CHAPTER XII.

UNDERGROUND WATERS OF THE CENTRAL DISTRICT.

INTRODUCTION

BY W. H. NORTON.

The central district comprises twelve counties situated in central Iowa—Boone, Dallas, Greene, Grundy, Guthrie, Hamilton, Hardin, Jasper, Marshall, Polk, Story and Webster. By far its larger part, including all the central and western portions, is underlain by Pennsylvanian rocks, which here consist predominantly of shales; the eastern part is underlain by the Mississippian, which also includes heavy shale beds. The presence of these heavy beds of shale makes the question of the deep water supply of special importance.

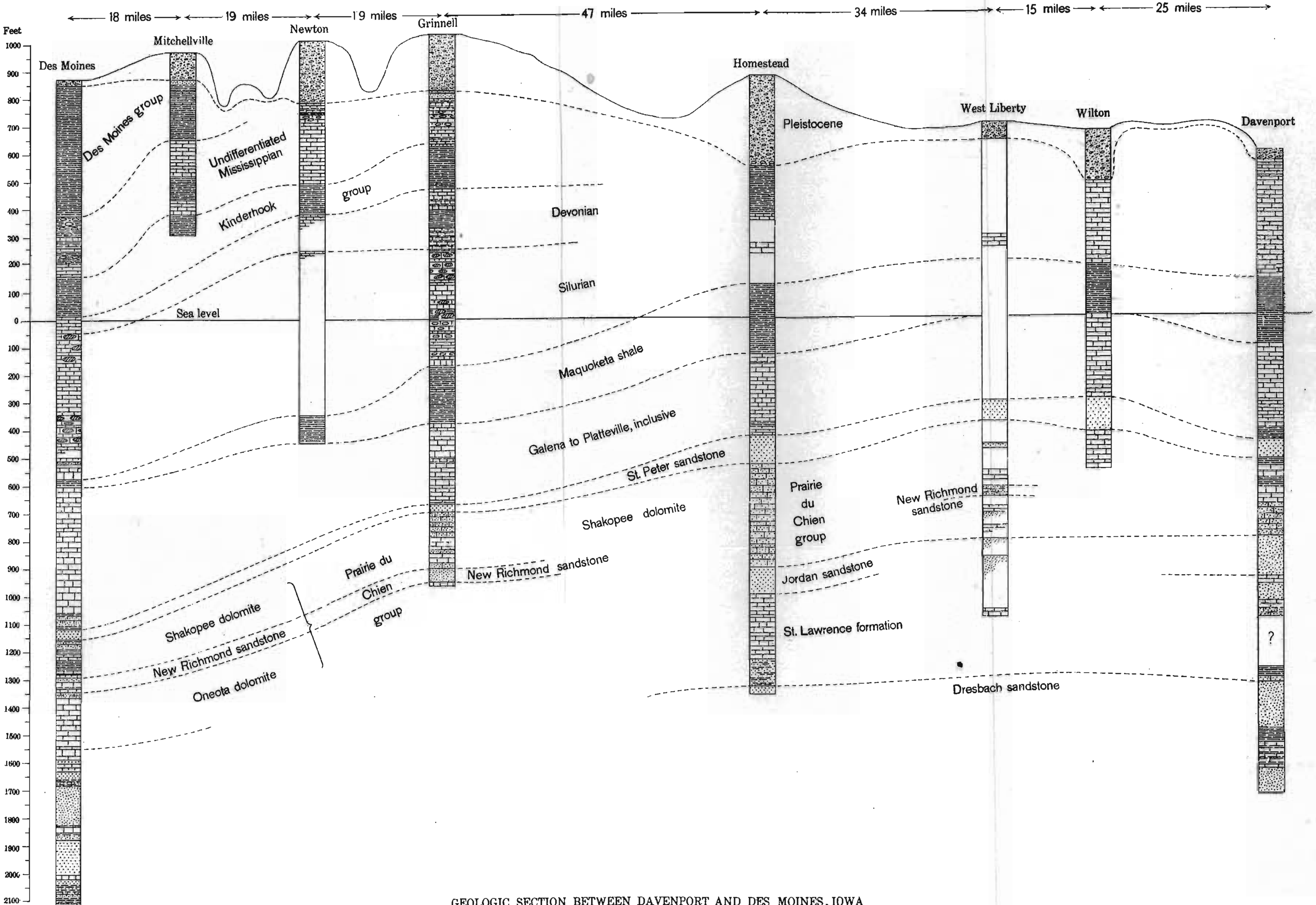
The Paleozoic terranes continue their southwestward dip well toward the western part of the area. From Waterloo to Ackley the average fall of the Saint Peter sandstone is eight feet per mile; from Ackley to Fort Dodge the fall decreases to 2⅓ feet per mile (Pl. VI, p. 310). The section along the Chicago & North Western railway shows a descent of the Saint Peter from Belle Plaine to Boone averaging four feet to the mile (Pl. XI, p. 458), but this dip is interrupted by the Ames anticline, discovered by Beyer and demonstrated by his section of the deep well at the Iowa Agricultural College. By this singular upwarp the Saint Peter at Ames stands 275 feet higher than at Boone, 15 miles farther west. From Boone a very gentle descent of about three feet to the mile continues to Ogden, but from Ogden the strata rise at the rate of 8⅓ feet to the mile as far as Jefferson. Along the main line of the Chicago, Rock Island & Pacific railway the Saint Peter dips west from Grinnell to a point 12 miles north of Des Moines at the rate of 6 feet to the mile. (See Pl. XV.) West of Des Moines the strata probably continue their westward dip through or nearly through Dallas county, beyond which a very gentle ascent probably occurs. From Waterloo to Des Moines the Saint Peter descends 1,143 feet, or a little less than 12½ feet to the mile.

The deep-water beds of this district are the Saint Peter sandstone, the Prairie du Chien stage, and the Jordan sandstone. The latter, however, may not be found well defined in the southern and southwestern parts. In the sections at Boone and Des Moines the terranes below the Saint Peter are not well demarked, even the boundary between the Prairie du Chien and the Jordan being indistinct. Though water-bearing sandstones will undoubtedly be found below the Saint Peter, their place can not be predicted and their correlation is not always determinable. In the central and southwestern parts of the district these sandstones are to be found only at great depths and the cost of reaching them should be well considered before a deep well is decided on. The history of the Boone wells is exemplary in this respect.

In the northern tier of counties the Saint Peter seems to be unusually thick and the terranes immediately underlying it are apparently markedly arenaceous. They lie within profitable drilling distance of the surface and may be expected to yield exceptionally large supplies of water.

Moderate amounts of water may be found in the Galena and Platteville limestones, but generally wells should be carried through the Saint Peter or the underlying water beds. The Herndon supply seems to come from the Galena, and it is quite possible that had the well been drilled a few score feet deeper the Saint Peter would have been encounterd.

The waters of the country rocks, especially those of the Pennsylvanian, are apt to be so highly mineralized as to be unpotable. The gypseous beds of the Silurian also furnish highly mineralized waters at a number of places. Special care should be taken to case out these upper waters from deep wells. The high



GEOLOGIC SECTION BETWEEN DAVENPORT AND DES MOINES, IOWA
By W. H. Norton

THE NORRIS PETERS CO., WASHINGTON, D. C.

mineral content of a number of the deep wells leads to a strong suspicion that their waters are derived in part from upper horizons, yet the lower waters—those of the Saint Peter and the subjacent beds—have come far, they have sunk deep, their circulation has no doubt become sluggish, and they have had opportunity to take up far more minerals in solution than have the waters of the same beds farther to the north and east.

Taking all factors into consideration deep wells can not be recommended for the extreme southern part of the district, including the southern half of Guthrie, Dallas, Polk and Jasper counties, except as experiments and where other sources are unavailable. The depth of the Ordovician formations along the axis of the downwarp from Boone southward renders deep-well drilling here, also, of doubtful expediency. Except in these parts of the district, however, wells may obtain water of fair quality without being carried to excessive depths. Other sources of supply should, however, be carefully considered before decision is made in favor of artesian wells.

BOONE COUNTY

BY W. J. MILLER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

The surface of Boone county is rather flat, although very gently rolling areas are not uncommon. The most striking modification of the general flatness is the broad, deep valley cut by Des Moines river from north to south across the middle of the county. A much less noteworthy depression is formed along Beaver creek in the western part.

Wisconsin drift and Kansan drift are spread over the whole county except along Des Moines river, where both have been completely eroded. The drift appears to be thinner on the west side of the river than on the east. It rests immediately on the Des Moines stage of the Carboniferous, which has been well exposed by erosion along Des Moines river.

The drift formations show rapid variations in thickness, but are generally horizontal. The rock formations dip rather strongly to the west in the eastern part of the county and lie about horizontal in the western part. (See Pl. XI, p. 458.)

UNDERGROUND WATER.

SOURCES.

Most of the wells in Boone county obtain water in the sand or gravel beneath the Wisconsin drift, at depths ranging in different districts from 50 to 120 feet. Where the gravels fail to yield sufficiently deeper wells must be drilled. Along Des Moines river the Wisconsin is altogether absent, and it also appears to be absent or very thin along the other watercourses.

Where the Wisconsin drift is very thin or absent, especially along certain watercourses, first water is obtained in the sand or gravel beneath the blue clay of the Kansan drift, which affords a persistent and satisfactory supply and is tapped by a good many wells. Because of rather rapid and local thickening and thinning of the Kansan, the depth of this water varies greatly even in any one part of the county. Depths ranging from 100 feet to nearly 300 feet have been noted, the most common being 150 to 200 feet; the greatest depth appears to be in the vicinity of Boone. Along Des Moines river the Kansan has been completely cut through. Unless a well has been sunk into the underlying rocks, it may be difficult to tell whether the water comes from beds below the Kansan or below the Wisconsin.

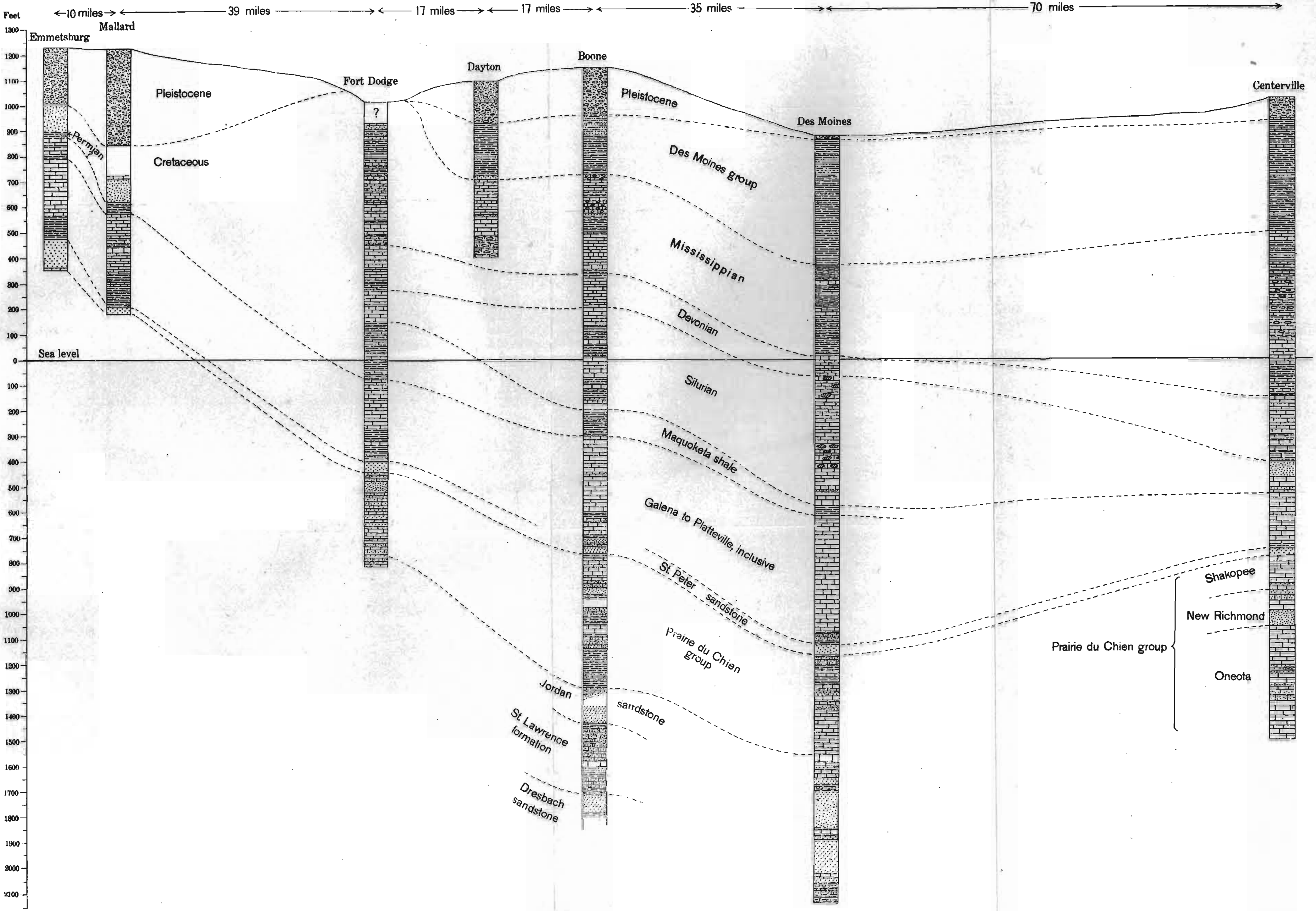
Local good supplies are found in sandy layers in the blue clays of either the Wisconsin or the Kansan drift sheets.

A number of wells obtain water from Carboniferous sandstones (Des Moines stage). A few very deep wells, as at Boone and Ogden, get water in Cambrian sandstone.

On the lowlands along stream courses the water in the drift may be under sufficient head to overflow at the surface. The most important flowing basin in Boone county is along Beaver creek and its branches. Flows are also obtained along Big creek in the southeastern part of the county, and at least one flowing well exists in the northeastern part of the county in the valley of Squaw creek. A flowing well has been reported in the northwestern part of Boone and another five miles north of Boone.

IOWA GEOLOGICAL SURVEY

PLATE XVI



GEOLOGIC SECTION BETWEEN EMMETSBURG AND CENTERVILLE, IOWA

By W. H. Norton

THE NORRIS PETERS CO., WASHINGTON, D. C.

The available data are not sufficiently accurate to determine definitely the source of these flows, but the best evidence indicates that those along Beaver and Big creeks are derived from the gravels beneath the Kansan drift, and the others from the sand and gravel beneath the Wisconsin. The flowing well in the northwest part of Boone and the one five miles north of Boone are almost certainly from the Wisconsin.

SPRINGS.

A few springs are found along Des Moines river and some of the smaller streams, but none are of notable size.

CITY SUPPLIES.

Boone.—Boone (population, 10,347) derives its water supply from four wells, 3,010, 2,900, 297 and 264 feet deep. (See Pls. XI, XVI.) The water is pumped by air lift to a reservoir and thence to an elevated tank, from which it is distributed by gravity with a domestic pressure of 40 pounds and a fire pressure of 100 pounds. Boone has 10½ miles of mains, 46 fire hydrants, and 500 taps. The system serves 2,500 people with 300,000 gallons a day. The water is plentiful but hard.

City well No. 1 has a depth of 3,010 feet and a diameter of 8, 5⅝, 4½, 3½ and 3 inches; casing, 5⅝ inches to 1,400 feet, 4½ inches from 1,300 to 1,875 feet, and smaller from 1,975 to 2,073 feet. The curb is 1,140 feet above sea level and the head 200 feet below the curb. The pump cylinder is set 276 feet below the curb; pumping at the rate of 70 gallons a minute produced no noticeable effect on water level. Water from depths of 45 feet and 195 feet rose to 35 feet below the curb and yielded 40,000 gallons a day; water from the Saint Peter sandstone at 1,875 feet rose to 60 feet below the curb; water from beds at depth of 2,700 feet stood 200 feet below the curb but gave largest yield. Date of completion, 1890. Temperature, 68° F.

The water is corrosive and scale forming; new water pipes in boilers are eaten out sometimes in six months; scale deposits at the rate of about one inch a week in heater and one-sixteenth of an inch in boiler tubes.

Record of strata in well No. 1 at Boone.[a]

	Depth
	Feet
Pleistocene (200 feet thick; top, 1,140 feet above sea level):	
Clay, yellow, sandy, variegated	10
Clay, light blue; mixed with angular gravel	24
Clay, light blue; gravel more conspicuous	34
Clay, yellowish gray, slightly arenaceous; and containing fragments of wood closely resembling red cedar; gravel persists but is less angular	45
Clay, gray-blue; more even in texture than preceding, but still containing a considerable percentage of arenaceous material; strongly calcareous	60
Clay, yellow-gray; changes gradually to yellow at 140 feet; even-textured, almost free from gravel, but slightly arenaceous throughout; 3 samples at 100, 110 and	140
Clay, grayish yellow; containing angular sand and gravel	150
Gravel, coarse; embedded in matrix of blue clay; gravel of quartzitic, cherty, and basic igneous rocks; many pebbles faceted	155
Clay, deep brown	165
Clay, blue, massive	175
Sand, quartz; fine uniform grain, containing a few grains of calcareous chert	185
Gravel, coarse; composed chiefly of granite, vein quartz, basic igneous rocks, quartzite and nodules of clay ironstone. The latter two bespeak strongly a Coal Measures origin. The rounded forms of many of the constituents bear evidence of prolonged attrition	195
Pleistocene (?) (70 feet thick; top, 940 feet above sea level); may belong to Des Moines stage of the Pennsylvanian:	
Shale, buff, arenaceous; containing a small amount of fine gravel probably carried down from overlying strata; slightly calcareous, loesslike in appearance, and with distinct soil odor; samples at 240 and 260 feet clay, drab, sandy, and pebbly; not molding readily when wet; sample at 230 feet effervesces freely in acid, and slightly calcareous below; appearance of old soil at 240 feet; a little wood at 250 feet; 7 samples at 200, 210, 220, 230, 240, 250 and	260
Carboniferous:	
Pennsylvanian—	
Des Moines stage (175 feet thick; top 870 feet above sea level)—	
Shale, blue, compact, brittle	270
Shale, blue; a little coal; 2 samples at 275 and	308
Shale, blue, calcareous, and slightly arenaceous	325
Shale, light blue, strongly calcareous; more arenaceous than the preceding	335
Shale, black, bituminous, fissile; 2 samples at 345 and	353
Shale, bituminous, mixed with ash-colored fire clay, coal, iron pyrites, and clay ironstone	355
Shale, black, noncalcareous, brittle; containing an abundance of iron pyrites	370
Shale, gray-blue; slightly arenaceous at 400 feet but practically noncalcareous throughout; 4 samples at 380, 390, 400 and	415
Shale, ash-colored, brittle, calcareous	430
Saint Louis limestone and Osage stage (155 feet thick; top, 695 feet below sea level)—	
Shale, gray; a little black shale, much flint partly in the form of geodes; some limpid quartz; 2 samples at 445 and	450
Mississippian—	
Shale, grayish black, calcareous and arenaceous	455
Limestone, rhombs of calcite	400
Limestone, slightly oolitic; 4 samples at 470, 475, 490 and	500
Shale, blue; strongly calcareous; 3 samples at 515, 525 and	540
Shale, gray-blue; more marly than preceding	550
Limestone, blue-gray; close-textured, brittle; sharply angular	552
Limestone, conchoidal or hackly fracture	560
Limestone; abnormal amount of chert	562
Limestone, oolitic facies, slightly quartzite; not angular	580
Sandstone, friable, fine-grained	590
Kinderhook stage (215 feet thick; top, 540 feet above sea level)—	
Shale, green-gray, slightly arenaceous	600
Shale, slightly calcareous; 2 samples at 610 and	620
Shale, more marly	630
Limestone, gray; 2 samples at 640 and	650
Limestone, gray, marly; from 660 to	777
Limestone, blue, compact, brittle	790
Limestone, apparently brecciated	800
Shale, gray	805
Devonian and Silurian (520 feet thick; top, 325 feet above sea level):	
Limestone, subcrystalline, gray; 2 samples at 815 and	830
Limestone; shows numerous reddish brown spots, probably due to oxidation of iron pyrites; 2 samples from 849 to	920
Limestone, magnesian, light buff; 2 samples from 930 to	1,015

a Adapted from Beyer, S. W., Geology of Boone County; Iowa Geol. Survey, vol. 5, 1895, pp. 194-198. The assignment to formations follows closely that of Dr. Beyer.

Record of strata in well No. 1 at Boone—Continued

	Depth
	Feet
Limestone, more or less argillaceous; fragments of a dark colored shale; 2 samples at 1,028 and	1,040
Shale, slightly calcareous	1,050
Limestone, magnesian, light buff; 2 samples at 1,065 and	1,070
Shale, gray-blue, slightly calcareous; sand present; 3 samples at 1,080, 1,090 and	1,100
Shale, arenaceous; many sand grains larger than those above, at	1,120
Limestone, gray, dolomitic; bituminous shale at 1,130 feet; 3 samples at 1,130, 1,140 and	1,150
Limestone, magnesian, buff, saccharoidal; 3 samples at 1,160, 1,170 and	1,180
Limestone, magnesian; some quartz grains, at	1,190
Limestone, dolomitic, marly; 2 samples at 1,200 and	1,210
Shale, greenish gray, at	1,220
Limestone, dolomitic, marly; 2 samples at 1,240 and	1,250
Limestone, argillaceous, at	1,260
Quartz, varicolored, chalcedonic, at	1,280
Clay, residual; a red ocherous substance, charged with white calcareous grains, at	1,282
Sand, quartz, varicolored, at	1,290
Limestone, crystalline, purplish; some fissile green shale, at	1,298
Limestone, buff; considerable green shale, at	1,305
Dolomite, gray, fine, even-textured, brittle, reduced to fine sand by drill; 2 samples at 1,315 and	1,325
Ordovician:	
Maquoketa shale (105 feet thick; top, 195 feet below sea level)—	
Shale, green, soft, plastic, only slightly calcareous, from 1,335 to	1,385
Shale, black, carbonaceous, at	1,395
Shale, buff, magnesian, 2 samples at 1,405 and	1,430
Galena dolomite and Platteville limestone (405 feet thick; top, 300 feet below sea level)—	
Limestone, argillaceous, at	1,440
Limestone, gray, magnesian; 2 samples at 1,450 and	1,480
Limestone, argillaceous, marly, at	1,490
Limestone, gray, magnesian; 2 samples, at 1,500 and	1,510
Limestone, buff, magnesian, finely granular, at	1,537
Limestone, slightly cherty; from 1,545 to	1,560
Limestone, buff, magnesian, containing flakes of gray limestone and small cleavage plates of gypsum; 3 samples at 1,580, 1,590 and	1,600
Dolomite, brownish yellow, marly, at	1,610
Dolomite, becoming progressively lighter colored; 2 samples at 1,620 and	1,630
Dolomite, buff, at	1,640
Dolomite, saccharoidal, at	1,650
Dolomite, buff; 2 samples, at 1,660 and	1,680
Dolomite, shaly, at	1,690
Dolomite, bluish gray, marly, argillaceous, at	1,700
Dolomite, buff; 3 samples, at 1,710, 1,720 and	1,730
Clay, residual, with some fine-grained quartz sand, at	1,740
Shale, greenish gray, at	1,750
Dolomite, brownish, at	1,760
Shale, greenish gray with dolomite sand, at	1,770
Dolomite, deep brown, at	1,780
Dolomite, color changes gradually from buff to greenish gray and texture becomes shaly; from 1,795 to	1,810
Shale, bluish gray, at	1,830
Shale, green, noncalcareous, at	1,835
Shale, bluish, at	1,840
Saint Peter sandstone (55 feet thick; top, 705 feet below sea level)—	
Sandstone, clear white, grains well rounded, at	1,845
Shale, green; small amount of sand, at	1,850
Shale, arenaceous; 2 samples at 1,860 and	1,870
Sandstone, clear white, even-grained quartz sand; 3 samples, at 1,880, 1,890 and	1,895
Prairie du Chien stage—	
Shale, arenaceous, at	1,900
Dolomite, gray; fine quartz sand, at	1,910
Dolomite, greenish gray, marly, at	1,915
Dolomite, gray; with quartz; sand finer and much more angular than that at 1,880 feet; 2 samples, at 1,940 and	1,950
Dolomite, cream-colored, slightly shaly, at	1,955
Dolomite, gray, shaly, at	1,975
Shale, red, noncalcareous, at	2,075
Shale, buff, highly calcareous, slightly arenaceous, at	2,165
Shale, green; 2 samples, at 2,200, and	2,250
Shale, dark blue, and marl, light gray, at	2,310

Record of strata in well No. 1 at Boone—Concluded

	Depth
	Feet
Cambrian:	
Jordan sandstone—	
Sandstone, highly calcareous, buff, fine-grained; 2 samples at 2,510 and	2,515
Saint Lawrence formation and earlier Cambrian strata—	
Shale, yellowish green, highly calcareous, at	2,560
Sandstone, yellowish, fine-grained, mostly subangular or rounded; many angular grains, at	2,585
Sandstone, light buff; grains fine, mostly angular; 2 samples at 2,640 and	2,660
Sandstone, brown, calciferous, fine-grained, at	2,700
Alternating bands of shale, red marl, and soft red sandstone, without limestone; from 2,700 to	3,000

City well No. 2 has a depth of 2,914 feet and a diameter of 16 inches to 195 feet, 12 inches to 294 feet, 10 inches to 500 feet, 6¼ inches to 1,973 feet, below this not reported. The curb is 1,140 feet above sea level; water at 195 feet rose to 35 feet below the curb; water at 1,870 to 1,885 feet rose to 100 feet below the curb; the largest yield came from 2,846 to 2,900 feet. The capacity of the pumping apparatus is 70 to 80 gallons a minute. Temperature, 62° F. The cost, including casing, was $15,000. The well was drilled by J. P. Miller & Co., of Chicago.

Both deep wells were abandoned in 1906 in favor of supply from shallower wells.

Driller's log of deep well No. 2 at Boone.

	Depth in feet
Soil	0-4
Clay, blue	13-45
Sand; with water	60
Sea mud	86
Clay	98
Sand; with water	185-195
Clay	2[illegible]0
Stone, light blue	355
Shale, black	370
Sandstone	430
Gravel and slate	450
Fire clay	457
Hard rock, gas	471
Limestone	520
Soapstone	610
Limestone	642
Stone, red, hard	1,282
Marl, red, sticky	1,290
Hard limestone	1,315
Shale, blue	1,335, 1,435
Limestone	1,735

Rock, light brown	1,752-1,800
Shale, blue	1,840-1,868
Sandstone; well tested; amount of water small	1,870-1,895
Sand, shale, limestone	1,900-1,975
Crevice	2,075
Limestone	2,140
Chalk	2,190
Limestone	2,200
Shale and limestone	2,360, 2,650, 2,800
Shale, blue	2,815-2,835
Sandstone, water bearing	2,846-2,909
Shale, blue, soft and sticky	2,914

Record of strata (below 2,009 feet) in well No. 2 at Boone.

	Depth
	Feet
Dolomite, cherty; much quartz sand, at	2,009
Dolomite, highly arenaceous, or sandstone, calciferous, at	2,035
Sandstone, brown; grains imperfectly rounded, at	2,045
Dolomite, arenaceous; 2 samples at 2,070 and	2,135
Dolomite, arenaceous; much shale, at	2,150
Shale, buff, highly calcareous, slightly sandy, at	2,165
Dolomite, arenaceous; much shale, at	2,170
Marl, drab, calcareous, argillaceous, and minutely arenaceous and cherty, at	2,190
Dolomite; with shale and sand; 2 samples at 2,218 and	2,243
Shale, green, at	2,250
Dolomite, highly arenaceous, at	2,257
Marl, drab, calcareous, argillaceous, minutely arenaceous and cherty, at	2,285
Sandstone, calciferous, at	2,292
Shale, dark blue, and marl, light gray, at	2,300
Marl, greenish yellow and blue; 4 samples, at 2,315, 2,360, 2,365 and	2,395
Sandstone, fine-grained; calcareous cement; glauconiferous; much argillaceous material; 2 samples at 2,425 and	2,435
Sandstone; rounded grains; highly argillaceous; green fissile shale, at	2,445
Sandstone of minute angular grains held in calcareous cement, with some greenish cryptocrystalline silica, argillaceous, at	2,460
Sandstone; fine rounded grains, calcareous cement, glauconiferous; considerable green shale in the drillings, at	2,620
Shale, hard, slate-colored; in chips; greenish yellow marl in concreted powder, at	2,685
Sandstone, buff, calciferous; disintegrating under acid into fine angular particles; much hard green laminated shale, at	2,700
Dolomite, glauconiferous; much shale, at	2,705
Sandstone, greenish, hard, fine-grained, calciferous, highly glauconiferous; in laminated chips; also chips of siliceous gray dolomite and much hard green shale, at	2,727
Shale, slate-colored, hard; in chips; much greenish argillo-calcareous and microscopically quartzose powder, at	2,730
Marl, light green-gray, quartzose; constituents microscopic; slightly glauconiferous; 2 samples, at 2,750 and	2,755
Dolomite, arenaceous, glauconiferous; much shale, at	2,780
Dolomite; as above; in buff meal; marl in green-gray concreted powder, at	2,800
Marl, green-gray, at	2,811
Marl, green-gray, glauconiferous, and dark slaty shale, at	2,817
Marl, green-gray, glauconiferous, and hard shale, at	2,840
Sandstone, buff; clean quartz grains, imperfectly rounded, very diverse in size, the largest reaching or exceeding 1.5 millimeters; water bearing, at	2,846
Sandstone; as above, but coarser; many grains reaching or exceeding 1.5 millimeters, at	2,855
Sandstone; as above, but somewhat finer grained than at 2,846 feet, at	2,862
Sandstone; at above; 3 samples, at 2,870, 2,877 and	2,890
Shale, light drab, slightly calcareous; drillings highly arenaceous, at	2,900
Shale or marl; in concreted powder, highly arenaceous; and hard, drab laminated shale, at	2,914

Driller's log of well at Boone.

	Thickness.	Depth.
	Feet	Feet
Soil, black, and yellow clay	20	20
Clay, blue, and pebbles	28	48
Sand, white and water	67	115
Sand (cleaner and coarser than above) and water	10	125
Gravel and water	18	143
Clay, blue, and pebbles	67	210
Clay, gray, hard	20	230
Sand and lignite	50	280
Shale, gray	10	290
Shale, black	5	295
Shale, bluish black	2	297

Madrid.—Madrid (population, 1,191) pumps its water from a well 100 feet deep by a double-action electric motor. The supply is furnished by gravity, with a domestic pressure of 42 pounds; the fire pressure is greater. The town has 1¼ miles of mains, supplying 17 fire hydrants and 10 taps to 70 people. The water is plentiful, but fairly hard.

Driller's log, Madrid well.

	Thickness.	Depth.
	Feet	Feet
Soil, black and yellow clay	16	16
Clay, blue	54	70
Clay, yellow, and sand; water	24	94
Clay, dark, hard (hardpan)	4	98
Gravel and water; light clay or shale	2	100

Ogden.—The town of Ogden (population, 1,298) draws its supply from a well 2,507 feet deep by steam pump and force pump combined. The water is distributed by gravity, with domestic pressure of 42 pounds and fire pressure of 42+ pounds. There are four-fifths mile of mains, 10 fire hydrants, and 26 taps. All business houses and four residences use the water, consuming 7,750 gallons daily. The supply is plentiful, but hard.

The city well (Pl. XI, p. 458) is 2,507 feet deep and 10 to 3 inches in diameter. The original head was 125 feet below curb. The head in 1905 was 140 feet below curb. The capacity is 26 gallons a minute, the water coming from 110, 1,650, and 1,820 to 1,851 feet. Date of completion, 1897. Drillers, J. P. Miller & Company, of Chicago.

Record of strata in city well at Odgen.

(Based on driller's log.)

	Thickness.	Depth.
	Feet	Feet
Pleistocene:		
Clay	50	50
Sand	15	65
Carboniferous:		
Pennsylvanian—		
Des Moines stage (top, 1,029 feet above sea level)—		
Shale, with coal at 190 and 290 feet	345	410
Mississippian—		
Saint Louis limestone and Osage stage (top, 684 feet above sea level)—		
Limestone	145	555
Kinderhook stage (top, 539 feet above sea level)	95	650
Carboniferous? (Mississippian?), Devonian and Silurian (top, 444 feet above sea level):		
Limestone	615	1,265
Ordovician:		
Maquoketa shale (top, 171 feet below sea level)—		
Shale and red marl	55	1,320
Galena dolomite (top, 226 feet below sea level)	440	1,760
Platteville limestone (top, 666 feet below sea level)	60	1,820
Saint Peter sandstone (top, 726 feet below sea level)	31	1,851
Prairie du Chien stage (649 feet thick; top, 757 feet below sea level)—		
Limestone	234	2,085
Limestone and shale	75	2,160
Limestone and sand	340	2,500

It is also noted that the "lime rock had mud veins in it from 650 to 1,265 feet and was the same from 1,320 to 1,760 feet." "The rock caves more or less down to the top of the sand rock about 1,820 feet; from that down to 2,460 feet (depth when noted) the rock stands up."

WELL DATA.

The following table gives data of typical wells in Boone county.

Typical wells of Boone County.

Number	Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (logs given in feet)
			Feet	Feet		Feet	
1	P. Miller	8 miles south, 4 miles east, Ogden.	102	(?)	Shale (?)	— 45	Bored well
2	J. Phralin	Buckley	126		Sand	30	Flowing well. No rock.
3	J. Wilson	Ogden	205	190(?)	Sandstone	— 30	Bored and drilled.
4	City	Boone	297	280	Shale (?)	— 55	Steam air lift used.
5	G. Tifler	do	75		Gravel	3	Bored well. No rock.
6	Charles Pilcher	3½ miles northwest, Boone.	371		Sandstone	—140	
7	Dodge Cooperative Creamery.	3½ miles southwest, Mackey.	101		Gravel	— 40	Pumped by steam for creamery uses.

Typical wells of Boone County—Continued

Number	Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (logs given in feet)
			Feet	Feet		Feet	
8	W. Abraham	5 miles southeast, Luther.	108		Sand	25	Black soil, 5; yellow clay and blue clay, 35; "sea-mud," so-called, 10; blue clay, 10; sandy layer and water (weak flow), 1; blue clay and "sea-mud," sand and water (flow) and fossil wood and gas, 47. No rock.
9	G. B. Abraham	3 miles southeast, Luther.	160		do	— 4	Formerly flowed +6 feet. Black soil, 3; yellow clay, 12; blue clay, 45; sand (gray) and water, 1; blue clay, 15; soft blue clay or "sea-mud," 83; green sand and water, 1. No rock.
10	Town	Madrid	100	100	Gravel	— 36	Bored well.
11	Blake farm	½ mile south of Angus	62		do	— 20	Bored well. No rock.
12	E. Ball	Near Napier	215		Sand	— 80	Black soil and yellow clay, 20; blue clay, 60; yellow clay, 20; blue clay (hard and dark), 111; sand and water, 4. No rock.
13	J. Nolan	7 miles northwest Madrid.	135		Gravel	—118	Bored well. No rock.

DALLAS COUNTY

BY O. E. MEINZER.

TOPOGRAPHY AND GEOLOGY.

Dallas county is just south and west of the center of the state. Along its south margin, principally south of Middle Raccoon river, the old loess-covered Kansan drift at the surface has been so profoundly eroded that the topography is rugged; but the rest of the county, including much the greater part of the total area, is covered with Wisconsin drift so recently deposited and so slightly eroded that it forms a typical youthful drift plain, with gently undulating topography and numerous undrained tracts. The entire drift mantle probably averages rather less than 100 feet in thickness and in certain localities is much thinner. Although the Wisconsin drift is superimposed upon the Kansan, it does not seem to increase the total depth to bedrock, probably because of the abrasion of a part of the Kansan drift by the Wisconsin ice sheet. Over extensive areas, especially in the northwestern part of the county, a layer of gravel lies between the drift and the bedrock. Thick accumulations of alluvial and outwash materials are found along the principal watercourses, not only below the flood plain levels but also underlying the terraces which border the valleys.

The rocks lying below the drift and outcropping at many points in the southern part of the county belong to the Des Moines stage of the Pennsylvanian and consist of several hundred feet of alternating beds of shale, sandstone and coal. (See Pl. XVI, p. 814.) In Dallas county the predominant rock is shale, but sandstone seems to be more abundant than is usual for this series. If traced laterally the sandstone strata show rapid changes in thickness and porosity.

The approximate section shown by a well in the valley of South Raccoon river, on the farm of Calvin Marshall in the SE. ¼ sec. 7, T. 78 N., R. 29 W., is reported by A. G. Leonard[1] as follows:

Section of the Marshall flowing well.

	Thickness.	Depth.
	Feet	Feet
Pennsylvanian:		
Shale, red and blue	65	65
Sandstone	6	71
Shale and slate, bituminous	200	271
Sandstone, white	20	291
Mississippian:		
Limestone, penetrated	8	299

UNDERGROUND WATER.

SOURCES.

In both the Wisconsin and the Kansan drift areas most of the wells are dug or bored and depend on seepage from the more or less porous seams in the drift. The wells in the Wisconsin area ordinarily yield the larger and more permanent supplies.

In much of the Wisconsin area the gravel at the base of the drift will furnish large amounts of water to drilled wells; and other beds of sand and gravel at different levels in the drift will also yield generously to drilled wells; but in some localities the drill passes into the bedrock before water in sufficient quantities is found. In the Kansan area drilled wells are much less

[1]Geology of Dallas County: Ann. Rept. Iowa Geol. Survey, vol. 8, 1898, p. 75.

successful, chiefly because of the radical difference in the head of the water, which results directly from the difference in the topography. In the Wisconsin area the surface is so nearly level and the drainage so imperfect that practically all porous deposits are saturated, and the water in the deeper beds is under sufficient pressure to rush forcibly into the wells that penetrate them and rise nearly or quite to the surface. In the Kansan area, on the other hand, the drift is deeply dissected and the porous deposits are either drained completely or their water is under such slight pressure that it will flow only sluggishly into wells. In accordance with this general difference, flowing wells are found in a number of low-lying tracts in the Wisconsin area and springs are plentiful in the valleys of the Kansan area.

The Pennsylvanian sandstone strata are water bearing and furnish the supply for a number of wells within this county. They are, however, so inconstant in character that drilling into bedrock always involves some uncertainty. The Marshall well (p. 823) was drilled in 1879 and has overflowed ever since. The water comes from the sandstone at the bottom, and the natural flow at the time it was visited was about 3 gallons a minute. The diameter of the well is 1½ inches. The flowing well in the valley at Redfield (p. 825) was carried to a total depth of 1,384 feet, but it is reported that the first flow was struck at the depth of 280 feet. In the wells located on higher ground the water does not rise to the surface, but it is generally under better head in the Wisconsin than in the Kansan area. In the former area it is not unusual for drilled wells to get their supplies from sandstone that lies a short distance below the bottom of the drift.

Two-inch sand wells require screens, which give trouble by becoming incrusted, but most wells of larger diameter, if not pumped rapidly, can be finished without screens and are more satisfactory (p. 222).

The drift water and some of the water from near the top of the Pennsylvanian is only moderately rich in calcium, magnesium, and the carbonates and does not generally contain large amounts of sulphates, but the water from the lower part of the Pennsylvanian, here as elsewhere in the state, is rich in sodium and the sulphates.

Water may be found below the Coal Measures in the Mississippian limestones, but in no large amount and perhaps of poor quality, although with good head.

As Dallas county lies in the trough of the Paleozoic strata the depth to the Ordovician and Cambrian water beds is probably too deep for profitable drilling. At Adel the Saint Peter sandstone need not be expected at less than 2,000 feet below the surface (1,100 feet below sea level) and the yield from it will hardly be enough for city supply. The water horizons below the Saint Peter are uncertain, but within 500 or 600 feet below the Saint Peter the supply should be largely augmented.

A drill hole made at Redfield, in search for oil or gas, is of special interest, as it shows the position of several water beds. The water, which is highly chalybeate, runs unused into Middle Raccoon river. The elevation of the curb is about 900 feet above sea level.

Record of strata in prospect hole at Redfield.

(Based on driller's log.)

	Thickness.	Depth.
	Feet	Feet
Quaternary:		
Surface material	18	18
Sand and pebbles	15	33
Pennsylvanian:		
Sandstone	37	70
Soapstone or fire clay; red between 85 and 105 feet	75	145
Cave rock	20	165
Slate, dark, caving	3	168
Coal, 18 inches; also 27 feet of sandstone, limestone, and cave rock	28	196
Mississippian, Devonian and Silurian:		
Glass rock	7	203
Mixed rock	3	206
Mixed limestone	28	234
Sand and lime streaks, bearing mineral water	19	253
Sand rock; bearing water, which comes to the surface	40	293
Limestone	40	333
No record	9	342
Limestone, dark	20	363
Limestone	10	373
Sticky cave rock	15	388
Sand; bearing water	10	398
Peculiar limestone	27	425
Rock, hard; traces of sand	13	438
Sand, hard; bearing water	12	450
Sand, hard; changing to limestone	13	463
No record	25	488
Sand; bearing heavy pressure of mineral water	10	498
Limestone, variegated	30	528
Cave rock	30	558
Limestone	50	608
Rock, hard; breaking into sand	8	616
Sand rock; bearing strong water	14	630

Record in strata in prospect hole at Redfield—Continued.

	Thickness.	Depth.
	Feet	Feet
No record	25	655
Slate, light	10	665
Limestone	43	708
Cave rock	20	728
Limestone and water sand	40	768
Hard drilling	20	788
Easy limestone	13	801
Brittle limestone	22	823
Traces of oil rock	27	850
Close and hard	10	860
Very hard, gray marble	8	868
Close sand; bears water	15	883
Close lime	22	905
Hard stone	32	937
Hard limestone	23	960
Water sand	48	1,008
Lime rock	17	1,025
Dark lime	12	1,037
Light lime	12	1,051
Traces of sand and water	5	1,056
Drilled hard	8	1,064
Limestone	18	1,082
Pronounced asphaltum	11	1,093
Sand rock	7	1,100
Limestone	8	1,108
Lime, dark	20	1,128
Lime, white	23	1,151
Lime, dark	17	1,168
Lime, soft, variegated	65	1,233
Radical change in lime	10	1,243
—— (?) water	15	1,258
Limestone	19	1,277
Water sand	13	1,290
No record	12	1,302
Very fine water sand	11	1,313
Sandstone	7	1,320
Sandstone	12	1,332
Sandstone	9	1,341
Stone, hard	9	1,350
Traces of lime and sand; water broke in	5	1,355
Rock, red	14	1,369
Rock, red, softer; at 1,376 feet water broke in	15	1,384

CITY AND VILLAGE SUPPLIES.

Perry.—The public supply for Perry (population, 4,630) is drawn from seven wells, of which three are reported to be four inches in diameter and 110 feet deep, one seven inches in diameter and 117 feet deep, and three 10 inches in diameter and 117 feet deep. They pass through 11 feet of sand and gravel and then through blue clay to a total depth of 84 feet, below which they penetrate a 45-foot bed of gravel that rests upon sandstone.

In making the wells, rocks as large as four inches in diameter were brought up—some glaciated, others consisting of soft brown sandstone obviously of local origin. All the wells are finished with screens except one which ends with perforated casing. At first they overflowed, but now the water level is said to be 34 feet below the surface. By the application of an air lift they together discharge 2,000 gallons a minute into an underground reservoir, from which the water is lifted into a standpipe by means of duplex pumps. The system includes about 11 miles of mains, 80 fire hyrdants, and 835 taps. The analyses given in the table (p. 190) show that the water is only moderately hard and is not otherwise heavily mineralized. It is used for domestic purposes by nearly the entire population, and is also utilized extensively in locomotive and stationary boilers. It is estimated that altogether an average of about 750,000 gallons is consumed daily.

The Chicago, Milwaukee & St. Paul Railway has five six-inch wells similar to those that furnish the public supply, and the Van Camp Milk Condensing Company has two wells of the same type, one six inches and one ten inches in diameter. In all these wells air lifts are used.

