction and booster pump. At that time, the well reportedly would yield 900 gallons a minute with a pumping level of 80 feet and 1,000 gallons a minute with a pumping level of 100 feet below the pumphouse floor.

Well 9A (89-28-19L5), drilled in 1927 as a test hole to a depth of 260 feet, had a large enough yield to warrant using it as a supply well. It was cased with 6-inch casing to 245 feet. The initial flow was reported to be 675 gallons a minute and the nonflowing head 37 feet above land surface in September 1927. On May 18, 1929, the nonflowing head was reported to be 41.5 feet above land surface and the natural flow 549 gallons a minute. The well was plugged and abandoned in November 1944.

Well 9 (89-28-19L6), located within a few feet of well 9A, was completed in August 1931 at a depth of 269 feet and deepened in November 1938 to a depth of 553 feet. At the latter date the well was reported to be cased with 20-inch pipe from 7 to 76 feet, 16-inch pipe from 4 to 243.6 feet, 12-inch pipe from 192.5 to 277.5 feet (perforated from 258 to 275 feet), and 8-inch pipe from 275 to 323 feet (perforated from 313 to 323 feet). Burlap packers were placed at depths of 214, 234, 246, 251, 256, 300, and 310 feet. The well is reported to have been pumped in August 1931 at a rate of 1,200 gallons a minute with a pumping level of 50 feet, 1,800 gallons a minute with a pumping level of 80 feet, and 1,925 gallons a minute with a pumping level of 89 feet. At the time the well was deepened in 1938, the reported flow was 350 gallons a minute at a drilling depth of 334 feet and about 500 gallons a minute when the well had reached a depth of 498 feet.

Well 9 was connected to a common suction line with other wells in the field about 1932. In December 1947 a turbine pump was installed on the well with a setting of 50 feet; this was lowered in March 1948 to 70 feet. When the turbine pump was installed, the yield of the well was reported to be 1,500 gallons a minute with a 50-foot pumping level; in March 1948 the yield was reported to be 1,550 gallons a minute with a 45-foot pumping level. Yields and pumping levels vary according to the operation of other wells, the duration of a test on a particular well, and the general nonpumping head for the field, which is at a varying height above land surface. Well 9 can be pumped by means of the common suction and booster pump, the turbine pump, or both.

Well 10 (89-28-19L7) was drilled in September 1931 to a reported depth of 432 feet and cased with 6-inch pipe to a depth of 243 feet. The initial flow was reported to be 200 gallons a minute, and because of the small yield the well was abandoned and plugged in July 1938.

Well 11 (89-28-19L8) was drilled in September 1931 to a reported depth of 530 feet and cased with 6-inch pipe to a depth of 245 feet. The reported flow at the time of completion was 600 gallons a minute. The well was connected to the common suction line for all the wells until November 1944, when it was abandoned and plugged.

Well 12 (89-28-19L9) is a few feet west of well 11 and was drilled in December 1931 to a depth of 541 feet. It was recased in 1949 to a depth of about 244 feet with 12-inch casing which is attached, by means of a swedge nipple, to 8-inch pipe extending to a depth of about 317 feet. The swedge nipple probably rests on top of an older 10-inch casing, which is reported as extending from 246 to 311 feet. The initial flow from this well was reported to be 1,000 gallons a minute, 80 percent of the water coming into the well in the interval between 345 and 528 feet. The nonflowing head was reported to be 28 feet above land surface in December 1931. The well was connected to the suction line common to all the wells, and in November 1944 was equipped with a turbine pump.

Well 15 (89-28-19L12) was completed in January 1949 at a depth of 2,307 feet, finishing in rocks of supposed pre-Cambrian age. Casing in the well includes about 308 feet of 20-inch pipe from about 10 feet above land surface to a depth of 298 feet (the upper 40 feet of pipe below land surface is cemented in the hole), 812.5 feet of 16-inch pipe from 271.5 to 1,084 feet, 173.5 feet of 14-inch pipe from 1,289.5 to 1,463 feet (perforated through St. Peter sandstone), and about 370 feet of 10-inch pipe from 1,750 to 2,120 feet (perforated in upper 200 feet).

By casing the well to 1,084 feet the aquifers developed by the other wells in the field are not drawn upon. Very little water entered the well between 1,084 and 1,350 feet, and when the well had penetrated the St. Peter sandstone a yield of approximately 90 gallons a minute was obtained. Setting off explosives opposite the Jordan sandstone between depths of 1,736 and 1,815 feet was successful in increasing the specific capacity of the well, which when put into production in 1949, yielded about 3,000 gallons a minute.

Hydrology of the well field. City wells 3, 8, 9, and 12 obtain all their supply from Mississippian rocks. Well 14 obtains a part of its water from the Mississippian but reportedly obtains most of its water from the underlying Devonian rocks. These two aquifers are separated by shale beds (pls. 3 and 4). Well 15, however, probably obtains most of its water from the Jordan sandstone and overlying Prairie du Chien formation.

Wells 3, 9, 12, and 14 are located in the graben created by faulting in the area (Fort Dodge fault). Well 15 penetrated the strata in the graben to a depth of about 770 feet and then passed through the fault into the upthrown section south of the graben. Well 8 is located immediately south of the graben. Faulting has probably disrupted the beds within the graben and for some distance on either side, producing favorable conditions for the local development of large fracture and solution cavities in the limestone beds.

The water-bearing beds seem to be connected at depth, possibly through porous materials developed along the fault and by disruption of the confining shale beds. The aquifers are also connected artificially in most of the wells, as the deeper wells, with the exception of well 15, have not been cased any deeper than is necessary to prevent caving material from entering the well. The several aquifers utilized now seem to have essentially the same head, thus suggesting further that the aquifers are interconnected in this locality. For instance, recovery measurements made on wells 3, 8, 9, 11, and 12 on October 15, 1944, when pumping was stopped for about 6 hours, indicate that the water levels in these wells rise at about the same rate and to within 0.4 foot of the same elevation. After completion of well 15, a measurement made on October 4, 1951, indicated that the water level was within 0.2 foot of the nonpumping level in the shallower wells. The connection between wells and aquifers is not uniform, however. For example, when well 12 is pumped it causes a greater drawdown in wells 8 and 9 than in well 14, which is closer to well 12 than either 8 or 9.

The transmissibility of the water-bearing beds in the Mississippian rocks within the graben and the immediately adjacent area at the well field is very high. Data collected during a pumping test made on well 12 indicate an apparent transmissibility of about 600,000 gallons a day per foot. Recovery measurements made on the wells during short periods when pumping is stopped temporarily also indicate an equally high transmissibility for these shallow aquifers. That this high transmissibility is local and probably confined to the rocks in the graben and immediately adjacent rocks is shown by changes in the recovery rate of the water levels when pumping ceases. Also, the aquifers within the graben are not uniformly permeable, inasmuch as a few test wells drilled within the graben have only small yields. The apparent transmissibility of the aquifers open to well 15 is about 110,000 gallons a day per foot. The transmissibility decreases at some distance from the well, however, possibly because of partial boundary conditions created by the faulting in the area.

Interference between the shallow wells in the field is small. For example, when well 12 is pumped at the rate of 1,600 gallons a minute for 3 hours it produces a drawdown of 1.0 foot in well 9, about 310 feet from well 12, and 0.7 foot in well 8, about 490 feet from well 12. The wells have specific capacities ranging between 10 and 55 gallons a minute per foot of drawdown after a few hours' pumping.

All the wells in the field, with the possible exception of well 15, may be considered to be one large well drawing water from the interconnected aquifers in or near the graben. The material in the graben is a highly permeable conduit into which water moves from the adjacent and much less permeable water-bearing beds of the limestones of Mississippian age and subjacent beds down to the sandstones of Cambrian age, although the effectiveness of the conduit probably decreases with depth. As the graben is known to persist for a distance of at least 2 miles, considerable water can drain into it even from relatively impermeable beds.

No records seem to be available on the magnitude of the artesian head when the initial development took place in the well field. No mention is made of any pressure differentials in the various aquifers encountered in well 1, drilled to the Jordan sandstone. The flow from this well increased with depth, but this could have been the case if the head had been the same in each aquifer, the increased flow simply representing the contribution of another aquifer. In 1911 the head in well 3 was reported as 62 feet above land surface or about 1,043 feet above sea level. The water level in well 9A was reported to be 37 feet above land surface, or 1,021 feet above sea level, in September 1927 and 41.5 feet above land surface in May 1929. The same water level above land surface was reported for well 8 in May 1929, but inasmuch as the land surface is lower at well 8 the altitude of the water level would be 1,019.5 feet, or 6 feet below that reported for well 9A. In December 1931 the nonpumping water level in the recently completed well 12 was reported to be 28 feet above land surface, or at an altitude of 1,103 feet. On completion of well 14, the water level was about 20 feet above land surface (altitude, 1,003 feet) in June 1935.

A few recovery tests have been made on the wells during short periods when no pumping was done. On October 12, 1944, the water level rose to an altitude of 995 feet after pumping had ceased for 2.6 hours. Again, on October 15, 1944, the water level rose to an altitude of 996 feet after the wells were idle for 6.6 hours. In the following year, on March 24, the water levels rose to an altitude of 995 feet after the well field had been idle for 3 hours. On October 4, 1951, after an idle period of 1.5 hours, the water levels in the wells recovered to an altitude of only 983 feet.

If pumping from the field had been at a constant, uniform rate, the rate of decline in water levels might be expected to diminish. The withdrawal of water, however, has increased markedly since 1930, and this has tended to maintain or increase the initial rate of drawdown in the well field. Table 7 shows the volume of water pumped from the well field from 1927 through 1950. A more detailed review of the pumpage is shown in figure 17. The consumption of water was increased substantially in 1934 when a meat-packing plant began operation. Since 1934 this company's use of water has increased to an average of about

TABLE 7. WATER PUMPED BY CITY OF FORT DODGE

Year	Gallons		Year	Gallons	
	Total (in millions)	Daily average (in thousands)		Total (in millions)	Daily average (in thousands)
1927	361.0	989	1939	797.6	2,165
1928	378.4	1,037	1940	809.7	2,218
1929	373.2	1,022	1941	822.1	2,252
1930	383.4	1,050	1942	842.3	2,308
1931	396.2	1,085	1943	943.4	2,585
1932	468.7	1,284	1944	994.0	2,726
1933	501.9	1,375	1945	992.3	2,710
1934	536.6	1,470	1946	1,078.3	2,954
1935	637.0	1,745	1947	1,224.6	3,355
1936	718.6	1,969	1948	1,300.2	3,552
1937	659.3	1,806	1949	1,363.3	3,735
1938	682.4	1,870	1950	1,300.1	3,562

1 million gallons a day in 1948 and 1949. Additional consumption of water has been created by several air-conditioning units, most of which were installed after 1944. Figure 17 shows the large increase in the use of water during the months of July and August, particularly during the last few years of record.

An accurate prediction of the trend in pumping levels in the well field is not feasible at present, but the available data suggest that water levels will decline 1 to 2 feet a year if the withdrawal increases about the same as during the past 15 years. If withdrawals are maintained at the present rate of about 3.3 million gallons a day, a decline of less than 10 feet is to be expected in the next 30 years.

Gowrie. The initial well (86-30-1P1) drilled for the town of Gowrie was completed in 1902, reportedly to a depth of 620 feet, and cased with 6-inch pipe to 350 feet. The principal water-bearing bed is probably the Hampton formation. The water level was reported to be 50 feet below land surface initially and 92.8 feet below land surface on September 14, 1942, when the drawdown was 35.8 feet at 34 gallons a minute. The temperature of the water was 53½°F. By 1950 the well was pumping dirty water, and it was plugged and abandoned in 1951.

A second well (86-30-1P2) was drilled in 1926 to a depth of 1,842 feet, finishing in the Shakopee dolomite member of the Prairie du Chien formation. It is cased with 16-inch pipe to a depth of 182 feet, 12-inch pipe from 175 to 385 feet, 10-inch pipe from 754 to 860 feet, two 8-inch liners totaling 226 feet set at 1,678 and 1,300 feet, and 6-inch pipe from 1,673 to 1,693 feet. The principal supply was reported to have been obtained from the St. Peter sandstone and underlying Shakopee dolomite

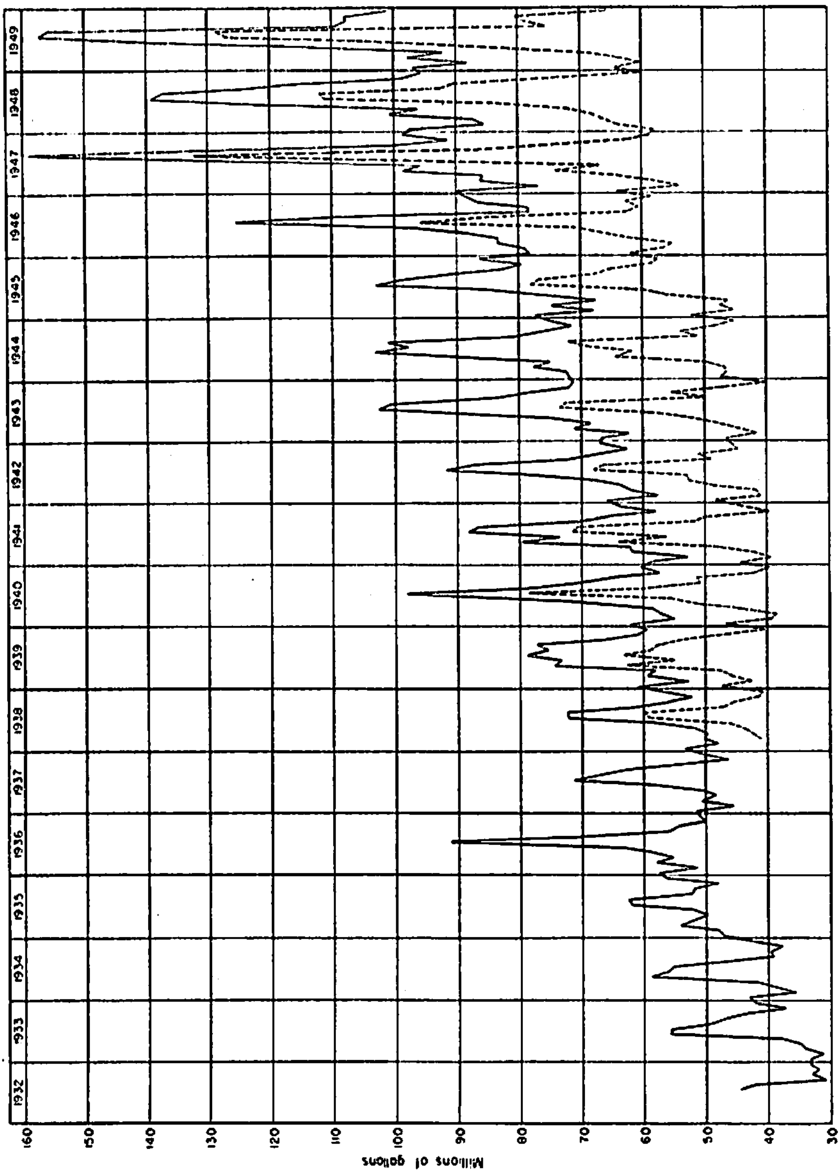


Figure 17.—Graph showing total pumpage by months from city wells at Fort Dodge (solid line) and pumpage excluding that used by one large consumer, which started operation in 1934 (dash line).

member. The initial water level was about 81 feet below land surface, and the reported yield was 300 gallons a minute with the pump set at 150 feet. As of 1942, the well was equipped with a turbine pump with a setting of 180 feet, and had a drawdown of approximately 20 feet when pumped at the rate of 160 gallons a minute. The nonpumping water level on September 14, 1942, was about 111 feet below land surface. The temperature of the water was 54½° F.

A shallower well (86-30-1Q1) was completed in July 1950 in sand and gravel in the basal part of the Pleistocene at a depth of 250 feet. It is cased with 12-inch pipe to a depth of approximately 231 feet, and about 16 feet of 8-inch screen, set at 249 feet, is attached to 8- and 10-inch pipe which extends up into the 12-inch pipe a distance of about 12 feet. The initial water level was 44.3 feet below land surface and the drawdown about 29.5 feet after a pumping period of 2 hours at approximately 180 gallons a minute. The pumping levels during this test, shown in figure 15, and the hydraulics of the aquifer are discussed on page 52. The well was equipped with a turbine pump and put in service in August 1951. The temperature of the water is 51° F.

The water pumped from the two producing wells is hard and has a high iron content; that from the deep well contains 2.0 parts per million fluoride. The water is first pumped through an iron-removal unit and then usually into the water tower, which has a capacity of 45,000 gallons. The town maintains records of the amount of water pumped; this information is given in table 8 by months from July 1941 through August 1950.

TABLE 8. WATER PUMPED BY TOWN OF GOWRIE
(Millions of Gallons)

	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950
January	....	1.36	1.46	....	2.03	1.83	1.66	2.04	4.10	3.09
February	....	1.46	1.42	2.62	1.78	1.87	1.51	2.47	4.01	2.63
March	....	1.33	1.22	1.33	1.63	1.72	1.42	1.96	2.71	2.21
April	....	1.42	1.30	....	1.60	2.07	1.67	2.22	2.79	2.57
May	....	1.37	1.40	....	1.75	2.47	1.87	2.63	3.39	2.80
June	....	1.86	1.66	1.63	2.00	2.63	2.62	3.57	3.91	3.49
July	2.14	1.87	1.94	1.74	2.21	3.05	2.89	3.64	4.12	4.18
August	2.17	1.87	2.15	2.31	2.26	3.08	4.18	3.70	4.45	4.15
September	2.53	2.28	2.16	2.38	2.94	2.95	2.32	4.44	3.47	....
October	2.04	1.91	2.03	2.41	2.63	2.75	2.98	3.88	3.26	....
November	1.55	1.50	1.98	2.39	2.35	2.64	2.60	3.88	3.34	....
December	1.37	1.46	1.50	1.89	2.06	2.11	2.60	3.05	3.24	....
Total	....	19.69	20.31	....	25.30	20.17	28.22	38.38	42.79	....

Harcourt. A well (86-29-13C1) was drilled in 1939 for the town of Harcourt to a depth of 1,092 feet and cased with 8-inch pipe to a depth of 197 feet, 6-inch pipe from 169 to 349 feet, 5-inch pipe from 338 to 425 feet, and with 4-inch pipe from 402 to 842 feet. The initial water level was reported to be 108 feet below land surface, and the drawdown was 52 feet after the well had been pumped for 24 hours at 30 gallons a minute. From water-level-recovery data submitted by the engineer on the project, the transmissibility is computed to be about 750 gallons a day per foot. The well is equipped with a turbine pump powered by an electric motor. The temperature of the water measured at the pump is 57° F.

The water is hard, contains an excessive amount of iron, and has a fluoride content of 2 parts per million. It is pumped under pressure through an iron-removal unit and directly into the water tower, which holds 25,000 gallons. The amount of water pumped is not metered, but it is estimated that the average pumpage in 1948 was about 3,000 gallons a day.

Lehigh. Two wells located in the valley of the Des Moines River supply the needs of the town of Lehigh. Well 87-28-12J1, 329 feet deep, is probably finished at the base of the Gilmore City limestone. It was cased with 6-inch pipe originally and recased with 4-inch pipe in 1951. The natural flow was reported to be 15 gallons a minute, and a turbine pump delivers 60 gallons a minute with a reported pumping level of 165 feet.

Well 87-28-12J2 was completed in 1937 at a depth of 1,005 feet in the Wapsipinicon limestone. It is cased with 12-inch cast iron pipe to a depth of 216 feet and with 10-inch pipe from 178 to 300 feet. The well flowed at a reported rate of 100 gallons a minute, about 25 gallons a minute being obtained from the Wapsipinicon limestone and the remainder largely from the Cedar Valley limestone and younger Devonian rocks. No pump has been installed on the well as the water is under sufficient pressure to flow into a small reservoir at the main pumphouse. The temperature of the water is 52½° F.

The water from the shallower well is hard, has an iron content of 0.5 part per million and a fluoride content of 2.0 parts per million; water from the deeper well is very hard and has a fluoride content of 2.0 parts per million. The water from the shallower well is pumped under pressure through an iron-removal and zeolite softening unit and into a small reservoir at the treatment plant. The treated water has a hardness of about

8 grains or 137 parts per million calculated as equivalent calcium carbonate. The water is then pumped from the reservoir into the mains under a pressure of about 240 feet of water, the overflow going into the 60,000-gallon water tower located on the upland level. The deeper well is used only in emergencies because of the excessive hardness of the water. During 1949 the average daily pumpage at Lehigh was estimated to be 27,000 gallons.

Moorland. The town of Moorland has no public water-supply system, and water is obtained from private wells bored to depths ranging between 40 and 70 feet. The Moorland Consolidated School obtains its water supply from a well drilled into rocks of the Osagian series at a depth of 325 feet. The water level is reported to be 145 feet below land surface. A force pump yields 7.5 gallons a minute, the drawdown being less than 40 feet. The water is hard, has a temperature of 51° F., and is passed through an iron-removal unit before entering a small pressure tank.

Stratford. The town supply for Stratford is obtained from two wells (86-26-7M1 and 86-26-7M2) in Hamilton County, in the NW¼SW¼ sec. 7, T. 86 N., R. 26 W. Town well 86-26-7M1 was completed in 1935 at a depth of 495 feet in limestone of Mississippian age and is cased with 12-inch pipe to a depth of 319 feet and 10-inch pipe from 291 to 462 feet. The water level is reported to have been initially 180 feet below land surface, and in September 1942 it was about 210 feet. The drawdown at 225 gallons a minute is approximately 10 feet at the end of the normal pumping period. The temperature of the water is 53° F. An older well (86-26-7M2), reportedly 500 feet in depth, is located about 10 feet north of the principal well. Both wells are equipped with turbine pumps.

The water pumped from the wells is hard and contains 1.0 part per million iron and 1.6 parts per million fluoride. Water is pumped directly from the wells through iron removal and zeolite softening equipment into two pressure tanks. The treated water has a hardness of about 5 grains or 85 parts per million calculated as equivalent calcium carbonate. It is estimated that an average of 20,000 gallons a day was pumped during 1942.

Vincent. The town of Vincent has no public water-supply system. Several privately owned drilled wells are finished in the basal sands and gravels of the Pleistocene or in the upper few feet of limestone comprising the bedrock in the locality, which yield ample supplies of water. The water level generally stands within 15 feet of the surface in these wells when they are idle. The temperature of the water pumped is 49°F. There are several bored wells in town about 25 feet in depth; the water in these wells stood within about 8 feet of the land surface in the fall of 1942.

Quality of Water

The general character of the ground waters in the different water-bearing beds in Webster County is indicated by the 67 water analyses presented in table 9. The water samples were collected by personnel of the Geological Survey and the Iowa State Department of Health and analyzed in the Water Analysis Laboratory of the State Hygienic Laboratories in cooperation with the Iowa Geological Survey and the Iowa State Department of Health.

Chemical Constituents in Relation to Use

Dissolved solids. When a water sample is evaporated to dryness, the residue consists of the constituents that were dissolved in water plus a small amount of water of crystallization and possibly some organic matter. Water containing less than 500 parts per million of dissolved solids generally is satisfactory for domestic use, although it may be hard and contain an excess of iron and fluoride. Water containing more than 1,000 parts per million is likely to have an objectionable taste or be unsatisfactory in other respects. Most of the water analyzed from wells in the county contains more than 500 parts per million, and a few samples contain more than 1,000 parts per million of dissolved solids.

Hardness. Calcium and magnesium contribute largely to the hardness of a water. These elements react with soaps to form insoluble salts; thus the reaction of the water with soap is a measure of hardness. The greater the calcium and magnesium content, the harder the water and the more soap required to obtain suds.

Calcium and magnesium bicarbonates cause carbonate hardness. This is often referred to as the temporary hardness inasmuch as calcium and magnesium carbonates are precipitated from solution to form scale when the water is boiled. The noncarbonate or permanent hardness is caused by calcium and magnesium sulfates or chlorides. The carbonate, noncarbonate, and total hardnesses of water from wells in Webster County are given in table 9.

TABLE 9. ANALYSES OF WATERS FROM

Dissolved constituents given in parts per million and in equivalents per million (in italic). One part per million is equivalent to one pound of substance per million pounds of water or 8.34 pounds per million gallons of water. An equivalent per million is a unit chemical equivalent weight of solute per million unit weights of solution. Concentration in equivalents per million is calculated by dividing the concentration in parts per million by the chemical combining weight of the substance or ion.

Well number	Location	Owner	Depth (feet)	Principal aquifer	Date of collection
	T. 86 N., R. 28 W.				
86-28-2P1	SE¼SE¼SW¼ sec. 2	E. & K. Gabrielson	720	Hampton limestone	Sept. 20, 1951
86-28-9R1	SE¼SE¼SE¼ sec. 9	Mary Ekstrand	31.0	Pleistocene deposits	Sept. 20, 1951
86-28-14H1	SW¼SE¼NE¼ sec. 14	Dayton, town well 2	1,240	Wapsipinicon limestone	Sept. 21, 1950
86-28-21B1	NE¼NW¼NE¼ sec. 21	DeKalb Hybrid Seed Co.	104	Pleistocene deposits	Sept. 20, 1951
86-28-31C1	NW¼NE¼NW¼ sec. 31	F. I. Johnson	58.9	Pleistocene deposits	Sept. 20, 1951
	T. 86 N., R. 29 W.				
86-29-3C1	NW¼NE¼NW¼ sec. 3	Edna Nelson	19.4	Pleistocene deposits	Sept. 20, 1951
86-29-13C1	SW¼NE¼NW¼ sec. 13	Harcourt, town well	1,092	Cedar Valley limestone	Sept. 21, 1950
86-29-26Q1	SW¼SW¼SE¼ sec. 26	Lanyon Cons. School	57.7	Pleistocene deposits	Sept. 12, 1942
86-29-35C2	SE¼NE¼NW¼ sec. 35	A. V. Mossberg	71.4	Pleistocene deposits	Sept. 11, 1942
	T. 86 N., R. 30 W.				
86-30-1P1	SE¼SE¼SW¼ sec. 1	Gowrie, town well 1	620	Gilmore City—Hampton for'tion	June 19, 1946
86-30-1P2	SE¼SE¼SW¼ sec. 1	Gowrie, town well 2	1,842	St. Peter—Prairie du Chien for'tions	June 19, 1946
86-30-1Q1	NW¼SW¼SE¼ sec. 1	Gowrie, town well 3	250	Pleistocene deposits	July 17, 1951
86-30-15P1	SE¼SE¼SW¼ sec. 15	C. J. Johnson	112	Pleistocene deposits	Sept. 20, 1951
86-30-31A1	SE¼NE¼NE¼ sec. 31	John Carstenson	60.0	Pleistocene deposits	Sept. 20, 1951
	T. 87 N., R. 27 W.				
87-27-10B1	NE¼NW¼NE¼ sec. 10	J. H. Goodrich	43.0	Pleistocene deposits	Sept. 21, 1951
87-27-18M1	SW¼NW¼SW¼ sec. 18	J. B. Marsh	355.8	Desmoinesian series	May 1, 1947
	T. 87 N., R. 28 W.				
87-28-12J1	SE¼NE¼SE¼ sec. 12	Lehigh, town well 1	329	Gilmore City limestone	Aug. 8, 1951
87-28-12J2	SE¼NE¼SE¼ sec. 12	Lehigh, town well 2	1,005	Wapsipinicon limestone	Dec. 7, 1937
87-28-15N1	NW¼SW¼SW¼ sec. 15	Burnside Cons. School	181.5	Desmoinesian series	Oct. 22, 1942
	T. 87 N., R. 29 W.				
87-29-9D1	NW¼NW¼NW¼ sec. 9	W. G. Larson	65.2	Pleistocene deposits	Sept. 20, 1951
	T. 87 N., R. 30 W.				
87-30-3C1	NW¼NE¼NW¼ sec. 3	W. R. Ingram	108	Pleistocene deposits	May 19, 1949
87-30-12E1	SE¼SW¼NW¼ sec. 12	Callender, town well 1	727	Mississippian rocks	Jan. 27, 1945
87-30-12L1	NE¼NE¼SW¼ sec. 12	Callender, town well 2	58	Pleistocene deposits	April 10, 1947
87-30-12L2	SW¼NE¼SW¼ sec. 12	Callender, town well 3	185	Desmoinesian series	Nov. 1, 1949
	T. 88 N., R. 27 W.				
88-27-3D1	SW¼NW¼NW¼ sec. 3	Duncombe, town (park)	974	Mississippian—Devonian Rocks	Jan. 25, 1945
88-27-11J1	SE¼NE¼SE¼ sec. 11	H. J. Dunbar	170	Pleistocene deposits	May 19, 1949
88-27-11N1	SW¼SW¼SW¼ sec. 11	Peter Ostblom	209	Pleistocene deposits	May 19, 1949
88-27-4A3	SW¼NE¼NE¼ sec. 4	Duncombe, town well 1	417	Mississippian rocks	Aug. 14, 1934

WELLS IN WEBSTER COUNTY, IOWA

Principal aquifer is given, but some water commonly is derived also from other formations in the uncased portion of the well (table 11).

pH: Determination commonly made several days after collection of sample and may not be identical with determination made at the well.

Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (calculated as $CaCO_3$) Total	Carbonate	Non-carbonate	Specific conductance (micromhos at 25°C)	pH
52	3.5	87 *4.34*	41 *3.37*	123 *5.35*	408 *6.69*	284 *5.91*	12 *.34*	2.2 *.12*	0.0 *.00*	800	386	334	52	1,070	7.5
55?	.1	206 *10.28*	65 *5.34*	57 *2.48*	493 *8.08*	271 *5.64*	59 *1.66*	.4 *.02*	116 *1.87*	1,130	781	404	377	1,520	7.4
58	.8	185 *9.23*	100 *8.22*	65 *2.83*	327 *5.36*	665 *13.85*	14 *.40*	2.8 *.15*	0 *.00*	1,260	872	268	604	1,560	7.4
52	1.1	131 *6.54*	47 *3.86*	76 *3.30*	598 *9.80*	166 *3.46*	1.5 *.04*	.5 *.03*	15 *.24*	776	520	490	30	1,090	7.2
54?	0.2	170 *8.48*	57 *4.69*	43 *1.87*	432 *7.08*	195 *4.06*	47 *1.33*	0.3 *.02*	138 *2.23*	947	658	354	304	1,520	7.4
52	.0	165 *8.23*	52 *4.28*	38 *1.65*	486 *7.97*	107 *2.23*	52 *1.47*	.4 *.02*	126 *2.03*	799	626	398	228	1,500	7.4
57	.8	123 *6.14*	70 *5.76*	62 *2.70*	358 *5.87*	385 *8.02*	12 *.34*	2.0 *.11*	1.8 *.03*	911	595	294	301	1,040	7.4
50?	.9	192 *9.58*	50 *4.11*	51 *2.22*	427 *7.00*	409 *8.52*	16 *.45*	.0 *.00*	22 *.35*	1,060	684	350	334	......	7.2
50?	.5	153 *7.63*	43 *3.54*	13 *.57*	366 *6.00*	147 *3.06*	84 *2.37*	.0 *.00*	13 *.21*	650	558	300	258	......	7.1
....	1.1	68 *3.39*	49 *4.03*	56 *2.43*	315 *5.16*	215 *4.48*	16 *.45*	2.4 *.13*	.0 *.00*	673	371	258	113	862	7.4
....	.5	91 *4.54*	49 *4.03*	67 *2.91*	415 *6.80*	219 *4.56*	17 *.48*	2.0 *.11*	.0 *.00*	712	428	340	88	975	7.5
51	2.7	93 *4.64*	39 *3.21*	98 *4.26*	515 *8.44*	148 *3.08*	9.0 *.25*	.6 *.03*	15 *.24*	715	392	392	0	1,010	7.6
....	4.1	134 *6.69*	53 *4.36*	82 *3.57*	568 *9.31*	212 *4.41*	6.0 *.17*	.8 *.04*	4.4 *.07*	898	552	466	86	1,050	7.4
....	.5	251 *12.53*	76 *6.25*	68 *2.96*	454 *7.44*	370 *7.70*	52 *1.47*	.4 *.02*	314 *5.06*	1,430	938	372	566	1,830	7.4
51	0.0	211 *10.53*	72 *5.92*	22 *.96*	625 *10.24*	206 *4.29*	55 *1.55*	0.05 *.00*	50 *.81*	985	822	512	310	1,500	7.0
51	4.3	120 *5.99*	50 *4.01*	66 *2.87*	476 *7.80*	259 *5.39*	14 *.40*	1.6 *.08*	.0 *.00*	778	530	390	140	1,140	7.5
....	.05	140 *6.99*	73 *6.00*	45 *1.96*	400 *6.56*	374 *7.79*	16 *.45*	2.0 *.11*	.0 *.00*	989	650	328	322	1,150	7.4
54	.20	231 *11.53*	111 *9.13*	57 *2.48*	322 *5.28*	816 *16.99*	15 *.42*	2.0 *.11*	2.2 *.04*	1,530	1,030	264	766	......	7.0
50	1.3	232 *11.58*	60 *4.93*	80 *3.48*	586 *9.60*	506 *10.53*	8 *.23*	.0 *.00*	3.1 *.05*	1,240	826	480	346	......	7.0
51	.1	621 *30.99*	125 *10.28*	200 *8.70*	417 *6.83*	1400 *29.15*	255 *7.19*	1.0 *.05*	538 *8.68*	3,790	2,060	342	1,718	3,950	7.1
51	1.0	156 *7.78*	46 *3.78*	57 *2.48*	568 *9.31*	240 *5.00*	1.0 *.03*	.5 *.03*	.0 *.00*	838	578	466	112	1,020	7.1
....	.9	101 *5.04*	42 *3.45*	69 *3.00*	408 *6.69*	215 *4.48*	13 *.37*	2.1 *.11*	1.3 *.02*	666	424	334	90	......	7.4
....	4.0	181 *9.04*	69 *5.66*	32 *1.39*	466 *7.64*	226 *4.70*	125 *3.52*	.2 *.01*	.0 *.00*	943	735	382	353	1,160	7.2
....	0.6	151 *7.53*	43 *3.54*	64 *2.78*	412 *6.75*	337 *7.02*	12 *.34*	0.9 *.05*	0:0 *.00*	891	554	338	216	1,220	7.3
51	1.4	105 *5.24*	31 *2.55*	72 *3.13*	534 *8.75*	133 *2.77*	5.5 *.15*	1.2 *.06*	Tr *.00*	642	390	390	0	......	7.4
51	4.5	150 *7.48*	47 *3.87*	95 *4.13*	766 *12.55*	124 *2.58*	.5 *.01*	.6 *.03*	3.1 *.05*	852	568	568	0	1,110	7.4
50	3.0	146 *7.28*	49 *4.03*	80 *3.48*	690 *11.31*	143 *2.98*	1.0 *.03*	.6 *.03*	4.9 *.08*	839	566	566	0	1,050	7.4
....	.5	95 *4.74*	52 *4.28*	50 *2.17*	425 *6.97*	186 *3.87*	11 *.31*	2.0 *.11*	.0 *.00*	635	451	348	103	......	7.4

TABLE 9. ANALYSES OF WATERS FROM

Well number	Location	Owner	Depth (feet)	Principal aquifer	Date of collection
	T. 88 N., R. 28 W.				
88-28-5D2	NW¼NW¼NW¼ sec. 5	Certain-teed Products, No. 4	2,060	Jordan sandstone	Oct. 3, 1951
88-28-6M1	NE¼NW¼SW¼ sec. 6	Vincent Clay Products Co.	355	Gilmore City limestone	Jan. 18, 1949
88-28-8R1	NW¼SE¼SE¼ sec. 8	Jordison Store	246	Osagian series	May 10, 1949
88-28-10B1	SE¼NW¼NE¼ sec. 10	A. D. Schnurr	55.6	Pleistocene deposits	July 9, 1940
88-28-31D1	NE¼NW¼NW¼ sec. 31	J. Y. Wickersham	370	Gilmore City limestone	Mar. 30, 1944
88-28-35N1	NE¼SW¼SW¼ sec. 35	Dolliver State Park	375	Hampton formation	Aug. 8, 1951
	T. 88 N., R. 29 W.				
88-29-23A1	NE¼NE¼NE¼ sec. 23	A. Edwards	60.4	Pleistocene deposits	Sept. 20, 1951
	T. 88 N., R. 30 W.				
88-30-13D1	NE¼NW¼NW¼ sec. 13	Moorland Cons. School	325	Osagian series	May 19, 1949
88-30-13J1	SW¼NE¼SE¼ sec. 13	Julia Fiala	230	Desmoinesian and Osagian series	May 19, 1949
88-30-26A1	SE¼NE¼NE¼ sec. 26	Howard Loehr	162	Dakota sandstone	Sept. 20, 1951
88-30-27N1	SW¼SW¼SW¼ sec. 27	H. R. Fiderlick	376	Gilmore City limestone	Oct. 28, 1945
	T. 89 N., R. 27 W.				
89-27-7A1	NE¼NE¼NE¼ sec. 7	Erwin Dencklau	244	Osagian series	April 22, 1949
89-27-7A2	NE¼NE¼NE¼ sec. 7	Erwin Dencklau	873	Devonian rocks	Oct. 7, 1949
89-27-8A1	NE¼NE¼NE¼ sec. 8	Dubbe	53.5	Pleistocene deposit	Aug. 11, 1939
	T. 89 N., R. 28 W.				
89-28-19K2	SE¼NW¼SE¼ sec. 19	Ft. Dodge Crmy., well 2	404	Mississippian rocks	Oct. 4, 1951
89-28-19L1	SE¼NE¼SW¼ sec. 19	Ft. Dodge, city well 3	218	Mississippian rocks	Aug. 15, 1934
89-28-19L4	SE¼NE¼SW¼ sec. 19	Ft. Dodge, city well 8	500	Mississippian rocks	Aug. 16, 1934
89-28-19L9	NW¼NE¼SW¼ sec. 19	Ft. Dodge, city well 12	541	Mississippian rocks	Aug. 15, 1934
89-28-19L11	NW¼NE¼SW¼ sec. 19	Ft. Dodge, city well 14	980	Devonian rocks	Nov. 23, 1935
89-28-19L12	SE¼NE¼SW¼ sec. 19	Ft. Dodge, city well 15	2,307	Jordan sandstone	Jan. 15, 1949
89-28-19L12	SE¼NE¼SW¼ sec. 19	Ft. Dodge, city well 15	2,307	Jordan sandstone	Oct. 5, 1951
89-28-19P5	NE¼SE¼SW¼ sec. 19	Cargill, Inc.	545	Mississippian rocks	Oct. 24, 1946
89-28-22A1	NE¼NE¼NE¼ sec. 22	G. H. Halverson	148	St. Louis limestone	April 28, 1946
89-28-32N1	SW¼SW¼SW¼ sec. 32	Peterson Bros.	325	Osagian series	June 21, 1944
	T. 89 N., R. 29 W.				
89-29-25N1	SW¼SW¼SW¼ sec. 25	B. Bergman	525	Hampton formation	Oct. 23, 1942
89-29-31F1	NE¼SE¼NW¼ sec. 31	A. J. Crawford	165	Fort Dodge formation	May 18, 1949
	T. 89 N., R. 30 W.				
89-30-2Q1	SE¼SW¼SE¼ sec. 2	V. F. Lentsch	623	Cretaceous rocks	May 17, 1949
89-30-11R1	NE¼SE¼SE¼ sec. 11	V. & M. McLaughlin	671	Devonian (?) rocks	May 17, 1949
89-30-23R2	NE¼SE¼SE¼ sec. 23	Johnson Twp. Cons. Sch.	55	Pleistocene deposits	Dec. 28, 1946
	T. 90 N., R. 27 W.				
90-27-22K1	NW¼NW¼SE¼ sec. 22	J. Riechert	66	Pleistocene deposits	Mar. 27, 1943
90-27-31N2	SW¼SW¼SW¼ sec. 31	C. S. Knudson	405	Kinderhookian series	Sept. 21, 1951
	T. 90 N., R. 28 W.				
90-28-15D1	NE¼NW¼NW¼ sec. 15	Badger, town well 1	280	Gilmore City limestone	Jan. 17, 1945

WELLS IN WEBSTER COUNTY, IOWA—Continued

Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (calculated as $CaCO_3$): Total	Hardness: Carbonate	Hardness: Non-carbonate	Specific conductance (micromhos at 25°C)	pH
57	.1	117 *5.84*	59 *4.85*	70 *3.04*	391 *6.42*	282 *5.87*	27 *.76*	1.8 *.10*	3.5 *.06*	779	535	320	215	1,240	7.8
....	2.0	109 *5.44*	52 *4.28*	47 *2.04*	490 *8.03*	155 *3.23*	9.0 *.25*	2.0 *.11*	.0 *.00*	642	486	402	84	862	7.3
53	1.0	116 *5.79*	39 *3.21*	46 *2.00*	464 *7.60*	151 *3.14*	2.0 *.06*	2.0 *.11*	.0 *.00*	......	450	380	70	744	7.1
....	0.0	168 *8.38*	50 *4.11*	29 *1.26*	468 *7.67*	218 *4.54*	33 *.93*	Tr *.00*	6.6 *.11*	814	624	384	240	......	7.1
49	.1	136 *6.79*	68 *5.59*	85 *3.70*	549 *9.00*	296 *6.16*	13 *.37*	.7 *.04*	1.3 *.02*	885	619	450	169	......	7.2
50	3.8	110 *5.49*	52 *4.28*	48 *2.09*	386 *6.33*	226 *4.71*	12 *.34*	2.4 *.13*	.0 *.00*	713	488	316	172	935	7.3
51	1.3	98 *4.89*	23 *1.89*	16 *.70*	312 *5.11*	71 *1.48*	5.0 *.14*	.5 *.03*	38 *.61*	438	339	256	83	619	7.0
51	10.0	213 *10.63*	54 *4.44*	59 *2.57*	451 *7.39*	476 *9.91*	1.0 *.03*	.5 *.03*	2.2 *.04*	1,130	754	370	384	1,210	7.1
51	1.2	120 *5.99*	31 *2.55*	24 *1.04*	520 *8.52*	41 *.85*	1.0 *.03*	.3 *.02*	3.1 *.05*	508	427	426	1	707	7.2
52	1.0	195 *9.73*	66 *5.43*	63 *2.74*	556 *9.11*	397 *8.27*	2.0 *.06*	.4 *.02*	.0 *.00*	1,050	758	456	302	1,540	7.1
....	.2	88 *4.39*	41 *3.37*	62 *2.70*	493 *8.08*	121 *2.52*	5.0 *.14*	1.2 *.06*	.0 *.00*	592	388	388	0	......	7.3
....	7.8	153 *7.63*	56 *4.61*	75 *3.26*	632 *10.36*	236 *4.91*	3.0 *.08*	1.6 *.08*	.0 *.00*	900	612	518	94	1,130	7.2
....	5.1	......	......	......	......	......	5.0 *.14*	......	......	......	......	......	......	1,070	7.2
....	.2	631 *31.49*	185 *15.21*	56 *2.43*	454 *7.44*	866 *18.03*	313 *8.83*	Tr *.00*	890 *14.36*	3,080	2,330	310	2,027	......	7.2
52	.9	135 *6.75*	52 *4.27*	47 *2.04*	481 *7.88*	218 *4.54*	5.0 *.14*	.7 *.04*	8.0 *.13*	728	552	394	158	1,000	7.5
51	1.2	90 *4.49*	58 *4.77*	38 *1.65*	476 *7.80*	154 *3.20*	4.0 *.11*	1.0 *.05*	.0 *.00*	634	463	390	73	......	7.0
52	.9	92 *4.59*	52 *4.27*	40 *1.74*	415 *6.80*	160 *3.33*	5.0 *.14*	1.0 *.05*	.0 *.00*	646	443	340	103	......	7.2
52	1.6	84 *4.19*	52 *4.27*	34 *1.48*	459 *7.52*	122 *2.54*	3.0 *.08*	Tr *.00*	.0 *.00*	581	423	376	47	......	7.3
52	1.0	119 *5.94*	43 *3.53*	2.70 *.12*	403 *6.61*	151 *3.14*	7.0 *.20*	Tr *.00*	.0 *.00*	617	474	330	144	......	7.1
59	.3	108 *5.39*	39 *3.21*	204 *8.87*	376 *6.16*	237 *4.93*	224 *6.32*	1.2 *.06*	.0 *.00*	1,030	430	308	122	1,470	7.8
57	1.2	118 *5.89*	45 *3.70*	106 *4.61*	436 *7.14*	192 *3.99*	89 *2.51*	.8 *.04*	.0 *.00*	779	479	357	122	1,380	7.7
....	.7	129 *6.44*	43 *3.53*	51 *2.22*	448 *7.34*	195 *4.06*	6.0 *.17*	.6 *.03*	.0 *.00*	693	498	367	131	926	7.3
51	2.5	156 *7.78*	49 *4.03*	43 *1.87*	500 *8.20*	227 *4.73*	2.0 *.06*	0.9 *.05*	0.0 *.00*	709	590	410	180	1,050	7.3
53	.4	108 *5.39*	40 *3.29*	188 *8.17*	437 *7.16*	412 *8.58*	16.0 *.45*	2.0 *.11*	.10 *.00*	996	434	358	76	......	7.3
50	2.0	125 *6.24*	40 *3.29*	52 *2.26*	466 *7.64*	174 *3.62*	11.0 *.31*	2.0 *.11*	22 *.35*	694	470	382	94	......	7.5
51	1.0	188 *9.38*	59 *4.85*	82 *3.57*	495 *8.11*	472 *9.83*	1.0 *.03*	.5 *.03*	.0 *.00*	1,160	712	406	306	1,240	7.0
54	11.5	112 *5.59*	32 *2.63*	98 *4.26*	483 *7.92*	206 *4.29*	8.0 *.23*	.5 *.03*	.0 *.00*	741	411	396	15	923	7.2
54	.45	112 *5.59*	41 *3.37*	19 *.83*	439 *7.20*	112 *2.33*	1.0 *.03*	.5 *.03*	.0 *.00*	540	448	360	88	724	7.4
....	4.1	146 *7.28*	30 *2.47*	50 *2.17*	410 *6.72*	247 *5.14*	6.5 *.18*	.7 *.04*	.0 *.00*	756	488	336	152	937	7.6
51	1.6	99 *4.94*	33 *2.71*	18 *.78*	449 *7.36*	51 *1.06*	2.0 *.06*	.0 *.00*	5.3 *.09*	417	382	368	14	......	7.2
....	3.0	107 *5.34*	53 *4.36*	40 *1.74*	456 *7.47*	154 *3.21*	8.0 *.23*	1.8 *.10*	3.1 *.05*	594	485	374	111	872	7.3
....	3.5	118 *5.89*	42 *3.45*	45 *1.96*	478 *7.83*	167 *3.48*	3.3 *.09*	0.4 *.02*	0.4 *.01*	650	467	392	75	......	7.4

TABLE 9. ANALYSES OF WATERS FROM

Well number	Location	Owner	Depth (feet)	Principal aquifer	Date of collection
90-28-15D2	NW¼NW¼NW¼ sec. 15	Badger, town well 2	530	Kinderhookian series	July 19, 1948
90-28-24J1	SE¼NE¼SE¼ sec. 24	C. S. Knudson	164	St. Louis limestone	Sept. 21, 1951
90-28-27E1	SW¼SW¼NW¼ sec. 27	E. McGill	140	St. Louis limestone	Nov. 17, 1942
	T. 90 N., R. 29 W.				
90-29-9K1	NE¼NW¼SE¼ sec. 9	H. & M. Neimeyer	91	St. Louis limestone	May 17, 1940
	T. 90 N., R. 30 W.				
90-30-3A1	NE¼NE¼NE¼ sec. 3	E. F. Beeh	165	Cretaceous rocks	Oct. 2, 1947
90-30-15N1	NW¼NW¼SW¼ sec. 15	R. E. Mason		Cretaceous rocks	May 17, 1940
90-30-35Q1	SW¼SW¼SE¼ sec. 35	Erling Malmin	710	Cretaceous rocks	May 17, 1940

WELLS IN WEBSTER COUNTY, IOWA—Continued

Temperature (°F)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness (calculated as $CaCO_3$) Total	Carbonate	Non-carbonate	Specific conductance (micromhos at 25°C)	pH
....	.8	99 *4.94*	50 *4.11*	45 *1.96*	439 *7.20*	163 *3.39*	6.0 *.17*	1.6 *.08*	.0 *.00*	634	452	360	92	852	7.6
....	1.8	104 *5.19*	39 *3.21*	31 *1.35*	490 *8.03*	55 *1.14*	1.4 *.04*	.3 *.02*	6.6 *.11*	479	420	402	18	753	7.4
49	.4	101 *5.04*	24 *1.97*	54 *2.35*	505 *8.28*	54 *1.12*	4.0 *.11*	.0 *.00*	.0 *.00*	520	350	350	0	......	7.2
51	.1	86 *4.29*	26 *2.14*	10 *.43*	344 *5.64*	40 *.83*	1.0 *.03*	.5 *.03*	5.3 *.09*	345	322	282	40	526	7.4
51	.0	198 *9.88*	64 *5.26*	64 *2.78*	447 *7.33*	465 *9.68*	3.0 *.08*	.7 *.04*	.7 *.01*	986	757	366	391	1,230	7.9
54	2.4	86 *4.29*	29 *2.38*	156 *6.78*	466 *7.64*	261 *5.43*	10 *.28*	.7 *.04*	.0 *.00*	1,150	334	334	0	1,160	7.4
54	1.0	150 *7.48*	40 *3.29*	55 *2.39*	490 *8.03*	229 *4.77*	5.0 *.14*	.5 *.03*	.0 *.00*	776	538	402	136	965	7.1

Water having a total hardness of 50 parts per million or less, calculated as calcium carbonate, is generally regarded as soft. The ground water of Webster County is hard, as are most of the waters of Iowa, but some waters are considerably harder than others. The range in hardness of the ground waters sampled in the county is between 300 and 2,400 parts per million, although most of the water utilized probably has a hardness of less than 1,000 parts per million. The hardest waters seem to be the near-surface waters, which are high in chlorides or nitrates, and the water in the Wapsipinicon limestone in the southern part of the county. The waters are too hard to be used satisfactorily in boilers without treatment.

Iron. An iron content of more than 0.3 part per million in water pumped from wells will generally result in the precipitation of iron hydroxide or oxide, yellowish or reddish in color, which will stain plumbing fixtures, utensils, and clothing. Except for water pumped from shallow bored wells, most of the water analyzed in Webster County contained enough iron to cause staining.

Iron can generally be removed by aeration and filtration although it sometimes has to be removed by other methods. The iron can often be held in solution or stabilized by the addition of certain chemicals such as phosphates.

Manganese is frequently associated with iron in water and may cause black stains; however, the water in Webster County does not seem to contain enough manganese to be troublesome.

Fluoride. Although fluoride is commonly only a minor constituent of ground water, it seems to have a well-substantiated effect in dental hygiene. Small amounts of fluoride in the water supply seems to be beneficial to children's teeth during the period of growth in that tooth decay is definitely decreased. Mottling of teeth, however, is likely to become increasingly pronounced as the fluoride content increases above 1.5 parts per million (Wieter, 1938). Adults' teeth apparently are unaffected by the continued use of water high in fluorides. As shown in figure 18, the fluoride content of water from aquifers below the St. Louis (Mississippian) limestone often is more than 1.5 parts per million, the upper acceptable limit in the Public Health Service Drinking Water Standards. The fluoride content in water from Cambrian strata appears to fall within the acceptable limits.

Nitrate. Nitrate is often an important constituent in water pumped from shallow bored wells in the county. Deep wells

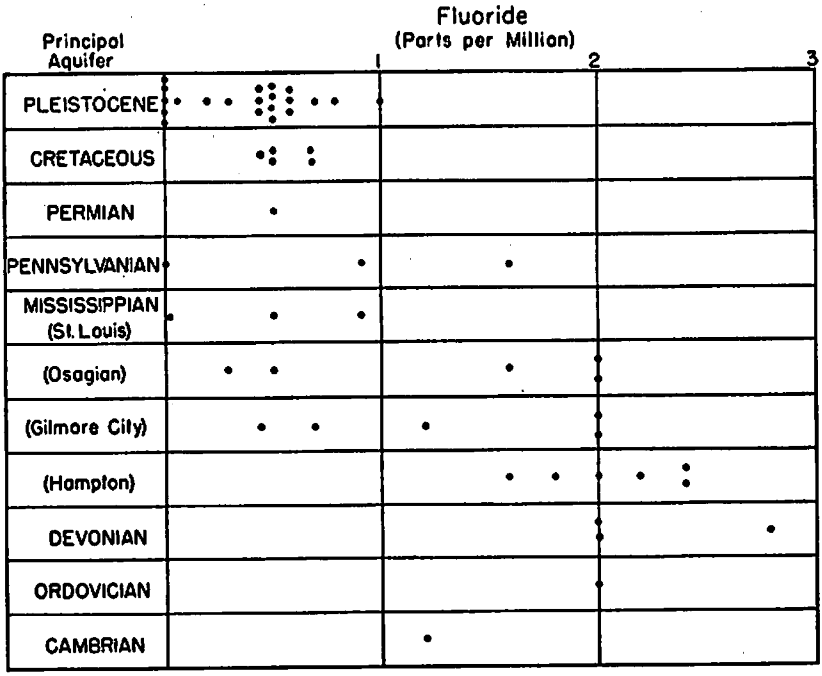


Figure 18.—Fluoride content of samples of water from wells in Webster County.

which yield water with a high-nitrate content may be suspected to receive shallow water at the surface through the mouth of the well or near-surface water through holes in the casing. High-nitrate content of well water also suggests that the supply may be bacterially contaminated. I. H. Borts (1949) states that of 874 wells in Iowa yielding a water with a nitrate nitrogen content of more than 20 parts per million (88 parts per million of nitrate), 87 percent were bacterially unsafe or unsatisfactory. Boiling water eliminates the bacteria, but the nitrate is not removed and may actually be increased by concentration resulting from evaporation of the water.

The nitrate content of well water has received considerable attention since the recognition by Comly (1945, p. 112-116) that nitrate water used in formulas in infant feeding is a cause of cyanosis in some infants. Cyanosis gives the baby a bluish color and may be accompanied by vomiting, excessive crying, and irritability. Prolonged ingestion of high-nitrate water by infants may be very dangerous. The Iowa Department of Health suggests that a nitrate content of 10 parts per million (as NO_3) or more in water may cause cyanosis in infants using that water, and that water containing nitrates in excess of 50 parts per million definitely should not be used in the feeding of infants.

Other constituents. Several aquifers seem to yield water containing a noticeable amount of hydrogen sulfide, which gives the water an odor similar to that of rotten eggs. The gas is easily eliminated by aeration.