GREENE COUNTY

BY W. J. MILLER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

The general flatness of surface so characteristic of all areas covered by the Wisconsin drift is in Greene county considerably modified by the broad valleys, with long gentle slopes to the stream bottoms, cut and occupied by North Raccoon river and its few branches, which flow in a general southeasterly direction across the county.

Earlier drift than the Wisconsin is found over the entire county, but the combined thickness of these deposits is in most places less than 200 feet.

In the western part of the county rocks of Cretaceous age, here very thin, immediately underlie the drift; in the eastern part the underlying rocks belong to the Des Moines stage of the Pennsylvanian series. From Jefferson a tongue of the Des Moines, without Cretaceous above it, extends some distance up North Raccoon river. (See Pl. XI, p. 458.) So far as known none of the formations show any great departure from horizontality.

UNDERGROUND WATER.

SOURCES.

Nearly all of the water used in Greene county is derived from wells in the drift. Most of these wells strike the important water-bearing sandstone or gravel stratum beneath the Wisconsin drift, and therefore the depth to this aquifer varies a good deal over the county, well records showing differences of 20 to 150 feet or more. The greatest depths, as a rule, are found in the western part of the county. Water from this bed is very satisfactory and is practically unaffected by the weather.

Another important aquifer lies beneath the blue clay of the Kansan drift at depths ranging from 72 to 270 feet, the greatest depth being in the western part of the county. Although this is the most important and persistent water bed in the drift comparatively few wells are deep enough to reach it. As the Wisconsin and Kansan drift sheets are not always clearly separable in a single section, it is sometimes difficult to tell with which one is dealing.

Sand or gravel beds of consderable thickness are found locally within the Wisconsin or Kansan drift sheets, and a good many wells undoubtedly get their water supply from such deposits.

ARTESIAN BASINS.

In several places in the county wells in the drift yield flowing water. One of these local artesian basins is in the southwestern part along the Willow creek bottom, where flows are easily obtained by wells ranging in depth from 26 to 100 feet or more. The water probably comes from gravel beneath the Wisconsin drift.

Another basin is in the vicinity of Jefferson, where a number of wells along North Raccoon river and Hardin creek bottoms yield flowing water. The aquifer from which the water comes has not been definitely determined, but it is probably the gravel beneath the Wisconsin drift at depths of 100 to 125 feet; west of Jefferson at least one well, 270 feet deep, derives flowing water from gravel beneath the Kansan drift.

A third important basin lies along the principal stream bottoms in the northeastern part of the county. Good well records are not available to show the source of the water, but in some places, as in the vicinity of Grand Junction, the water seems to come from the base of the Kansan drift. In other places the wells are much shallower, and the water horizon appears to be at the base of the Wisconsin drift.

A number of deeper wells have penetrated the drift and have gone into the Des Moines stage, obtaining water chiefly in sandstones. The deepest well (2,026 feet) in this county, that at Jefferson, derives its supply from Cambrian sandstone.

SPRINGS.

Springs of small size drawing water from the drift deposits are rather common along the main stream courses.

CITY AND VILLAGE SUPPLIES.

Jefferson.—The city well (Pl. XI, p. 458) at Jefferson (population, 2,477) has a depth of 2,026 feet and a diameter of 8 inches; cased to 1,400 feet. The curb is 1,110 feet above sea level, and the head 40 feet below curb. The capacity is 200 gallons a minute, the water coming from 1,400 feet. The well was completed in 1886 by J. P. Miller & Company, of Chicago. The water is pumped by compressed air to a reservoir, from which it is forced to an elevated tank. It is distributed by gravity pressure of 60 pounds through 3½ miles of main to 22 fire hydrants and about 200 taps. About 1,200 persons use the supply, and the daily consumption is 50,000 gallons. The water is hard but is otherwise good.

The strata penetrated by this well are shown in the following record:

Record of strata in city well at Jefferson.

	Depth in feet.
Carboniferous:	
Pennsylvanian—	
Sandstone, dark buff; moderately fine grains, imperfectly rounded	260
Shale, dark, unctuous, noncalcareous	270

Mississippian—	
Sandstone, argillaceous, slightly calcareous; grains of pure quartz, from fine to coarse and but little rounded by attrition	340
Chert, gray; large to small grains of limpid quartz, probably from above, and a little white limestone	350
Limestone, white, nonmagnesian; highly arenaceous, with minute quartzose particles and some rounded grains	355
Limestone, dark and light drab; hard	525
Shale, green-gray, pyritiferous, calcareous (Kinderhook)	700
Devonian(?):	
Limestone, light buff, crystalline, pure	800
Silurian and Galena (Ordovician):	
Limestone, magnesian; in white powder; pure	1,000
Limestone, magnesian, or dolomite; some shale in brown powder; residue cherty	1,100
Limestone, magnesian; brown; in fine sand; effervescence rather rapid	1,200, 1,300
Limestone, magnesian, light blue-gray; luster earthy	1,350
Dolomite, light buff; in fine sand; highly cherty	1,450
Dolomite or magnesian limestone, brown, cherty; slow effervescence	1,500
Ordovician:	
Platteville limestone—	
Shale, green, slightly calcareous	1,670
Saint Peter sandstone—	
Sandstone, fine, white, clean; rolled grains, 50 feet thick	1,700
Prairie du Chien stage—	
Dolomite; in fine sand deep brown; some chert	1,745
Sandstone; in yellow powder and sand of angular particles of quartz with a few round grains	1,800, 1,880

Scranton.—The water supply of Scranton (population, 845) is derived from a well somewhat over 200 feet deep. The water is pumped to an elevated tank from which it is distributed by gravity through about a mile of mains to five fire hydrants and 45 taps. The domestic pressure is 50 pounds and the fire pressure 100 pounds. About 250 people use the supply, the daily consumption averaging 15,000 gallons.

WELL DATA.

Information concerning typical wells in Greene county is presented in the following table:

Typical wells of Greene County.

Owner	Location	Depth	Source of supply	Head above or below curb	Remarks: (Logs in feet)
		Feet		Feet	
D. Fitz	8 miles west of Churdan.	190	Sand	—60	
Minneapolis & St. Louis Ry.	Grand Junction	325	Sandstone	—13	Engine supply. Black soil, yellow clay, blue clay, fire clay (white), shale (white), ½ foot iron pyrites, 120; shale (dark) and black jack, 30; coal, 1½; fire clay, 64; sandstone and water at bottom shale, 110.
Dr. Arthur	6 miles south of Ralston.	26	Sand	+ 2	Flowing well.
William Anderson	6 miles southeast of Jefferson.	192	Gravel	—80	
Electric light plant	Jefferson	134	Sand	—60	Boiler use.
Albert Head	1 mile west of Jefferson.	270	do	+3	Black soil, 10; yellow clay, 15; sand and water, 15; clay (dark brown and tough), 16; potter's clay (white), 12; blue clay, 100; sand (hardened) and water, 50; sand, 52.
Mr. Weant	2 miles west of Paton	159	Sand and gravel.	—30	
R. Townsend	5 miles east 2 miles north of Churdan.	146	do	—13	
R. Adamson	2 miles north of Bayard.	127	Sand	—30	Black soil, 16; sand, 80; blue clay, black "muck" and fossil wood, 16; sand and water, 15.
John McCarthy	2 miles north of Jefferson.	105	Gravel and sand.	+20	Hard, iron bearing.
Town of Grand Junction.	Grand Junction	75	do	+25	Public well.
William Diamond farm.	7 miles northwest of Jefferson.	103	Sand	+ 4	
Ed. Jones	4 miles northeast of Grand Junction.	390	Sandstone	—40	
Chas. Reidel	1 mile south of Rippey	160	Sand	—60	

GRUNDY COUNTY.

BY W. J. MILLER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

Grundy county comprises an area of low, broad hills which give its surface a slightly undulating appearance. As a rule the hills are just high enough to cause the land to be fairly well drained. There are no large streams to produce noteworthy topographic irregularity.

Iowan drift deposits underlain by Kansan drift extend over the whole county. In some small areas loess may be present. Beneath the drift are sedimentary formations—limestones and shales—belonging to the Mississippian series (Lower Carboniferous). These extend over the whole county except in the extreme northeast corner, where the drift rests on Devonian rocks (Pl. VI, p. 310), and in the middle western portion, where it lies above shale and limestone of the Des Moines stage of the Pennsylvanian series (Upper Carboniferous).

The drift deposits are practically parallel to each other except for local thickening or thinning and there appears to be a general slight eastward dip of all. The underlying rock formations dip slightly westward.

UNDERGROUND WATERS.

SOURCES.

The most important aquifer in the drift is the sand or gravel bed at the bottom, which nearly everywhere yields a good supply of water. The depth to this aquifer ranges from 125 to 230 feet, according to the thickness of the drift sheets in different parts of the county. This aquifer is rarely lacking in Grundy county. Higher up and within the blue clay there are some local water-bearing sandy layers. In many localities, however, the water supply from these is small and may fail altogether after a time. Surface wells in the drift fluctuate with the seasons and very few farmers depend on them.

In the rock formations below the drift water is obtained by the deeper wells, many of which have been sunk in recent years.

SPRINGS.

Springs of any considerable size are not known in the county. Those that do exist are merely seepage flows from the drift deposits.

CITY AND VILLAGE SUPPLIES.

Grundy Center.—The water supply of Grundy Center (population, 1,354) is obtained from a well 469 feet deep, drilled in 1897 (?) by P. Pfiffner, of Traer. The well is eight to four inches in diameter and is cased to the bottom. The water level is 80 feet below the curb.

The strata penetrated are indicated by the following log:

Driller's log of city well at Grundy Center.

	Thickness.	Depth.
	Feet	Feet
Pleistocene:		
Clay, yellow	10	10
Clay, blue, and some water-bearing sand	180	190
Carboniferous (Mississippian):		
Limestone	5	195
Shale, some water	4	199
Limestone	6	205
Shale, some water	80	285
Devonian:		
Limestone	184	469

The water is distributed by gravity, under a pressure of 56 pounds, through 0.26 mile of mains, to 21 fire hydrants and 120 taps. About 600 people use the supply. It is reported that about 5,000 gallons are used daily. A larger supply might be obtained by sinking wells through the Devonian and Silurian limestones to the Maquoketa shale (Ordovician), which here lies 675 to 725 feet below the surface. The Galena and Platteville limestones would also probably yield some water. The Saint Peter sandstone should be reached at 270 to 350 feet below sea level or at a depth at most of 1,325 feet below the surface. Probably these formations would give sufficient water for the needs of the town for many years, but a large supply may be had from the Prairie du Chien stage and the Jordan sandstone, which would be reached by a well a little more than 1,800 feet deep. The water should be of good quality.

Reinbeck.—The town well at Reinbeck (population, 1,205), 339 feet deep, yields a good supply of hard water.

The section reported by the driller is as follows:

Driller's log of Reinbeck town well.

	Thickness.	Depth.
	Feet	Feet
Clay, yellow	4	4
Clay, blue, and sandy beds; water	225	229
Shale	20	249
Limestone; water	90	339

The water is pumped by steam pump and is distributed under gravity pressure of 43 pounds through three miles of mains to 13 fire hydrants and 140 taps. About 700 persons are supplied; the daily consumption is estimated at 24,000 gallons.

WELL DATA.

Information concerning typical wells in this county is presented in the following table:

Typical wells of Grundy County.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
Geo. Finlayson	7 miles north of Morrison.	242	202	Limestone	60	Pumped by windmill. Yellow clay, 12; sand (some water), 190; shale, 20; limestone and water, 20.
Henry Muller	5 miles southeast of Grundy Center.	580	200	do	60	Yellow clay, 8; blue clay full of pebbles in sand layers, 192; limestone, some sandy, 377; shale, ½; limestone and heavy flow of water, 2. Pumped by windmill.
John Gange	3 miles east of Reinbeck.	273	140	do	100	Black soil, yellow clay and blue shale with some sand beds and water, 140; shale, dark hard rock, and iron pyrites, 60; limestone and water, 18 to 20.
L. G. Benken	3½ miles northeast of Grundy Center.	344	277	Sandstone	140	Yellow clay, 37; blue clay, and some sand, 220; sand and much water, 20; shale, 60; sandstone, red, 7.

Typical wells of Grundy County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
Mickley Bros.	6 miles southeast of Ackley.	152	146	Gravel	70	Enters limestone 6 feet.
S. Sinneng	4 miles southeast of Ackley.	393	215	No water		Abandoned. Yellow clay and sand, 32; yellow clay, 58; blue clay, 70; hardpan, 10; yellow clay, 20; blue clay, 18; black clay, 7; sand rock (yellow), 2; soapstone or hard shale, 35; soapstone or soft shale, 6; soft soapstone or shale, 85; very hard blue shale, 60.

GUTHRIE COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY.

The topography of Guthrie county is of two strikingly different types. South and west of Middle Raccoon river the old loess-mantled Kansan till lies at the surface and is thoroughly dissected and perfectly drained; northeast of that stream the much younger Wisconsin till overlaps the Kansan and presents a typical gently undulating drift plain, almost untouched by stream erosion and hence poorly drained, marked with abundant ponds, swamps, and sloughs.

GEOLOGY.

Several formations differing widely in age and character overlap in Guthrie county, making the geology peculiarly interesting and the ground-water conditions more varied than in most of the other counties of the state. The oldest rocks exposed are of Carboniferous age and belong to the Des Moines stage of the Pennsylvanian series, which underlies the entire county, with a thickness of several hundred feet, consisting of shale alternating with numerous thin beds of limestone, sandstone, and coal.

Near the south margin of the county the Des Moines is capped by the basal limestone of the Missouri stage, also of the Pennsylvanian series. Upon the eroded surface of these old formations lie Cretaceous sandstones and shales, well developed and nearly continuous in the western half of the county, but thin or entirely absent in the eastern half. Finally, Cretaceous and Carboniferous alike are in general deeply buried beneath the glacial drift.

UNDERGROUND WATER.

SOURCES.

The Pennsylvanian series includes some sandstone strata that yield moderate amounts of mineralized water under sufficient head to rise nearly or quite to the level of the deepest valleys, but these sandstone strata are so scarce and so readily give place laterally to impervious beds that attempts to tap them are very liable to failure.

In the western half of the county the Cretaceous is a fairly reliable aquifer, but in the eastern half it is commonly too thin and irregularly distributed to be of consequence. In the former section it is found with considerable regularity about 250 feet below the upland surface, and its less cemented beds supply water freely, though the water is not under much pressure and does not rise many feet in the wells. Wells of four inches or six inches diameter with independent pumps are more successful than two-inch "tubulars."

The upper part of the Kansan drift is sufficiently porous to allow a slow seepage of scanty water to wells of large circumference. Associated with this drift are also beds of sand and gravel whose value as water bearers is entirely different where the Wisconsin drift is present from that where it is absent. Where it is absent, they are either drained or contain water under slight pressure only, and hence do not generally supply drilled wells; where it is present, they are charged with water under sufficient pressure to flow freely into a drilled well and to fill it nearly to the top or even to rise above the surface. The village well at Stuart (p. 841) is supplied from a bed of sand beneath Kansan till. Its head is low and its yield not great, but if this same bed of sand occurred in the area of Wisconsin drift the water would be under much greater pressure, would rise much higher in the well, and could be recovered at a much more rapid rate.

PROVINCES.

In respect to ground water the county is divisible into three provinces—one in which the Wisconsin drift is at the surface, one in which the older loess-covered Kansan drift is at the surface and is underlain by water-bearing Cretaceous beds, and one in which the older drift is at the surface and is not underlain by water-bearing Cretaceous beds. Very roughly, the first province may be said to comprise the area northeast of Middle Raccoon river, the second the western part of the area southwest of that stream, and the third the eastern part of this last area.

The first province has the most favorable ground-water conditions. The porous parts of the drift are saturated almost to the surface and flowing wells are frequently obtained, as, for example, in the village of Bagley and in Richland township, between Yale and Herndon. Water-bearing beds are likely to be encountered at any level in the drift, and many of the flows come from wells less than 100 feet deep.

In the second province seepage from the drift is largely relied on, but the drilled wells go to the Cretaceous and obtain supplies that are not influenced by drought. In the third province the Cretaceous is lacking, shallow drift wells are everywhere in use, and successful drilled wells are scarce.

CITY AND VILLAGE SUPPLIES.

Bagley.—In Bagley (population, 488) there are 12 or more flowing drift wells. A public system of waterworks has recently been installed.

Guthrie Center.—The public supply of Guthrie Center (population, 1,337) is derived from seven wells located in the valley 12 feet apart. The wells consist of $3\frac{1}{2}$-foot holes dug through sand and other loose materials to the Cretaceous bedrock at a depth of 28 feet, below which they are drilled to a gravelly stratum at about 50 feet. The water rises within 18 feet of the surface and the pumps are placed about eight feet below the surface and draw by suction from all the wells simultaneously. Pumping at the rate of 200 gallons a minute for several hours produces no noticeable effect except temporarily to lower the water level somewhat. The wells are finished with open ends and no difficulty with sand has been experienced. The water is only moderately hard and is preferred to the shallow well water. There are two standpipes situated on high ground, and about a mile of mains connect with an extensive system of smaller pipes leading to about 300 points of consumption. The water is used by nearly the entire population and also by the railway company for locomotive supplies. According to the records, the average daily consumption in 1908 was only a little less than 60,000 gallons.

The Mississippian limestones would probably yield a small supply of highly mineralized water under a head sufficient to bring it within easy pumping distance of the surface. Other and presumably better supplies can be had in the heavy beds of limestone which intervene between the Mississippian and the Saint Peter sandstone, but, as in all limestone beds, the water will occur in crevices and solution passages whose depth can not be predicted and which may not be struck by the drill. Guthrie Center is 1,077 feet above sea level; the Saint Peter sandstone probably lies about 1,000 or 1,100 feet below sea level, or about 2,100 to 2,200 feet below the surface. The water from this bed and other beds above may together be enough for the town supply. Unfortunately, little information is available as to the water beds below the Saint Peter in this area. Apparently the subjacent sandstones are less well defined than in eastern Iowa, but a well sunk 2,750 feet below the surface should test their capacity and would probably obtain a supply adequate to a town of 2,000 people.

Herndon.—Little except the depth is known concerning the Chicago, Milwaukee & St. Paul Railway well at Herndon. It was drilled by W. H. Gray & Brother of Chicago to a depth of 1,700 feet (?) from a curb elevation of 1,062 feet above sea level. The well does not appear to have found water. The record of the strata, as made out from drillings furnished to the United States Geological Survey, is as follows:

Record of strata in Chicago, Milwaukee & St. Paul Railway well at Herndon.

	Thickness.	Depth.
	Feet	Feet
No samples	534	534
Shale, drab, calcareous; a few chips of limestone and a little white chert	20	554
Shale, drab	20	574
Shale, greenish; 2 samples	40	614
Shale, blue	20	634
Shale, green, slightly calcareous	20	654
Limestone, blue-gray; in small chips; effervescence slow; some shale from above	20	674
Limestone, light blue-gray; crystalline; in large flaky chips; moderately rapid effervescence; 2 samples	40	714
Limestone, blue-gray; effervescence slow; 5 samples	100	814
Limestone, blue-gray; slow effervescence; some chert	20	834
Limestone and shale; limestone, light blue-gray, with slow effervescence; shale, hard, dark blue	20	854
Limestone, blue-gray and buff; slow effervescence	20	874
Limestone, light buff; slow effervescence; in chips; 6 samples	126	1,000
Limestone, drab; slow effervescence; 2 samples	50	1,050
Limestone, buff; slow effervescence; drillings contain an unchipped fishtooth (of Mississippian age) apparently from some higher horizon	25	1,075
Limestone, buff, crystalline; slow effervescence; 2 samples	50	1,125
Limestone, blue-gray and buff; slow effervescence	25	1,150
Limestone, drab; slow effervescence	25	1,175
Shale or marl; highly calcareous; much anhydrite; in concreted powder	25	1,200
Limestone, hard, drab; slow effervescence; 2 samples	50	1,250
Shale, drab; facies of Maquoketa shale; 3 samples	75	1,325
Shale, light yellow, highly calcareous; in concreted powder; 3 samples	75	1,400
Limestone, white; but drillings stained with ferruginous films so as to be buff in mass; in fine sand; slow effervescence; with considerable chert and crystalline quartz in irregular grains and with some secondary enlargements	25	1,425
Limestone, white, crystalline; slow effervescence; drillings stained deep ocher-yellow; in fine sand	25	1,450
Chert, in small chips; white and gray	25	1,475
Chert and shale, blue; in large concreted mass	25	1,500
Limestone and chert; in fine sand; buff in mass; effervescence slow	25	1,525
Limestone and chert; as above; some microscopic quartz particles and some imperfectly rounded small quartz grains	25	1,550
Limestone, argillaceous, or shale, calcareous; white; in concreted masses; gritty with lime particles; residue argillaceous and siliceous with microscopic crystalline quartz	25	1,575
Limestone, gray; in fine chips; slow effervescence; much gray chert	25	1,600
Limestone, buff in mass, in fine sand; much chert; residue of microscopic crystalline quartz; 2 samples	40	1,640
Limestone and shale; limestone, dark drab, argillaceous, crystalline to earthy, slow effervescence; shale, in chips, hard, green, fissile	20	1,660
Limestone and shale; limestone light buff or gray, crystalline to earthy; rapid effervescence; in flaky chips; shale as above	20	1,680
Limestone, gray and buff; rapid effervescence; in sand; some drab flint and minute imperfectly rounded grains of quartz	20	1,700

Analysis of rock from depth of 794 to 814 feet in railway well at Herndon.[1]

$CaCO_3$	48.10
$MgCO_3$	35.51
SiO_2	13.55
Al_2O_3	1.74
Fe_2O_3	.59
	99.49

[1]Made in chemical laboratory of Cornell College, Mount Vernon, Iowa.

The National Refining & Manufacturing Company well at Herndon has a depth of 895 feet and a diameter of 13 to 8 inches. The curb is 1,052 feet above sea level and the head 60 feet below curb. The water comes from 20 feet, 165 feet, and between 720 and 895 feet, in rock reported as "honeycombed limestone." Date of completion, 1908. The water is heavily charged with sodium and foams so much as to prevent its use in locomotive boilers.

Record of strata in National Refining & Manufacturing Company well at Herndon.

	Thickness.	Depth.
	Feet	Feet
Unknown	20	20
Till, blue, clayey	115	135
Sand, gray; grains angular, almost loessial in fineness, with some coarser; this is the "gas sand" of the region and blows out with the gas by the wagonload when not drowned with water	10	145
Sand, yellow, coarse, and gravel, glacial	15	160
Sand, orange, coarse	10	170
Shale, blackish, fissile	90	260
Shale, red	10	270
Limestone, argillaceous and finely arenaceous, dark buff or drab; rapid effervescence; and chert, dark drab, with much chalcedonic silica in large chips and a little drusy quartz; chalcedony reported as "water granite"	10	280
Limestone, drab, highly argillaceous, microscopically quartzose; with chert and chalcedony; shale of same color, calcareous	25	305
Chert, dark drab and blackish; highly conchoidal fracture; a little milky white translucent chalcedony	55	360
Limestone, gray, highly argillaceous; milky white chalcedony and white chert	30	390
Limestone, blue-gray; rapid effervescence; argillaceous; crystalline-granular; much white chalcedony	30	420
Limestone, almost white, coarse, crystalline-granular and limestone, light cream-colored, soft, in flaky chips; effervescence rapid, considerable blue-gray flint	10	430
Limestone, dark buff and drab, finely crystalline; effervescence moderately rapid; with embedded, irregular, minute masses of blue flint; residue contains minute grains of quartz	10	440
Limestone, whitish, macrocrystalline, soft; rapid effervescence; some joints of crinoid stems and oolites or perhaps tests of foraminifers almost too minute to be seen with naked eye	160	600
Shale, green, plastic, fissile, noncalcareous	20	620
Dolomite or magnesian limestone, blue-gray, hard, subcrystalline; effervescence slow	20	640
Shale, pinkish gray, slightly calcareous	15	655
Limestone, magnesian, blue-gray, subcrystalline; effervescence rather slow; 2 samples	40	695
Limestone, yellow-gray, hard, fine-grained; some lithographic, subconchoidal fracture; rapid effervescence	25	720
No samples	175	895

The sets of drillings from the two wells at Herndon are, fortunately, complementary and afford a fairly complete section. It will be noted that the Chicago, Milwaukee & St. Paul Railway well stopped near the summit of the Saint Peter sandstone in shale resembling much the Decorah shale. Had drilling been carried a few hundred feet farther into the dolomite of the Prairie du Chien stage, an abundant water supply would probably have been obtained.

Geologic section at Herndon.

Well of National Refining & Manufacturing Company.

Geologic Division.	Thickness.	Elevation above sea level.
	Feet	Feet
Pleistocene series	180	882
Des Moines stage	100	782
Saint Louis limestone and Osage stage	254	528

Well of Chicago, Milwaukee & St. Paul Railway Company.

Geologic Division.	Thickness.	Elevation above sea level.
Kinderhook shale	120	408
Devonian (?) and Silurian	590	—182
Maquoketa shale	75	—257
Galena and Platteville limestones	381	—638

Panora.—The public well at Panora (population, 1,080) is 16 feet in diameter and 40 feet deep and ends in sand. At present it furnishes about 9,000 gallons a day, but its maximum capacity is much more than this amount. The water is pumped by means of water power transmitted through an electric current. It is lifted into an elevated tank and is thence distributed by gravity through about two miles of mains to 10 fire hydrants and 75 taps. It is used by perhaps one-third of the people.

Stuart.—The well that furnishes the public supply of Stuart (population, 1,826) is six inches in diameter and 92 feet deep. It is on the upland, extends through clay, and is finished with an open end in a bed of sand or gravel from which the water rises to a level 76 feet below the surface, or 1,130 feet above sea level. With the cylinder placed three feet above the bottom, the well has been pumped continuously for three weeks at 16 to 20 gallons a minute; this rate of pumping lowers the water to the bottom of the cylinder and the well can by no device be made to yield more. Wells ending with screens in the same bed of sand were at first used, but the screens became clogged and the wells were lost. The water from this source is of good quality, though it contains considerable calcium carbonate, which gives it a temporary hardness. (See analysis, p. 190.)

The waterworks include a small tank set on a low tower and connected with about one-fourth mile of mains. In spite of the small service, the consumption at present approaches the maximum capacity of the well. As the system is inadequate in pressure, reserve of water, and extension of mains for fire protection, a number of large wells have been dug in different parts of the town and a portable fire engine is kept in readiness.

HAMILTON COUNTY.

BY W. J. MILLER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

The surface of Hamilton county shows the topography characteristic of the Wisconsin drift areas and is for the most part so flat and poorly drained that ponds and lakes are numerous. In the northeastern part of the county this topographic monotony is somewhat relieved by the valley of Boone river. South Skunk river, which rises in the east-central part and flows southward, is the only other stream of any importance.

The drift sheets, Wisconsin and Kansan, which extend over the whole county, rest on Carboniferous rocks belonging to the Des Moines stage of the Pennsylvanian series except in the small area along Boone river from Webster City northward, where they are underlain by the Mississippian.

As a rule the drift deposits lie flat except along Boone river, where they follow the slopes toward the stream bottom. The deep rock formations show little or no variation from the horizontal. (See Pl. VI, p. 310.)

UNDERGROUND WATER.

SOURCES.

By far the greater number of the wells in Hamilton county obtain water from the Pleistocene deposits, which here contain two principal water beds of about equal importance—one in sand or gravel beneath the Wisconsin drift, and the other in sand or gravel beneath the blue clay of the Kansan drift. Well data indicate that the depth to the gravels beneath the Wisconsin drift ranges from 90 to 120 feet below the ground surface. Many wells, however, fail to find water at this horizon and must be sunk deeper. The sands and gravels beneath the Kansan drift are reached at depths of 150 to 200 feet. They are lacking in but few places and form the most satisfactory aquifer in the Pleistocene deposits. In some wells, however, the water is not good because charged with organic matter. Some wells appear to derive their supply from local sand or gravel pockets within the drift sheets, but such supplies often fluctuate or even fail. Little dependence is placed on very shallow surface (dug) wells. A few wells obtain water in the older rock formations—limestones or sandstones—the water coming from different depths.

Along the bottoms of the principal streams the water is under sufficient head to overflow at the surface. A number of flowing wells are located along Boone river, as, for example, the thirteen wells owned by Webster City. Other flowing wells are found along South Skunk river in the southeastern part of the county. As far as could be learned the water in these wells comes from the sands and gravels beneath the blue clay of the Kansan drift, since the Wisconsin drift sheet in the localities named is thin or absent.

SPRINGS.

In the high level parts of Hamilton county springs are almost entirely lacking, but a few emerge from drift deposits along Boone river.

CITY AND VILLAGE SUPPLIES.

Jewell.—The public water system of Jewell (population, 941) is used only for fire protection and by business houses. The water is pumped by steam and is distributed under direct air pressure of 50 pounds through three-fourths of a mile of mains to 12 fire hydrants and 18 taps. The water is hard.

Webster City.—The water supply of Webster City (population, 5,208) is obtained from 13 wells, ranging in depth from 90 to 110 feet, ending in gravel beneath the blue clay of the Kansan drift. (See Pl. VI, p. 310.)

The water is distributed under pressure of 55 pounds through six miles of mains to about 350 taps. For fire protection pressure can be increased to 150 pounds. About 1,600 people use the supply, which is ordinarily sufficient.

The gas company well has a depth of 1,250 feet and a diameter of eight to six inches; casing to or near the bottom. The curb is 1,048 feet above sea level, and the head 16 feet above the curb. The water comes from 675 feet and 1,200 feet, and the original flow was 70 gallons a minute. The well was completed in 1888. The water has both the odor and taste of sulphur and so rapidly corrodes iron that the best galvanized pipe withstands it for only about two years. For these reasons the well has never been used except to supply a public watering trough.

Record of strata in well at Webster City (Pl. VI, p. 310).

	Thickness.	Depth.
	Feet	Feet
Soil, clay, sand, thin layers of rock, etc.	180	180
Limestone, light yellow; earthy luster; much quartz sand, yellow, pink, and black, grains imperfectly rounded	20	200
Limestone, light gray, soft, earthy, in flaky chips; fossiliferous	150	350
Shale, blue	10	360
Limestone, dark drab; mottled with white calcite; crystalline	100	460
Limestone, magnesian, hard, brown, crystalline	40	500
Shale, calcareous, dark gray, siliceous; microscopic particles of quartz	20	520
Dolomite or magnesian limestone, dark brown, compact crystalline	30	550
Limestone, dark blue-gray, crystalline; effervescence slow	45	595
Limestone, light yellow-gray, soft, crystalline; effervescence slow	55	650
Dolomite or magnesian limestone	30	680
Limestone, light gray, saccharoidal	95	775
Limestone, close-grained, blue-gray	45	820
Limestone, brown, crystalline	60	880
Limestone or shale, highly argillaceous, blue-gray; white concreted masses of anhydrite powder	120	1,000
Shale, drab, calcareous	75	1,075
Limestone, magnesian, brown, crystalline	15	1,090
Limestone, in pure, white, crystalline sand	40	1,130
"Limestone (?), pure white"; no sample	120	1,250
Limestone, light buff; in fine sand		1,250

The record given above is based on but 20 samples and entries, and is difficult to interpret. The Mississippian probably extends to the base of the shale at 520 feet (528 feet above sea level). No line can be drawn between the Devonian and Silurian, and the latter seems to include the anhydrite-bearing limestone and shale, stated to extend from 880 to 1,000 feet, the 75 feet of subjacent shale falling in with the Maquoketa shale. From 1,075 feet to the bottom of the well the drill seems to have been working in the Galena and Platteville limestones. Had the drilling been continued 150 feet deeper the Saint Peter sandstone would probably have been struck, and 400 to 600 feet deeper the creviced limestones and the sandstones which yield the chief supply for the Iowa wells would have been tapped. A well about 1,850 feet deep would have given a largely increased yield of much better water, the sulphate content being greatly lessened. Hence the failure of the well to get a good water need not deter other enterprises.

WELL DATA.

Information in regard to typical wells in Hamilton county is presented in the following table:

Typical wells of Hamilton County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
Peter Nelson	Jewell	105	None	Sand or gravel.	—30	
Peter House	3½ miles northeast of Jewell.	183	116?	Limestone.	—40	
Ole Litre	6 miles southwest of Jewell.	328	107		—50	
E. Challey	2 miles south of Jewell.	95	None	Sand and gravel.	+15	Flowing well. Black soil, 5; yellow clay, 15; blue clay, 30; blue clay, putty-like, 15; sand and gravel, 30.
A. Bloom	7 miles northeast of Jewell.	295	105	Limestone.	—35	
O. Brudos	6 miles southeast of Stanhope.	155	None	Gravel	—25	
J. E. Olmstead	¾ mile west of Webster City.	181	181	do	—50	Black soil, 4; yellow clay, 14; blue clay, 83; yellow clay, 40; black muck with leaves, etc., 40; gravel; limestone.
M. Fahoney	2 miles northeast of Duncombe.	176	None	do	—34	
Jos. Welch	2 miles north of Homer.	181	None	do	—30	Black soil, 4; yellow clay, 10; blue clay, 16; sand and some water, 3; "hardpan" (hard blue clay), 17; sand and some water, 50; tough black clay, 75; sand and gravel and water, 6.
G. Robinson	2 miles west of Blairsburg.	167	(?)	Sand	—40	Water bed at 156 feet.
S. Bateman	2 miles south of Webster City.	68	None	Gravel	+25	Flows 10 gallons per minute; pumped by steam. Yellow sand, 8; blue clay, 27; sand and water (flow 30 gallons per minute, but too much sand), 3; blue clay, 28; gravel and water (flow 10 gallons per minute).
M. H. Brinton	Ellsworth	91	None	Sand and gravel.	+14	Flows 10 to 15 gallons a minute.
Lars Severson	6 miles northwest of Radcliffe.	240	162		—45	
N. E. Waugh	3½ miles north of Roland.	108	30	Limestone.	+25	Flows 13 gallons a minute.

HARDIN COUNTY.

BY W. J. MILLER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

An area of loess-covered Kansan drift in the southeastern part, a smaller area of Iowan drift in the northeastern, and a much larger area of Wisconsin drift in the western parts are the controlling factors in the topography of Hardin county.

The surface of the Kansan drift area is well drained. The larger streams have deposited some alluvium, and their tributaries have cut well back toward the divides. The Iowan area is part of the great Iowan drift plain and is comparatively flat. The Wisconsin drift area comprises more than four-fifths of the entire county. Its eastern margin is marked by a chain of hills and knobs that rise 30 to 60 feet above the adjoining uplands. Back of this ridge the general surface is characteristically a plain, marked by many saucer-like depressions and knoblike eminences. Drainage lines are few and broad areas are almost wholly undrained.

The most striking feature of the eastern part is Iowa river channel, which has been cut down well below the general level. In the vicinity of Iowa Falls, Iowa river cuts through ledges of solid limestone. Except very locally along Iowa river, where it has been eroded away, the Kansan drift sheet is probably present throughout the region, extending beneath the Iowan sheet in the northeastern part and beneath the Wisconsin in the western.

From the northern part of the county to a little south of Iowa river, and probably also in the extreme southeast corner of the county, the drift rests on limestone belonging to the Mississippian series of the Carboniferous. (See Pl. VI, p. 310.) Throughout the remaining and larger part of the county the underlying rock is the shale or limestone of the Des Moines stage of the Pennsylvanian series.

The drift formations lie in general nearly horizontal; the underlying rocks show a slight westward dip.

UNDERGROUND WATERS.

SOURCES.

The most important and persistent aquifer in the drift deposits of the county appears to be the sand or gravel beneath the blue clay of the Kansan drift. As the drift formations vary in thickness from a few feet to a maximum of 300 feet, this aquifer may be found at any depth up to 300 feet; nearly everywhere, however, it lies between 100 and 200 feet.

The next most important aquifer in the drift is the sand or gravel beneath the Wisconsin drift. Well data indicate that this aquifer, where present, lies at a depth of less than 100 feet. In many places, however, the sands or gravels are absent or they do not yield sufficient water.

Some wells obtain water from local sand or gravel pockets in one or the other of the blue clays, but such supplies are rarely satisfactory. Nearly all the very shallow surface (dug) wells show seasonal fluctuations.

Some wells have passed through the drift into the shales, sandstones, and limestones below, obtaining water from the limestones and calcareous sandstones.

Many wells sunk in the depressions obtain water under sufficient head to flow at the surface. All such are comparatively shallow, ranging in depth from 25 to 75 feet; their water comes from sands or gravels, thought to be at the base of the Kansan drift, below a blue clay, which acts as a retaining layer. Such local basins are found in the western portion of the county along the more important streams between Iowa Falls and Hubbard. A number of wells along Rock Run near Iowa Falls and others southwest of Iowa Falls in the vicinity of Buckeye and Cottage yield flowing water.

Several wells obtain flows from the underlying rock formations; for example, the city well of Iowa Falls and a well three and one-half miles west of Hubbard.

SPRINGS.

Many springs emerge from both the drift and the underlying formations along the course of Iowa river. The water of the springs north of Eldora comes from the Coal Measures and carries iron and sulphur. Small springs are common along other streams, especially in the local artesian well basins.

The Siloam mineral springs, owned by Mr. E. E. Cannon, of Iowa Falls, are on Maplehurst farm, one and one-half miles northwest of Iowa Falls. The springs emerge near the stream bottoms along a small branch of Iowa river, and the water apparently comes from limestone, which is here near the surface. The water is used both for drinking and as a medicine. About 50 families in Iowa Falls are supplied.

CITY AND VILLAGE SUPPLIES.

Ackley.—Two wells are owned by the city of Ackley (population, 1,244), one 2,032 feet deep, the other 119 feet deep. The deep well, which was put down some time prior to 1894, was abandoned because it did not yield sufficient water. The curb of this well is 1,110 feet above sea level; the head is reported to have been 82 feet below the curb, or 1,028 feet above sea level; another report gives the head as 25 feet below the curb. Water was recorded as occurring 50 feet from the top; other veins were not recorded. The strata penetrated are indicated by the following section:

Record of strata in city well at Ackley (Pl. VI, p. 310).

	Thickness.	Depth.
Quaternary (100 feet thick; top, 1,110 feet above sea level):	Feet	Feet
Alluvium, or drift	100	100
Carboniferous (Mississippian):		
Kinderhook stage (207 feet thick; top, 1,015 feet above sea level)—		
Shale, fine, blue, somewhat calcareous; 2 samples	35	135
Limestone, coarse, buff, vesicular	5	140
Shale, blue, fine, slightly calcareous; 2 samples	23	163
Sandstone, fine, bluish white, friable		163
No samples	62	225
Shale, fine, blue, slightly calcareous; 3 samples	35	260
Sandstone, fine, bluish white, friable	5	265
Shale, blue-gray; with black ferruginous concretions; calcareous	25	290
Shale, fine, blue, somewhat calcareous	17	307
Devonian (328 feet thick; top, 803 feet above sea level):		
Limestone, magnesian, light buff, highly pyritiferous; contains a little chert	13	320
Shale and limestone; shale, blue, calcareous, with a few particles of black carbonaceous shale; limestone, blue, argillaceous, some gray and purer, fossiliferous	15	335
Limestone, dark gray, magnesian, at		335
No samples	65	400

Record of strata in city well at Ackley—Continued.

	Thickness.	Depth.
	Feet	Feet
Limestone, argillaceous, nonmagnesian; small fragment of brachiopod resembling Atrypa reticularis Linn	10	410
Limestone, light gray; some green shale, at		410
No samples	50	460
Limestone, light gray	13	473
Limestone, light yellow-gray, argillaceous and slightly siliceous, at		473
No samples	27	500
Limestone, blue, argillaceous; 2 samples	70	570
Limestone, brown, slightly magnesian; 3 samples	65	635
Silurian (180 feet thick; top, 475 feet above sea level):		
Limestone, magnesian, light brown; 30.74 per cent $MgCO_3$, at		635
No samples	95	730
Dolomite, brown and buff; much white chert; 5 samples	27	757
Dolomite, light gray; some chert	2	759
Dolomite, cherty, 5 samples	38	797
Dolomite; with green shale and chert; 3 samples	18	815
Ordovician:		
Maquoketa shale (160 feet thick; top, 295 feet above sea level)—		
Shale, green	60	875
Dolomite, brown, hard, crystalline, cherty; 2 samples	29	904
Dolomite and shale, dark drab; much green shale in drillings	11	915
Dolomite and shale; chiefly shale, at		915
No samples	25	940
Shale, green and buff; in cuttings, as if washed; 2 samples	35	975
Galena and Platteville limestones (385 feet thick; top, 135 feet above sea level)—		
Limestone, light gray, cherty; 2 samples	40	1,015
Limestone, light gray, soft; fossiliferous at 1,205, 1,230, and 1,238 feet; 10 samples	235	1,250
Limestone, light buff, dark gray, and light gray; 3 samples	50	1,300
Limestone, highly argillaceous; fine blue-black calcareous sand, highly pyritiferous, with much clayey matter and minute particles of quartz	25	1,325
Shale, green and bright green, indurated, slaty, highly pyritiferous; 3 samples	35	1,360
Saint Peter sandstone (85 feet thick; top, 250 feet below sea level)—		
Sandstone; grains white, well rounded, somewhat uniform in size; 3 samples	85	1,445
Prairie du Chien stage—		
Shakopee dolomite (120 feet thick; top, 335 feet below sea level)—		
Dolomite, white, subcrystalline, oolitic; much quartz sand, at		1,445
No samples	35	1,480
Dolomite; in fine, light yellow meal	10	1,490
Dolomite; considerable light green shale; much quartz sand	10	1,500
Dolomite, buff; quartz sand and shale	5	1,505
Dolomite, white; some chert, quartz grains, and green shale; 2 samples	25	1,530
Dolomite, light yellow; a little quartz sand	10	1,540
Dolomite, hard, gray, subcrystalline; some sand grains	8	1,548
Dolomite, white	2	1,550
Dolomite, hard, rough, light buff	15	1,565
New Richmond sandstone (80 feet thick; top, 455 feet below sea level)—		
Sandstone, calciferous; white, rounded grains; numerous minute chips of dolomite	15	1,580
Sandstone; as above, but with much less dolomite	15	1,595
Sandstone, light colored, friable; grains rounded and varying widely in size, the largest reaching 1 millimeter in diameter	15	1,610
Sandstone, light gray, hard, moderately fine-grained; much green shale (probably from above) and considerable dolomite	25	1,635
Sandstone, white; grains rounded and resembling Saint Peter in general uniformity of size; many from 0.7 to 0.9 millimeter in diameter, largest grain over 1 millimeter	10	1,645
Oneota dolomite (175 feet thick; top, 535 feet below sea level)—		
Dolomite, buff; drillings chiefly quartz sand	15	1,660
Dolomite; much quartz sand	15	1,675
Dolomite; drillings chiefly quartz sand. If sand is native in this and the two samples above, the rock should be called calciferous sandstone	10	1,685
Dolomite, hard, gray, subcrystalline, pyritiferous	35	1,720
Dolomite, light gray, at		1,720
No samples	100	1,820
Cambrian:		
Jordan sandstone (210 feet penetrated; top, 710 feet below sea level)—		
Sandstone, white; fine-rolled grains with some dolomite sand and chert, at		1,820
Sandstone, calciferous; mostly quartz sand, well rounded, rather coarse, some dolomite and grains of chert-oolite; some quartz grains seen in dolomite matrix, at		1,950
Sandstone; as above; grains reach 1 millimeter in diameter; detached grains and chips of sandstone with dolomitic matrix and minute cuttings of dolomite, some arenaceous, at		2,000

Chemical analyses of well drillings.[a]

	Sample from depth of—		
	835 feet	787 feet.[b]	1,540 feet
$CaCO_3$	60.45	60.97	50.96
$MgCO_3$	30.74	34.85	43.82
$CaSO_4$	.58	.62	1.06
SiO_2	4.99	----------	2.47
Al_2O_3	2.56	2.07	.59
Fe_2O_3	.58	1.11	.33
H_2O	.37	.37	.79
Total	100.27	99.99	100.02

The section of the shallower well, which furnishes the present abundant supply of medium hard water, is reported by the driller as follows:

Driller's log of Ackley city well.

	Thickness.	Depth.
	Feet	Feet
Clay, yellow	10	10
Sand, yellow	2	12
Clay, blue	23	35
Sand	2	37
Clay, blue	8	45
Gravel and sand	19	64
Sandstone and water	55	119

The water is pumped by an electric motor and distributed by gravity under pressure of 40 pounds through four-fifths of a mile of mains to 59 taps and 11 fire hydrants. About 300 people use the supply. The daily consumption is estimated at 10,500 gallons.

Eldora.—The public water supply of Eldora (population, 1,995) is obtained from two wells—one 200 feet, the other 250 feet deep—that end in limestone. The water stands 135 feet below the curb and is pumped by steam to an elevated tank, from which it is distributed under gravity pressure of 35 pounds. For fire protection a pressure of 105 pounds is available. The distribution system comprises three and one-half miles of mains, 30 fire hydrants, and 193 taps. Practically everybody uses the city water, the consumption of which is estimated at 6,000 gal-

[a]Chemical laboratory, Cornell College, Mount Vernon, Iowa.

[b]Silica, which formed about one-third of sample in the form of chert, discarded from analysis.

lons daily. Long pumping is required to keep up the supply. The water is medium hard.

The strata penetrated by the shallower well are indicated by the following log:

Driller's log of Eldora town well.

	Thickness.	Depth.
	Feet	Feet
Clay, yellow	30	30
Clay, blue	10	40
Black "muck," with logs 1 foot in diameter	20	60
Sand, yellow, and water	8	68
Clay, blue	40	108
Shale, black	17	125
Fire clay	10	135
Limestone and water	65	200

Eldora is 1,060 feet above sea level, and a deep well will reach the base of the Kinderhook stage about 400 feet below the surface. The drill will then pass through Devonian and Silurian limestones in which some water may be found. A heavy dry shale, the Maquoketa, possibly exceeding 100 feet in thickness, will be encountered at about 970 feet from the surface. Below the Maquoketa the Galena and Platteville limestones may be found to contain water, especially toward the base of the Platteville. The Saint Peter sandstone, the first reliable water bed, should be reached at about 1,500 feet from the surface, but to obtain a large supply drilling should be carried 500 or 600 feet deeper still through creviced limestones and porous sandstones, which will yield an ample supply.

If a thoroughly water-tight casing is carried down somewhat below the base of the Kinderhook stage, the waters from the lower aquifers should make a very fair drinking water. The quality of all inflows above the Saint Peter should be tested.

Hubbard.—The town of Hubbard (population, 568) obtains a good supply of medium hard water from a well 325 feet deep. The water is pumped by gasoline engine and distributed under gravity pressure of 30 pounds through one-half mile of mains to 11 taps and seven fire hydrants. About 100 people use the water. The daily consumption is estimated at 3,000 gallons.

The strata penetrated by this well are indicated by the following log:

Driller's log of Hubbard well.

	Thickness.	Depth.
	Feet	Feet
Clay, yellow, and sand	75	75
Clay, blue	150	225
Clay, yellow, hard; with sand layers	25	250
Limestone	25	275
Sandstone	25	300
Limestone, white	25	325

Iowa Falls.—The water supply of Iowa Falls (population, 2,797) is derived from two flowing wells, one 276 feet, the other 240 feet deep. (See Pl. VI, p. 310.) The water is pumped by two steam pumps and distributed under gravity pressure of 55 pounds through four miles of mains to 300 taps and 31 fire hydrants. About 1,700 people use the supply; the daily consumption is estimated at 70,000 gallons. The water is hard. The city wells end near or at the base of the Kinderhook stage (Mississippian). If a well is sunk below these shales, the drill will first penetrate heavy limestones of Devonian and Silurian age, which probably continue with little interruption to a depth of about 850 feet below the surface, where they give place to the Maquoketa shale (Ordovician), here about 150 feet thick. The Devonian and Silurian limestones will probably yield some water. Near their base thin beds containing more or less of gypsum or anhydrite may be encountered, the water from which should be cased out. The Maquoketa shale will of course be dry. Below the Maquoketa shale will be found the Galena and Platteville limestones, which extend to about 1,475 feet from the surface and should contain considerable water under a head which should bring it within easy pumping distance of the surface. The water so far encountered will considerably increase the present supply, but will not improve its quality, and the well should be sunk to the Saint Peter sandstone or about 300 feet below that formation in order to obtain the large supplies which are to be found in the deep formations. To obtain the largest amounts of the best waters, therefore, the well should be sunk to a depth ranging from 1,900 to 2,100 feet. Analyses of the different waters will show which ones should be cased out because of their poor quality.

Radcliffe.—The public water system of Radcliffe (population, 660) is obtained from two wells, the older 130 feet, the newer 95½ feet deep, which yield a good supply of hard water.

The system is equipped with two steam pumps and the water is distributed by gravity under pressure of 35 pounds through two-thirds of a mile of mains to 40 taps and 11 fire plugs. About half the population use the town water. The daily consumption is estimated at 8,000 gallons.

WELL DATA.

Information in regard to typical wells in Hardin county is presented in the following table:

Typical wells of Hardin County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
Mr. Lake	3 miles east-southeast of Buckeye.	58	56	Sand at 53 feet.	+ 2	Flows good stream. Yellow clay, 15; blue clay, 38; sand and water, 3; limestone (?), 2.
M. Thompson	2 miles north of New Providence.	250	250	Drift sand.	—100	Limestone under water-bearing stratum.
Mr. Bump	5½ miles south of Iowa Falls.	172	160	Sandstone.	— 80	Yellow clay, 20; blue clay, 97; sand, gravel, and water, 3; blue clay, 25; sand, 5; "hardpan" (tough yellow clay), 10; sandstone (soft) or sand and much water, 2; shale 6; limestone, 4.
J. B. Parmelee	T. 89 N., R. 20 W.	56	No rock	Sand and gravel.	+ 16	Temperature, 47 degrees; flows 80 gallons per minute. Black soil, 3½; sand, 2; blue clay, 5½; fine sand, 3½; blue clay, sand, gravel, and water, 41½.
Fred Silas	3 miles southeast of Ackley.	236	236	Limestone.	— 96	Yellow clay, gravel, bowlders, and sand at top; blue clay and 1 foot hardpan at depth of 90; sand at 194; clay at 197; rock (probably a bowlder) at 198; blue clay at 234; limestone and water at 236.

Typical wells of Hardin County—Continued

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks (Logs given in feet)
State Industrial School.	1 mile west of Eldora.	250	92	Limestone (?)	— 40	Steam pump. Black soil, 6; yellow clay, 15; blue clay, 40; very soft coal (?), 7; sand, 20; white clay, 4; sandstone, 1; black shale, 5; sandstone and water, 5; white clay, 2; black shale, 15; gray limestone and sandstone and water alternating, 130.
D. M. Leach	2 miles southwest of Abbott.	245	(?)	Limestone	—170	Water-bearing stratum at 239. Yellow clay (sandstone and water, 10 feet), 15; blue clay, 35; yellow clay, 40; blue clay, 107; hard rock (bowlder), 1; blue clay, 36; hard sandstone (bowlder), 4; soft clay, 1; rock (bowlder), 1½; sandstone and much water, 5.
William Haynes	Steamboat Rock	265	225	do	—110	Limestone, 40. Pumped by windmill.
J. Smuck	½ miles north of Hubbard.	70	70		+ 16	Water in sand over rock.
Mr. Ledge	3½ miles west of Hubbard.	350	298	Limestone	+ 1	Flowing well. Yellow clay, 15; blue clay and pebbles, 240; sand and gravel, 43; limestone and water, 52.

JASPER COUNTY.

BY HOWARD E. SIMPSON.

TOPOGRAPHY.

Jasper county exhibits two distinct phases of erosional topography. By far its greater part shows the well-drained, maturely dissected surface of the Kansan drift sheet; the remainder, comprising a small area in the northwest corner of the county, including most of Clear Creek township, the west half of Poweshiek township, and the northwest quarter of Washington township, shows the imperfect drainage and level surface of the latest drift sheet, the Wisconsin.

The area is drained chiefly through South Skunk river and its tributaries, the larger streams flowing in a general southeasterly course. A small area in the southwest corner, however, is drained southward through the tributaries of the Des Moines.

All the larger streams meander through broad, deep valleys floored with alluvial deposits. The divides are also rather broad and flat topped, showing less complete dissection than is characteristic of the Kansan plain farther south and nearer the larger rivers. The upland plain slopes gently southward from a maximum of about 1,050 feet above sea level in the north and about 950 feet in the south to 750 feet in the bottoms of the greater valleys.

GEOLOGY.

The entire area of Kansan drift is covered by several feet of loess,, a pebbleless gray clay easily distinguished from the drift clay. The latter is in places 100 to 200 feet thick and contains much sand, gravel, and even bowlders, locally stratified but generally unstratified. In the Wisconsin area the bowlder clay overlies the loess, which in turn rests on the older Kansan.

All of the larger stream valleys contain alluvial deposits of interbedded silt, gravel, and sand, those in the valley of the Skunk being especially deep and from one to three miles wide.

So far as known, the unconsolidated surface deposits of the county everywhere rest on Carboniferous rocks belonging to the Des Moines stage of the Pennsylvanian series. (See Pl. XV, p. 812.) Sandstones are more common in the shales of this group than in counties farther south. These Coal Measures are underlain in the northeastern part of the county by the Kinderhook stage, and in the southwestern by the Saint Louis limestone, both of which belong to the Mississippian series.

UNDERGROUND WATER.

SOURCES.

The water supply of Jasper county is derived from alluvial deposits, the loess, the drift, sandstones of the Des Moines stage, sandstones in the Saint Louis limestone, and from deeper formations.

Alluvial sands and gravels are important aquifers only along South Skunk river and its two chief tributaries in this county, Indian creek and North Skunk river, where they have accumulated to considerable depths and are sufficiently loose and porous to permit a very strong underflow. Most of the wells in the alluvial deposits are shallow, as a rule less than 40 feet in depth.

Over large parts of the loess-Kansan area the loess mantle is several feet thick and the basal portion is so sandy that it furnishes a water supply that is utilized by shallow wells to an extent greater than in any other county. The loess on the uplands produces conditions favorable to shallow water supplies such as are used for the public supply of the town of Eddyville, on Des Moines river.

In the region of the Wisconsin drift the underlying loess becomes an important aquifer, for owing to the imperfect surface drainage the ground-water level is high, the younger bowlder clay forms an excellent protecting covering, and the sandy loess is a suitable reservoir. The seepage springs favored by such conditions are unusually common in the valleys crossing the margin of the Wisconsin drift area and are not uncommon from the base of the sandy loess overlying the Kansan, but those from the latter horizon are unsatisfactory for stock supply owing to the certainty that they will dry up just when they are most needed. Few loess wells exceed 25 feet in depth.

The Wisconsin drift in this county is thin, yet, because of the undrained character of its surface, it yields a supply of water to many shallow wells. The water is chiefly from small seeps and veins and is closely akin to surface water in quality.

Seeps from sand pockets and small veins in the Kansan clay supply many wells, and an abundant supply of good water is found in beds of sand and gravel beneath the Kansan drift and above the underlying shales. The great thickness of the drift in this region makes it expensive to reach these sands, as in some places they lie 200 to 300 feet below the surface. Flowing wells from these sands are not uncommon in the valleys.

The Coal Measures as a rule furnish unsatisfactory water. Water is everywhere found in the seams and beds of coal, and is locally so abundant as to interfere seriously with mining operations, but this water is never potable. The shales which compose the greater part of the Coal Measures are comparatively dry and unimportant as water bearers. Limestone lenses are common. The only available water of importance is found in the thick lenses of sandstone, which are more common in this county than in the coal region farther south; but this water, like most water of the Coal Measures, is frequently so strongly impregnated with iron as to be unfit for use. One of the most striking exceptions to this rule is afforded by the Red Rock sandstone, a channel deposit consisting of coarse, friable, gray to purplish-red ferruginous rock, which has been found in an area two to four miles wide extending from the southern boundary of the county east of Monroe to a point some distance northeast of Kellogg. Its precise area and extent are, however, very uncertain. Wells in this sandstone furnish an abundant supply of excellent water and good springs from it are found in several places.

Regarding the Coal Measures as a source of springs, I. A. Williams[1] says:

> Springs issuing from the Coal Measures strata are not uncommon. The water is, however, often so charged with sulphuric acid as to make it valueless, where it comes from beds associated with coal seams. Two instances may be cited of springs which come from Coal Measures strata and furnish never-failing supplies of good water. In the NE. ¼ NW. ¼ sec. 9, Rock Creek township, is such a spring, flowing from near the base of the Red Rock formation. A spring on the farm of Mr. P. W. Mowry in section 34, Des Moines township, furnishes an abundant supply of excellent water.

The Saint Louis limestone is an important aquifer in Jasper county as elsewhere. In this county it supplies the most famous wells in the state, the Colfax artesian wells known as the Colfax Mineral Springs. From observations elsewhere the Saint Louis limestone is believed to wedge out in the northeast part of Jasper county; elsewhere other hard limestones, known as the Kinderhook stage, directly underlie the Pennsylvanian or the drift.

[1]Ann. Rept. Iowa Geol. Survey, vol. 15, p. 360.

SOUTH SKUNK RIVER ARTESIAN BASIN.

The lower portion of the valley of South Skunk river and its more important tributaries, including practically all of the present flood plain, the terrace known as the "second bottom," and in places the lower slopes of the valley sides, form an irregular artesian basin, ranging in width from one to four miles and extending from the middle of the west county line to the middle of the south county line. Nearly all the wells in this basin range in depth from 250 to 350 feet and are supplied by the same aquifer, the Saint Louis limestone. Two of the wells however, are shallower. One on the farm of Bert Furch, six miles west of Newton, in section 34, T. 80 N., R. 20 W., is but 150 feet in depth, and is reported to end in "a crevice in rock," probably limestone, has a natural flow of three-fourths of a gallon a minute and a head of 20 feet above the valley floor; the water is not reported as mineral, but simply as "hard," and is in general use for domestic and farm purposes. The other well, 163 feet deep, is on the farm of John Raitchner, two and one-half miles southwest of Metz; the flow comes from sandstone at a depth of 150 feet, and the well yields one and one-quarter gallons a minute under a head more than 10 feet above the valley floor; the water is reported as only slightly mineral.

The deeper wells are generally less strongly mineral than the Colfax wells (see p. 861), but none are cased through the Des Moines stage, and all probably receive a mixed supply of water. Detailed data of several of these wells are presented in the table of typical wells (p. 868).

Near North Skunk river in the southeast corner of Malaka township is a small area in which several wells yield small flows under low head. Two of these wells are on the Riverside stock farm in section 35.

COLFAX MINERAL WATERS.

The Colfax mineral water was discovered in 1875 by parties prospecting for coal. The drill, located on the south bank of South Skunk river about a mile east of town, had reached a depth of 315 feet when water began to flow from the top of the hole. Drilling was discontinued, and this coal prospect hole became the first of the "mineral springs" which furnish the water now so widely known as Colfax Mineral Water. Since the original well, known as the "Old M. C. Spring" or the Colfax Hotel well, was put down, at least 14 other wells have been sunk to depths differing but slightly from this one and all obtaining a very moderate flow from the same aquifer—the Saint Louis limestone, of the Mississippian. Some of the wells are four inches and others six inches in diameter; the diameter of some is reduced to two or three inches at the bottom.

Until the fourteenth well was drilled, in 1905, no record was kept. The driller's log of this well, as recorded by the owner, C. W. Mills, is as follows:

Record of artesian well at Mills House at Colfax.

(Drilled by M. Neff.)

	Thickness.	Depth.
	Feet	Feet
Surface and yellow clay	33	33
Sand and gravel (heavily water bearing)	28	61
Sand rock	1	62
Slate, black (shale)	30	92
Coal	1½	93½
Clay, fine	8½	102
Sandstone	4	106
Soapstone (shale)	6	112
Sandstone (water bearing)	40	152
Soapstone, hard (shale)	10	162
Sandstone	40	202
Rock, white, porous (water bearing)	4	206
Flint rock	1	207
Sandstone	20	227
Soapstone, hard (shale)	10	237
Sandstone	15	252
Iron band rock	1	253
Sandstone (water bearing)	30	283
Magnetic rock (?)	7	290
Chert, white	12	302

To a depth of 61 feet the formations are Pleistocene; from 61 to 283 feet they belong to the Pennsylvanian series (Des Moines stage); the lowest formation is probably Mississippian (Saint Louis limestone).

The natural yield of the wells has decreased as the number of wells has increased, the maximum now being about three gallons a minute. The intimate relation of the wells is shown by the fact that when the Colfax Bottling Works well was flowing at the rate of eight gallons a minute, before casing was inserted, the Mason House well, near by and up the slope from it, practically ceased to flow and all other wells were somewhat weakened.

The log of the Mills House well harmonizes with the various reports given from memory by those who had most to do with the earlier wells, all placing the mineral-water aquifer at between 285 and 315 feet below the surface. The samples preserved by Dr. Turner of the water-bearing rock of the fifteenth and latest well—that of the Turner Sanitarium—are of hard magnesian limestone. All of these facts indicate the upper limestone beds of the Saint Louis limestone as the mineral-water horizon.

Several other aquifers are reported in each of these wells, including the sand and gravel bed at the base of the drift, and one to four of the sandstone layers of the Des Moines stage (Pennsylvanian). Not only must the water from these upper formations be cased out, but the well must be carefully sealed by means of a seed bag or rubber packing about the base of an inner and smaller tube put down to the aquifer itself in order to obtain the proper mineral flow. Although the sympathetic variation of many of the wells indicates a uniform source, a fairly decided difference in the taste and color, especially in those of a sulphurous character, suggests that some of the wells may draw a portion of their supply from the Pennsylvanian rocks, the lowest of which is reported as causing an artesian flow in at least one well.

The rise of the water above the surface varies with the elevation of the well site. The highest level reported, 17 feet, has been since reduced by the drilling of new wells. Probably the water of none of the wells will rise more than eight or ten feet above the surface, and some of the wells on the hillside have ceased to flow except as piped out below the surface to a lower level.

It is an interesting fact that the surface relations are so delicately adjusted that changes both of flow and pressure are affected by the changes of the weather. The decrease of barometric pressure before a storm brings an increase of flow and pressure from the wells, which is easily noticed in certain wells carefully controlled by bottling machinery. Especially hard storms produce a milky or oily color, such as water ordinarily carries after standing in the open air, and the water tends to "sour" more quickly than usual; both facts indicate loss of the natural supply of CO_2 with the lessening of the atmospheric pressure.

A complete list of the mineral wells in the town of Colfax, together with the fullest data obtainable, is presented in the following table.[1] The results of chemical and sanitary studies of the water are discussed on pages 191, 266, 267, 273, 274.

Statistics of the Colfax mineral wells.

Owner	Location	Year completed	Depth	Depth to rock	Head above or below curb	Discharge	Remarks
			Feet	Feet	Feet	Gallons a minute.	
Hotel Colfax	1 mile east of Colfax.	1875	325	------	------	------	Old "M. C. Spring." Former discharge, 3 gallons a minute. Diameter, 3 inches. Curb 12 feet above level of Chicago, Rock Island & Pacific Ry. Temperature 54 degrees. Water bed at 306.
Colfax Bottling Works.	Second bottom, 1½ blocks southeast of plant.	About 1880	300	35	+ 6	2+	Diameter, 3 inches. Former flow 3 gallons a minute. Curb 10 feet above level of Chicago, Rock Island & Pacific Ry. "First water at 140 feet, head 25 feet below curb; second water at 225 feet, head at surface; third water at 245 feet, all cased out." Bottled and sold.
Grand Hotel Sanitarium.	------------------	About 1880	312—	------	— 1	2	No flow. Former head of 6 feet has fallen to 1 foot below curb, and well is now pumped by hand. Curb 36 feet above level of Chicago, Rock Island & Pacific Ry. Diameter, 4 inches and 3 inches. Used for medicinal and table purposes.

[1]See also Norton, W. H., Artesian wells of Iowa: Rept. Iowa Geol. Survey, vol. 6, pp. 293-294. Also Williams, I. A., Geology of Jasper County: Ann. Rept. Iowa Geol. Survey, vol. 15, pp. 307, 363-366.

Statistics of the Colfax mineral wells—Continued.

Owner	Location	Year completed	Depth	Depth to rock	Head above or below curb	Discharge	Remarks
			Feet	Feet	Feet	Gallons a minute.	
Mason House		1881	357		+ 3	4	Diameter, 4 inches. Temperature 54½ degrees. Curb 2 feet above level of Chicago, Rock Island & Pacific Ry. Used for baths, table, and medicinal purposes.
D. C. Frye & Co. (Inc.).		1882	315		+ 8	2	Diameter, 3 inches. Curb 3 feet above level of Chicago, Rock Island & Pacific Ry. Temperature, 51 degrees. Pumped by rotary pump, 5 gallons a minute. Bottled and sold for medicinal and table purposes. Water bed at 310.
Purox-Colfax Co.		1890	350—		+10	1½	Flow decreased from 3½ to 1½ gallons a minute, and head from 12 to 10 feet. Diameter, 4 inches. Odor more sulphurous than others. Bottled and sold for medicinal and table purposes.
Town of Colfax city park.			300	200+		3	Decrease of flow from 4 to 3 gallons. Diameter, 4 inches. Temperature, 52 degrees. Level with Chicago, Rock Island & Pacific Ry.
The Centropolis					+ 4		Used for medicinal purposes and for bathing. Sold to patrons.
Thos. E. Jordan			350	47		1½	Decreased from 2 to 1½ gallons a minute. Bottled and sold for medicinal and table purposes.
	Corner Montgomery Street and Broadway.				+18	3	Diameter, 3 inches. Flows without control. Used only for watering stock.
Colfax Bottling Works No. 2.	At plant	1901	300	100	+20	5	Decrease of head from 20 to 18 feet. Diameter, 4 and 2 inches. Other water at 150 feet and 225 feet. Curb 3 feet below level of Chicago, Rock Island & Pacific Ry. Flow increases after being shut off for some time. Bottled and sold for medicinal and table use. Water bed, limestone.
Hotel Colfax No. 2			294			1½	"Second M. C. well."
Victoria Sanitarium		1903	391		— ½	½	Flows from pipe through hillside. Used for medicinal purposes and for bathing. Sold to patrons.

Statistics of the Colfax mineral wells—Continued.

Owner	Location	Year completed	Depth	Depth to rock	Head above or below curb	Discharge	Remarks
			Feet	Feet	Feet	Gallons a minute.	
Turner Sanitarium	Side of hill	1906	365	80	−12	------	Diameter, 4 to 3 inches. Curb about 36 feet above level of Chicago, Rock Island & Pacific Ry. Heavy water at 235 feet. Water lift. Used for medicinal purposes and for bathing. Sold to patrons. Water bed, porous magnesian limestone.
Mills House	------------------	1905	291	95	+ 5	½	Curb about 22 feet above level of Chicago, Rock Island & Pacific Ry. Temperature, 53½ degrees. Curb sunk into 5-foot pit for better flow. Pumping Turner well while drilling decreased this flow. Used for medicinal purposes and for bathing. Sold in bulk to patrons. Water bed, limestone.

CITY AND VILLAGE SUPPLIES.

Colfax.—The public supply of Colfax (population, 2,524) is drawn from the coarse gravels underlying the flood plain of South Skunk river, by means of a series of Cook well points, six inches in diameter and 36 feet long. The sands and gravels are reached at a depth of 23 feet and are overlain by a heavy black clay. The water stands between five and 17 feet below the surface in these points, and is pumped by steam into a steel standpipe, 13 by 80 feet (capacity about 92,000 gallons). This standpipe is so situated on the bluff that the base is about 160 feet above the source and the main portion of the town. From it the water is distributed by gravity through about two miles of mains. The pumping capacity is about 750 gallons a minute, and about 60,000 gallons are used daily. The domestic pressure of about 80 to 104 pounds is sufficient for fire protection, except in the residential section in the bluffs, where direct pressure may be used if necessary. Owing to the fact that this water forms a rather solid scale in boilers, the railroads and the boilers at the pumping station use river water for steam making.

Kellogg.—The public water supply of Kellogg (population, 610) is from two drilled wells 120 and 160 feet deep, drawing their supply from the shales of the Des Moines stage and the underlying limestone, respectively.

The water of the 120-foot well is pumped by windmill, and though the head is but 30 feet below the surface the supply is scanty, a characteristic common to all shale wells. This well is used only as a reserve supply.

The 160-foot well is much stronger, but the water is somewhat roily, probably because of improper casing in the shaly beds. The well is pumped by gasoline engine, the water being forced to a cistern on the hill about 50 feet above the level of the town. This cistern is 10 feet in diameter and 20 feet deep and is walled with brick and cemented. From this reservoir the water is distributed through a four-inch main about one-fourth mile in length to four fire hydrants and 20 private taps.

Most of the private wells in the town are either open or driven and range in depth from 25 to 35 feet. The gravels at this depth are open but grade into fine sand above, overlain by yellow clayey alluvium and deep soil. The supply is abundant and the water exceptionally good for use in boilers. No treatment is required before it enters the boilers, only a slight flaky scale or soft white precipitate being formed. The Gould Balance Valve Company and the Patten Grain Company use the water from driven-point wells.

Newburg.—Practically all wells in Newburg (population, 200) and in the extreme northeastern corner of the county are dug or bored in the drift at various depths.

The railroad supply comes from four 26-foot wells in a ravine below the town. The best supply comes from gravels in the lower part of the Kansan drift.

Newton.—The water supply for the city of Newton (population, 4,616) is taken from eight gravel wells on South Skunk river bottom, six miles southwest of the city, in the NE. 1/4 section 13, T. 79 N., R. 20 W., 170 feet below the level of the

Chicago, Rock Island & Pacific Railroad station (elevation, 944 feet above sea level). These wells were put down in 1904 by drilling to depths ranging from 43 to 56 feet, and then inserting in each hole an eight-inch strainer, eight to ten feet long, attached to the lower end of the casing. The wells are distributed over an area of about 130 feet radius, and so connected that any number or all may be pumped at the same time.

A pumping station, located at the wells, is equipped with a low-service suction pump, capacity 700 gallons a minute, which pumps into an 11,000-gallon reservoir, walled with brick, cemented, and arched over. From the reservoir two high-pressure duplex pumps, capacity 250 gallons a minute each, lift the water 190 feet into the supply tank on a stone tower in the city. The tank has a capacity of 90,000 gallons and the tower is 56 feet high, giving a domestic pressure from gravity of about 25 pounds. The fire pressure is, however, direct and may be raised to 115 pounds. An eight-inch main leads from the wells into the city, and the 75 fire hydrants are supplied through six-inch and four-inch mains. Probably more than one-third of the population is supplied through over 400 taps from this source. The daily consumption is estimated to be 70,000 or 80,000 gallons. The meter system is in general use.

The water is clear, abundant, and excellent, and is used for all public and domestic purposes and very extensively by the manufacturing plants of the city and by the railroads. Slight scale forms in the boilers, and the supply has proved in all respects satisfactory.

The city supply was formerly taken from two deep wells, described as city wells Nos. 1 and 2.

City well No. 1, completed in 1890, is 1,400 feet deep and five inches in diameter, and the water stood 90 feet below the curb. Rock was entered at 90 feet and water was obtained at depths of 550 feet and 1,300 (?) feet. (See Pl. XV, p. 812.)

The water of this well is described as a poor potable water and bad in its effects on boilers. It is apparently derived from the Osage stage (Mississippian), a short distance above the summit of the Kinderhook (Mississippian), and is augmented by water coming in above the Maquoketa shale (Ordovician), which caved badly and caused the loss of a drill. As the drill could not be extricated, the hole was abandoned and a second was sunk a few feet distant. In this well also a drill was lost at about the same depth, and the attempt to carry the boring deeper was abandoned. In 1895 the supply was said to be abundant, continued pumping failing to lower the level of the water; but some years later the well was given up and another sunk.

City well No. 2, 705 feet deep and ten to eight inches in diameter, has also been abandoned. The water in this well stood 50 feet below curb, coming from a depth of 500 feet.

Driller's log of city well No. 2 at Newton.

	Depth in feet.
Gravel	70
Gravel and clay	150
Rock and shale	172
Shale	202
Rock, white, hard	214
Limestone	240
Through limestone	470
Shale	500
Limestone	575
Well completed	705

It should be noted that the very scanty data for these wells seem to indicate that they stopped a good deal short of the main artesian supplies of Iowa, going little if any below the Maquoketa shale. If any other deep wells are sunk they should be carried not only to a depth of 1,750 feet from the surface, where the Saint Peter sandstone should be reached, but to as great a depth as 2,050 feet in order to tap the still larger supply of the formations underlying that well-known sandstone.

Prairie City.—The water supply of Prairie City (population 764) was originally taken from a well 85 feet deep ending in sands and gravels at the base of the drift. The supply was ample, but so much trouble was caused by quicksand that it was found necessary to drill deeper and case the well throughout. During 1904 and 1905 the well was deepened to 390 feet, and the approximate record is given by I. A. Williams as follows:

Log of well at Prairie City.

	Thickness.	Depth.
	Feet	Feet
Loess and drift	85	85
Coal Measures shales and sandstones	140	225
Limestone	65	290
Sandstone, coarse, white	2	292
Shale, compact	63	355
Limestone, dense, gray, magnesian	35	390

The limestone from 225 to 290 feet probably belongs to the Saint Louis limestone (Mississippian). This well was not used, as it was said to be impossible to shut out sand and mud in the Pennsylvanian (Coal Measures) at depths of 180 to 190 feet, though water was abundant below this level.

The well in present use was drilled in 1905 to a depth of 390 feet. The Saint Louis limestone was entered at a depth of 220 feet, and the water-bearing sandstone from which the chief supply of water comes about 65 feet lower. The well is cased to the limestone with eight-inch casing; below this a six-inch bit was used and at the bottom a four-inch bit.

The well is pumped by steam, and the head varies from 80 feet below the surface to about 140 under the pump.

The water is distributed by gravity from a 2,200-barrel tank elevated on an 80-foot steel tower, through about two and one-half miles of mains. The water used is chiefly for fire protection, a few private taps taking only a few barrels per day in addition to that used by the 12 fire hydrants. The water is unsatisfactory for drinking on account of its mineral taste, and it is too hard for use in boilers.

Reasnor.—Reasnor (population, 250) is located on the bottom lands of South Skunk river, where sand point wells may be had at depths of 30 to 40 feet. Small flowing wells may be had in this vicinity on the river bottoms with depths of about 250 feet to sandstone in the Saint Louis limestone, and good wells may be obtained at about half that depth in the Red Rock sandstone. The town well, sunk only 30 feet on the flood plain of the river, flows slightly, the water probably being derived from the Red Rock sandstone.

WELL DATA.

Information concerning typical wells in Jasper county is presented in the following table:

Typical wells of Jasper County.[1]

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
T. 80 N., R. 18 W. (Kellogg).						
		Feet	Feet		Feet	
Town of Kellogg		120	85	Shale (Des Moines)	— 30	A weak well.
Do		160	110	Carboniferous limestone.		Water somewhat roily.
Geo. B. Kelton	1 mile southeast of Kellogg.	104	15	Red Rock sandstone.	— 60	On "bottoms." Good.
Ed. Craven	1 mile north of Kellogg.	245	200	Limestone below shale.	— 80	Good farm well.
Gifford Rogers	3 miles north of Kellogg.	174		do		
A. B. Craven	5 miles north of Kellogg.	265		do		
Joe Pierce	3 miles north and 1½ miles east of Kellogg	175	175	Over limestone		Good. Plenty.
Ed. Mershon	NE. ¼ sec. 6	325	317	Limestone	—100	High hill.
Albert Harrab	SW. ¼ sec. 36	135		Sand		Bottom. Flows. No rock.
T. 80 N., R. 17 W. (Rock Creek).						
A. J. Simpson	SE. ¼ sec. 31	172		Sandstone	—130	
T. 81 N., R. 19 W. (Malaka).						
Mrs. Cassie Preston	NE. ¼ sec. 2	300		Sand		Sand interferes. No rock.
Christ Wehrman	SW. ¼ sec. 14	200	160	Limestone	—100	Hard and mineral.
T. 81 N., R. 18 W. (Mariposa).						
S. Morrison	NE. ¼ sec. 34	254	120	Limestone	— 30	Strong well.
Henry Korf	Sec. 31	400				No water.
Do	do	175	75	Limestone	— 60	
T. 80 N., R. 19 W. (Newton).						
L. M. Baker	NW. ¼ sec. 20	140	100	Limestone	— 60	Strongly mineralized.
T. 79 N., R. 20 W. (Mound Prairie).						
L. A. Greenleaf	SE. ¼ sec. 15	360	100	Sandstone	— 56	Hard water.
G. W. Miller	½ mile east of Metz.	300	22		+ 9	Flows ¼ gallon a minute. Slightly mineralized.
John Kartchner	2½ miles southwest of Metz.	163	50	Sandstone (Des Moines).	+ 10	Flows 1½ gallons a minute. Slightly mineralized.
Mrs. M. L. Slaughter.	Sec. 8	337	100	"Gravel" (?)	+ 17	
T. 80 N., R. 20 W. (Sherman).						
W. J. Leeper	NE. ¼ sec. 2	159	30	Gravel	+(?)	Slight flow. Mineral.
Lawson Walt	SW. ¼ sec. 16	204			— 80	Mineral.

[1]For Colfax mineral wells see table on p. 861.

Typical wells of Jasper County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
Bert Furch	Sec. 34	150	50	"Solid rock"	+ 20	Flows ¾ gallon a minute. Hard.
E. W. Bodley	NE. ¼ sec. 26	90	40	Sandstone	— 30	
T. 78 N., R. 21 W. (Part of Des Moines).						
R. W. Brubaker	NE. ¼ sec. 36	376	140	Limestone	—150	Abandoned. Very weak well.
T. 78 N., R. 20 W. (Parts of Des Moines and Fairview).						
Sam Scharf	NE. ¼ sec. 36	268	95	Sandstone	—137	Strong well.
S. F. Oldham	SE. ¼ sec. 22	376	160	do	—125	Strong well. Fine water.
Jas. Fouche	SE. ¼ sec. 9	240		Sandstone		Good well.
T. 78 N., R. 19 W. (Parts of Fairview, Elk Creek and Palo Alto).						
Robt. Marshall	6 miles east of Monroe.	209		do	—100	
J. A. Oldham	Sec. 16	260	60	Sandstone	+ 10	Flow 1 gallon a minute; water slightly mineralized.
Lester Vaugh	Sec. 28	312	140	do	—160	Mineral.
Town of Reasnor		130		do	+ 2½	Bottom land. Flows into tank at present, 1 gallon a minute.
J. H. Loar	Sec. 27	250		do	— 25	
Chicago, Rock Island & Pacific Ry.	Monroe	300		do		Scales boilers some.
Oscar Efnor	1½ miles west of Reasnor.	167	100	Red Rock sandstone.	— 67	Good well.
T. 79 N., R. 19 W. (Parts of Palo Alto and Fairview).						
George Lisle	Sec. 32	252	117	White sandstone	+ 22	Bottom land. Temperature 52 degrees. Mineral.
George Lisle	SW. ¼ sec. 32	252	54	"White sand"	+ 22	Flows 1½ gallons a minute. Mineral.
Jas. A. Oldham	Sec. 16	260	60	Sandstone	+ 10	Flows 1 gallon a minute. "Hard and salty."
J. M. Woodrow	NE. ¼ sec. 29	233	100	do	+ 8	Mineral, similar to Colfax.
F. H. Griggs	NE. ¼ sec. 20					Flowing well.
Ed. Ross	5 miles south of Newton.	280	100	Limestone	+ 16	Flows 1 gallon a minute.

MARSHALL COUNTY.

BY HOWARD E. SIMPSON AND W. H. NORTON.

TOPOGRAPHY.

Marshall county lies immediately east of Story, the central county of the state. Though its prairie plain does not, to the casual observer, differ materially from that in other portions of central Iowa, the careful student will recognize in the topography as many as three distinct types of plain, the distinctions being chiefly the result of differing periods of time during which running water has worked upon the till.

The youngest drift, the Wisconsin, overlaps a narrow strip on the western edge of the county, varying in width from practically nothing on the southern border to three and one-half miles on the northern border. Here is found the knob and kettle topography characteristic of terminal moraines, though in rather subdued form. Small ponds and sloughs are common and the region is generally one of poor and undeveloped drainage. The area does not exceed 50 square miles.

Almost filling the triangle in the northeast, separated from the remainder of the county by Iowa river, is an area of drift of Iowan age. The slight sag and swell topography and the lack of marked stream dissection away from the master streams indicate the topographic youth of the area, though the lack of ponds and undrained tracts suggests a later stage of dissection than the Wisconsin. This area contains approximately 100 square miles.

Except for the Iowa river valley, the remainder of the county, nearly 400 square miles, possesses a more undulating topography in which stream valleys are broad, divides much more clearly marked, and drainage complete. This area covered by the Kansan drift is, therefore, in topographic maturity.

The broad, flat flood plain of Iowa river is the most striking topographic feature of the county. On the valley floor the river meanders widely and from it many smaller flat-bottomed valleys extend to every part of the county save the southwest corner, which is drained to the south by tributaries of North Skunk river.

GEOLOGY.

All the country rock of Marshall county is of Carboniferous age. Underlying the entire county is a thickness of about 150 feet of the Kinderhook stage, consisting chiefly of a heavy limestone overlain by thin shales and underlain by thin sandstone and shales. Overlapping this in the western two-thirds of the county lies the Des Moines stage, consisting here chiefly of shales with some sandstones. (See Pl. XI, p. 458.)

The general surface relations of the drift sheets have already been indicated. The depth is variable, but in the uplands 100 to 200 feet is common and 400 feet has been reported. This latter thickness is so great as to indicate a preglacial channel. The Kansan drift, everywhere present, is the most important of the superficial deposits, but distinct evidence of the earlier Nebraskan drift is found in the presence of a dark blue-black till in places beneath heavy beds of sub-Kansan sands and gravels which are evidently of Aftonian age. These gravels are reported in beds locally 30 feet thick.

In many places between the later deposits and the Kansan are found other sand and gravel beds of Buchanan age. These, however, are thinner and less important than the Aftonian except in the stream valleys, where, as valley trains, they underlie and are interstratified with alluvium. The Iowan till in the northeast and the Wisconsin till in the west overlie the Kansan. The Iowan is very thin and relatively unimportant, but the Wisconsin, because of its morainal character and undeveloped drainage, has a marked effect on ground-water conditions. Throughout the Kansan area and in places underlying the Wisconsin is a mantle of yellow loess passing below into sand. As this reaches thicknesses of 15 to 20 feet over some portions of the uplands it is of importance in shallow wells.

The alluvium which fills the Iowa valley and the narrower valleys of all the larger creeks of the county includes extensive valley train deposits, chiefly of Buchanan age.

UNDERGROUND WATERS.

SOURCES.

The gravels of valley trains of Buchanan age and those beneath the drift and interstratified with it form the chief sources of the abundant waters of the alluvium. Though not so pure as those of the deeper drift and the rock, these waters are not often seriously contaminated, and their abundance and softness render them especially valuable. The public supply for the city of Marshalltown is drawn from the alluvium.

The drift beds are so numerous and in general so prolific of good water that they form the chief source of supply for Marshall county. Dug, bored, and drilled wells reach all the subhorizons at such different depths and with such different results that it is usually impossible to identify the age of the water bed. Depths of 30 to 40 feet are most common and, in general, the greater the depth the greater the supply. For domestic purposes very shallow wells suffice and are satisfactory if not contaminated from the surface, but for stock many of 100 to 250 feet are drilled with good results. In many of the deeper wells the Aftonian gravel is the water bed.

Owing to the lack of drainage shallow wells on the western margin of the county may find water closely akin to surface water in the Wisconsin till.

The Iowan till is too thin to afford any important source of water for even the shallowest wells, but the loess attains depths of 15 to 20 feet in many places on uplands, and its sandy base forms storage for shallow ground waters. Formerly this base was more important, but drainage and cultivation have generally reduced the ground-water level far below it, and it can now be used only by the shallowest wells and is very susceptible to drought.

Where the Buchanan gravel underlies the loess and the later till sheets on the upland in scattered patches, it is unimportant, but where associated with the alluvium it forms an important source of water.

The Kansan till is very thick; open wells sunk into it expose so much surface to seepage and small veins and afford so large a reservoir that it is one of the most important sources of water. A few gravel and sand layers furnish bountiful supplies, but, in general, wells to it are easily pumped out and are liable to fail in extreme drought.

Wells reaching the Aftonian gravel are abundantly supplied with the purest and most wholesome water. Depths of 100 to 150 feet are not uncommon.

The Nebraskan drift is too vague and indefinite to be of importance. Sands and gravels below the Kansan or at the base of a pre-Kansan till suggest the Nebraskan, and are generally water bearing just above bedrock, as is any drift in such a position.

The shales of the Des Moines stage are so dry and the water they bear is so mineralized that the rock is valueless except for a few sandstone lenses from which excellent water may be obtained. Wells deriving water from these sandstones are common in some parts of Marion and Jasper counties, but rare in Marshall county. Wells penetrating the rock in the western portion of the county are liable to find 30 to 50 feet or more of dry shale.

Practically all rock wells in Marshall county draw their supply from the Kinderhook stage, in sandy layers that generally underlie a heavy bed of limestone, which in turn may underlie a few feet of shale. Some excellent deep wells are had in these layers, though in many the water is not abundant. The flow is, however, very constant and not subject to drought. The water is generally hard, though pure and wholesome and excellent for stock. Depths of 150 to 200 feet are common.

DISTRIBUTION.

Two ground-water provinces may be distinguished in this county—(1) the Iowa valley floor, including the lower valleys of several of the larger creeks, in which the alluvium only is used; (2) the remainder of the county, in which the drift and Kinderhook are used.

Water in abundance may be had near Le Grande and Quarry. In the river valley the alluvial gravels supply it to driven wells, and on the adjacent uplands the shallowness of the drift, especially to the north, brings gravel and sand beds near the surface, from which a good supply may be had at 30 or 40 feet or less. To the south, in Le Grande township, extreme depths of drift are found; 100 to 200 feet to limestone is common and 300 feet or more in drift wells is not unusual. The sand well of O. Beyngelson is 355 feet in depth.

Rock wells 80 to 120 feet deep are common, but 200 to 300 feet is not an unusual depth south of the river, where excellent water is obtainable. Near the edge of the river bluffs the upper limestones give rise to some fine springs.

Near Green Mountain the greater depths of the drift make sand and gravel wells somewhat expensive and uncertain. Drift wells 100 feet or more deep are not uncommon, but the chief dependence for larger stock supplies is in the limestone, where water is obtained at depths of 125 to 300 feet. The flow is in a few places scant for large stock supplies, but the quality is good.

The alluvial gravels yield abundantly along the river bottoms at Liscomb, Albion, Marietta, and vicinity, in some places giving rise to flowing wells. A well on the farm of C. E. Asney, located on the Iowa river bottom, in section 35, Iowa township, was dug as an outlet for drain tile, but proved a flowing well. On uplands near the river drift wells are most common at depths of 30 to 50 feet, and the limestone supplies are unfailing, generally from depths of 80 to 200 feet. None of these villages are provided with waterworks. West of the river in Marietta township most of the deep wells are in drift and have depths of 200 to 300 feet. Some reach limestone at similar or greater depths.

In the Wisconsin drift area near Saint Anthony and Clemons shallow drift wells are generally relied upon. Driven wells are found all along the broad bottoms of Minerva creek and its southern tributary, which flows through Clemons. Excellent water for stock wells is found in limestone at reasonable depths, 100 to 200 feet being common.

Near State Center wells 20 feet deep were formerly abundantly supplied with water; at present drift wells are more commonly 50 feet and a few are 100 feet deep. Reports generally indicate the presence of the Nebraskan till below the Kansan here, but good beds of Aftonian gravel are few and, except in very deep drift wells, do not afford strong supplies. Not uncommonly quicksand and mud are found above shales of the Des Moines stage, making drilling difficult. These shales are 10 to 40 feet thick and overlie limestones; in only a very few wells is water found in thin sandstone beds at this horizon. Whenever a considerable quantity is desired drilled wells which draw their supply from the limestone at depths of 100 to 250 feet are put down. These are not very strong, but are constant in supply, three to 15 gallons a minute being common.