The chloride content of ground water utilized in Webster County is generally negligible except in some of the very shallow wells, where it still is not sufficient to give a salty taste to the water. Higher concentrations probably occur in the water-bearing beds below the St. Lawrence formation at great depths.

Quality of Water in Relation to Water-Bearing Formation

Water obtained from wells finished in sand and gravel of Pleistocene age, sandstones of Cretaceous, Permian, and Pennsylvanian age, and limestone and sandstone of the St. Louis limestone is likely to represent a particular water-bearing bed, whereas water from most wells finished in rocks at a greater depth than that of the St. Louis limestone probably comes from more than one water-bearing formation. Thus, a comparison of waters in the deeper wells is necessarily more general. The general quality of water encountered in the various water-bearing beds in Webster County is shown in figure 19.

Waters from Mississippian, Ordovician, and Cambrian rocks generally seem to be less highly mineralized than waters from other aquifers in Webster County. The most highly mineralized waters are obtained from aquifers near the surface and in Devonian rocks. In some areas in Iowa, water from below the deep-lying St. Lawrence formation is highly mineralized and contains a large amount of sodium chloride.

Sanitary Considerations

The analyses given in table 9 show only the mineral constituents and do not indicate the sanitary condition of the well water. Certain constituents such as nitrate may, however, suggest pollution.

Inasmuch as nearly all domestic supplies in Webster County are developed from wells, every precaution should be taken in their construction to avoid contamination. Bored and dug wells are most likely to be contaminated because they utilize the more

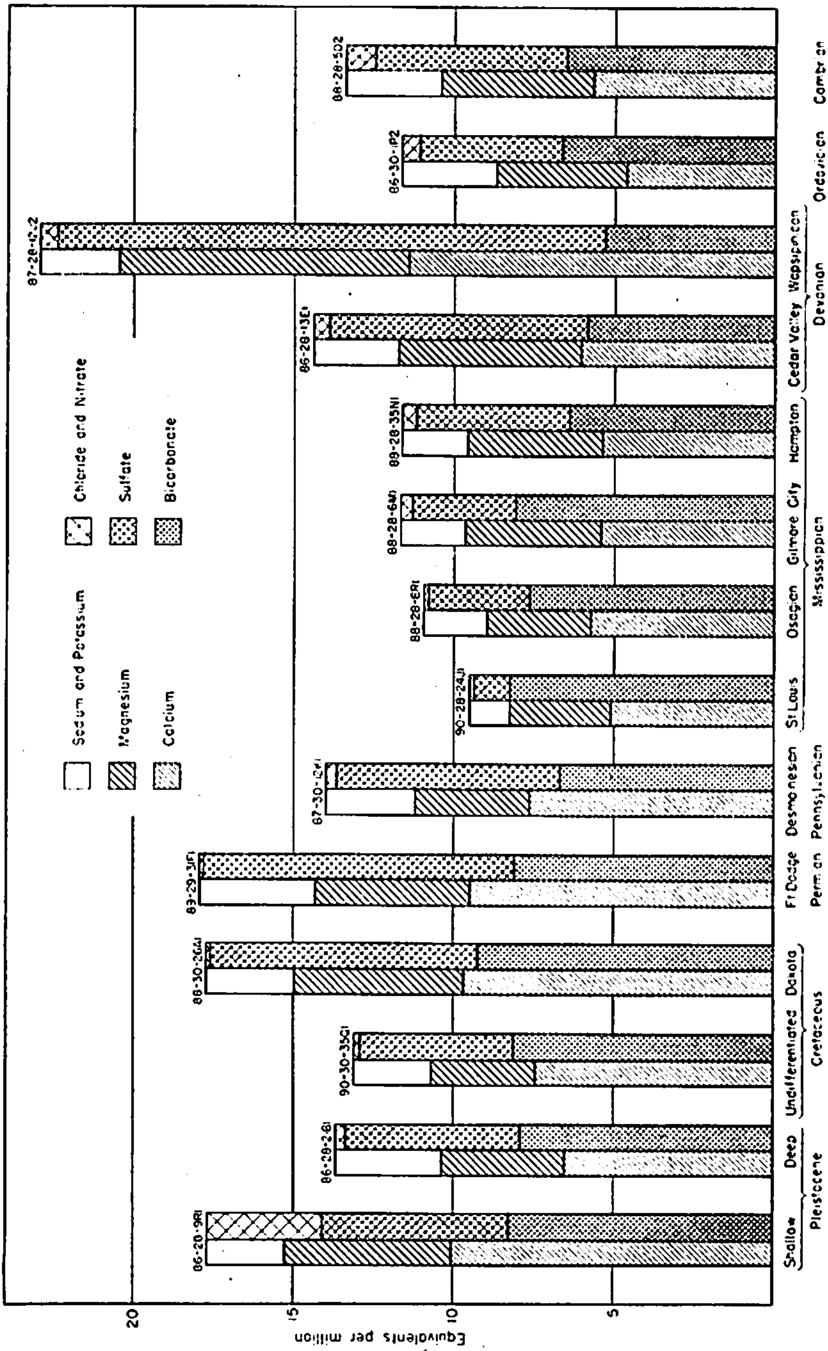


Figure 19.—Graphic representation of analyses of water samples from wells finished in the different water-bearing beds in Webster County.

easily contaminated near-surface water, and they may permit unsafe water to seep through the joints in the curbing. Drilled wells are usually much safer in that casing extends to a considerable depth and prevents near-surface water from entering the well.

A well, of any type, that is located in an undrained pit is commonly polluted by the entry of surface water through the mouth. (See fig. 13.) The abnormally high water levels measured at times in well 86-30-5C1 are caused by water spilling into the well from the pit in which the well was drilled. If a well is to be finished in a pit, it is desirable that a tile drain be provided; even so, water levels may rise high enough at times to make the tile drain ineffective and to let water enter the well. A watertight seal may be installed between the casing and the pump, but even this may sometimes fail to keep out all the water.

It is desirable to locate wells as far as possible from sources of contamination such as barnyards, privies, etc. The practice of constructing well pits to protect pumping equipment during cold weather adds to the convenience of operating the well, but for sanitary considerations it is more desirable to finish the well above the land surface.

Geologic Formations and Their Water-bearing Characteristics

Pre-Cambrian Rocks

Character, distribution, and thickness. Pre-Cambrian crystalline rocks of igneous and metamorphic origin and stratified rocks of sedimentary origin probably underlie Webster County. The sedimentary rocks, which consist of soft, flaky, red, slightly dolomitic shale were only partly penetrated in the subsurface by Fort Dodge city well 15, hence only meager lithologic details are known. Correlated subsurface information obtained from deep borings throughout the State of Iowa suggests that the 17 feet of red shale encountered in Fort Dodge city well 15 may be part of a thicker section of undifferentiated beds of shale and sandstone lying east of Webster County. However, an additional possibility is that the red shale is a residual deposit upon subjacent crystalline rocks.

In Iowa, red shale and sandstone that underlie known strata of Late Cambrian age commonly have been assigned to pre-Cambrian systems (Trowbridge and Atwater, 1934, p. 29).

Thicknesses of pre-Cambrian sedimentary rocks in Webster County are not known definitely, but subsurface data from deeper borings in adjacent counties suggest that these sediments are only a few tens of feet thick. Owing, therefore, to this probably limited thickness and the fine-grained texture of the rocks, these strata would yield very little ground water in Webster County.

Cambrian System

St. Croixan Series

Dresbach Formation

Character, distribution, and thickness. The Dresbach formation, the oldest Cambrian formation recognized in Iowa, is represented in the subsurface in Webster County by strata tentatively assigned to the Eau Claire and underlying Mt. Simon sandstone members. The uppermost member, the Galesville sandstone, has not been recognized in Webster County. The Mt. Simon member, as indicated by samples from city well 15 in Fort Dodge, consists of poorly sorted, clear to orange, angular to rounded frosted quartz sand having some argillaceous grayish-green calcareous siltstone beds from a depth of 2,225 to 2,290 feet. The Eau Claire member is composed of glauconitic and silty, fine-grained limestone with minor amounts of shale.

The Mt. Simon and Eau Claire members are probably present throughout Webster County except in the Manson area. The Mt. Simon member at Fort Dodge is about 65 feet thick and the Eau Claire about 95 feet thick. The Dresbach formation probably thins to the north and west. The Mt. Simon member thickens progressively eastward, where the Galesville is present.

Age and correlation. The Dresbach formation (Winchell, 1886, p. 334-337) as restricted by Trowbridge and Atwater (1934, p. 38-45, 79) includes all beds between the base of the Mt. Simon sandstone and the base of the Ironton sandstone member of the Franconia sandstone. The Dresbach sandstone as restricted by Walcott (1914, p. 354, from Ulrich's ms.) is named the Galesville sandstone by Trowbridge and Atwater (1934, p. 45, 79) and is reduced to member status in the Dresbach formation along with the Eau Claire and Mt. Simon sandstones. This usage is adopted by Twenhofel, Raasch, and Thwaites (1935, p. 1691).

The formation crops out in Minnesota and Wisconsin and a part of it in the extreme northeastern part of Iowa. It has been traced from this area westward in the subsurface into Webster County, where it rests on shale and probably on crystalline rocks of supposed pre-Cambrian age. It is overlain by the Franconia sandstone.

Water supply. At Fort Dodge, the Mt. Simon sandstone probably yields a small amount of water to city well 15. During the drilling of the Dresbach formation the slight increase in the rate of flow of the well was accompanied by an increased chloride content. It is inferred that small quantities of water can be obtained from the Mt. Simon member in this area and that the water is likely to be highly mineralized. No appreciable quantity of water is thought to occur in the Eau Claire member in the county.

Franconia Sandstone

Character, distribution, and thickness. Strata assigned to the Franconia sandstone were penetrated in city well 15 at Fort Dodge between depths of 1,870 and 2,130 feet. The upper 105 feet of beds are composed of gray very glauconitic dolomitic siltstone and are underlain by 155 feet of highly glauconitic very finely crystalline gray and buff limestone with light- and dark-green glauconitic shales. Near the base the formation is composed mostly of glauconite.

The Franconia sandstone is probably present throughout Webster County except in the Manson area. At Fort Dodge the formation is 260 feet thick, and like the underlying Dresbach, it probably thins to the north and west.

Age and correlation. The Franconia sandstone is deeply buried over most of Iowa but crops out in the extreme northeastern part of the state. The formation includes beds between the top of the Dresbach and the base of the St. Lawrence formation, all of Late Cambrian age. In the outcrops in Iowa, Minnesota, and Wisconsin, the beds are heavily glauconitic, a characteristic that persists westward. In Webster County the base of the formation is considered to be at the base of the highly glauconitic beds overlying the less glauconitic beds of the Dresbach. The top of the formation is considered to be at the upper limit of glauconitic siltstone, beneath the slightly glauconitic dolomite of the St. Lawrence formation.

Water supply. Very little water is reported to have been encountered in the Franconia sandstone in Fort Dodge city well 15. The composition of the beds is such that no appreciable amount of water is expected to be transmitted by them. Farther east the Franconia contains more sand, but it usually is fine grained and yields only small quantities of water to wells.

St. Lawrence Formation

Character, distribution, and thickness. The St. Lawrence formation has been penetrated by two wells in the county, namely, Fort Dodge city well 15 (89-28-19L12) and the Certain-teed Products Corp. well (88-28-5D2), southeast of Fort Dodge. At both wells the formation consists chiefly of silty, fine-grained cream to gray dolomite. At well 88-28-5D2, a 20-foot bed of medium- to coarse-grained frosted sand occurs near the middle of the formation, and the lower beds are slightly glauconitic.

The St. Lawrence formation is probably present throughout Webster County except in the Manson area. At Fort Dodge it is between 80 and 95 feet thick, at Rockwell City, 12 miles west of Webster County, it is 65 feet thick, and 13 miles south of the county it is 80 feet thick.

Age and correlation. The Cambrian St. Lawrence formation, like other Cambrian and Ordovician strata in Iowa, crops out only in the northeastern part of the State. It has been traced in the subsurface from northeastern Iowa to Webster County and beyond. The formation is overlain by the Jordan and underlain by the Franconia sandstones. The various members of the formation were not differentiated in the subsurface in Webster County.

Water supply. Locally in the central and eastern parts of the State, large supplies of water are obtained from the dolomite where it contains large crevices. In the vicinity of Fort Dodge and at the city well drilled in 1951 at Jefferson, Greene County, the dolomite beds seem to be too dense to yield much water. The Jefferson city well apparently obtained about 10 gallons a minute with a drawdown of over 300 feet from the Franconia sandstone and St. Lawrence formation. The quality of the water in the St. Lawrence is inferred to be similar to that in the overlying Jordan sandstone as there appears to be no restriction to the movement of water between the two formations.

Jordan Sandstone

Character, distribution, and thickness. The Jordan sandstone in Webster County is shown by well cuttings to be composed primarily of a white to light-gray rounded frosted quartz sand. Most of the formation is tightly cemented by dolomite, but some loosely cemented beds occur.

The Jordan sandstone occurs throughout the county with the probable exception of the northwestern part, adjacent to the Manson area. It is between 55 and 60 feet thick at Fort Dodge and probably exceeds 40 feet throughout the county. The present general configuration and altitude of the top of the Jordan sandstone in Webster County is shown by figure 20.

Age and correlation. The Upper Cambrian Jordan sandstone has been traced by means of well cuttings from its outcrop area in eastern Iowa to other parts of the State. In Webster County it includes the sandstones and very sandy dolomite beds lying below the Oneota member of the Prairie du Chien formation and above the dolomite of the St. Lawrence formation. As such, it includes the Madison sandstone, which Trowbridge and Atwater (1934, p. 21-79) state is equivalent to the Jordan sandstone.

Water supply. The Jordan sandstone, supplemented by parts of the St. Lawrence formation and the overlying Oneota member of the Prairie du Chien formation, composes the most extensive and consistently prolific aquifers in the State. The water is hard (table 9) but otherwise acceptable for most purposes. Equal or larger yields, however, are obtained in more limited areas from sands and gravels in the larger river valleys of the State, from the Dresbach in eastern Iowa, and locally from the aquifers in younger rocks.

Four wells have been drilled through the Jordan sandstone in Webster County. Fort Dodge city well 1 (89-28-19P1) developed a reported flow of 571 gallons a minute when it reached

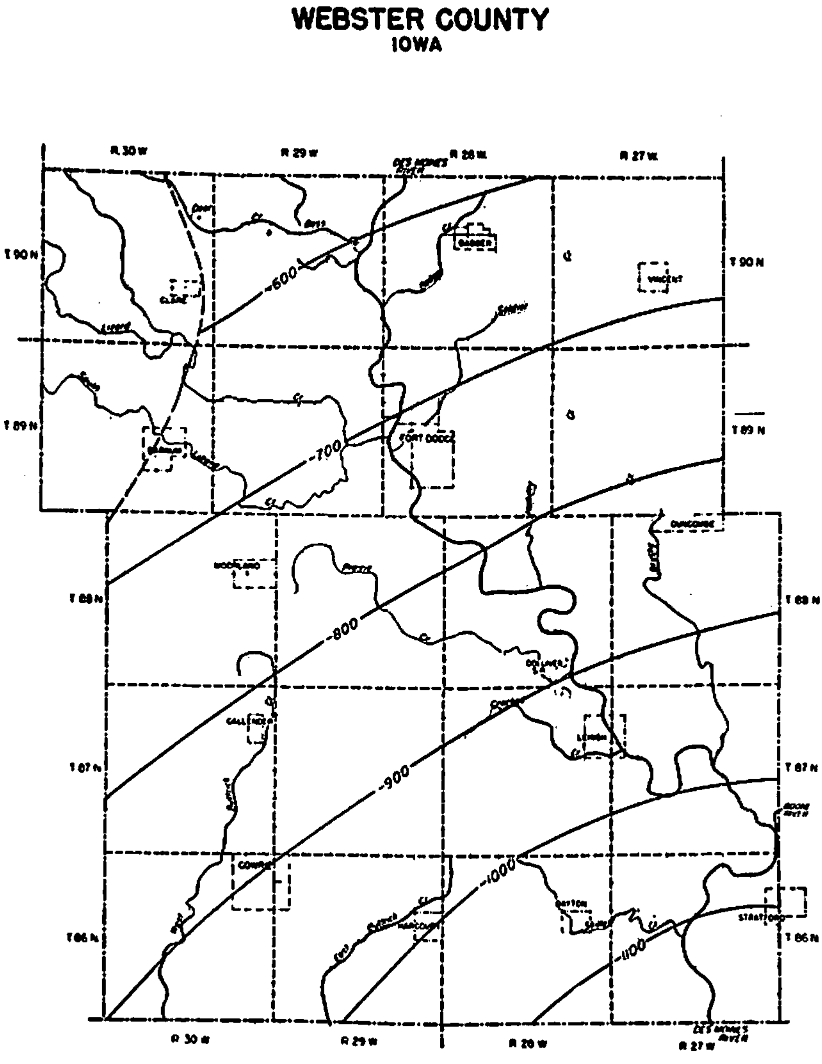


Figure 20.—Map of Webster County showing the general configuration and altitude with reference to mean sea level, of the top of the Jordan sandstone.

the Jordan sandstone. Of this flow, about 200 gallons a minute was possibly obtained from the Oneota dolomite and Jordan sandstone. The head on the aquifers was apparently not measured at the time of completion of this well in 1907, and it has since been abandoned. (Details of this and other city wells are recorded under the heading of Fort Dodge water supply.) The yield from the Wahkonsa Hotel well, drilled in 1923 to the Jordan sandstone and subsequently abandoned, is not known. The Certain-teed Products Corp. well (88-28-5D2) was completed in 1950 at a depth of 2,060 feet in the Franconia sandstone. Most of the water is believed to enter the well from the Oneota dolomite member and the Jordan sandstone between 1,690 and 1,910 feet. The initial nonpumping water level is reported to have been 117 feet below land surface (altitude approximately 998 feet), and the drawdown is reported as 40 feet when pumped at 620 gallons a minute for more than 24 hours. The temperature of the water is 57° F.

Fort Dodge city well 15 (89-28-19L12) is apparently finished in pre-Cambrian rocks but obtains most of its water from the Jordan sandstone and probably some from the Oneota dolomite and overlying aquifers. The well is reported to have flowed at 350 gallons a minute on completion in 1949, the mouth of the well being about 980 feet above sea level. On October 4, 1951, the water level was at an altitude of 982.2 feet after the well had been idle for a few days, and the drawdown was 70 feet after 8.5 hours of pumping at about 2,900 gallons a minute. The coefficient of transmissibility of the aquifers open to the well, calculated from brief pumping tests made in the Fort Dodge city well field, is between 80,000 and 110,000 gallons a day per foot. The temperature of the water was 59° F. in January 1949.

ORDOVICIAN SYSTEM

Beekmantownian Series

Prairie du Chien Formation

Character, distribution, and thickness. The three members of the Prairie du Chien formation, the Oneota dolomite, Root Valley sandstone, and Shakopee dolomite, are recognizable, in part, from well cuttings in and near Fort Dodge. The upper member of the Shakopee dolomite, is composed of sandy, finely crystalline, brown, cream, and gray dolomite. The middle member, the Root Valley, is predominantly a white medium- to coarse-grained frosted sand with dolomite cement and sandy, finely crystalline dolomite. The upper boundary of the Root Valley sandstone member is not clearly defined in Webster County. The lower member, the Oneota dolomite, is represented by cherty and sandy, finely crystalline buff-gray dolomite.

The Prairie du Chien formation probably is present throughout the entire county with the exception of the northwestern part adjacent to the Manson area.

The formation is about 270 feet thick in the vicinity of Fort Dodge, thinning in a northwest direction from about 450 feet in central Story County to about 210 feet at Rockwell City in Calhoun County, a distance of about 65 miles. The Oneota dolomite member in Fort Dodge ranges in thickness between 145 and 170 feet.

Age and correlation. The Prairie du Chien formation rests on the Jordan sandstone and is overlain by the St. Peter sandstone in Webster County. It is equivalent to the Prairie du Chien group of Bain (1906, p. 18). The Shakopee dolomite member was named by Winchell (1874, p. 138-147) and includes beds between the St. Peter sandstone and underlying New Richmond or Root Valley sandstone. These beds were named the Willow River dolomite by Wooster (1882, p. 106), which name was later adopted by Trowbridge and Atwater (1934, p. 65-73) and Powers (1935, p. 171); however, the earlier name, Shakopee member, is used in this report.

The name Root Valley was used by Stauffer and Theil (1941, p. 59-62) for a sandstone between the Oneota and Shakopee dolomite members. It is well exposed in the valley of Root River in southeastern Minnesota. The name New Richmond was applied by Wooster (1882, p. 106) to sandstone thought to lie between the Shakopee and Oneota dolomite along the Willow River at New Richmond, but Sardeson (1934, p. 29-34) found important parts of Shakopee fauna in the interbedded dolomites of the sandstone at this location. It therefore seems desirable to follow the proposal of Stauffer and Theil and adopt the name Root Valley for the sandstone between the Shakopee and Oneota dolomite members in Iowa.

The Oneota dolomite member was named by McGee (1891, p. 331, 332) for dolomite between the Root Valley sandstone and the underlying Jordan sandstone. It is considered to be the basal member of the Prairie du Chien formation, which is of Early Ordovician age (Trowbridge and Atwater, 1934, p. 78, 79).

Water supply. Aquifers in the Prairie du Chien formation generally yield large supplies of water to wells in most of the State. In the vicinity of Fort Dodge, the water in the aquifers above the Oneota dolomite member seems to be more closely related to the water in the St. Peter sandstone; that in the Oneota seems to be more closely related to the water in the Jordan sandstone. In the drilling of the well for Certain-teed Products Corp. (88-28-5D2), the water level is reported to have lowered from a depth of 69 feet to 117 feet when the upper part of the Oneota dolomite had been penetrated. There is no record of a production test made prior to the time the water level lowered in this well. An older well (88-28-5D1) drilled for the same plant in 1925 (then Beaver Products Co.), was finished in the Root Valley sandstone at a depth of 1,669 feet. Some water was reported to have been encountered in the Shakopee and Root Valley sandstone members, but the principal supply was presumably from the overlying St. Peter sandstone. The water level reportedly stood 62 feet below the curb in 1925.

Chazyan Series

St. Peter Sandstone

Character, distribution, and thickness. The St. Peter sandstone in Webster County is shown by well cuttings to be predominantly a medium grained white frosted quartz sand. It differs little in general appearance from the sands of the Prairie du Chien formation or Jordan sandstone. Heavy-mineral studies, however, may indicate considerable difference (Stauffer and Thiel, 1941, p. 75). In southeastern Minnesota the St. Peter sandstone contained only a trace of garnet and appreciable zircon, whereas the Root Valley sandstone member of the Prairie du Chien formation and Jordan sandstone had a high percentage of garnet and relatively little zircon.

The St. Peter sandstone probably is present over Webster County except near the Manson area of Calhoun County. In Webster County the formation seems to range between 55 and 65 feet in thickness, the present configuration and altitude of the top of the formation being shown on figure 21.

Age and correlation. In Webster County, the St. Peter sandstone is underlain by the Shakopee dolomite member of the Prairie du Chien formation and is overlain by the Glenwood shale member of the Platteville limestone. The sandstone crops out in northeastern Iowa. The formation was named for sand-

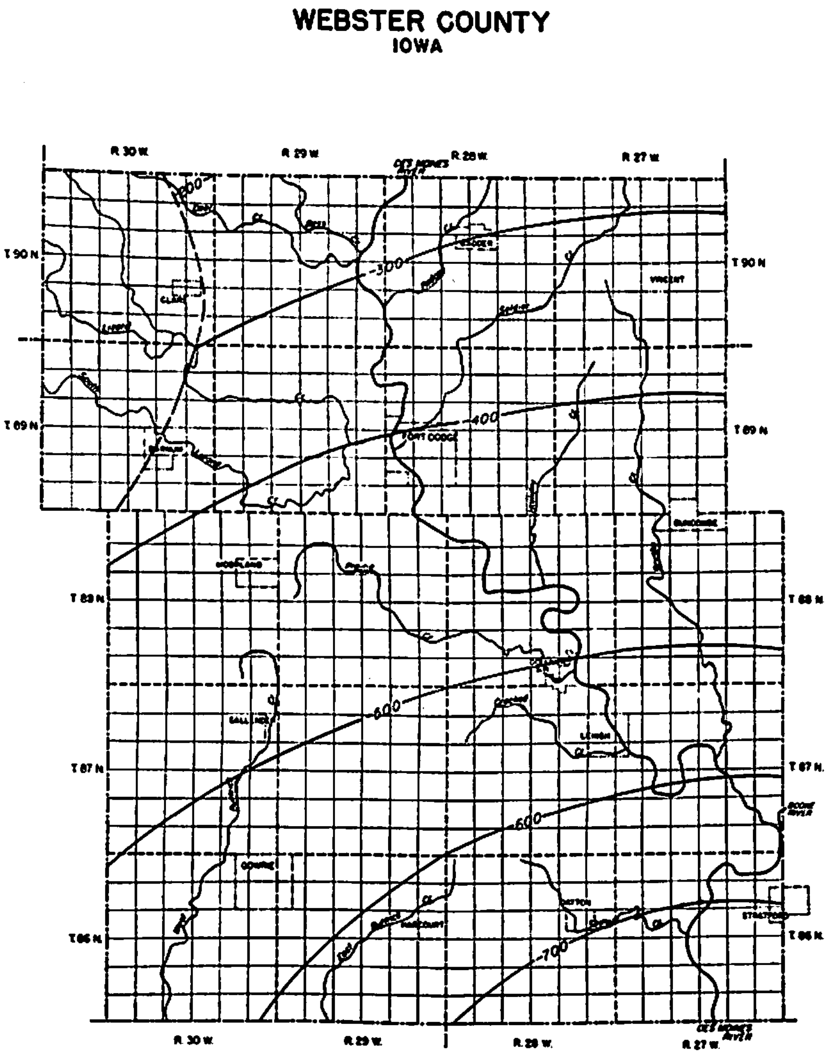


Figure 21.—Map of Webster County showing the general configuration and altitude, with reference to the mean sea level, of the top of the St. Peter sandstone.

stone above Shakopee dolomite and below Glenwood shale along the Minnesota River (formerly St. Peter's River) by Owen (1847, p. 169-170). It is regarded as Lower Ordovician by Edson (1935, p. 1110).

Water Supply. The St. Peter sandstone generally yields a moderate amount of water to wells, and in Webster County a few wells have been finished in it or obtain a part of their supply from it. Gowrie town well 2 (86-30-1P2) was finished in 1926 at a depth of 1,842 feet in the Shakopee dolomite a short distance below the St. Peter sandstone. The principal supply was reported to have been encountered in the St. Peter sandstone and the Shakopee dolomite. The static water level was reported to be 81 feet below land surface and the pumping level less than 150 feet at a pumping rate of 300 gallons a minute.

The now-abandoned well (88-28-5D1) of the Certain-teed Products Corp., drilled to a depth of 1,669 feet in 1925, was finished in the Root Valley sandstone. The main supply is reported to have been developed from the St. Peter sandstone. The water level stood 62 feet below land surface at the time of completion and the yield is reported to have been 275 gallons a minute with a pumping level of less than 132 feet. The temperature of the water was 56° F.

Fort Dodge City well 8 (89-28-19L4) was finished in 1923 at a depth of 1,436 feet in the St. Peter sandstone. Most of the water in the well, which is reported to have had an initial flow of 750 gallons a minute, was encountered above the sandstone. Within a few years the well had filled in to above the St. Peter sandstone, and little water probably comes from below 600 feet at present. City well 15 (88-28-19L12), 2,307 feet deep, had a reported yield of about 90 gallons a minute at 1,500 feet, about 40 feet below the St. Peter sandstone, the aquifers above 1,084 feet having been cased out.

The town of Boxholm, situated about 3 miles south of the Webster County line, drilled a well in 1949 to the St. Peter sandstone. The 1,955-foot well is located in NW¼SW¼NW¼ sec. 15, T. 85 N., R. 28 W., and had a reported water level of 146 feet below land surface, or at an altitude of approximately 1,006 feet. The yield was reported as 50 gallons a minute, the pumping level being 367 feet.

Water from the St. Peter sandstone well at Gowrie is hard and has a fluoride content of 2.0 parts per million. That from the Boxholm well had a hardness of 888 parts per million, calculated as equivalent calcium carbonate, an iron content of 1.7 parts per million, and a fluoride content of 2.4 parts per million in August 1949.

Mohawkian Series

Platteville Limestone and Decorah Shale

Character, distribution, and thickness. Limestone and shale comprise the Platteville and Decorah formations in Webster

County as in the outcrop area in northeastern Iowa. The basal member of the Platteville limestone, the Glenwood shale, is composed of slabby, soft to hard, green and some brown shale, which frequently caves during drilling. Casing is often required to reach the St. Peter sandstone. The light-buff to light-brown sublithographic limestone overlying the Glenwood may be the McGregor limestone member of the Platteville limestone. Resting on the limestone is a green shale, which contains black fossil fragments and probably represents the Spechts Ferry shale member of the Platteville limestone. Over the Spechts Ferry shale member is a gray to brown limestone with some dolomite, which is probably the Guttenberg limestone member of the Decorah shale. The Ion dolomite member, resting on the Guttenberg member, is composed of calcareous gray shale and gray limestone, mottled black.

The Platteville limestone and Decorah shale probably extend throughout the county with the exception of the area bordering Manson, Calhoun County. The two formations are about 125 feet thick in the vicinity of Fort Dodge and probably do not vary in thickness appreciably over the county.

The Glenwood shale member is about 35 feet thick, the McGregor limestone member between 5 and 15 feet, the Spechts Ferry shale member about 15 feet, and the Guttenberg-Ion members between 60 and 70 feet.

Age and correlation. The Platteville limestone and Decorah shale include all beds between the top of the St. Peter sandstone and the base of the Galena dolomite. The lower contact is clearly defined by the St. Peter sandstone, and the upper contact lies at the top of the Ion dolomite member and below the cherty buff to brown dolomite of the Galena dolomite in Webster County. The formations are considered by Kay (1935, p. 286, 287) to be Middle Ordovician.

Water supply. The shales and argillaceous limestones of these formations probably transmit very little water and act as barriers to the vertical movement of water between the Galena dolomite and St. Peter sandstone. No wells in the county are known to obtain water from these formations, and because of the caving nature of the shales, these strata have been cased off.

Galena Dolomite

Character, distribution, and thickness. The Galena dolomite is composed mostly of buff to brown dolomite containing some white opaque chert in the lower part. The top of the formation is often marked by orange specks referred to as "cinnamon specks." The Galena dolomite is probably present throughout the county with the exception of the northwestern part. It is generally about 125 feet thick, but in the Fort Dodge area may reach 200 feet locally.

In Webster County the Galena dolomite rests on the limestone of the Ion dolomite member of the Decorah formation and is overlain by cherty and argillaceous dolomite of the Maquoketa shale. The Galena dolomite includes three members in its area of outcrop in northeastern Iowa, which are in ascending order the Prosser cherty member, Stewartville massive member, and Dubuque shaly member. In subsurface studies, the first heavy chert appearing in the dolomite is taken as the top of the Prosser member. In Webster County, the Dubuque member was not distinguished from the Stewartville member. The formation is considered by Bays and Raasch (1935, p. 299) to mark the termination of the Mohawkian in Wisconsin.

Water supply. The Galena dolomite does not ordinarily yield even moderate supplies of water to wells. In Webster County the Cargill, Inc., well (89-28-19P5) finishes in the Galena dolomite but probably obtains most of its water from overlying strata ranging in age from Devonian to Mississippian. In August 1950 the well flowed a few gallons a minute and had a reported yield of 305 gallons a minute at a pumping level of 210 feet. The Dakota City town well, 6 miles north of the Webster County line, probably finishes in the Galena dolomite at its reported depth of 1,025 feet. On its completion in May 1948, the water level was reported to be 72 feet below land surface and the drawdown 5 feet at 200 gallons a minute. The water has a hardness of 530 parts per million and a temperature of 53° F.

Cincinnatian Series

Maquoketa Shale

Character, distribution, and thickness. Well cuttings show that the Maquoketa in Webster County is a cherty argillaceous cream and brown dolomite containing some thin shale beds. The Maquoketa is probably present throughout the entire county with the exception of the northwestern part. Within the county the formation varies considerably in thickness. Near Fort Dodge it is between 65 and 100 feet; 3 miles south of the county line it is about 185 feet thick; and to the west in Calhoun County and north in Humboldt County it is about 50 feet thick.

Age and correlation. The Maquoketa rests on the Galena dolomite and is overlain by the Kenwood shale member of the Wapsipinicon limestone of Devonian age in Webster County. In the area of outcrop in northeastern Iowa it is overlain by Silurian rocks. White (1870, p. 180, 181) named the formation from the exposures of shale and limestone between the Galena and Niagara dolomites along the Little Maquoketa River, and he agreed with Meek and Worthen (1865, p. 155) that these strata were a westward extension of the Cincinnatian series of Late Ordovician age. Calvin (1905, p. 97, 98) subdivides the Maquoketa formation into four members in ascending order as follows: the Elgin shaly limestone, Clermont shale, Fort Atkinson limestone, and Brainard shale; this terminology was adopted later by Ladd (1929). In Webster County the two predominantly shale members are absent, leaving the Fort Atkinson limestone and Elgin shaly limestone members to represent the Maquoketa.

Water supply. No wells in Webster County are known to be finished in the Maquoketa; however, the few wells penetrating it may obtain a small part of their supply from it. A creamery well at Humboldt, north of Webster County, finishes at a depth of 870 feet in dolomites of the Maquoketa and may develop its principal supply from them. The well flowed and yielded about 170 gallons a minute at a pumping level of 68 feet below land surface in October 1944. The temperature of the water was 54° F. and the hardness 345 parts per million, calculated as equivalent calcium carbonate. The iron and fluoride content were not excessive.

DEVONIAN SYSTEM

Middle Devonian Series

Wapsipinicon Limestone

Character, distribution, and thickness. The Wapsipinicon limestone is represented in the subsurface in Webster County largely by buff to brown dolomite, which is argillaceous in places. At Fort Dodge the basal part of the formation is composed of calcareous shale containing frosted quartz sand and dark-gray to black chert sand. In the southeastern part of the county the formation probably contains thick beds of gypsum, as the Boxholm town well, about 3 miles south of the Webster County line, encountered approximately 55 feet of gypsum, composing the bulk of the formation at that place.

The Wapsipinicon limestone is probably present throughout Webster County with the exception of the northwestern part. It ranges in thickness from 115 to 125 feet in the vicinity of Fort Dodge and is believed to thin to about 100 feet in the northern part and to about 80 feet in the southern part of the county.

Age and correlation. The name Wapsipinicon limestone was used by Norton (1895, p. 127) for beds of Devonian age underlying the Cedar Valley limestone. The formation crops out along parts of the Cedar and Wapsipinicon rivers in eastern Iowa. Stainbrook (1935, p. 248-252) divides the formation in ascending order into the Coggon, Otis, Kenwood, Spring Grove, and Davenport members. In the subsurface in Webster County, the Kenwood shale member seems to be the sole representative of the Wapsipinicon limestone. It rests on the Maquoketa shale and is overlain by the Cedar Valley limestone. The Wapsipinicon limestone is believed to be of Middle Devonian age (Cooper, 1942, p. 1788).

Water supply. Two town wells in Webster County probably obtain a large part of their supply from aquifers in the Wapsipinicon limestone. The deepest town well at Lehigh (87-28-12J2) was finished in April 1937 in the Wapsipinicon limestone at a depth of 1,005 feet and obtained a flow of 100 gallons a minute. Of this flow, approximately 25 gallons a minute was developed from the Wapsipinicon limestone, about 60 gallons a minute from Upper Devonian rocks and about 15 gallons a minute from Mississippian rocks.

The deeper town well at Dayton (86-28-14H1), drilled in 1931 to a depth of 1,240 feet, probably obtains a part of its supply from the Wapsipinicon limestone. The well yielded about 130 gallons a minute in November 1942, the drawdown being approximately 76 feet after pumping 1.3 hours. The waters pumped from the deeper wells in Lehigh and Dayton are very hard and have a high fluoride content. Furthermore, the water from the Dayton town well has an objectionable iron content.

Upper Devonian Series

Cedar Valley Limestone, Shell Rock Limestone, and Lime Creek Shale

Character, distribution, and thickness. Well cuttings show that the Cedar Valley limestone in Webster County is predominantly a cream-colored dolomite. Overlying the dolomite are limestone and shale beds which probably belong to the Lime Creek and Shell Rock formations, respectively. Beneath the typical Cedar Valley limestone is a fine-grained to sublithographic brown limestone and dolomite, locally containing black fossil fragments and interbedded gray shale. This lower shale and limestone sequence is thought to represent the Solon limestone, the lowest member of the Cedar Valley limestone. In the southeastern part of the county the Cedar Valley limestone probably contains gypsum beds as it does at Boxholm, south of Webster County.

These three formations, which measured about 600 feet at Boxholm, are probably present over all of Webster County except the northeastern part. At the Lehigh town well (87-28-14H2) they are about 375 feet thick and at Fort Dodge approximately 390 feet, typical thicknesses except for the southeastern part of the county. The Lime Creek shale ranges from 50 to 100 feet in thickness, as does the Shell Rock; the Solon limestone member of the Cedar Valley limestone is commonly about 50 feet thick.

Age and correlation. The Lime Creek shale and Shell Rock limestone crop out in north-central Iowa. The Lime Creek shale is the name used by Williams (1883, p. 97-104) for fossiliferous beds along Lime Creek in north-central Iowa. Stainbrook (1935, p. 256, 257) includes the Juniper Hill shale, Cerro Gordo, and Owen beds as members in the Lime Creek shale. He states that the Lime Creek shale lies unconformably on the Shell Rock limestone and beneath the Sheffield formation. The Lime Creek shale is probably present in the subsurface in Webster County, but modified in lithology from the type section. It was not separated from underlying formations in the present work. Additional subsurface study will aid in tracing the formation from its outcrop area, but in this report it is grouped with other Upper Devonian strata.

The name Shell Rock limestone was used by Thomas (1920, p. 411, 412) and further defined by Belanski (1927) for strata between the Lime Creek shale and the Cedar Valley limestone. This formation probably is present in the subsurface in Webster

County but was not definitely separable from the Lime Creek shale and Cedar Valley limestone.

The Cedar Valley limestone crops out in a broad strip along either side of the Cedar River in northeastern Iowa. The name was applied by McGee (1891, p. 314) to strata between the Independence shale member and overlying Hackberry shale. It has since been restricted by Belanski (1928) to include beds between the Independence shale member and the base of the Shell Rock limestone. The members of the Cedar Valley limestone as redefined by Stainbrook (1941) are in ascending order the Solon (formerly Linwood), the Rapid (formerly Littleton), and the Coralville. The Solon member persists as an identifiable unit into Webster County, but positive identification of the other two was not made. The Lime Creek shale and Shell Rock limestone are Upper Devonian, but the Cedar Valley limestone is considered by some to be of Middle Devonian age (Cooper, 1942, p. 1750, 1751).

Water supply. The limestones and dolomites of the Lime Creek, Shell Rock, and Cedar Valley formations yield water to several wells in the county. Very large yields have been obtained from wells in these aquifers in the Fort Dodge city well field, but the exceptionally large yields may result from the development of large fractures and cavities produced by faulting. Outside this small area, the yields obtained from the aquifers are small to moderate.

The Duncombe town well (88-27-3D1) was finished in the Cedar Valley limestone at a depth of 974 feet in 1945. A part of the supply is developed from Devonian rocks, but most of the water comes from the Mississippian rocks. The initial water level was 49.2 feet below land surface, the yield 37 gallons a minute with a drawdown of 48 feet, and the temperature 50° F.

The Harcourt town well (86-29-13C1) produces 35 gallons a minute with a reported drawdown of 51 feet, principally from aquifers in the Cedar Valley limestone. The temperature of the water is 57° F.

Two farm wells are known to have obtained a supply of water from limestone in the Lime Creek, Shell Rock, and upper part of the Cedar Valley. Well 89-27-7A1 is finished in the Cedar Valley limestone at a depth of 873 feet. The static water level was 78 feet below land surface and the yield 3 gallons a minute with a drawdown of less than 12 feet. Another farm well (89-30-11R1) finished in the limestone of the Lime Creek shale at a depth of

671 feet obtained a supply of 6 gallons a minute with a reported drawdown of 124 feet.

The water from these strata is hard, and in the Harcourt town well the fluoride content was 2.0 parts per million.

Sheffield Shale

Character. A thin bed, which is probably the Sheffield formation as restricted by Stainbrook (1950, p. 365, 366), overlies the Lime Creek shale in places in Webster County. Well cuttings indicate that this gray and green calcareous shale contains thin beds of argillaceous dolomite. The shale is identified in the Lehigh town well (87-28-12I2), a part of the well log being given below.

	Thickness (feet)	Depth (feet)
Mississippian system:		
Hampton formation:		
Dolomite, brown, finely crystalline, with some gray to drabbish white chert	155	330-485
Dolomite, buff, finely crystalline, calcareous	10	485-495
Dolomite, gray, finely crystalline, silty	5	495-500
Undifferentiated beds:		
Siltstone, gray, soft, friable	10	500-510
Shale, gray and green, slightly calcareous	10	510-520
Aplington dolomite:		
Dolomite, light to dark brown, finely crystalline, with some light-gray chert	10	520-530
Devonian system:		
Sheffield shale:		
Shale, light-green and gray, calcareous, with some gray argillaceous dolomite	20	530-550
Lime Creek shale:		
Dolomite, cream, medium to finely crystalline	5	550-555
Limestone, cream, with imbedded dolomite rhombohedrons	10	555-565

Distribution and thickness. The Sheffield shale was distinguished in one other well (89-30-11R1) in the western part of the county, and it is probably present at other localities. The shale is 20 feet thick at the Lehigh well and 15 feet at well 88-30-11R1.

Age and correlation. Fenton (1919, p. 355-376) used the name Sheffield for shales underlying a part of Lime Creek shale probably exposed at Sheffield in Franklin County. Thomas (1925, p. 116) called attention to the fact that the name was applied to two shales, and he renamed the shale beneath the limestone beds of the Lime Creek the Juniper Hill shale, retaining the name Sheffield for the beds overlying the Lime Creek shale at Sheffield. Van Tuyl (1925, p. 91) referred the shale to the Kinderhookian series of the Mississippian but thought the lower shales might be of Late Devonian age. Laudon (1931, p. 346) refers the shale and overlying dolomite of the Sheffield formation to late Late Devonian. Stainbrook (1950, p. 365-385) separates the dolomite from the Sheffield, giving it the name Aplington. He refers the Aplington to the Kinderhookian series of Mississippian rocks and the restricted Sheffield to Upper Devonian rocks.

In this report the shale below the Aplington dolomite and above the Lime Creek shale is referred to the Sheffield shale. Where the Aplington dolomite is not present, this shale is probably included in the undifferentiated beds above the Aplington dolomite.

Water supply. The Sheffield shale probably yields no water to wells and acts as an effective barrier to the vertical movement of water. The shale is generally cased off from wells penetrating it.

MISSISSIPPIAN SYSTEM

Kinderhookian Series

Aplington Dolomite

Character, distribution, and thickness. The Aplington dolomite as found in the subsurface at two wells in Webster County is composed of buff, medium to finely crystalline dolomite and some white to light-gray chert. It was identified in the Lehigh town well (87-28-12J2) and in one well (89-30-11R1) in the western part of the county, where it is 15 feet thick. Its relation to adjacent beds in the Lehigh well is given in the discussion of the Sheffield shale.

Age and correlation. Stainbrook (1950, p. 365-385) separates the dolomite in the upper part of the Sheffield formation from that unit and names it the Aplington dolomite, from exposures in Butler County in northeastern Iowa near Aplington. In sections given by Stainbrook, the Aplington directly overlies the Sheffield shale and underlies the Chapin limestone. He states that the Sheffield is of Late Devonian age and that the Aplington, on faunal evidence, belongs to the Kinderhookian series.

Where the Aplington is recognized in the subsurface in Webster County, it is overlain by undifferentiated shales which in turn are overlain by the Hampton formation.

Water supply. The Aplington dolomite probably does not yield an appreciable quantity of water to wells in Webster County, and no wells are known to be finished in it there.

Undifferentiated Beds

Character, distribution, and thickness. A shale or series of shales overlies the Aplington dolomite or occurs at this stratigraphic position in Webster County. It is primarily a gray noncalcareous shale; silty beds may occur in the upper part or the shale may contain considerable silt, as in the Dencklau farm well (89-27-7A1). The shale often caves in wells penetrating it and then requires casing. The casing is usually extended through the Aplington dolomite and Sheffield shale, when the lower shale is present. In the Duncombe and Lehigh town wells, the shale was found to be firm and was left uncased.

This shale horizon, which may include the Sheffield shale in places, probably extends over the entire county with the exception of the area adjacent to Manson. It usually ranges in thickness from 20 to 45 feet.

Age and correlation. The shales above the Aplington dolomite in Webster County may belong to the Maple Mill shale; however, there is a possibility that they are a part of the Prospect Hill formation. They are underlain by the Aplington dolomite where it is present and in other places in the county may rest on the Sheffield shale and Lime Creek shale. They are overlain by the Hampton formation.

Water supply. These undifferentiated shales do not yield water to wells in Webster County and probably act as an effective barrier to the vertical movement of water between the overlying and underlying waterbearing beds of limestone and dolomite.

Hampton Formation

Character, distribution, and thickness. The Hampton formation as used in this report comprises three members which in ascending order are the Maynes Creek, Eagle City, and Iowa Falls. The Maynes Creek member as observed in the subsurface in Webster County is primarily a brown, finely crystalline dolomite containing some gray to drabbish white chert. The Eagle City member consists primarily of lithographic to oolitic limestone. The Iowa Falls member is predominantly a buff to brown coarsely to medium crystalline dolomite. The dolomites of the Hampton formation are locally very porous, but not necessarily permeable. A dolomitic limestone near the base of the Hampton formation in places is 10 to 20 feet thick and may be a part of the Chapin limestone, which in this report, however, is included in the Hampton formation.

The Hampton formation probably extends over the whole county except the northwestern part. It ranges in thickness from 130 to 210 feet, the general thickness being about 160 feet. (Table 12 lists the thickness of the formation at various places in the county.)

Age and correlation. The Hampton formation, which does not crop out in Webster County, is exposed about 40 miles east in Franklin and Hardin Counties and in a belt extending to the southeast. Laudon (1930, p. 174) named the formation for the county seat of Franklin County, where the formation is best developed, and subdivided it into the Chapin, Maynes Creek, Eagle City, and Iowa Falls members (1931, p. 387). Later (1935, p. 246, 247) he removed the Chapin member from the formation in north-central Iowa and its inferred correlative, the North Hill, in southeastern Iowa. In the type area the Hampton is underlain by the Chapin limestone and overlain by the Alden limestone. Subsurface studies in Webster County show that the Hampton is overlain by the Gilmore City limestone (Alden limestone) and overlies the undifferentiated shale beds of Mississippian age.

Laudon (1931, p. 344) assigned the Hampton formation to the Kinderhookian series and later (1935, p. 246) strongly stated that not only the Hampton but the overlying Gilmore City limestone also is of Kinderhookian age.

Water supply. Several farm wells, one each of the town wells at Badger, Callender, Dayton, and Gowrie, a former town well at Duncombe, and several wells in Fort Dodge are finished in the Hampton formation. Although aquifers in Mississippian rocks younger than the Hampton are generally open to these wells, it is inferred that the principal supply is obtained from the Hampton formation. The supplies are generally moderate, ample for farm use, but not always enough for municipal use.

The town well at Badger, which completely penetrates the

Hampton, obtains 55 gallons a minute with a reported drawdown of 102 feet. The standby well at Dayton produces 20 gallons a minute, the former town well at Duncombe 17 gallons a minute, largely from this formation, and the town well at Callender 11 gallons a minute with a large drawdown.

In Fort Dodge, some wells have obtained large supplies of water from the Hampton formation. A creamery well (89-28-19K2) is reported to produce 500 gallons a minute with a drawdown of 13 feet. The Cargill, Inc., well (89-28-19P5), initially finished a short distance below the base of the Hampton formation, furnished 255 gallons a minute with a pumping level of 100 to 110 feet. Fort Dodge city wells 8, 9, and 12, finished in the Hampton formation, obtain large quantities of water, but the formation may be more permeable here because of brecciation and solution of the rocks due to faulting.

Water from the Hampton formation is hard, and the iron content is generally objectionably high. In some wells, as at Badger, Callender, Gowrie, in the older well at Duncombe, and at Dolliver State Park, the fluoride content of the water is above the generally acceptable limit of 1.5 parts per million.

Gilmore City Limestone

Character, distribution, and thickness. The Gilmore City limestone in Webster County is a cream to white sublithographic and oolitic limestone. Because of its distinctive appearance and appreciable thickness, it is one of the most easily recognized formations encountered in drilling. Where the Iowa Falls member is absent, it is difficult to separate the Gilmore City from the subjacent Eagle City oolitic limestone member in the Hampton formation.

The Gilmore City limestone is present throughout the county with the exception of the northwestern part, ranging between 85 and 125 feet in thickness. The configuration and altitude of the top of the Gilmore City limestone are shown in figure 22.

Age and correlation. The Gilmore City limestone, which is not exposed in Webster County, crops out at several places in Humboldt County to the north. The type section is located about 13 miles north of the northwest corner of Webster County, in Pocahontas County near Gilmore City. A limestone that crops out in western Hardin County to the east of Webster County was named the Alden limestone by Van Tuyl (1925, p. 52, 92, 99). This light-gray thin-bedded slightly oolitic limestone over-

WEBSTER COUNTY
IOWA

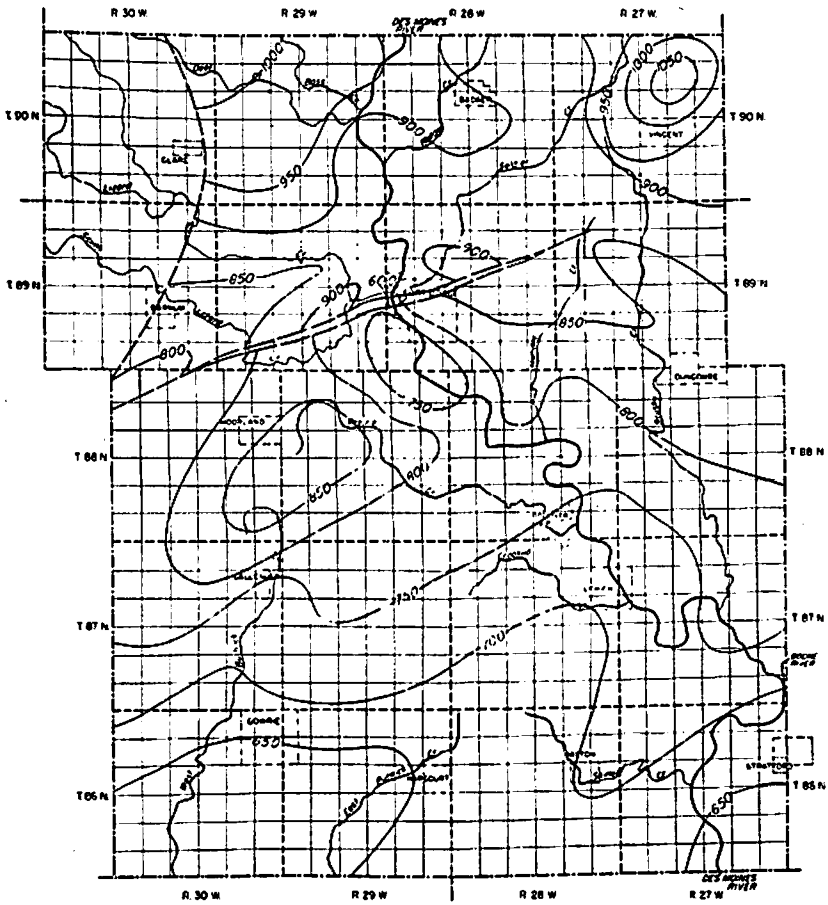


Figure 22.—Map of Webster County showing the general configuration and altitude, with reference to mean sea level, of the top of the Gilmore City limestone.

lies the Iowa Falls member of the Hampton formation in the vicinity of Alden and was tentatively referred to the top of the Kinderhookian series. Van Tuyl further noted the similarity in lithology of these beds and the limestones exposed in quarries in the vicinity of Gilmore City. Laudon (1931, p. 349, 416, 417) correlated the Alden limestone with the Gilmore City limestone and later (1933) treated them as the top formation of the

Kinderhookian series. He stated that the formation was unconformably overlain by the St. Louis limestone and underlain by the Iowa Falls member of the Hampton formation. In parts of central Iowa the Gilmore City limestone is overlain by the Burlington limestone of the Osagian series.

The Alden limestone has been traced in the subsurface from the vicinity of Alden into Webster County. In the county, the Gilmore City (Alden) limestone rests on the Iowa Falls member in most places but in the northern part of the county it may rest on the Eagle City member of the Hampton formation. It is mantled by rocks tentatively assigned to the Osagian series.

Water supply. Several farm wells in the county and the shallower town wells at Badger and Lehigh are finished in the Gilmore City limestone. Yields are generally small to moderate. The Badger town well (90-28-15D1) yields 23 gallons a minute, the drawdown being unknown. The Lehigh town well (87-28-12J1) penetrated the entire thickness of the Gilmore City limestone at a depth of 329 feet and flowed 15 gallons a minute in 1948. Pumping yielded 60 gallons a minute with a reported pumping level of 165 feet.

Several farm wells finished in the formation obtain adequate supplies with little drawdown; however, a few wells with yields of 4 to 6 gallons a minute have drawdowns of more than 100 feet. This indicates that the beds are very dense at some localities but permeable and capable of yielding moderate to large supplies to wells a short distance away, a condition found in many limestones.

The water from the Gilmore City limestone is hard and in the town wells of Badger (90-28-15D1) and Lehigh (87-28-12J1) and several farm wells there is an objectionable amount of iron. In addition, the Lehigh well yields water with a high fluoride content (table 9).

Osagian Series

Undifferentiated Beds

Character, distribution, and thickness. Below the sandstone, sandy limestone, and dolomite of the St. Louis limestone and above the buff to white lithographic and oolitic limestone of the Gilmore City limestone in Webster County, there are beds that resemble the Warsaw, Keokuk, and Burlington limestones of the Osagian series in southeastern and central Iowa.

The beds, in descending order, are represented by a gray shale, a chocolate-brown to tan medium crystalline brilliant dolomite, a fine-grained fragmental glauconitic limestone, and, near the base, gray argillaceous limestone and dolomite with beds of gray shale. Minor amounts of chert and chalcedony are commonly present at various horizons in the series.