At Rhodes and Melbourne shallow wells generally furnish abundant water from drift and alluvium. On all the creek bottoms, however, good flows may be had. Three aquifers are reported at approximately 150, 200, and 250 feet. From the last, which underlies the Des Moines stage, a head of 27 feet above the surface is sometimes obtained. The water is mineral, closely resembling the Colfax water, and may come from the same aquifer, the Saint Louis limestone, although this has not been positively identified in this county.

At Melbourne the brick factory well draws its supply from a lens of sandstone in the Des Moines stage at a depth of 230 feet. Other deep wells are in limestone of the Kinderhook stage at similar depths.

The well of H. Knoll, Sr., four miles north of Haverhill, is reported to draw water from a sandstone of the Des Moines stage at a depth of 170 feet. Near Van Cleve, Haverhill and Laurel limestone wells in the Kinderhook stage are common at depths of 200 to 300 feet. Drift waters are commonly used for small supplies, but these do not hold out in dry weather, as the location on the upland divide between Iowa and Skunk rivers is not favorable for shallow wells.

Near Gilman and Ferguson bored wells to depths of 100 feet are common, and drilled rock wells are rare. A few stock wells on uplands draw from the limestone at about 300 feet.

CITY AND VILLAGE SUPPLIES.

Gilman.—Gilman (population, 430) has a small waterworks system supplied by springs. The plant is owned by a canning company. An elevated tank supplies water to one or two fire hydrants at low pressure. The water is reported to be soft and of excellent quality.

Marshalltown.—The water supply of the city of Marshalltown (population, 13,374) is drawn from the gravel beds underlying the flood plain of the Iowa river valley opposite the city near the junction of Asher creek (SE. ¼ section 22, T. 84 N., R. 18 W.). The water is collected by 40 wells, averaging 32 feet in depth, arranged in a straight north-south line 50 feet apart. Twelve-foot Cook strainers are used on the bottom of a six-inch casing. The gravel immediately overlies the limestone in at least one well. The general section is reported to be as follows:

General section of Marshalltown shallow wells.

	Thickness	Depth
	Feet	Feet
Loamy soil	4	4
Gumbo	1½	5½
Gravel, fine, and sand	3½	9
Gravel, coarse	4	13
Sand, fine, white	14	27
Limestone	5	32

All wells feed by a closed pipe into a two-foot main which leads across the river to the pumping plant on the south side, where a storage reservoir holding 1,000,000 gallons receives all of the water for aeration. At present rate of consumption this is replaced once each day. A low-service triplex Worthington pump draws the water from the reservoir for a distance of 4,720 feet, discharging it by gravity into the pump well.

At times the ground-water level in the field is reduced below the top of the strainers and, in order to avoid breaking the vacuum, suction is had through inner pipes inserted to the middle of the strainers. Even with this precaution, the vacuum is sometimes broken in case of drought, and then the consumption of water is limited, otherwise it must be drawn direct from the river through the intake provided for emergency. Such an emergency should be nothing short of a conflagration on account of the foulness of this water. Means are provided for cleaning the well strainers by flushing back water through them under high pressure, this being done once each month to insure the best flow.

Two Gordon duplex pumps, with an easy working capacity of 5,000,000 gallons daily, supply the mains directly at an ordinary pressure of 65 pounds, which may be increased to 135 pounds in case of fire. This pressure at the plant is decreased about 40 per cent in the business portion of the city. Twenty-eight miles of mains supply 200 fire hydrants besides many private consumers.

The large number of rock wells in the city is supplied by the waters from the limestone of the Kinderhook stage at depths ranging from 75 to 200 feet, and when properly cased and protected from surface contamination these deep-seated waters are of excellent quality and many are of almost ideal purity. They are superior even to the city water for domestic purposes and should be used wherever convenient to do so. The hardness of the water renders it unsuitable for boilers and many manufacturing purposes, except after artificial softening.

Excellent examples of the wells reaching this horizon are the two wells of the Iowa Artificial Ice & Refrigeration Company. The water is very hard but of almost ideal purity. The mineral present in all other waters of this vicinity found above bedrock is absent in this, and the ice manufactured from it is clear and brilliant. The two wells have furnished 75,000 gallons in 48 hours without any apparent depletion. During the season 30 tons of ice are made daily from this water, and large amounts are used in the refrigeration process and also, after softening, in the boilers.

Supplies from private wells in the sands and gravels of the drift underlying the city may be pure and wholesome, but they should be looked upon with suspicion because of the ease of surface and sewer contamination and should be used only after bacteriologic examination by competent authority. Such wells in rural regions are generally wholesome if properly guarded at the surface.

All of the water obtained above the rock contains some carbonate of iron, which, on standing, oxidizes to the brown hydrated oxide of iron, and the water becomes milky and precipitates a brownish sediment. In all large supplies this may be removed by aeration, and for domestic use on a small scale it is not objectionable except to the esthetic sense.

A prospect hole for coal and gas, drilled on the bank of Iowa river near Marshalltown (W. ½ NW. ¼ section 25), has a depth of 1,020 feet. (See Pl. XI, p. 458.) Its curb is about 885 feet above sea level.

Record of strata in prospect hole at Marshalltown.

	Thickness.	Depth.
Carboniferous (Mississippian):		
Kinderhook stage (320 feet thick; top, 885 feet above sea level)—		
Limestone, light gray; in fine sand; many angular fragments of limpid quartz at 68 feet	Feet 70	Feet 70
Limestone, light yellow, compact, earthy luster; 3 samples	45	115
Limestone, brown, crystalline, cherty at 115 feet	30	145
Shale, soft, light green, calcareous	175	320
Devonian (300 feet thick; top, 565 feet above sea level):		
Limestone (?); no samples	145	465
Limestone, hard, brown-gray, and brown; crystalline; rapid effervescence; samples at 465 and 560 feet	155	620
Silurian (305 feet thick; top, 265 feet above sea level):		
Dolomite, yellow, gypseous and cherty	55	675
Limestone, magnesian, brown, three samples; cherty at 675 feet	99	770
Dolomite, cherty; gypseous; mostly of white and translucent chert	30	800
Chert, white and translucent, at		800
No samples	75	875
Limestone; rapid effervescence; drillings almost wholly cherty; some gypsum; 2 samples	40	915
Dolomite, white, in powder; some chert and gypsum	10	925
Ordovician:		
Maquoketa shale (95 feet penetrated; top, 40 feet below sea level)—		
Shale, blue and green-gray; noncalcareous in sample at 925 feet	95	1,020

Marshalltown is 890 feet above sea level, and, according to the boring just given, the top of the Maquoketa shale was found at 925 feet below the surface, or 40 feet below sea level. Had the boring been continued the drill would have entered the Galena limestone within about 80 feet of the bottom of the drill hole, and considerable water might have been found in its cracked and porous layers. The Saint Peter sandstone may be expected at about 550 feet below sea level, or 1,440 feet below the surface. The drill should encounter below the sandstone dolomites, more or less sandy, with interbedded sandstone layers, and below the dolomites well-marked water-bearing sandstones. A very generous supply should be obtainable from these horizons by a well carried to a depth of 2,000 or 2,200 feet.

The water at each water horizon above the Saint Peter should be analyzed, and it may be found advisable to drive water-tight casing to the Galena to shut out deleterious veins.

By drilling several 8-inch or 10-inch wells and by the use of compressed air to increase the discharge it may be possible to obtain a supply sufficient for a city as large as Marshalltown. The water will hardly be good boiler water, a matter of importance in a manufacturing town. A forecast, essentially the same as the above, was made for the city on the request of the council in 1899.

State Center.—The town of State Center (population, 898) is provided with a waterworks system, used chiefly for fire protection. The water is pumped from wells into an elevated tank, capacity 60,000 gallons, whence it is distributed by gravity and direct pressure through a mile of mains to 16 fire hydrants. Only 12 private consumers use the water, and not more than a thousand gallons are pumped daily.

WELL DATA.

The following table gives data of typical wells in Marshall county:

Typical wells of Marshall County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
T. 84 N., R. 18 W. (Linn; parts of Taylor and Iowa).						
Iowa Artificial Ice Co.	Marshalltown	Feet 188	Feet 34	Limestone	Feet — 57	Strong well, hard water, but no iron. Water at 38, easily exhausted. Principal water bed 131 feet. Pumped by steam and used in manufacture of artificial ice. Softened for boiler. Heavy precipitate, indicating very hard water; curb 20 feet above Chicago & North Western railway. Diameter, 6 inches; temperature, 52 degrees. Surface and yellow clay, 22; blue clay, 12; soft limestone, 60; harder limestone, 94.
Brittain & Co.	do	162	71	Oolite limestone	— 24	Principal water bed, 138; minor bed at 76. Pumped with steam suction pump without lowering. Hard. Used for general packing purposes; curb 25 to 30 feet above Chicago Great Western railway. Yellow clay, 24; sand, 4; blue clay, 40; sand, 3; limestone (blue above, white below, streaked with hard layers), 79; shale, 12. Diameter, 6 inches; cased, 71 feet. A second well duplicates this, except 10 feet shallower.
Merritt Green	do	169	71	Shaly limestone	— 80	On slope 30 feet above Minneapolis and St. Louis railway; water bed in shaly limestone at 98. Pumps 15 gallons per minute with little lowering. Diameter 4½ inches; cased, 71 feet. Yellow clay, 20; sand, 10; blue clay 41; limestone, 29; shaly limestone, 69.

Typical wells in Marshall County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
Lennox Machine Co.	do	119	43	Hard blue limestone	— 9	Curb 10 feet below Chicago Great Western railway, on Linn creek bottom. Water bed 100 feet. Minor bed at 25, in sand. Pumped by steam, lowers to —23 feet. Clay, 20; sand and blue clay, 23; blue and gray limestone, 76. Diameter 6 inches, cased 43 feet.
	do	70	20	Limestone		Water bed at 67 feet.
Diesing Bros.	do	82	35	do		Water bed at 59 feet.
Fourth Ward School	do	145	45	do		
Second Ward School	do	98	60	do		
Arnold School	do	86	62	do		
Third Ward School	do	79	33	do		
Woodbury School	do	156	80	do		
Anson School	do	106	33	do		
Glucose Manufacturing Co.	do	300	19	do	— 19	10 other wells similar, except average 200 feet deep. Curb 6 feet above Chicago & North Western railway. Second bottom. Open wells all through limestone. 3,000,000 gallons have been pumped in 24 hours. Used in manufacturing glucose. Diameter 4 inches; cased, 20 feet. Soil, 4; yellow clay, 14; sand and gravel, 1; limestone, 180; shale, blue and buff, 101.
Frank Graham	1½ miles east of Albion.	154	120	do	—100	Very strong flow.
B. H. Kokel	2 miles northeast of Marshalltown.	110	70	do		30-gallon test lowered 10 feet.
W. B. Beeson	3 miles north of Marshalltown.	128	88	Gray limestone.	— 90	Good and strong. Not lowered. Yellow clay, 45; blue clay, 43; limestone, 40.
T. 84 N., R. 17 W. (Marion).						
L. H. Wallace	North Green Mountain.	190	170	Limestone		Water bed in sand with wood at 160.
W. M. Stewart	3 miles northeast of Marshalltown.	198	198	Blue sand	— 80	Chief water in 30-foot bed of sand.
L. Mickley	4½ miles east of Marshalltown.	246		Sand		No rock.
L. Mickley	4 miles east of Marshalltown.	303	300	Oolite limestone.	—140	Strong well. Water hard. Yellow clay, 90; blue clay and muddy sand, 210; oolitic limestone, 3.
D. Yetley	1 mile northeast of Marshalltown.	162	150	Limestone	—100	Very strong. Yellow clay and sand, 60; blue clay and sand, 90; limestone, 12.

Typical wells in Marshall County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
T. 83 N., R. 17 W. (Le Grande).						
Col. Dougherty	2 miles north of Le Grande.	92	9	Limestone	— 80	Hard rock exposed in Le Grande quarry, near by. Strong well. Water very hard. Yellow clay, 9; limestone, 83.
D. Holken	SE. ¼ sec. 21	306	300	Soft limestone.	—140	Lowers 100 feet on pumping. Yields 5 gallons per minute. Yellow clay, 60; blue clay, 190; quicksand 56.
F. B. Brenecke	2 miles north of Ferguson.	562	408	Shale and sandstone	—180	Test of 5 gallons lowers water 20 feet. Yellow clay, 35; blue clay, 85; sand and clay, 70; blue clay, 110; soft shale, 108; slate and limestone, 40; shale and sandstone, 114.
O. Bryngelson	Le Grande	355		Sand	—135	No rock.
E. Harem	do	337		do	—137	Do.
J. Hanks	do	232	225	Limestone	—132	
D. Wolken	do	306	300	do	—156	
S. R. Piper	do	325		Sand	—150	Do.
J. J. Mote	do	280	120	Limestone and shale.	— 40	
T. 83 N., R. 18 W. (Timber Creek).						
John Goshon	3½ miles south of Marshalltown.	281	120	Shaly limestone.	—100	Not a strong well.
H. Knoll, Sr.	4 miles northwest of Haverhill.	170	130	Sandstone (Des Moines).		
J. F. Cooper	Northeast Haverhill	183	120	Shaly limestone.	—120	Pumping 5 gallons a minute lowers water 50 feet.
Chas. Lodge	6 miles southeast of Marshalltown.	260		Gravel and sand.	—120	No rock.
T. 82 N., R. 18 W. (Jefferson).						
T. Breekweg	½ mile south of Haverhill.	180	140	Limestone	—110	First water bed at 140.
T. 82 N., R. 17 W. (Green Castle).						
Chas. Coulbrom	N. ½ sec. 32	308	207	Oolitic limestone.	—140	Strong flow.
T. 83 N., R. 19 W. (Washington).						
J. H. Harff	3 miles southeast of Lamoile.	210	132	Limestone and shale.		
H. Mesinesse	2 miles west of Luray.	286	140	do	—140	
T. 82 N., R. 19 W. (Logan).						
Poffamburger & Walker.	NE. ¼ sec. 5	231	190	Sand in shale (Des Moines).	—130	Used in manufacture of brick and tile.

Typical wells in Marshall County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
William Fort	NE. ¼ sec. 1	258	205	Shaly limestone.	−150	Capacity 10 gallons a minute without lowering.
T. 83 N., R. 20 W. (State Center).						
Mrs. Bishop	6 miles southwest of State Center.	232	190	Limestone	−140	
Louis Ricker	W. ½ sec. 15	255	192	do		3-inch vein; no sand or sediment.
C. H. Lehman	NW. ¼ sec. 15	109		Sand and gravel.	− 18	Good gravel well. No rock.
	State Center	346		do		Pumps dry 1½ hours by steam.
T. 84 N., R. 19 W. (Marietta).						
W. E. Tomlins	S. ½ sec. 22	225				No rock.
H. Monninger	5 miles southwest of Albion.	320		Gravels and sand.		Strong water in sand at 300. No rock.
T. 85 N., R. 20 W. (Liberty).						
Thos. Andrews	SE. ¼ sec. 22	223	180	Limestone	− 80	Yellow clay (seep water), 30; blue clay (streaks of sand with little water), 143; soapstone, 30; shaly limestone, 5; limestone, blue and hard, 20.
C. M. Smith	SW. ¼ sec. 4	235		do		
W. E. Elliott	NE. ¼ sec. 14	132	129	do		No shales.
T. 85 N., R. 19 W. (Bangor; parts of Iowa and Liscomb)						
Susan J. Brown	SE. ¼ sec. 9	130	100	Limestone		Very strong vein in crevice in limestone. Yellow clay, 35; blue clay, 55; sand and gravel (seep water), 10; blue clay, 100; sand, 20; blue clay, 105; shaly, light colored rock, 25; hard limestone, 10; quicksand (?), 3; limestone, 2.
Carrie E. Arney	NW. ¼ sec. 35	208	204	do	− 40	Yellow clay, 30; sand and clay, 10; blue clay, 35; sand, 10; blue clay, 65; sand, 6; blue clay, 99; soapstone, 35; coal, 1; white clay, 2; limestone, 10.

Typical wells in Marshall County—Concluded.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
T. 84 N., R. 20 W. (Minerva).						
Henry Busse	SW. ¼ sec. 13	365	325	Limestone	−150	
Joe Goodman	SW. ¼ sec. 34	303	225	do		Yellow clay, 20; sand and clay, 5; blue clay, 75; sand, 10; blue clay, 72; gravel and sand (heavy water), 10; shaly rock, 10; hard limestone, 53.

POLK COUNTY.

BY HOWARD E. SIMPSON AND W. H. NORTON.

TOPOGRAPHY.

Polk county is located immediately south of the geographic center of Iowa, and the location of Des Moines, the capital and chief city of the state, within its borders, has made it the political and commercial center. The surface is that of the gently rolling prairie plain characteristic of northern and central Iowa, modified only by its stream-carved valleys. The general elevation of this plain is approximately 1,000 feet above sea level.

Two distinct phases of the drift plain are present, differing chiefly in maturity of dissection and topographic age. The line separating the younger Wisconsin plain on the north from the older Kansan on the south passes just south of Mitchellville, Rising Sun, Des Moines, and Valley Junction. About five-sixths of the county is therefore within the area covered by the latest glacial invasion, the Wisconsin, and this line marks its southernmost extension in the United States. The Wisconsin area is remarkably level, only slight sags and swells being noticeable. The former are frequently saucer-shaped and hold sloughs and shallow ponds. The latter are but gentle rises of land between the sags. The stream valleys are narrow and shallow, and the whole area has the appearance of extreme topographic youth. The Kansan area, on the other hand, presents narrower, flat-topped divides and broader, deeper stream valleys, the whole showing the well-drained, maturely dissected topography of a much older type.

Polk, like the counties of southeastern Iowa, is crossed by master streams flowing southeastward through broad preglacial valleys. The most important is the Des Moines, meandering in its broad valley from the northwest to the southeast corner, 150 to 200 feet below the upland, and dominating almost the entire drainage. Of less importance is South Skunk river, paralleling the Des Moines to the northeast, in a valley only slightly less broad and deep. Raccoon river furnishes a marked exception to the general trend of master streams and enters Des Moines river at Des Moines from a direction somewhat south of west.

GEOLOGY.

Alluvial deposits are found on the broad flood plains of Des Moines, Raccoon and South Skunk rivers and on some of their leading tributaries. These deposits are especially thick south of the line marking the limit of the Wisconsin ice, comprising heavy deposits of gravel in the form of valley trains in valleys leading southward. These are so covered with alluvium that they can not be distinguished and will therefore be classed with the alluvial deposits.

The limits of the Wisconsin drift have been outlined in discussing its topography. The loess forms a thin veneer over the uplands lying outside of the Wisconsin limits and underlies the Wisconsin in places. The Kansan drift underlies the Wisconsin drift and the loess and controls the topography of the latter. It is the most important superficial deposit in this area. Beneath the Kansan extensive gravel deposits and buried soil beds and an older drift have been noted in places. The gravels are believed to belong to the interglacial Aftonian stage and the drift to the Nebraskan stage.

The country rock beneath the drift of Polk county everywhere belongs to the Des Moines stage of the Pennsylvanian series. Shales and sandstones, with a few limestones and here and there a coal seam, constitute the chief rocks. The Des Moines stage rests unconformably upon a very uneven surface of Saint Louis limestone. (See Pls. XIII, p. 626; XV, p. 812; XVI, p. 814.)

UNDERGROUND WATER.

SOURCES.

The aquifers utilized in Polk county are the alluvium and valley train gravels, the loess, the drift, and the sandstones of the Des Moines stage.

Polk county is well supplied with shallow drift waters. Countryrock water, however, is very variable and is generally of poor quality owing to the large amount of mineral matter it holds in solution.

A valuable water horizon is that of the gravels and sands interstratified with alluvium and underlying the flood plains of Des Moines, Raccoon, and South Skunk rivers and other smaller streams of lesser importance, such as Beaver, Big, Fourmile, Mud, and Camp creeks, tributaries of the Des Moines; Walnut creek, a tributary of the Raccoon; and Indian creek, a tributary of the Skunk.

Drive points and open wells find an abundance of good water at very shallow depths in these valleys. The deposits are especially valuable in the southern part of the county, owing to the large amount of gravel spread out upon these valley floors as valley trains by streams from the melting Wisconsin ice. The public supply for Des Moines is secured from these beds by a series of infiltration galleries built into the gravels of the Raccoon river valley. Valley Junction also derives a small public supply from the same source by means of an open well.

In the area south of the Wisconsin ice front the thick deposit of fine porous clay, known as the loess, is an important source for shallow wells from which but a small supply is needed. The chief importance of the loess lies in the fact that it grades downward into a fine sand, becoming coarser and overlying the relatively impermeable till sheet of Kansan age. The common depth of loess wells is 10 to 20 feet; one well, that of J. G. Berryhill, in section 19, T. 78 N., R. 25 W., has a depth of 70 feet, but this is exceptional. This loess in the Kansan area is a very uncertain source for water—except in the certainty with which its wells go dry during droughts.

Within the area occupied by the Wisconsin drift many wells penetrate the loess and draw excellent water from it, but owing to the difficulty of distinguishing it from the drift, the two are better classed together. The water is plentiful because this porous deposit, lying between the two till sheets, forms a good storage reservoir and does not dry out so readily as it does where it is exposed, as in the surface overlying the Kansan. This is a condition usually favorable for seepage springs, and such springs are common in the valleys cutting the margin of the Wisconsin drift.

The drift furnishes water for the great majority of wells in Polk county. The wells are so variable in depth and the drift sheets so variable in thickness that it is difficult to distinguish the different water beds, though several are worthy of mention.

The Wisconsin drift is thin, yet owing to the undrained character of the surface, it yields much water to shallow wells, which may be obtained almost anywhere by means of a spade or an auger. The water comes from small seeps and veins associated with sand pockets or from thin layers of sand and gravel. With the usual depression of the ground-water level in dry summer seasons many of these fail and the wells have to be dug deeper.

A better supply may be found in the sandy lower portion of the loess wherever this is present between the Wisconsin and the Kansan. Even in the absence of the loess this horizon is frequently marked by a gravel or sandy layer which is a strong water bearer and source of springs.

The Kansan is the most commonly used of all the drift horizons, the water being found, as in the Wisconsin, in small seeps and veins.

The Aftonian gravel, underlying the Kansan drift, forms a most valuable source of well water where it occurs, but in this region it can not often be found unless the gravels immediately overlying the country rock are of this age.

The Nebraskan is not clearly distinguished, but where found it generally consists of a thin layer of gravel and sand lying on the bedrock beneath the Aftonian gravel, thus adding another possible source of water.

The drift is present everywhere throughout the county, except where replaced in river valleys by the alluvium, which is in itself an even better aquifer. It is therefore rarely necessary to enter country rock except for a larger supply than the drift affords.

Although water can be found in the sandstones and coal seams in the Des Moines stage, it is rarely potable on account of its impregnation with many minerals. The only available sources in this group are the thick lenses of sandstone, some of which usually carry excellent water. Unfortunately such thick and persistent lenses are relatively uncommon in this area. Some beds exist in the southeast corner and to the north of Ankeny. but nowhere are they more than local as compared with the Red Rock sandstone of Marion and Jasper counties.

FLOWING WELLS.

Several deep wells are located in Polk county, the deepest and best known of which is the Greenwood Park well in Des Moines, with a depth of 3,000 feet. Water flowed from the Saint Peter sandstone, but stood 45 feet below curb upon completion of the well. Others are the courthouse well in Des Moines, 381 feet deep, flowing from the Des Moines, and the well on the river bank in front of the Des Moines public library, 461 feet deep, flowing from a sandstone bed at 360 feet. A flow on the farm of M. R. Sadler, near Mitchellville, from a coal prospect hole 100 feet in depth, is an example of another class of shallower wells, some in the drift and some in the Coal Measures.

GAS WELLS.

Gas has been reported in several of the drift wells near Saylorville and in the northern part of the county; one opening owned by Louis Brendel furnishes it in sufficient quantity to operate a gas burner.

CITY AND VILLAGE SUPPLIES.

Ankeny.—On the uplands about Ankeny (population, 445) drift wells 40 to 60 feet deep are common, though some go down 150 feet. These are supplied from layers of sand and gravel and are variable. Not uncommonly the drift supply is insufficient, and rock wells are drilled. As the highest rock (the shales of the Des Moines stage) is in many places 150 to 230 feet deep, it may be necessary to sink to depths ranging from 200 to 400 feet, the last hundred feet being in Saint Louis limestone. An excellent sandstone water is not infrequently found among the coal shales of this vicinity, but no well-defined sandstone layer occurs in the Saint Louis limestone, as it does in counties to the south and east.

Des Moines.—The public water supply of Des Moines (population, 86,368) is owned by the Des Moines Waterworks Company. The supply is derived from the gravel beds of the Raccoon river valley on the inside of the great bend opposite the ends of Nineteenth and Walnut streets, in the southwestern part of the city. The water is collected in infiltration galleries built 25 or 30 feet below the surface in such a way that the water flows from the bottom only. A section consisting of loam, river-washed sand and gravel, 45 feet of silt, sand and gravel, potter's clay, and sandstone is reported. More than half a mile of galleries are constructed in a layer of coarse, clean sand, and gravel, fine and free from silts. They lead by gravity through a 36-inch cast-iron main into a large pump well, 48 feet in diameter and 34 feet deep, located on the station grounds northeast of the river. This is bricked and cemented and arched like a great cistern.

An old gallery, 1,450 feet long extends from a small pump well in the station yard westward along the railroad tracks, and at its west end a short branch leads directly to Raccoon river. In times of great emergency water may be taken directly from the river, but this has been done only a few times. The estimated capacity of the present system of collecting galleries is 10,000,000 gallons a day at the lowest stage of water. At an ordinary stage it is inexhaustible with the present pumping plant. The actual daily consumption for the year 1911 was 5,258,770 gallons.

Within the pumping station three pumps—an 8,000,000-gallon Holly, a 7,000,000-gallon Gaskill, and a 6,000,000-gallon Worthington—give a daily capacity several times that yet required. The Worthington pump is held in reserve and with one of the others may be connected direct to the river intake in case of conflagration. The three are supplied with steam from a battery of five boilers of 110 horsepower each, by which a head of 100 feet is constantly maintained, a pressure ample for any fire. A direct pressure of 100 pounds for the business portion and 140 pounds for the higher northwest portion of the city is maintained. The lower pressure may be increased to 140 pounds in case of fire, though this is rarely necessary. About 130 miles of mains supply 1,303 fire hydrants and 12,315 taps, the latter through meters. Probably 80 per cent of the population depend on the public water supply.

The Des Moines Linseed Oil Company and the Des Moines Manufacturing & Supply Company have abandoned drive wells as unsatisfactory for steam purposes on account of boiler pitting and use the public supply. Both of these companies, together with the Des Moines Gas Company, treat the water with two or three pounds of soda ash for 1,000 gallons and find the results very satisfactory. The Edison Electric Light Company and the Des Moines Incubator Works, as well as many other manufacturing plants near Des Moines river, take their supply direct from the river. The Des Moines Ice Company secures its supply from four 26-foot point wells, drawing 40 gallons a minute at a temperature of 64 degrees, for use in the manufacture of ice and for the condensers. River water is used for the boilers. The Des Moines Hosiery Mills uses a supply from eight points varying in depth from 12 to 34 feet, in alluvium and gravel. The water stands 8 to 10 feet below the surface. The longer points furnish water carrying increasing amounts of iron salts in solution. The water is hard and requires compound to prevent boiler scale. Points are generally renewed every year or two, on account of ferruginous and calcareous cement collecting on the screen. A storage reservoir having a capacity of 10,000 gallons is used. At the former works of the National Starch Works Company, 1½ miles south of the fair grounds, a supply of 300,000 gallons daily was obtained from 50-foot collecting galleries. The plant is now abandoned, so the water system is not in use.

A large private water-supply system is that of the Agar Packing Company. This company uses the public water supply for washing and cooking, but does not find it economical for all purposes. Two sources are used. The first consists of a battery of seven four-inch Cook points, with five-foot screens, driven 40 feet into alluvium and gravel. The general section is as follows:

General section at factory of Agar Packing Company.

	Feet.
Filling	6
Clay, yellow	10
Gravel and sand	24
Clay, hard, blue	
	40

Water stands 15 feet below the surface, and the wells average 16 pounds vacuum while pumping. The water yields some scale and rust. This water is used first as a condenser of ammonia in the refrigeration plant and afterward for washing and scrubbing. About 500 gallons a minute is constantly pumped, except in freezing weather. The second source is a well 18 feet in diameter by 16 feet deep, connecting directly with the river by means of a 12-inch pipe opening with screen in the channel. About 900 gallons a minute may be thus obtained. This water is used for boilers, for which purpose the other waters are too hard, and for spraying hog pens and similar work. The river water scales but slightly, and this tendency is easily removed by the use of a small amount of boiler compound. Fire protection for the plant is had by the use of all the pumps and from the city system.

The courthouse well has a depth of 381 feet. Its curb is 805 feet above sea level. It flows at the surface from a depth of 370 feet. It was completed by George Garver in 1888.

Drillers' log of well at courthouse at Des Moines.

	Thickness.	Depth.
	Feet	Feet
Sand and gravel	63	63
Slate, black	18	81
Coal	3	84
Fire clay	5	89
Slate	24	113
Sandstone	10	123
Slate	10	133
Iron pyrites	1½	134½
Slate	4	138½
Coal blossom	½	139
Sandstone and granite	101	240
Shale with pyrites; shale layers 2 to 4 feet thick	60	300
Sandstone	39	339
Slate	6	345
Sandstone, with two bands of flint, 18 inches and 9 inches thick, respectively	17	362
Sandstone	19	381

The Greenwood Park well (Pl. XVI) has a depth of 3,000 feet and a diameter of 10 to 3 inches. Its curb is 872 feet above sea level, and its head 45 feet below the curb. The tested capacity is 400 gallons per minute. Sulphureted water from depths of 498 and 668 feet (Mississippian) rose within 30 feet of the surface. Water beds were indicated by changes of level of water in the tube at several depths between 1,011 and 1,208 feet (Silurian); water from depth of 1,425 feet (Niagaran) rose above surface; water was found at 2,025 feet (Saint Peter); at 2,208 feet (New Richmond), and 2,330 feet (Oneota). Date of completion, 1896. Drillers, J. P. Miller & Company, of Chicago. T. Van Hyning, who supervised the drilling of the well, reported that when the drill entered the Saint Peter the flow of water increased until it amounted to 1½ gallons a minute; pumping 52 gallons a minute for 18 hours lowered the water level 125 feet; when the pump was stopped the water rose within six feet of the top but did not flow again. When the drill entered the New Richmond the water level fell to 50 feet below the surface; in the Oneota it fell to 80 feet below the surface. Probably other water beds were struck, for on the completion of the well the water stood 45 feet below the curb. It still maintained this level when, in 1902, the city water mains were extended to the park and the well was closed.

Record of strata in Greenwood Park well at Des Moines (Pl. XVI, p. 814).

	Thickness.	Depth.
Pleistocene (14 feet thick; top, 872 feet above sea level):	Feet	Feet
Till, buff, sandy, with a few pebbles; noncalcareous	14	14
Carboniferous:		
Pennsylvanian—		
Des Moines stage (484 feet thick; top, 858 feet above sea level)—		
Shale, black, brittle, carbonaceous	1	15
Shale, gray, "fossiliferous"	1	16
Shale, black, carbonaceous, calcareous, highly pyritiferous	3	19
Shale, gray	4	23
Shale and limestone, bluish gray, highly fossiliferous	15	38
Shale, varicolored	67	105
Shale, bluish gray, highly and finely arenaceous, hard	10	115
Shale, bluish gray, slightly calcareous	60	175
Shale, dark drab and black, carbonaceous	11	186
Shales, gray, drab, and purplish; practically noncalcareous; 1 foot of grey chert at 284 feet	312	498
Mississippian—		
Saint Louis limestone and Osage stage (200 feet thick; top, 374 feet above sea level)—		
Chert and shale; heavy bed, very hard to drill; most of the sample is an argillo-calcareous powder; the shale is reported as caving in from above, but its calcareous nature indicates that it is in part interstratified with chert and limestone	170	668
Limestone and chert, brownish gray	30	698
Kinderhook stage (160 feet thick; top, 174 feet above sea level)—		
Shale, light blue and gray	40	738
Shale, terra cotta red, highly calcareous	10	748
Shale, light blue-gray	25	773
Shale, light gray, highly calcareous; fine cherty residue	85	858
Devonian (80 feet thick; top, 14 feet above sea level):		
Limestone, light buff; much gray chert	80	938
Silurian (507 feet thick; top, 66 feet below sea level):		
Limestone, light blue-gray, crystalline, saccharoidal; effervescence slow; considerable white gypsum	20	958
Limestone, cherty, crystalline, blue-gray; effervescence moderately rapid	53	1,011
Limestone, cherty, crystalline, saccharoidal, dark blue-gray and buff; effervescence indicates magnesian limestone, but not dolomite	97	1,208
Gypsum and shale; gypsum gray and white, in flakes; shale green, perhaps from above	15	1,223
Limestone, light blue-gray, highly seleniferous; some flakes of gypsum	145	1,368
Limestone, cherty, arenaceous; grains of sand, minute, rounded; much shale in rounded fragments, perhaps from above	22	1,390
Dolomite, buff, crystalline, granular with much chert and some chalcedonic silica; 3 samples	55	1,445
Ordovician:		
Maquoketa shale (33 feet thick; top, 573 feet below sea level)—		
Shales; in large fragments; purplish yellow and green; noncalcareous; finely laminated	33	1,478
Galena dolomite to Platteville limestone (508 feet thick; top, 606 feet below sea level)—		
Dolomite; in yellow-gray powder; cherty	260	1,738
Dolomites, yellow, buff and brown; mostly cherty; residue finely quartzose; 5 samples	200	1,938
Shale, green, very slightly calcareous	8	1,946
Dolomite, brown, arenaceous	30	1,976
Shale, dark green, hard, "fossiliferous"; practically noncalcareous	10	1,986
Saint Peter sandstone (39 feet thick; top, 1,114 feet below sea level)—		
Sandstone, fine, white; grains moderately well rounded	39	2,025
Prairie du Chien stage—		
Shakopee dolomite (124 feet thick; top, 1,153 feet below sea level)—		
Shale; greenish powder of dolomite, chert, fine quartz sand, green shale, and pyrite	7	2,032
Dolomite, arenaceous, cherty	30	2,062
Shale, drab, calcareous; in finest powder; grains of buff, cherty dolomite	23	2,085
Dolomite, gray	5	2,090
Dolomite, gray; minute rounded vesicles resembling matrix of oolite from which grains have been dissolved	5	2,095
Dolomite	5	2,100
Shale; as at 2,085 feet; "exceedingly hard to drill"	40	2,140
New Richmond sandstone (94 feet thick; top, 1,277 feet below sea level)—		
Dolomite, arenaceous, gray; 2 samples	9	2,149

Record of strata in Greenwood Park well—Continued.

	Thickness	Depth
	Feet	Feet
Shale, drab, calcareous	5	2,154
Sandstone, white, fine, calciferous	10	2,164
Dolomite, buff	8	2,172
Sandstone, clean white quartz sand; grains rounded	10	2,182
Dolomite, buff	15	2,197
Sandstone, buff; grains broken, much dolomite	11	2,208
Sandstone, friable, white, fine	2	2,210
Shale, drab, slightly calcareous	4	2,214
Sandstone, white	5	2,219
Dolomite, buff, white; much quartz sand	3	2,222
Shale	2	2,224
Sandstone, gray and buff, calciferous; most of grains broken	14	2,238
Shale, light blue	5	2,243
Oneota dolomite (175 feet thick; top, 1,371 feet below sea level)—		
Dolomite of various tints, many cherty; argillaceous at 2,250, 2,272, 2,333, 2,340 feet; arenaceous at 2,270 and 2,333 feet; at 2,305 feet there is 17 feet of white, blue, and green chert; 32 samples	175	2,418
Cambrian (582 feet penetrated; top, 1,546 feet below sea level):		
Sandstone, white; fine grains, mostly rough surfaced; some dolomite	12	2,430
Dolomite, brown; in chips	2	2,432
Sandstone	4	2,436
Dolomite, rough, gray, and brown	4	2,440
Sandstone, fine, white and reddish; 3 samples	12	2,452
Shale, light blue-gray	2	2,454
Sandstone, calciferous, buff	4	2,458
Dolomite, arenaceous, gray, buff, and brown; 6 samples	30	2,488
Shale, light blue-gray	10	2,498
Dolomite, gray and buff, siliceous	9	2,507
Sandstone, gray, fine, calciferous	27	2,534
Marl, highly quartzose, dolomitic, argillaceous; yellowish powder; 2 samples	19	2,553
Sandstone, calciferous, gray and white; 3 samples	12	2,565
Sandstone; in sand and small chips superficially resembling dolomite; calciferous, glauconitic, close-grained; grains white, gray and buff; 10 samples	145	2,710
Shale and dolomite; shale hard, bright green, slaty; dolomite white, highly siliceous, with much greenish, translucent amorphous silica, 2 samples; over one-half of the second sample soluble in acid	20	2,730
Sandstone, buff; in powder, glauconiferous; rock is termed sandstone although composed chiefly of light colored particles which effervesce freely in acid; fragments of crystalline quartz form but a small proportion of the drillings	20	2,750
Sandstone, saccharoidal; dark with purplish tinge, dark color due to numerous grains of glauconite, purplish tinge to ferruginous stains on quartz sand; sand grains of crystalline silica, rough surfaced, imperfectly rounded, many fractured	130	2,880
Dolomite, dark gray, greenish, macrocrystalline, glauconiferous; sparingly arenaceous	5	2,885
Sandstone, greenish; grains microscopic	5	2,890
Shale, dull gray, fine-grained, and exceedingly finely laminated	5	2,895
Sandstone, glauconiferous, calciferous; grains imperfectly rounded, with hard, dark green slaty shale	15	2,910
Marl; in buff flour; microscopically arenaceous; calciferous; glauconiferous	50	2,960
Marl, pink; calciferous, arenaceous; one-third of drillings by weight insoluble in acid; to bottom of well	40	3,000

Mitchellville.—The State Industrial School for Girls at Mitchellville is supplied with water from several wells. (See Pl. XV, p. 812.)

Water is forced into a tank of 1,600 barrels capacity, elevated on a 90-foot tower, from which 10 fire hydrants and taps in each building are supplied at a pressure of 45 pounds. The school consumes about 8,000 gallons of water a day, less than one-fifth the capacity of the plant.

Well No. 1 has a depth of 865 feet. The water is strongly saline and is not potable and the well was abandoned. Driller, F. J. McCarthy, Minneapolis.

Well No. 2 has a depth of 470 feet and a diameter of 8 inches to 103 feet, 6 inches to 350 feet, 4½ inches to 370 feet, 3½ inches to the bottom; 6-inch casing to 103 feet, and 4½-inch from 348 to 360 feet to shut out a foot of soapstone. The curb is 987 feet above sea level and the head 102 feet below curb. Water came in at 100 feet but was cased out; also from 320 to 350 feet, heading 50 feet below curb, but the supply was small and easily reduced by pumping; also from 440 to 452 feet in porous rock; tested capacity 20 gallons a minute. Date of completion, 1901.

By August, 1904, this well had filled with sediment to 340 feet above its base, or nearly 200 feet above the working barrel of the pump.

Well No. 3 had a depth of 563 feet and a diameter of 10 inches to 107 feet, 8 inches to 317 feet, and 6 inches to the bottom, casing to 542 feet. The curb is 987 feet above sea level and the head 63 feet below curb. Tested capacity 15 gallons a minute at completion of well; present capacity 45 gallons a minute; water at depth of 550 and 563 feet. Temperature, 60° F. The well was drilled by J. H. Shaw, of Sioux City, and was completed in January, 1907.

In October, 1912, Mr. Shaw deepened the well to a total depth of 625 feet with a six-inch bit. At the same time 4½-inch perforated casing was inserted from a depth of 477 feet, 6 inches to the bottom. The cylinder is 5½ feet long and 4½ inches in diameter. Its top is 461⅓ feet below curb and a suction pipe extends 22 feet below the foot valve.

Driller's log of well No. 1 of the State Industrial School, Mitchellville.

	Thickness.	Depth
	Feet	Feet
No samples	296	296
Shale	269	565
Rock	45	610
Shale, green	75	685
Limestone and shale	180	865

Record of strata in well No. 2[1] of the State Industrial School, Mitchellville.

	Thickness.	Depth.
	Feet	Feet
Soil, black	4	4
Clay, yellow	10	14
Sand	3	17
Clay, blue	35	52
Clay, gravel, and small stones	2	54
Clay, yellow	30	84
Clay, cobblestones, and gravel	3	87
Clay, yellow	5	92
Clay and sand mixed	10	102
Sandstone	3	105
Soapstone	7	112
Rock, red	10	122
Rock, hard, with layers of flint	2½	124½
Soapstone and slate	12	136½
Rock, blue	2½	139
Slate and soapstone	10	149
Rock, hard, gray	6	155
Soapstone with hard layers of slate (dark)	18	173
Rock, hard, gray	8	181
Soapstone	2	183
Rock, hard	12	195
Soapstone, hard	5	200
Rock, hard, gray	10	210
Soapstone	2	212
Rock, hard, with 1 foot of iron pyrites	12	224
Slate	5	229
Rock, hard, with bands of flint	7	236
Soapstone, hard	5	241
Slate, hard, gray	10	251
Sandstone	15	266
Iron pyrites	2	268
Sandstone, hard	4	272
Slate	2	274
Sandstone	15	289
Slate, gray	5	294
Sandstone, hard, with crushy layers	24	318
Slate, gray	2	320
Sandstone, hard	7	327
Iron pyrites	2	329
Sandstone, very hard	5	334
Limestone	10	344
Sandstone, hard	5	349
Soapstone	1	350
Limestone	2	352
Limestone, brown, crystalline, vesicular; with large masses of blue-gray chert	4	356
Limestone, brown; with irregular blue shaly masses	2	358
Shale, blue, calcareous, nearly gritless	2	360
Shale, blue-gray; with disseminated siliceous nodular masses	1	361
Limestone, brown, vesicular; effervescence moderately slow; crystalline; fossiliferous	5	366
Shale, blue-gray and buff mottled, massive, calcareous; highly siliceous, with minute quartzose particles		380
Limestone, blue, crystalline, somewhat vesicular; effervescence rather slow		400
Limestone, blue, crystalline, porous; fossiliferous, with casts and molds; minutely arenaceous, argillaceous		410
Limestone, mottled gray; much disseminated chert in grains and with geodic cavities with chalcedonic and crystalline quartz		420
Limestone, yellow and dark gray; mottled like diorite; rather slow effervescence; argillaceous, minutely arenaceous		430
Limestone, blue-gray, argillaceous, and green-gray, saccharoidal; macrocrystalline		445
Limestone, light brownish gray, saccharoidal, macrocrystalline; rapid effervescence		450
Limestone, mottled dark and light gray, vesicular; effervescence rather slow; macrocrystalline-earthy, siliceous, with green disseminated particles of clay		460
Limestone, blue-gray, vesicular, with cavities lined with chalcedonic and crystalline drusy quartz; with disseminated green clay as above		470

[1]Driller's log to 352 feet; from 352 to 470 description of samples.

Record of strata in well No. 3,[1] State Industrial School, Mitchellville.