The rocks of the Osagian series probably occur over the entire county with the exception of the northwestern part. Where covered by the St. Louis limestone, they range between 65 and 100 feet in thickness, but where erosion has removed the St. Louis limestone, as in the eastern half of the county, they range between 25 and 45 feet in thickness.

A few feet of gray shale and brown dolomite belonging to the Osagian series is exposed beneath the St. Louis limestone on South Lizard Creek in the SE¼SW¼ sec. 23, T. 89 N., R. 29 W. Other exposures of these beds probably occur in the extreme northern part of the county and in Humboldt County in the valley of the Des Moines River.

Age and correlation. Only a few fragments of crinoids were observed in strata assigned to the Osagian series exposed in the limestone mine located in parts of secs. 23 and 24, T. 89 N., R. 29 W. The assignment of the beds below the sandy limestone and dolomite of the St. Louis limestone and above the cream-colored limestone of the Gilmore City to the Osagian series is based entirely on lithologic similarities to this series of rocks in southeastern Iowa. These beds are less sandy and more evenly bedded than the St. Louis strata. Additional investigation may indicate, however, that a part of these beds belong to the St. Louis or Spergen limestone. The results of the present investigation did not permit subdivision of the Osagian series into the formations defined in the southeastern part of the State.

Water supply. Several farm wells within the central and northern part of the county are finished in Osagian rocks although in most of these wells a part of the supply is probably developed from the St. Louis limestone. The yields are generally small.

Recharge to the aquifers probably occurs in the northeastern, northwestern, and a portion of the east-central parts of the county through aquifers in the overlying drift and St. Louis limestone. In these areas, water levels in wells stand higher than in the central part of the county.

Water from the Osagian series, like that from other aquifers in Webster County, is hard. In some wells it contains more than

1 part per million of iron and more than 1.5 parts per million of fluoride.

Shales in the Osagian rocks often require casing, which is slotted opposite water-bearing beds.

Meramecian Series

St. Louis Limestone

Character, distribution, and thickness. The St. Louis limestone as it occurs in Webster County is composed of sandstone, sandy limestone and dolomite, limestone and dolomite, and a minor amount of shale. The beds in many places are lenticular and brecciated, giving the formation a very heterogeneous appearance in exposures.

A sandstone which is commonly present at the top of the formation is exposed in places along Lizard Creek, Deer Creek, and the Des Moines River in the northern part of the county. The sandstone is a medium-to-fine-grained frosted quartz sand and is cream to buff in exposures, where it is poorly cemented. Below the sandstone there is in many places a few feet of gray to beige-colored lithographic to sublithographic limestone containing fragments of brown chert. Below the limestone are gray and brown dolomites, which are lenticular and interbedded with gray to greenish-gray calcareous sandstone. Much of the dolomite is sandy and the beds are commonly brecciated. Near the base of the formation a brown sandy evenly bedded dolomite is ordinarily present. Thin beds of gray shale occur within the sandstones and dolomites, but seldom are they over 5 feet thick.

To the south of Fort Dodge a small exposure of St. Louis limestone may be seen at low stages of the Des Moines River in the NW¼NE¼ sec. 8, T. 88 N., R. 28 W. The St. Louis limestone is exposed almost continuously from the mouth of Lizard Creek northward along the left bank of the Des Moines River for a distance of approximately 2 miles, to the NE¼ sec. 7, T. 89 N., R. 28 W. Here the sandstone, limestone, and dolomite beds form bluffs reaching 15 feet above the river level and are overlain by shales and sandstone of Pennsylvanian age. Farther upstream, a few feet of gray well-cemented sandstone is exposed in a small tributary on the right side of the Des Moines River, near the center of sec. 1, T. 89 N., R. 29 W. Farther north, along Badger Creek near its confluence with the Des Moines River, the following section is exposed:

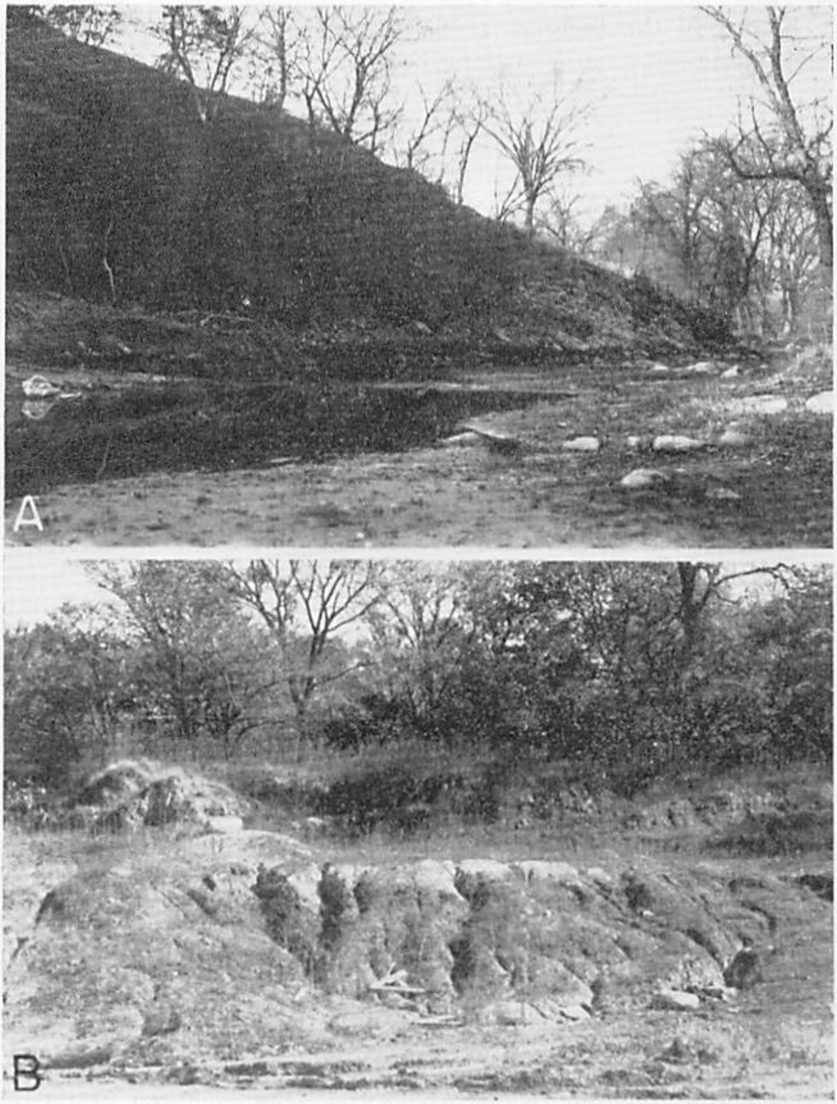


PLATE 10.—*A*, EXPOSURE OF ST. LOUIS LIMESTONE ALONG SOUTH LIZARD CREEK IN THE SE¼SW¼ SEC. 23, T. 89 N., R. 29 W.; *B*, EXPOSURE OF STE. GENEVIEVE LIMESTONE ALONG THE LEFT VALLEY WALL OF THE DES MOINES RIVER AT FORT DODGE IN THE CENTER OF THE NW¼ SEC. 19, T. 89 N., R. 28 W. THE LIGHT-COLORED SHALE IS VERY FOSSILIFEROUS.

Exposure of St. Louis limestone near mouth of Badger Creek in the SW¼SW¼NW¼ sec. 30, T. 90 N., R. 28 W.

Bed	Description	Thickness (feet)
	Mississippian system:	
	Meramecian series:	
	St. Louis limestone:	
4.	Limestone, beige, sublithographic to lithographic, with many thin calcite lenses	2.5
3.	Dolomite, beige and buff, finely crystalline, argillaceous, with thin sandstone and shale beds, unevenly bedded	4.5
2.	Limestone, gray, sublithographic, thin and evenly bedded	1
1.	Sandstone, light-gray, medium-grained, frosted, calcareous, unevenly bedded, to level of Badger Creek	3
	(Altitude of Badger Creek approximately 1,015 feet)	

Along the right bank of the Des Moines River in the SW¼NW¼SW¼ sec. 24, T. 90 N., R. 29 W., the contact between the St. Louis limestone and the sandstones of Pennsylvanian age may be observed.

Exposure of St. Louis limestone in the SW¼NW¼SW¼ sec. 24, T. 90 N., R. 29 W.

Bed	Description	Thickness (feet)
	Pennsylvanian system:	
	Desmoinesian series:	
	Undifferentiated beds:	
5.	Sandstone, buff and pale gray, cross-bedded, containing many large dull polished pebbles and some ironstone and pyrite concretions	15.0
4.	Conglomerate, composed almost entirely of chert cobbles 1 to 2 inches in diameter	1.5
3.	Sandstone, buff and gray, cross-bedded, iron-stained	5.0
2.	Conglomerate, sand, calcareous, with large chert pebbles and impressions of tree branches or trunks; some gray shale	0.5-1

Mississippian system:
Meramecian series:
St. Louis limestone:

1.	Sandstone, medium-grained, frosted, calcareous, interbedded with limestone to water level	0-7.0

(Altitude of Des Moines River approximately 1,020 feet)

Northward from the section just described, the St. Louis limestone is exposed almost continuously to the county line. Along this stretch of the river is an interesting section in the right bank near the center of sec. 12, T. 90 N., R. 29 W.

Exposure of St. Louis limestone near center sec. 12, T. 90 N., R. 29 W.

Bed	*Description*	*Thickness* (feet)
	Permian system:	
	Fort Dodge (?) formation:	
7.	Limestone, gray, sandy, pebbly, containing large brown fragments	10
6.	Shale, buff and green, noncalcareous, micaceous; containing some selenite crystals	5
	Mississippian system:	
	Meramecian series:	
	St. Louis limestone:	
5.	Sandstone, cream to buff, medium- to coarse-grained, angular to round, pitted, poorly cemented by dolomite	15
4.	Dolomite, tan, very sandy; medium to coarse frosted sand grains; trace of glauconite	7
3.	Shale, gray, soft, unctuous, noncalcareous	2
2.	Dolomite, grayish-brown, finely crystalline, silty	5
1.	Dolomite, medium brown, finely crystalline, dense; trace of glauconite; veins of milky white and bluish white chert, to water level	6

(Altitude of Des Moines River about 1,025 feet)

Beds 1 through 5 probably represent the St. Louis limestone which is here 35 feet thick. Beds 6 and 7 are assigned to the Fort Dodge formation although they may possibly represent a phase of the Pennsylvanian system of rocks.

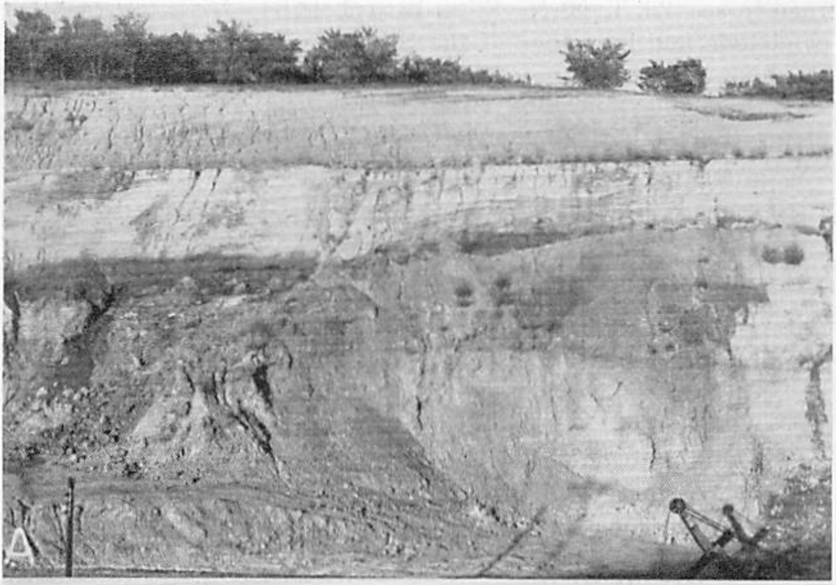
The St. Louis limestone crops out along the stream bed and banks of Deer Creek for about 0.5 mile west of the north-south road in sec. 23, T. 90 N., R. 29 W. (pl. 11B). Near the road the sandstone and limestone of the St. Louis limestone are overlain by shale and sandstone of Pennsylvanian age near stream level. The St. Louis limestone rises to the west and forms a bluff about 18 feet high along the right bank of the stream in the SW¼NE¼ sec. 23, T. 90 N., R. 29 W.

Bluff section in the SW¼NE¼ sec. 23, T. 90 N., R. 29 W.

Bed	*Description*	*Thickness* (feet)
	Mississippian system:	
	Meremecian series:	
	St. Louis limestone:	
10.	Sandstone, medium-grained, calcareous, cross-bedded, soft	6
9.	Sandstone, light gray, medium-grained, very calcareous, thin-bedded, softer toward top	5
8.	Dolomite, light grayish brown, very finely crystalline	1
7.	Chert, brown, dense, nodular, bedded in buff sandy dolomite	.1
6.	Sandstone, pale greenish gray, medium-grained slightly calcareous	.4
5.	Dolomite and limestone, buff, fragmental	.5
4.	Chert, brown, in lenslike layer	.1
3.	Dolomite, grayish buff, silty, earthy, sandy, very finely crystalline, fractured	1.4
2.	Dolomite, brown, very finely crystalline, glauconitic, thin-bedded	2.0
1.	Dolomite, brown, finely crystalline, glauconitic, medium-bedded, to stream level	2.0

(Altitude of Deer Creek approximately 1,040 feet)

Exposures of the St. Louis limestone occur along Lizard Creek at intervals from its mouth westward for a distance of about 1.5 miles. Here the limestone is overlain by shales of the Ste. Genevieve limestone. On South Lizard Creek along the left bank of the stream near the center of the SE¼SW¼ sec. 23, T. 89 N., R. 29 W., there is an exposure of St. Louis limestone in which the beds dip about 20° to 30° (pl. 10A). The strike is about N. 15° W. at the south end of the exposure. The limestones



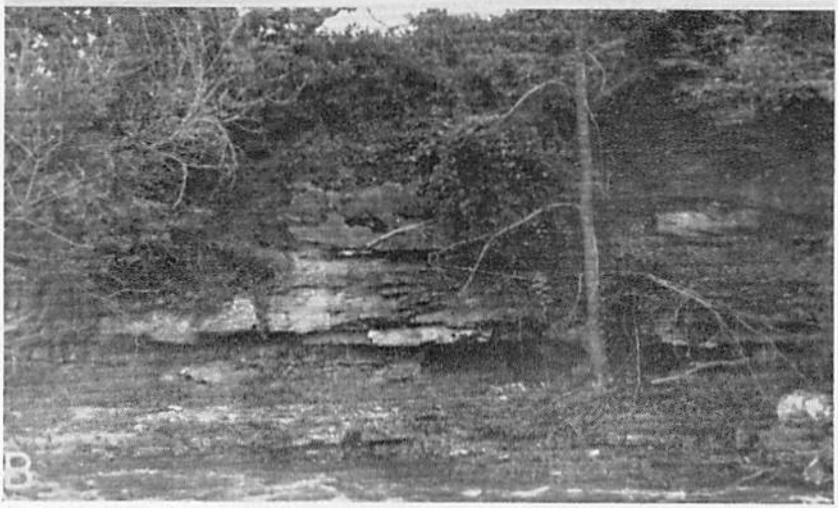


PLATE 11.—A, VIEW OF FACE OF SHALE PIT SHOWING, BENEATH THE GLACIAL DRIFT, SANDSTONE AND SHALE OF THE DESMOINESIAN SERIES; B, EXPOSURE OF ST. LOUIS LIMESTONE ALONG THE RIGHT BANK OF DEER CREEK IN SEC. 23, T. 90 N., R. 29 W.

end abruptly and possibly mark the north fault line of the Fort Dodge fault system. The section exposed is as follows:

Exposure near center SE¼SW¼ sec. 23, T. 89 N., R. 29 W.

Bed	Description	Thickness (feet)
	Mississippian system	
	Meramecian series	
	St. Louis limestone	
7.	Sandstone, gray, very calcareous; overlying rock mantle	3
6.	Dolomite, brown to gray, granular, and calcite	5
5.	Limestone, gray, lithographic, argillaceous, heavy-bedded	2.5
4.	Limestone, gray, lithographic, with thin shale beds	3
3.	Sandstone, gray, medium-grained, calcareous	17
	Osagian series:	
	Undifferentiated beds:	
2.	Shale, gray, containing selenite crystals	5.5
1.	Dolomite, dark brown, very finely crystalline, glauconitic; contains some mottled gray and brown chert, to water level	3.0

(Altitude of South Lizard Creek approximately 1,010 feet)

No exposures of the St. Louis limestone have been observed farther upstream on South Lizard Creek or on Lizard Creek above the junction with South Lizard Creek.

A few exposures of the St. Louis limestone occur along a stretch of Soldier Creek between 0.5 mile and 1.3 miles above the mouth of the stream in parts of secs. 17, 18, and 19, T. 89 N., R. 28 W. One of the better exposures is about 400 feet west of the bridge on 6th Street and is as follows:

Section on Soldier Creek in the center NE¼ sec. 19, T. 89 N., R. 28 W.

Bed	Description	Thickness (feet)
	Mississippian system:	
	Meramecian series:	
	St. Louis limestone:	
4.	Sandstone, pale cream and buff, medium- to coarse-grained, predominantly soft	10

3.	Limestone, gray, finely crystalline	1
2.	Limestone, buff and gray, dolomitic, 3- to 12-inch beds, thinner toward base; few thin beds of grayish-green shale, dolomitic in lower part	8
1.	Sandstone, grayish-green, calcareous, thin and irregular bedded, very argillaceous in lower part, to water level	6

(Altitude of Soldier Creek approximately 1,055 feet)

Along Soldier Creek, the St. Louis limestone is directly overlain by the Ste. Genevieve limestone in some places and by shale and sandstone of Pennsylvanian age in others. Additional exposures of the St. Louis limestone in the county are described by Wilder (1923, p. 139-147).

The St. Louis limestone occurs over most of the county except the northwestern part and a few smaller areas as indicated in figure 23. In the vicinity of Lehigh and in the areas to the south and west, where the St. Louis limestone is lacking, it was removed by pre-Pennsylvanian erosion. In the vicinity of Duncombe and Vincent, it was probably removed at a much later date.

The St. Louis limestone in Webster County rests upon the rocks tentatively assigned to the Osagian series. It is overlain by the Ste. Genevieve limestone where present (fig. 24). Over a large part of the southern three-fifths of the county, rocks of Pennsylvanian age rest on the St. Louis limestone. In the extreme northern part and in the large buried valley along the eastern margin of the county, the St. Louis limestone is directly overlain by tills and sands and gravels of the Pleistocene. In places in the north-central part of the county, the St. Louis limestone is directly overlain by the Fort Dodge formation. In the area where it is overlain by the Ste. Genevieve limestone, the St. Louis limestone is about 50 feet thick. Over a large part of the area where the limestone directly underlies rocks of Pennsylvanian age it is generally between 30 and 50 feet thick. The configuration and altitude of the base of the St. Louis limestone in Webster County are shown in figure 23.

Age and correlation. The St. Louis limestone in Webster County includes the beds below the clay shale of the Ste. Genevieve limestone and above the shale and cherty limestone and dolomite tentatively assigned to the Osagian series of rocks. The basal beds are generally sandy dolomites and sandstones.

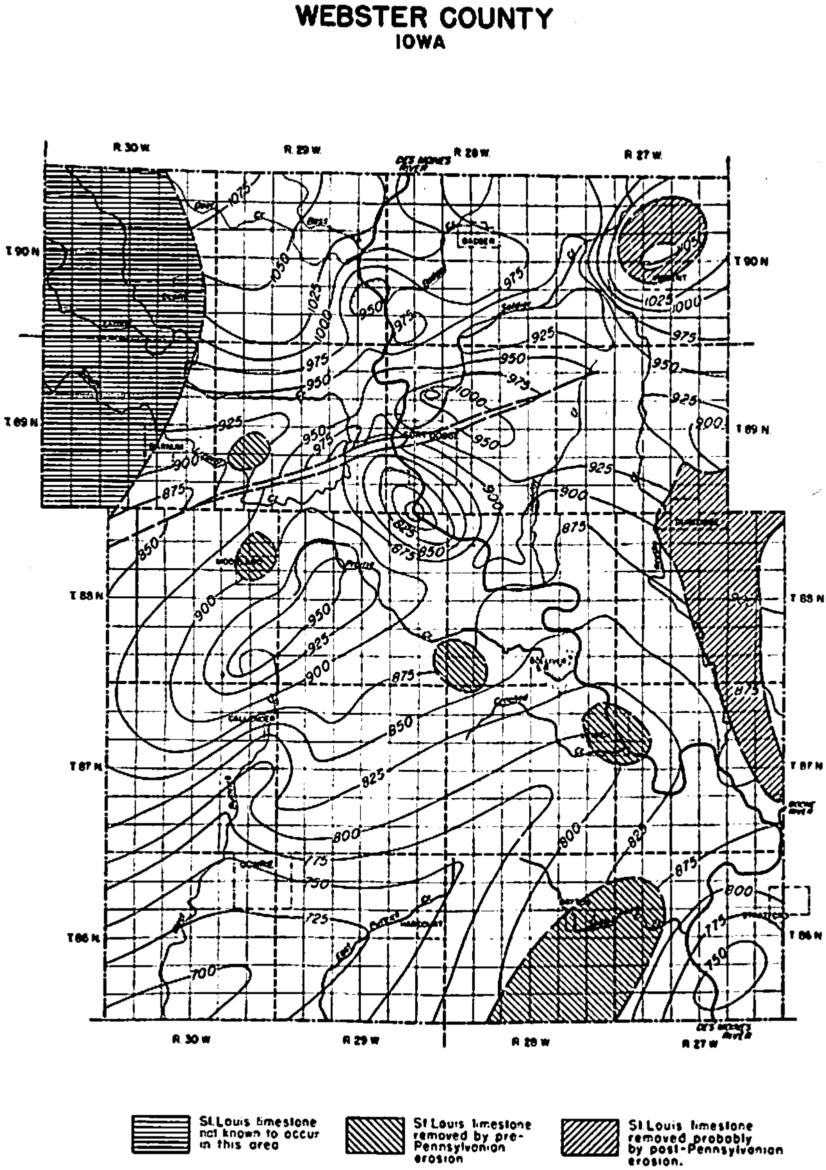


Figure 23.—Map of Webster County showing the general configuration and altitude, with reference to mean sea level, of the base of the St. Louis limestone.

As such the St. Louis may include strata belonging to the Spergen limestone, which directly underlies the St. Louis limestone in southeastern Iowa. In that area the Spergen limestone is composed, in part, of sandstone and sandy limestone and dolomite (Van Tuyl, 1925, p. 214). The Spergen is not generally distinguishable from the St. Louis limestone in subsurface studies.

Wilder (1902, p. 78), in discussing exposures in Webster County, stated that the Pennsylvanian rocks rest on the St. Louis limestone. He thus included shale beds later assigned to the Ste. Genevieve limestone in the St. Louis. Van Tuyl (1925, p. 282-284) and others removed the upper shales from the St. Louis limestone but retained the underlying limestones exposed in the county, correlating them with the St. Louis limestone in southeastern Iowa primarily on the basis of their lithology. These strata in the southeastern part of the State between the Ste. Genevieve and Spergen limestones were correlated by Van Tuyl (1925, p. 230-232) and other workers with the St. Louis limestone in its type locality in the vicinity of St. Louis, Missouri.

Water supply. In the northern part of the county several farm wells obtain a moderate amount of water from the St. Louis limestone, yields of about 1 gallon a minute per foot of drawdown being obtained from some wells. In several places the static water level is less than 50 feet below the upland plain; this higher water level suggests that the limestone is being recharged here through water-bearing beds in the adjacent drift. In the central part of the county a few wells obtain small but adequate supplies of water from this formation. Yields of 2 to 10 gallons a minute have been obtained with a drawdown of 40 to 90 feet in most wells finished in the limestone in this area. The initial water level in most of these wells is more than 100 feet below the upland. In other places in the county the limestone probably contributes some water to wells drilled to greater depths, inasmuch as the St. Louis limestone is generally left uncased.

The water in the St. Louis limestone is hard, usually containing more than 0.5 part per million of iron; it contains less than 1 part per million of fluoride.

Ste. Genevieve Limestone

Character. The Ste. Genevieve in Webster County is composed primarily of light-green and dark-red unctuous calcareous clay shales; however, thin argillaceous limestone beds, lenses, and nodules are increasingly prominent in the lower part of the formation. Where the limestone beds attain a thickness of more than 2 inches, the texture is usually lithographic and the color beige, but thinner beds are usually nodular. The grayish-green shales commonly contain pyrite, and the clays and limestones are almost entirely free of sand and silt. The more calcareous green clays and limestones are very fossiliferous in places, and a particularly fossiliferous zone which in outcrop usually weathers to a greenish yellow occurs within 25 to 40 feet of the base of the formation. The shales are poorly bedded and weather with a starchlike fracture.

Distribution and thickness. Shales of the Ste. Genevieve limestone crop out in places along the Des Moines River, Lizard Creek, and Soldier Creek in the general vicinity of Fort Dodge. A few feet of green calcareous shale is exposed near the level of the Des Moines River in the NW¼NW¼ sec 6, T. 89 N., R. 28 W. Here the shale is overlain by Pleistocene deposits. Farther downstream along the right bank of the river in the SW¼NE¼ sec. 12, T. 89 N., R. 29 W., shale a few feet thick is exposed above river level and is overlain by sandstone and shale of Pennsylvanian age. In Fort Dodge, on the left bank of the Des Moines River, a few hundred feet east of the east end of the bridge and near the center of the NW¼ sec. 19, T. 89 N., R. 28 W., a thickness of several feet of red and green shales has recently been exposed (pl. 10B), as follows:

Section north of Highway 5 on left bank of Des Moines River about center NW¼ sec. 19, T. 89 N., R. 28 W.

Bed	*Description*	*Thickness* (feet)
	Pleistocene system:	
7.	Soil, black, pebbly	5
6.	Sand and gravel, iron-stained	13
	Mississippian system:	
	Meramecian series:	
	Ste. Genevieve limestone:	
5.	Shale, pale yellowish green, calcareous; upper part very fossiliferous	5.5
4.	Shale, red, calcareous, some mottled green and some thin lenses of green shale. Weathers with starchlike fracture	5.5

3.	Shale, grayish-green, with small limestone nodules; upper 1.5 feet yellowish-brown	5
2.	Limestone, gray, nodular; nodules are composed of lithographic limestone	1
1.	Covered from east end of bridge over Des Moines River eastward to exposure	14

On the opposite side of the river and on the north side of Lizard Creek, at the junction of the valleys of Lizard Creek and the Des Moines River, shales of the Ste. Genevieve are exposed at intervals along the north road cut of Highway 5 and along the north bank of Lizard Creek. The section from the level of Lizard Creek is approximately as follows:

Section in the NW¼NW¼ sec. 19, T. 89 N., R. 28 W.

Bed	*Description*	*Thickness* (feet)
Pleistocene system:		
18.	Drift	?
Permian (?) system:		
	Fort Dodge formation:	
17.	Gypsum	3
Pennsylvanian system:		
	Desmoinesian series:	
	Undifferentiated beds:	
16.	Covered interval	3
15.	Shale, dark-gray	3
14.	Sandstone, fine-grained, stained pink, some pale-gray	3
13.	Covered interval	2
12.	Shale, black, fissile	1
11.	Sandstone, pale grayish-cream, coarse-grained, calcareous; contains pink sand grains	3
10.	Shale, dark-gray, fissile; contains many ironstone concretions	11
9.	Covered interval	18
Mississippian system:		
	Meramecian series:	
	Ste. Genevieve limestone:	
8.	Shale, yellowish-gray, calcareous, fossiliferous	3.5
7.	Shale, red and green, calcareous, poorly exposed	20.5
6.	Limestone, gray, sublithographic	2.0
5.	Shale, grayish green to buff, calcareous	.5

St. Louis limestone:

4.	Sandstone, light-buff, medium-grained, soft	5.5
3.	Limestone, brown, sublithographic	1
2.	Dolomite, buff, porous, very unevenly bedded, sandy; green, medium- to coarse-grained, calcareous	5
1.	Dolomite, buff, finely crystalline, evenly bedded, to river level of Lizard Creek	4

Additional exposures of the Ste. Genevieve occur at intervals upstream along Lizard Creek for a distance of about 2 miles to the north line of sec. 23, T. 89 N., R. 29 W.

South of Fort Dodge, about 3 feet of fossiliferous shales is exposed along the left bank of the Des Moines River in the NW ¼SW¼ sec. 5, T. 88 N., R. 28 W. Farther south, on the left bank of the river at the north line of sec. 8, T. 88 N., R. 28 W., a few feet of St. Louis limestone is overlain by 5 to 6 feet of sparingly fossiliferous shales of the Ste. Genevieve limestone, which is overlain in turn by 16 feet of black fissile shale and 4 feet of carbonaceous fossiliferous limestone belonging to the Pennsylvanian system of rocks. Here the beds dip very gently to the north.

The most southerly exposures of the Ste. Genevieve limestone occur along the right bank of the Des Moines River in the N½ SE¼ sec. 16, T. 88 N., R. 28 W. Here fossiliferous shales extend to a height of 3 to 13 feet above low-river level and are overlain by shales of Pennsylvanian age.

The general configuration of the base of the Ste. Geneveive and the distribution of this formation in the county are shown in figure 24. The Ste. Genevieve limestone appears to have the same general distribution as the younger Fort Dodge beds. A maximum thickness of 70 feet of Ste. Genevieve occurs in secs. 30 and 31, T. 89 N., R. 28 W., in the vicinity of the depression in the base of the formation south of Fort Dodge, and thicknesses decrease from this center.

Age and correlation. The fossils in the marls above the limestones at Fort Dodge were described in part by Worthen (1858, p. 178, 179). White (1870, p. 221, 222) mentioned that the marls at Fort Dodge contain fossils similar to those in the marls in southeastern Iowa, which he included in the St. Louis limestone. Bain (1894, p. 282) gave the name Pella to the upper beds, retaining them as a member of the St. Louis limestone.

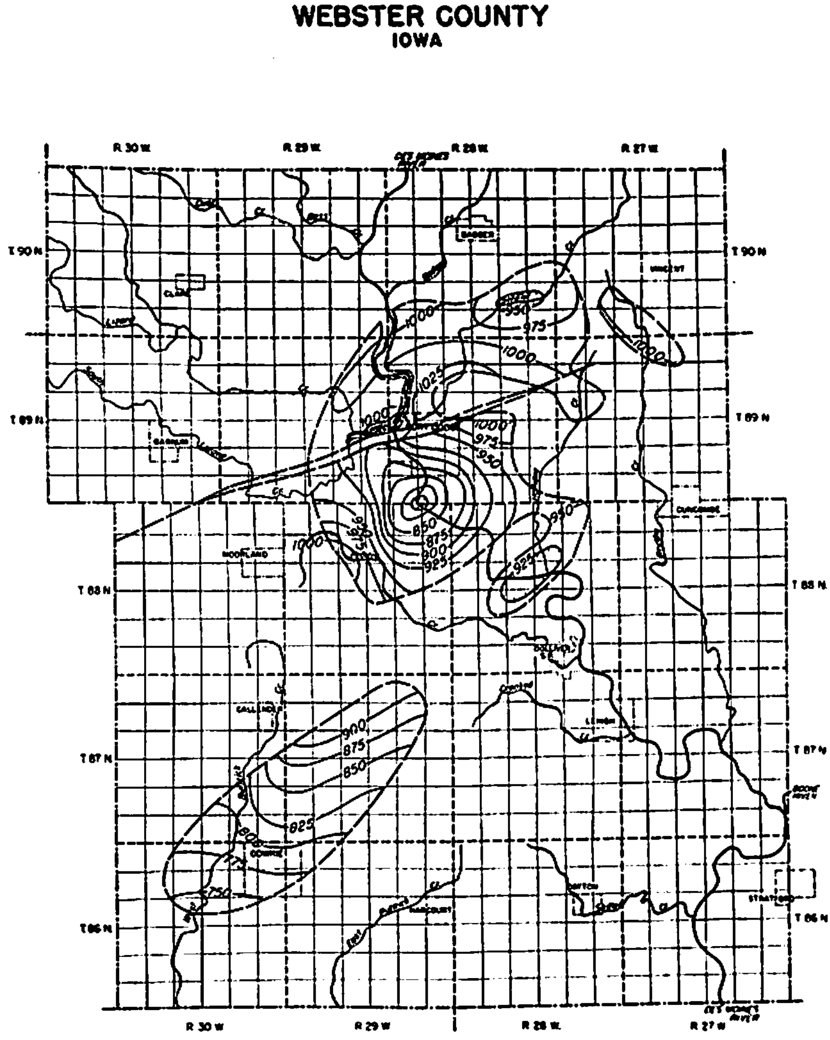


Figure 24.—Map of Webster County showing the distribution of the Ste. Genevieve limestone and the general configuration and altitude, with reference to mean sea level, of its base.

Nickles and Bassler (1900, p. 166, 180) referred the Pella beds to Ste. Genevieve on the basis of Ulrich's description of some of the bryozoan fossils from the Pella beds. Later, Lees and Thomas (1919, p. 599-616) described the marls above the St. Louis limestone at Fort Dodge and correlated the marls at Fort

Dodge with the Pella beds, thus reaffirming the earlier correlation made by White.

In southeastern Iowa, the Pella beds constitute the youngest unit of the Mississippian system in Iowa. They rest on the St. Louis limestone and are overlain by rocks of Pennsylvanian age. This is the relationship of the Ste. Genevieve limestone at Fort Dodge. It everywhere rests on the St. Louis limestone and over most of its area of occurrence is overlain by shale and sandstone of Pennsylvanian age. In a few localities in the northern part of the country, the Ste. Genevieve limestone is overlain by Pleistocene deposits, and at least one locality (SW¼ sec. 31, T. 90 N., R. 28 W.) it is directly overlain by the Fort Dodge formation of inferred Permian age.

Water supply. The shales of the Ste. Genevieve limestone yield very little water in Webster County, and because of the caving nature of the shales, the formation requires casing in wells drilled into the underlying sandstone and limestone. It undoubtedly restricts the vertical movement of ground water between overlying aquifers and the St. Louis limestone aquifer below.

PENNSYLVANIAN SYSTEM

Desmoinesian Series

Undifferentiated Beds

Character. The strata comprising the Desmoinesian series are predominantly gray to black shales with some sandstone and a few coal and limestone beds. Thick channel sandstone deposits trending in a general southerly direction occur in the north-central and southeastern parts of the county. Wells drilled on the upland plain commonly encounter fine-grained and silty sandstone beds of Pennsylvanian age generally not more than 20 feet thick at a depth ranging from 100 to 175 feet. They are commonly overlain by light-colored shales and thin coal beds, usually less than 2 feet thick, and underlain by black shales, and occasional coal seams. Near the base of the Pennsylvanian strata a dark-gray to black limestone containing fossils is usually present. One of the characteristic features of the Pennsylvanian rocks is the lenslike nature of many of the beds, indicative of shallow-water deposition. Descriptions of the Pennsylvanian strata in various parts of the county based on the study of well cuttings are given in the section on well logs.

Distribution and thickness. Rocks belonging to the Desmoinesian series compose the bedrock over most of the southern part and much of the north-central part of the county. Outcrops of these strata frequently occur along the valley of the Des Moines River and its tributaries.

In the northern part of the county along either side of the river in secs. 13 and 24, T. 90 N., R. 29 W., cross-bedded calcareous coarse-grained sandstone forms bluffs 15 to 20 feet in height (pl. 12B). This sandstone rests on limestone and sandstone beds of the St. Louis limestone and is overlain by drift.

About 2 miles north of Fort Dodge along the right bank and at a sharp bend of the Des Moines River near the center of sec. 7, T. 89 N., R. 28 W., black fissile shale with some sandstone is exposed from near water level to a height of more than 40 feet. The shale here rests on the St. Louis limestone and are overlain by till. Exposures of shale and sandstone overlying the St. Louis limestone occur along the left bank southward from this location to Fort Dodge.

South of Fort Dodge, the sections exposed in three clay pits opened in the valley walls of the Des Moines River and one on Crooked Creek near Lehigh have been described by Gwynne (1943, p. 339-344). His description of the section at the Vincent Clay Products Co. pit, in the SW¼ sec. 6, T. 88 N., R. 28 W., is as follows:

Section: Vincent Clay Products Co.,
Fort Dodge, Webster County

Member	*Description*	*Thickness* (feet)
16.	Till	0-15
15.	Gypsum in irregularly shaped erosion remnants	0- 8
14.	Sandstone, red and brown, conglomeratic toward top, calcareous	0- 3
13.	Shale, gray and buff, with bright red streaks, soft from weathering	4.5
12.	Shale, very silty, banded light gray and red	1.5
11.	Sandstone, dull-red, argillaceous, softened by weathering; grades into bed 10	1.2
10.	Shale, light-gray, laminated	1
9.	Shale, dark-gray, laminated, notable number of clay ironstone concretions	2.6
8.	Clay (underclay), gray, coal smut at top	.3
7.	Shale, dark-red	1.5

6.	Shale, dark-gray, laminated	.5
5.	Shale, silty, nodular fracture	.3
4.	Shale, argillaceous, dark slate blue and gray, fissile, particularly toward bottom; contains numerous calcareous concretions approximately in middle; streaks of crumbly red sandy clay	10.6
3.	Clay (underclay?), gray-buff; angular fracture, no lamination	1.8
2.	Shale, laminated, red and light-gray	.2
1.	Sandstone, white, noncalcareous, slightly cross-bedded	4.0

The uneven bedding of some of the Pennsylvanian rocks is shown in plate 11A, a view of the shale pit in the SW¼SE¼ sec. 8, T. 88 N., R. 28 W. The section, in descending order, consists of till, a bed of fine-grained sandstone irregularly overlying a gray to black shale, and a buff to gray shale. The shales and sandstone together are about 65 feet thick, including a few feet of coal near floor level in the southwestern part of the pit. Subsurface control indicates that the top of the limestone of Mississippian age is 135 feet below the top of the sandstone.

Farther south, thick sandstones are exposed along the banks of the Des Moines River from sec. 14, T. 88 N., R. 28 W., downstream to the vicinity of Lehigh in sec. 1, T. 87 N., R. 28 W., and are described by Wilder (1902, p. 85-88) as follows:

"The Coal Measure sandstones are the striking stratigraphic feature in the southern part of the county where a maximum thickness of 60 feet is exposed. Most of the layers are ferruginous, but near Lehigh the upper courses at certain points are cemented with carbonate of lime. The bond between the grains is slight when iron is the cementing substance. The layers containing carbonate of lime, however, are firm and suitable for building. Typical exposures of these sandstones may be seen on Prairie Creek in Otho Township, section 35, the so-called copperas beds, and at Wild Cat cave in Pleasant Valley Township, sec. 11, SW¼.

Section at 'Copperas Beds' near the mouth of Prairie Creek

		Feet
4.	Drift	5-50
3.	Sandstone, cross-bedded, soft, ferruginous, containing concretions	30
2.	Sandstone, conglomeratic, containing large blocks of	

sandstone found in the vicinity, with fossil wood in large pieces. The surface of this portion of the bluff is usually white with $FeSO_4$..........15

1. Conglomerate, consisting of pebbles; quartz especially abundant, though some granites and greenstones, waterworn, small, none above half an inch in diameter, cemented by iron so that perhaps 25 or 30 percent of the whole mass is iron. In the center there is a two-inch streak of clay ironstone and three inches of soft shale.... 4

"The concretions in the sandstone are very abundant and of all sizes from a foot to a fraction of an inch. Many of the smaller ones are hollow. Cross-bedding is everywhere conspicuous. . . .

"The iron conglomerate, containing iron and northern pebbles, was found only near the mouth of Prairie Creek and in a ravine a mile farther south. Perhaps one-half of the rock consists of small pebbles and the rest of the cementing iron. The rock so formed is very hard and seems to weather very little. Where it has been long exposed to the air the pebbles have fallen out and the rock has a vesicular appearance, in color and structure resembling lava."

The foreset beds of this channel sandstone have a southward dip in the area of exposure. The sandstone has been encountered in a well at some distance from the area of outcrop in the NE¼NW¼ sec. 30, T. 87 N., R. 28 W. Other wells have been finished in the sandstone at points nearer the outcrop area. These control points suggest that the channel trends in a southwesterly direction from its outcrop area. The channel sandstone seems to have a width of at least 3 miles.

The strata assigned to the Desmoinesian series of rocks reach their greatest thickness in the southern part of the county. At Dayton, these rocks are about 230 feet thick. At Harcourt and in the vicinity of Callender they reach a thickness of approximately 200 feet. Farther north, in the vicinity of Fort Dodge, they are about 100 feet thick, and from there northward they become thinner rather abruptly.

Age and correlation. The shales and sandstones rest on the Ste. Genevieve limestone in its rather limited area of occurrence and on the St. Louis limestone over a large part of the area. In a few places where the St. Louis limestone is absent, the Pennsylvanian strata rest on rocks of the Osagian series. The Pennsylvanian strata are overlain locally by the Fort Dodge formation or by Cretaceous rocks. However, over a large part of the county

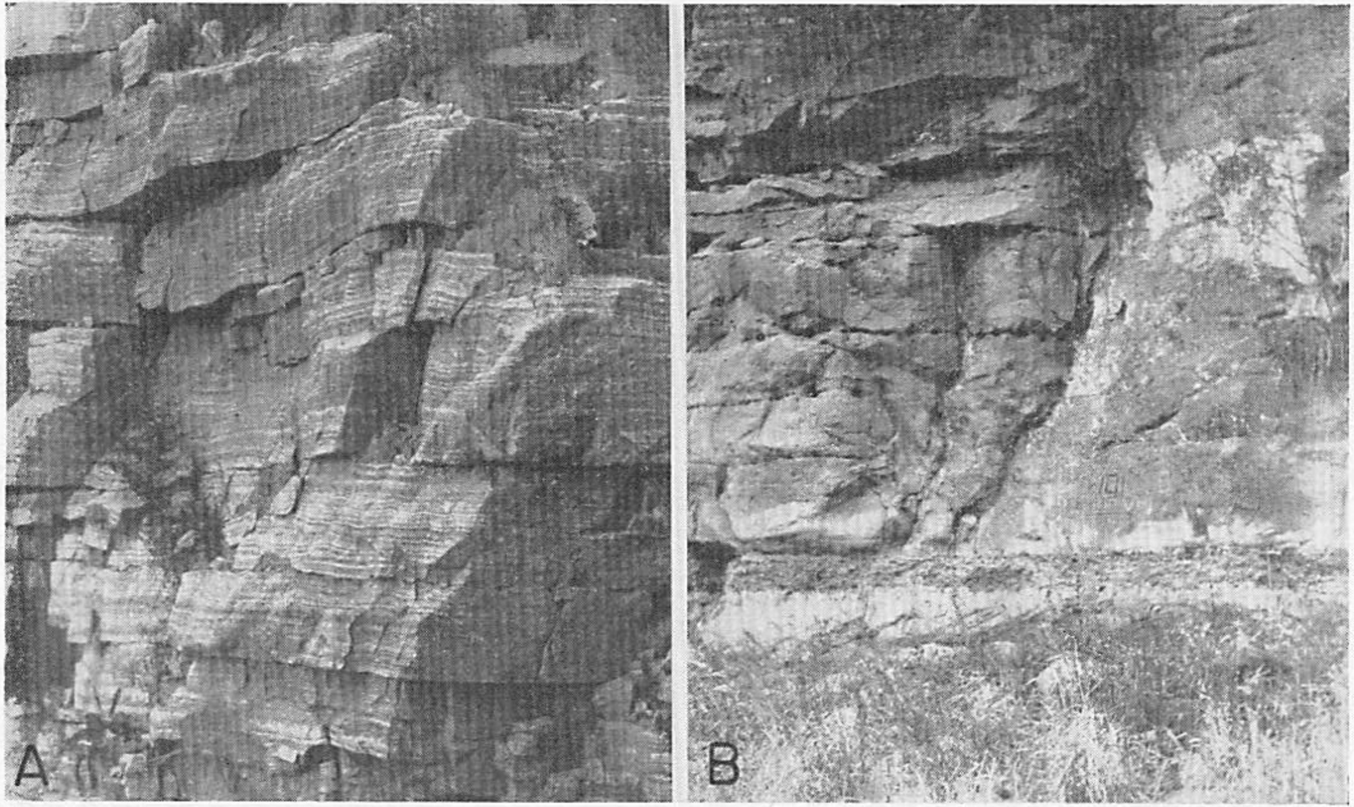


Plate 12.—A, Exposure of banded gypsum of the Fort Dodge formation in a quarry in the NW¼ sec. 26, T. 89 N., R. 28 W.; B, Exposure of sandstone of Desmoinesian series along the right bank of the Des Moines River in the NW¼ SW¼ sec. 24, T. 90 N., R. 29 W. A conglomerate composed of chert pebbles occurs near the base of the bluff.

they are overlain by Pleistocene deposits. The Pennsylvanian rocks in Webster County are assigned to the Desmoinesian series by Keyes (1893), Wilder (1902), and other workers in the area. Detailed study of these strata has not been made in Webster County.

Water supply. A number of wells, including one municipal supply well, have been finished in sandstones of Desmoinesian age; most of these are in the southern part of the county. Yields obtained outside the area of the channel sandstones are generally adequate for farm use. The town well at Callender (87-30-12L2), which is finished in sandstone of Pennsylvanian age at a depth of 185 feet, is reported to yield 12 gallons a minute with a drawdown of 113 feet.

Wells finished in the channel sandstone in the general vicinity of Lehigh yield 1 or more gallons a minute per foot of drawdown. The school well at Burnside (87-28-15N1) yields 9 gallons a minute with a drawdown of 3 feet, the Kling farm well (87-28-30C1) obtains a supply of 10 gallons a minute with a reported drawdown of 10 feet, the Jensen farm well (88-28-34D1) farther northeast reportedly yields 12 gallons a minute with a small drawdown, and the Spike farm well (88-28-13F1) develops a supply of 10 gallons a minute with a small drawdown.

The nonpumping water level in wells finished in the channel sandstone is between 90 and 110 feet below the upland surface, whereas in the thinner sandstones away from the Des Moines River the nonpumping water level is between 30 and 60 feet below the upland surface. The water in these sandstones appears to be moving toward the valley of the Des Moines River.

The water from the sandstones of Pennsylvanian age is hard and commonly has a high iron content. The fluoride content is probably below 2 parts per million.

PERMIAN (?) SYSTEM

Fort Dodge Formation

The occurrence of gypsum in the vicinity of Fort Dodge was noted by Owen (1852, p. 126), and since that time the gypsum and associated shales and sandstone have been studied extensively in regard to their age and origin, because of the commercial value of the gypsum.

Character. The main body of the gypsum is light gray-white and massive. On weathering, it is prominently banded gray-white and dark gray (pl. 12A). Beneath the gypsum in the southern part of the area of occurrence there is commonly a red to gray conglomerate (pl. 13), which was first reported by Lees (1919, p. 587-591). The conglomerate is composed largely of limestone pebbles some of which are more than an inch in diameter. It is cemented by hematite and on weathered surfaces has the appearance of clinker. The bed contains fossils, but they seem to be reworked from older strata. Locally, the gypsum is underlain by shales of Pennsylvanian age (pl. 14B).

The gypsum is overlain in places by unevenly bedded red, gray, and green calcareous sandy shales and fine-grained calcareous sandstones (pl. 15B). The beds are poorly consolidated and individual shale beds are particularly lenticular. On weathered surfaces the shales have crumbled into a mass of sandy, silty clay. Some of the fine-grained sandstones in the upper part of the section are more persistent and durable. Although the strata are variable from place to place, the following detailed description of the beds above the gypsum is presented to show the various lithologies that occur. The exposure described is located on the left bank of Soldier Creek in Snell Park in the northern part of Fort Dodge.

Exposure of the Fort Dodge formation in Snell Park in the NE¼SE¼SW¼ sec. 17, T. 89 N., R. 28 W.

Bed	*Description*	*Thickness* (feet)
	Pleistocene system.	
	Undifferentiated beds:	
11.	Till, buff, unleached	11
	Permian (?) system.	
	Fort Dodge formation:	
10.	Shale, red and some light-green, very calcareous, soft, slightly sandy, with doubly terminated quartz crystals	5
9.	Sandstone, pink, very fine-grained, angular, soft, very calcareous; contains a few coarse, rounded quartz grains and occasional pink and gray chert fragments	3
8.	Shale, bright red and pale-red with green lenses and blotches, soft; lower part calcareous; upper pale-red shales are noncalcareous; thin, lenticular beds of calcite contain doubly terminated quartz crystals	3

7.	Shale, pastel-red with some green lenses, soft, slightly silty, calcareous. There is a 1-inch bed of calcite containing doubly terminated quartz crystals about 1 foot from the base	8.5
6.	Sandstone, pale gray-pink, very fine-grained, soft, argillaceous, calcareous	2.5
5.	Shale, red, soft, silty, calcareous, and some flakes of mica	4
4.	Shale, olive-gray near base to gray-green in upper part, soft, silty, calcareous	2.5
3.	Sandstone or shale, red to pink, hard to soft, calcareous. Clay, with inclusions of subrounded course limestone grains, predominates in places. Roughly 10 percent of limestone grains are worn fusulinid and other fossil fragments. These small limestone pellets make up bulk of rock in places. Occasional fragments of gray-brown chert, bright-orange quartz, and coarse rounded sand grains	4.5
2.	Shale, gray, buff, soft, very calcareous; contains druses and gray watery chert nodules	0.8
1.	Gypsum, gray-white, massive, banded, heavily bedded. To water level in Soldier Creek	8
	(Altitude of water level about 1,025 feet)	

The shales and sandstones of the Fort Dodge formation have been assigned to other formations in some places where the gypsum is absent or not exposed. Most often they have been confused with the shales of the Ste. Genevieve limestone, which are also predominantly red and green and are calcareous. There are several differences in the lithology of the two formations, however. The shales of the Ste. Genevieve are a darker red and green and more unctuous than those of the Fort Dodge formation. The sands, silts, and doubly terminated quartz crystals that commonly occur in the Fort Dodge beds were nowhere observed in the Ste. Genevieve. The shale containing the rounded limestone pellets as described in bed 3 of the park section seems to be restricted to the Fort Dodge formation. The shales belonging to the Desmoinesian that commonly underlie the Fort Dodge formation are generally very dark, laminated, and carbonaceous. Locally they may be bright red and green and contain thin partings of gypsum where they underlie the gypsum, but they are rarely calcareous.

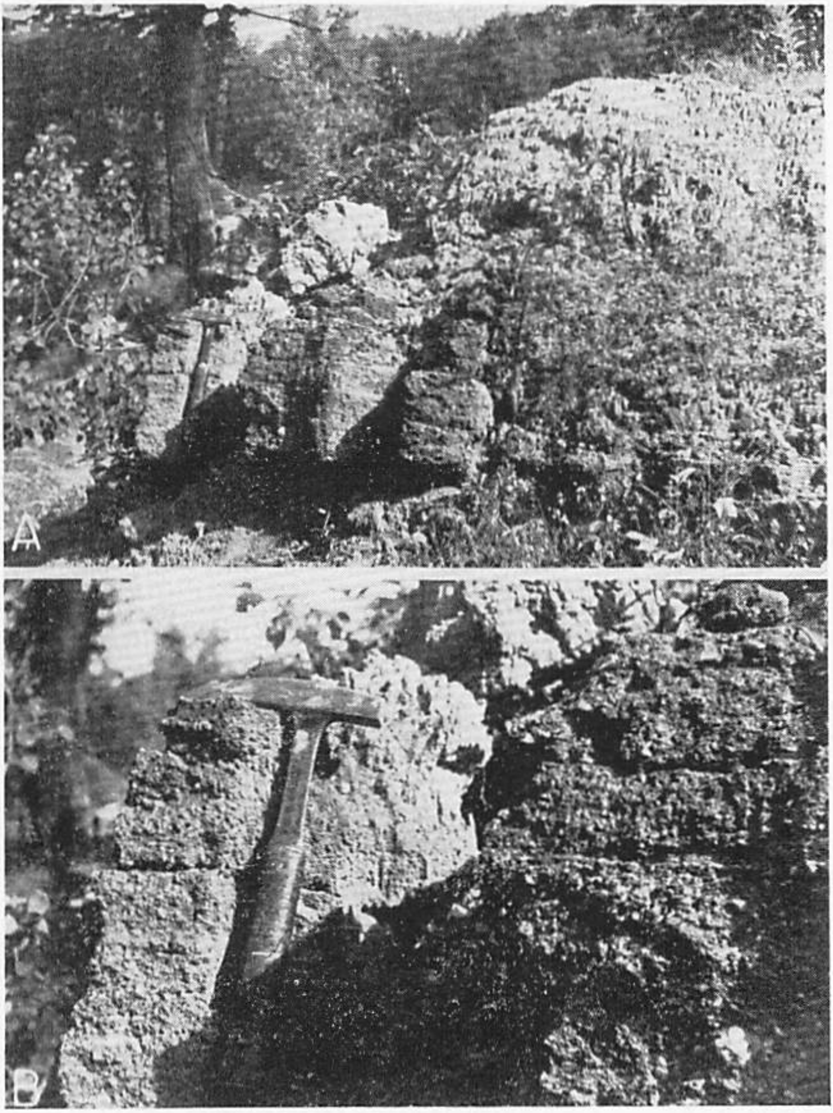


PLATE 13.—EXPOSURE OF THE BASAL CONGLOMERATE OF THE FORT DODGE FORMATION IN NW¼ SEC. 7, T. 88 N., R. 28 W.: A, BASAL CONGLOMERATE OVERLAIN BY GYPSUM AND UNDERLAIN BY SHALES OF PENNSYLVANIAN AGE; B, CLOSEUP VIEW SHOWING TEXTURE OF THE BASAL CONGLOMERATE OF THE FORT DODGE FORMATION. (Photographs by R. M. Jeffords.)