	Depth in Feet
Sandstone, fine, gray; some effervescence in hot hydrochloric acid, indicating magnesian cement; some carbonaceous shale in coarse grains	112-120
Sandstone, similar to the above; brisk effervescence in hot hydrochloric acid, none in cold acid; a few crystals of pyrite	163-174
Shale, blue-gray, fine, rather hard, no grit	174-186
Limestone, subcrystalline, gray, fine-grained; some dark carbonaceous shale, also some similar to that at 174 feet	186-191
Shale, dark, fissile, fine-textured	191-207
Shale, light to dark gray: light colored is hard and fine-textured; dark gray is gritty and crumbles more easily; some calcareous content is indicated by effervescence in cold hydrochloric acid; a little sandstone similar to that at 112 and 163 feet	207-211
Shale, gray, fine-textured	211-240
Shale, variegated, gray, red, green; sample shows some crystal grains which probably come from magnesian limestone; slight effervescence in hot hydrochloric acid	234-240
Limestone, blue-gray, fine-grained, subcrystalline; some fragments of fine textured shale like that at 211 feet	240-250
Shale, dark gray, fine	250-260
Clay shale, dark gray, no laminae evident; darker than the above; slightly gritty, hard, clay concretions	260-317
Limestone, light gray, fine-grained, pyritiferous, crystalline, brisk effervescence in cold hydrochloric acid	317
Limestone, gray, similar to above	317-327
Clay shale, gray, fine-textured; effervesces slightly in cold hydrochloric acid	327-330
Limestone, light to dark gray, subcrystalline; grains of vesicular pyrite present; brisk effervescence in hydrochloric acid	330-340
Limestone, as above, containing water	350-357
Chert and limestone; chert gray, fine-grained, one fragment being part of a quartz geode; limestone, gray calcite and dark gray granular limestone; effervescence brisk with cold hydrochloric acid	360-370
Limestone, magnesian, light to dark gray; finely granular; some grains of quartz	395-419
Shale, blue-gray, fine	419-420
Limestone, white and crystalline to dark gray; brisk effervescence in cold hydrochloric acid; considerable dark sand and some quartz crystals; water	420-434
Limestone and chert; chert, milk-white, with numerous well-formed quartz crystals; limestone, gray, granular	434-440
Chert and limestone; chert predominates in sample, in small angular, blue-gray chips; limestone in light yellowish gray powder and fine sand; abundance indicated chiefly by brisk effervescence in cold HCl. Large residue of clay and chert, with a few sand grains, after thorough digestion. Sample contains some blue-gray shale which may have come from above	565½-574½
Chert and limestone, in about equal amounts; chert similar to that in sample above; limestone subtranslucent, crystalline-granular, somewhat iron stained. Residue after digestion in acid chiefly chert with some quartz grains and ferruginous granules; sample at	575
Limestone with some chert; limestone in crystalline granules and yellowish powder; chert as above. Residue almost entirely chert, some fine, light gray silica, a few pyrite grains. Sample lighter gray than preceding; sample at	579
Limestone in fine, clear, granular sand, brownish gray from coating of calcareous powder; some chert and a little shale, the latter possibly from above. Effervesces readily, residue small, chiefly chert, with some small grains of translucent quartz; sample at	595
Limestone, similar to above, but less chert, pyritiferous, effervescence more rapid than that of higher strata. Residue small, chiefly quartz; sample at	610
Limestone, similar to above, little chert, cleavage faces of calcite give sparkling appearance. Residue small, chert and quartz grains, together with some clay, as in previous samples; sample at	615
Limestone, in fine gray and subtranslucent sand; digestion in acid reveals presence of considerable quartz in fine grains, also a little blue-gray chert. Some shale and numerous small masses of limestone fragments held by ferruginous cement; sample at	620

[1]Description of drillings by James H. Lees, Assistant State Geologist of Iowa.

A combination of the data of wells 2 and 3 gives the following section:

	Thickness.	Depth.
	Feet	Feet
Quaternary (987 to 885 feet above sea level)	102	102
Carboniferous:		
Pennsylvanian—		
Des Moines stage (885 to 670 feet above sea level)	215	317
Mississippian—		
Saint Louis limestone and Osage stage (670 to 517 feet above sea level)	153	470
Probably same as last (517 to 377 feet above sea level)	140	610
Kinderhook stage (377 to 302 feet above sea level)	75	685

Below the green shale from 610 to 685 feet "the lime rock and shale," extending, according to the log of well No. 1, to 865 feet (122 feet above sea level) may be in part Kinderhook, but in all probability it includes also some Upper Devonian. If the saline water of this well is considered as native to the lower sources, it is possible that the drill penetrated to the Salina (?) formation of the Silurian.

Another well at Mitchellville, 95 feet deep, draws from a gravel layer at 80 feet. The water is excellent and is used for all purposes. The supply may, however, be readily exhausted by hard pumping.

Saylorville.—A boring 1,800 feet deep is reported from the vicinity of Saylor, in section 12, T. 79 N., R. 24 W., but no reliable data regarding it are available. A flowing mineral well, less than 400 feet deep, situated near Saylorville, in section 3, T. 79 N., R. 24 W., is said to discharge about 5,000 gallons an hour. The source of the water is probably in or immediately above the Mississippian.

Valley Junction.—The public supply of Valley Junction (population, 2,573) is owned by the Valley Junction Water & Light Company, which owns two wells that furnish the supply. One is a flowing well 278 feet in depth which receives its water from a sandstone bed near the bottom and has a head 16 feet above the curb. The water is strongly mineral and is permitted to flow into a cistern, whence it is pumped for fire and emergency use.

The common supply is taken from a large open well 24 feet in depth, which draws its waters from the alluvial gravels found at depths of 12 to 24 feet anywhere in the town. Water stands within 12 feet of the surface, but it may be pumped out. Water is pumped from the second well into a tank 22 feet in diameter and 16 feet high, elevated on a 75-foot tower from which it is distributed by gravity through two miles of mains to 17 fire hydrants and 30 taps; 90 pounds pressure is generally maintained.

Driven wells may be had almost anywhere in the lower part of town at depths of 12 to 25 feet. The water stands so near the surface that in case of flood in Raccoon river the cellars are filled and water occasionally breaks up through the streets. The open sands and gravels lie immediately under the surface soils, except where they are covered with a layer of gumbo, and the ground water rises and falls with the river. Thus water is easy to get, but is liable to be contaminated. On the hill bored wells 40 to 50 feet in depth are the rule.

WELL DATA.

The following table gives data of typical wells in Polk county:

Typical wells of Polk County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (logs given in feet)
		Feet	Feet		Feet	
Mrs. Jennie E. Day	3 miles south of Ankeny.	------	------	Des Moines	+ 20	Coal prospect. Water bed, 250 (?).
Fort Dodge, Des Moines & Southern R. R.	Ankeny	150	------	Sand and gravel.	— 20	No rock. Other water beds, 75 to 125.
W. M. Donnaghy	6 miles north of Ankeny.	274	200	---- do ----	— 70	Filled to 274; other water beds 150 to 200, in fine sand.
F. H. Hunter	2 miles northeast of Ankeny.	265	140	Sandstone (Des Moines).	— 80	Other water beds, 150 to 200.
Henry Wagner	½ mile from Ankeny	380	240	Sandstone	— 60	
City of Des Moines	City Library	461	44	Gray sandstone.	+ 7	Till (alluvium), 44; soapstone, 10; sandstone, 7; fine clay, 111; slate, 17; coal, 4; sandstone, 80; sandstone, striped, some water, 30; sandstone, 120; sandstone, hard, striped, water bearing, 38. Principal water bed at 360; another at 225; flows freely as a park well.

Typical wells in Polk County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
Girls Industrial School.	Mitchellville	470	102	Sand and gravel.	—102	Other water beds in rock.
Do.	do	865		At 350 feet.	— 60	Very hard water.
Do.	do	95		Gravel		No rock.
T. S. Sayre	NW. ¼ sec. 20, T. 79 N., R. 22 W.	220		Sand	— 80	No rock. Slight sulphur taste.
J. O. Lee	SW. ¼ sec. 16, T. 78 N., R. 22 W.	175		do	— 25	No rock. Hard water. Drift, 25; blue clay, 25; yellow clay, 20; hard black clay, 100; yellow clay, with gravel, 5; gravel and water.
Beaver Township	NE. ¼ sec. 25, T. 79 N., R. 22 W.	65		do		No rock. Hard water. Drift or soil, 21; blue clay, 44; soft blue sand rock (drift conglomerate); sand and water.
Valley Junction Water & Light Co.	Valley Junction	24		Gravel and quicksand	— 12	10 feet in diameter. No rock.
Do.	do	278		Sandstone	+ 16	Flows ½-inch stream; mineral.

STORY COUNTY.

BY HOWARD E. SIMPSON AND W. H. NORTON.

TOPOGRAPHY.

Story county is at the geographic center of Iowa. Its surface, as a whole, is so nearly level, compared with the southern and eastern parts of the state, that it appears nearly flat—a condition due to the drift deposited over it by the last great ice sheet. Since this deposition too little time has elapsed to permit much modification of the gently rolling surface, and the area remains one of physiographic or topographic youth. Swales and shallow saucer-shaped basins are very common, but only the largest streams have developed well-marked valleys. The hills are inconspicuous low swells, save in a few places where kames and morainal ridges are well developed. Local relief is slight and the maximum difference in elevation, between the highest point on the moraine hills near Summit, with an altitude of 1,075 feet, and the point where South Skunk river leaves the county, is less than 250 feet.

South Skunk river, which drains the western half of the county, and Indian creek, which drains the eastern half, both flow southward through fairly well developed preglacial valleys. Their tributaries, however, are few and poorly developed, and ponds, small sloughs, and undrained areas are common. Many of the smaller tributaries as well as most of the ponds are intermittent, frequently disappearing in dry seasons.

GEOLOGY.

The glacial drift is thickly spread over the surface of the entire county except in the valley floors of South Skunk river and its chief tributaries, Squaw and Indian creeks, where it has been eroded away or covered with alluvium. In the South Skunk river bottoms below Ames and along Indian creek at Maxwell these deposits have been found to be from 50 to 100 feet thick, showing the preglacial character of the lower portions of the valleys.

Two drift sheets at least are present, the Wisconsin and the Kansan. They are separated by the loess and in many places by sands and gravels (the Buchanan), beneath the loess. Beneath the Kansan another gravel bed (the Aftonian) is locally present. The bedrock is everywhere the Coal Measures (Des Moines stage), except in the west-central portion about Ames, where South Skunk river and Squaw creek have cut through these into the Saint Louis limestone. The cutting was made possible by a decided arching of the strata. Surface exposures of the bedrock are comparatively rare, owing to the depth of the superficial deposits.

Aside from the low anticline which elevates the Saint Louis limestone along South Skunk river about Ames and the minor irregularity of the surface, Story county shows no structural features worthy of mention. The Des Moines stage has a maximum thickness of about 200 feet, is of varying character, and dips slightly southeast. (See Pl. XI, p. 458.) The thickness of the drift layers is extremely variable.

UNDERGROUND WATER.

SOURCES.

In Story county water is drawn from the alluvium, the Wisconsin drift, the loess, the underlying interglacial sands and gravels (Buchanan), the Kansan drift, the sands and gravels (Aftonian) beneath the Kansan, the Des Moines stage, the Saint Louis limestone and deeper beds.

Alluvium in quantity sufficient to form a water bed is limited to the valleys of South Skunk river and Squaw and Indian creeks. Here, not only beneath the flood plain but under the well-marked terraces which lie from 20 to 30 feet above it, coarse gravels and sands of glacial and fluvial origin alternate with clay and silt for depths of 50 to 100 feet and form a fairly distinct water province, whose importance is enhanced by the fact that several towns, including Ames and Cambridge on South Skunk river, and Maxwell and Iowa Center on Indian creek, are situated within it. All these towns draw their supplies from these deposits, which yield a satisfactory quantity of good water.

The creamery well at Cambridge[1] illustrates the character of the strata.

Record of creamery well at Cambridge.

	Thickness.	Depth.
	Feet	Feet
Loam and yellow clay	10	10
Sand and gravel	10	20
Clay, blue	25	45
Sand, fine	10	55
Gravel, coarse	10	65

The width of the alluvial area averages about half a mile along each stream, except on South Skunk river from Ames southward, where it is about two miles.

As in all the other areas covered by the Wisconsin drift sheet, the drainage of the Wisconsin area in this county is immature and the ground-water level so near the surface that the chief source of underground water for all purposes has been shallow bored and dug wells. The depth of the Wisconsin till, 20 to 80 feet over the general upland, is so great that in the earlier

[1]Beyer, S. W., Geology of Story County: Iowa Geol. Survey, Vol. 9, p. 206.

days comparatively few wells penetrated it even to the loess. Cultivation and artificial drainage have, however, lowered the ground-water level and this, together with the increased demand for stock water, has necessitated the deepening of old wells or the sinking of new ones, and the latter as a general rule have been bored or drilled. Most of them draw their supplies from the sand and gravels between the two great drift sheets, which still remain the source most commonly utilized in the county. These beds give rise to many springs where they are exposed in the stream valleys, and though some are intermittent many are perennial and form an excellent supply for stock pastures.

Deeper drift wells reach a fairly persistent and satisfactory bed beneath the Kansan, in the sands and gravels immediately overlying the bedrock, though many good wells are obtained in local sand layers higher up. The depth is variable owing to the great variations in thickness not only of the Kansan but of the overlying Wisconsin; depths of 100 to 130 feet are common in the western portion of the county, and depths of 150 to 300 feet are not uncommon in its eastern portion.

The relations of the Kansan aquifer to the bedrock below, as well as the general drift relations, are shown in a well section given by S. W. Beyer,[1] and interpreted by Norton.

Log of Larson well in the NE. ¼ sec. 5, Lafayette Township.

	Thickness.	Depth.
	Feet	Feet
Wisconsin drift:		
Soil and yellow clay	10	10
Clay, blue	5	15
Loess:		
Quicksand	5	20
Kansan drift:		
Clay, blue and yellow mixed	5	25
Quicksand	1	26
Clay, blue	77	103
Aftonian gravel:		
Sandstone, gravel, water bearing	50	153
Des Moines stage:		
Sandstone	6	159
Chert	2	161
Shale, blue and black; coal; fine clay; and shale, black	15	176

The heavy deposit of sand and water-bearing gravel is somewhat anomalous and may signify a preglacial channel. In some portions the Kansan is so thin that it is difficult to distinguish its upper beds.

[1]Geology of Story County: Iowa Geol. Survey, Vol. 9, p. 197.

The record kept in the sinking of the Iowa State College well is of value in showing the relations of the drift horizons.

Record of upper portion Iowa State College well.

	Depth. Feet
Till, yellow and gravelly; upper portion modified into soil	1- 16
Till, blue, sandy	16- 32
Till, blue; some yellow clay	32- 35
Sand, yellow	35- 40
Till, bluish green, contains an abundance of gravel	40- 50
Silt, ash-brown; with greenish tinge, loesslike, but finer	62- 97
Silt, slightly arenaceous	102
Sand, very fine, light yellow	105
Sand; with coarse gravel; water bearing	110-120
Shale, light bluish gray, calcareous, and cherty	126

A gravel layer about 16 feet below the surface is the probable source of a spring which furnished the earlier water supply of the college. A sand and gravel bed 10 feet in thickness at a depth of 40 feet and the coarse sand and gravel near the base of the well all indicate excellent supplies sufficient for ordinary use, though they have in late years proved insufficient to meet the demands of the college.

A few wells penetrate the entire drift and, entering the bed-rock, find a satisfactory supply in sandstone lenses in the Coal Measures (Des Moines stage). These layers are so local and variable that no general prediction can be made concerning them, and their water is in places too highly impregnated with sulphur salts to be valuable for domestic use. As a rule, this group is here chiefly composed of shales and therefore practically dry. These beds are absent in the small area about Ames and Soper's mill, but reach a maximum thickness of 200 feet in the southwestern portion of the county. A driller's log indicates the type of well.

Log of Tilden well, in the NE. ¼ sec. 12, Franklin Township.

	Thickness.	Depth.
	Feet	Feet
Soil and yellow clay (Wisconsin)	45	45
Sand and clay (loess)	10	55
Clay, blue (Kansan)	63	118
Slate	12	130
Sand; with coal and water	8	138

The Saint Louis limestone lies so deep over most of the county as to be beyond the reach of ordinary wells, and its shaly character makes it less certain as a water bearer than it is farther south. However, sandy layers mingling with the shaly beds beneath the heavy upper limestone supply a number of wells ranging from 130 to 400 feet in depth.

At the Iowa State College, at Ames, and at Nevada, the deeper beds have been drawn upon.

DISTRIBUTION.

In the eastern part of the county the stock wells are generally deeper than in the western part. Depths of 200 to 300 feet are not uncommon, the water being drawn mostly from sandstone beds of the Des Moines stage. Bored wells in drift are sufficient for ordinary household purposes and small farms.

Throughout the southwestern portion of the county farm wells 200 to 400 feet in depth are most common, but few of them enter bedrock, abundant water being supplied by heavy gravel layers in the base of the drift. Cambridge, Maxwell, and Iowa Center, in the southern portion of the county, draw their supplies from the alluvial sands interstratified with the silts of South Skunk river and Indian creek. Wells 200 to 300 feet deep are common in the southeastern section. One of these is utilized for a small town supply at Collins.

Several small and well-defined artesian basins are found in the northern part of Story county, in the bottoms of valleys, and have their origin in the drift. Beyer[1] describes these basins as follows:

Of these, Keigleys Branch, Zearing, and Dyes Branch constitute the most noteworthy artesian basins in the order of their importance. Watkins's well is the strongest well in the Keigleys Branch basin and may be considered typical of the area. The sequence of strata passed through is as follows:

Soil, 3 feet; clay, yellow, 17 feet; clay, blue, 35 feet; gravel and sand, water bearing, 7 feet; blue clay penetrated.

It is reported that the drill dropped 9 feet on reaching the gravel and that water carrying gravel with it spouted out with great violence. Bowlders of several pounds weight were thrown out. The water contains much suspended sediment. Temperature, 48° F.; rate of flow, 28,000 gallons per hour.

[1]Geology of Story County: Iowa Geol. Survey, Vol. 9, pp. 230-232.

There are numerous other flowing wells in this vicinity, but all of small flow. In the majority of instances the temperature is 2° or 3° higher than in the case of Watkins's well and about 5° higher than in ordinary shallow wells in the same locality, which show a temperature of about 45° to 46° F.

In the Zearing basin all of the wells are located on the bottom land along Minerva creek, within a radius of a mile from the town of Zearing. All are of small capacity and vary from 60 to 90 feet in depth.

Along Dyes Branch several flowing wells have been developed. The water-bearing stratum is reached at from 80 to 120 feet below the surface, the depth depending upon the position of the mouth of the well. The water is of good quality, but, as in the case of the preceding basins, it carries considerable ferruginous matter, as evidenced by the taste and by the brownish rust which coats all vessels in which the water has been allowed to stand.

Several other flowing wells are known at widely separated points in the county, but in every case they are of small capacity and possess little of general interest.

The Skunk valley at Story City and the Bear creek valley at Roland are also noteworthy artesian basins. In the former is located the city well of Story City.

CITY AND VILLAGE SUPPLIES.

Ames.—The location of Ames (population, 4,223) on the terraces of South Skunk river and Squaw creek insures an abundant supply in the alluvial sands at no great depth. The city supply is drawn from a well 10 inches in diameter, drilled within the casing, which was driven as fast as the well was drilled to a depth of 99 feet, and finished with a 10-foot screen. The water is thus drawn from coarse sands and gravels at a depth beyond danger of surface contamination. The head is usually about 48 feet below the surface.

The Chicago & North Western Railway uses a similar well in which a Cook strainer was sunk to a depth of 104 feet. The water stands 30 feet below the surface. The log is of interest in this connection.

Record of Chicago & North Western Railway well at Ames.

	Thickness.	Depth.
	Feet	Feet
Loam, sandy	20	20
Sand, blue, and clay	35	55
Gravel, coarse	10	65
Sand, water bearing	39	104

One of the most important supplies in this vicinity is that of the Iowa State College of Agriculture and Mechanic Arts. (See Pl. XI, p. 458.) Formerly an abundant and excellent supply had been obtained from the gravels underlying the Wisconsin till, but this source failed entirely in the dry summers of 1894 and 1895. The well has a depth of 2,215 feet and a diameter of 12 inches for 120 feet, 10 inches for 300 feet, 8 inches for 648 feet, 6 5-6 inches for 362 feet, 5⅜ inches for 505 feet, and 5 inches for 280 feet, to the bottom. It is cased within 280 feet of the bottom; no repairs made. The curb is 1,000 feet above sea level, and the present head is 20 feet below the curb. The original pumping capacity was 100 gallons a minute; present yield, 100 gallons a minute; yield can be materially increased by speeding the pumps. The well was completed in 1897 by Gray Brothers, of Chicago.

The water beds are stated by Beyer to be the Jordan, the New Richmond, and the Saint Peter. Pumping tests indicate that the water-yielding ratio of these formations is 15 to 4 to 1, respectively.[1]

The temperature observations of this well made by Byer[2] are of especial value. When the tests were made the well was practically full of water and had not been disturbed for more than a month. No corrections were made for convection currents nor for conduction. A Miller-Casella self-registering maximum-minimum thermometer was used. The instrument was lowered and the depth measured by a steel wire which passed around a calibrated drum. Readings were taken every 100 feet. The mean annual temperature at Ames is 47.2° F.; the temperature at 2,100 feet below the surface is 63.4° F.; and the average gradient is 1° F. for every 129.6 feet of depth.

Record of strata in deep well at Ames[3] (Pl. XI, p. 458).

	Depth in feet.
Pleistocene (120 feet thick; top, 1,000 feet above sea level):	
Till, yellow, sandy to gravelly; upper portion modified into soil	1-16
Till, blue, sandy	16-32
Till, blue; some yellow clay	32-35
Sand, yellow	35-40
Till, greenish blue; abundance of gravel and cherty limestone pebbles; matrix effervesces freely with dilute hydrochloric acid	40-50

[1]Beyer, S. W., Iowa Agricultural College water supply, Ames, 1897, p. 11.
[2]Idem, pp. 13-14.
[3]Idem, pp. 6-9.

Silt, ash-brown; with greenish tinge, calcareous and absorbent, loesslike but finer	62-97
Silt, slightly arenaceous	102
Sand, very fine, light yellow	105
Sand; with coarse gravel, water bearing; quartz pebbles abundant; limestone fragments present	110-120
Carboniferous (Mississippian) (300 feet thick; top, 880 feet above sea level):	
Shale, light bluish gray, calcareous, cherty	126
Limestone, blue-gray, argillaceous, pyritiferous	151
Limestone gray, argillaceous; some quartz	160-170
Limestone, light gray, soft, even-textured, cherty; effervesces very freely with weak hydrochloric acid	185
Limestone, slightly argillaceous	200
Limestone and shale	210
Shale and limestone	240
Shale, blue, noncalcareous, pyritiferous	310
Limestone, argillaceous; tending toward an oolitic facies; effervesces strongly with dilute hydrochloric acid	315
Shale, with fragments of white limestone; fossiliferous and pyritiferous	320
Shale, earthy, blue, arenaceous	325
Shale, light reddish brown; some green shale, slightly calcareous	330
Limestone, blue-gray; some green shale and brown limestone	375
Limestone, brown, pyritiferous	385
Limestone, brown; fragments of white cherty limestone and angular quartz grains	395
Limestone, brown, argillaceous	400
Shale, light gray, highly calcareous	415
Shale, gray-blue, calcareous	416-420
Devonian (310 feet thick; top, 580 feet above sea level):	
Limestone, yellowish gray; some carbonaceous matter	420
Limestone, white, compact	440-456
Shale, light bluish gray	460-475
Shale and limestone	495
Shale and limestone	540
Limestone, white, and shale, greenish blue, noncalcareous	550
Shale, ash-blue, calcareous	560
Limestone, gray-blue; fragments of brown limestone and green shale	570
Limestone, gray-blue	580
Limestone, gray, and shale, blue and green	590
Limestone, fossiliferous	600-610
Limestone, gray-brown, subcrystalline	615-640
Limestone, gray-brown, and shale	645-660
Limestone, buff, subcrystalline	660-680
Silurian (150 feet thick; top, 270 feet above sea level):	
Limestone, buff; earthy luster; soft; effervesces moderately with hydrochloric acid	690
Limestone, blue and buff; the latter in part vesicular and magnesian	700
Limestone, drab, highly argillaceous	710
Limestones; several kinds; one a buff earthy limestone, finely laminated, effervescing slowly, the laminae marked by dark gray bands	720
Dolomite, light gray	730
Dolomite, brown and gray, subcrystalline; varying in hardness and color	740
Limestone, buff	750
Shale, olive-green	755
Limestone, buff	775, 815-830
Shale and limestone	840-850
Dolomite, ash-gray	860
Dolomite, white	870

Ordovician:	
Maquoketa shale (160 feet thick; top, 120 feet above sea level)—	
Shale, green, plastic, noncalcareous	880
Shale, brown; slightly or not at all calcareous; 2 samples	890, 900
Shale, blue and green, noncalcareous	930
Shale, brownish, slightly calcareous	940
Shale, brownish; white fragments	950
Shale, blue, noncalcareous	960
Shale, earthy brown, calcareous	970
Shale, blue, calcareous	980-1,030
Galena and Platteville limestones (380 feet thick; top, 40 feet below sea level)—	
Limestone; sharp drillings in an argillaceous powder	1,040
Limestone, white	1,050-1,060
Limestone, white; much argillaceous material	1,080-1,090
Limestone, gray-blue, with blue shale and white chert	1,100
Limestone, gray-blue, compact; white chert in abundance; drillings sharply angular	1,110-1,130
Limestone; as above, but less chert	1,140-1,170
Limestone, slightly earthy, gray-blue	1,180-1,190
Limestone, gray-blue, marly	1,200
Limestone, buff, magnesian, marly	1,210-1,230
Limestone, ash-gray	1,240-1,260
Limestone, ash-gray; fragments of noncalcareous black and green shale	1,270
Limestone, brown, soft	1,280
Limestone, gray and brown, cherty	1,290
Limestone, gray; considerable reddish brown residual material	1,300
Limestone, cherty	1,310
Limestone, gray, with green shale	1,320
Limestone, gray, siliceous	1,330-1,380
Shale, green, fissile, noncalcareous, fossiliferous and pyritiferous; fossils identified, Dalmanites pygidia and Isotelus (Asaphus) pygidia resembling some forms of I. gigas DeKay; Rafinesquina alternata, Orthis subequata, O. fissicosta, and other Orthides	1,385-1,410
Saint Peter sandstone (70 feet thick; top, 420 feet below sea level)—	
Sandstone, fine-textured, white; grains even and well waterworn	1,420-1,460
Sandstone, calciferous	1,470-1,480
Prairie du Chien stage (610 feet thick; top, 490 feet below sea level)—	
Dolomite	1,490-1,500
Dolomite and sandstone; some doubly terminated quartz crystals	1,510
Sandstone	1,520
Dolomite	1,530
Dolomite, coarse sand, and green shale	1,540
Sandstone and dolomite; sandstone varying in size of grain	1,550
Sandstone; grains angular	1,560
Dolomite	1,570
Dolomite, arenaceous	1,580
Dolomite, arenaceous and cherty	1,590-1,600
Sandstone, fine-grained, angular, calcareous cement	1,610
Sandstone, yellow; much siliceous dolomite	1,620
Dolomite, highly arenaceous	1,630-1,640
Dolomite, white, finely quartzose	1,650
Dolomite, arenaceous	1,660-1,680
Marl, yellow; in argillo-calcareous powder, cherty, quartzose	1,690
Dolomite	1,700-1,710
Dolomite, highly arenaceous	1,720-1,730
Dolomite	1,740-1,750
Dolomite; chert and sand	1,760
Sandstone	1,770-1,790
Dolomite	1,800-1,830
Dolomite, arenaceous	1,840

Dolomite, argillaceous and arenaceous	1,850
Dolomite	1,860-1,880
Dolomite and sand	1,890-1,910
Dolomite, highly arenaceous	1,920
Sandstone	1,930
Dolomite	1,950-1,960
Dolomite, arenaceous, grains well waterworn	1,970-1,990
Dolomite, arenaceous; some green shale	2,000-2,010
Dolomite	2,020-2,040
Dolomite, highly arenaceous	2,050
Dolomite	2,060-2,070
Dolomite, argillaceous	2,080
Shale, blue, noncalcareous	2,090
Cambrian:	
Jordan sandstone (115 feet penetrated; top, 1,100 feet below sea level)—	
Sandstone; with dolomite and a little blue shale	2,100
Sandstone, white and waterworn; a small percentage of the grains contained iron	2,110
Sandstone, white; grains fine, sharp	2,120
Sandstone; as above, with coarser well-rounded grains	2,130
Sandstone, white; grains fine, even, well worn	2,140-2,175
Sandstone, white; texture variable	2,185
Sandstone; grains stained red with iron oxide; red and green shale; grains larger than above and more angular; iron pyrites and a black metallic mineral present	2,195
Shale, brownish red, arenaceous	2,205
Shale, green	2,215

Nevada.—The city of Nevada (population, 2,138) has two distinct sources of supply, a shallow open well 25 feet in depth, drawing its water from a coarse gravel bed, presumably at the base of the Wisconsin, and a drilled well 980 feet in depth, reaching the Silurian aquifers. Water is pumped chiefly from the shallow well and the deeper one is held in reserve, because of the expense of pumping the latter from a depth of 300 feet and because its water is strongly mineral.

The shallow well yields only about 500 barrels a day and is easily pumped out in dry summers. The water is distributed by gravity from a tank, capacity 35,000 gallons, elevated on a 90-foot tower, and a pressure of 50 pounds is maintained on the main streets. Mains 5½ miles long supply 35 fire hydrants and about 140 taps. About one-fourth of the population use the city supply, and all others are provided with shallow wells from the same aquifer.

The drilled well (Pl. XI, p. 458) has a depth of 980 feet and a diameter of 11, 8 and 6 inches; casing to 810 feet. The curb is 1,005 feet above sea level and the original head 103 feet below curb. The water bed is at 940 feet (Silurian), and the tested capacity, 200 gallons a minute. Date of completion, 1895. Drillers, Palmer & Sandbo, of Caledonia, Minnesota.

Driller's log of city well at Nevada.

	Thickness	Depth
	Feet	Feet
Clay, yellow	30	30
Clay, blue	6	36
Clay, yellow	10	46
Sand	55	101
Clay, tile	20	121
Shale	50	171
Clay, black	75	246
Slate	3	249
Coal and slate	3	252
Clay, light gray	15	267
Shell lime rock	15	282
Lime rock, white, mixed with flint	50	432
Granite, blue	50	482
Limestone, blue	93	575
Shale, red	8	583
Limestone, blue	80	663
Soapstone	8	671
Limestone, white	98	769
Limestone, blue	32	801
Clay, blue	3	804
Limestone, blue	55	859
Limestone, white	40	899
Sandstone, dark	35	934
Sandstone, white	10	944
Sandstone, red	12	956
Sandstone, white	8	964
Sandstone, red	4	968
Limestone, white	12	980

The clay shales and coal from 101 to 267 feet may be interpreted as the Des Moines stage. The Mississippian includes the "limestone mixed with flint" and the so-called "granite," and the Kinderhook may be represented in at least the upper part of the blue limestone from 482 to 663 feet. Under this interpretation the limestones from 671 to 899 feet may be Devonian, and the sandstone beneath them may be dolomites of the Silurian. Certainly no sandstone is to be looked for at this horizon.

Nevada is 1,005 feet above sea level. The artesian water used for city supply is so highly mineralized that it is important to know whether a better water could not be had by drilling deeper. This question may be answered in the affirmative. The records of the present city well are regrettably incomplete and inconclusive, but the very scant data seem to show that the supply is drawn from the Silurian and higher strata. Had the well been drilled deeper it would have found a much better water and the supply would also have been increased. Should the present well be deepened or another drilled, the Maquoketa shale may be expected within 50 or 100 feet below the bottom of this well, and this dry shale may reach a thickness of 150 feet. The Galena and Platteville limestones, underlying the Maquoketa, should yield some water, especially above the green shale at or near the base of the Platteville, but the drill may fail to find water by failing to strike a crevice. The Saint Peter sandstone, the first reliable water bed, would normally be encountered at about 600 feet below sea level, or about 1,600 feet below the surface, but the presence of an upwarp of the strata in this vicinity, as shown by the deep well at Ames, may bring this sandstone 100 or even 200 feet higher. Below the Saint Peter abundant stores of water will be found in the Prairie du Chien stage and the Jordan sandstone, and the well may be sunk with advantage to 2,300 or 2,400 feet, although a supply sufficient for present needs may be found within 2,000 feet. The well should be cased water-tight to the Maquoketa or to the Galena.

Story City.—The public supply of Story City (population, 1,387) comes from a flowing well which just reaches rock at 100 feet, the aquifer being the Aftonian gravel at the base of the Pleistocene. This overflows at the surface at the rate of about 50 gallons a minute into a cistern from which it is pumped into an elevated tank which furnishes a pressure of about 40 pounds on the mains. The flow has slightly decreased.

The same aquifer is generally drawn upon by the deeper wells in this vicinity. In those located on lowlands the water frequently flows and in all it rises nearly to the surface. The supply from these wells is very abundant and good. Where but a moderate quantity is needed, it is obtained at depths of 25 to 30 feet.

Minor supplies.—Though shallow bored wells are common near Gilbert (population, 235) for household purposes, drilled wells 100 to 200 feet in depth are generally necessary for stock wells, and both the lower drift gravels and the country rock furnish the water. Maxwell (population, 754) has two wells 80 and 100 feet in depth; a tank with a capacity of 1,300 barrels, elevated 60 feet from the ground, receives the water from the pumps, and from this it is distributed by gravity to the few fire hydrants and taps necessary for the village. Direct pressure is available in case of fire.

WELL DATA.

The following table gives data of typical wells in Story county:

Typical wells of Story County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
H. C. Wickham	SW. ¼ sec. 10, T. 85, R. 21.	365	120	"Rock" (Des Moines).	— 60	
R. D. Tresseler	2 miles southwest of Gilbert.	98	90		+4	Flow 16 gallons a minute.
J. Weigle	7½ miles north of Gilbert.	386	150	"Rock" (Saint Louis?)	— 40	Pleistocene: Yellow clay, 18; sand, 12; blue clay, 120. Des Moines: Slate, 50. Saint Louis: Fine clay mingled with streaks of hard rock, 186.
City	Ames	99		Sand and gravel.	— 48	10 inches diameter 10 foot screen.
Henry Byal	5½ miles south of Collins.	420	200	Saint Louis sandstone.	—180	Soil, 2; yellow clay, 25; blue clay, 53; sand, 2; blue clay, 118; slate, 10; sand rock, 8; slate, 2; sand rock, 12; slate, 1; sand rock, 20; slate, 1; rock, various changes, 176. No water above 418.
Jos. Olinger	2½ miles northeast of Maxwell.	288	125	Sandstone	—138	"In alternating hard rock and sand rock."
Sam Miller	2½ miles northwest of Maxwell.	118	100	do	— 6	
Frank Fish	Collins	298	180	Brown sandstone.	— 90	
G. Elliott	3 miles east of Collins.	60		Aftonian (?) sand.	— 20	Soil and yellow clay (Wisconsin), 12; sand (loess?), 6; sand, coarse (Buchanan), 8; clay, yellow (Kansan), 8; clay, blue (Kansan), 23; sand and water (Aftonian?), 3.
B. Olson	3½ miles north of Slater.	100			— 60	Bored. Cased with 12-inch tiling. Soil and yellow clay, 16; blue clay, 50; yellow clay, sand and water, hard dark clay, 34. Good supply of hard water.
Chicago & North Western Railway Co.	Ames	104		Sand and gravel.	— 30	Cook well strainer.
City	Nevada	25		Coarse gravel.	— 10	12 foot diameter; capacity 500 barrels a day.
Do	do	980	100	Silurian sand rock.	—150	Mineral. Poor boiler water. Sand water beds at 25 and 100 feet.

WEBSTER COUNTY.

BY W. J. MILLER AND W. H. NORTON.

TOPOGRAPHY.

Webster county is situated in the middle of the Wisconsin drift and in most parts shows the almost perfectly flat surface configuration so common to all the counties covered by that drift sheet. One very marked deviation from the generally flat country is the deep valley cut out by Des Moines river, which enters the north-central portion of the county and passes out at the southeast corner. Several tributaries of the Des Moines in the northwest have also considerably modified the flat country.

GEOLOGY.

The drift is represented by both the Kansan and the Wisconsin sheets, each of which extends over practically the whole county. The rock formations under the drift are represented by the Mississippian, Pennsylvanian (Des Moines stage), and Permian. The Des Moines stage extends over all except the northern part of the county, which is underlain by the Mississippian. The Permian, which carries gypsum, occurs in isolated areas on either side of Des Moines river in the vicinity of Fort Dodge.

The drift deposits have been for the most part laid down horizontally, although abrupt thickening and thinning of the beds are shown. Along Des Moines river they appear to follow the slopes of the river bottom. Little is known regarding the structure of the older rocks, but they are probably nearly horizontal. (See Pls. VI, p. 310; XVI, p. 814.)

As is generally the case in counties of central Iowa that are covered by the Wisconsin drift, Webster county has two important drift-water horizons, one beneath the Kansan and the other beneath the Wisconsin. Some wells have gone through the drift and into the underlying rocks, where they have obtained water from limestone or sandstone.

In Webster county comparatively shallow drift wells are numerous and yield good supplies of water. Rock wells are scarce. Nearly all water is rather hard.

UNDERGROUND WATERS.

SOURCES.

So far as the existing supply of water is concerned, the most important aquifer in this county is the sand or gravel beneath the Wisconsin drift, which in most places lies within 100 feet and in some places within 35 to 50 feet of the surface. Except along the stream bottoms the sand or gravel beneath the Kansan drift is reached at not less than 100 feet and in places at not less than 200 or 230 feet. Locally the Wisconsin has been completely removed by erosion along the main waterways and the first important aquifer to be reached is that beneath the Kansan instead of that beneath the Wisconsin. This is particularly true in the vicinity of Fort Dodge. Locally water-bearing sand beds may occur within either the Wisconsin or the Kansan drift.

Some wells have gone into the rock formations below the drift, as along the river north of Fort Dodge, where the Saint Louis limestone is reached, and farther south along the river near Lehigh, where the Coal Measures (Des Moines stage) have been reached. A few deeper wells in the high-level country have also gone through the whole drift and into the Coal Measures, where water is obtained either from limestone or sandstone.

DISTRIBUTION.

No distinct water provinces exist in Webster county. Conditions are very similar over the entire county, except along the principal drainage lines where some flowing wells occur, as along Des Moines river near Fort Dodge and along the tributaries of the Des Moines near Lehigh and Dayton. It is thought that the source of water in these flowing wells is at the base of the Kansan, the Wisconsin having generally been stripped along the streams.

SPRINGS.

Springs are uncommon in Webster county, except along drainage lines—the Des Moines and its branches. Several large springs occur along Lizard creek near Fort Dodge. A mineral spring is utilized at Kalo and many small springs may be found along the larger streams.

CITY AND VILLAGE SUPPLIES.

Dayton.—Dayton (population, 717) pumps its water by gasoline engine from a well 688 feet deep and distributes it by gravity with a pressure of 45 pounds. There are 1 1-5 miles of mains and 16 fire hydrants; 400 persons use 10,000 gallons daily. The water is hard. The well (Pl. XVI) has a diameter of 10 to 6 inches. The curb is 1,089 feet above sea level and the head 111 feet below the curb. The water, which comes from 570 to 688 feet, is lowered 100 feet by pumping. The well was completed in 1895 by J. H. Shaw, of Sioux City.

Driller's log of well at Dayton.

	Thickness.	Depth.
	Feet	Feet
Soil and yellow clay	25	25
Clay, blue	50	75
Sand, white, and bowlder	5	80
Clay, blue, or shale	25	105
Clay, yellow, or shale	20	125
Clay, blue or shale	83	208
Coal	3	211
Clay, blue, or shale	24	235
Clay, black or shale	25	260
Clay, blue or shale	110	370
Limestone, brown	48	418
Limestone, white	247	665
Limestone, blue	15	680
Limestone, white	8	688

Record of strata in well at Dayton (Pl. XVI, p. 814).

	Thickness.	Depth.
Quaternary (163 feet thick; top, 1,089 feet above sea level):	Feet	Feet
Soil	4	4
Clay, stiff, light gray, calcareous	21	25
Till, blue; 3 samples	50	75
Sand, coarse	8	83
Till, blue	22	105
Till, yellow, and fine gravel	20	125
Till, blue; 3 samples	38	163
Carboniferous:		
Pennsylvanian—		
Des Moines stage (207 feet thick; top, 926 feet above sea level)—		
Shale, drab, calcareous; 4 samples	45	208
Coal and coaly shale	3	211
Shale, hard, drab	24	235
Shale, dark reddish brown, nearly black	25	260
Shale, drab	40	300
Shale, black; 4 samples from 300 to 350	70	370
Mississippian—		
Saint Louis limestone and Osage stage (155 feet thick; top 719 feet above sea level)—		
Sandstone, light gray, fine-grained; in chips	20	390
Limestone, brown, and chert, drab; some chips of black shale from above	28	418
Limestone, light yellow-gray; brisk effervescence; in part oolitic, in part encrinital; 5 samples	107	525
Kinderhook stage (163 feet penetrated; top, 564 feet above sea level)—		
Dolomite, hard, light brown, crystalline, porous; in sand; 2 samples	30	555
Limestone, magnesian, drab, crystalline; moderately slow effervescence; in thin chips; 3 samples	45	600
Chert, light gray; siliceous oolite, drab; some brown limestone; 3 samples	65	665
Chert, light gray, and brown limestone	15	680
Limestone, gray, cherty; slow effervescence; some fine quartz sand; fine sand	8	688

Fort Dodge.—The water supply of Fort Dodge (population, 15,543) is obtained from a deep well and is distributed by direct pressure and by gravity. The domestic pressure is 100 pounds and the fire pressure 125. There are 20½ miles of mains, 122 fire hydrants, and 1,359 taps. The daily consumption in summer is 1,600,000 gallons and in winter 900,000 to 1,200,000 gallons.

The city well at Fort Dodge (Pl. XVI) has a depth of 1,827½ feet and a diameter of 15 inches to 278 feet, 13½ inches to 328 feet, 12 inches to 499 feet, 10½ inches to 1,056 feet, 8½ inches to 1,390 feet, 6 inches to 1,421 feet, and 5 inches to the bottom of the well. It is cased between 1,036½ and 1,056 feet, 1,332 and 1,390 feet, and 1,375 and 1,438¾ feet. The curb is about 1,011 feet above sea level. A flow from "gravel" at 328 feet was 144 gallons a minute; at 1,497 feet it had increased to 316 gallons a minute; at 1,535 feet it measured 314 gallons a minute; at 1,578 feet it had risen to 484 gallons a minute; and at the completion of the well supplies from still lower beds raised the total amount to 571 gallons a minute. Temperature, about 55° F. The well was completed in 1907, at a cost of $8,000, by the Miller Artesian Well Company, of Chicago.

Since 1908 two additional wells have been drilled for city supply. Well No. 2 has a depth of 670 feet and a diameter of 20 inches at the top and 13½ inches at the bottom. It is a flowing well and discharges 150 gallons a minute. Well No. 3 is located 1,000 feet from the other wells. It is 215 feet deep, 8 inches in diameter and flows 600 gallons a minute. The combined flow of the three wells in March, 1912, was reported at more than 1,500,000 gallons in 24 hours.

Record of strata in city well No. 1 at Fort Dodge (Pls. VI, p. 310; XVI, p. 814).

	Thickness.	Depth.
	Feet	Feet
No samples		98
Carboniferous (Mississippian) (450 feet thick; top, 913 feet above sea level)		
Limestone, buff; slow effervescence; in sand		98
Sandstone, yellow-gray, calciferous and argillaceous	10	108
Shale, tough, greenish	20	128
No record	10	138
Limestone, light yellow-gray, in finest meal, residue argillaceous and siliceous; and shale, greenish gray; minutely sandy and limy	10	148
Shale, tough, greenish; 3 samples	30	178
Limestone and shale	10	188
Shale, bluish	10	198
Shale and limestone	10	208
Shale; two samples	20	228
Limestone, oolitic, white or light yellow, soft; rapid effervescence; 2 samples	20	248
Limestone, minutely arenaceous and pyritiferous	10	258
Limestone; rapid effervescence	10	268
Shale	10	278
Limestone; rapid effervescence; light colored; 3 samples	30	308
Limestone, magnesian	10	318
Limestone, white, crystalline	10	328
Limestone, buff; slow effervescence	10	338
Limestone, yellow, crystalline; rapid effervescence	10	348
Limestone, buff, moderately slow effervescence	10	358
No samples	30	388
Limestone, cherty	10	398
Limestone, buff, moderately slow effervescence	10	358
Limestone, buff, hard, vesicular; considerable calcite; slow effervescence	10	418
Limestone, as above; drab, cherty	10	428
Limestone; rapid effervescence; in large chips	10	438
Limestone, as above; cherty	10	448
Limestone; slow effervescence; cherty	10	458
Limestone; drab; rapid effervescence	10	468
Shale; in concreted powder; light blue-gray; calcareous	10	478
Shale and limestone; shale, green, noncalcareous; limestone, yellow; rapid effervescence	10	488
Dolomite, dark blue-gray; in fine sand	10	498
Dolomite, dark drab, porous, subcrystalline; in chips	10	508
Limestone, in fine drab sand; slow effervescence, residue pyritiferous, argillaceous, and minutely quartzose	10	518
Shale, greenish gray; in concreted calcareous powder	10	528
Limestone, blue-gray; slow effervescence; some yellow limestone of rapid effervescence; some chips of calcareous greenish shale	10	538
Shale, hard, green, finely laminated; somewhat calcareous	10	548
Devonian and Silurian (310 feet thick; top, 463 feet above sea level):		
Limestone, buff and light yellow, soft; rapid effervescence; some shale from above	10	558
Limestone, in fine white meal; rapid effervescence	10	568
Limestone; light buff and drab; moderately slow effervescence	10	578

Record of strata in city well No. 1 at Ft. Dodge—Continued.

	Thickness.	Depth.
	Feet	Feet
Dolomite, light blue or light yellow-gray; in fine sand; at 598 macrocrystalline; highly vesicular; in large chips; 5 samples	50	628
Limestone, blue-gray; rapid effervescence	10	638
Dolomite, hard, compact, subcrystalline, yellow and blue-gray; 2 samples; some greenish shale at 648 feet	20	658
Limestone, yellow and gray; rapid effervescence; some greenish shale	10	668
Limestone, buff, compact; slow effervescence; some shale	10	678
Dolomite, blue-gray, compact, subcrystalline; in large chips; some shale	10	688
Dolomite, light and darker blue-gray; 2 samples; in fine sand	20	708
Shale, highly calcareous, in light gray loosely concreted powder; some dolomite	10	718
Shale, as above; light blue	10	728
Dolomite; buff	10	738
Dolomite and shale; dolomite drab, rough; shale, blackish, bituminous, burns with flame	10	748
Dolomite; drab, earthy	10	758
Dolomite; light buff, dense	10	768
Dolomite; drab; considerable blackish shale; 2 samples	20	788
Shale, blue, clayey, and buff dolomite; chips of both rusted on surface to ocher yellow	10	798
Limestone, magnesian, or dolomite; drab, earthy	10	808
Dolomite; drab or buff; mostly in crystalline sand; 5 samples	50	858
Ordovician—		
Maquoketa shale (250 feet thick; top, 153 feet above sea level)—		
Shale, blue; in calcareous, concreted powder; 4 samples	40	898
Limestone; rapid effervescence; buff and gray, soft	10	908
Shale and limestone; shale, green, pyritiferous; limestone, light buff, fine crystalline, granular; slow effervescence	10	918
Shale; in highly calcareous, blue-gray concreted powder	10	928
Limestone or dolomite, buff, hard; in sand, some greenish shale, probably from above	10	938
Limestone and shale; limestone, light gray, rather soft, moderately slow effervescence, fine crystalline granular; in sand; shale, in blue powder	10	948
Shale; in light blue-gray, highly calcareous powder, concreted; 15 samples; some white chert at 958 feet, much white chert at 968 and 988 feet; limestone, gray magnesian at 988 feet, cherty from 1,058 to 1,098 feet	150	1,098
Shale, bright green; in chips; chips of white nonmagnesian limestone and white chert	10	1,108
Galena dolomite (170 feet thick; top, 97 feet below sea level)—		
Dolomite and chert, light gray	10	1,118
Shale, in gray concreted powder, calcareous	10	1,128
Dolomite, gray; in fine sand, mingled with powder of shale; 2 samples	30	1,158
Shale or marl, in light yellow concreted powder; highly calcareous; residue cherty and argillaceous	10	1,168
Limestone, gray; in sand; much chert	10	1,178
Dolomite, crystalline, vesicular, yellow-gray and blue-gray; 4 samples	40	1,218
Dolomite, light buff; much white chert	10	1,228
Dolomite, light buff and drab; 2 samples	20	1,248
Dolomite, gray and buff; subcrystalline; much chert; effervescence slow; 3 samples	30	1,278
Platteville limestone (130 feet thick top, 267 feet below sea level)—		
Shale, highly calcareous; in greenish gray, loosely concreted powder; residue cherty and minutely arenaceous; 5 samples	50	1,328
Dolomite or magnesian limestone; buff; like that at 1,258 feet	10	1,338
Shale, green-gray, calcareous; chips of argillaceous limestone at 1,338 feet; 4 samples	40	1,378
Shale, bright green, hard, fissile	10	1,388
Shale, dark brown, fissile, bituminous; burning with flame; with limestone of rapid effervescence	10	1,398
Shale, as at 1,378 feet, a few fragments of brown, bituminous shale	10	1,408
Saint Peter sandstone (50 feet thick; top, 397 feet below sea level)—		
Sandstone, light gray; largest grains 0.8 millimeter diameter	10	1,418
Sandstone, white and light yellow, clean; 4 samples	40	1,458
Prairie du Chien stage (310 feet thick; top, 447 feet below sea level)—		
Dolomite, gray, hard; some quartz sand; 3 samples	30	1,488
Sandstone, clean, white; grains rounded; 5 samples	50	1,538
Dolomite and oolitic chert and quartz sand	10	1,548
Dolomite and quartz sand; 5 samples	50	1,598
Sandstone	10	1,608
Dolomite, gray, crystalline; arenaceous in chips	10	1,618
Sandstone and dolomite; white fine-grained sandstone; a very little admixture of dolomite; 3 samples	60	1,678
No samples	40	1,718
Dolomite, gray, hard, crystalline; in fine clean sand; 2 samples	20	1,738

Record of strata in city well No. 1 at Ft. Dodge—Concluded.

	Thickness.	Depth.
	Feet	Feet
Sandstone, white, and dolomite; chiefly quartz sand with a few grains of dolomite	10	1,748
Dolomite, in small chips; with much white quartz sand	10	1,758
Sandstone and dolomite; as at 1,738 feet	10	1,768
Cambrian:		
Jordan sandstone (59 feet penetrated; top, 757 feet below sea level)—		
Sandstone, clean, white; 2 samples	20	1,788
Dolomite and chert with sandstone; mostly sand	10	1,798
Sandstone, clean, white; 2 samples	20	1,818
Dolomite and sandstone; dolomite, gray; sandstone, white; drillings chiefly sand	9	1,827

Analyses of drillings from city well at Fort Dodge[a].

	Depth of samples, in feet				
$CaCO_3$	56.35	49.24	47.09	45.48	47.05
$MgCO_3$	39.49	40.01	40.63	31.25	41.26
$CaSO_4$	.11	.92	1.00	----------	.67
SiO_2	2.16	1.65	2.01	17.60	7.69
Al_2O_3	.39	7.37	8.54	.96	2.42
Fe_2O_3	.25	.37	.33	1.50	.80
H_2O	.94	.48	.61	3.21	.65
	99.69	100.04	100.21	100.00	100.04

A flowing well at Fort Dodge has a depth of 127 feet.

Driller's log of Fort Dodge flowing well.

	Thickness.	Depth.
	Feet	Feet
Black soil, yellow clay, and blue clay	31	31
Limestone	6	37
Shale, blue	27	64
Limestone	6	70
Sandstone, white, and water	2	72
Sandstone, white	40	112
Limestone (no water)	15	127

Gowrie.—Gowrie (population, 829) pumps its public supply from a well 620 feet deep, and distributes it by gravity with a pressure of 40 pounds through one-half mile of mains to 10 fire hydrants and 10 taps. Sixty persons use the water, consuming 15,000 gallons daily. The water is hard. The well has a diameter of eight inches to 200 feet and six inches to bottom; casing to about 350 feet. The head is 50 feet below the curb and the

a Made in chemical laboratory of Cornell college, Mount Vernon, Iowa.

temperature 45° F. The well was completed in 1902, at a cost of $1,150, by Mattock & Louke, of Jefferson, Iowa.

According to the driller's log, soil, yellow clay, blue clay, and shale prevail to a depth of about 155 feet, limestone from 155 to 315 feet, and water-bearing sandstone from 315 to 620 feet; according to another report, the well is mostly clay and shale to the depth of 200 feet.

WELL DATA.

The following table gives data of typical wells in Webster county:

Typical wells of Webster County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks (Logs given in feet)
		Feet	Feet		Feet	
Charles Daniels	8 miles east-northeast of Lehigh.	235	187	Sandstone	— 55	Black soil, 2; yellow clay, 15; blue clay, 170; black jack or shale, 30; sandstone, 15; very white sandstone and water, 3.
W. H. Goodrich	4 miles east of Lehigh.	120	112	Sand	+ 15	Flow from drift sand. Black soil, 2; yellow clay, 28; blue clay, 36; sand, 40; blue clay, 3; fine sand and water (flow), 3; limestone, 8.
	Fort Dodge	127	31	Sandstone	+ 3	Pressure, 12 pounds; water bed, 72.
County Farm	4 miles west-southwest Fort Dodge	366	85	Limestone	— 75 to —100	Pumped by gasoline engine. Black soil, 5; yellow clay, 15; blue clay, 65; gypsum, 10; light colored shale, 11; coal, 4; limestone, 5; shale and limestone alternations, 91; limestone, 59; potter's clay, 2; limestone and water, 99.
A. W. Hawley	2½ miles east-southeast Pioneer.	227	112	Sandstone	— 40	First water in drift sand at 100 feet. Black soil, yellow clay, blue clay, 100; sand and water, 12; black-jack or shale 114; sandstone and water, 1.
Peter Nelson	3 miles northeast Vincent.	125		Sand	— 50	No rock.
Z. W. Thomas	5 miles southwest-south Barnum.	219		do	— 40	Do.
J. Mann	8 miles east-northeast Fort Dodge.	68		do	— 8	Bored well, 12-inch tiling. No rock.
Plymouth Gypsum Co.	1½ miles southeast Fort Dodge.	54	54	do	— 12	Bored well to gypsum.

Typical wells in Webster County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
Minneapolis & St. Louis R. R.	Gowrie	625	41	Sandstone	— 60	Steam pump for locomotive. Black soil, 3; yellow clay, 8; blue clay, 30; shale, 70; harder shale, 45; limestone, 160; sandstone and water at bottom, 309.
Town of Dayton	Dayton	688	208	Limestone	—111	Gasoline engine pump (see p. 916.)
Chicago & North Western Ry.	do	68		Soft muck (?)	+ 2	Flows, used for locomotive. No rock. Yellow clay, blue clay, sand, gravel, 60; clay or soft shale, 7; soft mucky clay or shale and water, 1.

CHAPTER XIII.

UNDERGROUND WATERS OF THE SOUTH-CENTRAL DISTRICT.

INTRODUCTION.

BY W. H. NORTON.

The south-central district embraces the twelve counties of Adair, Appanoose, Clarke, Decatur, Lucas, Madison, Marion, Monroe, Ringgold, Union, Warren and Wayne. The entire area is underlain by the Pennsylvanian series, the Des Moines stage forming the country rock over the eastern counties and the Missouri stage that over the larger part of the six western counties.

Deep wells have been drilled at six points—Centerville (Pl. XVI), Pella (Pl. VIII), Flagler, No. 10 Junction, Corydon and Osceola. Of the first five wells sets of drillings, or the drillers' logs, have been preserved; but four of these wells are situated along the eastern border of the area, and of the Osceola well nothing is known except the depth. Both geologic structure and artesian conditions are thus left largely to inference. The deeper strata of southern Iowa form a trough whose axis extends from Des Moines to the southwestern counties of the state. In south-central Iowa the water-bearing beds of the early Paleozoic terranes dipping toward this axis reach their maximum depth in the southwestern counties of the district. The surface, moreover, rises toward the west. For these reasons the Saint Peter sandstone lies more than 2,000 feet beneath the surface, except along the eastern border. (See Pl. XVI, p. 814.)

The sandstone at the base of the Pennsylvanian series is not persistent in the eastern part of the district, but the meager facts at hand indicate that it thickens to the west. It yields water at Glenwood and at Bedford, in the southwest district of the state.

In the eastern counties, where the cover of the Pennsylvanian is thin and is cut by the major river valleys, the base of the Pennsylvanian is found to vary widely in elevation. This is due not only to local upwarps and downwarps of the strata but also to the strong unconformity that parts the Mississippian series from the Pennsylvanian. The map (fig. 7, p. 1101) exhibits the conjectural elevation above sea level of the base of the Pennsylvanian in south-central and southwestern Iowa. The data on which the map is constructed consist of a few drill holes, sunk in search of coal, and deep wells at several points in Iowa and northern Missouri. From Polk county southwest to Bedford the Mississippian descends about 650 feet; from Polk county due south to Chillicothe, Missouri, it falls in the aggregate but 250 feet. From Centerville west to Bedford it falls 733 feet; from Bedford west-northwest to Glenwood it rises 140 feet (Pl XVIII, p. 1100) and west to Nebraska City it rises 150 feet. From the map it will be seen that the Mississippian floor forms a shallow trough extending from near Des Moines to the southwest corner of the state. The line of the maximum depth may not coincide with the Des Moines to Bedford axis, although it is necessarily so drawn, as these two points are those of maximum known depth. The sag may also be narrower than represented and be bounded on each side by more level surfaces. In the eastern counties the contours bend somewhat sharply southward, and as shown by the depth to the Mississippian at Chillicothe, Missouri, they must bend to the southwest before reaching that town. To the west the contours also extend southward, as shown by the gentle dip of the floor from Lincoln, Nebraska, to Glenwood, a dip averaging some three feet to the mile. In using the map (fig. 7, p. 1101) it should be remembered that the known points are far apart and between them may intervene minor sags and swells entirely unknown. Erosion valleys cut into the Mississippian before the Pennsylvanian was deposited may lower the floor in places 100 or 200 feet below the estimate.

In southeastern Iowa the Mississippian series; especially the white limestone of the Burlington and the sandstones in the Saint Louis limestone, are aquifers of local value, but although these beds continue under this area they yield small and uncertain supplies. A sandstone of Silurian age is known to occur at Pella and at Centerville and sandstones apparently too high for the Saint Peter and probably to be placed in the Silurian are reported at Ottumwa, Bloomfield, and No. 10 Junction in Monroe county. How far west these sandstones may extend is altogether problematic; but the Silurian continues to be a water bearer by means of its limestones beyond the western limits of the district. The heavy magnesian limestones assigned, because of their anhydrite beds, to the Salina (?) formation of the Silurian yield water at both Bedford and Glenwood, and will probably also yield water in this area at depths nowhere exceeding 1,000 to 1,100 feet below sea level. The water at Bedford, however, is so highly mineralized that it is worthless.

Soon after well No. 3 at Centerville was drilled in 1904 its water contained 1,228 parts of solids, but the solids regularly increased to 2,545 parts in 1908, probably due to the deterioration of the casing and the entrance of the upper harder waters. Well No. 2 reaches only into the Silurian and, according to the analysis by Dr. J. B. Weems, contains a very much larger amount of mineral matter than the other Centerville well.

The Maquoketa shale may not extend far into the south-central district, and probably to the south and west the Silurian and Galena merge in an unbroken series of magnesic limestones. These limestones should be water bearing, but at what particular levels can not be predicted, nor is it certain that any given well will find a water-bearing crevice. Moreover, the quality of the water is unknown, but very probably, in the western part of the area at least, it is too highly mineralized for an acceptable city supply.

In the eastern counties the Saint Peter and the water beds subjacent are to be reckoned as dependable artesian assets, and here artesian wells can be recommended, though the water is as a rule highly mineralized. The failure of the deep city well at Pella (Pl. XIII, p. 626) to secure potable water has had a discouraging effect in its own and adjacent counties—an effect not wholly counteracted by the successful wells at Bloomfield and Centerville (Pl. XVI, p. 814). The Pella well was sunk only about 60 feet below the Saint Peter. The mineralized waters of the higher formations were first cased out, but as the supply from the Saint Peter proved insufficient, the casing was pulled and all waters allowed to mingle. No analysis was made of the Saint Peter water while it alone was admitted to the well. Had the casing been retained and the well drilled a few hundred feet deeper, an abundant supply of good water would probably have been obtained, as at Ottumwa (Pl. X, p. 448).

Except in the eastern tier of counties the depth to the Saint Peter and the water beds below it is so great that the sinking of deep wells to these deeper formations is not recommended. Nowhere south and west of Des Moines have these deep terranes been reached by the drill.[1] At Chillicothe, Missouri, almost due south of Des Moines and a little more than 50 miles beyond the state line, a deep well found at 250 feet below sea level a sandstone referred by Shepard to the Saint Peter,[2] the overlying Ordovician and the Silurian being supposedly absent. If this reference is correct—and it is corroborated by the rise of the sandstone southward from Chillicothe to outcrops near Missouri river—there may be a gentle rise of the Saint Peter from Polk and Warren counties due south as well as southeast. As the Chillicothe section is made up from a driller's log, it is possible that the sandstone in question is the Silurian sandstone found at Centerville and elsewhere in southeastern Iowa. In this case there is still a rise of the strata southward from Des Moines, but one much more gentle. To the west the first accurate data obtainable as to the Saint Peter are from the deep well at Lincoln, Nebraska, where the Saint Peter was reached at 127 feet below sea level. The wells at Council Bluffs, Glenwood and

[1]A deep boring at Nebraska City, Nebraska, reached the Saint Peter sandstone in 1912 at a depth of 2,783 feet, 1,853 feet below sea level.

[2]Underground waters of Missouri: Water-Supply Paper U. S. Geol. Survey No. 195, 1907, p. 67.

Bedford, as well as those of Forest City and Burlington Junction, Missouri, all fail of reaching this terrane. The drill hole at Nebraska City, Nebraska, reached the summit of the Decorah shale at 1,824 feet below sea level and the Saint Peter was reached at a depth of 1,853 feet below that level. These facts point to a wide trough in the older Paleozoic rocks, whose axis extends southwest from Des Moines to the southwestern counties of the state. The descent of the axis is probably very gentle, being much less than the southwestern dip of the strata of northeastern Iowa, unless the strata below the Pennsylvanian thicken toward the southwest. From the axis the rise of the strata to the east is exceedingly gentle; to the west and north it seems considerably steeper. The hypothetical elevation of the Saint Peter is seen in the map (Pl. III), which is based on several assumptions—that the Saint Peter descends from Des Moines to the southwest as other terranes are known to do as far as Forest City, Missouri; that it descends from Glenwood eastward, as other terranes are found to do as far as Bedford (Pl. XVIII, p. 1100); that the upwarp of the strata seen at Chillicothe, Missouri, deflects the contours somewhat to the southwest in the southern counties of the district; that along the axis of the trough the strata between the base of the Mississippian and the Saint Peter maintain and somewhat increase the thickness which they show at Des Moines.

The table below shows the elevation above sea level of the chief towns of the district, and the estimated depths to the base of the Pennsylvanian and that to the top of the Saint Peter. These estimates are not so accurate as those made for the eastern and northern parts of Iowa, but even if they are as much as 300 feet in error, they will serve to indicate in a general way the depth to which wells must be sunk to reach these horizons. Another unfavorable condition is the high altitude of towns along the divide between the Missouri and the Mississippi, on account of which the water will stand low in the wells.

Artesian estimates for towns in the south-central district of Iowa.

Town	Elevation above sea level	Hypothetical depth— To base of Pennsylvanian	Hypothetical depth— To top of St. Peter
	Feet	Feet	Feet
Albia	959		1,700
Chariton	1,042	575	2,100
Corydon	1,105	750	2,050
Creston	1,312	1,225	2,900
Greenfield	1,368	1,150	2,650
Indianola	976	450	2,175
Knoxville	909		1,850
Leon	1,019	820	2,325
Osceola	1,137	875	2,550

ADAIR COUNTY.

BY HOWARD E. SIMPSON.

TOPOGRAPHY.

Adair county is in the southwestern part of the state. Its surface is a high, slightly rolling drift plain, across which runs the "Great Divide." The crest of the divide passes southeastward through Adair and on across the county. North of Greenfield it branches and the secondary extends through Greenfield to Creston in Union county and southward beyond the state line. West of this branch the drainage is southward to the Missouri through tributaries of the Nodaway. The drainage of the small triangle between the two branches passes southeastward to Grand river, another tributary of the Missouri. The northeast one-third of the county is drained into the Mississippi through Middle and North rivers, tributaries of the Des Moines. The county contains no ponds or undrained areas.

GEOLOGY.

Loess mantles the uplands of the entire county, in the eastern part with the fine, light, clayey type typical of southern Iowa, and in the western part with the darker, less clayey kind, characteristic of the Missouri valley. The Kansan drift thickly covers the area, and well sections in many parts of the county indicate that heavy beds of Nebraskan drift are general. The drift is very thick, especially in the western half of the county.

The Dakota sandstone underlies the drift in the western third of the county, and is in turn underlain by Carboniferous rocks (Missouri stage). The Missouri stage, which lies beneath the drift in the eastern two-thirds of the county, comprises heavy limestones, interbedded with thin, light shales.

UNDERGROUND WATER.

SOURCE AND DISTRIBUTION.

Few wells in the county fail to obtain water from the drift. In many places sandy beds are found beneath the loess, beneath the Kansan, and beneath the lowest drift sheet, and as a rule all of these are water bearing. Many shallow wells rely entirely on seepage from the loess, but such wells are likely to fail in dry seasons. On the uplands the entire drift yields so scantily that many stock farms resort to ponded storm water.

All wells passing through the drift into the soft, porous Dakota sandstone find, at depths ranging from 150 to 300 feet, an abundant supply of good water that rises within 100 to 230 feet of the surface. Neither dry holes nor undesirable water have been reported. In the area underlain by the limestones of the Missouri stage the drift is a little thinner. The wells in that part of the county range in depths from 100 to 250 feet, and the water is invariably hard. No deep wells have been bored in this county.

The southeastern portion of the county is the most favored in the matter of ground water. Bored wells, ranging from 20 to 50 feet, are common, and a few are much deeper. Drilled wells obtain excellent water from the Dakota sandstone at depths ranging from 200 to 300 feet.

SPRINGS.

The sandy layers of the drift supply water to seepage springs, but few such springs yield sufficient water for a stock farm. A few stronger springs, whose waters may come from the Dakota sandstone on the adjacent divide, are reported in the southwestern part of the county along the valley sides of the East Nodaway and its tributaries.

CITY AND VILLAGE SUPPLIES.

Adair.—Adair (population, 900) is situated on the crest of the Mississippi-Missouri divide, a region where the drift is so thick that it is difficult to obtain a satisfactory supply of water. An unsuccessful well was sunk by the city to a depth of several hundred feet, but unfortunately no complete record exists.

Most of the residents are supplied with water by wells dug or bored into the loess or by cisterns. Five cisterns, with a capacity of 200 to 350 barrels each, a gasoline fire engine, and 900 feet of hose furnish the fire protection for the city.

Greenfield.—In Greenfield (population, 1,379) drift wells 30 to 60 feet in depth afford the general supply. A public supply used for drinking and for fire protection is obtained from 30 dug wells eight feet in diameter. A city well drilled some years ago into limestone of the Missouri stage to obtain boiler water for the electric light plant was abandoned because the water contained so much sulphate of lime and magnesia that it was unfit for the purpose. The well was 221 feet deep and was sunk 13 feet into the limestone. The water rose within 75 feet of the surface. The strength of this well suggests a supply from the lower drift rather than from the limestone. Since abandoning this well the lighting plant has used storm water collected in an artificial surface reservoir.

A well on the farm of W. W. Whittams, one and one-half miles west of Greenfield, was abandoned at a depth of 274 feet, the last 34 feet of which was in limestone of the Missouri stage; the well was quickly pumped dry.

WELL DATA.

The following table gives data of typical wells in Adair county:

Typical wells in Adair County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks
T. 74 N., R. 33 W. (Washington).		Feet	Feet		Feet	
J. A. Hulbert	4½ miles southeast of Bridgewater.	286	276	Sandstone (Dakota).	100	Strong; slightly mineral.
T. 76 N., R. 32 W. (Prussia).						
John Montgomery	1¾ miles southwest of Canby.	187	180	do	127	Hard; roily before storms.
T. 77 N., R. 33 W. (Summit).						
William Turner	1½ miles west of Adair	345	307	Fine sandstone.	230	
T. 75 N., R. 32 W. (Summerset).						
W. W. Whittams	1½ miles west of Greenfield.	274	240	Limestone (Missouri).	137	Scanty supply; abandoned.
Henry Hida	3 miles south of Fontanelle.	316	300	Sandstone (Dakota).	146	Slightly mineral.
John Mangle	2 miles west of Fontanelle.	315	299	do	125	
H. W. Adams	NW. ¼ sec. 21	254	240	Limestone (Missouri).	75	Hard water; strong well.
T. 76 N., R. 33 W. (Eureka).						
Frank H. Seers	6 miles northwest of Fontanelle.	282	260	Sandstone (Dakota).		Strong well.
T. 75 N., R. 33 W. (Jackson).						
Truman Lewis	5 miles north of Bridgewater.	317	300	do	120	Strong well.
Henry Rose	2 miles north of Bridgewater.	286	270	Limestone	176	Fine, hard.
Al. Bowers	3 miles north of Bridgewater.	270	260	Sandstone	160	
T. 75 N., R. 31 W. (Greenfield).						
Electric light plant	City of Greenfield	221	208	Drift and limestone (Missouri).	75	Strong well.
T. 77 N., R. 30 W. (Lincoln).						
G. D. Whittams	Sec. 19	148	136	Sandstone (Dakota).	108	Soft water; strong well; 20 gallons per minute.
W. H. Barnett	SE. ¼ sec. 23	78		Drift sand		Plenty; good.
T. 76 N., R. 30 W. (Harrison).						
William Wallace	SE. ¼ sec. 23	135	56	Limestone (Missouri).		No water.
David Johnson	NE. ¼ sec. 19	82	36	do	78	Good hard water.
T. 76 N., R. 31 W. (Grove).						
Harriet Guthiel	NE. ¼ sec. 14	134	122	do		Abundant from black shale; bad taste.
Nate Brinton	SE. ¼ sec. 12	200		Gravel		Insufficient; abandoned.

APPANOOSE COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY.

The surface of Appanoose county consists essentially of a much-eroded drift plain sloping very gently toward the east. Chariton river, the principal stream, enters at the northwest corner and flows southeastward diagonally across the county in a flat-bottomed valley approximately 150 feet deep and several miles in maximum width. From the west it receives a number of relatively long tributaries, all of which, with their branches, have cut into the upland plain, but from the east it is fed by very short streams, the divide separating its drainage system from that of Soap creek and Fox river being only a few miles east of the Chariton. Apparently the minor streams tend to flow in the direction of the general upland slope.

GEOLOGY.

The following formations are exposed within the county: (1) Alluvium, which is confined to the principal valleys; (2) loess, which is only a few feet thick, but which lies at the surface over much of the region; (3) glacial drift, which is generally found at the surface or immediately below the loess; and (4) Carboniferous rocks belonging to the Des Moines stage of the Pennsylvanian series, which crop out at many points along the principal streams.

In a large part of the county the drift sheet is thin, but in places, especially near the east margin, it is more than 100 feet thick. The irregularities of the rock surface produce many corresponding local irregularities in the thickness of the overlying drift. The glacial material is reported to contain a large amount of wood, leaves, and shells. The Pennsylvanian is several hundred feet thick and consists of shale with minor amounts of limestone, sandstone and coal. Below it lie the rocks of the

Mississippian series, which consist chiefly of limestone. (See Pls. X, p. 448; XVI, p. 814.)

UNDERGROUND WATER.

SOURCES.

The rocks of the Pennsylvanian series furnish water to a few wells, but in general they are unsatisfactory as a source of water. They consist chiefly of impervious shale with porous beds few and far apart, and therefore yield meagerly; also their water is undesirable for many purposes because of its high mineralization. Below the Pennsylvanian are formations that yield more freely, but the cost of drilling to these is so great that it can be undertaken only by municipalities or by railway companies or other large industrial concerns, and as far as exploration has gone the water is so high in different dissolved solids that it is ill adapted for use in boilers and is not desirable for public supplies. Moreover, its head is so low that in many places it would have to be lifted several hundred feet to bring it to the upland surface.

In some of the largest valleys the alluvial materials yield abundant and reliable supplies of only moderately hard water to shallow and inexpensive dug or driven wells, but many of the settlements and a vast majority of the farms are remote from valleys and their principal underground source of supply consists of irregularly distributed sandy and gravelly deposits associated with the bowlder clay. Whether these yield a sufficient amount is very much a matter of hit and miss. In some localities gravel beds occur that will furnish enough for waterworks and locomotive supplies; in others it proves difficult to extract enough water from the drift to meet the consumption on an ordinary stock farm, and in years of severe drought the lack of water for household and stock purposes may become an acute problem. The shallow water is rich in calcium and the bicarbonate radicle, but is usually superior to the water from the Pennsylvanian or deeper formations for both domestic and boiler use.

Because of the unsatisfactory status of underground sources, Appanoose county has come to depend to a great extent on surface water for household, stock and boiler supplies. For the household rain water is stored in cisterns; for stock, the wash from rains is collected by constructing dams across ravines; and for boiler feed, different plans are employed, as, for example, the reservoir of the Chicago, Milwaukee & St. Paul Railway Company at Mystic, into which surface and spring waters are gathered. In resorting to surface supplies, quality is the chief consideration for the household, soft water being desired; quantity is the chief consideration for live stock supplies; and both quality and quantity are factors in railway and other industrial enterprises.

In the many villages of Appanoose county the water for drinking is drawn mainly from shallow private wells in close proximity to a variety of contaminating agencies. The situation is especially bad in valley towns, where shallow wells on the bottom lands at the foot of populated slopes are peculiarly exposed to pollution. It is not easy, however, to find feasible means of improving the conditions. Something would be gained if each householder would protect his own well, but a really adequate remedy requires a system of waterworks drawing from a source safe from pollution. In spite of difficulties it is probable that systematic search will discover a sufficient sanitary and otherwise satisfactory source of public supplies for most of the villages.

CITY AND VILLAGE SUPPLIES.

Centerville.—Information concerning the three deeps wells that have been sunk in Centerville (population, 6,936) is presented in the following paragraphs (Pl. XVI, p. 814):

City well No. 1 is 2,495 feet deep. Its diameter is 12 inches to 55 feet, 10 inches to 95 feet, 9 inches to 155 feet, 8 inches to 335 feet, 7 inches to 492 feet, 6 inches to 616 feet, 5 inches to 2,335 feet, and 4 inches to bottom of well. It is cased to 804 feet. Its curb is 1,017 feet above sea level, and its head 260 feet below the curb. It obtains water at 1,200 and 2,450 feet. Tested capacity at completion, 200 gallons a minute. It was completed earlier than 1893 by J. P. Miller & Company, Chicago.

The strata penetrated are indicated in the following table:

Record of strata in deep well No. 1 at Centerville.

	Thickness	Depth
	Feet	Feet
Quaternary (top, 1,017 feet above sea level)	90	90
Carboniferous:		
Pennsylvanian (436 feet thick; top 927 feet above sea level)—		
Shales	67	157
Coal and coaly shale	1	158
Shale, with a few thin seams of limestone, none more than 5 feet thick; sample of calcareous shale at 500	368	526
Mississippian—		
Saint Louis limestone and Osage stage (515 feet thick; top, 491 feet above sea level)—		
"Rock;" probably limestone	34	560
Shales, variegated, arenaceous toward bottom	50	610
Limestone, rough, gray, siliceous; 2 samples	30	640
Shales, seleniferous, with some limestone and chalcedony; 7 samples	65	705
Limestone, nonmagnesian, blue-gray, highly cherty; shale, arenaceous; in concreted powder; 4 samples	55	760
Shales, cherty; limestone; 4 samples	55	815
Limestone, white; rapid effervescence; much white flint and chalcedony; 3 samples	40	855
Limestone and shale; limestone, brisk effervescence, soft, white, dark brown, blue-gray, in places clayey, siliceous, and pyritiferous; shales in places arenaceous; shale marked at 855, 895 and 915; 18 samples, in concreted powder	186	1,041
Kinderhook stage (59 feet thick; top, 24 feet below sea level)—		
Shale, blue and green-gray; 6 samples	59	1,100
Devonian (260 feet thick, top 83 feet below sea level):		
Shale, with white and gray nonmagnesian, soft limestone; 6 samples	60	1,160
Limestone, gray, rather soft; rapid effervescence	8	1,168
Shale, arenaceous	21	1,189
Limestone, gray, rapid effervescence, siliceous; water bearing	11	1,200
Shale; arenaceous at 1,210 feet	20	1,220
Limestone, argillaceous	10	1,230
Limestone, light gray, argillaceous; brisk effervescence	10	1,240
Limestone, compact, fine-grained, light blue-gray	20	1,260
Shale, calcareous; or limestone, argillaceous, light yellow	10	1,270
Limestone, hard, somewhat argillaceous, light yellow	10	1,280
Limestone, white (some gray), compact, moderately hard, nonmagnesian; much shale in flakes	20	1,300
Limestone and shale, in gray concreted powder; limestone, yellow and gray, crystalline, soft, in fine meal; nonmagnesian; cherty residue; at 1,350 residue of fine rounded quartz grains; 6 samples	60	1,360
Silurian (180 feet thick, top, 343 feet below sea level):		
Limestone, buff, magnesian, argillaceous at 1,360 feet; 2 samples	20	1,380
Shale, blue, and limestone; in concreted powder	10	1,390
Limestone, soft, blue, nonmagnesian, with some white chert and much shale	10	1,400
Limestone, blue-gray, hard, compact, fine-grained, nonmagnesian	10	1,410
Limestone and shale, blue, calcareous, in light gray powder and meal	20	1,430
Sandstone; grains fine and only fairly well rounded; many pointed with secondary enlargements; in fine powder containing also particles of light colored limestone	10	1,440
Sandstone, light gray, calciferous; as above	10	1,450
Sandstone, buff, calciferous	10	1,460
Sandstone, white, fine; grains fairly uniform in size and well rounded, mostly smooth, but many show crystalline secondary enlargements, giving the sand a sparkling appearance	10	1,470
Sandstone, calciferous, with some fragments of blue shale in drillings	10	1,480
Limestone, in gray meal; moderate effervescence; highly siliceous with rounded quartz grains and chips of chert; 4 samples	60	1,540
Ordovician:		
Galena dolomite and Platteville limestone, 200 feet thick; top, 523 feet below sea level—		
Dolomite or magnesian limestone, buff and gray; many drillings have cherty and arenaceous residues	160	1,700

Record of strata in deep well No. 1 at Centerville—Continued.

	Thickness	Depth
Limestone, dark and light gray; moderate effervescence; much green shale in drillings	20	1,720
Limestone, buff; moderate effervescence	10	1,730
Shale, blue, soft, unctuous, noncalcareous	10	1,740
Saint Peter sandstone, 40 feet thick; top 723 feet below sea level—		
Sandstone; white, clean; rounded grains, moderately fine; 4 samples	40	1,780
Prairie du Chien stage (715 feet penetrated; top, 763 feet below sea level)—		
Shakopee dolomite—		
Dolomite, buff and gray; arenaceous at 1,820 feet; 6 samples	110	1,890
New Richmond sandstone—		
Sandstone and dolomite, light gray and white; drillings consist of rounded grains of quartz and angular chips of dolomite; 8 samples	105	1,995
Sandstone, light yellow-gray, in fine angular grains; a little white dolomite and green shale in drillings	65	2,060
No samples	65	2,125
Oneota dolomite—		
Dolomite, light gray and white, highly cherty from 2,140 to 2,185 feet; somewhat arenaceous at 2,125 and 2,240 feet; 9 samples	135	2,260
No samples	92	2,352
Sandstone, calciferous, or dolomite; arenaceous; grains rounded, smooth, of moderate size; chips of hard gray dolomite	------	2,352
No samples	68	2,420
Dolomite, gray; buff at 2,455 feet; somewhat arenaceous from 2,440 to 2,465 feet	75	2,495

This well was drilled in the public square of the town long before waterworks were installed, and was never pumped except at the driller's test. When waterworks were built it was thought best to drill another well in a convenient location rather than to erect the pumping station in the public square.

City well No. 2 is 1,540 feet deep. Its diameter is 10-inch to 368 feet, 8⅝-inch to 480 feet, 7¼-inch to 630 feet, 6¼-inch to 826 feet, 5-inch to 1,160 feet. Uncased from 1,160 feet to bottom of well. The curb is 1,017 feet above sea level; and the head 280 feet below the curb. Water is obtained from 1,439 feet to bottom; tested capacity, 350 gallons a minute. The well was drilled in 1895 by J. P. Miller & Company, of Chicago.

The driller reported a sand rock extending from 1,470 to 1,510 feet and yielding water that rose within 60 feet of the surface; beneath the sand rock the drill passed into a fissured rock, and the water sank to 280 feet below the curb, and the drillings were washed away.

City well No. 3 is 2,054 feet deep. Its diameter is 16-inch to 73.25 feet; 12-inch to 180 feet, 10-inch to 500 feet, 8-inch to 733.25 feet, 6-inch to 118.15 feet, 4⅞-inch (uncased) to bottom. The curb is 1,017 feet above sea level, and the head 286 feet below curb. The tested capacity is 200 gallons a minute. The well was drilled by L. Wilson & Company of Chicago, and was completed in 1904, at a cost of $10,000.

The casing of this well is admirably designed to keep out the upper waters. The 10-inch pipe extends to the curb, and it and all other piping of smaller diameters are sealed at bottom with lead.

Driller's log of well No. 3 at Centerville.

	Thickness	Depth
	Feet	Feet
Clay, yellow	50	50
Clay, blue	10	60
Gravel	10	70
Cap rock	4	74
Soapstone and shale	51	125
Shale of different colors	25	150
Shale streaked with rock	9	159
No record	6	165
Coal blossom	5	170
Shale, at		185
Soapstone, at		200
No record	60	260
Soapstone with some sand	20	280
No record	13	293
Soapstone and shale	47	340
No record	21	361
Shale, at 361, 380, 425, 450, 475, 500 and		585
Sand, white	15	600
Shale	30	630
Rock and shale, shale caving badly	20	650
Shale, blue, hard	30	745
Limestone and shale, at		790
Limestone, at		830
Limestone and shale, at 860, 900, 925, 950, 980, 1,015 and		1,127
Solid limestone; traces of natural gas in black rock at 1,190 feet	213	1,340
Shale, blue	100	1,440
Limestone	10	1,450
Sandstone	46	1,496
Limestone	256	1,752
Sandstone	40	1,792
Limestone	108	1,900
Streaks of sand and limestone	50	1,950
Sand	100	2,050

The water is lifted from the well into a surface reservoir and thence pumped into a standpipe from which it is distributed, by gravity pressure, through 8¼ miles of mains to 74 fire hydrants and 352 service pipes. It is estimated that about one-fifth of the homes are connected with the waterworks and that an average of 63,000 gallons of water is consumed daily.

The chief deterrent to the extensive use of well No. 3 is its heavy mineralization. The water, as shown by analysis (p. 201), is so hard that it is undesirable for toilet, laundry, or boiler uses; its iron content discolors vessels in which it is used, and it is so salty that it is somewhat unpalatable. If, as seems not improbable, enough water can in years of normal rainfall be obtained from a system of wells or infiltration galleries in the drift gravels known to exist in the vicinity of the city, this source would be preferable to a deep well, as the water is better and would probably be much more extensively used by the people. The pumping lift would also be much less. The deep well could be held in reserve to furnish a supplemental supply when needed. A third possible source of water for Centerville is filtered water from Chariton river.

The Chicago, Rock Island & Pacific Railway well is situated on an upland, which is trenched, at no great distance from the well, by deep ravines that lead to tributaries of Chariton river a few miles away at a level 150 feet lower. The well was dug to a depth of about 37 feet and ends in a bed of sand from which about 3,500 gallons of water an hour are recovered.

Moulton.—The Electric Light Company well at Moulton (population, 1,233) has a depth of 538 feet and a diameter of 6 to 3½ inches. It is cased to 498 feet. The curb is 987 feet above sea level, and the head 230 feet below the curb. It yields 16 gallons of highly mineralized water a minute from 40 feet of hard white sandstone at 530 feet depth. It was completed in 1905 by F. D. Tuttle, of Cedar Rapids.

Driller's log of well at Moulton.

	Thickness	Depth
	Feet	Feet
Clay	100	100
Sand, fine, at		100
No record	300	400
Shale, dark, sticky	63	463
Limestone	24	487
Sand, white, fine	43	530
Limestone	2	532

CLARKE COUNTY.

BY HOWARD E. SIMPSON.

TOPOGRAPHY AND GEOLOGY.

Clarke county is in the southern portion of the state, on the divide between Mississippi and Missouri rivers. The crest of the divide has here an easterly trend and pitch, so that though the drainage of the northern slope is toward Des Moines river and that of the southern slope toward the Missouri, the drainage of the main eastern slope is divided between the two. The area is primarily a drift plain into which the stream valleys have been carved, and all parts of it are well drained by open valleys separated by broad flat-topped uplands.

The entire surface is mantled with loess and Kansan drift which, in many places, is 100 to 150 feet thick.

Throughout the county the drift rests on Carboniferous rocks, for the most part belonging to the Missouri stage and consisting of limestone, shales, and some thin coal seams. The Missouri stage thins eastward and is absent in the valleys of some of the larger creeks on the eastern and northern borders of the county, thus bringing the rocks of the Des Moines stage directly beneath the drift. The Des Moines stage consists chiefly of shales and sandstones with some limestone and beds of coal and is the productive coal formation in the state. Though well-marked local dips occur, the strata are in general practically horizontal.

UNDERGROUND WATER.

SOURCES.

The water supply of Clarke county is obtained chiefly from shallow wells in the drift, which are in general satisfactory for domestic and stock use but are inadequate for public supplies.

Two important water horizons occur in the drift, one in the sand immediately underlying the loess, locally known as first sheet-water, and the other in the sand and gravel beneath the Kansan, locally known as second sheet-water. In some localities other water-bearing sands and gravels are found higher within the drift, but the water is likely to be so polluted with decayed vegetable matter as to have a disagreeable taste and odor.

On the lower ground in the county water is obtained as a rule from shallow wells dug and bored to the first horizon, though many of the stock-farm wells reach the second. On upland divides the water from the first horizon, though fairly satisfactory in quality, often fails in dry seasons owing to the general lowering of the ground-water level. The depth at which it is reached ranges from 10 to 40 feet, depending on the thickness of the loess. Where sufficient water is not obtained from the subloessial sand, wells are bored or drilled to the sand and gravel just beneath the drift, which horizon may be within 50 feet of the surface or may not be within 250 feet; the supply, however, seldom fails.

Water from this deeper sand and gravel is obtained on the farm of Adam C. Rarick (SE. 1/4 sec. 18, T. 72 N., R. 26 W.) from a well 163 feet deep in which the water level is but 16 feet below the surface. The water is hard and slightly mineral.

Local failures to find water in the drift have resulted in the sinking of a few wells into the bedrock. Those reported range in depth from 250 to 300 feet, and probably draw supplies from the limestone of the Missouri stage. The water is said to be very satisfactory for stock, but the data are insufficient to warrant very definite conclusions as to the general value of this limestone as an aquifer. From evidence obtained in the surrounding counties, however, it is known to be generally unsatisfactory on account of hardness of the water and its meager quantity. One of the deepest and best wells of this type is that of Louis A. Brown, three miles northeast of Murray (SE. 1/4 sec. 35, T. 73 N., R. 27 W.). This well is 298 feet deep, enters rock at a depth of 189 feet, and draws its chief supply from the limestone of the Missouri stage at a depth of 260 feet. The water is hard and stands 80 feet from the surface. R. Arnold, seven miles southwest of Murray, failing to find a satisfactory supply of water by digging 90 feet, drilled 340 feet to water; and John Diehl, 4½ miles northeast of Osceola, drilled 320 feet to find water. Drilled wells are more common in the west-central part of the county.