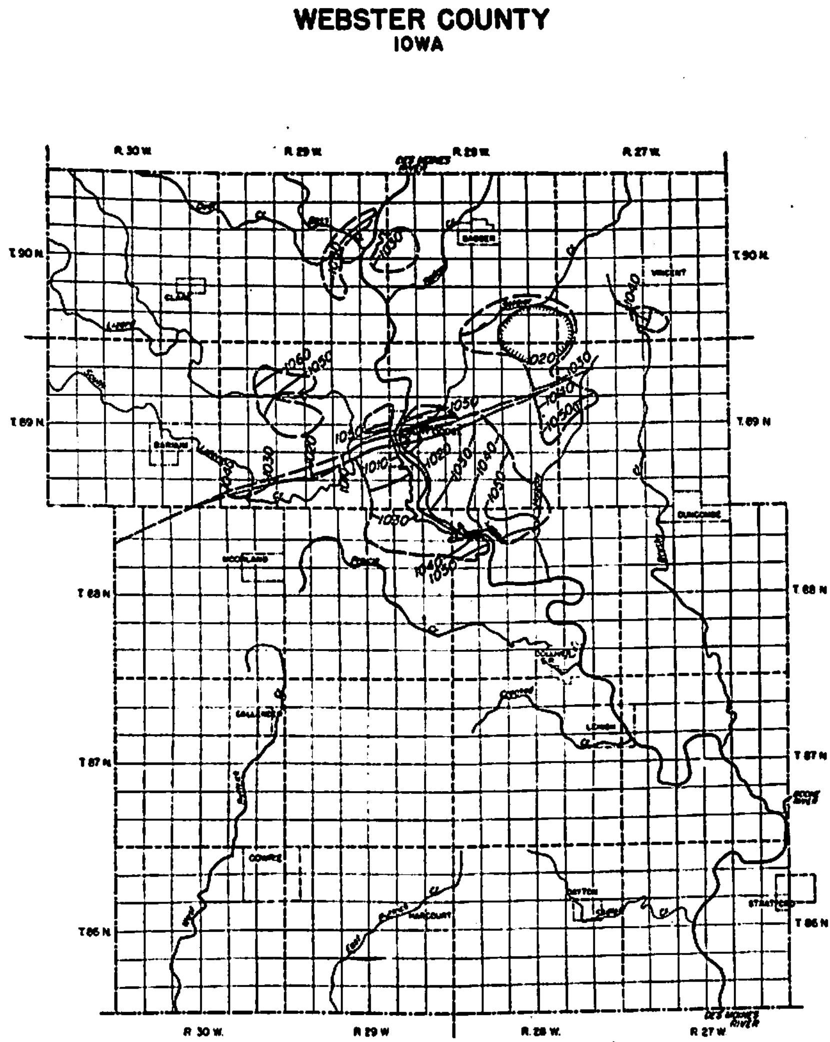


Figure 25.—Map of Webster County showing the distribution of the Fort Dodge formation and the general configuration and altitude, with reference to mean sea level, of its base.

Distribution and thickness. Originally the Fort Dodge formation may have been continuous over a fairly large area in Iowa, but it is now known only in Webster County. Here the formation occurs in small to very large patches in the northern two-fifths of the county. Figure 25 shows its inferred distribution as determined from outcrops and well data.

Exposures occur locally in bluffs along the Des Moines River and in small tributary ravines northward from the northern part of sec. 8, T. 88 N., R. 28 W., to Fort Dodge. Exposures also occur along the valley walls of some of the larger tributaries of the Des Moines River. In Gypsum Creek, south of Fort Dodge, exposures of the Fort Dodge formation occur at intervals for about a mile above the mouth of the creek. Some of the thickest sections are exposed along Soldier Creek, the last exposure observed along this stream being about 2 miles from its mouth, in the SE¼NE¼ sec. 17, T. 89 N., R. 28 W. Along Lizard Creek, the Fort Dodge formation was well exposed formerly in clay pits (pl. 14A), which were operated on either side of the stream near its mouth. Many of the exposures along the streams cited have been described by Keyes (1895, p. 268-284), Wilder (1902, p. 99-102), and Lees (1924, p. 113-118). Later, Wilder (1923, p. 137-156, 168-170) reviewed the descriptions given in previous publications.

The exposures of sandstone and red and green sandy shale that occur along South Lizard Creek in secs. 23 and 26, T. 89 N., R. 29 W., and along Lizard Creek and small tributaries in sec. 8, T. 89 N., R. 29 W., were originally correlated with the Fort Dodge formation by Keyes (1895, p. 279) and Wilder (1902, p. 103). Later, Lees (1918, p. 601, 602) assigned these shales and sandstones to the Ste. Genevieve limestone, as did Wilder (1923, p. 166). These exposures were re-examined in some detail during the present investigation.

In the left bank of South Lizard Creek about 500 feet upstream from the scarp of St. Louis limestone, SE¼SE¼SW¼ sec. 23, T. 89 N., R 29 W., the following section is exposed at low-water level:

Bed	*Description*	*Thickness* (feet)
	Permian (?) system.	
	Fort Dodge formation:	
4.	Shale, gray and red, silty, calcareous	2
3.	Shale or sandstone, red, calcareous, soft. Clay is red, silty, calcareous. Sand composed of subrounded, coarse limestone grains, composed in part of fossil fragments	3
2.	Shale, clayey, red, calcareous, containing a few limestone pellets and sand grains	2

1. Shale, gray, green, silty, micaceous, very slightly calcareous, to water level 2

(Altitude of water level about 1,005 feet)

About 500 feet farther upstream, at a sharp bend in the stream, red and green shales are exposed in a bluff from stream level to a height of about 19 feet. These shales are calcareous in places and contain lenses of calcite with doubly terminated quartz crystals. The shales are overlain by 6 feet of calcareous fine-grained buff sandstone. On top of the sandstones are about 12 feet of red calcareous clay shale. Around the bend and upstream for an additional 700 feet, red and green silty calcareous shales are exposed along the left bank for a few feet above the stream bed. The lithology of this group of exposures is similar to the section of the Fort Dodge formation at Snell Park in the north part of Fort Dodge, and for this reason the beds are reassigned to the Fort Dodge formation.

The exposures on Lizard Creek in the SE¼ sec. 8, T. 89 N., R. 29 W., and on the small tributary stream meandering northward through the center of section 8 have a lithology similar to the beds exposed on South Lizard Creek and the strata at the park. Furthermore, in the SE cor. sec. 8, T. 89 N., R. 29 W., black shales of the Pennsylvanian system can be seen at low-water stages of Lizard Creek beneath the red and green calcareous shales containing limestone pellets near the base. This group of exposures is reassigned also to the Fort Dodge formation.

The gypsum reaches a maximum known thickness of about 30 feet in the vicinity of the present open quarries of the gypsum companies. It is much thinner over most of the area because of preglacial erosion and solution and in part because the deposit seems to thin radially from this center. The red shale and sandstone that overlie the gypsum extend beyond the gypsum strata to the west and north. The maximum observed thickness of the clay shales, nearly 50 feet, was observed along the right bank of Soldier Creek in the NE¼NW¼SE¼ sec. 19, T. 89 N., R. 28 W., near the north end of the high bridge on State Highway 5 in the northwestern part of Fort Dodge. The conglomerate below the gypsum has not been observed to exceed a thickness of 3 feet.

Age and correlation. Pleistocene glacial deposits are the only strata known to overlie the Fort Dodge formation. The relation

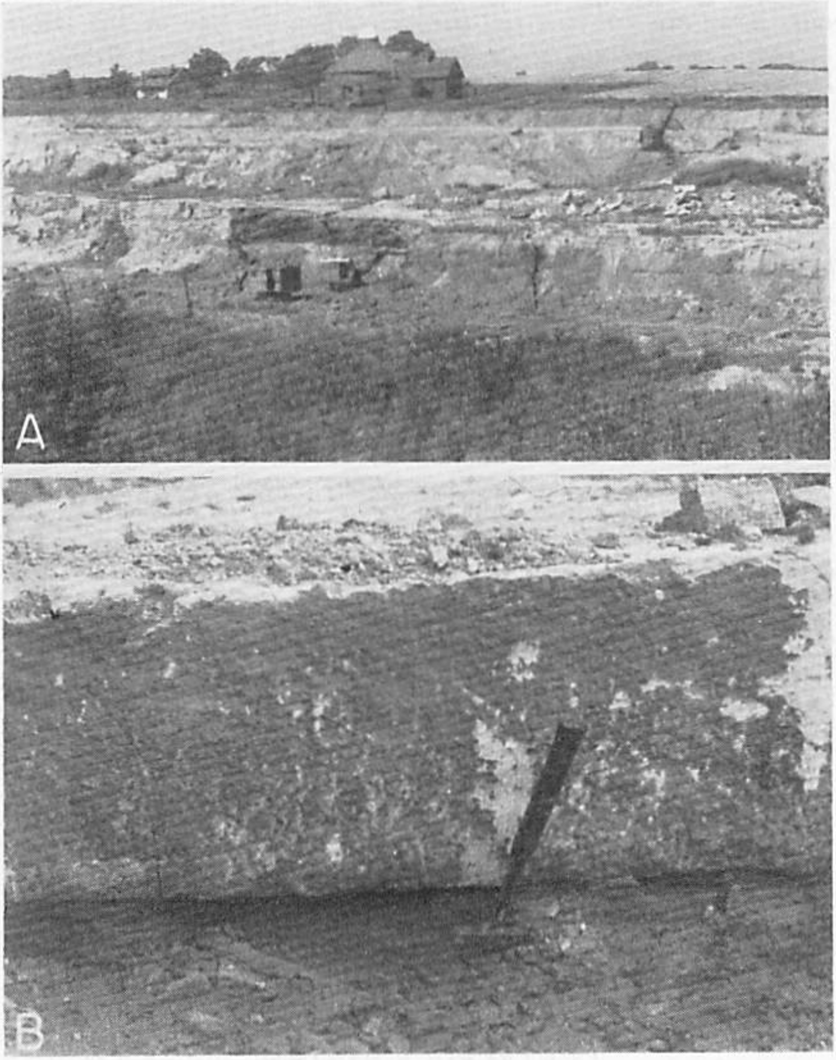


Plate 14.—*A*, View of a quarry in NW¼ NE¼ sec. 8, T. 88 N., R. 28 W. Sand and gravel is being stripped in background. Gypsum has been removed, forming the bench above shale beds of Pennsylvanian age. The shales provide raw material for manufacture of clay products; *B*, Contact of gypsum of Fort Dodge formation with underlying shale of Pennsylvanian system in a quarry in the SW¼NW¼ sec. 6, T. 88 N., R. 28 W. (Photographs by R. M. Jeffords).

of Cretaceous deposits to the Fort Dodge is not definitely known. In the western part of the county, Cretaceous deposits rest on silty gray and green clays in places, but the age of the latter strata is not known. They may be a part of the Fort Dodge or Desmoinesian series of rocks.

The Fort Dodge formation rests unconformably mostly on the grayish black shales and gray to orange sandstones of the Desmoinesian series of rocks and, in places, on the Ste. Genevieve limestone. It probably rests on the St. Louis limestone in still other places.

Much has been written regarding the age of the Fort Dodge formation. Keyes (1895, p. 290) regards the gypsum and associated red shales as Cretaceus in age, probably laid down during the latter part of the Niobrara epoch. Wilder (1923, p. 171-173) stated, in his final work on the gypsum, that the Fort Dodge formation appears to be more closely related to the Permian beds of Kansas than to any younger or older rocks, an opinion he had stated almost 20 years previously. Fusulinids collected from the Fort Dodge formation seem to be of late Pennsylvanian age, and Moore and others (1944, p. 692) suggest on this evidence that the formation is of mid-Virgilian age. The fusulinids observed in the formation are badly worn from transportation and may therefore be reworked from older beds.

Water supply. The sandstones in the upper part of the formation commonly contain a little water, but only one well (89-29-31F1) is known to have been finished in them and it obtained a very hard water (analysis, p. 78). The reported yield from this well is 5 gallons a minute with a 15-foot drawdown, adequate for a farm supply. The calcareous shales in the formation are effective barriers to the downward movement of water in the area of their occurrence.

CRETACEOUS SYSTEM

Keyes (1895, p. 290) in his report on the gypsum in Webster County infers that the gypsum and associated deposits are of Cretaceous age and were laid down during the latter part of the Niobrara epoch. Later, Wilder (1902, p. 111-116), in his report on the geology of Webster County, favors a Permian age for the gypsum and associated red beds. None of the other strata he described were assigned to the Cretaceous system. His geologic map (1902, p. 191) of the county infers most of the upland to be underlain by rocks of Pennsylvanian age.

The closest to Webster County where exposures of rocks of Cretaceous age have been reported in the literature is southwestern Calhoun County; this locality is described briefly by St. John (1870, p. 149). Later, Balster (1950) in his report of the geology of Calhoun County traces deposits of inferred Cretaceous age, in the subsurface, to the eastern border of the county.

Along Lizard Creek in Webster County are exposures of sandstones and sand and gravel, heretofore described, which have lithologic characteristics similar to some of the strata of the Dakota formation farther west in the state. Also, in a few wells in the western part of Webster County, but east of the Manson area, similar strata have been encountered. In the Manson area the upper indurated rocks are tentatively assigned to the Carlisle shale.

Dakota (?) Sandstone

Character. Strata of inferred Cretaceous age in Webster County and east of Manson, Calhoun County, are mostly sandstones and sand and gravel. The sands and gravels are composed primarily of quartz and chert. The larger sand grains and pebbles have a high polish characteristic of the pebbles in the Cretaceous farther west. Furthermore, there are many pink quartz and small black chert sand grains in the sands and gravels which are also characteristic of the sands and gravels of the Dakota (?) sandstone to the west. Some of the associated brown noncalcareous clays contain many polished pebbles. The gray clays contain considerable carbonaceous material. The sandstones are primarily a fairly uniform medium-grained angular quartz sand, containing some pink and black sand grains and, in places, a scattering of polished pebbles. In outcrop the sandstones are stained an orange brown and appear to be massive in some places while at other localities the sand is distinctly cross bedded.

Distribution and thickness. The only exposures of Cretaceous age observed in the county are along Lizard Creek (pl. 15A). The most easterly exposure is along the right bank of the stream about 0.2 mile north of State Highway 5 and about 1.5 miles west of Fort Dodge in the NW¼SW¼SE¼ sec. 14, T. 89 N., R. 29 W. Here about 14.5 feet of Cretaceous strata is exposed, as follows:

PLATE 15.—*A*, EXPOSURE OF SANDSTONE OF CRETACEOUS AGE ALONG THE LEFT BANK OF LIZARD CREEK IN THE CENTER S½ SEC. 12, T. 89 N., R. 30 W.; *B*, EXPOSURE OF CALCAREOUS SANDSTONE OF THE FORT DODGE FORMATION IN THE SW¼ NE¼ SEC. 8, T. 89 N., R. 29 W.

Section on right bank of Lizard Creek
NW¼SW¼SE¼ sec. 14, T. 89 N., R. 29 W.

Bed	*Description*	*Thickness* (feet)
Pleistocene		
Undifferentiated beds:		
8.	Sand and gravel, buffish-brown, oxidized and leached, containing boulders of highly weathered granite. To level of terrace	1.0
7.	Till, grayish-brown, oxidized and leached, containing some highly weathered granite boulders	4.0
Cretaceous system		
Dakota (?) sandstone:		
6.	Clay, brown, silty, noncalcareous, containing some quartz sand and some polished pebbles	2.5
5.	Sand and gravel, creamish-buff, clean, containing many small pink quartz and brown to black chert grains, and subrounded, highly polished pebbles	7.0
4.	Sand, coarse, mostly clear quartz, some pink; contains many large angular to subrounded, well-polished siliceous pebbles	1.5
3.	Sand, coarse, quartz, clear, some pink	1.7
2.	Clay, gray, noncalcareous, containing very large, angular, highly polished siliceous pebbles	0.3
1.	Sand and gravel, buffish-cream, clean, containing polished siliceous pebbles. To water level	1.5

(Approximate altitude of water level 1,005 feet)

The next exposure observed is about 4.5 miles upstream in the NE¼SE¼SE¼ sec. 7, T. 89 N., R. 29 W. Here sand and gravel with polished pebbles and brown clay with polished pebbles rest on strata of undetermined age as follows:

Section along left bank of Lizard Creek
NE¼SE¼SE¼ sec. 7, T. 89 N., R. 29 W.

Bed	*Description*	*Thickness* (feet)
Cretaceous system		
Dakota (?) sandstone:		
7.	Sand and gravel, with some tan clay; sand mostly quartz. Pebbles are subrounded, highly polished, siliceous	2

6. Clay, brown, noncalcareous, containing sand and subrounded, highly polished, siliceous pebbles	3
Pennsylvanian system (?)	
Desmoinesian series (?)	
Undifferentiated beds:	
5. Shale, vivid pea-green, silty, grading downward into greenish-gray shale	9
4. Sandstone, gray, fine-grained, very hard, highly calcareous, with small fragments of grayish-brown chert and sandstone, gray, coarse-grained, calcareous, weathering into brown pea-size pellets	5
3. Shale, gray to gray-green, soft, silty, slightly calcareous in places	5
2. Marl, very sandy, very fine grained, hard with small pieces of pyrite resting unevenly on bed 1 near water level	2
1. Shale, gray, noncalcareous, silty, exposed near water level	0-1

(Altitude of water level about 1,070 feet)

Upstream around a sharp bend, in the SW¼SE¼SE¼ sec. 7, the brown clay of bed 6 in the above-described section grades into an ironstone containing polished pebbles and may represent the basal beds of the Cretaceous deposits. Continuing upstream about a quarter of a mile to the NE¼SE¼SW¼ sec. 7, coarse sand and gravel with many polished pebbles is interbedded with gray somewhat silty clay containing much fragmental carbonaceous material. These beds are overlain by iron-stained medium-grained massive sandstone. This particular exposure is in a small gully heading northward from Lizard Creek for a distance of 300 to 400 feet from the main stream. Farther upstream, the iron-stained sandstone is exposed almost continuously along the banks of the stream for a distance of about 1.5 miles, to the NE¼NW¼SW¼ sec. 12, T. 89 N., R. 29 W. In places the sandstone stands in bluffs rising more than 20 feet above the stream. The sandstone appears massive in most of the exposures but is distinctly crossbedded at other places. Only a few polished pebbles were observed in the sandstone.

Cretaceous-type sands were encountered in some wells north of Lizard Creek, apparently occurring as cavern filling in the St. Louis limestone and older rocks. South of Lizard Creek, a well located near Tara in the NW¼SW¼SW¼ sec. 20, T. 89 N., R. 29 W., penetrates 30 feet of sand and gravel and dark- to light-gray shale beneath 125 feet of glacial deposits. Most of the pebbles of the gravel are polished. Farther south, in the vicinity of Moorland, a few wells penetrate sand and gravel with associated brown noncalcareous clay, all containing polished pebbles and free of Pleistocene sands and gravels.

The thickest section of rocks in Webster County assigned to the Dakota (?) sandstone, except in the Manson area, occurs at a well in the SE¼ sec. 24, T. 88 N., R. 30 W., where 38 feet of sand and gravel with brown clay underlies the drift.

The strata assigned to the Dakota (?) sandstone probably occur as scattered patches in the west-central part of the county, and inferred distribution of two such patches is shown on the geologic map (pl. 1). About 2 miles north of Webster County near the mouth of Indian Creek, which enters the Des Moines River from the west, sands and gravels containing many polished pebbles are exposed. These deposits also seem to be a part of the Dakota (?) sandstone.

Age and correlation. No fossils were observed in the sandstone and sand and gravel, but the presence of highly polished pebbles together with the pink quartz and occasional black sand grains and the lack of igneous or limestone pebbles make them very similar lithologically to sandstone and conglomerates present in the lower part of the Dakota formation in the western part of the State. The gray clay associated with the sand and gravel in places contains fragments of plants, but these are too small for identification.

The Dakota (?) formation rests on rocks of Pennsylvanian age. At present no exposure or well sections show positively the relationship of the Fort Dodge formation to the Dakota (?) sandstone. There is a possibility that the exposed silty shales, calcareous sandstones, and marl underlying Cretaceous sands and gravels in sec. 7, T. 89 N., R. 30 W., may be a phase of the Fort Dodge formation. Inasmuch as the correlation is not positive at present, these strata are retained in the undifferentiated Pennsylvanian strata of the county.

Undifferentiated Beds
(Rocks of the Manson Area)

Character. Rocks of Cretaceous age have been preserved by down-faulting in the Manson volcanic basin. Logs of two wells drilled at Manson, Calhoun County, are given by Norton (1912,

p. 1016-1017; 1828, p. 246-248), who discusses the great divergence of the rocks penetrated from the normal sequence in the general area. The log of well 2, greatly generalized from Norton's description (1928), shows drab shales with some limestones below the drift from a depth of 200 feet to approximately 540 feet. From 540 feet to the bottom of the well, drab and red shales alternated with increasingly arkosic sandstones. Norton (1928, p. 250) suggests the possible existence of a deep erosional channel, the lower part of which had been filled with sediments of continental origin and the remainder filled with marine sediments of Pennsylvanian or Cretaceous age.

More recently, several sample sets of well cuttings from the locality have better defined the area, and its inferred limits are shown on figure 26. The present control suggests a basin whose length in a general northeastward direction is about 25 miles and whose width is roughly 18 miles.

Near the center of the basin, microcline feldspar rock or serpentinized basaltic tuff is encountered at a depth of about 100 feet. Wells away from this center encounter like material at increasing depths, but several wells, which have been drilled in the area away from the central core, have failed to reach the crystalline material. These wells, one of which attains a depth of 1,532 feet, have encountered shale and sandstone and a minor amount of dolomite and siderite.

In Webster County, well 90-30-4E1 was drilled to a depth of 1,105 feet, penetrating a predominantly shale section below the drift to a depth of 850 feet. From 850 to 1,000 feet, sandstone was the principal rock encountered. From 1,000 to 1,105 feet, gray and very black carbonaceous shales and lignite were penetrated. Other wells drilled in this area, which range in depth from 165 to 710 feet, have been finished in sandstone. Logs of the wells drilled in this sequence of rocks in Webster County for which the Survey has samples are given in the section on well logs.

Distribution and thickness. The area underlain by the abnormal strata is shown on figure 26. They are known to crop out only in the NE¼NE¼SE¼ sec. 11, T. 89 N., R. 30 W. The beds comprising this sequence of rocks extend in places to a depth of at least 1,500 feet in Calhoun County and to a depth of at least 1,100 feet in Webster County.

Age and correlation. The upper part of the section consists of Cretaceous sandstone and shale. In well 90-30-35P1 *Ino-*

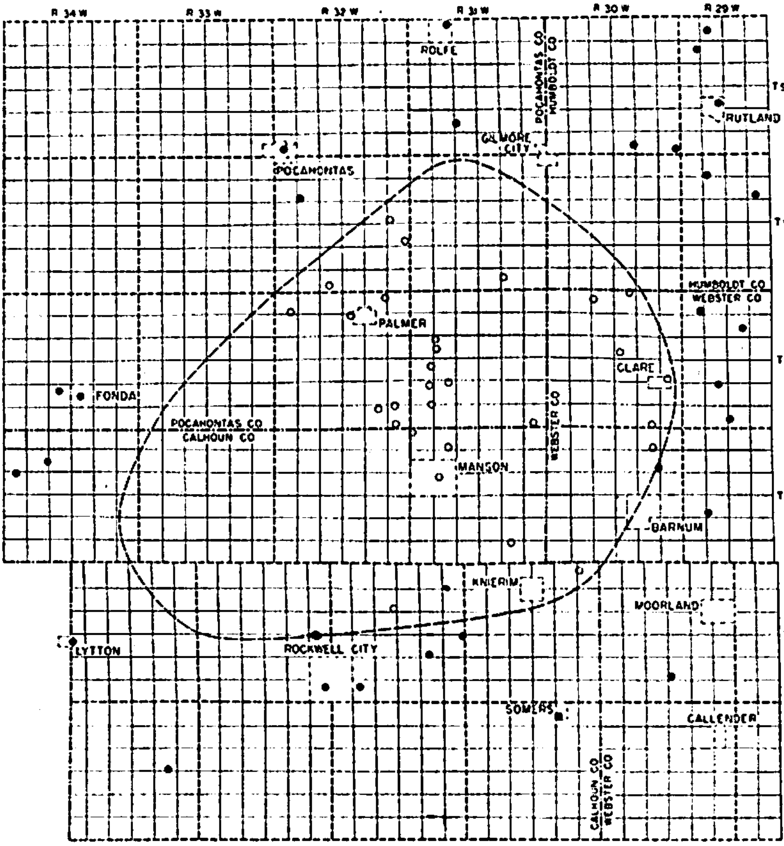


Figure 26.—Map of parts of Calhoun, Humboldt, Pocahontas, and Webster Counties showing the area occupied by the abnormal sequence of rocks in the vicinity of Manson, Calhoun County. Solid circles represent wells that encounter a normal Paleozoic section; open circles represent wells that encounter no Paleozoic rocks at equivalent depths.

ceramus fragments occur in limestone and shale cuttings between depths of 250 and 500 feet, suggesting that these strata may include the Greenhorn limestone. The overlying shales may belong to the Carlisle shale. Lignite, which is suggestive of the Dakota sandstone, was encountered in this well between depths of 500 and 650 feet. Also, in the lower part of the section at this site, siderite pellets, which are characteristic of the Dakota sandstone in other parts of the State, are present in the shale between depths of 570 and 655 feet.

Lignite was penetrated near the bottom of well 90-30-4E1, at a depth of 1,065 feet. *Inoceramus* fragments and siderite pellets were encountered at higher elevations in the well.

The fish scales found in the shale exposure in the NE¼NE¼SE¼ sec. 11, T. 89 N., R. 30 W., are no older than the Mesozoic era, according to M. A. Stainbrook (oral communication). The poorly preserved cephalopods in the same exposure are suggestive of the Cretaceous, according to A. K. Miller (oral communication).

Data are insufficient at present to correlate the rocks in the lower part of the section because of the intensity of the faulting and brecciation, but it seems likely that they are Pennsylvanian in age.

Water supply. A few successful wells, ranging in depth from 165 to 710 feet, have been finished in the sandstones of this sequence of rocks in Webster County. The shallower wells are near the northeastern rim of the basin.

A supply of 10 gallons a minute was obtained from well 89-30-2Q1 from sandstone at a depth of 610 feet, the reported drawdown being 7 feet; a yield of 28 gallons a minute was obtained from well 90-30-35Q1 (about 1 mile north of 89-30-2Q1) from sandstone at a depth of 710 feet, the reported drawdown being 32 feet. Farther north at Clare, 14 gallons a minute was developed from sandstone at a depth of 180 feet. In these three wells the static water level was approximately 1,100 feet above sea level or about 50 feet below the general land surface. There are places in the area, however, where the sandstones are too thin, silty, or cemented to yield an ample supply of water. Well 90-30-4E1, drilled to a depth of 1,100 feet, developed a supply of only 2 gallons a minute with a large drawdown; sandstones encountered in the well closer to the surface did yield some water, which failed to clear on development.

It appears that the rocks in the structural basin are generally too tightly cemented to yield water. An occasional fracture may still be uncemented, and if it has access to recharge a successful well may be obtained. Wells in the central igneous area west of Webster County have been more productive, but possibilities of developing supplies by deep wells do not appear good.

The water developed from the sandstones at depths of less than 800 feet in this locality is hard and generally has a high iron content. Mineral analyses of water from wells 89-30-2Q1, 90-30-3A1, 15N1, and 35Q1, which develop their supply from the sandstones, are given in table 9. None of the water is of the sodium chloride and sulfate type such as that pumped from the deep wells at Manson, which has a hardness of only about 70 parts per million, a fluoride content of 4, and a pH value of 8.5. Petrographic studies of the rocks in the Manson area may show the presence of zeolites, which could account for the softness of the Manson supply; glauconite, which also has water-softening properties and has been seen in some of the strata, could cause it.

PLEISTOCENE SYSTEM

The yellow, buff, brown, and gray unstratified pebbly clays that almost everywhere mantle the consolidated rocks in Iowa are the deposits left as a result of the melting of continental glaciers which invaded this area from time to time during the Pleistocene period. In addition to these unstratified pebbly clays, called tills, the melt waters from the glaciers carried away large amounts of sand, gravel, silt, and clay and deposited them in valleys as stratified drift forming valley trains. The name assigned to a till is applied also to the related stratified drift and to the associated continental glacier. Wind-blown silts, originating from the silts in the valley trains, accumulated on the surface during glacial times to form deposits known as loess. During interglacial time, the tills and stratified drift were altered by weathering and in part removed by erosion, the extent depending largely upon the length of time between ice invasions. The eroded materials formed deposits of clay, silt, sand, and gravel in places.

The geology of the glacial and interglacial deposits of Iowa has been summarized in two principal papers. One, by Kay and Apfel (1929, p. 1-304), presents the results of intensive field investigations with special reference to the pre-Illinoian glacial and interglacial deposits of Iowa; the second, by Kay and Graham (1943, p. 1-262), discusses the Illinoian and post-Illinoian glacial and interglacial deposits of Iowa. More recent studies in northwestern Iowa by Smith and Riecken (1947, p. 706-713) and Ruhe (1950) have resulted in a reclassification and remapping of the drift sheets in that area.

The present classification of the Pleistocene system of Iowa used by the Iowa Geological Survey is presented in table 10. All the glacial and interglacial stages may be represented in places in Webster County by till, loess, or stratified deposits. The Illinoian till is probably absent, as it is known to occur only in

Table 10. *Classification of the Pleistocene of Iowa*

Stage	*Substage*	
Wisconsin	Mankato Cary Tazewell Iowan	(Till and stratified drift and loess)
Sangamon (weathering and erosion, Loveland loess, formation of Illinoian gumbotil)		
Illinoian (till and stratified drift, Loveland loess)		
Yarmouth (weathering and erosion, formation of Kansan gumbotil)		
Kansan (till and stratified drift)		
Aftonian (weathering and erosion, formation of Nebraskan gumbotil)		
Nebraskan (till and stratified drift)		

a part of eastern Iowa, but loess and other deposits of equivalent age are thought to have been deposited in the county.

Pre-Wisconsin Glacial and Interglacial Deposits

Character. The fresh pre-Wisconsin till of this area seems to be, in general, a brownish gray as compared with the light gray of the Wisconsin tills. Furthermore, it seems somewhat less calcareous and more silty than the younger tills. The Kansan till at several wells is oxidized to a yellow orange for a thickness of 20 to 30 feet. In places a gumbotil-like, oxidized and leached gray and buff till has been preserved. The Nebraskan till has been tentatively identified at a few wells. Its character is similar to that of the Kansan till. The sands and gravels underlying and overlying these older tills are generally heterogeneous in composition and calcareous.

At the Harcourt town well (86-29-13C1) and at the Fiala Farm well (88-30-24R1) thin, brown, noncalcareous silt beds, which may be Loveland loess, occur above the Kansan till.

Distribution and thickness. The Kansan till is generally preserved in the southern part of the county where it attains a maximum thickness of at least 80 feet. In the central and northern parts of the county, where the bedrock is higher, the Kansan till is thin or absent. The Nebraskan till seems to occur as thin patches in a few places within the county. Where an exposure of only one pre-Wisconsin till occurs, it is difficult to identify it definitely. A few exposures of older tills were observed along the valley walls and banks of the Des Moines River and Lizard Creek (pl. 16A).

In the valley of Lizard Creek 0.2 mile north of State Highway 5 in the SE¼ sec. 14, T. 89 N., R. 29 W., a brown leached till 4 feet thick overlies sand and gravel of the Dakota (?) sandstone. The till is overlain by a foot or more of leached sand and gravel to the level of the low terrace. Here the till may be Nebraskan and the overlying sand and gravel of either Nebraskan or Aftonian age. Several miles farther upstream on the right bank of Lizard Creek in the NW¼NE¼NE¼ sec. 12, T. 89 N., R. 30 W., a gray gumbotil about 5 feet thick rests on Dakota (?) sand-

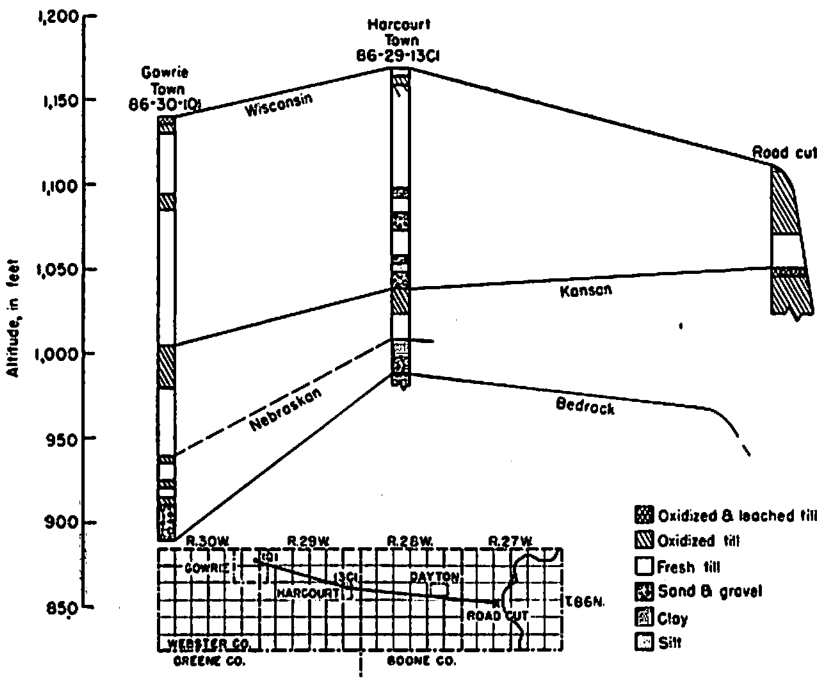


Figure 27.—Profile of the Pleistocene deposits across a part of southern Webster County.

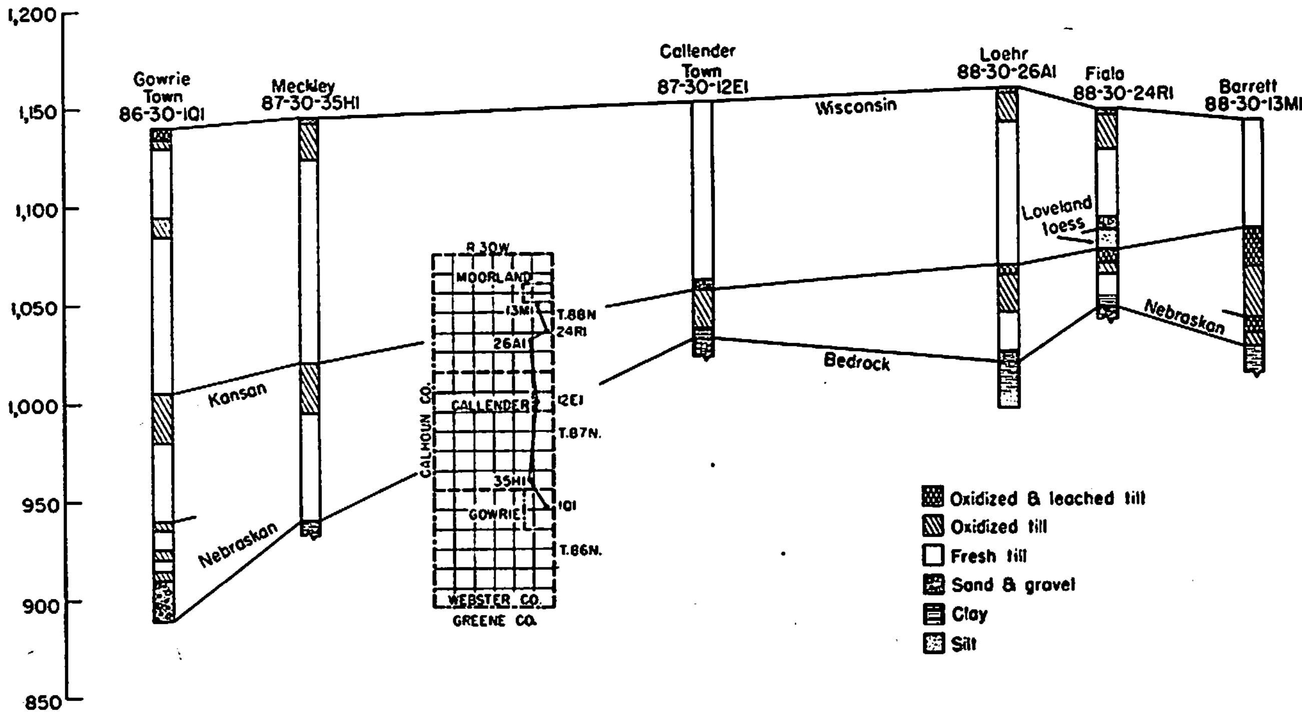


Figure 28.—Profile of the Pleistocene deposits along a north-south line from Gowrie to Moorland in the southwestern part of Webster County.

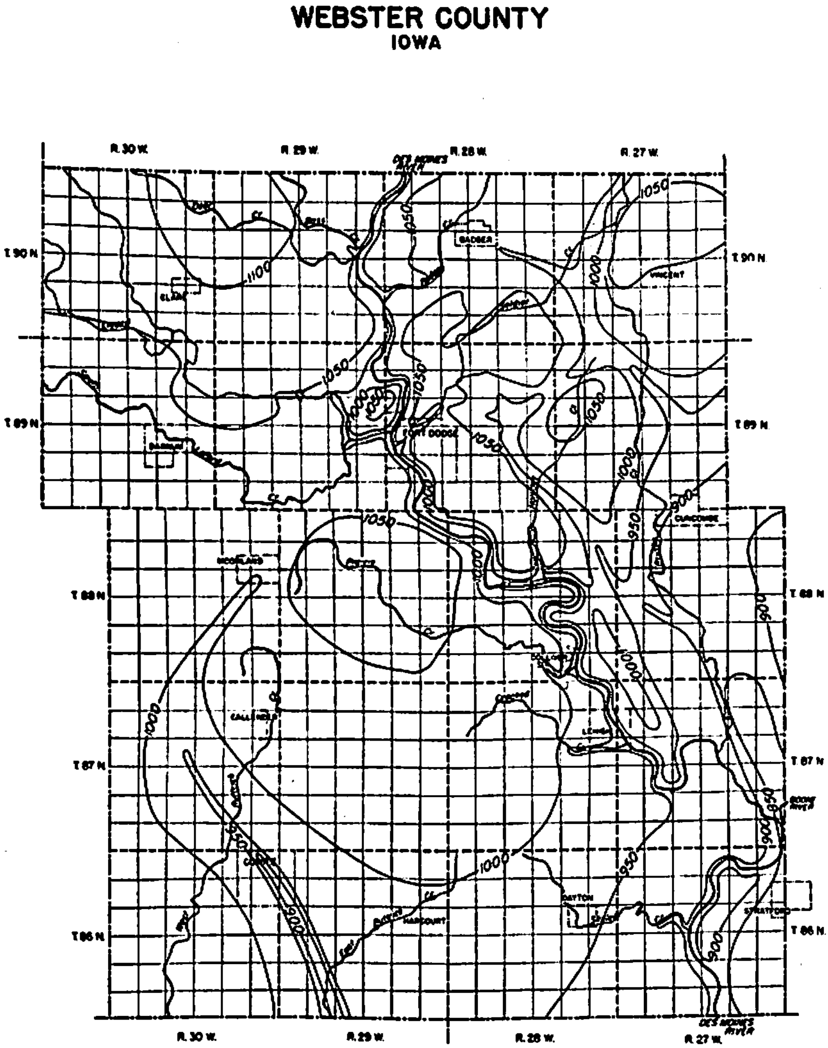


Figure 29.—Map of Webster County showing the general configuration and altitude, with reference to mean sea level, of the bedrock surface.

stone about 20 feet above water. The gumbotil is overlain by about 4 feet of leached brown silty and sandy clay. The remainder of the section is mantled. Here the gumbotil may be Kansan and the overlying brown silty clay the Loveland loess. The gumbotil is approximately 80 feet below the upland, at an altitude of roughly 1,070 feet.

In the southern part of the county, Kansan gumbotil was found under approximately 60 feet of Wisconsin tills in the NW¼ sec. 21, T. 86 N., R. 27 W., in a road cut along the west valley wall of the Des Moines River. The suggested relationship of this exposure to subsurface sections across the southern part of the county is shown in figure 27. The general position of the Kansan till and possible Nebraskan till in the southwestern part of the county is shown in figure 28 as a cross section extending northward from Gowrie to the vicinity of Moorland.

The sand and gravel of the Pleistocene of Iowa occur largely as fill material in small channels on the various till or bedrock surfaces. In places, however, particularly on the bedrock surface, there are very wide buried channels which may be filled to a considerable depth with outwash sand and gravel. In the eastern part of Webster County there seems to be one of these larger buried channels, which has a general southerly course through Duncombe. The Duncombe town well encountered bedrock at a depth of approximately 235 feet and about 190 feet below the higher bedrock in portions of the central part of the county. The map showing the configuration of bedrock surface (fig. 29) suggests the course of this valley in Webster County. The valley is probably pre-Pleistocene in age and is partly filled with sand and gravel of pre-Wisconsin age and partly with Wisconsin gravel. At the Duncombe town well, sand and gravel occur at depths of 100 through 105, 106 through 185, and 210 through 235 feet. At well 88-27-11L1, about 2 miles southeast of Duncombe, sand and gravel were encountered at depths of 10 through 70 feet, 100 through 145, and 155 through 170 feet, the bottom of the well.

In the southwestern part of the county at Gowrie, the town well encountered sand and gravel at a depth of 230 through 250 feet. These beds rest on bedrock and are overlain by Kansan and possibly Nebraskan till. On the basis of data obtained from a pumping test, this sand-and-gravel-filled channel is inferred to have a width of about 200 feet.

Wisconsin Glacial and Interglacial Deposits

Character, distribution, and thickness. The tills constitute the bulk of the material deposited in Webster County during Wisconsin time. They are composed predominantly of gray to light-gray calcareous unstratified pebbly and sandy clay. The pebbles in the tills are of limestone, dolomite, shale, and igneous rocks. Alteration of these fresh gray tills to a buff yellow by oxidation of the iron compounds has occurred at the top of the youngest till. At least one oxidized zone of an earlier Wisconsin till has been preserved in places. Leaching of the upper 2 to 4 feet of till, including the present soil, has occurred generally over the entire county.

The sands and gravels related to the Wisconsin tills are similar to the sand and pebbles found in the till and are invariably calcareous and mostly iron stained.

The loess, which has developed on the older Wisconsin tills outside the county, is poorly developed on the Mankato till. In Webster County no loess was seen in exposures and none was identified between the various tills of the Wisconsin stage in well cuttings.

The tills and sands and gravels of the Wisconsin stage occur over all the upland area in the county and range in thickness from about 50 feet in the north and central parts to about 130 feet in the southern part of the county.

The upper till, the Mankato, is inferred to occur everywhere over the county. This till sheet extends southward into Boone County, but the northern expression of the Altamont terminal moraine, marking the limits of the Mankato glacier, occurs along the southern boundary of Webster County. An intermediate or recessional moraine of the Mankato, known as the Humboldt moraine (Kay and Graham, 1943, p. 239), extends through the northern part of Webster County. In these terminal and recessional morainal belts the Mankato till is probably thicker than in the ground-moraine areas although the moraine, in part, may be the expression of older morainal belts (Gwynne, 1942).

The thickness of the individual tills of the Wisconsin stage is not known. In the exposures observed and from subsurface data only one oxidized zone was found at any one site between the Wisconsin oxidized zone at the surface and the top of the Kansan till. More than one gravel bed was found in some subsurface sections in this interval, but it is not known whether these beds separate till sheets or are inclusions within one sheet.

Sands and gravels of Wisconsin age underlie high terraces preserved in places along the Des Moines Valley and Lizard Creek (pl. 16B), and a number of sand and gravel pits have been opened in them. The sands and gravels are useful for a number of purposes, but the gravel in places is reported to have too many

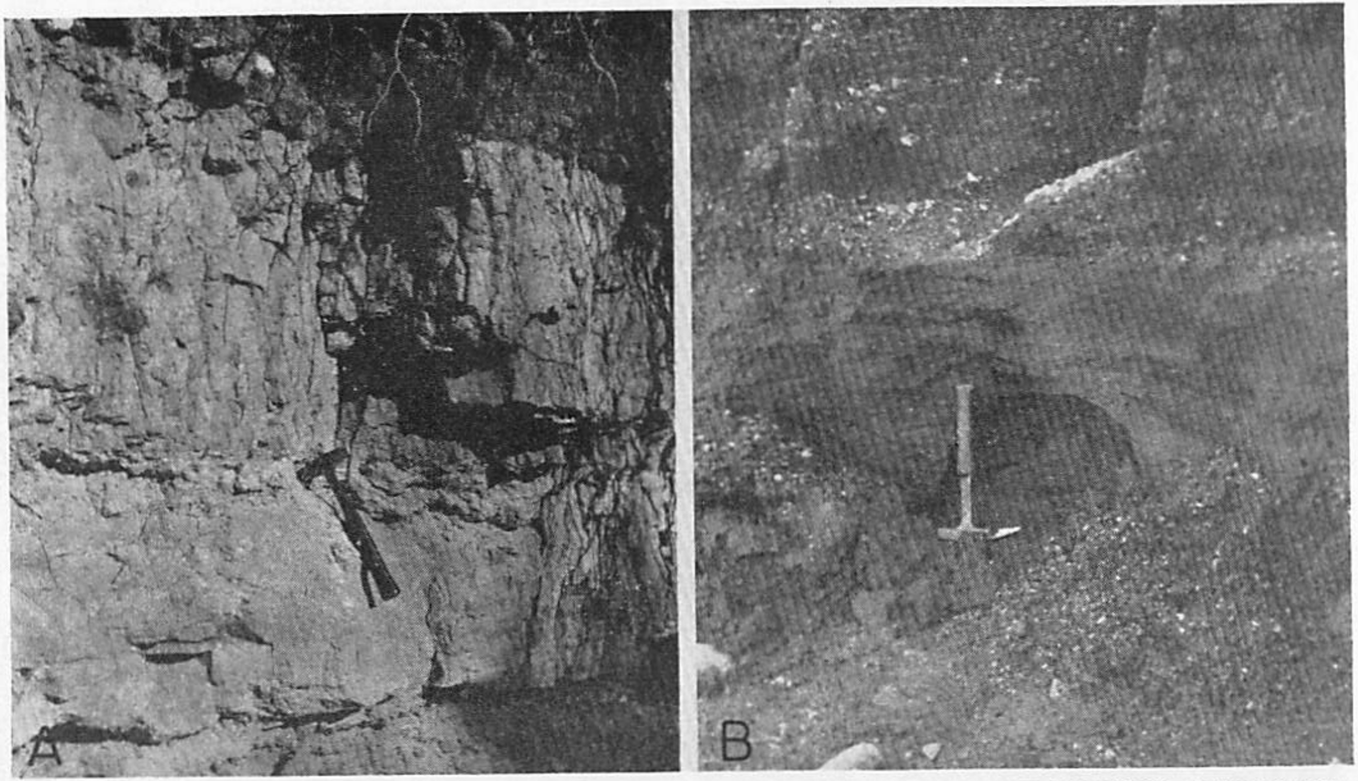


PLATE 16.—A, CONTACT OF GLACIAL DRIFT OF THE PLEISTOCENE AND UNDERLYING SHALE AND SANDSTONE OF THE DAKOTA (?) SANDSTONE ALONG RIGHT BANK OF LIZARD CREEK IN THE SE¼ SEC. 14, T. 89 N., R. 29 W.; B, EXPOSURE OF SILT, SAND, AND GRAVEL IN A TERRACE ALONG LIZARD CREEK IN THE SE¼SW¼ SEC. 10, T. 89 N., R. 29 W. WOOD FRAGMENTS ARE ABUNDANT IN THE SILT BED AT THIS LOCALITY.

shale pebbles for use in better grades of concrete. Drilling indicates that the most persistent occurrence of sands and gravels of Wisconsin age is in the vicinity of Duncombe.

Water supply. Several hundred shallow bored wells in the county obtain their water supply from the drift. In general, the yield obtained is small, and many of these wells are deepened beyond the water-bearing bed to provide for additional storage of water in the well.

In the larger buried channels filled with sand and gravel moderate to large yields can be developed, at least initially. In places where the channels are narrow the rate of decline of water levels might prohibit continued pumping from the aquifer at high rates, for, although the sand and gravel might have a high permeability, most of the channels in the drift are believed to be small and hence incapable of supporting large producing wells. This may be the situation at Gowrie, as described on pages 52 and 53. In the larger channel, in the vicinity of Duncombe, farm wells finished in the sands and gravels develop an adequate supply with very small drawdown. This aquifer may be large enough to yield large volumes of water, but it is essentially undeveloped at present.

Sand and gravel underlying the high terraces in the Des Moines River valley and Lizard Creek will probably yield moderate supplies of water to wells, but where the deposits are narrow the water supply may fail during periods of drought. Water in the drift deposits is hard, generally contains an excessive amount of iron, and has a low fluoride content.

Recent Sediments

Character, distribution, and thickness. The depressions on the Mankato drift surface have been partially filled by wash from the adjacent drift during Recent time. Some of the depressions have been filled largely with carbonaceous material to form peat bogs or peaty soil. The soils developed over the remainder of the county also are of Recent origin.

Silt, clay, and some sand and gravel constitute the Recent alluvium that occurs in the lower levels of the Des Moines River and some of its larger tributaries, but most of the sand and gravel in the Des Moines River valley may be remnants of earlier Pleistocene deposits.

The depressions on the upland may be filled with Recent sediments to depths of 15 or 20 feet in places. These deposits are lenticular and occur as patches generally covering only a few acres.

In the valley of the Des Moines River north of Fort Dodge the alluvium is thin or absent. At Fort Dodge the unconsolidated deposits reach a thickness of 30 feet. Well 88-28-32N1, located in the valley about a mile south of Fort Dodge, penetrated 40 feet of clay and gravel. The lower 10 feet was composed of dirty sand and gravel. The unconsolidated deposits reach a thickness of about 40 feet in the vicinity of Lehigh also, and probably at places farther south. These deposits, however, are very narrow, seldom extending over 500 feet from the bank of the river.

Water supply. The city of Fort Dodge initially obtained its water supply from a large dug well finished in the sand and gravel in the Des Moines River bottom. This source of supply was augmented by wells finished at greater depths, and was finally abandoned in 1919.

The town of Lehigh at one time obtained its supply from a large-diameter well about 25 feet deep finished in sand and gravel. It is reported that continued difficulty with sand was the principal cause of the development of a source of supply from underlying limestones. More recently, several shallow test wells were drilled in the alluvial sand and gravel in an attempt to develop a satisfactory water supply. A promising quantity of water was located, but the water was very hard. The source of the hard water was possibly the adjacent water-bearing beds in the Pennsylvanian system of rocks. If such a supply were developed the quality of water might improve as the nearby river water was drawn into the sands and gravels. At other localities in the Des Moines River valley south of Lehigh, the unconsolidated sediments may be expected to yield ample supplies of water for farm use.

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TABLE 11. RECORDS OF TYPICAL

The well number also represents the well location. Well-numbering system described on page 7. Well for which water analyses are given in table 9 are indicated by parentheses; wells for which logs are given in the following section are indicated by an asterisk.

Types of wells: B, bored; Dg, dug; DR, drilled.

Measured depths of wells given to tenths of a foot; depths given to even feet are reported.

Type of casing: B, brick; I, iron or steel; R, rock; S, screen; T, tile.

Depth of casing: Parentheses around figures indicate there is additional casing at intervals below the continuously cased part of the well; such data may be given in remarks column.

Well number	Location	Owner or name	Well construction					Method of lift	
			Type	Depth (feet)	Diameter (inches)	Casing Type	Casing Depth (feet)	Pump	Power
	T. 86 N., R. 27 W.								
86-27-4D1....	NW¼NW¼NW¼ sec. 4..	A. B. Davis..............	DR	226.3	5	I	200	L	E
86-27-23M1...	SW¼NW¼SW¼ sec. 23..	J. C. Ritchie..............	DR	552	....	....	....	......	......
86-27-32C1...	NW¼NE¼NW¼ sec. 32.	F. Olson..................	B	55.3	12	T	56?	L	H
86-27-34F1...	NE¼SE¼NW¼ sec. 34..	John Peterson............	B	12.2	24	T	13?	S	H
	T. 86 N., R. 28 W.								
*(86-28-2P1)...	SE¼SE¼SW¼ sec. 2....	E. & K. Gabrielson........	DR	720	6- 5	I	508	L	E
(86-28-9R1)...	SE¼SE¼SE¼ sec. 9.....	Mary Ekstrand...........	B	31.0	14	T	31?	F	H
86-28-9R2....	SE¼SE¼SE¼ sec. 9.....	Mary Ekstrand...........	B	60	....	T	60?	F	E
(86-28-14H1)..	SW¼SE¼NE¼ sec. 14...	Dayton, town well 2.......	DR	1,240	13- 8	I	(505)	T	E
86-28-14H2...	SW¼SE¼NE¼ sec. 14...	Dayton, town well 1.......	DR	688	10- 6	I	....	F	E
(86-28-21B1)..	NE¼NW¼NE¼ sec. 21..	DeKalb Hybrid Seed Co...	DR	104	....	I	104	......	......
86-28-29Q1...	SE¼SW¼SE¼ sec. 29...	C. & G. Kulild...........	B	87.2	12	T	88?	L	G, H
(86-28-31C1)..	NW¼NE¼NW¼ sec. 31.	F. I. Johnson............	B	58.9	14	T	70?	F	E
86-28-32H1...	SW¼SE¼SE¼ sec. 32...	R. W. Skoglund..........	DR	374	6- 4	I	350	L	E
86-28-32R1...	SE¼SE¼SE¼ sec. 32....	R. C. Strand.............	B	59.6	20	T	60?	L	W
86-28-35A1...	NW¼NE¼NE¼ sec. 35..	Hubert Will...............	DR	109	5	I	....	L	H, W
86-28-35A2...	NW¼NE¼NE¼ sec. 35..	Hubert Will...............	B	60.6	....	T	70?	......	......
	T. 86 N., R. 29 W.								
(86-29-3C1)...	NW¼NE¼NW¼ sec. 3..	Edna Nelson.............	B	19.4	14	T	20?	L	W
86-29-4C1....	NE¼NE¼NW¼ sec. 4...	C. V. LeRoy.............	B	68.2	16	T	60?	L	H
86-29-4C2....	NE¼NE¼NW¼ sec. 4...	C. V. LeRoy.............	B	38.3	12	T	30?	L	G
*(86-29-13C1)..	SW¼NE¼NW¼ sec. 13..	Harcourt, town well.......	DR	1,092	8- 4	I	840	T	E
86-29-13F1...	NW¼SE¼NW¼ sec. 13..	Nelson...................	B	15.6	14	T	16?	L	H
86-29-14A1...	NE¼NE¼NE¼ sec. 14..	F. E. Castenson	B	38.6	12	T	39?	L	H
86-29-14H1...	NE¼SE¼NE¼ sec. 14...	F. E. Castenson..........	B	40.3	....	T	41?	L	E
86-29-18D1...	SW¼NW¼NW¼ sec. 18.	A. Soderbeck............	B	43.2	12	T	44?	L	H
(86-29-26Q1)..	SW¼SW¼SE¼ sec. 26...	Lanyon Cons. School......	B	57.7	18	T	58?	F	E

WELLS IN WEBSTER COUNTY, IOWA

Type of pump: F, force; J, jet; L, lift; N, none; P, pressure; S, suction; T, turbine.

Power: E, electric; G, gasoline engine; H, hand; W, wind.

Altitude of land surface: Measurements made by altimeter or hand level given to nearest 5 feet; those estimated from topographic sheets given to nearest 5 feet and indicated by parentheses.

Water level: Measured levels given to hundredths of a foot; reported levels given to even feet.

Use of water: A, abandoned; D, domestic; I, industrial; M, municipal supply; PS, other public supply; S, stock; Un, unused.

Principal water-bearing beds		Water level: Measuring point							
Character of material	Geologic subdivision	Description	Distance above or below land surface (feet)	Altitude of land surface (feet)	Distance of water level above (+) or below land surface (feet)	Date of measurement	Use of water	Remarks (yield given in gallons a minute; drawdown in feet)
Sandstone	Desmoinesian	Drilled hole in pump base	1.4	(1,105)	105.61	Oct. 19, 1942	D, S	Yield, 3.5; drawdown 2.9 after 40 min. Temperature 50°F.
Limestone	Gilmore City	......	......	1,125	150	......	......	
Sand	Pleistocene	Top of casing	0	......	18.74	Oct. 25, 1942	D	Meager water supply reported.
Sand	Pleistocene	Top of casing	.5	(1,000)	1.34	Oct. 25, 1942	S	
Limestone	Hampton	......	......	1,140	......	......	D, S	
Drift	Pleistocene	Top inner lip of tile casing	.8	(1,150)	5.80	Sept. 17, 1942	D, S	Good water, poor yield reported.
Sand	Pleistocene	Top of pump platform	.5	(1,150)	4.95	Sept. 17, 1942	D, S	Adequate yield reported.
Limestone	Wapsipinicon	Drilled hole in pump base	.6	1,120	69.54	Sept. 17, 1942	M	Additional casing, 770 to 966 feet; temperature 56°F. Yield, 130, November 1942; drawdown 76.
Limestone	Hampton	......	......	1,120	111	1895	M	Used very little; reported yield, 20.
......	Pleistocene	......	......	1,165	30	1948	D, S	Reported yield, 45; small drawdown.
Drift	Pleistocene	Top of wood platform	.2	......	7.69	Sept. 11, 1942	S	
Drift	Pleistocene	Top of casing in pit	—4.5	......	16.58	Sept. 12, 1942	D, S	Water reported to be hard, with low iron content.
Sandstone	Desmoinesian	......	......	......	75	1922	S	Temperature, 51°F; yield, 5; reported drawdown, 75. Water reported not hard, high iron content.
Sand	Pleistocene	Top of concrete well cover	.5	......	19.32	Oct. 25, 1942	S	
Sand	Pleistocene	Top of casing	.4	......	4.75	Oct. 25, 1942	S	
Sand	Pleistocene	Top of casing	0	......	6.00	Oct. 26, 1942	..	
Drift	Pleistocene	Top of tile casing	1.0	(1,140)	3.26	Sept. 15, 1942	S	
Drift	Pleistocene	Top of platform	.4	(1,160)	12.46	Sept. 15, 1942	D	
Drift	Pleistocene	Top of casing	1.3	(1,160)	11.40	Sept. 15, 1942	S	
Dolomite	Cedar Valley	......	......	1,170	110	Jan. 1939	M	Reported yield, 35; drawdown, 51.
Drift	Pleistocene	Top cement curb	0.0	(1,170)	4.24	Sept. 17, 1942	D	
Sand	Pleistocene	Top of pump base	1.0	(1,150)	4.47	Sept. 9, 1942	S	Small yield reported.
Gravel	Pleistocene	Top of platform	1.0	(1,160)	7.62	Sept. 9, 1942	D, S	Temperature 52°F; yield, 7; drawdown, 4 after pumping 15 min.
Drift	Pleistocene	Top of concrete curb	1.8	......	4.44	Sept. 14, 1942	Un	Very hard water reported.
Sand	Pleistocene	Flange on pump column	—6.2	......	21.91	Sept. 12, 1942	PS	Yield, 13.3; drawdown, 11.6 after pumping 60 min.

TABLE 11. RECORDS OF TYPICAL WELLS

Well number	Location	Owner or name	Well construction					Method of lift	
			Type	Depth (feet)	Diameter (inches)	Casing		Pump	Power
						Type	Depth (feet)		
86-29-27N1...	SW¼SW¼SW¼ sec. 27..	J. A. Johnson............	B	35.5	36- 6	T	36?	F	E
86-29-27P1...	SE¼SE¼SW¼ sec. 27...	O. T. Engquist...........	B	45.5	14	T	46?	L	H
86-29-27P2...	SE¼SE¼SW¼ sec. 27...	O. T. Engquist...........	B	101	14	T	101?	......	......
86-29-29P1...	SE¼SE¼SW¼ sec. 29...	C. Bloomgren............	B	34.4	12	T	35?	......	......
86-29-29P2...	SE¼SE¼SW¼ sec. 29...	C. Bloomgren............	B	45.5	14	T	46?	L	H, W
86-29-30P1...	NW¼SE¼SW¼ sec. 30..	J. C. Nordin Estate........	B	140.7	16	T	141?	L	H, W
86-29-30Q1...	SE¼SW¼SE¼ sec. 30...	A. A. Franzeen............	B	47.0	14	T	47?	L	H, W
86-29-32B1...	NE¼NW¼NE¼ sec. 32..	Robert Youngquist........	B	63.1	16	T	64?	L	H
86-29-35C1...	NE¼NE¼NW¼ sec. 35..	Emil Rohden.............	DR	260	....	......	....	......	......
(86-29-35C2)..	SE¼NE¼NW¼ sec. 35..	A. V. Mossberg...........	B	71.4	12	T	72?	P, S	E
86-29-35C3...	SE¼NE¼NW¼ sec. 35..	Lanyon community........	B	08.7	12	T	09?	L	H
86-29-35F1...	SE¼SE¼NW¼ sec. 35...	Carl Carlson..............	B	51.5	....	T	52	L	H
	T. 80 N., R. 30 W.								
(86-30-1P1)...	SE¼SE¼SW¼ sec. 1....	Gowrie, town well 1.......	DR	620	6	I	350	T	E
(86-30-1P2)...	SE¼SE¼SW¼ sec. 1....	Gowrie, town well 2.......	DR	1,842	16- 6	I	(385)	.T	E
*(86-30-1Q1)...	NW¼SW¼SE¼ sec. 1...	Gowrie, town well 3.......	DR	250	12-10	I, S	250	T	E
86-30-5C1....	NW¼NE¼NW¼ sec. 5..	E. C. Monson............	DR	225	6+	I	214	L	E
86-30-8N1....	SW¼SW¼SW¼ sec. 8...	C. E. Johnson............	B	44.3	18	T	45?	F	E, W
86-30-12B1...	NW¼NW¼NE¼ sec. 12.	Frank Schwarts..........	B	76.5	12	T	77?	L	H
(86-30-15P1)..	SE¼SE¼SW¼ sec. 15...	C. J. Johnson............	DR	112	5	I	106	L	E
86-30-20R1...	SW¼SE¼SE¼ sec. 20...	P. & D. Lohr............	B	51.5	10	T	52?	L	W
86-30-30R1...	SE¼SE¼SE¼ sec. 30....	W. H. Cathcart...........	B	54.0	....	T	54?	L	H, W
(86-30-31A1)..	SE¼NE¼NE¼ sec. 31...	John Carstenson..........	B	60.0	18	T	60?	F	H, E
86-30-31C1...	NE¼NE¼NW¼ sec. 31..	N. D. Sperry............	B	55.3	12+	T	56?	L	H, E
86-30-31J1....	SE¼NE¼SE¼ sec. 31...	E. O. Nahnsen...........	DR	130	4	I	130	F	E
86-30-31J2....	SE¼NE¼SE¼ sec. 31...	E. O. Nahnsen...........	B	58	14	T	58	L	H
86-30-33B1...	NW¼NW¼NE¼ sec. 33.	O. & N. Monson..........	B	23.0	20	W, T	50?	L	H
86-30-33D1...	NW¼NW¼NW¼ sec. 33.	L. & J. Berning..........	B	73.5	14	T	74?	L	W
86-30-35C1...	NE¼NE¼NW¼ sec. 35..	B. B. Elmore............	B	91.5	14	T	04?	F	E
86-30-36D1....	NE¼NW¼NW¼ sec. 36.	John Frambam..........	B	52.6	14	T	53?	L	E
80-30-36D2...	NE¼NW¼NW¼ sec. 36.	John Frambam..........	B	45.4	12	T	46?	......	......
80-30-36G1...	NW¼SW¼NE¼ sec. 36..	F. C. Klippel............	B	54.5	12	T	55?	L	H
	T. 87 N., R. 27 W.								
87-27-4N1....	SW¼SW¼SW¼ sec. 4...	W. H. Goodrich..........	B	51.7	16	T	52?	......	......
87-27-6N1....	SW¼SW¼SW¼ sec. 6...	Allen Porter.............	DR	378.9	6	I	....	L	E
(87-27-10B1)..	NE¼NW¼NE¼ sec. 10..	J. H. Goodrich...........	B	43.0	24	T	43?	L	E
87-27-11A1...	NW¼NE¼NE¼ sec. 11..	G. D. Goodrich...........	B	64.0	12	T	64?	J	E
87-27-12B1...	NE¼NW¼NE¼ sec. 12..	H. F. Vigors.............	B	51.0	....	T	51?	L	H, W
87-27-17C1...	SE¼NE¼NW¼:sec. 17..	H. O. Hale..............	B	41.4	16	T	42?	L	H

IN WEBSTER COUNTY, IOWA—Continued

Principal water-bearing beds		Water level						
		Measuring point						
Character of material	Geologic subdivision	Description	Distance above or below land surface (feet)	Altitude of land surface (feet)	Distance of water level above (+) or below land surface (feet)	Date of measurement	Use of water	Remarks (yield given in gallons a minute; drawdown in feet)
Sand	Pleistocene	Top of platform	1.1	....	5.70	Sept. 11, 1942	D, S	Small yield.
Sand	Pleistocene	Top of platform	.8	....	4.05	Sept. 11, 1942	D, S	Small yield.
Drift	Pleistocene	....	......	....	6	Sept. 11, 1942	S	
Drift	Pleistocene	Top of platform	.4	....	11.74	Sept. 11, 1942	Un	Small yield.
Sand	Pleistocene	Top of cement platform	.4	....	......	....	D, S	Yield, 4; pumping level, 21.1.
Drift	Pleistocene	Top of platform	.4	....	44.72	Sept. 11, 1942	D, S	Water level affected by recent pumping. Small yields reported; water hard with high iron content reported.
Sand	Pleistocene	Top of casing	0	....	19.37	Sept. 10, 1942	Un	
Drift	Pleistocene	Top of casing	0	....	5.84	Sept. 11, 1942	S	
....	....	....	......	1,170	......	....	......	Test well; dry and abandoned.
Drift	Pleistocene	Top of platform	.4	....	6.52	Sept. 11, 1942	D	Supplies water to two families.
Drift	Pleistocene	Top of platform	1.0	....	0.60	Sept. 11, 1942	PS	
Drift	Pleistocene	Top of wood frame	0	....	0.80	Sept. 11, 1942	Un	
Limestone and dolomite	Gilmore City and Hampton	Base of pump	0.9	1,140	92.77	Sept. 14, 1942	M	Depth to water reported to be 50 feet in 1902.
Sandstone and dolomite	St. Peter and Prairie du Chien	....	......	1,140	......	....	M	
Gravel	Pleistocene	Top of casing	1.5	1,140	44.3	June 1950	M	
Sandstone	Desmoinesian	Top of concrete platform	.8	....	56.61	Sept. 14, 1942	D, S	Temperature, 50°F; yield, 5.4; drawdown, 10.3 in 13 minutes
Drift	Pleistocene	Top of casing in pit	−3.2	....	11.05	Sept. 14, 1942	D, S	Water reported hard, moderate iron content.
Drift	Pleistocene	Top of platform at drilled hole	.7	....	4.82	Sept. 14, 1942	D	
Sand	Pleistocene	....	......	1,115	28	May 10, 1951	D, S	Reported yield, 5, drawdown, 32.
Drift	Pleistocene	Top of casing	− .1	....	12.60	Sept. 9, 1942	S	Small yield reported.
Drift	Pleistocene	Top of 8"x8" timber	1.4	....	16.04	Sept. 9, 1942	D, S	Adequate supply reported.
Sand	Pleistocene	Top of platform	−4.0	....	14.44	Sept. 9, 1942	D, S	
Drift	Pleistocene	Top of platform	1.3	....	17.35	Sept. 9, 1942	D, S	Water temperature, 51°F; water reported high in iron content. Yield, 5.5; drawdown, 12.1 after 55 min.
Sand	Pleistocene	Top of casing	−4.4	....	14.48	Sept. 10, 1942	S	Water reported hard, high in iron content.
Sand	Pleistocene	Top of casing	1.0	....	12.9	Sept. 10, 1942	D	Water reported softer than in 31J1.
Sand	Pleistocene	Top of platform	.6	....	4.85	Sept. 10, 1942	D	Adequate supply reported.
Sand	Pleistocene	At hole in pump base	.0	....	9.05	Sept. 9, 1942	D, S	Water reported hard.
Sand	Pleistocene	Top of platform	.3	....	49.28	Sept. 10, 1942	D, S	Water level affected by recent pumping, temperature, 51°F; yield, 6.
Drift	Pleistocene	Top of wood platform	1.1	....	18.82	Sept. 10, 1942	D, S	
Drift	Pleistocene	Top of inner lip of tile casing	0	....	15.95	Sept. 10, 1942	Un	
Sand	Pleistocene	Top of platform	1.4	....	17.06	Sept. 10, 1942	D	
....	Pleistocene	Top of casing	0.1	(1,105)	5.69	Nov. 9, 1942	Un	
Dolomite	Osagian (?)	At hole in pump base	.7	(1,090)	120.53	Oct. 16, 1942	D, S	
Sand	Pleistocene	Top of casing	1.0	....	21.15	Nov. 9, 1942	D, S	
Sand	Pleistocene	Top of platform	1.0	....	26.15	Nov. 9, 1942	D	
Drift	Pleistocene	Top of casing	0	....	30.07	Nov. 9, 1942	D, S	Water level affected by recent pumping.
Drift	Pleistocene	Top of casing	.8	(1,100)	4.86	Oct. 16, 1942	Un	

TABLE 11. RECORDS OF TYPICAL WELLS

Well number	Location	Owner or name	Well construction					Method of lift	
			Type	Depth (feet)	Diameter (inches)	Casing		Pump	Power
						Type	Depth (feet)		
(87-27-18M1)	SW¼NW¼SW¼ sec. 18	J. B. Marsh	DR	355.8	6- 3	I	......	L	E
87-27-19D1	NW¼NW¼NW¼ sec. 19	O. V. Peterson	B	61.3	......	......	62?	L	H
87-27-20H1	SW¼SE¼NE¼ sec. 20	Mike Casey	B	51.5	16	T	52	......	......
87-27-20H2	SW¼SE¼SE¼ sec. 20	Mike Casey	DR	210.5	6	I	......	L	G
87-27-24C1	SE¼NE¼NW¼ sec. 24	J. G. Guthrie	B	18.0	14	T	18?	......	......
87-27-27R1	SE¼SE¼SE¼ sec. 27	B. I. Bergman	B	51.0	14	T	52?	L	H
87-27-29N1	SE¼SW¼SW¼ sec. 29	Morris Thompson	DR	360	......	I	......	......	......
87-27-32E1	NW¼SW¼NW¼ sec. 32	L. Claasen	B	20.1	24	T	21?	L	H
87-27-35C1	SW¼NE¼NW¼ sec. 35	C. Bergman	DR	400	6- 5	I	310	......	......
	T. 87 N., R. 28 W.								
87-28-2N1	SW¼SW¼SW¼ sec. 2	Roy Heal	DR	112.3	6	I	......	F	E
87-28-5Q1	SE¼SW¼SE¼ sec. 5	E. Wrede	Dg	26.8	36	B	27?	......	......
87-28-6D1	NE¼NW¼NW¼ sec. 6	C. A. Tapper Estate	DR	125	5	I	122	......	......
87-28-10A1	NE¼NE¼NE¼ sec. 10	M. A. Heal	B	41.5	30	T	42?	L	H
87-28-10A2	NE¼NE¼NE¼ sec. 10	M. A. Heal	B	81.2	14	T	82?	L	H
87-28-12H1	SE¼SE¼NE¼ sec. 12	Unknown	B	18.6	24	T	19?	L	H
(87-28-12J1)	SE¼NE¼SE¼ sec. 12	Lehigh, town well 1	DR	320	4	I	......	T	E
*(87-28-12J2)	SE¼NE¼SE¼ sec. 12	Lehigh, town well 2	DR	1,005	12-10	I	300	......	......
87-28-12Q1	NW¼SW¼SE¼ sec. 12	Thomas Timmons	B	57.5	24	T	58?	L	H
87-28-12R1	NE¼SE¼SE¼ sec. 12	M. H. Williams	Dg	19.6	36	......	20?	L	H
87-28-13E1	SW¼SW¼NW¼ sec. 13	Lehigh Sewer Tile	DR	600	8- 6	I	(284)	......	......
(87-28-15N1)	NW¼SW¼SW¼ sec. 15	Burnside Cons. School	DR	181.5	6	I	......	F	E
87-28-16J1	NE¼NE¼SE¼ sec. 16	A. E. Gochenour	DR	191.0	8	I	......	F	G
87-28-16J2	NE¼NE¼SE¼ sec. 16	Olson	B	21.9	......	......	......	L	H
87-28-19J1	SE¼NE¼SE¼ sec. 19	Franklin Larson	DR	185	6	I	140	......	......
87-28-20H1	SE¼SE¼NE¼ sec. 20	R. E. Anderson	DR	147	5	I	147	......	......
87-28-25E1	NW¼SW¼NW¼ sec. 25	John Gallagher	DR	315.7	4	I	......	L	E
87-28-27R1	SW¼SE¼SE¼ sec. 27	L. J. Hoyer	B	79.1	14	T	80?	L, PS	H, E
87-28-29N1	SW¼SW¼SW¼ sec. 29	Grant Spangler	B	41.8	12	T	42?	......	......
*87-28-30C1	NE¼NE¼NW¼ sec. 30	Otto Kling	DR	186	5	I	140	......	......
87-28-30N1	SE¼SW¼SW¼ sec. 30	W. W. Wise	DR	207	5- 3	I	207	L	E
	T. 87 N., R. 29 W.								
87-29-2P1	SE¼SE¼SW¼ sec. 2	O. E. Bloomquist	B	28.8	24	T	29?	......	......
87-29-2P2	SE¼SE¼SW¼ sec. 2	O. E. Bloomquist	B	36.8	8	I	37?	L	H
*87-29-3R1	SE¼SE¼SE¼ sec. 3	Richard Paul	DR	380	8- 5	I	250	......	......
(87-29-9D1)	NW¼NW¼NW¼ sec. 9	W. G. Larson	B	65.2	12	T	66	L	H
87-29-10H1	SE¼SE¼NE¼ sec. 10	H. Samuelson	B, DR	131.2	16- 6?	T, I	......	L	H
87-29-17A1	NW¼NE¼NE¼ sec. 17	Lydia Hayek	DR	174	5- 4	I	174	F	E
87-29-19R1	SE¼SE¼SE¼ sec. 19	G. D. Staves	B	31.8	18	T	32?	L	H
87-29-19R2	SE¼SE¼SE¼ sec. 19	G. D. Staves	DR	750	6	I	......	F	W

IN WEBSTER COUNTY, IOWA—Continued

Principal water-bearing beds: Character of material	Principal water-bearing beds: Geologic subdivision	Water level: Measuring point: Description	Water level: Measuring point: Distance above or below land surface (feet)	Water level: Altitude of land surface (feet)	Water level: Distance of water level above (+) or below land surface (feet)	Water level: Date of measurement	Use of water	Remarks (yield given in gallons a minute; drawdown in feet)
Sandstone	Desmoinesian	At hole in pump base	1.4	(1,110)	123.63	Oct. 17, 1942	S	
Drift	Pleistocene	Top of platform	.6	(1,115)	4.34	Oct. 16, 1942	D, S	Hard water reported, moderate iron content.
Drift	Pleistocene	Top of casing, east side	.6	(1,035)	29.03	Oct. 16, 1942	Un	
Sandstone?	Desmoinesian	Top of casing	.5	(1,035)	67.59	Oct. 16, 1942	D, S	
Drift	Pleistocene	Top of casing	.6	....	8.25	Nov. 6, 1942	Un	
Drift	Pleistocene	Notch in casing	0.3	....	19.46	Sept. 16, 1942	D	
Limestone	Mississippian	....	......	(1,120)	118	Sept. 16, 1942	S	Water reported hard, high iron content.
Drift	Pleistocene	Top of inside rim of tile casing	0	(1,120)	9.66	Sept. 16, 1942	Un	
Limestone	Gilmore City	....	......	1,100	90	1935	S	Reported yield, 11; drawdown, 15.
Sandstone	Desmoinesian	At hole in pump base	−3.2	(1,120)	87.00	Oct. 21, 1942	D, S	Water of high iron content
Drift	Pleistocene	Top of platform	.3	(1,115)	3.82	Oct. 19, 1942	Un	
Sand	Pleistocene	....	......	1,125	20	March 1950	D, S	Reported yield, 10; drawdown, 15.
Sand	Pleistocene	Top of platform	1.0	(1,120)	12.42	Oct. 21, 1942	S	
Sand	Pleistocene	Top of inner tile	1.1	(1,120)	19.72	Oct. 21, 1942	S	
Alluvium	Recent	Top of platform	.6	(940)	12.44	Oct. 16, 1942	Un	On Oct. 16, 1942, water level in Des Moines River was 13.5 feet below land surface at well.
Limestone	Gilmore City	....	......	950	Flow	....	M	Flow in 1948, 15; yield 60; pumping level 165.
Limestone and dolomite	Mississippian-Devonian*	....	......	945	Flow	....	M	Initial flow, in April 1937, 100 g.p.m.
Drift	Pleistocene	At drilled hole in platform	1.0	(1,115)	5.61	Oct. 19, 1942	S	Destroyed in 1947.
Alluvium	Recent	Top of platform	.7	(945)	13.88	Oct. 16, 1942	S	
Limestone	Hampton—Upper Devonian	....	......	975	Flow	....	D	
Sandstone	Desmoinesian	Top of casing	−5.0	(1,140)	94.78	Oct. 19, 1942	PS	Yield 9; drawdown, 3.0 in two hours
Sandstone	Desmoinesian	Top of platform	1.0	(1,140)	100.19	Oct. 19, 1942	D, S	Water reported hard, of high iron content.
Drift	Pleistocene	Top of platform	1.0	(1,140)	6.76	Oct. 19, 1942	I	
Sandstone	Desmoinesian	....	......	1,145	60	Sept. 1950	D, S	Reported yield, 10; drawdown, 20.
Sandstone	Desmoinesian	....	......	1,145	100	August 1949	D, S	Reported yield, 10; drawdown, 11.
Limestone?	Mississippian (?)	....	......	(1,125)	107.50	Sept. 16, 1942	S	Water reported hard, of high iron content.
Drift	Pleistocene	Top of platform	0	(1,140)	8.14	Sept. 16, 1942	D	Adequate supply reported; water hard.
Drift	Pleistocene	Top of tile casing	1.0	(1,165)	3.64	Sept. 16, 1942	Un	
Sandstone	Desmoinesian	....	......	1,150	63	July 1949	D, S	Reported yield, 10; drawdown, 10.
Sandstone	Desmoinesian	....	......	(1,160)	95	1917	S	Temperature, 50°F; water reported hard.
Drift	Pleistocene	Top of casing	0.2	(1,150)	2.80	Oct. 19, 1942	Un	
Drift	Pleistocene	Top of platform	.9	(1,150)	7.24	Oct. 19, 1942	Un	
Limestone	Gilmore City	....	......	1,150	......	Nov. 1950	D, S	Reported yield, 7.5; pumping level, 240.
Drift	Pleistocene	Top of platform	0	(1,150)	12.68	Oct. 15, 1942	D	Not used for drinking.
Drift	Pleistocene	Top of casing	.5	(1,155)	3.44	Oct. 19, 1942	S	
Sandstone	Desmoinesian	At hole in pump base	.9	1,170	31.65	Oct. 22, 1942	D, S	Reported water level, 25 feet in May 1939.
Drift	Pleistocene	Top of inner lip of tile casing	1.5	....	5.27	Oct. 15, 1942	D, S	
Limestone	Mississippian	Top of platform	0	....	112.6	Oct. 15, 1942	S	Water level affected by previous pumping. Water reported hard, of high iron content.

TABLE 11. RECORDS OF TYPICAL WELLS

Well number	Location	Owner or name	Well construction					Method of lift	
			Type	Depth (feet)	Diameter (inches)	Casing		Pump	Power
						Type	Depth (feet)		
87-29-23Q1...	SW¼SW¼SE¼ sec. 23...	Kenneth Larson..........	DR	151	6	I	151	......	......
87-29-24D1...	NW¼NW¼NW¼ sec. 24.	School No. 6..............	B	49.8	14	T	50?	L	H
87-29-30D1...	NE¼NW¼NW¼ sec. 30.	Otto Norberg..............	B	32.4	18	T	33	L	H
87-29-31N1...	NW¼SW¼SW¼ sec. 31..	Margaret Davis...........	B	91.9	14	T	92?	F	H, W
87-29-36B1...	NE¼NW¼NE¼ sec. 36..	Ruth O'Connell...........	B	42.4	14	T	43?	L	H
87-29-36D1...	SW¼NW¼NW¼ sec. 36.	C. J. Youngquist..........	B	25.0	12	T	25	......	......
	T. 87 N., R. 30 W.								
(87-30-3C1)...	NW¼NE¼NW¼ sec. 3..	W. R. Ingram............	DR	108	5	I	108	......	......
87-30-6N1....	SW¼SW¼SW¼ sec. 6...	J. E. Mack...............	B	42.8	16	T	43	L	E
87-30-9A1....	NE¼NE¼NE¼ sec. 9...	L. Robiner...............	B	42.7	14	T	43	......	......
87-30-9A2....	NE¼NE¼NE¼ sec. 9...	L. Robiner...............	DR	135	6	I	....	F	W
*(87-30-12E1)..	SE¼SW¼NW¼ sec. 12..	Callender, town well 1.....	DR	727	8- 6	I	440	T	E
87-30-12F1...	SE¼SE¼NW¼ sec. 12...	Town of Callender.........	B	50.0	....	T	....	L	H
(87-30-12L1)..	NE¼NE¼SW¼ sec. 12..	Callender, town well 2.....	DR	60	8	I, S	58	J	E
(87-30-12L2)..	SW¼NE¼SW¼ sec. 12..	Callender, town well 3.....	DR	185	....	T	....	......	E
87-30-12L3...	NE¼NE¼SW¼ sec. 12..	Callender, town well.......	DR	90.2	....	I	....	L	H
87-30-13B1...	NW¼NW¼NE¼ sec. 13.	H. G. Anderson...........	DR	395	....	......	....	......	......
87-30-13E1...	SW¼SW¼NW¼ sec. 13..	Alvin Jorgensen...........	DR	97	5	I	97	F	E
87-30-17N1...	NW¼SW¼SW¼ sec. 17..	Chicago, Rock Island & Pacific Railroad	B	21.0	16	T	21?	F	H
87-30-18Q1...	SE¼SW¼SE¼ sec. 18...	C. Peterson..............	Dg, B	64.4	....	T	....	L	H
87-30-28C1...	NW¼NE¼NW¼ sec. 28.	R. E. Peterson............	DR	155	6	I	152.5	......	......
87-30-30R1...	SE¼SE¼SE¼ sec. 30....	School District 9..........	B	41.5	14	T	....	L	H
87-30-33C1...	NE¼NE¼NW¼ sec. 33..	M. Roberts	DR	125	5- 4	I	....	L	G
87-30-34Q1...	SE¼SW¼SE¼ sec. 34...	J. R. Smeltzer............	B	48.0	12	T	....	F	E, W
*87-30-35H1...	SE¼SE¼NE¼ sec. 35...	Elza Meckley.............	DR	357	5	I	303	......	......
	T. 88 N., R. 27 W.								
88-27-1R1....	SE¼SE¼SE¼ sec. 1.....	Ely Jensen...............	Dg, B	34.5	36	B, T	....	L	H, W
*(88-27-3D1)...	SW¼NW¼NW¼ sec. 3..	Duncombe, town..........	DR	974	10- 8	I	290	T	E
88-27-4A1....	NE¼NE¼NE¼ sec. 4...	Ill. Central RR...........	B	47.1	24	T	48	L	H
8-27-4A2....	NE¼NE¼NE¼ sec. 4...	Jones....................	B	40.0	14	T	40	L	H
(88-27-4A3)...	SW¼NE¼NE¼ sec. 4...	Duncombe, town..........	DR	546	6- 5	I	....	F	E
88-27-8A1....	NE¼NE¼NE¼ sec. 8...	T. Gaynon Estate.........	DR	200	3	I	....	L	H, W
88-27-8A2....	NE¼NE¼NE¼ sec. 8...	T. Gaynon Estate.........	B	59.4	12	T	....	L	H
(88-27-11J1)..	SE¼NE¼SE¼ sec. 11...	H. J. Dunbar.............	DR	170	5	I	170	......	......
(88-27-11N1)..	SW¼SW¼SW¼ sec. 11..	Peter Ostholm............	DR	209	5	I	209	......	......
88-27-13R1...	NE¼SE¼SE¼ sec. 13...	Hanna Johnson...........	B	36.8	....	T	....	L	E

IN WEBSTER COUNTY, IOWA—Continued

Principal water-bearing beds: Character of material	Principal water-bearing beds: Geologic subdivision	Water level: Measuring point: Description	Water level: Measuring point: Distance above or below land surface (feet)	Water level: Altitude of land surface (feet)	Water level: Distance of water level above (+) or below land surface (feet)	Water level: Date of measurement	Use of water	Remarks (yield given in gallons a minute; drawdown in feet)
Sand	Pleistocene	...	...	1,160	30	Sept. 1950	D, S	Reported yield, 7; drawdown, 20.
Drift	Pleistocene	Top of casing	.8	(1,155)	5.11	Oct. 21, 1942	PS	
Drift	Pleistocene	Top of platform	1.0	...	4.25	Oct. 15, 1942	Un	
Drift	Pleistocene	Top of platform	0	...	41.7	Oct. 14, 1942	D, S	Water level probably affected by previous pumping. Water pumped contains blue clay.
Drift	Pleistocene	Top of casing	.4	(1,160)	4.71	Sept. 15, 1942	D	
Drift	Pleistocene	Top of casing	.5	(1,160)	6.25	Sept. 15, 1942	Un	100-ft. bored well on farm; reported to have hard water, high iron content.
Sand and gravel	Pleistocene	...	...	1,165	60	Sept. 1948	D, S	Reported yield, 10; drawdown, 10.
Drift	Pleistocene	Top of platform	1.3	...	22.59	Oct. 15, 1942	D, S	Report small yield.
Drift	Pleistocene	Top of casing	.3	...	5.63	Oct. 15, 1942	Un	Not used because of poor yield.
Drift	Pleistocene	...	...	...	30	1930	D, S	Water reported hard, high iron content.
Limestone	Mississippian	...	...	1,150	94	Dec. 22, 1938	M	Casing perforated from 277 to 297 feet, from 420 to 440 feet. Yield, 11; drawdown, 224.
Drift	Pleistocene	...	...	...	8.0	Oct. 15, 1942	PS	
Drift	Pleistocene	...	...	...	17	July 1946	M	Reported yield 15; drawdown, 16.5.
Sandstone	Desmoinesian	...	...	...	35	Sept. 1940	M	Reported yield, 12; drawdown, 113.
Drift	Pleistocene	...	...	...	14.6	Oct. 15, 1942	PS	
...	...	...	...	1,150	...	...	...	Test hole drilled into Mississippian; dry and abandoned.
Sand and Gravel	Pleistocene	...	...	1,150	35	Oct. 1948	D, S	Reported yield, 10; drawdown, 20.
Drift	Pleistocene	Top of platform	0.1	...	4.65	Oct. 15, 1942	Un	
Drift	Pleistocene	Top of platform	1.0	...	5.38	Oct. 15, 1942	Un	
Sand and gravel	Pleistocene	...	...	1,160	60	July 1950	D, S	Reported yield, 6; drawdown 30.
Drift	Pleistocene	Top of platform	...	...	7.72	Sept. 14, 1942	Un	Temperature, 51°F.
Sand and gravel	Pleistocene	At hole in pump base	1.9	...	32.82	Oct. 22, 1942	S	Reported water level, 40 feet below land surface in 1939.
Drift	Pleistocene	Top of platform	1.5	...	9.07	Sept. 14, 1942	D, S	Water supply adequate; water reported to contain some iron.
Dolomite and sandstone	St. Louis	...	...	1,145	60	June 1950	D, S	Reported yield, 5; drawdown, 90.
Drift	Pleistocene	Top of platform	.4	...	10.82	Nov. 9, 1942	D	
Limestone	Mississippian-Devonian	...	...	1,115	40.2	Jan. 1945	M	Casing slotted from 251 to 290 feet. Yield 33; drawdown, 46.8; temperature 51°F.
Gravel	Pleistocene	Top of platform	.6	1,110	7.15	Aug. 21, 1942	D	
Gravel	Pleistocene	Top of platform	.2	1,110	9.02	Aug. 21, 1942	Un	
Limestone	Mississippian	...	...	...	40	1942	A	Reported yield, 16.5 in 1942; abandoned about 1945.
Drift (?)	Pleistocene	Top of casing	.3	(1,105)	25.33	Nov. 11, 1942	D, S	Water reported to have high iron content.
Drift	Pleistocene	Top of casing	.5	(1,105)	6.72	Nov. 11, 1942	Un	
Sand and gravel	Pleistocene	...	...	1,110	16	May 1945	D, S	
Sand and gravel	Pleistocene	...	...	1,110	31	1948	D, S	Reported yield, 12; drawdown 9.
Drift	Pleistocene	Top of platform	0.2	...	8.58	Nov. 6, 1942	D, S	

TABLE 11. RECORDS OF TYPICAL WELLS

Well number	Location	Owner or name	Well construction					Method of lift	
			Type	Depth (feet)	Diameter (inches)	Casing		Pump	Power
						Type	Depth (feet)		
88-27-21D1	SE¼NW¼NW¼ sec. 21	Steven Powers	B	57.8	12	B	57?	L	H
88-27-21M1	NW¼NW¼SW¼ sec. 21	William Martin	DR	168	5	I	166		
88-27-32N1	SE¼SW¼SW¼ sec. 32	C. E. Sonnickson	DR	340	6-5	I	280		
88-27-33D1	NW¼NW¼NW¼ sec. 33	Bridget Hannon	B	63.7	14	T	64?	L	H
88-27-36A1	SE¼NE¼NE¼ sec. 36	E. M. Mulholland	B	39.9	12	T	40?		
	T. 88 N., R. 28 W.								
88-28-3E1	SW¼SW¼NW¼ sec. 3	E. & H. Rogers Estate	DR	350	5-4	I	260		
88-28-5D1	NW¼NW¼NW¼ sec. 5	Certain-teed Products	DR	1,669	12-6	I	(365)	T	E
*(88-28-5D2)	NW¼NW¼NW¼ sec. 5	Certain-teed Products 4	DR	2,060	12-8	I	(320)	T	E
(88-28-6M1)	NE¼NW¼SW¼ sec. 6	Vincent Clay Products Co.	DR	355	8-5	I	355		
88-28-8H1	SE¼SE¼NE¼ sec. 8	John Frandson	DR	350	5-4	I	220		
(88-28-8R1)	NW¼SE¼SE¼ sec. 8	Jordison Store	DR	246	5-4	I	216		
88-28-9H1	SE¼SE¼NE¼ sec. 9	H. I. Moore	DR	188	5-4	I	188		
88-28-9J1	NE¼NE¼SE¼ sec. 9	W. W. Bowen	DR	313	6	I		L	E
88-28-11C1	NE¼NE¼NW¼ sec. 11	Carl Zimmerman	DR	209	5-4	I	(180)		
88-28-12D1	NW¼NW¼NW¼ sec. 12	L. E. Hively	DR	198				L	H, W
88-28-12D2	NW¼NW¼NW¼ sec. 12	L. E. Hively	B	22.8	12	T	25	L	H
88-28-13F1	SE¼SE¼NW¼ sec. 13	Glen Spike	DR	208	5-4	I	208		
88-28-13P1	SE¼SE¼SW¼ sec. 13	Edith Barnes	B	52.6	8	T	54	L	H
88-28-14P1	SE¼SE¼SW¼ sec. 14	Alton Hudson	Dg	12.0	30	T		L	H
88-28-18E1	NW¼SW¼NW¼ sec. 18	T. B. Opland	DR	241	5	I	180		
88-28-19A1	SE¼NE¼NE¼ sec. 19	Otho Cons. School	DR	467	6-4	I		L	E
(88-28-19B1)	SE¼NW¼NE¼ sec. 19	A. D. Schnurr	B	55.6	12	T		L	H
88-28-20H1	NE¼SE¼NE¼ sec. 20	R. W. Lindner	Dg	26.7				L	H
(88-28-31D1)	NE¼NW¼NW¼ sec. 31	J. Y. Wickersham	DR	370	5	I		F	G
88-28-34D1	SW¼NW¼NW¼ sec. 34	Alfred Jensen	DR	187	5	I	123		
(88-28-35N1)	NE¼SW¼SW¼ sec. 35	Dolliver State Park	DR	375		I	375		
	T. 88 N., R. 29 W.								
88-29-1A1	NE¼NE¼NE¼ sec. 1	National Gypsum Co.	DR	273	5	I	254		
88-29-2E1	NW¼SW¼NW¼ sec. 2	Dr. Maggio	DR	500	5-3	I	330		
88-29-3L1	NE¼NE¼SW¼ sec. 3	Webster County Home	DR	366	8	I		T	E
88-29-4A1	NE¼NE¼NE¼ sec. 4	Anna Reilly	DR	246	6			L	H, W
88-29-4A2	NE¼NE¼NE¼ sec. 4	Anna Reilly	Dg	33.5	48	B			
88-29-6H1	SE¼SE¼NE¼ sec. 6	F. E. Harbacheck	DR	69.8	5	I		L	H, W
88-29-6J1	SE¼NE¼SE¼ sec. 6	Thomas Jondle	B	61.0	12	T	70	L	H, W
88-29-9L1	SE¼NE¼SW¼ sec. 9	Anna Sullivan	DR	256	5	I	143		
88-29-11C1	NE¼NE¼NW¼ sec. 11	C. F. Madson	B	51.6	14	T		L	H
88-29-20D1	SW¼NW¼NW¼ sec. 20	Martin Wesley	B	28.0	12	T		L	H, G
(88-29-23A1)	NE¼NE¼NE¼ sec. 23	A. Edwards	B	66.4	12	T		L	H
88-29-25N1	SW¼SW¼SW¼ sec. 25	R. W. Sheker	B	29.9	12	T	30	L	H
	T. 88 N., R. 30 W.								
88-30-5R1	SW¼SE¼SE¼ sec. 5	J. F. Kusterer Estate	B	62.0	12	T		L	H
88-30-13C1	NE¼NE¼NW¼ sec. 13	Max Spilka	B	36.3	8	T		L	H

IN WEBSTER COUNTY, IOWA—Continued

Principal water-bearing beds		Water level						
		Measuring point						
Character of material	Geologic subdivision	Description	Distance above or below land surface (feet)	Altitude of land surface (feet)	Distance of water level above (+) or below land surface (feet)	Date of measurement	Use of water	Remarks (yield given in gallons a minute; drawdown in feet)
Drift	Pleistocene	Top of pump base	.2	....	15.20	Nov. 9, 1942	D, S	Small yield of good water reported.
Sand and gravel	Pleistocene	....	......	1,100	57	1949	D, S	Reported yield, 18; small drawdown.
Limestone and dolomite	St. Louis and Osagian	....	......	1,100	87	Dec. 1950	D, S	Reported yield 12.5; small drawdown.
Drift	Pleistocene	Top of casing	1.0	(1,095)	14.37	Nov. 9, 1942	D, S	Small supply reported.
Drift	Pleistocene	Top of casing	0.4	....	7.75	Nov. 6, 1942	Un	
Limestone	Gilmore City	....	......	1,110	85	March 1947	D, S	Reported yield, 8.5; drawdown, 75.
Sandstone	St. Peter	....	......	1,115	62	July 1925	I	Reported yield, 275; small drawdown.
Sandstone	Jordan	....	......	1,115	117	Jan. 1950	I	Reported yield, 620; drawdown, 40.
Limestone	Gilmore City	....	......	980	Flow	....	I	Casing perforated 340-355. Reported flow, 35.
Limestone	Gilmore City	....	......	1,110	65	1948	D	Reported yield, 12; small drawdown.
Dolomite	Osagian	....	......	1,110	80	Oct. 1947	D	Reported yield, 8; drawdown, 54; 26 feet of 4-inch casing on bottom, perforated.
Sandstone	St. Louis	....	......	1,115	110	Nov. 1949	D	Reported yield, 10; drawdown, 40; casing slotted near bottom.
Limestone	Osagian	....	......	1,115	60	Oct. 1942	D, S	
Dolomite	Osagian	....	......	1,115	90	....	D, S	Reported yield, 12; drawdown, 90.
Sandstone	Desmoinesian	....	......	(1,110)	54	Nov. 1942	D, S	Water reported to have high iron content.
Drift	Pleistocene	Top of casing	1.4	(1,110)	4.24	Nov. 11, 1942	Un	
Sandstone	Desmoinesian	....	......	1,105	111	1948	D, S	Reported yield, 10; small drawdown.
Drift	Pleistocene	Top of casing	0	1,110	17.8	Nov. 11, 1942	D	
Gravel	Pleistocene	Top of casing	1.0	(1,050)	6.09	Oct. 20, 1942	D, S	
Sandstone	St. Louis	....	......	1,115	90	Jan. 1947	D, S	Reported yield, 10; drawdown, 50.
Limestone	Gilmore City	....	......	(1,110)	40	Oct. 21, 1942	PS	
Sand	Pleistocene	Top of casing	0.5	(1,120)	13.66	Nov. 19, 1942	D	
Drift	Pleistocene	Top of platform	0	(1,115)	4.30	Oct. 20, 1942	D, S	
Limestone	Gilmore City	....	......	1,125	......	....	D, S	Yield, 5; temperature, 49°F.
Sandstone	Desmoinesian	....	......	1,110	104	....	D, S	Reported yield, 12; small drawdown.
Limestone	Hampton	....	......	(980)	Flow	....	PS	Reported flow, 35 in 1931; temperature, 50°F. Casing perforated.
Sandstone	St. Louis	....	......	1,125	128	1945	I	Reported yield, 12.5.
Limestone	Hampton	....	......	(1,125)	108	Oct. 1949	D	Reported yield, 5; drawdown, 107.
Limestone	Gilmore City	....	......	1,140	100	Nov. 1942	Un	Reported yield, 50.
Sandstone	St. Louis	Top of platform	1.0	1,125	93.56	Nov. 16, 1942	D, S	Adequate yield reported.
Drift	Pleistocene	Top of platform	0.3	1,130	14.00	Nov. 16, 1942	D	
Drift	Pleistocene	Top of casing	0.5	....	47.15	Oct. 23, 1942	Un	
Sand	Pleistocene	Top of casing	-3.6	....	44.70	Oct. 22, 1942	S	
Sandstone	St. Louis	....	......	1,145	90	April 1950	D, S	Reported yield, 2.5; drawdown, 90.
Drift	Pleistocene	Top of casing	0.5	(1,130)	5.97	Oct. 21, 1942	D	
Drift	Pleistocene	Top of platform	0.3	....	5.28	Oct. 20, 1942	D, S	
Drift	Pleistocene	Top of platform	0.3	(1,120)	5.49	Oct. 20, 1942	D, S	
Drift	Pleistocene	Top of platform	0	....	4.74	Oct. 21, 1942	D	Adequate supply reported
Drift	Pleistocene	Top of casing	1.5	....	20.1	Nov. 12, 1942	Un	
Drift	Pleistocene	Top of platform	0	....	17.40	Oct. 22, 1942	D	Reportedly went dry at times in 1935.

TABLE 11. RECORDS OF TYPICAL WELLS

Well number	Location	Owner or name	Well construction: Type	Well construction: Depth (feet)	Well construction: Diameter (inches)	Casing: Type	Casing: Depth (feet)	Method of lift: Pump	Method of lift: Power
88-30-13C2	SW¼NE¼NW¼ sec. 13	E. Whannel	DR	319	5	I	263	......	......
(88-30-13D1)	NE¼NW¼NW¼ sec. 13	Moorland Cons. School	DR	325	5- 3	I	325	F	E
(88-30-13J1)	SW¼NE¼SE¼ sec. 13	Julia Fiala	DR	236	5- 4	I	(135)	......	......
88-30-13M1	NW¼NW¼SW¼ sec. 13	J. Barrett	DR	262	5- 4	I	262	......	......
88-30-21N1	NW¼SW¼SW¼ sec. 21	Andrew Sorenson	DR	138	5	I	138	......	......
88-30-24N1	SW¼SW¼SW¼ sec. 24	E. Thomas	DR	152	......	......	......	......	......
88-30-24R1	SW¼SE¼SE¼ sec. 24	V. A. Fiala	DR	245	5- 4	I	245	......	......
*(88-30-26A1)	SE¼NE¼NE¼ sec. 26	Howard Loehr	DR	162	6	I	162	F	E
(88-30-27N1)	SW¼SW¼SW¼ sec. 27	H. R. Fiderlick	DR	376	6- 4	I	276	......	......
88-30-30R1	SE¼SE¼SE¼ sec. 30	Amandel Nelson	B	33.7	12	T	34?	L	H
88-30-33N1	SE¼SW¼SW¼ sec. 33	Moore Trust Estate	DR	138	5	I, S	138	......	......
88-30-35M1	SW¼NW¼SW¼ sec. 35	V. Warner	DR	234	5- 4	I	234	......	......
	T. 89 N., R. 27 W.								
89-27-3B1	NW¼NW¼NE¼ sec. 3	H. H. Bunker	B	41.0	12	T	......	L	G
89-27-6A1	NE¼NE¼NE¼ sec. 6	L. Rasmann	B, DR	85	......	T, I	......	L	E
(89-27-7A1)	NE¼NE¼NE¼ sec. 7	Erwin Dencklau	DR	244	5- 3	I	188	F	H, W
*(89-27-7A2)	NE¼NE¼NE¼ sec. 7	Erwin Dencklau	DR	873	5- 3	I	638	J	E
(89-27-8A1)	NE¼NE¼NE¼ sec. 8	Dubbo	B	53.5	12	T	......	L	H
89-27-12P1	SW¼SE¼SW¼ sec. 12	F. I. Schmoker	B	43.3	12	T	......	F	W
89-27-13M1	NW¼NW¼SW¼ sec. 13	William Anderson	DR	260	5- 4	I	(194)	......	......
89-27-16D1	NE¼NW¼NW¼ sec. 16	C. M. Scoular	B	25.0	12	T	......	......	......
89-27-19N1	SE¼SW¼SW¼ sec. 19	Henry Scharf	B	51.6	18	T	......	L	H
89-27-19N2	SE¼SW¼SW¼ sec. 19	Henry Scharf	DR	182	6	I	......	......	......
89-27-24N1	SE¼SW¼SW¼ sec. 24	A. M. Heman	B	14.7	18	T	......	L	H
89-27-24Q1	SW¼SW¼SE¼ sec. 24	Myron Erickson	DR	205	5- 4	I	205	......	......
89-27-27D1	NW¼NW¼NW¼ sec. 27	M. Mallinger	B	38.1	12	T	......	L	H
89-27-27D2	NW¼NW¼NW¼ sec. 27	M. Mallinger	B	37.1	12	T	......	L	E
89-27-36N1	SW¼SW¼SW¼ sec. 36	John Ledden	B, DR	200	16- 5	T, I	......	L	H, W
	T. 89 N., R. 28 W.								
89-28-2B1	NE¼NW¼NE¼ sec. 2	J. Crowley	DR	104.3	6	I	......	L	W
89-28-6D1	NW¼NW¼NW¼ sec. 6	Roy Baker	DR	230	4- 3	I	140	......	......
89-28-6E1	SW¼SW¼SW¼ sec. 6	Dawson & Breen	DR	110	5- 4	I	72	......	......
89-28-8L1	NE¼NE¼SW¼ sec. 8	A. Weiss	DR	248	5	I	(86)	......	......
89-28-8P1	NE¼SE¼SW¼ sec. 8	Clifford Messerly	DR	290	5	I	290	......	......

IN WEBSTER COUNTY, IOWA—Continued

Principal water-bearing beds		Water level						
		Measuring point						
Character of material	Geologic subdivision	Description	Distance above or below land surface (feet)	Altitude of land surface (feet)	Distance of water level above (+) or below land surface (feet)	Date of measurement	Use of water	Remarks (yield given in gallons a minute; drawdown in feet)
Dolomite	Osagian	......	......	1,155	170	Oct. 1948	D, S	Reported yield, 5; drawdown, 100.
Limestone	Osagian	......	......	1,150	145	1945	PS	Reported yield, 7.5; drawdown less than 40; temperature, 51°F. Bottom length of casing perforated.
Sandstone and dolomite	Desmoinesian and Osagian	......	......	1,135	86	Dec. 1947	D, S	Reported yield, 16; small drawdown; 95 feet of 4-inch pipe on bottom lower part perforated.
Limestone	Osagian	......	......	1,140	159	Sept. 1947	D, S	Reported yield, 14; small drawdown. Lower part of casing slotted.
Sand	Pleistocene	......	......	1,160	66	Sept. 1950	D	Reported yield, 5; small drawdown.
Sandstone	Dakota (?)	......	......	1,160	......	......	......	
Dolomite	Osagian	......	......	1,145	120	Jan. 1950	D, S	Reported yield, 10; drawdown, 25. Bottom part of casing perforated.
Sandstone	Dakota (?)	......	......	1,160	100	July 1950	D, S	Reported yield, 20; small drawdown.
Limestone	Gilmore City	......	......	1,145	150	Oct. 28, 1945	D, S	Reported yield, 6; small drawdown.
Drift	Pleistocene	Top of platform	1.6	......	9.48	Nov. 12, 1942	D, S	Inadequate supply at times reported.
Drift	Pleistocene	......	......	1,180	40	May 1949	D, S	Reported yield, 12; drawdown, 20.
Dolomite	Osagian	......	......	1,160	91	Aug. 1948	D, S	Reported yield, 8; drawdown, 46. Lower part of casing slotted.
Drift	Pleistocene	Top of casing	1.5	(1,130)	19.24	Aug. 17, 1942	S	
Drift	Pleistocene	Top of platform	1.0	(1,130)	18.57	Aug. 18, 1942	D, S	Temperature, 50°F.
Limestone	Osagian	Top of platform	.5	1,125	67.6	Nov. 14, 1942	D, S	Adequate supply reported; abandoned after well 7A2 was drilled, because of contamination.
Dolomite	Devonian	......	......	1,125	78	Oct. 7, 1949	D, S	Yield, 3; drawdown, less than 12; temperature, 51°F.
Drift	Pleistocene	Top of casing	.6	(1,125)	6.38	Nov. 14, 1942	D	
Drift	Pleistocene	Top of 2x6 timber at pit opening	2.0	......	18.25	Aug. 19, 1942	D, S	Small yield reported.
Limestone	Gilmore City	......	......	1,120	84	1948	D, S	Reported yield, 9.5; drawdown, 53.
Drift	Pleistocene	Top of concrete base	0.8	(1,120)	7.34	Aug. 19, 1942	Un	
Drift	Pleistocene	Top of platform	1.0	(1,110)	8.11	Nov. 7, 1942	Un	Water reported to be contaminated.
......	St. Louis (?)	......	......	(1,110)	60	Nov. 1941	D, S	Temperature, 49°F.
Drift	Pleistocene	Top of casing	0.2	......	6.96	Nov. 6, 1942	S	Used very little.
Sandstone	St. Louis	......	......	1,105	45	1948	D, S	Reported yield, 25; drawdown, 10. Casing perforated near bottom.
Drift	Pleistocene	Top of platform	1.2	(1,110)	13.65	Nov. 9, 1942	D	
Sand	Pleistocene	Top of casing	1.0	(1,110)	14.25	Nov. 9, 1942	D, S	
Sand	Pleistocene	Top of casing	0.7	......	17.60	Nov. 9, 1942	D, S	Used very little.
Drift	Pleistocene	Top of casing	1.0	(1,130)	15.08	Aug. 18, 1942	Un	
Limestone	Gilmore City	......	......	1,015	Flow	1951	D, S	
Limestone	Osagian	......	......	1,005	13	July 1949	D	Reported yield, 3; drawdown, 47.
Limestone	Gilmore City	......	......	1,120	135	March 1949	D, S	Reported yield, 14; drawdown, 19; 17 feet of 5-inch casing from 123 to 140 feet.
Limestone	Gilmore City	......	......	1,125	127	1951	D, S	Reported yield, 10; drawdown, 25; bottom part of casing perforated.