SPRINGS.

In the more hilly portions of the county many good stock springs are found on steeper slopes, where the sand and gravel layers of the drift outcrop. Shallow wells dug on hillsides tap similar strata and are made to flow into cattle troughs by means of pipes let into the lower side a few feet below the surface. For a fuller discussion see Lucas county, p 953.

CITY AND VILLAGE SUPPLIES.

Murray.—Murray (population, 796) has no public system of water supply. Fire protection is afforded by a half dozen open wells 30 feet deep, pumped by hand.

Osceola.—The public supply of Osceola (population, 2,416) is secured from an artificial reservoir, 2.72 acres in area, which collects the surface drainage of 280 acres of pasture land. A triplex pump (capacity 250 gallons a minute) raises the water from the intake well to a 60,000-gallon tank elevated on a 90-foot tower. The water is distributed by gravity through about four miles of mains to 27 fire hydrants and 50 taps. In case of fire direct pressure of 120 pounds may be applied by pumping. The average consumption is 10,000 gallons daily, sold at rates ranging from 35 to 20 cents a thousand gallons, according to the amount used. The Osceola Light, Heat, & Power Company, which pumps the water, finds it satisfactory for use in boilers. It is customary to treat it with a small quantity of kerosene. The city system is connected with the Chicago, Burlington & Quincy Railroad tank, so that in case of emergency either system may supply the other.

Sediment is removed from the water by a mechanical filter. The supply is sufficient to meet all demands and is fairly satisfactory.

Unfortunately information regarding the underground-water supply in this county is exceedingly meager. A well is said to have been sunk at Osceola to a depth of 1,953 feet, diameter eight to four inches; but no further information was obtainable.

WELL DATA.

The following table gives data of typical wells in Clarke county:

Typical wells in Clarke County.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks
		Feet	Feet		Feet	
A. C. Rarick	SE. ¼ sec. 18, T. 72 N., R. 26 W.	163	------	Drift sand	16	Hard and slightly mineral.
William Beebe	SE. ¼ sec. 29, T. 71 N., R. 27 W.	250	250	Sand above bed rock.	100	
L. A. Brown	SE. ¼ sec. 35, T. 73 N., R. 27 W.	298	189	Limestone	80	Water bed at 260 feet.

DECATUR COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY.

The upland level in Decatur county lies 1,100 to 1,200 feet above sea level, and is cut by numerous southward-trending stream valleys into parallel ridges and trenches that must be crossed by east-west railways and wagon roads. The principal stream, Grand river, occupies a broad flat-bottomed vallay 200 feet below the flat-topped ridges and plateaus.

GEOLOGY.

Beneath the uplands and, to some extent, beneath the valley sides, is a thin but widespread deposit consisting of loess and related gray-blue plastic clay, in some places partly oxidized to yellow. This plastic clay is nearly free from grit but includes locally some tiny pebbles, as can be seen in the railway cut at Lamoni. In fineness of grain and imperviousness to water it differs sufficiently from the typical loess to influence profoundly the agricultural value of the land. Over the wide flood plains of the principal streams the surface formation consists of alluvium.

Next below the loess and clay, or in many localities lying at the surface, is an accumulation of bowlder clay with minor amounts of sand and gravel. The bowlder clay is weathered and yellow at the top, but is darker, more compact, and quite unweathered at some distance below the surface. The upper part is Kansan in age, but there is reason to believe[1] that the basal deposits belong to an older drift sheet. Beneath the uplands the average thickness of the drift and associated material is probably not far from 200 feet, but in many places the streams have cut through to the bedrock.

The rocks upon which the drift rests belong to the Pennsylvanian series of the Carboniferous. Throughout most of the area the upper rock is predominantly a limestone, well exposed in the quarry 1½ miles southwest of Davis City; it marks the base of the Missouri stage of the Pennsylvanian and overlies the Des Moines stage of the same series. The latter consists of several hundred feet of strata that are predominantly shale, though they include numerous thin beds of sandstone, limestone, and coal, with heavy beds of sandstone near the bottom. Shales belonging to the Des Moines stage outcrop in the valleys in the southern part of the county. The sandstone near the bottom of the Des Moines stage is shown in the lower part of the section of the Biggs or Hazlett well (p. 949). Its occurence is noteworthy, as no sandstone corresponding to it has been reported in the counties directly east. A higher bed of sandstone was penetrated in the Sharp boring at Leon.

[1]Bain, H. F., Geology of Decatur County: Ann. Rept. Iowa Geol. Survey, Vol. 8, 1897, pp. 283-292.

Section of Sharp prospect hole at Leon.

(NW.¼ NE.¼ sec. 32, T. 69 N., R. 25 W.)

[Altitude of surface, about 1,050 feet.]

	Thickne	Depth
	Feet	Feet
Bowlder clay	23	23
Sand (dry)	3	26
Glacial drift	274	300
Sand (with water)	5	305
Shale	34	339
Limestone or calcareous shale	2	341
Shale	41	382
Sandstone, fine-grained	7	389
Shale	19	408
Limestone	½	408½
Coal	1 7-12	410
Shale	20½	430½
Coal	1 1-12	431½
Shale	14	445½
Limestone	¾	446
Shale	2	448
Coal	2	450
Shale	22⅔	473
Coal	1½	474½
Shale	2½	477
Limestone	[illegible]	478
Shale	4½	482½
Coal	2¾	485
Shale	8 11-12	494
Limestone	¾	494½
Shale	6	500½
Coal	1 7-12	502
Shale	7½	509½
Sandstone	4⅔	514
Shale	4	518
Coal	1½	519½
Shale	2	521½
Coal	1½	523
Shale	3½	526½
Limestone	2	528½
Shale	2	530½
Sandstone, entered	23⅔	554

A complete description of the drill core of the Sharp boring has been prepared by James H. Lees, Assistant State Geologist of Iowa, and is published in Iowa Geol. Survey. Vol. XIX, pages 247 to 251.

UNDERGROUND WATER.

SOURCES.

In Decatur county water is obtained from (1) the alluvium, (2) the upper layer of the glacial drift, and (3) sand beds at the base of the drift or incorporated between deposits of bowlder clay. Reliance is placed chiefly on shallow dug or bored wells which end near the contact of the loesslike clay with the oxidized bowlder clay or which penetrate the latter, ending if possible in a gravelly zone. The extent to which the surficial water table follows the irregularities of the surface is remarkable. Thus, for instance, in ascending a hillside at Leon one may find a succession of shallow wells, each with water near the surface and with the water level differing notably within the space of a few rods. This condition is also illustrated by the fact that in some places artificial springs are made by projecting an iron pipe horizontally from the bottom of a hillside well to the surface farther down the slope. It is obvious that the steep gradients of the water table are correlated with imperfect porosity of the water-bearing material and small yields of the wells. The shallow water is moderately hard but otherwise good, except that in many places it is obviously exposed to pollution, some hillside wells, especially in villages, being so located that they must receive the direct seepage from privies on higher ground and not many yards distant.

Altogether a number of wells have been drilled to the lower part of the drift and beds of sand have generally been encountered, but it seems that the water from these is likely to be meager in quantity and poor in quality, though further prospecting might develop more favorable results.

The water-bearing strata in the Pennsylvanian series are for the most part so thin and imperfectly porous that their yield is small. The water is rich in sulphates, which give it a certain medicinal value as a laxative, but make it undesirable for general household use and also cause foaming in boilers, especially in locomotives. In hardness and scale-forming properties it differs widely, the water from some wells being relatively soft.

In the valley of Pot Hole Branch (sec. 29, T. 68 N., R. 26 W.), where Pennsylvanian strata are at the surface, a six-inch well was drilled through limestone, shale, and a little sandstone, etc., to a depth of 118 feet, where a porous seam was pierced, from which mineralized water with a laxative effect issued and rose to a level 30 or 40 feet below the surface.

Two miles south of the state line, near the southeast corner of the county (NW. 1/4 sec. 1, T. 66 N., R. 24 W.), in a valley bottom whose altitude is about 672 feet above the sea, a feeble flow was obtained by drilling into Pennsylvanian strata to a bed of quicksand at the depth of 153 feet. The water is rich in sodium sulphate and is used for medicinal purposes. Several other wells in this locality are of the same character except that they have never overflowed.[1]

It is evident from the above that the water from different seams does not rise to an accordant level and that there is a possibility of striking a flow in any deep valley. However, such flows are invariably weak and of very little, if any, practical value.

By expensive drilling, deeply buried water-bearing formations can be tapped, but the water is likely to have a low head and to be of bad mineral quality.

With present prospects, deep drilling can hardly be recommended, yet, on the other hand, run-off waters stored in surface reservoirs must be regarded as far from satisfactory and the condition of the private wells is most insanitary. Preliminary to installing water-works, every municipality can afford to explore the resources of the drift and other unconsolidated deposits above the bedrock, and it seems probable that if right methods are pursued enough water can in most places be secured from such a source. If no bed of sand that will furnish enough water of reasonably good mineral quality is found in the deeper parts of the drift, then it may be possible to develop a sufficient supply from the shallower parts of the drift. It is seldom advisable to dig a single well of great diameter. If, instead, smaller holes are bored at proper distances apart, the excavation of a given amount of earth will result in a much larger infiltrating surface, and the expenditure of a given amount of money ought to result in a larger supply. Moreover, such a system is elastic, for the number of bored wells can be increased indefinitely and the contributing area can thus be enlarged until the requisite amount of water is secured. It is not generally understood that any number of bored wells can, without difficulty or great expense, be connected at the

[1]Shepard, E. M., Underground Waters of Missouri: Water Supply Paper No. 195, U. S. Geol. Survey, 1907, p. 68.

bottom by horizontal iron pipes so that one pump can draw from all of the wells simultaneously. This method of connecting a series of wells could also be employed to much advantage on stock farms.

If the wells are spaced about 25 feet apart and are not less than two feet in diameter they can be connected by boring horizontal holes an inch or two in diameter from the bottom of one well to the bottom of the next, so that the water contributed by all can be lifted by means of a single pump placed in any one of the wells. These horizontal holes can be bored most conveniently with an auger consisting of detachable links which can be added as the boring progresses. The links should be attached to each other like the links of the chains used in pipe tongs, so that the auger can be withdrawn without disconnecting them. The horizontal holes should be provided with iron pipes, to make sure that the connections are kept open; but if these pipes are small enough to fit loosely the seepage on the outside of them will, in some wells, add materially to the total yield.

CITY AND VILLAGE SUPPLIES.

Lamoni.—At Lamoni (population, 541) a system of waterworks has recently been installed. The water is obtained from a reservoir which holds the run-off from a ravine west of the town and has a capacity of 3,500,000 gallons. The water is pumped into a tank elevated on a steel tower and is distributed by gravity through about three and one-fourth miles of mains, tapped by 29 fire hydrants and about 20 service pipes.

In the town two holes have been drilled into Pennsylvanian strata. The well of C. Brown was sunk near the railway bridge, where the surface is about 1,110 feet above the sea. It is five and one-half inches in diameter and 300 feet deep. The drill passed through yellow and blue clay to about 150 feet, where a two-foot bed of sand was found that contained some water; it then penetrated light colored limestone and dark shale and sandstone, with three feet of red shale at a depth of about 200 feet. The well ends in limestone from which a small amount of water rises to the surface and trickles over the rim of the casing. The other drill hole was a coal prospect and is located on higher ground. It was carried to a depth of 425 feet and revealed a similar stratigraphic section.

Leon.—At Leon (population 1,991) the electric light plant obtains one of the best water supplies in the county from three open wells located in a small valley at the east margin of the town. Two of the wells are six feet and the other is ten feet in diameter; all are cased with brick and go to a depth of about 40 feet. The water is reported to stand 12 to 25 feet below the surface, according to the season. In an ordinary day the pump is operated for about 2½ hours, in which time approximately 7,000 gallons are drawn from the wells and the water level is thereby temporarily lowered less than ten feet. The wells have been in use for a number of years and are reported never to have failed. The water is tolerably satisfactory for boiler feed, though it forms some scale.

One well and several coal prospects at Leon have been sunk into the Pennsylvanian strata.

The well was drilled for William Biggs in 1902 at a point a few rods west of the city square. It is 803 feet deep and is cased with 350 feet of 4½-inch, 152 feet of 3½-inch, and 210 feet of 2¾-inch pipe. The curb is 1,120 feet above sea level. Water was found in sandstone at a depth of 700 feet. No other water was reported. The normal water level is 340 feet below the surface or approximately 780 feet above sea level. With the suction pipe extending 36 feet below water level the yield is not sufficient to supply the pump, somewhat less than 40 gallons a minute having been reported. In 1906 Mr. Biggs reported the yield to be 15 gallons per minute. The analysis (p. 201) shows that the water is only moderately hard but that it contains sufficient sodium and the sulphates to render it mildly laxative and give it some reputation as a medicinal water. The water is said to be more or less roily at all times. The driller's log follows:

Driller's log of Biggs or Hazlett well at Leon.

	Thickness	Depth
	Feet	Feet
Clay, yellow	55	55
Clay, blue and stone	80	135
Limestone	5	140
Clay, yellow	23	163
Clay, blue	22	185
Sand	1	186
Clay, blue	40	226
Gravel	14	240
Clay, blue	25	265
Limestone, blue	2	267
Clay, blue	20	287
Clay and gravel	6	293
Clay, blue	40	333
Limestone	2	335
Coal	2	337
Soapstone	7	344
Blue stone	10	354
Blue soapstone	23	377
Coal	1	378
White soapstone	62	440
Limestone	4	444
Slate, black	6	450
Hard soapstone	20	470
Slate, black	1	471
Coal	4	475
Soapstone, blue	33	508
Limestone, white	7	515
Soapstone, white	6	521
Soapstone, hard, white	44	565
Coal	4	569
Soapstone, blue	66	635
Sandstone, white	158	793
Unknown	10	803

LUCAS COUNTY.

BY HOWARD E. SIMPSON.

TOPOGRAPHY.

Lucas county lies on the eastern slope of the high plain which forms the divide between Mississippi and Missouri rivers. The area as a whole slopes gently eastward, but there is a slight slope both northward and southward from Chariton, the highest point on the divide in Lucas county. From this vicinity Whitebreast and Cedar creeks flow northward through Marion county into the Des Moines, and Chariton river, approaching from the southwest, bends away southeastward and thence toward the Missouri.

The entire area is part of a drift plain whose flat and almost level surface has been cut by a few broad stream valleys and an innumerable network of smaller ones until every portion of the region is well drained. The divides are broad and flat-topped, and pass gradually into the gently rolling hills which border the valleys.

GEOLOGY.

In the broad bottom lands along the Chariton river and Whitebreast and Cedar creeks the alluvial deposits of sand and gravel alternating with silt and mud are many feet in depth.

Over the uplands and extending well down into the valleys lies a mantle of the fine yellow clay called loess. Beneath this and covering the entire county lies the Kansan drift, a bowlder clay containing pebbles of all sizes and shapes, many of which are granite or dark red quartzite. The maximum depth encountered in any of the coal prospect drillings of the Inland Coal Company was near the center of section 1, Lincoln township (T. 72 N., R. 21 W.) at an elevation of 1,017 feet above sea level. The section here is not only remarkable for depth but for the amount of sand contained.

Log of coal prospect hole in section 1, Lincoln Township.

	Thickness	Depth
	Feet	Feet
Soil and loess	18	18
Till (Kansan)	42	60
Sand	74	134
Sand, with bands of blue clay	14	148

The bedrock immediately underlying the drift of the entire county belongs to the Pennsylvanian series of the Carboniferous (Pl. XVI, p. 814) and, with the exception of an irregular strip averaging less than a mile in width along the western border, to the Des Moines stage. The Des Moines stage consists chiefly of shales, sandstones, and a few limestones and coal seams. This narrow western margin is slightly overlapped by the rocks belonging to the Missouri stage, in which limestone and shale predominate.

The sandstone of the Saint Louis limestone, which constitutes so important an aquifer in the counties to the east as to be known as the "white water sand rock," is not utilized in Lucas county. The top of the upper limestone of the Saint Louis, which immediately overlies the sandstone of that terrane, is reported to be about 350 feet beneath the surface. In NW. ¼ sec. 15, Liberty township (T. 73, R. 22) the Inland Coal Company gives the following section, the surface being 832 feet above sea level:

Log of coal prospect hole in Liberty Township.

	Thickness	Depth
	Feet	Feet
Drift	20	20
Des Moines stage	198	218
Limestone	46	264
Sandstone	42	306

SURFACE WATERS.

The large streams of Lucas county afford a permanent supply of running water which is not only economical but good for stock. The springs along the margin of the "bottoms" and in the broken lands in the vicinity of the larger streams are greatly valued by the stock farmers.

On many stock farms where running water is not available a dam is built across a small ravine, behind which storm water collects and usually remains throughout the summer, as the drift forms an impervious bottom and prevents rapid drainage. The water thus impounded is, however, very unsatisfactory, and the condition of such stock ponds toward the close of a warm, dry summer may be better imagined than described. Such water is suitable for use only in boilers, and for this purpurpose it is probably the least objectionable that can be obtained in this region.

UNDERGROUND WATERS.

SOURCES.

Alluvial bottoms of Chariton river and Whitebreast and Cedar creeks afford frequent shallow wells for many stock pastures. The newer public supply at Chariton is derived from this source.

Most of the wells of the county are shallow and draw their water from sandy lenses irregularly distributed through the drift or from the sand and gravel deposit commonly found at the base of the drift. The remarkable sand layer noted in the section given on page 950 seems fairly persistent between the Kansan till and the blue clay below (possibly the Nebraskan drift); at other points in the eastern part of the county it is said to be 40 feet thick and to supply some large and permanent springs.

Except on the upland divides wells in the drift yield water that is satisfactory both in quantity and quality for ordinary demands for stock and domestic uses.

Few wells in the county enter bedrock and none are known to pass through the Coal Measures, but the many coal prospect holes afford sufficient evidence of the quantity and quality of the contained waters. Beds of sandstone and sandy shale occur irregularly in the shales of the Des Moines stage, and though many of these sandstone beds are reported dry, some are so heavily water bearing as to interfere seriously with mining operations.

Concerning mine waters in the western part of the county Mr. Verner, formerly State Mine Inspector, says:

> Mine waters in this part of the state come from the surface or from sandstone lying over a shale roof covering coal. This shale runs from nothing to 70 feet in thickness, and when it is thick it permits little water to percolate through. When this roof shale is thin, the mines are, as a rule, very wet and it is difficult to keep the roof from falling, and it may be necessary to abandon the mine.
>
> Some mine waters are so strongly charged with hydrogen sulphide as to be unfit for general use. Shaft waters are not good for steam making, for they pit and corrode the boilers rapidly, and as the waters of the drift wells are generally too hard, the boilers of many of the mining plants are supplied with impounded storm waters.

The sandstone of the Saint Louis limestone, which in this county may be reached at depths of 400 to 600 feet, would probably produce moderate quantities of pure and wholesome hard water provided the water from the overlying Des Moines stage were thoroughly cased out.

The depth and arrangement of the drift and the sandstone layers of the Des Moines stage that might be water bearing are indicated by the following driller's log of a coal prospect hole drilled by the Inland Coal Company. The hole is located on Chariton river bottoms a little northeast of the southwest corner of sec. 30, T. 72 N., R. 21 W.

Log of coal prospect hole near Chariton.

[Elevation of mouth above sea level, 971.95 feet.]

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Soil	7	0	7	0
Clay, yellow	7	0	14	0
Clay, dark	6	0	20	0
Sand	2	0	22	0
Clay, black	18	0	40	0
Sand	5	0	45	0
Clay, black	30	0	75	0
Sand	3	0	78	0
Shale, soft, dark blue	9	0	87	0
Shale, gray	17	0	104	0
Shale, green	4	0	108	0
Shale, dark	3	0	111	0
Coal	0	11	111	11
Clay, fine	3	1	115	0
Shale, light	2	0	117	0
Limestone, red	1	8	118	8
Shale, light	4	4	123	0
Limestone	1	0	124	0
Sandstone	20	0	144	0
Sandstone, soft	27	0	171	0
Bowlder	2	0	173	0
Coal		1	173	1
Shale, black	7	0	180	1
Shale, soft, light	3	10	183	11
			183	11

SPRINGS.

Many excellent springs emerge from heavy beds of sand and gravel of the drift outcropping on the sides of the valleys in Lucas county. They are as a rule very constant in flow and are of great value on stock farms, as they yield streams of pure water, cool in summer and warm in winter, sufficient for 500 to 1,000 head of cattle, without expense of time, labor, or money except the initial cost of walling up and piping to a suitable tank. A spring on the farm owned by Hanna Kent, three miles west of Lucas, is typical. This spring flows in a good, strong stream from an outcropping layer of sand at the bottom of a hill. On the J. M. Taylor farm, 3¼ miles north of Derby, a spring of excellent water is located on the "old Mormon trace road", so called because the locality was used by the Mormons in their western migration as a camping ground on account of the "plenteous water." The "Black Spring," owned by Mr. George Johnson, five miles northeast of Russell, flows a perennial stream of clear, hard water.

CITY AND VILLAGE SUPPLIES.

Chariton.—The public water supply of Chariton (population, 3,794) is drawn from shallow wells in the alluvial gravels and sands underneath the bottom lands along the Chariton river about two miles south of the city and about 89 feet below the level uplands. The water is pumped into an elevated tank in the city and supplies seven miles of mains leading to 60 fire hydrants with water under about 50 pounds pressure. This normal pressure is supplemented by a steamer service for fire protection.

The Chicago, Burlington & Quincy Railroad formerly obtained water for engines, roundhouses, and shops by a dam across a branch of Chariton river immediately west of the city, supplemented by two wells 12 feet in diameter and 30 feet deep. The better well yielded 35,000 gallons of water daily. The water was a good boiler water for this region, but the reservoir was unsatisfactory on account of the tendency of the river to flood in spring and to go dry in summer.

Recently the company constructed a new reservoir a short distance farther west of the city, by damming a small stream fed by permanent springs. The dam is 30 feet high in the middle and the resulting pond is 1¼ miles long. Abundant supply of satisfactory boiler water is secured.

The deepest well reported at Chariton, that at the Electric Light Company plant, is 70 feet deep; little water is obtained below 33 feet, and that little is very hard.

Derby.—At Derby (population, 326) bored wells 10 to 60 feet deep, averaging 33 feet, are commonly used, as they furnish a good supply of water which rises within a few feet of the surface. There are several fine springs in the neighborhood.

Lucas.—At Lucas (population, 666) water is obtained from drift wells ranging in depth from 15 to 50 feet.

Russell.—Wells at and about Russell (population, 612) are shallow, averaging about 30 feet. The city well, 6 feet in diameter and 30 feet deep, is used by the public for drinking and for teams. A well 9 feet in diameter and 31 feet deep, and two cisterns 10 by 12 feet, constitute the supply for fire protection. The water is pumped directly by a gasoline fire engine. The city well yielded 120 gallons per hour when dug.

A composite well section in and about Russell, showing fairly persistent gravel layers, is as follows:

Composite well section near Russell.

	Thickness in feet.
Soil and loess	8 to 20
Subloessial sand; scanty water.	
Yellow till (Kansan)	9 to 30
Gravel at base of Kansan till; water bearing.	
Clay, blue	10 to 60
Coarse sand and gravel; much water.	
Coal shales.	

WELL DATA.

The following table gives data of typical wells in Lucas county:

Typical wells of Lucas County.

Owner	Location	Depth	Depth to rock	Source of supply	Remarks: (Logs given in feet)
T. 72 N., R. 21 W. (Lincoln).					
		Feet	Feet		
A. Culbertson	NE. ¼ sec. 18	342	94	Drift sand; sandstone (Des Moines).	Clay, 10; sand and gravel, 84; Coal Measures, 248.
D. G. Bennett	SE. ¼ sec. 24	304	70	Drift sand	Loess, 10; drift, 60; Coal Measures, 234.
J. A. Slattengren	SW. ¼ sec. 23	324	65	do	Clay, 50; sand, 15; Coal Measures, 259.
L. C. Whitten	NE. ¼ sec. 13	131	17	Sandstone (Des Moines).	Drift, 17; Coal Measures, 114.
J. M. Cowan	NW. ¼ sec. 8	174	22	Drift sand	Clay, 11; sand, 11; Coal Measures, 152.
C. G. Erickson	NE. ¼ sec. 2	148	21	Sandstone (Des Moines).	Clay, 18; sand, 3; Coal Measures (with 45 feet of sandstone at base), 127.

MADISON COUNTY.

BY HOWARD E. SIMPSON.

TOPOGRAPHY.

Madison county is on the eastern slope of the divide between Mississippi and Missouri rivers. On the whole the area is a maturely dissected drift plain sloping gently to the northeast, in which direction the principal streams, North river, Middle river, Clanton creek, and South river, flow toward Des Moines river. The southwest corner of the county is drained by Grand river, which flows southward toward the Missouri.

In the western and southern parts of the county the relief is very slight; in the northeast part the flat-topped uplands are trenched 100 to 300 feet by deep broad valleys with abrupt sides.

GEOLOGY.

The loess, a whitish buff clay, free from gravel, covers all uplands in Madison county and extends well down the slopes into all the larger valleys. This deposit is not so thick as it is in the counties to the south and east. The Kansan drift underlies the entire county except where eroded away from some of the steeper valley sides. In its upper parts much woody and vegetable matter is found and in some places gas has been reported. These facts suggest that the deeper sand is an interglacial gravel of Aftonian age.

The drift in the western and southern portions of the county rests directly upon the Missouri stage, here represented by some heavy beds of limestone with shale. The limestone of the Missouri stage is much altered above and the well sections frequently show a few feet of geest, or residual soil, between the drift and the unaltered limestone. In the northeastern portion the drift rests upon the Des Moines stage, which consists chiefly of shales and sandstones with some limestones and coal seams.

All the formations are nearly horizontal except for slight local dips.

UNDERGROUND WATER.

SOURCE AND DISTRIBUTION.

Sandy layers within and at the base of the loess yield small quantities of water to wells, few of which exceed 30 feet in depth. The loess is extensively used except on the uplands where it has been found very unsatisfactory owing to the serious diminution and frequent failure of its water supply in dry seasons. The upper sand bed and loess is dry in "ridgy" ground except in the middle of ridges.

The water-bearing sands and gravels beneath the Kansan drift form the chief source of water supply for the county and are tapped at depths ranging from 20 to 200 feet. Locally, water may be obtained by sandy layers within the Kansan drift.

In the uplands about St. Charles water is found in the Kansan by wells about 30 feet deep, and in deeper drift sands overlying blue clay practically free from pebbles at depths ranging from 50 to 60 feet.

In view of the importance of the drift waters in Madison county a composite section on the uplands about Winterset is of interest.

Composite section on upland near Winterset.

	Thickness in feet.
Soil and yellow loess, dry	10-17
Loess, blue-gray, water bearing	3-10
Sand, water bearing	2
Till, yellow; some sand beds and pockets, the latter usually water bearing	10-30
Till, blue, variable and often wanting; water very scarce	40
Clay, light blue; much sand and gravel and many bowlders; generally much water immediately over bedrock	1-3

The surface of the uplands underlain by limestone of the Missouri stage is so nearly level that, though the drift is but a few feet thick, few wells penetrate to rock. An abundance of good water is found in the limestone or in sandy layers at the base of the loess. Ground-water level is so high that water stands near the surface in the shallow dug wells or overflows as in the 13-foot well on R. A. Lenscher's farm (SE. 1/4 sec. 19, T. 77 N., R. 29 W.). An excellent type of the deeper drift well in this vicinity is that of J. M. Hochstetter (SE. 1/4 sec. 29, T. 77 N., R. 29 W.), a 50-foot well to sub-Kansan sands, which yields an abundance of fine water, with head 15 feet from the surface. An interesting result of the ease with which water is obtained in this region is noted in the absence of windmills over the farm wells. Such conditions are found in the vicinity of Earlham and the region southwest.

On the higher divides about Macksburg the loess is generally dry and the wells are bored to depths of 20 to 60 feet, many of them drawing their supply from the gravels beneath the Kansan. Not uncommonly the higher farms find serious difficulty in obtaining a full supply.

In the broad belt of broken ground lying east of Earlham, Winterset, and Barney, the stream valleys are cut through to the soft shales and the uplands between are capped with the limestone. Here the loess and upper sands are well drained except in the middle of the broad divides, and wells are sunk to the sands at the base of the drift. The many outcrops of limestone in the sides of the valleys suggest why even these are dry in some localities. On the farm of G. W. Bowles (SW. 1/4 sec. 20, T. 74 N., R. 27 W.) five dry holes, ranging in depth from 75 to 170 feet, were sunk; and on that of Jesse Roberts, 1½ miles northeast of St. Charles (SE 1/4 sec. 12, T. 75 N., R. 26 W.), 14 dry holes were dug before water was obtained from a valley well 35 feet deep. The aquifer in this well is a sandy layer at the base of the drift and above the shale, as shown by the following section:

Section of Roberts well near St. Charles.

	Thickness	Depth
	Feet	Feet
Clay, yellow	25	25
Sand	3	28
Shale	7	35

The drift sands overlying limestone in the broken region are thoroughly drained, but the water in those over shale is retained.

Few wells in the county completely penetrate the drift. Some of those in the western and southern portions of the county find a good hard water in the second or third heavy limestone beds of the Missouri stage, since these are interbedded with thin layers of clay or shale. In the northeastern portion of the county, where the drift overlies the Des Moines stage, the rock wells are even more uncertain. A few obtain good supplies from sandstone beds, but the water is frequently highly mineralized. One well, that of Finley McDonald (see p. 960), penetrates the entire Coal Measures and draws a fair supply from the Saint Louis limestone at a depth of 799 feet.

SPRINGS.

Strong flowing springs are common along margins and outcrops of the limestone of the Missouri stage, and seepage springs are more or less frequent where drift sands outcrop in broken lands. The former afford valuable supplies of stock water on the margin of the deeper valleys.

CITY AND VILLAGE SUPPLIES.

None of the towns of the county except Winterset have public supplies other than that furnished by shallow dug wells on the main streets, the water being drawn by hand pumps.

Winterset.—At Winterset (population, 2,818) water is obtained chiefly from drift wells ranging in depth from 10 to 100 feet, the supply varying greatly with the season. One of the four wells which supply the Electric Light Company plant may be considered typical. The section is as follows:

Log of Electric Light Company well at Winterset.

	Thickness	Depth
	Feet	Feet
Loam	3	3
Loess, yellow	10	13
Clay, blue	22	35
Sand and gravel	1	36
Till, blue	16	52
Limestone		

Water is found chiefly just over the limestone and is very hard and requires considerable treatment to render it fit for use in boilers. The wells are four feet in diameter and the four yield about 200 barrels daily in the drier seasons.

The prospect of obtaining water from the deeper formations at Winterset is indicated by the record of the Finley McDonald well (NE. 1/4 NE. 1/4 sec. 1, T. 76 N., R. 28 W.), which has a depth of 799 feet and a diameter of 3 1/4 inches. The curb is approximately 1,100 feet above sea level and the head 190 feet below curb. Water was found at 248, 433, 538 (2 1/2 gallons a minute), 630 to 648 (2 3/4 gallons, heading two feet below curb, strong flow in sandstone), and 758 to 770 (strong flow in crevice at 797 feet). The capacity of the well is 300 gallons per hour, lowering 21 feet under 10-hour test.

Driller's log of McDonald well.

	Thickness	Depth
	Feet	Feet
Clay (Pleistocene)	28	28
Limestone (Missouri)	22	50
Shale (Des Moines) of various colors; fire clay, sandstone, limestone, and some coal	562	612
Sandstone	36	648
Shale, white	12	660
Shale, black, bituminous	60	720
Sandstone, hard, flinty	26	746
Sandstone, dark colored	12	758
Sandstone, white (base of Des Moines)	12	770
Limestone, white, hard, cherty (Mississippian)	29	799

WELL DATA.

The following table gives data of typical wells in Madison county.

Typical wells of Madison County.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
T. 76 N., R. 26 W. (Crawford).						
		Feet	Feet		Feet	
Peter Cunningham	2 miles north of Patterson.	103	64	Sand, at base of drift.	------	Abandoned; insufficient.

Typical wells in Madison County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
T. 75 N., R. 29 W. (Webster).		Feet	Feet		Feet	
T. D. Peterman	NW.¼ sec. 5	301	115	Sandstone (Des Moines); limestone (Missouri).	------	Drift, 115; Missouri, 148; Des Moines, 38. All waters only 1½ gallons per minute. Mineral.
T. 75 N., R. 28 W. (Lincoln).						
Dave McCleary	5 miles southwest of Winterset.	577	100	Sandstone (Des Moines).	260	Drift, 100; Missouri, 56; Des Moines, 421. A weak well. Mineral.
T. 76 N., R. 28 W. (Douglas).						
Finley McDonald	NE.¼ sec. 1	799	28	Sandstone (Saint Louis).	190	Mineral. Test 300 gallons per hour for 21 hours. Drift, 28; Missouri, 22; Des Moines, 720; Saint Louis, 29.
T. 76 N., R. 29 W. (Jackson).						
Dave Ford	NE. ¼ sec. 25	133	21	Missouri	40	Good hard water. Drift, 21; Missouri, 20; Des Moines, 92.
Rush Tate	SW.¼ sec. 13	95	------	do	50	2½ gallons per minute
T. 76 N., R. 27 W. (Union).						
S. A. Foley	3½ miles east of Winterset.	485	27	Des Moines	90	20 barrels per day; insufficient. Drift, 27; Missouri, 27; Des Moines, 431. Abandoned.
T. 74 N., R. 27 W. (Walnut).						
H. W. Tate	SE.¼ sec. 18	113	8	Limestone (Missouri).	75	Excellent well.
H. Hatterbuhr	SW.¼ sec. 20	315	------	do	------	Scant; abandoned.
T. 75 N., R. 26 W. (South).						
Jesse Roberts	SE.¼ sec. 12	185	70	Coal (Des Moines).	------	Unsatisfactory; abandoned.
Flouring mill	St. Charles	114	99	Drift and sandstone (Des Moines).	16	
T. 77 N., R. 27 W. (Jefferson).						
A. D. Fletcher	SE.¼ sec. 36	268	100	Sandstone (Des Moines).	160	Soft water.
T. 77 N., R. 29 W. (Penn).						
J. M. Hochstetter	SE.¼ sec. 29	50	------	Drift sand	15	Abundant and fine.

MARION COUNTY.

BY HOWARD E. SIMPSON AND W. H. NORTON.

TOPOGRAPHY.

Marion county lies slightly southeast of the center of Iowa. The surface is a fair type of the Kansan till plain, approaching a mature stage of dissection. Des Moines and South Skunk rivers, conforming to the general trend of the master streams of the eastern portion of the state, flow southeastward across the northern part of the county, the former draining the major portion of the county through Whitebreast, English, and Cedar creeks, which flow parallel to each other from the southwest and enter the Des Moines almost at right angles. This attitude is probably due to a slope of the plain to the northeast.

The broad upland divides are gently rolling and vary but slightly from 900 feet above sea level; near the main streams the land is somewhat rough and broken. Des Moines and South Skunk rivers and Whitebreast creek have completely developed flood plains with meanders and cut-offs in valleys largely preglacial. All other drainage is probably postglacial, though English and Cedar creeks are also well graded. No morainal depressions or ridges remain to impede the drainage.

GEOLOGY.

The entire county is covered with loess, Kansan drift, and possibly Nebraskan drift, save where the streams have cut through to bedrock or have deposited alluvium on their flood plains.

The bedrock underlying the drift consists chiefly of Carboniferous shale with some beds of sandstone and coal, all of which have been assigned to the Des Moines stage of the Pennsylvanian series. (See Pl. XIII, p. 626.) In the deeper valleys of the eastern portion of the county the drift rests on limestone or, more rarely, on the underlying sandstone of the Saint Louis division of the Mississippian series. Formations below the Carboniferous are not exposed in the county and are known only through deep wells put down at Pella and Flagler.

The Saint Louis strata have a slight southwestern dip and are somewhat irregular, owing to the presence of numerous anticlines and synclines of small extent.

The Des Moines stage rests unconformably upon the Saint Louis limestone and contains many minor unconformities, due probably to contemporaneous erosion between its beds, which dip slightly and thicken toward the southwest. The usual great unconformity exists between the Des Moines stage and the drift.

UNDERGROUND WATER.

SOURCES.

Each of three series, the Pleistocene, the Pennsylvanian, and the Mississippian, furnishes an important source of water supply in Marion county, though all are variable both in quantity and quality.

The chief supply of water in the county is obtained from shallow wells dug in the drift, which is a fairly homogeneous bowlder clay ranging in thickness from 10 to 80 feet, though in few places exceeding 60 feet, and which is found throughout the county. Water lies within 15 to 40 feet of the surface, generally in small sand pockets, veins, or seeps, and almost invariably at the base of the drift where it rests on shale.

The drift water, where uncontaminated, is of good quality and is very generally used for household purposes, since it is easily accessible and comparatively free from mineral matter. It is, however, subject to pollution in the larger towns and near coal mines. Its quantity is generally insufficient except for household use and for small farm supplies. Stock farmers find it inadequate and either dig large open wells into the shale to form reservoirs or drill into the bedrock.

The Coal Measures rocks consist of coal, shale, and sandstone with occasional beds of limestone and conglomerate. Water is usually found in the seams and beds of coal, but this water is never potable owing to the abundance of iron and sulphur compounds in solution. The shales which compose the greater part of the group are comparatively dry and where water is found in them it is so strongly impregnated with mineral matter as to be unfit for use. This is characteristic of almost all waters of the Des Moines stage. Exceptions occur, however, in the case of thick local lenses of sandstone, several of which are found in the county. The best known of these is the channel deposit known as the Red Rock sandstone, which occupies an area of less than 30 square miles in the north-central portion of the county and has a maximum thickness of about 100 feet. Since it lies near the surface and furnishes an abundance of good water no wells go through it, but, owing probably to contemporaneous erosion, it is lacking in many wells where it might reasonably be expected.

Another important water horizon is in many places found at depths of 100 to 200 feet in sandstone lenses some distance above the base of the Des Moines and usually above the coal seams. The rock varies in color from light blue to nearly white and in thickness from 10 to 40 feet, and contains pyrite and ironstone concretions, coal, fossils, and shale bands. The water is usually of good quality for stock though occasionally mineralized. The quantity is satisfactory; no well drawing water from this horizon has been known to fail under ordinary windmill or horsepower pumping, and no severer tests have been reported. Beds at this horizon are on the whole the most satisfactory source of supply for stock farms, quality and quantity both considered.

The third water-bearing bed of the county, known among drillers as the "white water sand rock," is a sandstone immediately underlying a heavy-bedded limestone (the upper bed of the Saint Louis limestone of the Mississippian). It is a white, compact, granular sandstone with numerous flinty layers of cherty limestone from one to three inches in thickness. At many points it is dry above, but at depths of 300 to 350 feet it contains an abundant supply of water for all stock wells. All wells to this sandstone stand windmill and horsepower tests, and several have been pumped with a steam pump with no apparent exhaustion. The water is generally hard and in some places mineralized, but is usually considered good for stock and for domestic uses. The Saint Louis will probably prove the most satisfactory source in the county, but it is not yet much used except in the eastern part, on account of the expense of drilling to the depth at which it lies. Wells to the Saint Louis are reasonably sure of finding good wholesome hard water, which may be utilized in many kinds of manufactures but is unsuitable for boiler purposes on account of the lime carbonate and other minerals it carries in solution.

Only two wells in the county, those at Pella and Flagler, go below the Saint Louis water rock.

DISTRIBUTION.

A few small areas of sand-veneered upland are found in Marion county in which the water supply is so interesting and unusual as to deserve mention. They lie in secs. 1, 11, and 12, T. 77 N., R. 18 W.; secs. 11 and 12, T. 76 N., R. 20 W.; and secs. 10, 15 and 16, T. 75 N., R. 20 W. In all the sand is mixed with loess and has been wind borne to the northeast from the flood plain of a stream near a point where the erosion of thick beds of soft sandstone has been in progress.

A supply of good water may be obtained in shallow wells near the base of the sand stratum, but some difficulty has been experienced on account of clogging of screens. Several permanent hillside springs rise from the same source. Though the quantity is scant and variable the possibitities of obtaining a supply from this source have been demonstrated in the private plant which furnishes water to the town of Eddyville in Wapello county.

Along the bottom lands of Des Moines river and its tributaries are a number of small flowing wells, most of which are prospect holes sunk for coal. Most interesting of these is the 752-foot well drilled by the Whitebreast Fuel Company at Flagler, in the valley of English creek. A flow was obtained at 320 feet, and a stronger one at 626 feet, probably in the Devonian; the water has been used locally for medicinal purposes.

Three artesian wells have been sunk for stock with good success on the Des Moines bottoms south of the river from Dunreath, and about two miles west of Red Rock. One of these, owned by James Worthington, on the line between secs. 3 and 4, T. 76 N., R. 20 W., is about 215 feet deep and is believed to penetrate the Saint Louis, though a slight flow was found in the Coal Measures, which increased to 2½ gallons. The Robinson and Coffin wells are believed to be not so deep. All are slightly mineral, but are good stock wells. Several coal-prospect holes about Swan produced flowing wells, which have now disappeared and become only boggy places, owing to the pulling or rusting out of the casings. All are believed to be 200 to 300 feet deep.

Across the river in Morgan Valley and down toward Dunreath other flowing coal holes have been utilized for stock wells. Another is in sec. 8, T. 77 N., R. 18 W., in South Skunk valley.

Most of the water of Knoxville and vicinity is drawn from shallow wells bored or dug into the drift, where a sufficient quantity for domestic use is found within 15 to 30 feet of the surface. When uncontaminated this is a good source, since it is usually free from the minerals which give an unpleasant taste to most of the waters from the Coal Measures. The water comes chiefly from the sand pockets and small veins characteristic of the drift. The supply is, of course, limited, and is decreasing, requiring the digging of more and deeper wells.

Probably the best source of water in this vicinity, quality and quantity both considered, is the layer or layers of Pennsylvanian sandstone which outcrop extensively in Competine creek valley on the east side of town and also in Whitebreast creek on the west side. This sandstone is the source of good wells on all sides of Knoxville but it seems to die out about three miles west of town; at least it is missed from several wells in that direction.

This sandstone is from 10 to 40 feet thick, light blue to white in color, and bears some concretions or bands of iron sulphide. It is frequently dry above, but near the base at depths of 170 to 210 feet contains water, which rises within 90 to 120 feet of the surface. It is a very good stock water, and many wells drilled for this purpose are also used for domestic purposes and are as a rule very satisfactory. The water is rather hard, but in only a few places is reported mineralized. Wells drawing their supply from this bed are not exhausted by the windmill and horsepower pumps in ordinary use on the stock farms.

Where the sandstone is not found or where its waters are unsatisfactory on account of excess of minerals, the Mississippian "white water sand rock" may be found at depths of 250 to 350 feet, underlying a bed of heavy limestone. This granular white sandstone may also be found dry above, but it contains an abundant supply of water toward the base. Though hard and frequently of strong mineral taste, it is a good stock water.

In coal-prospect holes about Dallas a heavy lens of sandstone is found below coal seams 180 to 220 feet below the upland and 80 to 100 feet below the Whitebreast creek bottoms. This will probably prove a helpful source of supply for farm wells where the shallow wells prove unsatisfactory. As yet, 20 to 40-foot wells in drift are in general use. Near Gosport and Attica coal-prospect holes to a depth of 150 to 200 feet show little sandstone and slight water. A dry well 210 feet deep has been drilled in the northern edge of Attica, but at depths of 250 to 350 feet the sandstone immediately below the upper limestone of the Saint Louis produces some excellent wells. Bored wells, 10 to 40 feet deep are common about Marysville, Bussey, Tracy, and Hamilton, and in the latter place some are flowing. At Harvey 10 to 15 foot sand points are common along Des Moines river and English creek bottoms.

SPRINGS.