TABLE 11. RECORDS OF TYPICAL WELLS

Well number	Location	Owner or name	Well construction					Method of lift	
			Type	Depth (feet)	Diameter (inches)	Casing		Pump	Power
						Type	Depth (feet)		
89-28-9Q1....	SW¼SW¼SE¼ sec. 9....	Christopher Weyen.......	DR	200	6- 5	I	(54)	......	......
89-28-10P1...	SE¼SE¼SW¼ sec. 10...	H. Ascherl Estate.........	Dg	40.0	40	B	40	L	H, W
89-28-10P2...	SE¼SE¼SW¼ sec. 10...	H. Ascherl Estate.........	DR	358	5	I	93	......	......
89-28-11N1...	NE¼SW¼SW¼ sec. 11...	W. H. Black..............	B	10.6	8?	T	....	L	H
89-28-11N2...	SE¼SW¼SW¼ sec. 11...	W. H. Black..............	B	78.0	14	T	....	L	W
89-28-11N3...	SE¼SW¼SW¼ sec. 11...	W. H. Black..............	B	51.7	10	T	....	L	H
89-28-14R1...	SW¼SE¼SE¼ sec. 14...	Clarence Pingel...........	DR	192	5	I	120	......	......
89-28-18K1...	SE¼NW¼SE¼ sec. 18...	Louis Charon.............	DR	94	....	......	....	......	......
89-28-19K1...	SE¼NW¼SE¼ sec. 19...	Ft. Dodge Crmy. Co., well 1	DR	375	....	I	....	T	E
(89-28-19K2)..	SE¼NW¼SE¼ sec. 19...	Ft. Dodge Crmy. Co., well 2	DR	404	10	I	162	T	E
89-28-19L1...	SE¼NE¼SW¼ sec. 19...	Ft. Dodge, City No. 3.....	DR	215.5	17	I	215.5	......	......
89-28-19L2...	SE¼NE¼SW¼ sec. 19...	Ft. Dodge, City No. 5.....	DR	624	8- 6	I	(162)	......	......
89-28-19L3...	SE¼NE¼SW¼ sec. 19...	Ft. Dodge, City No. 6.....	DR	283	8	I	253	......	......
89-28-19L4...	SE¼NE¼SW¼ sec. 19...	Ft. Dodge, City No. 8.....	DR	500	16- 8	I	257	T	E
89-28-19L5...	SE¼NE¼SW¼ sec. 19...	Ft. Dodge, City No. 9A....	DR	260	6	I	245	S	E
89-28-19L6...	SE¼NE¼SW¼ sec. 19...	Ft. Dodge, City No. 9.....	DR	553	16- 8	I	323	T	E
89-28-19L7...	NW¼NE¼SW¼ sec. 19..	Ft. Dodge, City No. 10....	DR	422	6	I	242	......	......
89-28-19L8...	NW¼NE¼SW¼ sec. 19..	Ft. Dodge, City No. 11....	DR	530	6	I	245	......	......
89-28-19L9...	NW¼NE¼SW¼ sec. 19..	Ft. Dodge, City No. 12....	DR	541	12- 8	I	390	T	E
89-28-19L10...	NW¼NE¼SW¼ sec. 19..	Ft. Dodge, City No. 13....	DR	830	....	......	....	......	......
89-28-19L11...	NW¼NE¼SW¼ sec. 19..	Ft. Dodge, City No. 14....	DR	980	16-14	I	(281)	A	A
89-28-19L12...	SE¼NE¼SW¼ sec. 19...	Ft. Dodge, City No. 15....	DR	2,307	20-10	I	(1,084)	T	E
89-28-19P1...	NE¼SE¼SW¼ sec. 19...	Ft. Dodge, City No. 1.....	DR	1,827	10- 5	I	(328)	......	......
89-28-19P2...	NE¼SE¼SW¼ sec. 19...	Ft. Dodge, City No. 2.....	DR	670	15-10	I	(152)	......	......

IN WEBSTER COUNTY, IOWA—Continued

Principal water-bearing beds		Water level						
		Measuring point						
Character of material	Geologic subdivision	Description	Distance above or below land surface (feet)	Altitude of land surface (feet)	Distance of water level above (+) or below land surface (feet)	Date of measurement	Use of water	Remarks (yield given in gallons a minute; drawdown in feet)
Limestone	Gilmore City	......	......	1,110	117	April 1945	D, S	Reported yield, 13; drawdown, 10; 120 feet of 5-inch casing on bottom; lower part perforated.
Sand	Pleistocene	Top of brick curbing	1.5	(1,125)	......	......	D, S	Temperature, 49°F.
Limestone	Gilmore City	......	......	(1,120)	127	April 1951	D, S	Reported yield, 12; drawdown about 33.
Sand	Pleistocene	Top of platform	0.6	(1,120)	12.33	Aug. 19, 1942	D	
Sand	Pleistocene	Top of casing	0.7	(1,120)	18.11	Aug. 19, 1942	D, S	
Drift	Pleistocene	Top of platform	0.6	(1,120)	8.60	Aug. 19, 1942	D	
Limestone	St. Louis	......	......	1,120	27	Nov. 1945	D, S	Reported yield, 12; drawdown, 33.
......	......	......	......	1,055	3	1930	......	
Limestone	Gilmore City	......	......	......	60	1942	I	
Limestone	Kinderhookian	......	......	1,065	70	Feb. 1946	I	Reported yield, 500; drawdown, 13.
Limestone	Mississippian	......	......	980	Flow	1950	M	Reported flow, 600 in 1911
Limestone	Mississippian	......	......	980	Flow	1913	A	Reported flow, 50 in 1913; 10 in 1919, when abandoned.
Limestone	Mississippian	......	......	980	Flow	1914	A	Reported flow, 190 in 1914; reported yield, 250; pumping level, 75 in 1919; abandoned, 1938.
Limestone	Mississippian	......	......	980	Flow	1950	M	Original depth 1,436 feet; original flow, 250; reported yield, 1,000, pumping level, 100 in 1948.
Limestone	Mississippian	......	......	985	Flow	......	A	Reported flow, 675 in 1927; abandoned, Nov. 1944.
Limestone	Mississippian	......	......	985	Flow	1950	M	Reported flow, 500 in 1938; reported yield, 1,550; pumping level, 45 in March 1948.
Limestone	Mississippian	......	......	985	Flow	1931	A	Reported flow, 200 in 1931; abandoned and plugged, 1938.
Limestone	Mississippian	......	......	985	Flow	1931	A	Reported flow, 600 in 1931; abandoned and plugged, 1944.
Limestone	Mississippian	......	......	985	Flow	1950	M	Reported flow, 1,000; head 28 feet in 1931. Reported yield, 1,550; pumping level, 45 in June 1948.
Limestone	Mississippian	......	......	985	Flow	1935	A	Reported flow, 440 in 1935; well abandoned because of relatively small yield in 1935.
Dolomite	Devonian	......	......	980	Flow	1950	M	Reported flow, 3,000 in Oct. 1935; water level, 18.5 above land surface, Oct. 1935. Reported yield, 3,000; pumping level, 34 in Oct. 1944.
Sandstone	Jordan	......	......	980	Flow	1949	M	Reported flow, 350 in Jan. 1949. Yield, 2,900; drawdown, 70.2 in 8.5 hours.
Limestone and sandstone	Prairie du Chien and Jordan	......	......	980	60+	1907	A	Reported flow, 571 in 1907. Reported yield, 600; pumping level, 55 in 1919; abandoned and plugged, 1938.
Limestone	Kinderhookian	......	......	980	Flow	1911	A	Reported flow, 150 in 1911; abandoned and plugged, 1938.

TABLE 11. RECORDS OF TYPICAL WELLS

Well number	Location	Owner or name	Well construction: Type	Depth (feet)	Diameter (inches)	Casing: Type	Casing: Depth (feet)	Method of lift: Pump	Method of lift: Power
89-28-19P3	NW¼SE¼SW¼ sec. 19	Ft. Dodge, City No. 4	DR	400	8- 6	I	105		
89-28-19P4	NW¼SE¼SW¼ sec. 19	Ft. Dodge, City No. 7	DR	498	8	I	138		
89-28-19P5	NE¼SE¼SW¼ sec. 19	Cargill, Inc., No. 1	DR	545	8	I	156	T	E
89-28-19P5	NE¼SE¼SW¼ sec. 19	Cargill, Inc., No. 1	DR	1,190	8	I	156	T	E
89-28-20M1	SE¼NW¼SW¼ sec. 20	Wahkonsa Hotel	DR	1,870	12- 6	I			
89-28-21Q1	SE¼SW¼SE¼ sec. 21	Litchfield Realty Co.	B	48.7	12	T			
89-28-21Q2	SE¼SW¼SE¼ sec. 21	Litchfield Realty Co.	DR	150.0	5	I, S		L	W
(89-28-22A1)	NE¼NE¼NE¼ sec. 22	G. H. Halverson	DR	148	5	I	102	J	E
89-28-24N1	SW¼SW¼SW¼ sec. 24	A. Pingel	B	63.2	16	T		L	H
89-28-24N2	SW¼SW¼SW¼ sec. 24	A. Pingel	DR	125	5	I		L	E
*89-28-26E1	NW¼SW¼NW¼ sec. 26	Certain-teed Products Corp.	DR	247	5	I	(153)		
89-28-31M1	SW¼NW¼SW¼ sec. 31	L. E. Armstrong	DR	407					
89-28-31R1	SE¼SE¼SE¼ sec. 31	H. Peschau	DR	170	5	I	160		
(89-28-32N1)	SW¼SW¼SW¼ sec. 32	Peterson Bros.	DR	325	5	I	169		
89-28-34K1	NE¼NW¼SE¼ sec. 34	Wasem Plaster Co.	DR	445	6	I	187	F	E
	T. 89 N., R. 29 W.								
89-29-1D1	NW¼NW¼NW¼ sec. 1	Schlieschardt Estate	B	22.1	24	T		L	H
89-29-1P1	SW¼SE¼SW¼ sec. 1	E. Zenke	DR	105	5	I	70		
89-29-1Q1	NW¼SW¼SE¼ sec. 1	Tobin Farms Co.	DR	200	5- 4	I	200		
89-29-12G1	SW¼SW¼NE¼ sec. 12	L. V. Rogers	DR	97	5- 4	I	97		
89-29-13E1	SE¼SW¼NW¼ sec. 13	F. Larrabee	DR	315		I			
89-29-13N1	SW¼SW¼SW¼ sec. 13	C. Anderson	B	10.9	6	T		L	H
89-29-14H1	SE¼SE¼NE¼ sec. 14	O. D. Walton	DR	153	5	I	107		
89-29-16N1	SW¼SW¼SW¼ sec. 16	J. Stromberg	DR	429	5	I		L	G
89-29-20A1	NE¼NE¼NE¼ sec. 20	G. H. Warner	B	42.5	12	T		L	G
*89-29-20N1	NW¼SW¼SW¼ sec. 20	Swaney Motor Co.	DR	290	5- 4	I	(223)		
89-29-23A1	NE¼NE¼NE¼ sec. 23	J. Monaghan	Dg	13.7	36			L	H
89-29-24A1	SW¼NE¼NE¼ sec. 24	Boy Scouts of America	DR	105	4	I	79		
(89-29-25N1)	SW¼SW¼SW¼ sec. 25	B. Bergman	DR	525	6- 4	I	418	L	E
*(89-29-31F1)	NE¼SE¼NW¼ sec. 31	A. J. Crawford	DR	165	5	I	145		
89-29-35H1	NW¼SE¼NE¼ sec. 35	John Scripps	DR	486				L	E
	T. 89 N., R. 30 W.								
*(89-30-2Q1)	SE¼SW¼SE¼ sec. 2	V. F. Lentsch	DR	623	6- 4	I	610	J	E
*(89-30-11R1)	NE¼SE¼SE¼ sec. 11	V. & M. McLaughlin	DR	671	6- 4	I	343	L	E
89-30-16N1	SW¼SW¼SW¼ sec. 16	L. O'Hern	B	62.4	14	T		L	W
89-30-18J1	NE¼NE¼SE¼ sec. 18	D. L. Cain	B	35.2	15	T			
89-30-23R1	NE¼SE¼SE¼ sec. 23	Johnson Twp. Cons. School	DR	202.5	4	I			
(89-30-23R2)	NE¼SE¼SE¼ sec. 23	Johnson Twp. Cons. School	B	55		T		F	E
89-30-24B1	NE¼NW¼NE¼ sec. 24	H. J. Winninger	B	20.5	30	T		L	H

IN WEBSTER COUNTY, IOWA—Continued

Principal water-bearing beds: Character of material	Principal water-bearing beds: Geologic subdivision	Water level: Measuring point: Description	Water level: Measuring point: Distance above or below land surface (feet)	Water level: Altitude of land surface (feet)	Water level: Distance of water level above (+) or below land surface (feet)	Water level: Date of measurement	Use of water	Remarks (yield given in gallons a minute; drawdown in feet)
Limestone	Mississippian	......	......	980	Flow	1913	A	Initial flow, 160 in 1913; 15 in 1919 when abandoned.
Limestone	Mississippian	......	......	960	Flow	1914	A	Reported flow, 80 in 1914; abandoned about 1925.
Limestone	Kinderhookian	......	......	990	Flow	Oct. 4, 1946	I	Reported yield, 255; pumping level, 100-110.
Limestone	Kinderhookian	......	......	990	+8	Aug. 1950	I	Reported yield, 305; pumping level, 210.
Sandstone	Jordan	......	......	(1,100)	......	......	Un	
Drift	Pleistocene	Top of casing	1.0	(1,110)	8.09	Nov. 6, 1942	Un	
......	St. Louis	At hole in pump base	0.5	(1,110)	85.30	Nov. 6, 1942	S	Water reported to have high iron content.
Dolomite	St. Louis	Top of casing	3.1	1,110	30.33	July 22, 1945	D, S	Reported yield, 6; drawdown, 18.
Drift	Pleistocene	Top of platform	0.5	(1,110)	9.44	Nov. 6, 1942	D	Small yield reported.
Sandstone (?)	St. Louis	......	......	(1,110)	70	Nov. 1942	D, S	Water reported to have high iron content.
Dolomite	Osagian	......	......	1,115	60	Nov. 1946	I	Reported yield, 16; drawdown, 60; 61 feet of 4-inch casing on bottom; bottom part perforated.
Dolomite	Mississippian	......	......	1,120	125	1927	D, S	
Limestone	St. Louis	......	......	975	+18	Oct. 1944	D	Reported yield, 5; drawdown, 36.
Limestone	Osagian	......	......	970	Flow	June 1944	D	Reported flow, 2.
Dolomite	Hampton	......	......	(1,110)	65	Nov. 1943	I	
Alluvium	Pleistocene	Top of casing	0.8	......	14.39	Oct. 23, 1942	D, S	Adequate supply reported.
Dolomite	Osagian	......	......	1,000	Flow	Nov. 1946	D, S	
Limestone	Gilmore City	......	......	1,005	10	Aug. 1949	D, S	Reported yield, 6; drawdown, 100; lower part of casing slotted.
Dolomite	Osagian	......	......	1,005	Flow	April 1946	D	Reported yield, 12; drawdown, 40.
Limestone	Gilmore City	......	......	(1,100)	100	1927	D, S	
Sand	Pleistocene	Top of casing	1.1	(1,105)	8.53	Oct. 23, 1942	D	Used very little.
Dolomite	St. Louis	......	......	1,105	90	Dec. 1948	D, S	Reported yield, 7; drawdown, 40.
Dolomite	Hampton	Top of platform	0.5	......	79.50	Nov. 12, 1942	S	
Drift	Pleistocene	Top of casing	0.7	......	10.77	Nov. 12, 1942	S	
Dolomite	Osagian	......	......	1,160	120	1947	D, S	Reported yield, 8; drawdown, 49; 42 feet of 4-inch casing on bottom, lower part perforated.
Drift	Pleistocene	Top of platform	1.0	(1,105)	6.59	Oct. 23, 1942	D	
Sandstone	St. Louis	......	......	1,050	......	......	D	
Dolomite	Hampton	......	......	1,130	130	1935	S	Reported yield, 8; drawdown, 40.
Sandstone	Ft. Dodge	......	......	1,170	125	July 1948	D, S	Reported yield, 5; drawdown, 15.
Limestone	Hampton	......	......	(1,120)	......	......	......	
Sandstone	Cretaceous	......	......	1,150	54	Jan. 1946	D, S	Reported yield, 10; drawdown, 7; temperature, 53°F. Lower part of casing slotted.
Dolomite	Devonian	......	......	1,175	69	May 1949	D, S	Reported yield, 6; drawdown, 124; temperature, 54°F; 86 feet of 4 inch casing on bottom.
Drift	Pleistocene	Top of concrete curb	1.7	......	25.94	Oct. 21, 1942	D, S	
Drift	Pleistocene	Top of casing	0	......	7.26	Oct. 21, 1942	Un	
Sandstone?	Cretaceous	Top of concrete pump base	−0.3	......	30.26	Oct. 21, 1942	Un	Inadequate supply.
Sand	Pleistocene	......	......	......	......	......	PS	
Drift	Pleistocene	Top of platform	0.2	......	9.96	Nov. 12, 1942	D	

TABLE 11. RECORDS OF TYPICAL WELLS

Well number	Location	Owner or name	Well construction					Method of lift	
			Type	Depth (feet)	Diameter (inches)	Casing		Pump	Power
						Type	Depth (feet)		
	T. 90 N., R. 27 W.								
90-27-2A1	NE¼NE¼NE¼ sec. 2	N. A. Christensen	DR	121	5	I	83	L	H
90-27-4D1	NE¼NW¼NW¼ sec. 4	L. Maage	B	38.9	18	T	......	S	H
90-27-4D2	NE¼NW¼NW¼ sec. 4	L. Maage	DR	110.2	6	I	100	L	H, W
90-27-8Q1	SW¼SW¼SE¼ sec. 8	R. Croden	DR	153	5	I	140	......	......
90-27-11K1	SW¼NW¼SE¼ sec. 11	J. L. Reddick	DR	66	5	I	49	J	E
90-27-11Q1	SW¼SW¼SE¼ sec. 11	J. L. Reddick	DR	196	5	I	70	......	......
90-27-16B1	NW¼NW¼NE¼ sec. 16	W. O. Christopher	B	49	12	T	......	L	E
90-27-16B2	NW¼NW¼NE¼ sec. 16	W. O. Christopher	DR	98	5	I	71	......	......
(90-27-22K1)	NW¼NW¼SE¼ sec. 22	J. Riechert	DR	96	3	I	96	J	E
90-27-22K2	NW¼NW¼SE¼ sec. 22	Art Swason	DR	88	4	I	......	......	......
90-27-22K3	SW¼NW¼SE¼ sec. 22	Paul Bastion	DR	88	4	I	......	......	......
90-27-22K4	NE¼NW¼SE¼ sec. 22	James McDonald	B	26	6	T	......	L	H
90-27-22L1	SE¼NE¼SW¼ sec. 22	Vincent Locker Plant	DR	121	6	I	98	......	......
90-27-22L2	NE¼NE¼SW¼ sec. 22	W. O. Wagner	B	12.8	12	T	......	L	H
90-27-22L3	NE¼NE¼SW¼ sec. 22	N. F. Thompson	B	25.6	8	T	......	L	H
90-27-27D1	NE¼NW¼NW¼ sec. 27	R. E. Carter	B	35.5	24	T	......	L	H, W
*90-27-28D1	NE¼NW¼NW¼ sec. 28	J. M. Engels	DR	420	6	I	86	L	E
90-27-29F1	NW¼SE¼NW¼ sec. 29	M. L. Sylvester	DR	210	5	I	165	......	......
90-27-31N1	SW¼SW¼SW¼ sec. 31	C. S. Knudson	B	53.0	15	T	......	L	H
*(90-27-31N2)	SW¼SW¼SW¼ sec. 31	C. S. Knudson	DR	405	5	I	150	J	E
	T. 90 N., R. 28 W.								
90-28-1B1	NW¼NW¼NE¼ sec. 1	E. Askland	B	43.3	18	T	......	L	H
90-28-1D1	NE¼NW¼NW¼ sec. 1	L. E. Larson	B	22.5	12	T	......	L	W
90-28-3D1	NW¼NW¼NW¼ sec. 3	P. DeLandst	DR	60.5	4	I	......	L	H, W
90-28-5D1	NW¼NW¼NW¼ sec. 5	Swenson Bros.	B	42.7	15	T	......	......	......
90-28-5D2	NW¼NW¼NW¼ sec. 5	Swenson Bros.	DR	120	6	I	60	......	......
90-28-6R1	SE¼SE¼SE¼ sec. 6	H. and W. Wasem	DR	330	......	I	......	......	......
90-28-8Q1	SE¼SW¼SE¼ sec. 8	S. E. Hovey	B	31.6	......	T	......	L	H
90-28-10F1	SW¼SE¼NW¼ sec. 10	Iver Amdahl	DR	193	5- 4	I	193	L	E
90-28-10J1	SE¼NE¼SE¼ sec. 12	W. S. Risetter	DR	90.3	5	I	......	L	H, W
90-28-10R1	SW¼SE¼SE¼ sec. 10	P. O. Knutson	B	69.0	12	T	70	......	......
90-28-12M1	NW¼NW¼SW¼ sec. 12	Berton Anderson	DR	105	5	I	105	......	......
(90-28-15D1)	NE¼NW¼NW¼ sec. 15	Badger, town well 1	DR	280	5- 4	I	208	F	E
(90-28-15D2)	NW¼NW¼NW¼ sec. 15	Badger, town well 2	DR	530	8- 6	I	220	T	E
90-28-15D3	NE¼NW¼NW¼ sec. 15	Badger Telephone Co.	B	54.2	12?	T	55?	L	H
90-28-15D4	NE¼NW¼NW¼ sec. 15	L. O. Myrland	B	29.5	16-12	T	30?	L	H
90-28-15E1	NW¼SW¼NW¼ sec. 15	Johnson	B	50.5	10	T	51?	......	......
90-28-16N1	SW¼SW¼SW¼ sec. 16	Earl Knudson	DR	127	5- 4	I	123	......	......
90-28-18D1	NW¼NW¼NW¼ sec. 18	V. A. Anderson	Dg	52	36	R	52?	L	H
90-28-18D2	NW¼NW¼NW¼ sec. 18	V. A. Anderson	DR	89.0	5	I	......	L	W
90-28-18E1	SW¼SW¼NW¼ sec. 18	Aaron Thompson	DR	180	5	I	120	......	......
90-28-19N1	SW¼SW¼SW¼ sec. 19	W. L. Mitchell	Dg	30	30	R	30?	L	H
(90-28-24J1)	SE¼NE¼SE¼ sec. 24	C. S. Knudson	DR	164	5	I	153	L	E
90-28-25A1	NE¼NE¼NE¼ sec. 25	Samuel Larson	DR	459	5	I	......	L	E
90-28-25D1	SE¼NW¼NW¼ sec. 25	O. J. Larson	DR	151	6	I	......	L	W
(90-28-27E1	SW¼SW¼NW¼ sec. 27	E. McGill	DR	149	5	I	89	......	......
90-28-28A1	NE¼NE¼NE¼ sec. 28	Frank Cronin	B	50.0	12	T	......	L	E
90-28-31P1	SW¼SE¼SW¼ sec. 31	E. Otto	DR	193	5	I	166	......	......

IN WEBSTER COUNTY, IOWA—Continued

Principal water-bearing beds		Water level						
		Measuring point						
Character of material	Geologic subdivision	Description	Distance above or below land surface (feet)	Altitude of land surface (feet)	Distance of water level above (+) or below land surface (feet)	Date of measurement	Use of water	Remarks (yield given in gallons a minute; drawdown in feet)
Dolomite	Osagian	....	......	1,130	22	May 1943	D, S	Reported yield, 15; drawdown, 12.
Drift	Pleistocene	Top of platform	1.6	(1,140)	4.92	Aug. 13, 1942	D	
Sandstone?...	St. Louis	Top of casing	1.0	(1,140)	29.88	Aug. 13, 1942	D, S	Temperature, 50°F.
Sandstone	St. Louis	....	......	1,130	48	Aug. 1945	D, S	Reported yield, 16; small drawdown.
Dolomite	Osagian	Top of platform	1.0	(1,135)	23.49	Aug. 14, 1942	D, S	
Limestone	Gilmore City	....	......	1,145	32	1944	D, S	
Drift	Pleistocene	Top of well curb	1.0	(1,135)	41.92	Aug. 14, 1942	D, S	
Limestone	Gilmore City	....	......	(1,135)	51	Nov. 1948	D, S	Reported yield, 12; small drawdown.
Gravel	Pleistocene	Top of platform	1.0	(1,135)	14.93	Aug. 20, 1942	D	Gravel reported to rest on bedrock.
Dolomite	Osagian	....	......	(1,135)	17	1941	D	
Gravel	Pleistocene	....	......	(1,135)	19	July 1940	D	
Sand	Pleistocene	Top of casing	0	(1,135)	7.40	Aug. 19, 1942	Un	
Dolomite	Osagian	....	......	1,135	15	1947	I	Reported yield, 60; small drawdown.
Drift	Pleistocene	Top of casing	0.2	(1,135)	5.74	Aug. 19, 1942	D	Well reported to be dry during dry periods.
Sand	Pleistocene	Top of casing	0	(1,135)	7.92	Aug. 11, 1942	D	
Drift	Pleistocene	Top of platform	1.6	(1,130)	24.91	Aug. 17, 1942	D, S	Water reported hard, high iron content.
Dolomite	Hampton	....	......	1,135	42	Sept. 1947	D, S	Reported yield, 45; drawdown, 45.
Sandstone	St. Louis	....	......	1,130	115	March 1946	D, S	Reported yield, 9; drawdown, 13.
Drift	Pleistocene	Top of platform	1.0	1,125	7.68	Aug. 19, 1942	Un	
Limestone	Kinderhookian	....	......	1,125	105	June 1945	D, S	Reported yield, 7; small drawdown.
Drift	Pleistocene	Top of casing	1.3	(1,155)	4.56	Aug. 13, 1942	Un	
Drift	Pleistocene	Top of platform	1.6	(1,150)	9.20	Aug. 13, 1942	D, S	
Drift	Pleistocene	Top of casing	1.6	(1,140)	18.17	Aug. 13, 1942	S	Adequate supply reported.
Drift	Pleistocene	Top of platform	1.4	....	4.37	Aug. 12, 1942	Un	
Limestone?	Mississippian	Top of casing	0	(1,110)	33.52	Aug. 12, 1942	Un	Report very small supply.
Dolomite	Hampton	....	......	1,135	......	....	......	
Drift	Pleistocene	Top of platform	0.2	(1,130)	7.05	Aug. 14, 1942	D	
Dolomite	Osagian	....	......	1,150	52	July 1051	D, S	Reported yield, 13; drawdown, 33; lower part of casing perforated.
Sandstone?	St. Louis	Top of casing	1.0	(1,130)	30.75	Aug. 14, 1942	D, S	
Drift	Pleistocene	Top of casing	1.0	(1,130)	6.47	Aug. 14, 1942	Un	
Sand	Pleistocene	....	......	1,165	......	1948	D S	
Limestone	Gilmore City	Top of casing	1.0	(1,155)	40	Aug. 1942	M	Yield, 23; temperature, 50°F.
Limestone	Kinderhookian	....	......	1,155	85	Feb. 1948	M	Reported yield, 55; drawdown, 102.
Drift	Pleistocene	Top of casing	0.5	(1,155)	6.52	Aug. 12, 1942	Un	Not used because of contamination.
Sand	Pleistocene	Top of platform	1.1	(1,155)	10.13	Nov. 16, 1942	D	
Drift	Pleistocene	Top of casing	0.3	(1,145)	7.20	Aug. 12, 1942	Un	
Sandstone	St. Louis	....	......	1,130	54	Feb. 1946	D, S	Reported yield, 13; drawdown, 16.
Drift	Pleistocene	Top of platform	0.3	....	18.92	Aug. 14, 1942	D, S	Temperature, 49°F.
Sandstone	Desmoinesian	Top of platform	2.0	....	39.43	Aug. 14, 1942	S	
Dolomite	Osagian	....	......	1,130	70	April 1946	D, S	Reported yield, 5; drawdown, 47 after 20 hours' pumping.
Sand	Pleistocene	Top of platform	0	(1,110)	17.17	Aug. 17, 1942	D	
Sandstone	St. Louis	....	......	1,125	99.2	May 1945	D, S	Reported yield, 7; drawdown, 6.
Dolomite	Hampton	....	......	1,125	90	Nov. 1942	D, S	Temperature, 50°F.
Sandstone	St. Louis	....	......	(1,120)	100	Aug. 1942	D, S	
Sandstone	St. Louis	....	......	1,130	84	Nov. 1942	D, S	Temperature, 50°F.
Drift	Pleistocene	Top of platform	0.4	(1,125)	18.62	Aug. 17, 1942	D, S	Temperature, 49°F.
Dolomite	Osagian	....	......	1,115	90	May 1947	D, S	Reported yield, 7; drawdown, 32.

TABLE 11. RECORDS OF TYPICAL WELLS

Well number	Location	Owner or name	Well construction					Method of lift	
			Type	Depth (feet)	Diameter (inches)	Casing		Pump	Power
						Type	Depth (feet)		
90-28-32N1	SE¼SW¼SW¼ sec. 32	A. & C. Evenson	Dg	14.6	24	B	....	L	H
90-28-34Q1	SW¼SW¼SE¼ sec. 34	J. A. McGill	B	40.5	12	T	....	L	H
*90-28-35D1	SW¼NW¼NW¼ sec. 35	E. I. Oleson	DR	220	5	I	166	......	......
90-29-3Q1	*T. 90 N., R. 29 W.* NW¼SW¼SE¼ sec. 3	Louis Schuster	DR	66	5	I	56	......	......
90-29-6Q1	SW¼SW¼SE¼ sec. 6	Albert Licht	DR	60	5	I	40	......	......
90-29-7A1	NE¼NE¼NE¼ sec. 7	M. Scheidemann	DR	43.0	6	I	....	......	......
90-29-9F1	SE¼SE¼NW¼ sec. 9	C. Driscoll	B	42.9	12	T	....	L	W
(90-29-9K1)	NE¼NW¼SE¼ sec. 9	H. & M. Neimeyer	DR	91	5	I	48	......	......
90-29-11E1	SE¼SW¼NW¼ sec. 11	John Schuster	Dg	20.8	42	......	....	L	G
90-29-14P1	SW¼SE¼SW¼ sec. 14	Alvin Behrens	DR	155	5- 4	I	155	......	......
90-29-23R1	NE¼SE¼SE¼ sec. 23	A. Jacobs	Dg	40.5	30	T	....	L	H
90-29-23R2	NE¼SE¼SE¼ sec. 23	A. Jacobs	DR	193	5- 4	I	167	......	......
90-29-24C1	NW¼NE¼NW¼ sec. 24	O. Maher	Dg	35	30	B	....	......	......
90-29-25D1	NW¼NW¼NW¼ sec. 25	M. L. Smith	DR	191	5- 4	I	(105)	......	......
90-29-25E1	SW¼SW¼NW¼ sec. 25	School District	B	19.5	6	T	....	......	......
*90-29-29B1	NE¼NW¼NE¼ sec. 29	W. C. Ulrich	DR	252	5- 4	I	(95)	......	......
90-29-33M1	NW¼NW¼SW¼ sec. 33	Walter Seltz	DR	136	5	I	64	......	......
90-30-2R1	*T. 90 N., R. 30 W.* SE¼SE¼SE¼ sec. 2	L. Westmoreland	B	47.7	16	T	....	L	H
*(90-30-3A1)	NE¼NE¼NE¼ sec. 3	E. F. Beeh	DR	165	6	I	128	......	......
*90-30-3A2	NW¼NE¼NE¼ sec. 3	E. F. Beeh	DR	160	8	......	....	......	......
*90-30-4E1	SW¼SW¼NW¼ sec. 4	Albert Licht	DR	1,105	....	......	....	......	......
90-30-4Q1	SW¼SW¼SE¼ sec. 4	C. R. Westmoreland	B	69	24	T	....	L	H, W
90-30-6R1	SW¼SE¼SE¼ sec. 6	M. McMahon	B	27.5	14	T, S	27.5	L	H
(90-30-15M1)	SW¼NW¼SW¼ sec. 15	R. E. Mason	DR	....	....	......	....	......	......
*90-30-24N1	SE¼SW¼SW¼ sec. 24	Catholic church and school	DR	180	5	I	151	......	......
90-30-24N2	SW¼SW¼SW¼ sec. 24	Town of Clare	DR	160	....	......	....	L	G
90-30-26A1	NW¼NE¼NE¼ sec. 26	Webster County	B	37.0	....	T	....	L	H
90-30-31A1	SE¼NE¼NE¼ sec. 31	W. J. Jandle	B	95	14	T	....	L	W
90-30-32D1	SW¼NW¼NW¼ sec. 32	W. J. Jandle	B	73.7	14	T	....	L	H
90-30-32D2	SW¼NW¼NW¼ sec. 32	W. J. Jandle	Dg	15.1	24	T	....	L	H
*(90-30-35Q1)	SW¼SW¼SE¼ sec. 35	Erling Malmin	DR	710	6- 5	I	697	......	......

IN WEBSTER COUNTY, IOWA—Continued

Principal water-bearing beds		Water level: Measuring point						
Character of material	Geologic subdivision	Description	Distance above or below land surface (feet)	Altitude of land surface (feet)	Distance of water level above (+) or below land surface (feet)	Date of measurement	Use of water	Remarks (yield given in gallons a minute; drawdown in feet)
Sand	Pleistocene	Top of casing, east side	0.4	(1,100)	3.79	Aug. 18, 1942	S	Unsatisfactory supply reported.
Drift	Pleistocene	Top of casing	0.9	(1,125)	5.66	Aug. 20, 1942	Un	Unused because of small yield.
Sandstone	St. Louis	......	......	1,125	112	Jan. 1940	D, S	Reported yield, 11; small drawdown.
Sandstone	St. Louis	......	......	1,130	36	Oct. 1949	D, S	Reported yield, 10; small drawdown.
Limestone	St. Louis	......	......	1,150	19	1940	D, S	Reported yield, 35; small drawdown.
Limestone	St. Louis	Top of casing	0.9	......	......	Oct. 23, 1942	S	Yield, 5; pumping level, 37.68.
Gravel	Pleistocene	Top of concrete curb	1.1	......	20.66	Oct. 21, 1942	D, S	
Dolomite	St. Louis	......	......	1,140	Flow	1947	D, S	
Sand	Pleistocene	Top of platform	0.6	(1,130)	15.52	Oct. 23, 1942	D, S	Adequate supply reported.
Dolomite	Osagian	......	......	1,120	45	1950	D, S	Casing perforated near bottom.
Sand and gravel	Pleistocene	Top of casing	1.1	(1,120)	36.08	Oct. 23, 1942	D, S	Inadequate supply reported.
Sandstone?	Osagian	......	......	(1,120)	115	1946	D, S	
Drift	Pleistocene	Top of wood plank	1.5	(1,100)	9.07	Aug. 17, 1942	Un	
Dolomite	Osagian	......	......	1,105	91	1949	D, S	78 feet of 4-inch casing on bottom.
Drift	Pleistocene	Top of casing	0.6	(1,135)	4.76	Oct. 23, 1942	Un	
Limestone	Gilmore City	......	......	1,175	50	May 1948	D, S	Reported yield, 4.5; drawdown, 103; 44 feet of 4-inch casing on bottom, perforated.
Dolomite	Osagian	......	......	1,115	51	1948	D, S	Reported yield, 16; drawdown, 16.
Drift	Pleistocene	Top of concrete pit curb	0.2	......	16.85	Oct. 21, 1942	D	
Sandstone	Cretaceous	......	......	1,175	13	Oct. 1947	D, S	Reported yield, 40; drawdown, 7; temperature, 51°F.
Shale	Cretaceous	......	......	1,175	......	......	......	Test hole; dry and abandoned.
Sandstone	Cretaceous(?)	......	......	1,200	......	......	......	Reported yield small.
Drift	Pleistocene	Top of casing	1.6	......	13.84	Oct. 21, 1942	D, S	
Sand	Pleistocene	Top of casing	0.3	......	13.12	Oct. 21, 1942	D	
Sandstone	Cretaceous	......	......	......	......	......	......	Temperature, 53°F.
Sandstone	Cretaceous	......	......	1,215	118	1950	PS	Reported yield, 14; drawdown, 12.
Sandstone	Cretaceous	......	......	......	......	......	Un	Well not used since 1930; reported filled with sand.
Sand	Pleistocene	Top of platform	0.3	......	10.85	Oct. 21, 1942	D	
Sand	Pleistocene	Top of well curb	0.2	......	19.98	Oct. 21, 1942	D, S	
Drift	Pleistocene	Top of platform	0	......	8.00	Oct. 21, 1942	D	
Drift	Pleistocene	Top of casing	2.2	......	4.38	Oct. 21, 1942	S	
Sandstone	Cretaceous	......	......	1,150	50	Aug. 1948	D, S	Reported yield, 28; drawdown, 32.

TABLE 12. DEPTH INTERVALS OF GEOLOGIC UNITS TO THE BASE OF THE HAMPTON FORMATION AT VARIOUS WELLS IN WEBSTER COUNTY (determined by studies of well cuttings).

An asterisk before well no. indicates that a generalized log is given in the following section on well logs.

Well number	Location	Owner or name	Altitude of land surface (feet)	Year drilled	Depth of well (feet)	Pleistocene	Cretaceous	Permian(?)	Pennsylvanian	Mississippian				
									Desmoinesian	Meramecian		Osagian	Kinderhookian	
						Undifferentiated (feet)	Undifferentiated (feet)	Fort Dodge formation (feet)	Undifferentiated (feet)	Ste. Genevieve formation (feet)	St. Louis limestone (feet)	Undifferentiated (feet)	Gilmore City formation (feet)	Hampton formation (feet)
	T. 86 N., R. 28 W.													
*86-28-2P1	SE¼SE¼SW¼ sec. 2	F. and K. Gabrielson	1,140	1947	720	0-180	....	....	180-318	....	318-	-445	445-560	560-707
86-28-14H2	SW¼SE¼NE¼ sec. 14	Dayton, town well 1	1,120	1895	688	0-163	....	....	163-395	....	....	395-418	418-535	535-688+
	T. 86 N., R. 29 W.													
*86-29-13C1	SW¼NE¼NW¼ sec. 13	Harcourt, town well	1,170	1939	1,092	0-180	....	....	180-380	....	380-425	425-500	500-625	625-775
86-29-35C1	NE¼NE¼NW¼ sec. 35	Emil Rohden	1,170	1949	260	0-184	....	....	184-260+	....	....	....	....	....
	T. 86 N., R. 30 W.													
86-30-1P2	SE¼SE¼SW¼ sec. 1	Gowrie, town well 2	1,140	1926	1,842	0-150	....	....	150-310	310-	-390	390-480	480-	-750
*86-30-1Q1	NW¼SW¼SE¼ sec. 1	Gowrie, town well 3	1,140	1950	250	0-249	....	....	249-250+	....	....	....	....	....
86-30-15P1	SE¼SE¼SW¼ sec. 15	C. J. Johnson	1,115	1951	112	0-112+	....	....	....	....	....	....	....	....
	T. 87 N., R. 28 W.													
87-28-6D1	NE¼NW¼NW¼ sec. 6	C. A. Tapper Estate	1,125	1950	a125	0-146	....	....	146-153+	....	....	....	....	....
*87-28-12J2	SE¼NE¼SE¼ sec. 12	Lehigh, town well 2	945	1937	1,005	0-30	....	....	30-198	....	....	198-232	232-330	330-497
87-28-19J1	SE¼NE¼SE¼ sec. 19	Franklin Larson	1,145	1950	185	0-125	....	....	125-185+	....	....	....	....	....
*87-28-30C1	NE¼NE¼NW¼ sec. 30	Otto Kling	1,150	1949	186	0-122	....	....	122-186+	....	....	....	....	....
	T. 87 N., R. 29 W.													
*87-29-3R1	SE¼SE¼SE¼ sec. 3	Richard Paul	1,150	1950	380	0-120	....	....	120-220	220-245	245-295	295-375	375-380+	....
87-29-17A1	NW¼NE¼NE¼ sec. 17	Lydia Hayek	1,170	1939	174	0-125	....	....	125-174+	....	....	....	....	....
87-29-23Q1	SW¼SW¼SE¼ sec. 23	Kenneth Larson	1,165	1950	151	0-151+	....	....	....	....	....	....	....	....
	T. 87 N., R. 30 W.													
87-30-3C1	NW¼NE¼NW¼ sec. 3	W. R. Ingram	1,165	1948	108	0-108+	....	....	....	....	....	....	....	....
*87-30-12E1	SE¼SW¼NW¼ sec. 12	Callender, town well 1	1,150	1938	727	0-118	....	....	118-275	....	275-310	310-410	410-510	510-727
87-30-13B1	NW¼NW¼NE¼ sec. 13	H. G. Anderson	1,150	1948	395	0-120	....	....	120-315	....	315-340	340-395+	....	....
87-30-13E1	SW¼SW¼NW¼ sec. 13	Alvin Jorgensen	1,150	1948	97	0-97	....	....	....	....	....	....	....	....
87-30-28C1	NW¼NE¼NW¼ sec. 28	R. E. Peterson	1,160	1950	b185	0-162	....	....	162-172	....	....	....	....	....
*87-30-35H1	SE¼SE¼NE¼ sec. 35	Elsa Meckley	1,145	1950	357	0-205	....	....	205-285	285-307	307-357	....	....	....

	T. 88 N., R. 27 W.													
*88-27-3D1	SW¼NW¼NW¼ sec. 3	Duncombe town	1,115	1945	974	0-235						235-280	280-405	405-555
88-27-11J1	SE¼NE¼SE¼ sec. 11	H. J. Dunbar	1,110	1945	170	0-170+								
88-27-11N1	SW¼SW¼SW¼ sec. 11	Peter Ostblom	1,110	1948	209	0-209+								
88-27-21M1	NW¼NW¼SW¼ sec. 21	William Martin	1,100	1949	168	0-168+								
88-27-32N1	SE¼SW¼SW¼ sec. 32	C. E. Sonnickson	1,100	1950	340	0-120			120-265		265-290	290-340+		
	T. 88 N., R. 28 W.													
88-28-3E1	SW¼SW¼NW¼ sec. 3	E. & H. Rogers Estate	1,110	1947	350	0-55		55-65	65-170		170-210	210-290	290-350+	
*88-28-5D2	NW¼NW¼NW¼ sec. 5	Certain-teed Products well 4	1,115	1950	2,060	0-55		55-65	65-140	140-197	197-245	245-325	325-420	420-595
88-28-6M1	NE¼NW¼SW¼ sec. 6	Vincent Clay Products Co.	980	1948	355				0-50	50-105	105-160	160-260	260-355+	
88-28-8H1	SE¼SE¼NE¼ sec. 8	John Frandson	1,110	1948	350	0-40			40-160		160-210	210-310	310-350+	
88-28-8R1	NW¼SE¼SE¼ sec. 8	Jordinson Store	1,110	1946	240	0-60			60-210		210-223	223-246+		
88-28-9H1	SE¼SE¼NE¼ sec. 9	H. I. Moore	1,115	1949	188	0-53			53-150	150-178	178-188+			
88-28-9J1	NE¼NE¼SE¼ sec. 9	W. W. Bowen	1,115	1939	313	0-30±			30±-150	150-190	190-220	220-313+		
88-28-11C1	NE¼NE¼NW¼ sec. 11	Carl Zimmerman	1,115		299	0-70			70-155	155-180	180-235	235-299+		
88-28-13F1	SE¼SE¼NW¼ sec. 13	Glen Spike	1,105	1948	208	0-50			50-208+					
88-28-18E1	NW¼SW¼NW¼ sec. 18	T. B. Opland	1,115	1947	241	0-60			60-175		175-225	225-241+		
88-28-31D1	NE¼NW¼NW¼ sec. 31	J. Y. Wickersham	1,125	1943	370	0-85			85-260			260-350	350-370+	
88-28-34D1	SW¼NW¼NW¼ sec. 34	Alfred Jensen	1,110	1950	187	0-60			60-187+					
	T. 88 N., R. 29 W.													
88-29-1A1	NE¼NE¼NE¼ sec. 1	National Gypsum Co.	1,125	1945	273	0-68		68-90	90-195	195-249	249-273+			
88-29-4A1	NE¼NE¼NE¼ sec. 4	Anna Reilly	1,125	1930	246	0-85			85-120	120-190	190-246+			
88-29-9L1	SE¼NE¼SW¼ sec. 9	Anna Sullivan	1,145	1950	256	0-82			82-123	123-143	143-203	203-256+		
	T. 88 N., R. 30 W.													
88-30-13C2	SW¼NE¼NW¼ sec. 13	E. Whannel	1,155	1948	319	0-137	137-142		142-262			262-319+		
88-30-13D1	NE¼NW¼NW¼ sec. 13	Moorland Cons. School	1,150	1945	325	0-110	110-130		130-240			240-325+		
88-30-13J1	SW¼NE¼SE¼ sec. 13	Julia Fiala	1,135	1947	236	0-95			95-170		170-220	220-236+		
88-30-13M1	NW¼NW¼SW¼ sec. 13	M. Barrett	1,140	1947	262	0-115	115-160		160-183		183-220	220-262+		
88-30-21N1	NW¼SW¼SW¼ sec. 21	Andrew Sorenson	1,160	1950	138	0-138+								
88-30-24N1	SW¼SW¼SW¼ sec. 24	E. Thomas	1,160	1942	152	0-150±	150±-152+							
88-30-24R1	SW¼SE¼SE¼ sec. 24	V. A. Fiala	1,145	1950	245	0-100	100-140		140-150		150-210	210-245+		
*88-30-26A1	SE¼NE¼NE¼ sec. 26	Howard Loehr	1,160	1950	162	0-140	140-162+							
88-30-27N1	SW¼SW¼SW¼ sec. 27	H. R. Fiderlick	1,145	1945	376	0-185			185-230			230-325	325-376+	
88-30-35M1	SW¼NW¼SW¼ sec. 35	V. Warner	1,160	1948	234	0-160			160-190		190-215	215-234+		
	T. 89 N., R. 27 W.													
*89-27-7A2	NE¼NE¼NE¼ sec. 7	Erwin Dencklau	1,125	1949	873	0-120			120-190			190-255	255-365	365-545
89-27-13M1	NW¼NW¼SW¼ sec. 13	William Anderson	1,120	1948	269	0-170			170-190			190-255	255-269+	
89-27-24Q1	SW¼SW¼SE¼ sec. 24	Myron Erickson	1,105	1948	205	0-185			185-205+					
	T. 89 N., R. 28 W.													
89-28-6D1	NW¼NW¼NW¼ sec. 6	Roy Baker	1,015	1951	230	0-20					20-50	50-140	140-230+	
89-28-6E1	SW¼SW¼NW¼ sec. 6	Dawson and Breen	1,005	1949	110	0-20					20-57	57-110+		
89-28-8L1	NE¼NE¼SW¼ sec. 8	A. Weiss	1,120	1949	248	0-40				40-100	100-165	165-240	240-248+	

TABLE 12. DEPTH INTERVALS OF GEOLOGIC UNITS OF THE BASE OF THE HAMPTON FORMATION AT VARIOUS WELLS IN WEBSTER COUNTY (determined by studies of well cuttings).—Continued

An asterisk before well no. indicates that a generalized log is given in the following section on well logs.

									Pennsylvanian	Mississippian				
						Pleistocene	Cretaceous	Permian(?)	Desmoinesian	Meramecian		Osagian	Kinderhookian	
Well number	Location	Owner or name	Altitude of land surface (feet)	Year drilled	Depth of well (feet)	Undifferentiated (feet)	Undifferentiated (feet)	Fort Dodge formation (feet)	Undifferentiated (feet)	Ste. Genevieve formation (feet)	St. Louis limestone (feet)	Undifferentiated (feet)	Gilmore City formation (feet)	Hampton formation (feet)
89-28-8P1...	NE¼SE¼SW¼ sec. 8....	Clifford Messerly........	1,125	1951	290	0-64	....	....	....	....	64-102	102-215	215-290+	....
89-28-9Q1...	SW¼SW¼SE¼ sec. 9....	Christopher Weyen......	1,110	1945	200	0-50	....	....	....	....	50-95	95-172	172-200+	....
89-28-14R1..	SW¼SE¼SE¼ sec. 14....	Clarence Pingel..........	1,120	1945	192	0-130	....	....	....	....	130-175	175-192+	....	....
89-28-18K1..	NW¼NW¼SE¼ sec. 18..	Louis Charon...........	1,055	1930	94	0-10	....	....	....	....	10-70	70-94+	....	....
89-28-19K2..	SE¼NW¼SE¼ sec. 19...	Fort Dodge Creamery, well 2..............	1,065	1946	404	0-75	....	....	75-90	90-132	132-175	175-265	265-360	360-404+
89-28-19L4..	SE¼NE¼SW¼ sec. 19...	Fort Dodge, city well 8...	980	1923	c500	0-	....	....	-170	....	....	170-240	240-310	310-480
89-28-19L11.	NW¼NE¼SW¼ sec. 19..	Fort Dodge, city well 14..	980	1935	980	0-	....	....	-190	190-250	250-300	300-385	385-485	485-655
*89-28-19L12.	SE¼NE¼SW¼ sec. 19...	Fort Dodge, city well 15..	980	1949	2,307	0-20	....	....	20-180	180-250	250-305	305-395	395-465	465-655
*89-28-19P5..	NE¼SE¼SW¼ sec. 19...	Cargill, Inc.............	990	1950	1,190	0-5	....	....	5-35	35-80	80-125	125-215	215-310	310-490
89-28-22A1..	NE¼NE¼NE¼ sec. 22..	G. H. Halverson........	1,110	1945	148	0-95	....	....	....	95-100	100-145	145-148+	....	....
*89-28-26E1..	NW¼SW¼NW¼ sec. 26.	Certain-teed Products....	1,115	1946	247	0-45	....	45-65	65-80	80-140	140-185	185-247+	....	....
89-28-31R1..	SE¼SE¼SE¼ sec. 31....	H. Peschau.............	975	1944	170	0-30	....	....	30-90	90-160	160-170+	....	....	....
89-28-32N1..	SW¼SW¼SW¼ sec. 32..	Peterson Bros..........	970	1944	325	0-40	....	....	40-130	130-180	180-220	220-320	320-325+	....
	T. 89 N., R. 29 W.													
89-29-1K1...	SW¼NW¼SE¼ sec. 1...	R. H. Castell...........	1,005	1949	200	0-10	....	....	....	....	10-55	55-145	145-200+	....
89-29-1P1...	SW¼SE¼SW¼ sec. 1....	E. Zenke...............	1,000	1946	105	0-10	....	....	....	10-15	15-64	64-105+	....	....
89-29-12G1..	SW¼SW¼NE¼ sec. 12..	L. V. Rogers............	1,005	1946	97	0-10	....	....	....	....	10-55	55-97+	....	....
89-29-14H1..	SE¼SE¼NE¼ sec. 14...	O. D. Walton...........	1,105	1948	153	0-107	....	....	....	....	107-153+	....	....	....
*89-29-20N1..	NW¼SW¼SW¼ sec. 20..	Swaney Motor Co.......	1,160	1948	290	0-125	125-155	....	155-270	....	....	270-290+	....	....
*89-29-31F1..	NE¼SE¼NW¼ sec. 31..	A. J. Crawford.........	1,170	1948	165	0-135	....	135-160	160-165+	....	....	....	....	....
	T. 89 N., R. 30 W.													
*89-30-2Q1...	SE¼SW¼SE¼ sec. 2....	V. F. Lentsch...........	1,150	1946	623	0-115±	115±-623+	....	....	....	....	....	....	....
*89-30-11R1..	NE¼SE¼SE¼ sec. 11...	V. & M. McLaughlin....	1,175	1946	671	0-140	....	....	140-170	....	170-230	230-310	310-450±	450±-585
	T. 90 N., R. 27 W.													
90-27-2A1...	NE¼NE¼NE¼ sec. 2...	N. A. Christensen.......	1,130	1943	121	0-80	....	....	....	....	80-97	97-121+	....	....
90-27-8Q1...	SW¼SW¼SE¼ sec. 8....	R. Croden..............	1,130	1945	153	0-144	....	....	....	....	144-153+	....	....	....
90-27-11Q1..	SW¼SW¼SE¼ sec. 11...	J. L. Reddick...........	1,145	1944	196	0-60	....	....	....	....	....	60-75	75-170	170-196+
90-27-16B1..	NW¼NW¼NE¼ sec. 16.	W. O. Christopher.......	1,135	1948	98	0-55	....	....	....	....	....	....	55-98+	....
90-27-22L1..	SE¼NE¼SW¼ sec. 22...	Vincent Locker Plant....	1,135	1947	121	0-95	....	....	....	....	....	95-121+	....	....

*90-27-28D1	NE¼NW¼NW¼ sec. 28	J. M. Engels	1,135	1947	420	0-85	...	...	...	...	85-100	100-170	170-270	270-420+
90-27-29F1	NW¼SE¼NW¼ sec. 29	M. L. Sylvester	1,130	1946	210	0-125	...	...	125-175	...	175-205	205-210+	...	...
*90-27-31N2	SW¼SW¼SW¼ sec. 31	C. S. Knudson	1,125	1945	405	0-70	...	70-110	...	110-140	140-185	185-265	265-380	380-405+
	T. 90 N., R. 28 W.													
90-28-6R1	SE¼SE¼SE¼ sec. 6	H. & W. Wasem	1,135	1945	330	0-140	...	...	...	...	140-150	150-210	210-310	310-330+
90-28-10F1	SW¼SE¼NW¼ sec. 10	Iver Amdahl	1,150	1951	193	0-112	...	...	112-163	...	163-181	181-193+	...	...
90-28-12M1	NW¼NW¼SW¼ sec. 12	Berton Anderson	1,165	1948	105	0-105+	...	...	...	...	...	...	...	...
*90-28-15D2	NW¼NW¼NW¼ sec. 15	Badger, town well 2	1,155	1948	530	0-140	...	...	...	...	140-165	165-245	245-340	340-525
90-28-16N1	SW¼SW¼SW¼ sec. 16	Earl Knudson	1,130	...	127	0-90	...	...	...	...	90-127+	...	...	...
90-28-18E1	SW¼SW¼NW¼ sec. 18	Aaron Thompson	1,130	1946	180	0-65	...	65-100	...	...	100-115	115-180+	...	...
90-28-24J1	SE¼NE¼SE¼ sec. 24	C. S. Knudson	1,125	1945	164	0-120	...	...	120-145	145-153	153-164+	...	...	...
90-28-25A1	NE¼NE¼NE¼ sec. 25	Samuel Larson	1,125	1931	459	0-	...	...	(d)	-135	135-180	180-250	250-350	350-459+
90-28-27E1	SW¼SW¼NW¼ sec. 27	E. McGill	1,130	1942	149	0-87	...	...	...	...	87-145	145-149+	...	...
90-28-31P1	SW¼SE¼SW¼ sec. 31	E. Otto	1,115	1947	193	0-70	...	...	...	70-100	100-140	140-193+	...	...
*90-28-35D1	SW¼NW¼NW¼ sec. 35	E. I. Oleson	1,125	1946	220	0-70	...	70-102	102-155	155-165	165-220+	...	...	...
	T. 90 N., R. 29 W.													
90-29-3Q1	NW¼SW¼SE¼ sec. 3	Louis Schuster	1,130	1949	66	0-53	...	...	...	...	53-66+	...	...	...
90-29-6Q1	SW¼SW¼SE¼ sec. 6	Albert Licht	1,150	1946	60	0-40	...	...	...	...	40-60+	...	...	...
90-29-9K1	NE¼NW¼SE¼ sec. 9	H. & M. Neimeyer	1,140	1947	91	0-40	...	...	...	...	40-85	85-91+	...	...
90-29-14P1	SW¼SE¼SW¼ sec. 14	Alvin Behrens	1,120	1950	155	0-75	...	...	...	...	75-101	101-155+	...	...
90-29-25D1	NW¼NW¼NW¼ sec. 25	M. L. Smith	1,105	1949	191	0-105	...	...	105-125	...	125-135	135-191+	...	...
*90-29-29B1	NE¼NW¼NE¼ sec. 29	W. C. Ulrich	1,175	1948	252	0-77	...	...	...	...	77-108	108-185	185-252+	...
90-29-33M1	NW¼NW¼SW¼ sec. 33	Walter Selts	1,145	1948	136	0-55	...	...	...	...	55-120	120-136+	...	...
	T. 90 N., R. 30 W.													
*90-30-3A1	NE¼NE¼NE¼ sec. 3	E. F. Bech	1,175	1947	165	0-95	95-165+	...	...	...	...	...	...	...
*90-30-3A2	NW¼NE¼NE¼ sec. 3	E. F. Bech	1,175	1947	160	0-90	90-160+	...	...	...	...	...	...	...
*90-30-4E1	SW¼SW¼NW¼ sec. 4	Albert Licht	1,200	1950	1,105	0-110	110-1105+	...	...	...	...	...	...	...
*90-30-24N1	SE¼SW¼SW¼ sec. 24	St. Matthew's Church	1,215	1950	180	0-125	125-180+	...	...	...	...	...	...	...
*90-30-35Q1	SW¼SW¼SE¼ sec. 35	Erwin Malmin	1,150	1948	710	0-80	80-710+	...	...	...	...	...	...	...

a Drilled to depth of 153 feet; plugged back to 125 feet.
b Drilled to depth of 172 feet; plugged back to 155 feet.
c Drilled to depth of 1,436 feet; has filled back to about 500 feet.
d Thickness of Pennsylvanian unknown.

WELL LOGS

86-28-2P1. Driller's and sample log of E. and K. Gabrielson farm well near Dayton in the SE¼ SE¼ SW¼ sec. 2, T. 86 N., R. 28 W. Drilled in 1947 by Harold Rasmussen, Callender. Altitude of land surface, 1,140 feet. Sample study by R. W. Screven. Driller's log to 447 feet.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (180 feet thick):		
Till, yellow	24	24
Till, blue	86	110
Sand	1	111
Till, blue	69	180
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (138 feet thick):		
Shale	54	234
Coal	3	237
Shale	13	250
Slate	2	252
Shale	8	260
Slate	4	264
Shale	54	318
Mississippian system.		
Meramecian series.		
St. Louis limestone (34 feet thick):		
Limestone	9	327
Shale	3	330
Limestone, soft	22	352
Osagian series.		
Undifferentiated beds (93 feet thick):		
Shale, green	10	362
Limestone, brown	8	370
Shale, dark	8	378
Limestone	42	420
Shale, dark	8	428
Limestone	17	445

Mississippian system—Continued		
Kinderhookian series.		
Gilmore City limestone (115 feet thick):		
Limestone, cream, buff, fragmental, oolitic; trace of pyrite	115	560
Hampton formation (146 feet thick):		
Dolomite, light-brown, finely to medium crystalline; some limestone, buff, finely crystalline	10	570
Limestone, buffish-white, sublithographic	30	600
Limestone, buffish-brown, medium saccharoidal; trace of sand, frosted, round	26	626
Dolomite, grayish-brown, finely granular; some chert, gray, granular, speckled	15	641
Dolomite, as above; limestone buff, sublithographic; trace of sandstone, gray, fine to medium	11	652
Dolomite, gray, finely granular; some chert, whitish-buff, mottled	8	660
Dolomite, dark-grayish-brown, finely granular, silty, cherty, argillaceous; some chert, gray, granular, mottled; small amount of limestone, buff, lithographic to sublithographic	38	698
Limestone, buff, lithographic to finely crystalline; limestone, white, gray, buff, mottled, finely to medium crystalline, fossiliferous; trace of sand, subrounded, frosted	8	706
Devonian system.		
Upper Devonian series.		
Sheffield shale (14 feet penetrated):		
No samples	13	719
Shale	1	720 T.D.

86-29-13C1. Sample log of Harcourt town well in the SW¼ NE¼NW¼ sec. 13, T. 86 N., R. 29 W. Drilled in 1939 by McCutchen Well Co., Des Moines. Altitude of land surface, 1,170 feet. Sample study by J. B. Carrier.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (180 feet thick):		
No sample	5	5
Till, brownish-gray, calcareous	10	15
Till, gray, calcareous	55	70
Sand and gravel, heterogeneous	5	75
No sample	10	85
Sand and gravel, heterogeneous	5	90
Till, gray, calcareous	20	110
Sand and gravel, heterogeneous	5	115
Silt, brown, some carbonaceous material	2	117
Clay, gray-brown, slightly calcareous	8	125
Sand and gravel	10	135
Till, brown, calcareous	20	155
No sample	5	160
Clay, brown, pebbly, calcareous	10	170
Sand, coarse to very coarse, heterogeneous	10	180
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (195 feet thick):		
Shale, gray, soft, silty, calcareous	10	190
Shale, red, calcareous	5	195
Sandstone, light-buff, very fine, silty, calcareous	5	200
Shale, light-buff, soft	10	210
Shale, light to dark-gray, trace of brown, soft, some micaceous	30	240
Sandstone, medium-gray, fine, micaceous, speckled black, calcareous	10	250
Sandstone, light-gray, medium, angular, poorly frosted	5	255
Shale, black, nonlaminated, calcareous	10	265
Shale, dark-gray, some coal	5	270

	Thickness	Depth
Pennsylvanian system—Continued		
Desmoinesian series—Continued		
Undifferentiated beds—Continued		
Sandstone, medium to coarse, angular to curvilinear, polished and frosted in part	5	275
Shale, gray, soft, nonlaminated, grading downward into sandstone, gray, fine, angular, friable	50	325
Shale, black, mottled light-gray and yellow	5	330
Sandstone, light-gray, fine, angular, free	5	335
Sandstone, medium to coarse, angular to curvilinear, finely pitted; some dark-gray and black	5	340
Shale, black, soft, poorly laminated	12	352
Shale, dark-gray, laminated	8	360
Shale, black, fissile, grading downward into sandstone, fine, frosted	15	375
Mississippian system.		
Meramecian series.		
St. Louis limestone (50 feet thick):		
Limestone, light-buff, finely crystalline, some silty; trace of chert, gray; trace of shale, green, waxy	30	405
Dolomite, medium brown, finely crystalline, silty; some sandstone, medium	5	410
Sandstone, fine to coarse, some frosted; shale, green, calcareous; trace chert, gray, quartzose	15	425
Osagian series		
Undifferentiated beds (75 feet thick):		
Limestone, light-buff, finely crystalline; dolomite, medium-gray, finely crystalline, slightly glauconitic; some chert, pale-gray, mottled	25	450
Limestone, buff, very finely crystalline, pseudo-oolitic	10	460
Shale, bright-green to gray, laminated, soft, calcareous	5	465

	Thickness	Depth
Mississippian system—Continued		
Osagian series—Continued		
Undifferentiated beds—Continued		
Limestone, buff, very finely crystalline; some shale, green	20	485
Dolomite, light-buff, finely crystalline, argillaceous	10	495
Dolomite, as above; limestone, very light buff, dense	5	500
Kinderhookian series.		
Gilmore City limestone (125 feet thick):		
Limestone, drab, sublithographic	5	505
Limestone, light-buff, finely crystalline, fragmental, oolitic; trace of chert, light-orange, opaque to quartzose, clear; trace of crystalline quartz	120	625
Hampton formation (150 feet thick):		
Eagle City member		
Limestone, light buff, finely crystalline, some pseudo-oolitic	40	665
Limestone, light buff, finely crystalline, mottled brown	8	673
Maynes Creek member		
Dolomite, light brownish-buff to gray, finely crystalline	32	705
Dolomite, gray, finely granular	10	715
Dolomite, as above; some chert, buff to gray, some mottled bluish gray, smooth to granular	55	770
Dolomite, brownish drab, some mottled gray, finely crystalline	5	775
Devonian system.		
Upper Devonian series.		
Sheffield shale (45 feet thick):		
Shale, light-green, soft, calcareous	45	820
Lime Creek, Shell Rock, and Cedar Valley formations (272 feet penetrated):		
Dolomite, light-brown, finely to medium crystalline, dense, hard	10	830
Shale, light-green, some speckled black; trace of sandstone	15	845

Devonian system—Continued		
Upper Devonian series—Continued		
Lime Creek, Shell Rock, and Cedar Valley formations—Continued		
Dolomite, light-buff to drab, finely to medium crystalline	5	850
Limestone, light-buff to drab, very finely granular	15	865
Dolomite, light-buff, finely crystalline; limestone, as above	15	880
Dolomite, drab to gray, medium to coarsely crystalline	10	890
Dolomite, drab to gray, medium crystalline	5	895
Limestone, drab to gray, medium crystalline; dolomite, drab to gray, medium crystalline and saccharoidal	10	905
Limestone, light-yellowish, drab, finely to medium crystalline	10	915
Limestone, light-brown, mottled buff, coarsely crystalline	5	920
Dolomite, light medium brownish-buff, finely granular, calcitic	15	935
Dolomite, light yellowish-buff, mottled medium-gray, coarsely crystalline	20	955
Dolomite, light-gray, very fine to finely crystalline	10	965
Dolomite, light-gray, medium crystalline	20	985
Limestone, buff to gray, mottled medium-gray, medium to coarsely crystalline	5	990
Dolomite, light-buff, finely crystalline to coarsely saccharoidal	5	995
Dolomite, light-drab, mottled gray, coarsely granular	5	1000
Dolomite, as above; some shale, medium-gray	5	1005
Dolomite, light-drab, medium to mostly coarsely crystalline	5	1010
Dolomite, light creamy gray, finely crystalline	5	1015

Devonian system—Continued		
Upper Devonian series—Continued		
Lime Creek, Shell Rock, and Cedar Valley formations—Continued		
Dolomite, light creamy gray, coarsely crystalline	20	1035
Dolomite, tawny-buff, finely granular	45	1080
Dolomite, very light buff to brown, finely crystalline	5	1085
Dolomite, as above, calcitic in part	5	1090
Limestone, very light to buff to light-tan, finely crystalline	2	1092 T.D.

86-30-1Q1. Sample log of Gowrie town well 3 in the NW¼ SW¼SE¼ sec. 1, T. 86 N., R. 30 W. Drilled in 1950 by Hoag and Ames, Lincoln, Iowa. Altitude of land surface, 1,140 feet. Sample study by L. F. Jenkinson.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (135 feet thick):		
Till, buff, calcareous	10	10
Till, gray, calcareous	35	45
Till, buff, calcareous	10	55
Till, gray, calcareous	80	135
Kansan stage (60 feet thick):		
Till, light-buff, calcareous	20	155
Till, brownish-gray, calcareous	40	195
Nebraskan stage (55 feet thick):		
Till, buffish-brown, calcareous	10	205
Till, brownish-gray, calcareous	10	215
Till, buff, calcareous	5	220
Till, brownish-gray, calcareous	5	225
Till, buff, calcareous	5	230
Sand and gravel, heterogeneous	20	250
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds:		
Sandstone, clear, loose, angular to round; siltstone, light-gray, noncalcareous	1±	251± T.D.

87-28-12J2. Sample log of Lehigh town well in the SE/c NE¼ SE¼ sec. 12, T. 87 N., R. 28 W. Drilled in 1936 and 1937 by Thorpe Well Co., Des Moines. Altitude of land surface, 947 feet. Sample study by R. C. Northup.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (27 feet thick):		
Soil, brown	10	10
Gravel	17	27
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (170 feet thick):		
Shale, gray, silty, trace of coal in lower part	93	120
Shale, dark brownish-gray	45	165
Sandstone, gray, fine, dirty, free	10	175
Shale, dark-gray	22	197
Mississippian system.		
Osagian series.		
Undifferentiated beds (66 feet thick):		
Shale, light-green, calcareous	8	205
Dolomite, brown, finely crystalline, calcareous; chert, chalcedonic, drusy	15	220
No sample	2	222
Limestone, gray, earthy	5	227
Dolomite, light-gray, finely crystalline	12	239
Limestone, cream, oolitic, fragmental, fossiliferous; trace of glauconite	6	245
Dolomite, brown, finely crystalline, calcareous in part; chert, grayish white, smooth	18	263
Kinderhookian series.		
Gilmore City limestone (67 feet thick):		
Limestone, cream, lithographic and fragmental	19	282
No sample	6	288
Dolomite, grayish-brown, finely crystalline, calcareous; trace of chert, grayish-white, smooth	12	300

Mississippian system—Continued		
Kinderhookian series—Continued		
Gilmore City limestone—Continued		
Limestone, cream, lithographic, some earthy and fragmental	30	330
Hampton formation (170 feet thick):		
Iowa Falls member (20 feet thick):		
Dolomite, light-brown, medium to coarsely crystalline, vuggy	10	340
No sample	5	345
Dolomite, light-brown, medium to coarsely crystalline, calcareous, vuggy	5	350
Eagle City member (40 feet thick):		
Limestone, cream, finely crystalline, also white, chalky, with few imbedded dolomite rhombs	20	370
No sample	10	380
Limestone, cream, finely crystalline	5	385
No sample	5	390
Maynes Creek member (110 feet thick):		
Dolomite, brown, finely crystalline calcareous; chert, gray, rough and tripolitic	35	425
No sample	5	430
Dolomite, brown, finely saccharoidal	15	445
Dolomite, brown, finely crystalline, and dolomite, gray, finely saccharoidal; chert, gray, rough	40	485
Dolomite, buff, finely crystalline, slightly calcareous	10	495
Dolomite, gray, finely granular, very silty	5	500
Maple Mill shale (20 feet thick):		
Siltstone, gray, soft, friable	10	510
Shale, pale greenish-gray, soft	10	520
Aplington limestone (10 feet thick):		
Dolomite, dark-brown, finely to medium crystalline; chert, white to light-gray, smooth	10	530

	Thickness	Depth
Devonian system.		
Sheffield shale (20 feet thick):		
Shale, pale greenish-gray; small amount of dolomite, gray, argillaceous	20	550
Lime Creek—Shell Rock formations (75 feet thick):		
Dolomite, cream, finely to medium crystalline, calcareous; limestone, cream, with imbedded dolomite rhombs	20	570
Limestone, light-gray and cream, finely crystalline, becoming chalky with dolomite rhombs near base	35	605
Dolomite, yellow, very coarsely crystalline, calcareous; shale, grayish-green, waxy, very calcareous	15	620
No sample	5	625
Cedar Valley limestone (295 feet thick):		
Dolomite, light-gray, cream, finely to medium crystalline	165	790
Dolomite, light-brown, finely crystalline	60	850
Solon member (70 feet thick):		
Limestone, cream, light brown, sublithographic	10	860
Dolomite, brown, finely saccharoidal, becoming light gray and very argillaceous; shale, medium gray, slightly dolomitic	50	910
Limestone, brown, finely crystalline	10	920
Wapsipinicon formation (85 feet thick):		
Dolomite, brown, finely crystalline	40	960
Limestone, white, finely crystalline	5	965
Dolomite, light-gray, finely crystalline	40	1,005 T.D.

87-28-30C1. Sample log of Otto Cling farm well near Harcourt in NE¼ NE¼ NW¼ sec. 30, T. 87 N., R. 28 W. Drilled in 1949 by Harold Rasmussen, Callender. Altitude of land surface, 1,150 feet. Sample study by G. C. Huntington.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (100 feet thick):		
Till, buff, calcareous	15	15
Till, gray, calcareous	85	100
Kansan stage (15 feet thick):		
Till, buff, calcareous	15	15
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (71 feet penetrated):		
Shale, light-gray, silty, arenaceous	22	137
Sandstone, fine to coarse, angular to curvilinear, loosly cemented	49	186 T.D.

87-29-3R1. Sample log of Richard Paul farm well near Callender in the SE¼SE¼SE¼ sec. 3, T. 87 N., R. 29 W. Drilled in 1950 by Four States Drilling Co., Fort Dodge. Altitude of land surface, 1,150 feet. Sample study by G. C. Huntington.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (70 feet thick):		
Till, yellow, calcareous	10	10
Till, gray, calcareous	25	35
Sand, fine to coarse, angular to curvilinear, heterogeneous minerals	5	40
Till, grayish-brown, calcareous	30	70
Kansan stage (50 feet thick):		
Till, tan, leached	5	75
Till, tan, calcareous	45	120
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (105 feet thick):		
Shale, black, laminated, hard	5	125
Shale, light- to dark-gray, massive; trace of coal	25	150
Shale, black	5	155
Shale, dark-gray	5	160
Sandstone, gray to clear, fine, calcareous, micaceous	6	166
Shale, black	49	215
Sandstone, gray to clear, fine to coarse, calcareous	10	225
Mississippian system.		
Meramecian series.		
Ste. Genevieve limestone (20 feet thick):		
Shale, red, soft, massive, calcareous	5	230
Shale, gray, massive, waxy	15	245
St. Louis limestone (40 feet thick):		
Limestone, brown, lithographic; trace of chert, gray	15	260
Limestone, as above; dolomite, brown, very finely crystalline, dull	15	275

Mississippian system—Continued		
Meramecian series—Continued		
St. Louis limestone—Continued		
Sandstone, medium to finely crystalline, curvilinear to rounded, frosted	10	285
Osagian series.		
Undifferentiated beds:		
Dolomite, brown, crystalline; trace of chert, white, porcelaneous; trace of druses	10	295
Shale, gray, calcareous; some druses	6	301
Dolomite, brown, medium crystalline, dense, brilliant	9	310
Limestone, gray, soft, lithographic	10	320
Dolomite, brown, medium, crystalline, calcitic	10	330
Limestone, gray, soft, lithographic	15	345
Dolomite, brown, medium, crystalline; chert, tripolitic	5	350
Shale, gray	5	355
Dolomite, dark gray, finely granular	20	375
Kinderhookian series.		
Gilmore City limestone (5 feet penetrated):		
Limestone, cream, lithographic, dense	5	380 T.D.

87-30-12E1. Sample log of Callender town well in the SE¼SW¼NW¼ sec. 12, T. 87 N., R. 30 W. Drilled in 1938 by Thorpe Well Co., Des Moines. Altitude of land surface 1,150 feet. Sample study by J. B. Carrier.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (97 feet thick):		
Till, drab, calcareous	40	40
Till, with some coarse sand and gravel	15	55
No sample	5	60
Till, gray, calcareous	30	90
Gravel, 1 to 5 mm, heterogeneous	7	97
Kansan stage (21 feet thick)		
Till, buff, leached	8	105
Till, light yellowish-brown, calcareous	13	118
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (159 feet thick):		
Shale, medium-gray, laminated, slightly micaceous	42	160
Shale, medium to dark-gray, laminated; some siltstone, medium yellowish-gray, hard	30	190
Shale, gray and some black, calcareous	5	195
Underclay, buff, waxy	5	200
Shale, dark-gray to gray; some siltstone near base	15	215
Shale, medium-gray, soft; some clay, light-buff, waxy	5	220
Shale, medium-gray, soft; trace of coal	20	240
Shale, medium-gray; some sandstone, light-buff, argillaceous	5	245
Shale, medium-gray, laminated, some silty	10	255
Shale, black, carbonaceous, fissile; underclay, buff, waxy, soft, splintery	5	260
Shale, light to dark-gray	10	270
No sample	7	277

	Thickness	Depth
Mississippian system.		
Meramecian series.		
St. Louis limestone (33 feet thick):		
Limestone, light-gray, very finely crystalline; trace of pyrite	3	280
Limestone, very light buff to tan, oolitic, finely crystalline; sandstone, fine to medium, angular, pitted; trace of chert, pale-gray	15	295
Shale, light grayish-green, calcareous	5	300
Dolomite, light-drab, fine, arenaceous; trace of sandstone; trace of chert, light-gray	10	310
Osagian series.		
Undifferentiated beds (100 feet thick):		
Shale, light greenish-gray, soft, calcareous	15	325
Dolomite, light-buff, some mottled pale-gray, finely granular; chert, pink, orange, pale-gray	5	330
Shale, medium gray, soft to hard	10	340
Dolomite, medium drab, mottled, finely granular, argillaceous; some chert, gray, some quartzose	15	355
Dolomite, medium drab, finely granular	15	370
Limestone, buff, finely granular	5	375
Limestone, buff to gray, fine to medium, crystalline, glauconitic	5	380
Limestone, as above; some chert, pale gray, mottled black	10	390
Dolomite, light medium drab, finely granular, mottled, argillaceous; some chert, as above	10	400
Limestone, drab, finely granular, mottled medium gray, argillaceous; some chert	10	410
Kinderhookian series.		
Gilmore City limestone (115 feet thick):		
Limestone, light-buff, finely crystalline, some fragmental, pseudo-oolitic	115	525

Mississippian system—Continued		
Kinderhookian series—Continued		
Hampton formation (195 feet thick):		
Iowa Falls member:		
Dolomite, light medium drab, medium granular; limestone, light-buff to gray, finely to medium granular; trace of chert, blue-gray waxy	10	535
Dolomite, medium buffish brown, mottled gray; limestone, very light buff, very finely crystalline	5	540
Dolomite, drabbish brown, medium crystalline; some limestone	15	555
Eagle City member:		
Limestone, light-buff, very finely crystalline, soft	10	565
Dolomite, brownish-drab, medium crystalline	10	575
Dolomite, brown, finely granular, some speckled black; trace of calcite crystals	25	600
Dolomite, medium-drab to gray, finely granular, silty, argillaceous	20	620
Dolomite, medium-drab, finely to medium crystalline; some limestone, light-buff, finely crystalline, oolitic	10	630
Dolomite, light medium drab to gray, finely granular, grading into limestone	15	645
Dolomite, light medium gray and drab, finely crystalline, dense; some chert, very light gray, imbedded oolites	45	690
Dolomite, light medium drab, mottled dark gray, finely crystalline	25	715
Chapin member:		
Limestone, very light drab, mottled, finely crystalline	5	720
Prospect Hill member:		
Sandstone, gray, very fine, silty, dolomite cement; trace sandstone, medium, frosted	7	727 T.D.

87-30-35H1. Sample log of E. Meckley farm well near Gowrie in the SE¼SE¼NE¼ sec. 35, T. 87 N., R. 30 W. Drilled in 1950 by Harold Rasmussen, Callender. Altitude of land surface, 1,145 feet. Sample study by G. C. Huntington.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (125 feet thick):		
Till, brown, leached; soil	3	3
Till, buff, calcareous	19	22
Till, gray, calcareous	28	50
Till, brownish-gray, calcareous	75	125
Kansan stage (80 feet thick):		
Till, buff, calcareous	25	150
Till, brownish-gray, calcareous	40	190
Till, brownish-gray, silty	15	205
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (80 feet thick):		
Sandstone, gray, very fine, very argillaceous, micaceous	80	285
Mississippian system.		
Meramecian series.		
Ste. Genevieve limestone (22 feet thick):		
Limestone, cream, coarsely crystalline, fossiliferous	5	290
Shale, green, calcareous	17	307
St. Louis limestone (50 feet penetrated):		
Limestone, cream to brown, dense, dull	9	316
Limestone, as above; some sandstone, medium to coarse; some quartz and chalcedony	12	328
Dolomite, brown, very finely crystalline; sandstone, as above	29	357 T.D.

88-27-3D1. Sample log of Duncombe town well in SW¼ NW¼NW¼ sec. 3, T. 88 N., R. 27 W. Drilled in 1945 by Layne-Western Company, Ames. Altitude of land surface, 1,115 feet. Sample study Ethylmae Schultz.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (235 feet thick):		
Soil developed on till, brown, sandy, leached	5	5
Till, buff, calcareous	10	15
Till, gray, calcareous	80	95
Sand and gravel, heterogeneous	5	100
Till, drab	60	160
Sand and gravel, very coarse	10	170
Sand, brown, fine, angular, some mica	5	175
Sand, white, medium, angular	10	185
Till, drab	25	210
Sand and gravel, heterogeneous, some clayey	25	235
Mississippian system.		
Osagian series.		
Undifferentiated beds (45 feet thick):		
Limestone, cream, finely crystalline	10	245
Dolomite, drab, finely crystalline; some chert, grayish-white, tripolitic	10	255
Dolomite, gray, finely crystalline, argillaceous; some chert, as above	5	260
Dolomite and chert, as above; some shale, gray, dolomitic	15	275
Dolomite, as above; chert, cream to white, banded	5	280
Kinderhookian series.		
Gilmore City limestone (125 feet thick):		
Limestone, cream, finely crystalline	15	295
Limestone, cream to buff, finely crystalline, fragmental, oolitic	110	405

Mississippian system—Continued		
Kinderhookian series—Continued		
Hampton formation (150 feet thick):		
Eagle City member:		
Limestone, finely crystalline to sublithographic, earthy; some dolomite rhombs; some dolomite, drab, finely granular	50	455
Dolomite, gray, finely granular	5	460
Dolomite, as above; some chert, gray, dull	15	475
Dolomite, as above	15	490
Dolomite, cream to brown, finely saccharoidal; some chert, gray; trace of calcite crystals	50	540
Dolomite, creamy drab, finely crystalline, grading into limestone, cream	10	550
Dolomite, cream, finely granular	3	553
Prospect Hill member:		
Siltstone, gray, calcareous	2	555
Devonian system.		
Upper Devonian series.		
Sheffield shale (25 feet thick):		
Shale, light gray, some silty, calcareous	25	580
Lime Creek, Shell Rock, and Cedar Valley formations (394 feet penetrated):		
Dolomite, cream and gray, finely granular	20	600
Limestone, light-cream and gray, sublithographic to lithographic; small amount of dolomite, cream, finely granular	45	645
Dolomite, buff; some limestone, as above	10	655
Dolomite, cream, sublithographic	5	660
Dolomite, beige, very finely granular; some shale, light-green, dull	10	670
Limestone, tan, finely crystalline	5	675
Dolomite, beige, very finely granular, with some calcite crystals	10	685
Dolomite, golden tan, finely granular	5	690
Dolomite, brown, finely granular, dense, hard with some shale, light-gray	15	705

Devonian series—Continued		
Upper Devonian series—Continued		
Lime Creek, Shell Rock, and Cedar Valley formations—Continued		
Dolomite, light-gray to light-brown, very finely crystalline, dense	25	730
Shale, light gray, soft, dull, calcareous	25	755
Dolomite, beige, sublithographic to very finely crystalline; some sandstone, medium	5	760
Dolomite, medium gray, very finely crystalline	20	780
Shale, light gray, dull, calcareous	10	790
Dolomite, cream, finely granular	10	800
Shale, gray	5	805
No sample	5	810
Dolomite, very light gray, finely crystalline	5	815
Dolomite, light cream, finely granular	25	840
Dolomite, beige, very finely granular	20	860
Dolomite, cream, sublithographic; trace of sand, fine, frosted	5	865
Dolomite, tan, finely saccharoidal	5	870
Shale, light-gray, soft	5	875
Dolomite, yellow, very finely crystalline, slightly argillaceous; trace of shale, brown and green	20	895
Limestone, yellow, very finely crystalline to sublithographic, earthy; some dolomite, yellow, finely crystalline; trace of sand, frosted, near base	30	925
Limestone, yellow and white, sublithographic; small amount of shale; trace of sand, frosted	10	935
Dolomite, cream, very finely crystalline	5	940
Limestone, yellow, sublithographic	5	945
Limestone, as above; shale, light-gray, soft, calcareous; shale content increasing with depth	29	974 T.D.

88-28-5D2. Sample log of Certain-teed Products Corp. well 4 near Fort Dodge in NW¼NW¼NW¼ sec. 5, T. 88 N., R. 28 W. Drilled in 1950 by Thorpe Well Co., Des Moines. Altitude of land surface, 1,115 feet. Sample study by G. C. Huntington.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (55 feet thick):		
Soil, leached	5	5
Till, gray, calcareous	35	40
Till, tan, leached	15	55
Permian (?) system.		
Fort Dodge formation (5 feet thick):		
Gypsum	5	60
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (60 feet thick):		
Shale, grayish-red, soft, micaceous	5	65
Shale, dark-gray, soft, with iron compound nodules	15	80
Shale, black, fissile	25	105
Shale, light-gray, soft, calcareous	5	110
Shale, dark-gray, soft	5	115
Shale, light-gray, unctuous; some sandstone, clear, angular	5	120
Mississippian system.		
Meramecian series.		
Ste. Genevieve limestone (77 feet thick):		
Shale, light gray, calcareous	20	140
Shale, dark red, calcareous	57	197
St. Louis limestone (48 feet thick):		
Limestone, cream, sublithographic, with imbedded sand	18	215
Dolomite, brown, very finely granular; some limestone, as above	10	225
Shale, red and green, soft calcareous with sand; some limestone and dolomite, as above	20	245

Mississippian series—Continued		
Osagian series.		
Undifferentiated beds (80 feet thick):		
Shale, gray, soft, slightly calcareous	10	255
Dolomite, brown, finely crystalline; limestone, grayish-brown, medium to coarsely crystalline; some fragmental; trace of chert, milky, banded, some speckled black	45	300
Shale, gray	5	305
Dolomite and limestone, as above; some shale, as above	20	325
Kinderhookian series.		
Gilmore City limestone (95 feet thick):		
Limestone, cream, lithographic	15	340
Limestone, cream, fragmental and oolitic, some lithographic; some limestone, silty	80	420
Hampton formation (178 feet thick):		
Iowa Falls member:		
Dolomite, light-brown, medium to coarsely crystalline	35	455
Dolomite, as above; limestone, gray, very finely granular	10	465
Eagle City member:		
Limestone, cream, lithographic, some oolitic	30	495
Maynes Creek member:		
Dolomite, brown, medium crystalline, calcitic; some chert, gray, granular, dull	15	510
Dolomite, gray, very finely saccharoidal; trace of chert and pyrite	40	550
Dolomite, as above; chert, gray, dull; trace of pyrite	25	575
Dolomite, as above; trace of chert	10	585
Chapin member:		
Limestone, grayish-brown, medium crystalline	12	597
Siltstone, gray	1±	598±

Devonian system.		
Upper Devonian series.		
Sheffield Shale (32± feet thick):		
Shale, grayish-green, calcareous, some silty	32±	630
Lime Creek, Shell Rock, and Cedar Valley formations (420 feet thick):		
Dolomite, grayish brown, very finely crystalline, sparkling	10	640
Shale, grayish green, calcareous	15	655
Limestone, brown, finely to medium crystalline, partly lithographic	10	665
Dolomite, gray, brown, finely to medium saccharoidal; some limestone, as above, increasingly dolomitic to base	50	715
Dolomite, gray, brown, finely to coarsely saccharoidal	50	765
Dolomite, grayish-brown, finely saccharoidal, some sublithographic	25	790
Dolomite, grayish-brown, finely saccharoidal; some shale, gray	25	815
Dolomite, grayish-brown, finely saccharoidal; some sublithographic	15	830
Dolomite, gray, finely to medium saccharoidal; trace siltstone	20	850
Dolomite, dark brown, finely crystalline, sparkling	30	880
Dolomite, gray, very finely saccharoidal	45	925
Dolomite, dark brown, medium to coarsely crystalline, sparkling	45	970
Solon member of Cedar Valley:		
Limestone, grayish brown, very finely saccharoidal, earthy	10	980
Limestone, as above; limestone, gray brown, sublithographic; trace arenaceous	15	995
Shale, gray, green, calcareous	15	1,010
Limestone, gray, finely crystalline; shale, as above	5	1,015

Devonian system—Continued		
Upper Devonian series—Continued		
Solon member of Cedar Valley:		
Limestone, gray, light-brown, medium crystalline, some sublithographic; trace of dolomite, brown, finely saccharoidal	35	1,050
Middle Devonian series.		
Wapsipinicon limestone (130 feet thick):		
Dolomite, brown, finely saccharoidal	25	1,075
Dolomite, light-gray, finely saccharoidal; some dolomite, gray, finely crystalline	35	1,110
Limestone, gray, finely granular	15	1,125
Dolomite, grayish brown, finely granular	40	1,165
Dolomite, as above; some chert sand, smoky; some shale, gray	15	1,180
Ordovician system.		
Cincinnatian series.		
Maquoketa shale (95 feet thick):		
Dolomite, grayish-brown, finely crystalline; some chert, white, smooth, dull, some rough	10	1,190
Dolomite, pinkish-brown, finely crystalline; some chert, white to buff, smooth and rough	15	1,205
Dolomite, cream, coarsely saccharoidal with pyrite and black fossils	15	1,220
Dolomite, as above; chert, gray, smooth, granular, with black fossils; trace of shale, gray	20	1,240
Dolomite, light grayish-brown, finely to medium crystalline; small amount of chert, gray, smooth to granular, trace of shale, brown	35	1,275
Mohawkian series.		
Galena dolomite (120 feet thick):		
Dolomite, pinkish brown, medium to coarsely saccharoidal, with orange specks (cinnamon specks)	25	1,300

Ordovician system—Continued		
Mohawkian series—Continued		
Galena dolomite—Continued		
Dolomite, pinkish-brown and cream, medium to coarsely saccharoidal	35	1,335
Prosser member:		
Dolomite, as above; some chert, white, dull, granular; trace black specks	60	1,395
Decorah shale and Platteville limestone (130 feet thick):		
Limestone, gray, medium crystalline, mottled black	25	1,420
Shale, gray, soft, very calcareous	15	1,435
Limestone, gray, finely crystalline, earthy, mottled black, with some dolomite rhombs, fossiliferous	27	1,462
Shale, green, hard, black fossils	13	1,475
Limestone, grayish buff, fine to lithographic, black fossils	17	1,492
Shale, green, soft to hard	33	1,525
Chazyan series.		
St. Peter sandstone (53 feet thick):		
Sandstone, fine to coarsely crystalline, loose, rounded, frosted	53	1,578
Beekmantownian series.		
Prairie du Chien formation (277 feet thick):		
Willow River member:		
Dolomite, brown, medium crystalline, hard	7	1,585
Dolomite, gray, finely saccharoidal, arenaceous	35	1,620
Dolomite, as above; sandstone, fine to coarse, frosted	20	1,640
Dolomite, brown, medium crystalline, hard, sparkling	10	1,650
Root Valley member:		
Dolomite, gray, very finely crystalline; some sandstone, fine to coarse	25	1,675
Sandstone, fine to coarse, rounded, frosted	10	1,685

	Thickness	Depth
Ordovician system—Continued		
Beekmantownian series—Continued		
Oneota member:		
Dolomite, grayish-brown, finely to coarsely crystalline, dull to sparkling; trace of sand; trace of chert, gray, smooth; trace of quartz, clear, massive, and drusy	155	1,840
Dolomite, cream, finely crystalline	15	1,855
Cambrian system.		
St. Croixian series.		
Jordan sandstone (55 feet thick):		
Sandstone, subwhite, fine to coarse, subround to round, frosted, loosely cemented	55	1,910
St. Lawrence formation (95 feet thick):		
Dolomite, light-gray, finely crystalline, silty	43	1,953
Sandstone, fine to medium, with some dolomite as above	22	1,975
Dolomite, light-gray, cream, medium to finely crystalline, slightly glauconitic	30	2,005
Franconia sandstone (55 feet penetrated):		
Dolomite, light gray, finely crystalline, very silty, very glauconitic; some siltstone, gray	55	2,060 T.D.

88-30-26A1. Sample log of Howard Loehr farm well near Moorland in the SE¼ NE¼ NE¼ sec. 26, T. 88 N., R. 30 W. Drilled in 1950 by Harold Rasmussen, Callender. Altitude of land surface, 1,160 feet. Sample study by W. E. Hale.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (90 feet thick):		
Soil, brown, leached	2	2
Till, buff, calcareous	18	20
Till, gray, calcareous	55	75
Till, buffish-gray, calcareous	15	90
Kansan stage (20 feet thick):		
Till, orangish buff, leached	15	105
Till, buff, calcareous	5	110
Nebraskan (25 feet thick):		
Silt, sandy, buffish-brownish, gray, leached	5	115
Till, buffish-brown, slightly calcareous	10	125
Till, buffish-brownish, gray, calcareous	10	135
Cretaceous system.		
Upper Cretaceous series.		
Dakota formation (27 feet thick):		
Clay, brown, sandy, noncalcareous	22	157
No sample	3	160
Sand, medium to coarse, angular; quartz and chert gravel, quartz, clear and pink, chert, brown; all gravel highly polished	2	162 T.D.

89-27-7A1. Sample log of Erwin Dencklau farm well near Vincent in NE¼ NE¼ NE¼ sec. 7, T. 89 N., R. 27 W. Drilled in 1949 by Northwest Drilling Co., Humboldt. Altitude of land surface, 1,125 feet. Sample study by R. M. Jeffords.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (120 feet thick):		
Till and soil developed on till, leached	10	10
Till, buff, calcareous	15	25
Till, light gray, calcareous	45	70
Till, buffish gray, calcareous, very sandy	10	80
Till, buff, calcareous with sand	5	85
Till, buff, calcareous	10	95
Sand and gravel, buff, calcareous	5	100
Till, brown, sandy, calcareous	20	120
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (70 feet thick):		
Shale, medium gray	5	125
Shale, dark gray, clayey, micaceous	5	130
Shale, black, micaceous	10	140
Shale, dark gray; trace pyrite	20	160
Limestone, medium gray, finely crystalline; some limestone, black	5	165
Sandstone, finely crystalline; shale, dark-gray, clayey	5	170
Shale, medium gray; some pyrite	20	190
Mississippian system.		
Osagian series.		
Undifferentiated beds (65 feet thick):		
Limestone, light-gray, fine crystalline to sublithographic	5	195
Dolomite, brown, medium, granular porous	10	205
Dolomite, brown, medium, crystalline, porous and dense	10	215
Dolomite, tan, finely crystalline	5	220
Dolomite, light gray to tan, medium crystalline, granular, porous; some chert, quartzose; trace of pyrite	15	235

Mississippian system—Continued		
Osagian series—Continued		
Undifferentiated beds—Continued		
Dolomite, light-gray, finely crystalline, argillaceous, calcareous; some chert, white; some quartz	5	240
Limestone, light gray, finely crystalline, argillaceous; trace of chert, rosettes	15	255
Kinderhookian series.		
Gilmore City limestone (110 feet thick):		
Limestone, cream-white, very finely crystalline to lithographic	20	275
Limestone, cream, predominantly fragmental, oolitic; some limestone, sublithographic	90	365
Hampton formation (180 feet thick):		
Iowa Falls member:		
Dolomite, tan, medium granular	35	400
Eagle City member:		
Limestone, cream, lithographic to sublithographic	10	410
Dolomite, cream, medium to coarsely crystalline, calcite cement; limestone as above	10	420
Limestone, cream, very finely crystalline; some dolomite or calcite crystals; fossils	23	443
Limestone, medium-gray; some chert, dark-gray, banded white	7	450
Maynes Creek member:		
Dolomite, tan, fine to medium crystalline, porous; some chert, light gray to tripolitic; some chert, light gray, speckled brown	30	480
Dolomite, medium gray, finely to medium crystalline, calcareous cement, porous; trace of chert, quartzose	15	495
Dolomite, tan, medium to dark gray, finely to medium crystalline; chert, light gray, dense, some speckled	30	525

	Thickness	Depth
Mississippian system—Continued		
Kinderhookian series—Continued		
Chapin member:		
Limestone, slightly dolomitic; small amount of chert; trace of pyrite	17	542
Prospect Hill member:		
Sandstone, fine to coarse, calcareous	3	545
Devonian system.		
Upper Devonian series.		
Sheffield shale (35 feet thick):		
Shale, light gray, clayey; trace pyrite	5	550
Shale, light gray, silty; trace pyrite	10	560
Shale, light gray, clayey; trace pyrite	20	580
Lime Creek, Shell Rock, and Cedar Valley formations (293 feet penetrated):		
Dolomite, light gray and buff, finely crystalline; trace dolomite	10	590
Limestone, medium gray, finely crystalline, dolomite	10	600
Limestone, pale cream, medium crystalline	6	606
Dolomite, light gray, medium crystalline; limestone, buff	14	620
Dolomite, light gray, medium saccharoidal, calcitic	30	650
Dolomite, as above; limestone, white to steel-gray, medium crystalline	42	692
No sample	8	700
Dolomite, cream, medium crystalline; limestone, white, finely crystalline	10	710
Dolomite, medium to light gray, medium to coarsely saccharoidal, some porous	15	725
Dolomite, light gray to tan, finely crystalline, dense, argillaceous, speckled	10	735
Dolomite, creamish white and brown, dense	15	750
Dolomite, medium gray, coarsely crystalline, friable, porous	20	770
Dolomite, as above; dolomite, dark-gray, dense, hard	5	775

Devonian system—Continued		
Upper Devonian series—Continued		
Lime Creek, Shell Rock, and Cedar Valley formations—Continued		
Dolomite, white, coarsely crystalline, friable, porous	20	795
Dolomite, tan, finely granular; some dolomite, dark brownish, black, dense	5	800
Dolomite, light gray, finely crystalline; some shale, dark brownish, black, waxy; trace of pyrite	5	805
Dolomite, brown, medium crystalline	20	825
Dolomite, cream, finely to medium crystalline	15	840
Dolomite, light gray, finely crystalline; speckled dark gray	5	845
Dolomite, brown, medium crystalline	5	850
Dolomite, tan to white, medium crystalline, calcitic	5	855
Dolomite, tan to white, medium crystalline, porous	18	873 T.D.

89-28-19L12. Sample log for Fort Dodge city well 15 in SE¼ NE¼ SW¼ sec. 19, T. 89 N., R. 28 W. Drilled in 1948 by Thorpe Well Co., Des Moines. Altitude of land surface, 980 feet. Sample study by R. W. Screven.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Recent (20 feet thick):		
Soil and cinders	5	5
Sand and gravel, heterogeneous	15	20
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (160 feet thick):		
Shale, red brown, soft, micaceous, slightly calcareous	5	25
Shale, gray, micaceous, slightly calcareous; limestone, gray	20	45
Shale, dark gray to black; some siderite, brown and black; some siltstone, gray; trace of coal and pyrite	135	180
Mississippian system.		
Meramecian series.		
Ste. Genevieve limestone (65 feet thick):		
Shale, red, some green, calcareous; minor amount of limestone, buff to pink, gray, very finely crystalline to lithographic; trace of pyrite	65	245
Limestone, buff, finely crystalline, sandy; sandstone, white, fine to medium, angular to round, some frosted grains, calcareous	20	265
Dolomite, light brown, very finely crystalline; sandstone, white, medium, calcareous; trace of pyrite	15	280
Sandstone, calcareous; argillaceous	5	285
Dolomite, buff, brown, and gray, fine, sandy; limestone, buff, sublithographic; some chert, buff, gray, mottled with nodular chalcedony; some sandstone, calcareous	20	305

	Thickness	Depth
Mississippian system—Continued		
Osagian series.		
Undifferentiated beds (80 feet thick):		
Dolomite, grayish buff, finely crystalline; limestone, white, medium crystalline; trace of glauconite	5	310
Dolomite, gray and brown, finely crystalline; limestone, light brown, finely crystalline	10	320
No sample	5	325
Limestone, pink, buff and brown, fine to medium crystalline, argillaceous, porous; trace of glauconite	25	350
Dolomite, gray, brown, granular, argillaceous; limestone, buff, fragmental; trace of glauconite	15	365
Limestone, buffish gray; limestone brown, finely granular, argillaceous; some chert, white, quartzose	5	370
Dolomite, gray, brownish buff, granular, argillaceous; some chert	5	375
Limestone, gray, buff, very finely to finely crystalline, argillaceous; trace glauconite	10	385
Kinderhookian series.		
Gilmore City limestone (80 feet thick):		
Limestone, buff to light brown, sublithographic; some chert, quartzose	15	400
Dolomite, gray-buff, finely crystalline, argillaceous	5	405
Limestone, white to cream, fragmental, oolitic; minor amount of dolomite, gray, finely granular, fossiliferous	60	465
Hampton formation (190 feet thick):		
Iowa Falls member.		
Dolomite, gray and cream, coarsely to very coarsely crystalline	5	470
Limestone, buff, finely to coarsely crysstalline	5	475
Dolomite, buff, medium to coarsely crystalline, calcareous cement	10	485

Mississippian system—Continued		
Kinderhookian series—Continued		
Hampton formation—Continued		
Iowa Falls member—Continued		
No sample	5	490
Dolomite, cream, medium crystalline; some limestone, oolitic	10	500
Eagle City member.		
Limestone, cream, lithographic, with scattered dolomite rhombs	25	525
Maynes Creek member.		
Dolomite, pink, brown, finely to medium crystalline, some saccharoidal, some porous; some chert, buff to light buff, granular	25	550
Dolomite, gray, finely crystalline; porous; some chert, as above; some chert, gray-white, granular, tripolitic	15	565
Dolomite, gray, finely crystalline; dolomite, buff, medium crystalline	15	580
Dolomite, as above, argillaceous	10	590
Dolomite, gray, grayish brown, finely to medium crystalline, porous; some chert, buffish white and gray, granular	10	600
No sample	5	605
Dolomite, gray, finely crystalline; chert, buffish-white and gray, oolitic, smooth to granular, dolomitic; minor amount of green shale	35	640
Dolomite, creamy buff, finely to medium crystalline, porous	15	655
Devonian system.		
Upper Devonian series.		
Sheffield shale (35 feet thick):		
Shale, light green, soft, calcareous; some limestone, light brown, finely to medium crystalline; some dolomite, light brown, medium crystalline	35	690

Devonian system—Continued		
Upper Devonian series—Continued		
Lime Creek, Shell Rock, and Cedar Valley formations (195 feet penetrated; fault cuts out about 210 feet of beds):		
Limestone, buffish-white and light brown, sublithographic to finely crystalline; some shale, dark green, laminated, glauconitic	10	700
Dolomite, pink to buff, finely crystalline; limestone, pink to buff, finely crystalline to sublithographic	40	740
Dolomite, cream, medium to coarsely crystalline	22	762
Shale, green, micaceous	3	765
No sample; inferred position of fault plane	5	770
Limestone and dolomite, light gray and cream, coarsely crystalline	15	785
Dolomite, buffish brown and gray, finely to coarsely crystalline; limestone, buff and gray, finely to coarsely crystalline	50	835
Limestone, cream to pink, very finely to coarsely crystalline; some dolomite, gray to buff, very finely crystalline	5	840
Shale, green, calcareous	10	850
Limestone, gray, buff, finely to medium crystalline; some shale, dark green, brittle, waxy; fossil fragments	15	865
Limestone as above, mottled; fossil fragments	5	870
Limestone, gray and gray-brown, fragmental	15	885
Dolomite, brown, finely granular; limestone, cream, coarsely crystalline	5	890

	Thickness	Depth
Devonian system—Continued		
Upper Devonian series—Continued		
Lime Creek, Shell Rock, and Cedar Valley formations—Continued		
Limestone, cream, finely crystalline, some fragmental, oolitic; fossil fragments	5	895
Middle Devonian series.		
Wapsipinicon limestone (120 feet thick):		
Dolomite, buffish brown and gray, very finely to coarsely crystalline	25	920
Dolomite, gray, some buff, very finely crystalline, argillaceous; some chert, grayish white, granular, speckled gray	15	935
Dolomite, as above	25	960
Dolomite, as above, with dark-gray streaks	5	965
Dolomite, grayish buff, very finely granular	20	985
Dolomite, as above; trace of chert, white, containing buff and gray fossils	20	1,005
Limestone, gray, finely crystalline; dolomite, grayish buff, granular; shale, green, calcareous; sandstone, medium, rounded, frosted; chert, milky, smoky, smooth to granular	10	1,015
Ordovician system.		
Cincinnatian series.		
Maquoketa shale (65 feet thick):		
Dolomite, light buff, finely crystalline; some limestone, buff and green, finely to medium crystalline; some limestone, buff and green, finely to medium crystalline; some chert, white to smoky, smooth	10	1,025
Dolomite, buffish-cream, finely to medium crystalline; some limestone, trace of chert	5	1,030

Ordovician system—Continued		
Cincinnatian series—Continued		
Maquoketa shale—Continued		
Dolomite, buff-cream, finely to medium crystalline; limestone as above; trace of chert, buffish white, granular, trace of speckled black	5	1,035
Dolomite, grayish buff, finely to coarsely crystalline; some chert, buffish white, granular, trace tripolitic; trace of limestone and shale	40	1,075
Shale, green, laminated	5	1,080
Mohawkian series.		
Galena dolomite (205 feet thick):		
Dolomite, buff, brown, gray, finely to medium crystalline	15	1,095
Dolomite and limestone, buff to gray, very finely to medium crystalline	15	1,110
Dolomite, cream to gray, finely to medium saccharoidal	55	1,165
Dolomite, grayish buff, finely crystalline, speckled orange	15	1,180
Dolomite, pinkish buff and gray, finely crystalline	20	1,200
Dolomite, cream to buff, very finely to finely crystalline; some chert, off-white, granular to tripolitic; contains fossils	40	1,240
Dolomite, light grayish buff, finely to medium crystalline; some chert, buff-white, granular to tripolitic, speckled black and buff	10	1,250
Dolomite, buff and gray, finely crystalline, mottled and speckled black with small amount of chert	35	1,285
Decorah shale and Platteville limestone (115 feet thick):		
Limestone and dolomite, gray, some pink, finely crystalline	35	1,320
Shale, green, soft, calcareous; some limestone, buff, black and white, finely crystalline; trace pyrite; fossils	40	1,360

Ordovician system—Continued		
Mohawkian series—Continued		
Decorah shale and Platteville limestone—Continued		
Shale, brown, flaky, calcareous	10	1,370
Shale, green, fissile; some limestone; some sandstone, frosted	20	1,390
No sample	10	1,400
Chazyan series.		
St. Peter sandstone (65 feet thick):		
Sandstone, white, fine to medium, rounded, frosted	40	1,440
Sandstone, as above; trace of shale, green	15	1,455
No sample	5	1,460
Sandstone, as above	5	1,465
Beekmantownian series.		
Prairie du Chien formation (325 feet thick):		
Willow River member.		
Dolomite, grayish buff, finely crystalline, some silty, sandy	30	1,495
Dolomite, pink, cream and brown, arenaceous; sandstone, fine to medium, frosted	55	1,550
Root Valley member.		
Sandstone, fine to coarse, round to subround, frosted; some dolomite, arenaceous	35	1,585
Oneota member.		
Chert, buff and white, containing oolites, some quartzose; some sandstone	10	1,595
Chert, buff and white, arenaceous, quartzose; small amount of dolomite, light buff to brown, finely crystalline, arenaceous	40	1,635
Dolomite, buff to gray, some pink, finely crystalline, arenaceous; some chert, as above; trace of sandstone	95	1,730

	Thickness	Depth
Cambrian system.		
St. Croixian series.		
Jordan sandstone (60 feet thick):		
Sandstone, fine to coarse, rounded, frosted, trace dolomite cement	60	1,790
St. Lawrence formation (80 feet thick):		
Dolomite, dark gray and buff, arenaceous, argillaceous; trace glauconite in lower part	80	1,870
Franconia formation (250 feet thick):		
Siltstone, gray; dolomite, very glauconitic	105	1,975
Shale, green, some fissile, calcareous; limestone, buffish brown, finely crystalline; much glauconite	135	2,110
Glauconite; some limestone and shale, as above	10	2,120
Dresbach formation (70 feet thick):		
Eau Claire member.		
Limestone, buff-white, silty; some glauconite; some shale, green, laminated	105	2,225
Mt. Simon member.		
Sandstone, grayish white, fine to medium, calcareous	15	2,240
No samples	10	2,250
Sandstone, clear to orange, medium to coarse, angular to round, frosted, coarseness increasing toward bottom; some siltstone, grayish green, argillaceous	40	2,290
Pre-Cambrian system (?)		
Undifferentiated beds (17 feet penetrated):		
Basalt, red, serpentinized	17	2,307 T.D.

89-28-19P5. Sample log of Cargill Co. well at Fort Dodge in NE¼SE¼SW¼ sec. 19, T. 90 N., R. 28 W. Drilled in 1946 to a depth of 545 feet and deepened to 1,190 feet in 1950, by Layne-Western Co., Ames. Altitude of land surface, 990 feet. Sample study by W. E. Hale and G. C. Huntington.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Recent (5 feet thick):		
Fill material, no samples	5	5
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (30 feet thick):		
Shale, gray to dark gray; trace coal	20	25
Shale, dark gray, pyritic; sandstone, white, medium, angular	5	30
Shale, drabbish white, pyritic	5	35
Mississippian system.		
Meramecian series.		
Ste. Genevieve limestone (50 feet thick):		
Shale, gray to pale pink, calcareous; trace pyrite	15	50
Limestone, pale pink, very finely crystalline to sublithographic	5	55
Shale, green and pink, calcareous; trace pyrite	25	80
Limestone, green, earthy, very finely crystalline	5	85
St. Louis limestone (50 feet thick):		
Dolomite, tan, coarsely to finely crystalline, arenaceous; sandstone, white, medium, angular to subround, frosted; some limestone, cream, lithographic; trace chert, brown, watery	15	100
Dolomite, buff to brown, very finely crystalline	5	105
Limestone and dolomite, gray, very finely crystalline	5	110
Shale, pale gray, silty, sandy	5	115

Mississippian system—Continued		
Meramecian series—Continued		
St. Louis limestone—Continued		
Dolomite, brown, very finely crystalline; limestone, light gray, lithographic; some sandstone, medium, frosted; trace chert, brown, watery ..	10	125
Shale, gray, sandy	10	135
Osagian series.		
Undifferentiated beds (80 feet thick):		
Dolomite, gray to dark brown, coarsely saccharoidal, porous, some speckled white; trace shale, green, glauconitic and pyritic	15	150
Dolomite, as above; some limestone; trace shale, gray; trace chert, drusy	10	160
Dolomite, brown, medium crystalline, silty	15	175
Dolomite, as above; some dolomite, earthy; some sandstone, medium	5	180
Dolomite, light brown, medium crystalline, vuggy; limestone, gray, very coarsely crystalline, earthy; trace pyrite	10	190
Shale, gray silty	5	195
Dolomite, grayish brown, medium crystalline; some vuggy, some silty and argillaceous; trace pyrite	20	215
Kinderhookian series.		
Gilmore City limestone (95 feet thick):		
Limestone, cream, lithographic to very finely crystalline	20	235
Limestone, as above: limestone fragmental, oolitic; trace of pyrite in lower part	75	310
Hampton formation (180 feet thick):		
Iowa Falls member.		
Dolomite, tan, coarsely crystalline, vuggy	15	325

Mississippian system—Continued		
Kinderhookian series—Continued		
Hampton formation—Continued		
Iowa Falls member—Continued		
Limestone, drabbish white, crystalline, oolitic	10	335
Dolomite, tan, coarsely crystalline, some silty	10	345
Eagle City member.		
Limestone, buff, medium to coarsely crystalline	10	355
Limestone, buff, lithographic	20	375
Maynes Creek member.		
Dolomite, tan, coarsely saccharoidal, porous; some chert, buff, smooth, trace watery brown; trace of pyrite	20	395
Dolomite, gray, finely to medium crystalline, argillaceous; trace of chert, gray	15	410
Dolomite, gray to buff, finely to coarsely crystalline; some limestone, gray to buff, finely to medium crystalline	25	435
Dolomite, gray, finely crystalline; some chert, gray, smooth, some speckled brown	10	445
Dolomite, gray, finely crystalline, silty; some limestone, gray, coarsely crystalline; some chert, as above	40	485
Dolomite, beige, medium crystalline; some limestone, gray, medium crystalline	5	490
Devonian system.		
Upper Devonian series.		
Sheffield shale (40 feet thick):		
Shale, light-green, smooth; trace of dolomite, light-gray, medium	40	530
Lime Creek, Shell Rock, and Cedar Valley formations (420 feet thick):		
Dolomite, light gray, fine, dense	10	540
No samples	40	580

Devonian system—Continued
Upper Devonian series—Continued
Note: Driller's log from 580 to 1,005 feet.

Limestone, hard	100	680
Shale, blue	10	690
Limestone	195	885
Shale, blue	15	900
Limestone	5	905
Shale	10	915
Limestone, hard	35±	950±
Middle Devonian series?		
Wapsipinicon limestone (approximately 120 feet thick):		
Limestone, hard	45±	995
Shale, blue	5	1,000
Limestone	5	1,005
Dolomite, gray, finely granular	45	1,050
Dolomite, gray, finely granular, some sandy; some chert, black sand grains	10	1,060
Shale, grayish green, soft, calcareous, sandy	10	1,070
Ordovician system.		
Cincinnatian series.		
Maquoketa formation (80 feet thick):		
Dolomite, gray, finely granular; some chert, white, smooth to granular, dull, some tripolitic; trace shale, green and brown	35	1,105
Dolomite, cream, medium to coarsely crystalline, dense, some arenaceous; some chert, as above	15	1,120
Shale, gray, dolomitic; cherty	30	1,150
Mohawkian series:		
Galena dolomite (40 feet penetrated):		
Dolomite, cream, medium to coarsely crystalline; some chert, cream, smooth to granular	15	1,165
Shale, very dark green; some chert, as above	5	1,170
Dolomite, cream, medium to coarsely crystalline; some chert as above	20	1,190 T.D.

89-28-26E1. Sample log of Certain-teed Products Corp. well near Fort Dodge in NW¼ SW¼ NW¼ sec. 26, T. 90 N., R. 28 W. Drilled in 1946 by Art Vinson, Fort Dodge. Altitude of land surface, 1,115 feet. Sample study by W. E. Hale.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (45 feet thick):		
No sample	5	5
Till, gray, calcareous	25	30
Sand and gravel, heterogeneous, dirty	15	45
Permian (?) system.		
Fort Dodge formation (20 feet thick):		
Shale, red, soft, silty, very calcareous	5	50
Gypsum, massive	14±	64±
Shale, red, calcareous	1±	65
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (15 feet thick):		
Shale, dark gray, laminated, waxy	15	80
Mississippian system.		
Meramecian series.		
Ste. Genevieve limestone (60 feet thick):		
Shale, gray, green and red, soft, calcareous, with some pyrite; some limestone, light gray, finely crystalline; fossils	60	140
St. Louis limestone (45 feet thick):		
Limestone, beige, very finely crystalline	5	145
Dolomite, beige to tan, finely to very finely crystalline, sandy, silty, some argillaceous; some sandstone, medium, frosted	35	180
Sandstone, fine to medium, frosted	5	185
Osagian series (50 feet penetrated):		
Undifferentiated beds:		
Shale, medium gray, unctuous; trace pyrite	15	200

Mississippian system—Continued		
Osagian series—Continued		
Undifferentiated beds—Continued		
Dolomite, buff, gray, mostly brown, medium saccharoidal; some chert, dull white and quartzose; trace glauconite	15	215
Dolomite, brown, medium saccharoidal, lower 10 feet porous	20	235
No sample	12	247 T.D.

89-29-20N1. Sample log of Swaney Motor Co. farm well near Moorland in the NW¼ SW¼ SW¼ sec. 20, T. 89 N., R. 29 W. Drilled in 1948 by Art Vinson, Fort Dodge. Altitude of land surface, 1,160 feet. Sample study by M. C. Parker.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (125 feet thick):		
Till, buff, sandy, calcareous	10	10
Sand, buff, fine, calcareous	5	15
Till, gray, calcareous	15	30
Sand and gravel, heterogeneous	20	50
Till, gray, calcareous	10	60
Till, buffish, orange, calcareous	20	80
Clay, buffish brown, silty, sandy, calcareous	5	85
Clay, as above, slightly calcareous	5	90
Till, gray and brown, calcareous	5	95
Clay, brown, silty, sandy, noncalcareous, micaceous	10	105
Clay, as above, slightly calcareous	20	125
Cretaceous system.		
Upper Cretaceous series.		
Dakota (?) formation (30 feet thick):		
Shale, light creamish gray, soft, unctuous, with fine sand	5	130
Sandstone, white and yellow, very fine to fine, angular, few coarse grains, polished	10	140
Shale, as above	5	145
Sandstone, white to yellow, fine to medium, angular, some pink and black grains, larger grains polished	10	155
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (115 feet thick):		
Sandstone, light gray, very fine, dolomite cement; shale, dark gray, laminated	10	165
Shale, dark gray, soft, unctuous, laminated; trace pyrite	10	175

Pennsylvanian system—Continued		
Desmoinesian series—Continued		
Undifferentiated beds—Continued		
Shale, black, laminated, soft, unctuous; some pyrite; some sandstone, very fine, angular; and shale, gray	30	205
Shale, medium gray, soft, laminated	10	215
Shale, black	22	237
Sandstone, light gray, calcareous; trace chert, light gray and buff, granular	8	245
Dolomite, buff, very finely crystalline, dense; some chert, grayish white and dark gray, granular	5	250
Shale, black, with some pyrite	10	260
Shale, green; some pyrite; trace of limestone, brown, finely crystalline	10	270
Mississippian system.		
Meramecian series.		
St. Louis limestone (10 feet thick):		
Dolomite, brown-black, mottled, fine to medium fragmental; some sandstone, frosted, subround	5	275
Limestone, gray, finely crystalline, argillaceous; some dolomite and sandstone, as above	5	280
Osagian series.		
Undifferentiated beds (10 feet penetrated):		
Dolomite, creamish brown, finely granular, porous; some chert, buff, mottled, nodular, fragmental	10	290 T.D.

89-29-31F1. Sample log of A. J. Crawford farm well near Moorland NE¼ SE¼ NW¼ sec. 31, T. 89 N., R. 29 W. Drilled in 1948 by Harold Rasmussen, Callender. Altitude of land surface, 1,171 feet. Sample by R. W. Screven.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (75 feet thick):		
No samples	30	30
Till, buff, calcareous	10	40
Till, grayish buff, calcareous	10	50
No sample	10	60
Sand and gravel, heterogeneous	5	65
No sample	10	75
Kansan stage (60 feet thick):		
Till, orangey-buff, leached	5	80
No sample	5	85
Till, orange, slightly calcareous	5	90
Till, orange, calcareous	5	95
Till, buff, calcareous	5	100
No sample	5	105
Till, buffish brown, slightly calcareous	10	115
Till, brownish gray, silty, slightly calcareous	5	120
Till, grayish buff, calcareous	10	135
Permian (?) system.		
Fort Dodge formation (23 feet thick):		
Shale, red, soft, sandy, silty, calcareous with authigenic quartz	10	145
Sandstone, pink, fine to very fine, calcareous	12	157
Shale, gray, calcareous, silty	5±	162
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (3± feet penetrated)		
Shale, black	3±	165 T.D.

89-30-2Q1. Driller's and sample log of V. F. Lentsch farm well near Clare in the SE¼ SW¼ SE¼ sec. 2, T. 89 N., R. 30 W. Drilled in 1946 by J. M. De Vaul, Havelock. Altitude of land surface, 1,150 feet. Sample study by Ethylmae Schultz. Driller's log to depth of 571 feet.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (116 feet thick):		
Clay, blue	94	94
Sand, yellow	10	104
Clay, gray	12	116
Cretaceous system.		
Undifferentiated section (507 feet penetrated):		
Rock	5	121
Shale, gray	32	153
Rock	4	157
Shale, gray	113	270
Shale, black	170	440
Shale; rock	26	466
Sandstone	6	472
Sandstone, hard	11	483
Shale; rock	88	571
Dolomite, yellowish gray, sublithographic, arenaceous	2	573
Shale, light gray, no structure, dull, arenaceous, dolomitic	17	590
Sandstone, yellowish white and pink, very fine to medium, angular to curvilinear, waxy	33	623 T.D.

89-30-11R1. Sample log of V. and M. McLaughlin (formerly B. Lentsch) farm well near Barnum in NE¼ SE¼ SE¼ sec. 11, T. 89 N., R. 30 W. Drilled in 1946 by Art Vinson, Fort Dodge. Altitude of land surface, 1,176 feet. Sample study by Ethylmae Schultz.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (110 feet thick):		
Till, yellow, calcareous	20	20
Till, gray, calcareous	10	30
Sand and gravel, heterogeneous, dirty	20	50
Sand, coarse (dry)	10	60
Clay, silty, brown, leached (Loveland loess?)	20	80
Sand and gravel, heterogeneous, silty	20	100
Sand, fine to meduim	5	105
Clay, gray; some sand, very fine	5	110
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (60 feet thick):		
Sandstone, very fine to fine, calcareous	30	140
Shale, gray, arenaceous, calcareous	5	145
Dolomite, brown and gray, dense, argillaceous	5	150
Shale, dark gray, unctuous; trace of sandstone, white, medium coarse, waxy, pyritic; trace of coal	20	170
Mississippian system.		
Meramecian series.		
St. Louis limestone (60 feet thick):		
Limestone, beige, earthy, very arenaceous; sandstone, white, frosted	2	172
Shale, light-gray, soft, unctuous	3	175
Sandstone, yellow, coarse, waxy (crevice filling)	10	185
Limestone, tan and beige, finely crystalline, arenaceous	15	200
Sandstone, coarse, dull, waxy (crevice filling)	5	205

Mississippian system—Continued		
Meramecian series—Continued		
St. Louis limestone—Continued		
Dolomite, cream, very finely crystalline to lithographic	5	210
Limestone, beige, very arenaceous	5	215
Limestone and dolomite, as above; sandstone (crevice filling)	15	230
Osagian series.		
Undifferentiated beds (80 feet thick):		
Dolomite, gray, very finely granular, argillaceous	5	235
Dolomite, brown, medium granular, very porous	10	245
Dolomite, cream, tan, very calcareous, with many dolomite rhombs	5	250
Dolomite, creamy biege, finely crystalline, earthy, with calcite crystals	5	255
Limestone, light brown, sublithographic	5	260
Limestone, greenish gray, finely crystalline, argillaceous; much glauconite	5	265
Dolomite, gray, very finely granular; small amount chalcedony, white; trace chert, gray; some glauconite	15	280
Limestone, light brown, fragmental, slightly oolitic	5	285
Dolomite, gray, very finely granular; some limestone; trace chalcedony, trace quartz, crystalline	10	295
Dolomite, medium gray, finely crystalline, argillaceous; trace of white chalcedony; trace of crystalline quartz	15	310
Kinderhookian series.		
Gilmore City limestone (145 feet thick):		
Limestone, buff and cream, lithographic	5	315
Limestone, cream, fragmental, oolitic, some sublithographic	85	400
Limestone, beige to tan, sublithographic, earthy, argillaceous	55	455

Mississippian system—Continued		
Kinderhookian series—Continued		
Hampton formation (50 feet thick):		
Limestone, tan, finely crystalline; dolomite, calcareous	25	480
Dolomite, gray, finely saccharoidal	20	500
Dolomite, as above; limestone, cream, finely crystalline	10	510
Dolomite, light brown, finely crystalline, slightly calcareous; some limestone	15	525
Dolomite, brown, finely crystalline, with included chert, gray; some chert, gray, dull; trace of chert, gray, oolitic	60	585
Dolomite, light brown, finely crystalline; siltstone, dolomitic	5	590
Shale, green; trace of pyrite	5	595
Dolomite, beige to gray, finely crystalline	5	600
Siltstone, beige	5	605
Devonian system.		
Upper Devonian series.		
Sheffield shale (10 feet thick):		
Shale, light-gray, soft; trace pyrite	10	615
Lime Creek shale (56 feet penetrated):		
Dolomite, cream to yellow, finely to medium crystalline; some white, medium crystalline; trace of chert, grayish white	15	630
Shale, gray, dolomitic	15	645
Dolomite, light-cream, medium crystalline	5	650
Limestone, reddish-brown, medium crystalline, fragmental	5	655
Dolomite, cream, finely crystalline, calcitic	16	671 T.D.

90-27-28D1. Sample log of J. M. Engels farm well near Vincent in NE¼ NW¼ NW¼ sec. 28, T. 90 N., R. 27 W. Drilled in 1947 by Northwest Drilling Co., Humboldt. Altitude of land surface, 1,135 feet. Sample study by S. E. Harris, Jr.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (85 feet thick):		
No samples	5	5
Till, yellow, calcareous	10	15
Till, brownish gray, calcareous	70	85
Mississippian system.		
Meramecian series.		
St. Louis limestone (15 feet thick):		
Sandstone, cream, calcareous, coarse sand is rounded and frosted, fine sand is angular to subangular	15	100
Osagian series.		
Undifferentiated beds (70 feet thick):		
Dolomite, grayish brown, dense, and yellowish gray, saccharoidal; some chalcedony, bluish white	15	115
Limestone, cream to light gray, lithographic to sublithographic; some dolomite, as above	35	150
Limestone, light gray, dense, with finely disseminated glauconite	5	155
Dolomite, light gray, saccharoidal, very silty, argillaceous; some chert, white; some chalcedony	15	170
Kinderhookian series.		
Gilmore City limestone (100 feet thick):		
Limestone, cream, lithographic with druses	20	190
Limestone, cream, fragmental, oolitic; some limestone, sublithographic	80	270
Hampton formation (145 feet penetrated):		
Dolomite, gray to tan, very finely crystalline, mottled black and orange in lower 5 feet, porous in places	30	300

Mississippian system—Continued		
Kinderhookian series—Continued		
Hampton formation—Continued		
Limestone, cream, sublithographic and pseudo-oolitic; dolomite, tan, finely crystalline, saccharoidal	15	315
Limestone, cream to light brown, sublithographic; some dolomite rhombs	20	335
Dolomite, tan, very finely crystalline; some chert, light gray and subwhite	5	340
Dolomite, drabbish gray, very finely crystalline, dense; some limestone, light to grayish buff, very finely crystalline; some chert, subwhite to light gray	45	385
Dolomite, light buff to light gray, very finely crystalline, dense	5	390
Dolomite, light buff to light gray, very finely crystalline, dense; some chert, cream to light gray, stony; some limestone, light buff to light gray	25	415
No samples	5	420 T.D.

90-27-31N2. Sample log of C. S. Knudson farm well near Vincent in SW¼SW¼SW¼ sec. 31, T. 90 N., R. 27 W. Drilled in 1945 by Art Vinson, Fort Dodge. Altitude of land surface, 1,125 feet. Sample study by S. E. Harris, Jr.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (70 feet thick):		
Till, yellowish buff, calcareous	15	15
Till, gray, calcareous	10	25
Sand and gravel, heterogeneous, containing grains and pebbles of limestone, dolomite, gray shale, quartz, and igneous rocks. Very dirty and apparently interbedded with till, buffish gray, calcareous	15	40
Till, gray, calcareous	25	65
Sand, yellowish, fine to medium, heterogeneous grains	5	70
Permian (?) system.		
Fort Dodge formation (43 feet thick):		
Shale, light gray, soft, micaceous, calcareous, containing some pyrite	5	75
Limestone, yellow, with interbedded sand, fine to medium. Also contains abundant rounded pellets of limestone, dolomite, and authigenic quartz	5	80
Sandstone, light gray, calcareous cement, very fine, angular, with coarse sand of quartz, angular chert, limestone, and dolomite	10	90
Limestone, light creamy gray, with fine sand; limestone and dolomite pellets embedded in the limestone. Many pellets are fragments of fusulinids and bryozoans	5	95
Gypsum, white and clear, crystalline and amorphous	15	110
Limestone, light yellowish gray and pinkish, fragmental, containing bryozoan, fusulinids, and crinoid fragments. Much pyrite	3	113

Mississippian system.		
Meramecian series.		
Ste. Genevieve limestone (27 feet thick):		
Marl, grayish green and red, with increasing amount of limestone, light grayish brown, very finely crystalline near base, fossiliferous	27	140
St. Louis limestone (45 feet thick):		
Sandstone, subwhite, calcareous, very fine, angular, with some medium sand; some sandstone, white, coarse, finely frosted; some limestone, buff, very finely crystalline to sublithographic, with some sand imbedded	10	150
Limestone, light brown, very finely crystalline; some chert, light brown and gray, subconchoidal	15	165
Sandstone, white, coarse, frosted, and fine, angular; some limestone, sublithographic; pink and yellow chert grains; trace of pyrite	20	185
Osagian series.		
Undifferentiated beds (80 feet thick):		
Dolomite, drab, fine to medium crystalline; limestone, grayish buff and brown, sublithographic	15	200
Dolomite, dark brown, saccharoidal, brilliant, fine to medium crystalline, vuggy; some quartz, brown, watery near base	20	220
Limestone, drabbish-gray, fine to nearly medium crystalline, speckled with small glauconite grains	5	225
Dolomite, drabbish-gray and buff, saccharoidal	10	235
Shale, green and gray, noncalcareous, some dolomite, drabbish brown, finely to nearly medium crystalline, argillaceous	15	250
Dolomite, brown and gray, finely crystalline, dense, argillaceous	15	265

Mississippian system—Continued		
Kinderhookian series.		
Gilmore City limestone (115 feet thick):		
Limestone, cream, sublithographic to lithographic; some quartz, clear	15	280
Limestone, cream to subwhite, fragmental, oolitic; some limestone, sublithographic	45	325
Dolomite, dark-brown, finely crystalline; some chert, white, banded	5	330
Limestone, cream to subwhite, fragmental, oolitic; some limestone, sublithographic	50	380
Hampton formation (25 feet penetrated):		
Dolomite, light yellowish gray, finely and medium crystalline, sparkling	10	390
Dolomite, light-gray, finely crystalline, dense, mottled with black specks	5	395
Dolomite, brown to buff, finely and medium crystalline, sparkling	10	405 T.D.

90-28-15D2. Sample log of Badger town well in the NW¼ NW¼ NW¼ sec. 15, T. 90 N., R. 28 W. Drilled in 1947 by Thorpe Well Co., Des Moines. Altitude of land surface, 1,155 feet. Sample study by W. E. Hale and R. M. Jeffords.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (80 feet thick):		
Till, brown, leached, silty, quartz sand	10	10
Till, buff, calcareous	10	20
Sand, fine to coarse, heterogeneous, dirty	5	25
Till, gray, calcareous	55	80
Kansan stage (40 feet thick):		
Till, orange, leached	5	85
Till, orange, calcareous	5	90
Till, brownish gray	15	105
Sand, heterogeneous	15	120
Nebraskan (?) stage (20 feet thick):		
Clay or till, chocolate brown, slightly calcareous, very silty and pebbly	20	140
Mississippian system.		
Meramecian series.		
St. Louis limestone (25 feet thick):		
Dolomite, buffish tan, very finely crystalline; sandstone, medium angular to round, some frosted grains, calcareous; trace of chert, pale gray, translucent	10	150
Sandstone, white, fine to medium, angular to rounded, frosted, calcareous	15	165
Osagian series.		
Undifferentiated beds (85 feet thick):		
Dolomite, light brown, finely crystalline; limestone, grayish cream, very finely crystalline, earthy	10	175
Dolomite, brown, medium crystalline, brilliant, vuggy in places	20	195
Unconformity?		

Mississippian system—Continued
Osagian series—Continued

Dolomite, light reddish brown, finely to medium crystalline, and grayish buff, medium crystalline, mottled with small glauconite grains; some limestone, gray, earthy, mottled by glauconite and druses	10	205
Shale, gray, calcareous; some chert, gray, smoky	10	215
Dolomite and limestone, yellowish gray, very finely crystalline, argillaceous, with some chalcedony	15	230
Limestone, gray to buff, sublithographic, argillaceous	20	250

Kinderhookian series.
Gilmore City limestone (90 feet thick):

Limestone, cream to subwhite, fragmental, in part oolitic and pseudo-oolitic	90	340

Hampton formation (about 190 feet thick):

Dolomite, buff to light brown, coarsely crystalline, calcite cement	5	345
Limestone, buff and cream, fragmental, with some dolomite rhombs	5	350
No sample	5	355
Dolomite and limestone, as above	5	360
Limestone, buff and cream, fragmental	20	380
Limestone, light brown to grayish cream, sublithographic	20	400
Dolomite, tan to brown, medium granular	10	410
Dolomite, as above, and gray, medium crystalline, argillaceous	15	425
Dolomite, gray and brown, finely saccharoidal; some chert, pale gray and cream, opaque, stony	15	440
Dolomite, gray, buff and brown, medium crystalline, porous	10	450

Mississippian system—Continued
Kinderhookian series—Continued
Gilmore City limestone—Continued

Dolomite, drab, medium crystalline; some chert, white to light gray, granular; some chert, milky white	15	465
Dolomite, drab, crystalline; chert, light brown and light gray, granular	5	470
Dolomite, drab, as above; some chert, dark brown and gray	10	480
Dolomite, light gray, silty; some chert, very light gray, speckled, granular....	20	500
Dolomite, light brown, porous, saccharoidal	25	525
No sample (may have reached Sheffield shale)	5	530 T.D.

90-28-35D1. Sample log of E. I. Oleson farm well near Badger in the SW¼ NW¼ NW¼ sec. 35, T. 90 N., R. 28 W. Drilled in 1946 by Art Vinson, Fort Dodge. Altitude of land surface 1,127 feet. Sample study by E. Schultz.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (70 feet thick):		
Till, buff, calcareous	20	20
Till, drab, calcareous	35	55
Sand and gravel, heterogeneous, dirty	5	60
Till, drab, calcareous	10	70
Permian (?) system.		
Fort Dodge formation.		
Sandstone, subwhite, very fine, angular, pitted	5	75
Shale, light buff, very silty, calcareous, soft	5	80
Shale, red, soft, very silty, calcareous, containing much authigenic quartz	15	95
Limestone and dolomite, light cream, composed of pellets about 1 mm in diameter; some sandstone, very fine, and authigenic quartz	5	100
Pennsylvanian system.		
Desmoinesian series.		
Undifferentiated beds (55 feet thick):		
Shale, gray; sandstone, fine; some siderite and hematite	5	105
Shale, light and dark gray, unctuous, much carbonaceous material; thin coal seams; few thin beds of sandstone, fine, white	50	155
Mississippian system.		
Meramecian series.		
Ste. Genevieve limestone (10 feet thick):		
Shale, gray, calcareous; trace of pyrite	10	165
St. Louis limestone (55 feet penetrated):		
Limestone, light cream, sublithographic	5	170

	Thickness (feet)	Depth (feet)
Mississippian system—Continued		
Meramecian series—Continued		
St. Louis limestone—Continued		
Sandstone, subwhite, very fine, calcite cement; trace chert, gray subconchoidal; trace pyrite	5	175
Limestone, light beige, sublithographic	10	185
Sandstone, fine to coarse, coarse grains frosted, calcareous, grading into limestone, subwhite, very arenaceous; some gray chert fragments	25	210
Dolomite, tan, finely crystalline, porous, some sandstone and limestone, as above	5	215
Sandstone, white, fine, frosted, angular to rounded	5	220 T.D.

90-29-29B1. Sample log of W. C. Ulrich farm well near Clare in the NE¼ NW¼ NE¼ sec. 29, T. 90 N., R. 29 W. Drilled in 1948 by Art Vinson, Fort Dodge. Altitude of land surface, 1,176 feet. Sample study by R. W. Screven.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (77 feet thick):		
Soil developed on till, brown	10	10
Till, orange, buff, calcareous	10	20
Till, gray, calcareous	10	30
Sand and gravel, heterogeneous, calcareous	20	50
Till, gray, calcareous	10	60
Sand and gravel, heterogeneous	5	65
Till, gray, calcareous	5	70
Sand and gravel, heterogeneous	7	77
Mississippian system.		
Meramecian series.		
St. Louis limestone (31 feet thick):		
Limestone, yellow to white, finely saccharoidal, sandy; sandstone, white, fine to coarse, coarse grains frosted, calcareous	31	108

Osagian series.		
Undifferentiated beds (77 feet thick):		
Dolomite, grayish brown, finely crystalline, some chert, light-gray, quartzose; trace of glauconite	12	120
Dolomite, light buff to buff, finely crystalline; trace glauconite and pyrite	5	125
Dolomite, brown, finely crystalline to sublithographic, porous; druses and chert, grayish white, mottled; trace glauconite and pyrite	20	145
Dolomite, pink to reddish brown, finely crystalline; trace glauconite	20	165
Dolomite, buff, sublithographic, calcite cement	10	175
Dolomite, gray, brown, finely crystalline	10	185
Kinderhookian series.		
Gilmore City limestone (67 feet penetrated):		
Limestone, white-buff to buff, lithographic	5	190
Dolomite, greenish gray, very finely crystalline	5	195
Limestone, buff, fragmental, oolitic; some dolomite, greenish-brown, silty, argillaceous	57	252 T.D.

90-30-3A1. Sample log of E. F. Beeh farm well, near Clare, in NE cor. sec. 3, T. 90 N., R. 30 W. Drilled in 1947 by Northwest Drilling Co., Humboldt. Altitude of land surface, 1,180 feet. Sample study by M. C. Parker.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (95 feet thick):		
Clay, black, sandy, silty	5	5
Till, yellow, calcareous	15	20
Till, gray, calcareous	30	50
Till, buff, calcareous	25	75
Till, buff and gray, calcareous	5	80
Silt, brown, sandy, micaceous, calcareous	5	85
Clay, buffish-brown, sandy, calcareous	10	95
Cretaceous system.		
Undifferentiated section (70 feet penetrated):		
Shale, gray, soft, unctuous, calcareous	5	100
Shale, light gray, very sandy; sand, medium, composed of many pink and clear quartz grains	10	110
Shale, dark gray, unctuous, fissile	5	115
Shale, light gray, sandy, much pyrite	8	123
Sandstone, medium to coarse, angular to subrounded, cemented in part by brown siderite and pyrite. Sand grains are composed of clear to pink quartz and greenish buff chert. A few granules and pebbles are dull polished	42	165 T.D.

90-30-3A2. Sample log of E. F. Beeh test hole near Clare, in NW¼ NE¼ NE¼ sec. 3, T. 90 N., R. 30 W. Drilled in 1947 by Northwest Drilling Co., Humboldt. This test hole is about one-fourth of a mile west of 90-30-3A1. Altitude of land surface, 1,180 feet. Sample study by S. E. Harris, Jr. Note: In 1945 an unsuccessful well was drilled at this site to a depth of between 500 and 600 feet. The driller reported a predominantly shale section with some beds of hard rock.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (90 feet thick):		
Till, brown, calcareous	5	5
Till, yellowish buff, calcareous, containing many shale pebbles	15	20
Till, gray, calcareous	30	50
Till, buff, calcareous	30	80
Sand and gravel, heterogeneous, containing a large amount of white to yellow limestone granules and pebbles	10	90
Cretaceous system.		
Undifferentiated Manson section (70 feet penetrated):		
Shale, gray, hard, carbonaceous, and pyrite specks; trace of platy minerals	35	125
Siltstone to sandstone, very fine, light gray, very glauconitic, calcareous	10	135
Shale, grayish-brown, slightly calcareous containing sand, fine to medium, angular	15	150
Shale, gray, with silt laminations	10	160 T.D.

90-30-4E1. Sample log of Albert Licht farm well near Clare in SW¼ SW¼ NW¼ sec. 4, T. 90 N., R. 30 W. Drilled in 1949-50 by Northwest Drilling Co., Humboldt. Altitude of land surface, 1,198 feet. Sample study by R. M. Jeffords and G. C. Huntington. Note: Driller's log to 220 feet. This well developed a very small supply of water.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (approximately 110 feet thick):		
Clay, yellow	40	40
Clay, blue	40	80
Clay, blue, sandy	5	85
Sand	5	90
Clay, yellow	20	110
Cretaceous system.		
Manson sequence (approximately 995 feet penetrated):		
Shale, black	110	220
Shale, dark gray, clayey, noncalcareous, micaceous	5	225
No samples	25	250
Shale, dark gray, clayey, slightly calcareous; trace siderite pellets, and pyrite	65	315
No samples	225	540
Shale, very light gray, soft, clayey, noncalcareous; some siderite pellets	5	545
Shale, grayish red, clayey; some siderite pellets	5	550
Shale, brownish gray, clayey; some siderite pellets	5	555
Shale, light gray, noncalcareous, no structure; siderite pellets up to 2 mm. in diameter; thin bed of sandstone, fine to medium, angular to curvilinear, clear, some frosted, at 620 feet	75	630
Shale, gray, no structure, noncalcareous, silty	15	645
Shale, gray, massive; trace of siderite pellets	85	730
Shale, gray laminated, soft	5	735

Cretaceous system—Continued		
Manson sequence—Continued		
Shale, light gray, no apparent laminations	25	760
Shale, gray, soft, laminated; shell fragments, buff, some with pearly luster. *Inoceramus?*	25	795
Shale, gray, hard	25	795
Shale, brownish gray; trace of columnar calcite and spicules	20	815
Shale, gray, soft, flaky; trace of pyrite and mica	10	825
Shale, light gray, soft, unctuous; trace of columnar calcite. *Inoceramus?*	15	840
Shale, gray, silty; siderite, massive, brown; many *Inoceramus* fragments and siliceous spicules	5	845
Shale, dark gray; some siderite, massive	20	865
Sandstone, fine to nearly medium, angular, clear, loose (report some water but would not clear)	10	875
Shale, light to medium gray, unctuous, silty, noncalcareous	15	890
Sandstone, fine to nearly medium, angular, clear; trace shale, black, carbonaceous (report water, but would not clear)	60	950
Siltstone, green and brown, calcareous cement	15	965
Sandstone, fine, angular, micaceous	20	985
No samples	25	1,010
Shale, medium gray, no laminations apparent, silty	15	1,025
Shale, black, with lignite containing imbedded resin nodules, slightly flammable; trace of pyrite	10	1,035
Shale, gray, no laminations apparent, calcareous	30	1,065

Cretaceous system—Continued		
Manson sequence—Continued		
Shale, black, carbonaceous, with lignite-like material and resin; some thin sandstone beds, medium to coarse, angular to curvilinear, clear, loose	20	1,085
Shale, as above, with some shale, gray, laminated, fissile and thin sandstone beds	18±	1,103±
Sandstone, medium to coarse, angular, clear (some water)	2±	1,105 T.D.

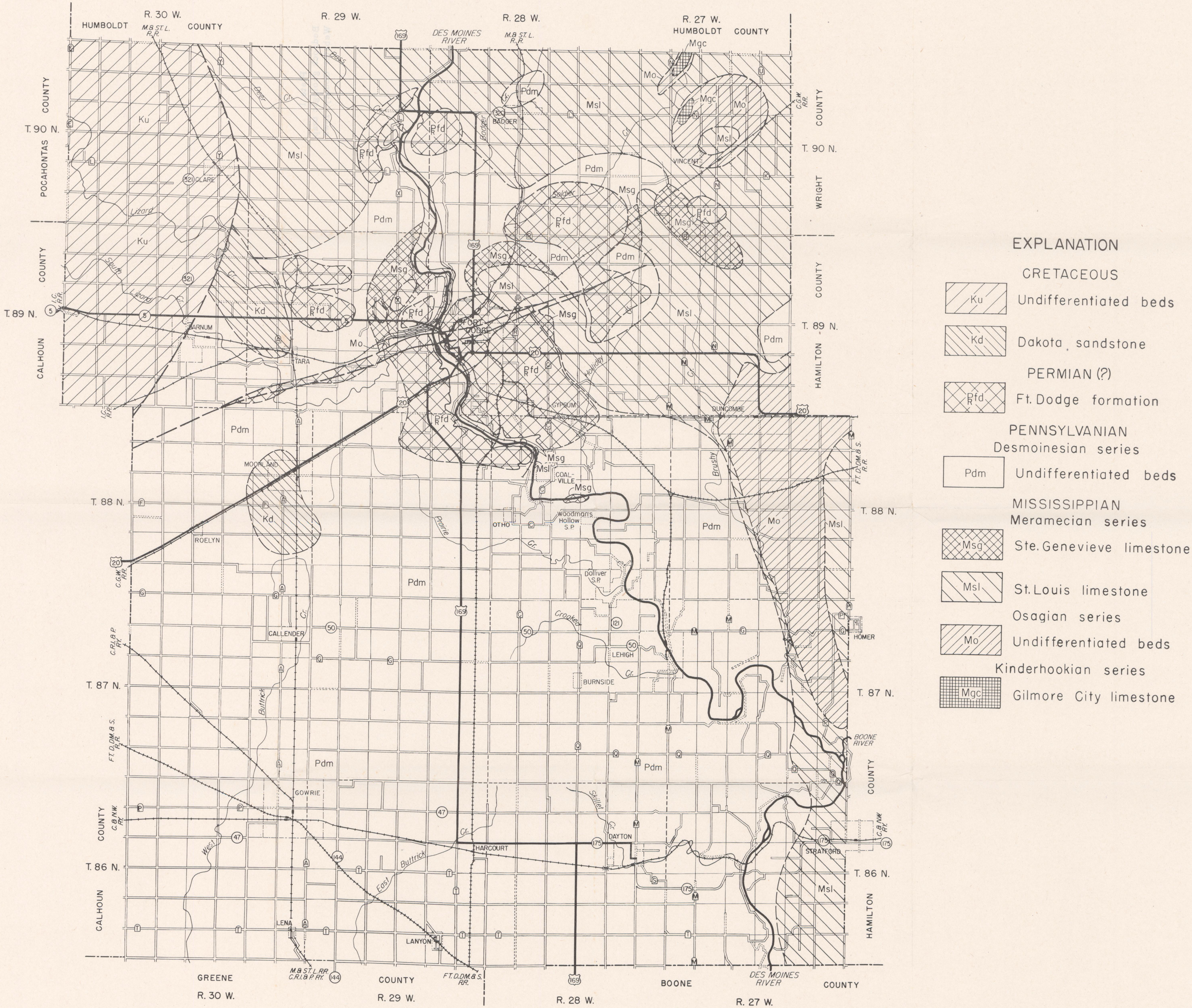
90-30-24N1. Sample log of St. Matthew's Church well at Clare, in SE¼ SW¼ SW¼ sec. 24, T. 90 N., R. 30 W. Drilled in 1950 by Art Vinson, Fort Dodge. Altitude of land surface, 1,214 feet. Sample study by G. C. Huntington and W. E. Hale.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Wisconsin stage (10 feet thick):		
Till, buff, some gray, calcareous	10	10
Till, gray, calcareous	40	50
Till, gray, some buff, calcareous	10	60
Till, gray, calcareous	40	100
Kansan stage (25 feet thick):		
Till, gray and buff, leached	5	105
Till, orange, leached	5	110
Till, buff, slightly calcareous	5	115
Sand and gravel, heterogeneous and dirty, and buff till	10	125
Cretaceous system.		
Undifferentiated section (55 feet penetrated):		
Shale, gray, soft, unctuous	20	145
Sandstone, fine to medium, much pink quartz, larger grains, dull, polished; much pyrite	35	180 T.D.

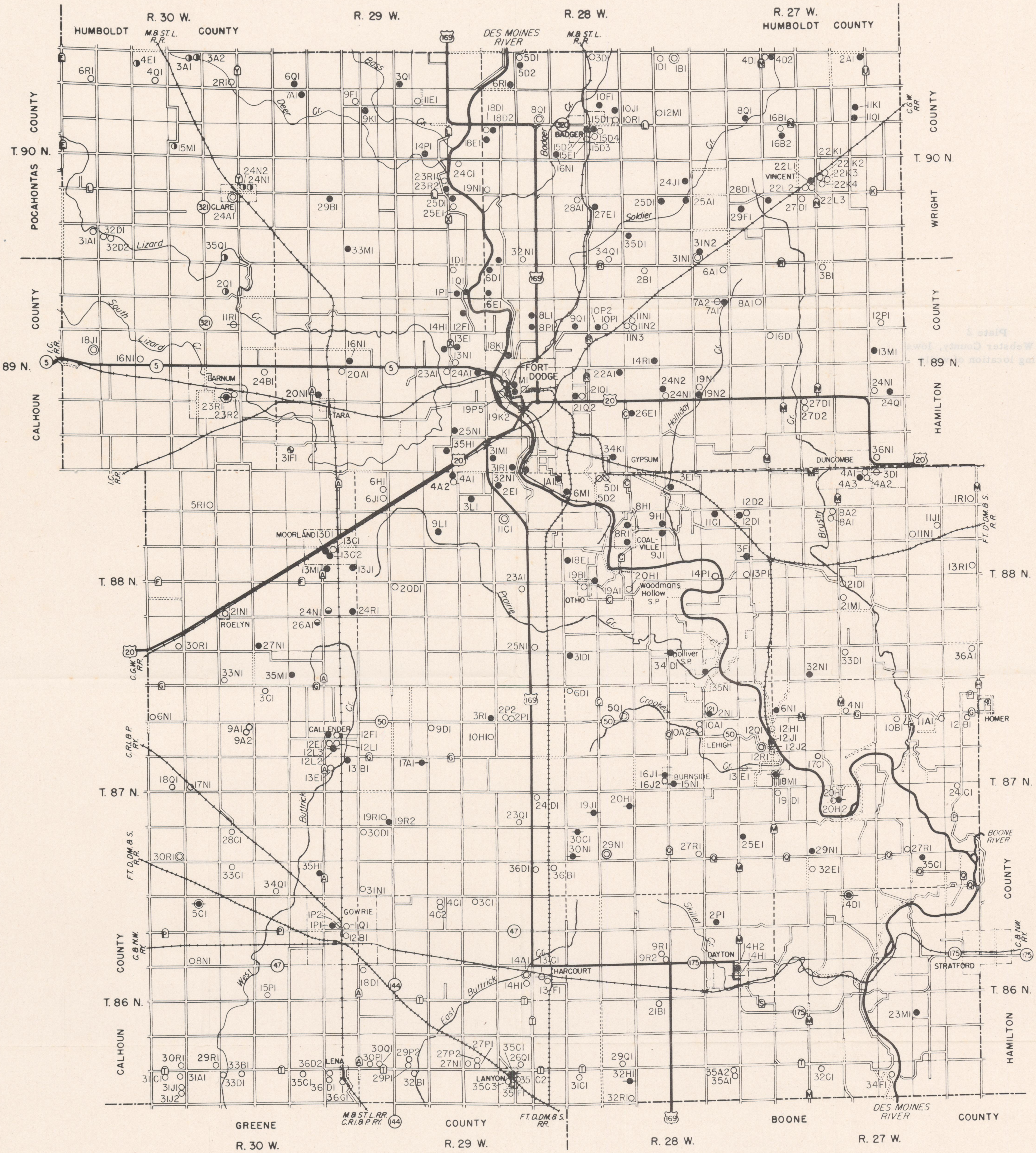
90-30-35Q1. Sample log of Erwin Malmin farm well near Clare in SW¼ SW¼ SE¼ sec. 35, T. 90 N., R. 30 W. Drilled in 1948 by Art Vinson, Fort Dodge. Altitude of land surface, 1,150 feet. Sample study by R. W. Screven.

	Thickness (feet)	Depth (feet)
Pleistocene system.		
Undifferentiated beds (80 feet thick):		
Till, brown, slightly calcareous	70	70
Till, orange, slightly calcareous	5	75
Till, light brown, calcareous	5	80
Cretaceous system (630 feet penetrated):		
Undifferentiated Manson section:		
Shale, gray, soft, micaceous	75	155
Shale, gray; some limestone, very dark gray, silty	45	200
Shale, light red to gray, soft, no laminations	15	215
Shale, gray, micaceous; some massive siderite and siderite pellets	35	250
Shale, dark gray, flaky, calcareous; some limestone, gray and buff, granular. *Inoceramus* fragments, fish tooth?	30	280
Shale, dark-gray, micaceous	20	300
Shale, gray with white specks, micaceous	5	305
Shale, gray	15	320
Shale, gray, mostly mottled white, calcareous, somewhat micaceous and pyritic; some beds of limestone, dark gray, granular	65	385
Shale, as above; much more limestone, as above. *Inoceramus* fragments, some fish teeth and scales	40	425
Shale, dark gray, mottled white, fissile, calcareous, fossiliferous	10	435
Shale, gray, calcareous, slightly micaceous and pyritic; much siderite, brown, massive fossils	35	470

Cretaceous system—Continued		
Undifferentiated—Continued		
Limestone, gray, very fine; trace of limestone, buff; fossil fragments; some siderite and shale as above	5	475
Shale, gray, slightly micaceous, pyritic; siderite, massive brown	25	500
Shale, gray, with some limestone, dark gray, granular	5	505
Dakota (?) formation.		
Shale, dark gray and black; siderite; some lignite	10	515
Siderite; some siltstone, gray; some shale, dark gray	5	520
Shale, gray; siderite; some pyrite	10	530
Shale, gray and black; sandstone, gray, very fine, angular; pyrite; and lignite	30	560
Shale, gray and black, micaceous	5	565
Shale, gray and black; sandstone, gray, fine; siderite, massive and as pellets	20	585
Shale, gray; siderite pellets	10	595
Sandstone, fine	5	600
Siderite, brown, massive and as pellets; some sandstone, fine; trace of shale, black	20	620
Shale, light gray, pyritic	15	635
Shale, black; some siderite, massive and as pellets; some lignite	15	650
Shale, light brown; some siderite pellets	10	660
Siderite, brown, massive, medium; some shale, gray and black; some sandstone; trace of dolomite, buff, fine fragmental	20	680
Sandstone, white, clean, fine to medium; some pink quartz, angular (water)	30	710 E.D.

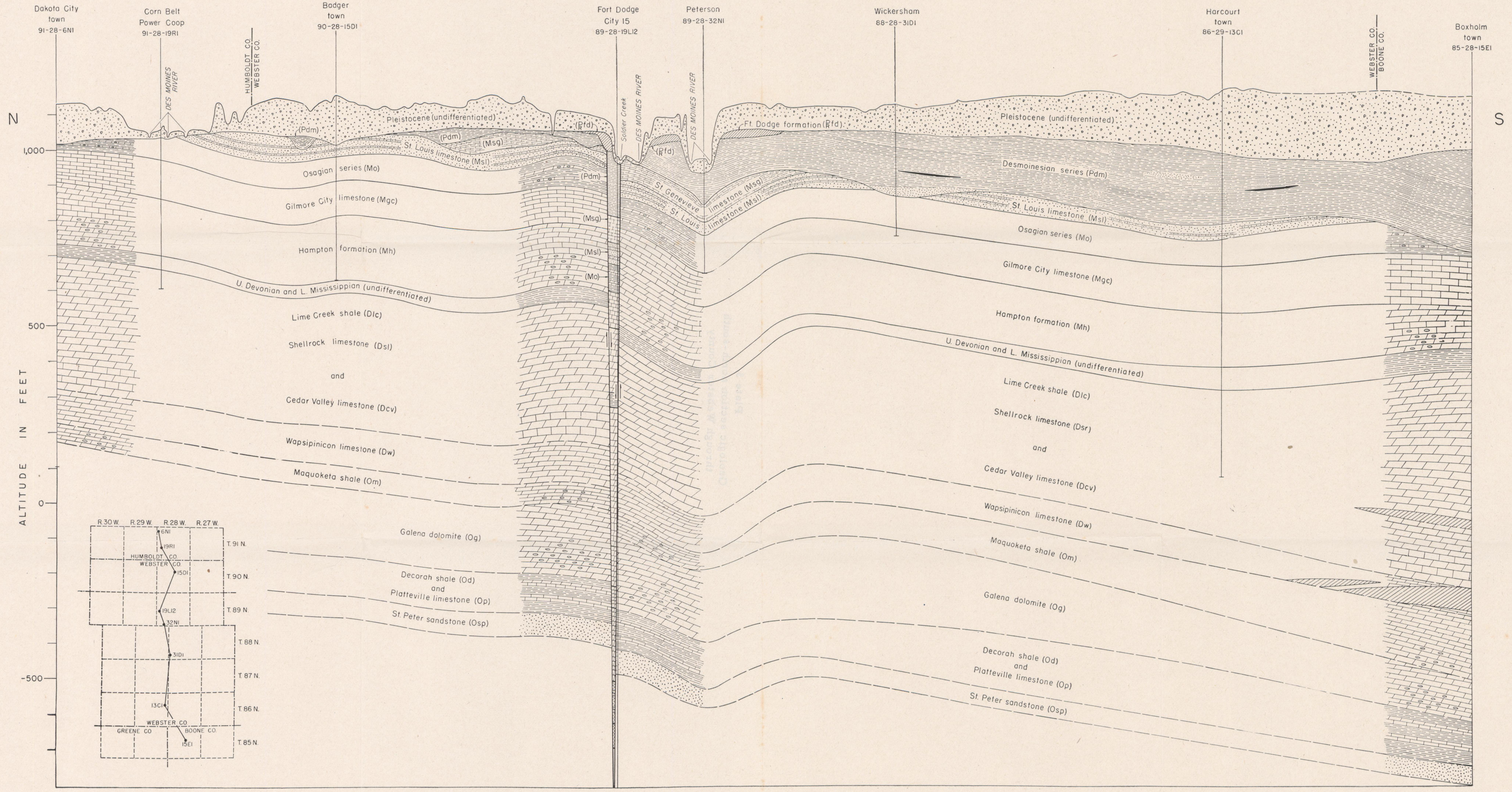


EXPLANATION
CRETACEOUS
Ku Undifferentiated beds
Kd Dakota sandstone
PERMIAN (?)
Pfd Ft. Dodge formation
PENNSYLVANIAN
Desmoinesian series
Pdm Undifferentiated beds
MISSISSIPPIAN
Meramecian series
Msg Ste. Genevieve limestone
Msl St. Louis limestone
Osagian series
Mo Undifferentiated beds
Kinderhookian series
Mgc Gilmore City limestone
HUMBOLDT COUNTY
POCAHONTAS COUNTY
CALHOUN COUNTY
WRIGHT COUNTY
HAMILTON COUNTY
GREENE COUNTY
BOONE COUNTY
R. 30 W.
R. 29 W.
R. 28 W.
R. 27 W.
T. 90 N.
T. 89 N.
T. 88 N.
T. 87 N.
T. 86 N.
DES MOINES RIVER
BOONE RIVER
M.& ST.L. R.R.
C.G.W. R.R.
I.C. R.R.
C.R.I.& P. RY.
FT. D.D.M.& S. R.R.
C.& N.W. RY.
M.& ST.L.RR. C.R.I.& P. RY.
FORT DODGE
BADGER
VINCENT
CLARE
BARNUM
TARA
GYPSUM
DUNCOMBE
MOORLAND
COALVILLE
OTHO
ROELYN
Woodmans Hollow S.P.
Dolliver S.P.
CALLENDER
LEHIGH
BURNSIDE
HOMER
GOWRIE
HARCOURT
DAYTON
STRATFORD
LENA
LANYON
Lizard
South Lizard Cr.
Deer Cr.
Bass Cr.
Badger
Soldier
Holliday
Brushy
Prairie Cr.
Crooked Cr.
Buttrick Cr.
East Buttrick
West
Skillet Cr.

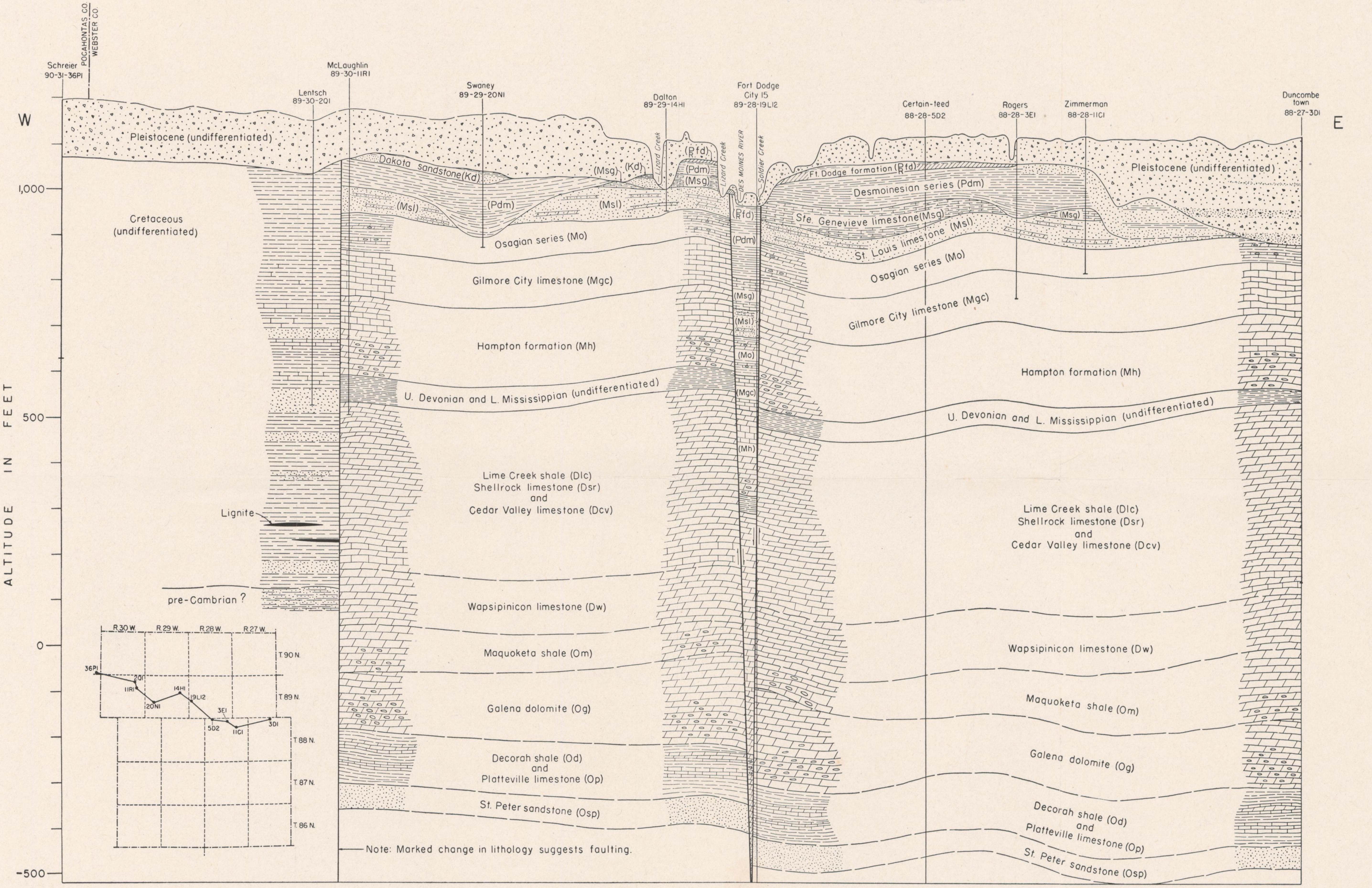


EXPLANATION

- Pleistocene
- Dakota sandstone
- Cretaceous (undifferentiated)
- Permian
- Pennsylvanian
- Mississippian
- Devonian
- Ordovician
- Cambrian
- Observation well



Dakota City town 91-28-6N1
Corn Belt Power Coop 91-28-19R1
Badger town 90-28-15D1
Fort Dodge City 15 89-28-19L12
Peterson 89-28-32N1
Wickersham 88-28-31D1
Harcourt town 86-29-13C1
Boxholm town 85-28-15E1
HUMBOLDT CO.
WEBSTER CO.
WEBSTER CO.
BOONE CO.
DES MOINES RIVER
Soldier Creek
DES MOINES RIVER
DES MOINES RIVER
N
S
ALTITUDE IN FEET
1,000
500
0
-500
Pleistocene (undifferentiated)
Ft. Dodge formation (Pfd)
(Pfd)
(Pdm)
(Msg)
St. Louis limestone (Msl)
Osagian series (Mo)
Gilmore City limestone (Mgc)
Hampton formation (Mh)
U. Devonian and L. Mississippian (undifferentiated)
Lime Creek shale (Dlc)
Shellrock limestone (Dsl)
and
Cedar Valley limestone (Dcv)
Wapsipinicon limestone (Dw)
Maquoketa shale (Om)
Galena dolomite (Og)
Decorah shale (Od)
and
Platteville limestone (Op)
St. Peter sandstone (Osp)
(Msl)
(Mo)
St. Genevieve limestone (Msg)
St. Louis limestone (Msl)
Desmoinesian series (Pdm)
Shellrock limestone (Dsr)
R. 30 W.
R. 29 W.
R. 28 W.
R. 27 W.
T. 91 N.
T. 90 N.
T. 89 N.
T. 88 N.
T. 87 N.
T. 86 N.
T. 85 N.
6N1
19R1
15D1
19L12
32N1
31D1
13C1
15E1
HUMBOLDT CO.
WEBSTER CO.
GREENE CO.
BOONE CO.



W
E
Schreier
90-31-36P1
POCAHONTAS CO.
WEBSTER CO.
McLaughlin
89-30-11R1
Lentsch
89-30-2D1
Swaney
89-29-20N1
Dalton
89-29-14H1
Fort Dodge
City 15
89-28-19L12
Certain-teed
88-28-5D2
Rogers
88-28-3E1
Zimmerman
88-28-11C1
Duncombe
town
88-27-3D1
Lizard Creek
Des Moines River
Soldier Creek
Pleistocene (undifferentiated)
Dakota sandstone (Kd)
(Kd)
(Msg)
(Msl)
(Pdm)
(Pfd)
Cretaceous
(undifferentiated)
Ft. Dodge formation (Pfd)
Desmoinesian series (Pdm)
Ste. Genevieve limestone (Msg)
St. Louis limestone (Msl)
Osagian series (Mo)
Gilmore City limestone (Mgc)
Hampton formation (Mh)
(Mo)
(Mgc)
(Mh)
U. Devonian and L. Mississippian (undifferentiated)
Lime Creek shale (Dlc)
Shellrock limestone (Dsr)
and
Cedar Valley limestone (Dcv)
Lignite
pre-Cambrian ?
Wapsipinicon limestone (Dw)
Maquoketa shale (Om)
Galena dolomite (Og)
Decorah shale (Od)
and
Platteville limestone (Op)
St. Peter sandstone (Osp)
Note: Marked change in lithology suggests faulting.
ALTITUDE IN FEET
1,000
500
0
-500
R.30 W.
R.29 W.
R.28 W.
R.27 W.
T.90 N.
T.89 N.
T.88 N.
T.87 N.
T.86 N.
36P1
2D1
11R1
20N1
14H1
19L12
3E1
5D2
11C1
3D1