Springs, though fairly common in outcrops of Coal Measures along the borders of the chief valleys, are generally so slight in flow as to be of no importance. The cover of the drift forms boggy places rather than springs. Among the best known in the county is one known as the Mineral Springs, located 1½ miles northwest of Hamilton on land owned by M. D. Flanders (sec. 27, T. 74 N., R. 18 W.).

CITY AND VILLAGE SUPPLIES.

Flagler.—The S. C. Johnson well has a depth of 752 feet and a diameter (at top) of 4 inches; casing of iron, cement, and tile to 51 feet. The curb is 745 feet above sea level. Water comes from depths of 320 and 626 feet, discharging at the rate of 1½ gallons per minute.

Record of strata in deep well at Flagler.

	Thickness.	Depth.
Pleistocene:	Feet	Feet
Clay	5	5
Sand	12	17
Carboniferous (Mississippian):		
Undifferentiated		
Limestone	28	45
Shale, sandy	6	51
Sandstone	72	123
Limestone	7	130
Magnesian limestone	13	143
Limestone	10	153
Shale, sandy	7	160
Limestone	25	185
Shale, sandy	6	191
Limestone	3	194
Shale, sandy	4	198
Limestone	93	291
Rock, hard, white	1	292
Limestone	162	454
Kinderhook stage—		
Shale, sandy	72	526
Devonian:		
Limestone	64	590
Shale, sandy	31½	621½
Limestone	65½	687
Do.	65	752

Knoxville.—The public supply of Knoxville (population, 3,190) is owned by the city and is drawn from Whitebreast creek and its underflow at a point about 2½ miles west from the city. The intake is a timbered tunnel cut through shale under the creek bed for a distance of 85 feet and filled in with broken brick. The tunnel drains into a large well 22 feet deep. A Knowles steam pump, capacity 500,000 gallons a day, forces the water through an eight-inch pipe to the city into an open reservoir, the capacity of which is 10,000,000 gallons. An electrically driven Gould triplex pump with a capacity of 1,000,000 gallons pumps the water for general use from the reservoir into a 100-foot standpipe with a capacity of 96,000 gallons. For fire purposes direct pressure is resorted to, a reserve steam pump of 1,000,000 gallons capacity being brought into use. The supply secured in this way is ample for fire protection, but the impurity of the water at the source is such as to render it generally unsatisfactory for domestic use.

Pella.—Near Pella (population, 3,021) the drift is the chief source of supply for domestic purposes, though a number of wells go 200 to 300 feet to the Coal Measures sandstones and a few probably to the lower sandstone, which, however, affords only a scanty supply of highly mineralized water. On the bottoms of both Des Moines and Skunk rivers and their larger tributaries sand points driven a few feet frequently produce quite satisfactory wells.

In 1895-6 the city of Pella drilled an 1,800-foot well. (See Pl. XIII, p. 626.) Water was first found in the drift at a depth of 150 feet and rose within 100 feet of the surface, close to which it has remained ever since, as in other good wells in the vicinity. Other water-bearing beds were found from 1,300 feet to the bottom in the Galena, Platteville, Saint Peter and Oneota formations. The supply from the latter formations was found to be insufficient. Tubing has been put down to a depth of 1,200 feet, but the amount of mineral matter present makes it probable that the water is at least partly from the Coal Measures. Analysis shows that it contains 9,116 parts per million of solids and is so highly mineralized that it is totally unfit for domestic or manufacturing or boiler purposes. The only uses to which it is put are sprinkling the streets and fire protection, for which purpose it is raised by a direct pump operated by a 10-horsepower gasoline engine (capacity 120,000 gallons) to an elevated tank with a capacity of 63,000 gallons. The original pumping capacity was 250 gallons a minute; present capacity, 50 gallons. Date of completion, 1896. Drillers, J. P. Miller & Company of Chicago.

The capacity of the lower water beds was tested by inserting a three-inch pipe with rubber packing at base 126 feet above the bottom of the well; through this pipe but one-half as much water could be drawn as on previous tests. Unfortunately no test of quality seems to have been made of the lower waters when thus separated.

Record of strata in city well at Pella (Pls. VIII, p. 420, XIII, p. 626, XIV, p. 660).

	Thickness	Depth.
Quaternary (135 feet thick; top, 868 feet above sea level):	Feet	Feet
Humus	6	6
Till, yellow, mottled with gray; clay predominant ingredient; ocherous nodules; calcareous	54	60
Till, blue, dense, tough, calcareous	50	110
Sand and gravel; pebbles mostly buff, impure limestone and greenish and black siliceous clay stone; a fragment of coal and one of fossil wood	25	135
Carboniferous:		
Pennsylvanian—		
Des Moines stage (195 feet thick; top, 733 feet above sea level—		
Clay, dark, yellow-gray, sandy; a few small pebbles and fragments of gray unctuous shale	55	190
Sand, very coarse; fragments of gray and black shale	2	192
Gravel, coarse; up to 5 centimeters in diameter; surfaces stained with ferric oxides; in a matrix of black ferruginous clay or shale. Pebbles: greenish black, argillo-siliceous, 22; clay ironstone, 13; flint, 6; limestone, 6; jasper and quartz, 6; sandstone, 2	3	195
Shale, black; gravelly at 235 to 245 feet; fissile and gravelly at 272 feet. Pebbles at 272: Limestone, 9; green argillo-siliceous, 6; flint, 12; red and yellow jasper, 3; 5 samples	90	285
Shale, dark gray	2	287
Shale, hard, black, finely laminated, pebbly; 2 samples	43	330
Mississippian—		
Saint Louis limestone and Osage stage (270 feet thick; top, 538 feet above sea level)—		
Limestone and shale; in bluish gray concreted argillo-calcareous powder; a few minute fragments of light gray limestone, some chalcedony, drusy quartz, and quartz crystals	15	345
Limestone; in fine cream-colored powder	30	375
Limestone and shale; in concreted powder; washing discloses gray limestone sand, discs of crinoid stems, chalcedony, white chert, and particles of hard blue-green shale	25	400
Shale, blue, highly calcareous	5	405
Shale, blue-gray, slightly calcareous	15	420
Shale and limestone; in light blue-gray argillo-calcareous powder; some limestone and chert	30	450
Limestone and shale; in light blue-gray, argillo-calcareous powder; some limestone and chert	10	460
Shale and limestone; in powder as above; some fragments of dark gray flint and a few of limestone	20	480
Limestone (?); highly argillaceous calcareous powder; many chips of blue and gray flint, a few of light yellow-gray limestone, and some of shale	30	510
Limestone; chips of blue and gray flint, drusy quartz, chalcedony, blue shale, and many chips of earthy buff limestone	5	515
Limestone, light yellow-gray; in sand, with argillaceous powder; some chalcedony	85	600
Kinderhook stage (125 feet thick; top, 268 feet above sea level)—		
Shale, green, fissile; some drab	100	700
Shale, green, somewhat calcareous; in molded masses	25	725
Devonian and Silurian (420 feet thick; top, 143 feet above sea level):		
Limestone, nearly white, soft; earthy luster; rapid effervescence	10	735
Limestone; as above, with sand of hard brownish gray magnesian limestone or dolomite	10	745
Limestone, magnesian, light brown, coarsely crystalline, close textured; effervescence slow; a few fragments of selenite noted; residue dark brown, argillaceous; 4 samples	55	800
Limestone, soft; in part chalky; effervescence rapid	20	820
Limestone, light gray-brown, magnesian; some "clod" shale of same color, 2 samples	20	840
Limestone, light gray, crystalline, highly cherty; drillings rusted so as to appear buff in mass	10	850
Limestone, blue-gray; in large flakes	10	860
Limestone, light brown-gray and gray; at 860 a few crystals of selenite; 4 samples	30	890
Marl, gypseous; in gray-white, concreted powder largely of gypsum; some limestone, argillaceous matter, and microscopic crystals of quartz; 2 samples	35	925
Limestone, light gray, mottled with dark drab; in large flaky chips; numerous crystals of selenite	10	935
Dolomite, hard, gray; in chips; 2 samples	20	955
Marl, gypseous, or gypsum; in light yellow, nearly white powder, concreted into tough masses; breaking with smooth, slightly conchoidal fracture; friable with difficulty; in acid does not disaggregate, though slightly calcareous; under the microscope anhydrite is seen to be an important constituent and some pyramidal crystals of quartz are observed	15	970

Record of strata in city well at Pella—Continued.

	Thickness	Depth.
	Feet	Feet
Shale, blue-gray, strongly calcareous; 2 samples	45	1,015
Limestone, magnesian, light brown, crystalline	11	1,026
Limestone and shale; limestone gray, earthy, pyritiferous; shale, light green, fossiliferous	19	1,045
Limestone, magnesian, light brown, crystalline	5	1,050
Limestone, mottled gray, crystalline, highly gypseous	5	1,055
Marl, gypseous; some light gray impure limestone and shale	25	1,080
Marl, gypseous; 4 samples; at 1,110 feet a few thin flakes of limestone	50	1,130
Limestone, magnesian, buff, gypseous	5	1,135
Limestone, earthy, soft, gypseous, light gray, in flaky chips	3	1,138
Dolomite, light blue-gray, hard; irregular fracture, microcrystalline; 2 samples	7	1,145
Ordovician:		
Maquoketa shale (190 feet thick; top, 277 feet below sea level)—		
Shale; green, green-gray, drab, and slightly purplish; slightly calcareous or non-calcareous; hard and fissile; 4 samples	115	1,260
Shale in molded masses, drab, somewhat calcareous; fine dolomitic sand	75	1,335
Galena and Platteville limestones (350 feet thick; top, 467 feet below sea level)—		
Dolomite; gray, crystalline, cherty; in fine sand; 4 samples	90	1,425
Limestone, rather soft; much gray flint and a little brown bituminous shale	10	1,435
Limestone, magnesian; in light buff sand; 2 samples	20	1,455
Limestone, soft, white; effervescence rapid	5	1,460
Limestone, magnesian, yellow-gray	5	1,465
Limestone, light brown, crystalline; effervescence rapid; 2 samples	10	1,475
Limestone, magnesian, buff, crystalline	5	1,480
Dolomite, cream-yellow, buff, and brown, mostly cherty; residue after digestion in acid microscopically arenaceous or quartzose in several samples; chert usually pyritiferous with embedded crystals; 11 samples	113	1,593
Limestone, brown, cherty; some small chips of dark brown bituminous shale; 2 samples	22	1,615
Limestone, magnesian, gray, crystalline, with hard, slaty, blue-green shale	20	1,635
Limestone, magnesian, light buff	15	1,650
Limestone, gray, earthy, crystalline; rapid effervescence; 2 samples	35	1,685
Saint Peter sandstone (15 feet thick; top, 817 feet below sea level)—		
Sandstone, clean, white, quartz sand; 2 samples	15	1,700
Prairie du Chien stage—		
Shakopee dolomite (60 feet penetrated; top, 832 feet below sea level)—		
Dolomite; drillings highly arenaceous, cherty, gray, and buff; 3 samples	40	1,740
Dolomite, buff	20	1,760

Pleasantville.—The entire water supply of Pleasantville, (population, 691) comes from sheets of sand in the drift at a depth of 20 to 35 feet. Two dug wells on the corners of the public square are used for drinking and afford the only means of fire protection. In the country a few stock wells are drilled 200 to 250 feet to sandstone.

WELL DATA.

The following table gives data of typical wells in Marion county:

Typical wells of Marion County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
T. 75 N., R. 21 W. (Franklin).		Feet	Feet		Feet	
J. Watkins	SE.¼ sec. 25	87	75	Des Moines		
T. 74 N., R. 19 W. (Indiana).						
J. Louden	NW.¼ sec. 23	105	30	Des Moines		
Thos. Craig	SE.¼ sec. 6	346	260	Saint Louis		High hill. Highly mineralized and salty. Stock prefer it to stream or pond water.
J. K. Cathcart	NW.¼ sec. 28	320	260	do		
	NW.¼ sec. 11	210		Des Moines		Dry.
Frank Caruthers	SW.¼ NW.¼ sec. 33	155	34	Sandstone Saint Louis		Strong flow, 60 gallons per minute. Soil and clay, 18; sand and clay, 16; soft dark shale, 2; coal, ½; medium soft dark shale, 28½; soft light shale, 7; limestone, 2; soft dark shale, 2; soft light shale with limestone bands, 12; hard limestone, seamy, 2; soft light sandstone heavily water bearing at base, 60; hard limestone, seamy, 5.
T. 74 N., R. 18 W. (Liberty).						
M. D. Flanders	SE.¼ sec. 25	84	12	Des Moines		High ridge.
W. B. Spillman	NW.¼ sec. 29	256	196	Saint Louis		High ridge. Mineral.
T. 76 N., R. 20 W. (Parts of Union and Knoxville).						
Jos. Worthington	NE.¼ sec. 4	215	30	Saint Louis?	+ 18	Just before sand rock occurs a hard, shelly limestone. Flow began in Des Moines and increased in Saint Louis. Slightly mineral.
W. R. Myers	SE.¼ sec. 33	56		Des Moines		Rapid flow 2½ feet from bottom in fine, compact buff sandstone.
David Horsman	Sec. 5	216		do		Dry hole.
Do.	do	191		do		
T. 77 N., R. 20 W. (Red Rock; part of Union).						
S. D. Robinson	NE.¼ sec. 34	172			+ 37	River bottoms. Flow from cavity in rock.

Typical wells of Marion County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
T. 75 N., R. 19 W. (Part of Knoxville).						
Walter Jenkins	SW.¼ sec. 8	171	72	Des Moines	—110	Soft water; river bottoms.
P. M. Stentz	SW.¼ sec. 5	169	16	do	— 80	
E. W. DeWitt	SE.¼ sec. 19	173		Sandstone	— 85	
John Smith	W. ½ sec. 33	253	about 100	Des Moines		
Chas. Bender	E.½ sec. 33	100		do		Good well.
State Inebriate Home.	Knoxville	340	33	Sandstone (Saint Louis).		"Second well."
S. C. Johnston	SW.¼ sec. 2	752	17	Devonian limestone.	+ 10	Mineral artesian.
T. 75 N., R. 20 W. (Part of Knoxville).						
B. M. Long	NE.¼ sec. 18	125	100	Des Moines		
John Fee	NE.¼ sec. 2	175		Sandstone	— 60	
John Bruitt	SW.¼ sec. 29	93		Des Moines		
John Ken	Sec. 14	94		do		Plenty of good water.
T. 76 N., R. 19 W. (Polk; part of Knoxville).						
John Bush	SE. ¼ sec. 31	277		Saint Louis	+ 6	Slightly mineral.
T. 75 N., R. 18 W. (Clay; part of Lake Prairie).						
	2½ miles west of Tracy.	185		do		Soft.
Brick and Tile Co.	Harvey	90	8		— 20	
T. 76 N., R. 21 W. (Pleasant Grove).						
Geo. Erb	4 miles southeast of Pleasantville.	283		Sandstone (Saint Louis).	—150	An excellent well.
T. 76 N., R. 18 W. (Parts of Lake, Prairie and Clay).						
Pella Canning Co.	Pella	250	160			Scant and soft.
Do.	do	300	290	Sandstone	—125	Strong, hard and salt.
Light & Power Co.	do	190		Drift gravel	—100	
Central College	do	299		Sandstone	—150	

MONROE COUNTY.

BY HOWARD E. SIMPSON AND W. H. NORTON.

TOPOGRAPHY.

The topography of Monroe county is of the type characteristic of the mature drift plain in southern Iowa. Being on the upland between Des Moines and Chariton rivers, the most southerly of the many parallel streams of Iowa flowing southeastward to Mississippi and Missouri rivers, the plain is well dissected by streams flowing irregularly out in all directions from the central divide on which the county seat, Albia, is located. The maximum elevation is approximately 1,000 feet above sea level on the divide at the center of the southern border of the county, where the Iowa Central and Wabash railroads enter the county, and the minimum is about 680 feet above sea level where Des Moines river touches the corner of the county at Eddyville. Creeks and smaller streams are sufficiently numerous to give complete drainage, though none are of importance for other purposes. Only the largest, Cedar creek, which truncates the northwest corner, and its tributary, Coal creek, which drains the western half of the county, are mature enough to have the broad well-developed flood plains characteristic of similar streams in Marion and Mahaska counties. Des Moines river has a broad flood plain seven-eighths mile in width and a much broader old preglacial valley which slopes very gradually to the upland level. Its immediate tributaries are so steep as to produce a rather rugged topography throughout the northeastern part of the county. A small and unimportant part of the drainage of the southwestern portion of the county flows into Chariton river.

GEOLOGY.

The surface deposit, except where it is removed by erosion, is loess, which overlies a fairly thick mantle of drift. The drift rests upon the Des Moines stage of the Pennsylvanian series, except over a very small area in the northeast corner, where Des Moines river and its tributaries, Grays and Mill creeks, have cut through to the Saint Louis limestone (Mississippian). The thickness of the Coal Measures (Des Moines stage) is probably 300 feet in the central part of the county, increasing to 400 feet in the southwestern part. The Carboniferous strata dip gently to the southwest and slight local anticlines and synclines are discovered in working for coal. There is a marked unconformity between the Des Moines stage and the Saint Louis limestone.

UNDERGROUND WATER.

SOURCES.

Monroe county draws for water on the alluvium, the Pleistocene drift, the Des Moines stage (Coal Measures), and the Saint Louis limestone. As in other counties underlain almost entirely by the Coal Measures, the waters from shallow or moderately deep wells are variable in quantity and frequently unsatisfactory on account of an unpleasant mineral taste. There are no distinct underground water provinces in the county.

Along Des Moines river in the extreme northeastern corner of the county, lies a belt of alluvium one to two miles wide, and along Coal, Cedar and Avery creeks narrow bands of the same deposit are found, in all of which water may be procured in the sandy or gravelly layers by points driven a few feet into the ground.

In the north-central part of the county near Buxton some wind-blown sand occurs (see p. 965). It is, however, little utilized, and is of importance as a water bearer over only a very small area.

The fine, yellow, clayey silt known as loess veneers all the uplands in depths ranging from a few feet to 30 feet, thinning out along stream valleys. It is so closely associated with the underlying glacial drift that the two are here treated together.

The Kansan drift consists of yellow clay mingled with bowlders, gravel and sand above, passing into a more compact blue bowlder clay below. The upper portion is stained yellow and red by the oxidized iron compounds which have been leached out, and the blue is the unaltered, unoxidized drift. Few places are known in which the drift is over 80 or 100 feet thick, and 70 feet is perhaps a fair average for the county. The drift is thickest in the southwestern part, where few wells penetrate to the rock.

The water which supplies most of the county for domestic purposes is procured from dug or drilled wells a few feet in depth which open sand pockets and small veins in clay. There is, however, below the Kansan till sheet a heavy sand and gravel layer five to twenty feet thick, in places cemented into conglomerate, which rests directly on bed-rock. This somewhat resembles the Aftonian gravel and suggests an older drift.

The Coal Measures (Des Moines stage) are composed chiefly of shales with irregularly bedded sandstones, but in the northern part of the county their upper parts contain coal seams of great economic importance. The shales are of no value as water bearers and even the sandstones, which in places grade into limestones, are so variable, so inclosed in shale, and so permeated with iron sulphate as to be of little value. A few local lenses, however, yield very satisfactory water.

The Saint Louis limestone consists of a compact, even-bedded limestone 20 feet in thickness overlying a coarse heavy-bedded sandstone. The latter, which is known as the "white water sand rock," is seldom used in Monroe county, though it lies only 250 to 350 feet below the surface. No wells in the county go below this. One prospect hole, sunk by the Consolidated Coal Company, is reported to have been driven down to 1,365 feet, but no data concerning it can be secured.

DISTRIBUTION.

Shallow dug and bored wells and drive points penetrating alluvial sands and gravels are common in the valley of Des Moines river and its tributary creeks. On the uplands the sands beneath the loess and the gravels beneath the drift furnish the chief supply. A few wells on the upland south and west of Eddyville penetrate the Coal Measures and procure water at depths ranging down to 220 feet.

At Lovilia, drift wells 20 to 50 feet in depth furnish an abundant supply of water, and water from some bored wells even flows away over the surface. The 50-foot wells draw their supply from the sands and gravels immediately overlying the bedrock sandstone.

Similar conditions prevail in the valleys of Coal and Cedar creeks. On the upland divide, however, as at Weller, a good supply of water is difficult to get, except with a boring machine in low places or in wet seasons. It is probable that good stock wells may be had by drilling 300 or 400 feet as at the place of Mr. M. A. O'Bryan, four miles southeast of Weller, where slightly mineralized water is secured from Coal Measures with a head but 60 feet below the surface.

Underlying most of Albia (T. 72 N., R. 17 W.) and vicinity, and immediately overlying the first vein of coal, is a bed of sandstone 25 to 60 feet in thickness. This is best known in the mining shafts three or four miles west about Tower, where it is so abundantly supplied with water as to seriously interfere with the working of the mines and to compel the closing of some of the shafts. A second sandstone, coarse, gray in color, and 25 to 75 feet thick, lies between the second and third veins of coal. The water-bearing capacity of these lenses is well illustrated in the abandoned shaft on the farm of D. A. Noble (NW. 1/4 sec. 24, T. 72 N., R. 18 W.). The shaft, 113 feet deep and seven by twelve feet across, was filled by water to a depth of 52 feet in 24 hours on cessation of pumping. It is a matter of regret that this supply was not more carefully investigated by the town of Albia before it resorted to surface waters for its public supply.

At about 300 feet the hard, buff limestone of the Saint Louis is reached, and this is immediately underlain by "white water sand rock" 20 to 30 feet in thickness. The latter is said to contain, as usual, a plentiful supply for ordinary wells though it would probably be insufficient for public supplies. One of the few wells reaching this horizon, that of H. K. Runkle, two miles north of Albia (NW. 1/4 sec. 10, T. 72 N., R. 17 W.), is situated on a hill and is 456 feet in depth. At 95 feet the water horizon at the base of the drift was reached; another vein in the base of the Coal Measures was tapped at 350 feet; and the "white water sand rock" was found at 440 feet. The water heads about 40 feet below the surface and is not materially lowered by windmill pumping. It is reported to be a good stock water.

On the uplands back of Melrose, in the southwest, many farm stock wells are drilled to depths of 157 to 200 feet. In a 380-foot well on the farm of William Bernard the Saint Louis limestone was reached at a depth of 340 feet.

At Hocking shallow bored wells a few feet in depth are used; some of them flow. Deeper drift wells on the upland secure water over shale at the base of the drift at depths of 65 to 105 feet. Two miles southwest, on the farm of M. J. McLaughlin, a 250-foot well gives a good flow from Coal Measures sandstone at a depth of 180 feet.

At Foster the drift wells range from 20 to 65 feet. On the upland to the northeast between Brompton and Avery many drift wells 30 to 100 feet in depth have been sunk, and though much sand is encountered they are frequently dry. Artificial ponds are generally used for stock water.

SPRINGS.

Springs are not uncommon in Monroe county and are generally found along the lower slopes of the valleys of the larger creeks, the water coming from the subloessial sands, the sands and gravel underlying the drift, or the outcropping edges of Coal Measures sandstone. They are little used except for stock water, for which they are of value to the farmers, who frequently wall them in and pipe the flow out to a small tank.

The waters of many shallow bored wells on hill sides or slopes of bluffs are led out through pipe or tile a few feet below the surface into a tank placed on lower ground. This type of artificial spring or modified flowing well provides good cool pasture water at slight expense.

CITY AND VILLAGE SUPPLIES.

Albia.—The public supply of Albia (population, 4,969) is taken from an artificial reservoir formed by the damming of a small stream. The ponded water is pumped into a supply tank and distributed by gravity pressure through about six miles of mains to 45 fire hydrants. A steamer is maintained to supply added pressure as needed. The water is not extensively used for domestic purposes.

Owing to the difficulty of procuring satisfactory ground water, cisterns supply many houses with rain water. Dug and bored wells, the only type used in the town, penetrate the drift 18 to 20 feet on the east side and 20 to 40 feet on the west side of the city square. Bedrock of sandstone or shale is reached at 40 to 70 feet.

A type section by Mock Brothers, well borers, is as follows:

Section at Albia.

	Thickness.	Depth.
	Feet	Feet
Clay, gray, (oxidized loess)	16	16
Joint clay, blue (unoxidized loess); including subloessial sands, water bearing	8	24
Water clay, yellow (often with sand layers)	6	30
Clay, blue (Kansan)	25	55

Buxton.—Buxton resorts chiefly to very poor cistern waters. Two wells in the drift 28 to 66 feet deep yield a scant supply. In the dry season of 1901 the people were supplied almost wholly with water brought from Des Moines river in tank cars. An eight-acre storm-water reservoir supplies a poor quality of water for the mining companies, machine shops, and heating plant. At No. 14 shaft, a few miles to the south, the air shaft, 145 feet deep, and the main shaft, 138 feet deep, have no water except a slight amount from drift near the surface. At Hiteman, shafts Nos. 3 and 4 are practically dry.

Melrose.—The location of Melrose (population, 459), in the valley of Cedar creek insures a supply from shallow drift wells 10 to 30 feet in depth. One of 65 feet does not reach bedrock. Springs are quite common, and a few of the wells overflow. The best of this type is perhaps a bored well owned by A. B.

Murray, which strikes a strong flow in gravel at a depth of 17 feet and delivers a constant two-inch stream three feet above the surface. This is used by many of the families of the town for domestic supply. The Chicago, Burlington & Quincy Railroad procures a supply from the creek. A system for fire protection is proposed, and this can no doubt be procured at comparatively small cost from springs or shallow wells.

No. 10 Junction.—The track well of the Chicago & North Western Railway (NW. 1/4 sec. 8, T. 73 N., R. 17 W.) has a depth of 1,345 feet and a diameter of 10 inches to 340 feet, 8 inches to 586 feet, 6 inches to bottom; casing to 195 feet. The curb is 895 feet above sea level. The tested capacity is 80 gallons a minute. The well was completed in 1901 by S. Swanson of Minneapolis.

Driller's log of railway well at No. 10 Junction.

	Thickness.	Depth.
	Feet	Feet
Earth	127	127
Sandstone	7	134
Limestone	87	221
Sandstone	11	232
Limestone	29	261
Shale	14	275
Limestone	312	587
Shale	9	596
Limestone	5	601
Shale	147	748
Limestone	78	826
Shale	52	878
Limestone	93	971
Shale	40	1,011
Limestone	15	1,026
Shale	75	1,301
Sandstone	18	1,319
Shale	11	1,330
Sandstone	15	1,345

The Saint Louis limestone and Osage stage seem to extend to a depth of 587 feet (308 above sea level) and the Kinderhook stage thence to 748 feet (147 feet above sea level). The Devonian and Silurian beneath can not be distinguished in the alternating shales and limestones of the log. The heavy shales from 1,026 to 1,301 feet may be the gypseous marls found in the Silurian of the region; and the sandstones at base, from which the water is probably derived, appear equivalent to the Silurian sandstones of southeastern Iowa.

WELL DATA.

The following table gives data of typical wells in Monroe county:

Typical wells of Monroe County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
T. 72 N., R. 17 W. (Troy).		Feet	Feet		Feet	
Dan O'Hare	SE.¼ sec. 18	180		Sandstone (Des Moines)		Strong.
H. K. Runkle	NW.¼ sec. 10	456	95	Sandstone (Saint Louis)	— 40	Slightly mineral. Water bed at 440.
T. B. Dotts	NW.¼ sec. 16	290				No water.
T. 71 N., R. 19 W. (Jackson).						
Wm. Bernard	SW.¼ sec. 9	380		Sandstone (Saint Louis)		Abandoned on account of lost drill, closing hole.
T. 72 N., R. 19 W. (Wayne).						
M. A. O'Bryan	NW.¼ sec. 2	360	80	Sandstone (Saint Louis)	— 60	Slightly mineral. Drift, 80; Des Moines, 225; limestone (Saint Louis), 45; sandstone (Saint Louis), 10.
James Smith	NE.¼ sec. 22	230	125	Sandstone (Des Moines)	+ 5	Flowing well.
James Foley	SE.¼ sec. 9		125	do		Do.
T. 73 N., R. 17 W. (Bluff Creek).						
James Gray	NE.¼ sec. 26	220		Sandstone (Des Moines)		Abandoned on account of scant yield.
T. 71 N., R. 17 W. (Monroe).						
N. J. McLaughlin	SE.¼ sec. 6	250	180	Sandstone (Des Moines)	+ 2½	Fine flow, 1-inch stream.
T. 73 N., R. 16 W. (Pleasant).						
Grant Cowley	NE.¼ sec. 11	192	188	Sandstone (Des Moines)	+ 15	Strong mineral flow.

RINGGOLD COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY AND GEOLOGY.

The streams of Ringgold county flow southward through deep valleys that are separated by dissected ridges and plateaus whose general altitude is slightly more than 1,200 feet above sea level. The bedrock lies essentially below the valley levels and is mantled with a thick accumulation of glacial and associated materials out of which the valleys have been carved. The glacial drift comprises very dark clay at the bottom (perhaps Nebraskan) and yellow gravelly clay at the top (Kansan) with layers of "hardpan" or beds of sand at intermediate positions (perhaps Aftonian). Widely spread over the yellow gravelly clay is a loesslike deposit, in few places 25 feet thick and averaging much less, which is yellow at the top but ashy blue and plastic at the bottom and which throughout is very nearly free of pebbles and grit. Upon the floors of the valleys a small amount of alluvium has been deposited. The bedrock consists of Upper Carboniferous (Pennsylvanian) strata whose character is indicated in the following section condensed from the driller's log of a drill hole on the farm of Al Dunsmoor, about two miles west of Tingley, on ground intermediate between the upland and valley levels:

Section near Tingley.

	Thickness.	Depth.
	Feet	Feet
Bowlder clay	12	12
Sand	13	25
Clay, blue	20	45
Sand and gravel	2	47
Drift	13	60
Sand	2	62
Clay	7	69
Shale, blue	40	109
Sand	45	154
Shale, sandy	36	190
Sand	5	195
Shale, blue	30	225

Section near Tingley—Continued.

	Thickness	Depth
	Feet	Feet
Potter's clay	9	234
Limestone (water bearing)	9	243
Shale; with 2-foot bed of limestone	19	262
Limestone; with 2-foot bed of shale	20	282
Shale; with 1-inch seam of coal	12	294
Impure limestone	22	316
Shale; with several thin beds of limestone, sandstone, etc.	173	489
Coal	½	489½
Fire clay	3	492½
Shale (black, blue, gray, green, and red)	87	579½
Coal	½	580
Fire clay	4	584
Shale; with thin bed of limestone and sandstone	40½	624½

UNDERGROUND WATER.

SOURCES.

The underground sources of water in Ringgold county can be grouped as (1) alluvium; (2) weathered gravelly clay underlying the ashy plastic clay; (3) sand beds in the deeper parts of the drift or at its base; (4) thin sandstone and limestone strata interbedded with Pennsylvanian shales; (5) basal sandstone of the Pennsylvanian; and (6) lower sandstones and limestones.

In the valleys the alluvium may furnish moderate amounts of fairly good water. Below the undissected upland the weathered gravelly clay contains a certain amount of good but moderately hard water which it contributes slowly to dug or bored wells, but on the ridges and valley sides this material may be dry. The sand beds that occur in places in the deeper parts of the drift generally yield ample and reliable supplies, but unfortunately these beds are not found in all localities. They seem to be best developed in the area west of West Fork of Grand river, where they are tapped by a number of successful wells. Their water is usually good, although rather hard, but some of it is mineralized in much the same way as the subjacent Carboniferous waters. Water-bearing seams of sandstone or limestone are almost invariably found when the drill penetrates the Pennsylvanian strata to any considerable depth, but as a rule they are not an important source of supply, for they yield but little water, and that is full of sulphates and other minerals. Here and there, however, seams are encountered which provide rather large amounts of water of fairly good quality except that it is rich in sodium sulphate and therefore has at least a mild cathartic effect when used for drinking. Very few wells in this county have entered the Pennsylvanian strata. So far as known, the basal sandstone of the Pennsylvanian has nowhere in the county been reached by the drill; something, however, can be inferred as to its occurrence and character as a water-bearing formation from the deep well at Leon, 14 miles east of the Decatur county line, in which it was found between 635 and 793 feet, and from the deep well at Bedford (Taylor county), about an equal distance to the west, in which it was found below 1,180 feet. At Leon the yield is moderate, the head low, and the quality fairly good except for large amounts of sodium sulphate.

CITY AND VILLAGE SUPPLIES.

At present there is no system of public waterworks in the county, a deficiency due no doubt in part to the difficulties of procuring an adequate supply. In view of the results obtained with deep wells in adjacent counties, drilling into the rock formations must be considered of doubtful expediency and should at best be viewed as a last resort, but every village can afford to prospect thoroughly the glacial drift and other unconsolidated deposits above the rock before being content with surface water or seepage from shallow wells. If, however, no satisfactory bed of sand or gravel is found in the drift, it may be possible to develop a sufficient supply by boring a large number of wells into the surficial layer of drift.

SUPPLIES FOR STOCK FARMS.

On most farms plenty of water can be obtained for ordinary purposes, but on some, especially the larger stock farms, the lack of it has been severely felt and much unsuccessful boring and drilling has been done. On farms adjoining the principal valleys supplies can usually be obtained from streams or springs, or from shallow wells in the alluvium. In some upland sections satisfactory supplies are found in deeper parts of the drift, but in others seepage from the upper part of the drift seems to be the only available source of water, and the amount of this seepage is in many places exceedingly small. In the past too much reliance has been placed upon a single shallow well or on isolated wells of this kind. A better method is to bore a series of shallow wells of large diameter close enough together to be connected with pipes at the bottom and thus drawn upon simultaneously by a single pump and windmill. (See p. 947).

On the farm of B. F. Talley (NW. 1/4 sec. 12, T. 69 N., R. 31 W.), about two miles southwest of Diagonal, a well was bored to a depth of 147 feet, passing through 125 feet of drift and 10 or 12 feet of loose yellow sand, and ending in black "sand" which contains pieces of wood, twigs, etc. The water, which is corrosive and apparently impregnated with a small amount of gas, rose within 57 feet of the surface. Other wells of this character were reported in the western part of the county. On the farm of G. W. Bentley, in the same section as the Talley well but on a creek bottom perhaps 65 feet lower, water flows from a hole 88 feet deep. Another flow was obtained on the farm of A. Harris, in the creek valley about two miles east of Benton. This well is only 30 feet deep, but is said to yield copiously.

WELL DATA.

A number of wells a few hundred feet deep, at least some of which enter bedrock, have been reported. Analyses (p. 201) of the water from the wells of L. Myers and Robert Hall, both south of Kellerton, show a large content of mineral matter, especially of sodium sulphate. Approximately at the west margin of sec. 3, T. 68 N., R. 29 W., 2½ miles east of Mount Ayr, in a valley just south of the railway, a hole was at one time sunk into the Pennsylvanian strata for the purpose of prospecting for coal, and a weak flow of water was obtained.

At the village of Diagonal both railway companies maintain locomotive supplies. The Chicago Great Western well is in the valley about 1,088 feet above sea level. It is 12 feet in diameter and 36 feet deep and is walled with stone. Its water level and yield vary somewhat with the season. The records at the pumping station show that it furnishes an average of about 35,000 gallons a day, and that on certain days it is required to furnish as much as 60,000 gallons, which, however, approaches its maximum capacity, especially in dry seasons.

In Mount Ayr a well was at one time sunk for the municipality to a depth of about 300 feet, where a water-bearing bed of sand was discovered. Because of difficulty with the sand or for some other reason, this well was never finished.

UNION COUNTY.

BY HOWARD E. SIMPSON.

TOPOGRAPHY.

Union county lies on that branch of the great divide that separates the southeasterly flowing waters of Grand river from those which flow southwesterly through the branches of Platte and East Nodaway rivers. The crest of the divide runs southward through Spaulding and Creston. At Creston the Chicago, Burlington & Quincy railroad attains an elevation of 1,312 feet, a rise of 261 feet from Afton Junction. By a peculiar adjustment of the drainage lines the entire run-off passes into the Missouri—that of the eastern slope through Grand river and that of the narrower western slope through Platte and East Nodaway rivers.

The surface is a slightly rolling drift plain. Maturity is shown by the absence of ponds and undrained areas, by the completeness of the drainage, and by the presence of the numberless small intermittent tributary streams. On the east, especially about Afton Junction, the plain is more dissected and broken.

GEOLOGY.

The country rock beneath the surface of the county belongs to the Missouri stage of the Pennsylvanian series, and consists chiefly of limestones, shales, and some beds of sandstone and seams of coal. Above these rocks, though separated from them by an unconformity indicating the lapse of a very long period of time, lie the loose, unconsolidated deposits of clay, sand, gravel, and bowlders known as the drift. This averages from 100 to 250 feet in thickness and is chiefly of Kansan age. Beneath the Kansan till, and separated from it by a heavy bed of gravel known as the Aftonian, from its discovery in the railway cuts west of Afton Junction, is an earlier till known as the Nebraskan drift. That this older drift is present throughout the greater portion of the county at least is shown by the presence within the drift of a very persistent gravel bed corresponding to the Aftonian, by the presence of old forest or soil deposits, and by peculiarities of the basal till, showing differences in composition and age.

Above the drift everywhere except on the bottoms of the deeper valleys lies the light yellow plastic clay, known as the loess. It is generally free from pebbles, but contains numerous white calcareous concretions. Widely associated with the lower layers of the loess is a sticky, black plastic clay called gumbo.

In all stream valley bottoms a deposit of alluvium has been formed, chiefly from the wash of the loess, gumbo, and drift. The alluvium is thinner and of less importance in Union county than in other counties of southwestern Iowa that are farther from the divide.

UNDERGROUND WATER.

SOURCES.

The chief shallow-water beds of the county are the alluvium, the loess, the Kansan till, the Aftonian gravel, the Nebraskan, and the limestone of the Missouri stage. All of these except the Aftonian gravel, which is one of the best aquifers in Iowa, are frequently unsatisfactory or insufficient.

Sufficient quantities of sand interstratified with silt are found in the alluvium of some of the larger tributaries of the Grand, in the southeastern portion of the county, to allow the use of drive-point wells, which, however, are not common.

The seepage at the base of the loess, especially where it overlies gumbo, supplies many shallow wells for domestic use, but the quantity is meager and uncertain.

The upper portion of the Kansan till usually contains much gravel and sand and these frequently supply sufficient water for many shallow wells, so that this horizon, together with the sandy base of the loess, is known as the "first water." A few wells find sand pockets in the Kansan till; the water from these is excellent in quality but is very variable in quantity, frequently failing altogether in dry seasons.

The Aftonian gravel, lying between the two till sheets, forms the best aquifer of this portion of the state, and its water is generally known on the uplands as the "second water." It is usually pure, wholesome, and abundant. In the valleys, owing to the absence of loess, the Aftonian is in many places the first water bed reached. The depth to it ranges from 30 to 200 feet. Wherever the gravel outcrops it forms a horizon of strong springs. A good illustration is found on the farm of John Leininger, 2½ miles north of Afton, where a powerful permanent spring flows from the base of a hill in which the gravel outcrops. In some places water from the Aftonian is rendered disagreeable and impotable by the presence of decaying organic matter of old soil, peat, and forest beds.

A "third-water" horizon is found in beds of sand and gravel in the base of the Nebraskan drift, immediately above the bedrock. This usually lies at depths of 100 to 200 feet, but its occurrence is uncertain; probably in many places the Aftonian gravel rests immediately on the bedrock.

The country rock, composed as it is of thinly bedded limestones and calcareous shales, is not a good water carrier, its supply being small and its water hard and locally mineralized. The great thickness of the drift also makes it an expensive source of supply, and it is not resorted to when it is possible to obtain water from the upper beds. If the supply is insufficient after deep drilling, it is advisable, before abandoning the well, to try "shooting" with nitroglycerin and puncturing the casings opposite higher beds, in order to combine the supplies.

Because of the scarcity of good ground water at ordinary depths on the higher uplands of the county about Creston and Spaulding, many of the larger stock farms resort to ponded storm waters.

The following composite section, from descriptions given by well men, shows the relations of the several water beds:

Composite well section about Creston.

	Thickness in feet.
Soil, black	1- 3
Loess; light yellow clay containing calcareous concretions	10- 20
Kansan till:	
Yellow gravelly clay, containing numerous sand and gravel beds; water bearing (first water)	2- 6
Blue bowlder clay, compact and hard	20-100
Aftonian; sand and gravel, yellow and coarse; heavily water bearing (second water)	2- 5
Nebraskan till:	
Yellow, hard and gravelly	10- 20
Blue and black, pebbles, and bowlders	20- 40
Sand and gravel, water bearing (third water)	2- 4
Shaly limestone.	

The upper portion of the Aftonian in many wells shows soil, peat, or forest beds, and the upper portion of the shaly limestone at the base of the section is often broken into a coarse rubble, mingled with residual gravel and soil and characteristic geest. The thickness of the drift at Creston is reported to be 260 feet.

SPRINGS.

Strong springs are numerous along the valley sides in the broken portion of the county. The Aftonian gravel, lying as it does between the till sheets, supplies one of the best spring horizons in Iowa. Little use is made of these springs, however, except as stock water, and even then they are rarely walled up and piped, but are simply permitted to flow, forming more or less of a bog in many cases.

CITY AND VILLAGE SUPPLIES.

Afton.—The public supply of Afton (population, 1,014) consists of five wells on the town square, ranging from 25 to 40 feet in depth. All are likely to fail in summer, except the 40-foot well, which usually contains 20 feet of water and is permanent.

A well at the creamery, in the northwestern portion of the town, is 365 feet in depth and reaches bedrock at 173 feet. It obtained abundant water in a gravel and sand layer in the drift a few feet above bedrock. The water was too hard for boiler use. Later the well was abandoned on account of clogging by mud and fine sand. The log follows.

Log of creamery well at Afton.

	Thickness.	Depth.
	Feet	Feet
Clay, yellow, and soil	58	58
Clay, blue	115	173
"Sandstone" (probably cemented sand and gravel)	4	177
Sand and gravel, fine	1	178
Mud, blue and black	3	181
Shale and "soapstone"	184	365
Limestone, hard		

An important deep well is that of C. C. Boys (SE. ¼ sec. 11, T. 72 N., R. 30 W.). This well is 671 feet deep and was originally drilled as a coal prospect hole. No good section or log can be obtained, but it is known that bedrock was reached at 116 feet and the most important water bed found in a 10-foot bed of sand and gravel 46 feet above this, probably in the Aftonian. This was cased out until the prospect hole was finished; it was then opened up for a well, which has furnished a large and permanent supply.

Creston.—The public supply of Creston (population, 6,924) is drawn from an artificial lake about two miles long, about one-half mile wide, and 30 feet deep. Similar though smaller ponds are used by many farmers about Creston to assure a stock supply in summer.

Minor supplies.—Most villages are supplied from shallow wells 15 to 20 feet deep. About Afton Junction, Talmage, and Thayer the Aftonian gravel lies within comparatively few feet of the surface.

WARREN COUNTY.

BY JOHN L. TILTON.

TOPOGRAPHY.

The upland of Warren county is a well-dissected plain sloping from 1,088 feet above sea level in the southwestern portion to 900 feet in the northeastern portion. It is drained chiefly by three streams, North, Middle, and South rivers, that flow toward the northeast, with tributaries extending back to all portions of the upland.

GEOLOGY.

The Des Moines stage with its shale, sandstone, and coal underlying all sections of the county, extends from near the surface to a depth of 250 to 300 feet. (See Pl. XVI, p. 814.) In a few square miles only in the western half of Virginia township the Missouri stage with its limestone and shale overlies the Des Moines. Between these Carboniferous strata and the overlying Pleistocene lies a thin deposit of subglacial sand and old soil, remnants of the old surface prior to the advent of the Nebraskan ice sheet.

The Nebraskan drift is a tough, impervious, bluish black till containing pebbles of greenstone, white quartzite, and light colored granite. It is especially thick in the southern and western portions of the county, where the Kansan drift is thin. The sands and gravels (Aftonian) which overlie the Nebraskan drift, were largely derived from the erosion of this older till.

The Kansan drift is bluish black where not weathered and yellowish where weathered, containing here and there fine sand and minute pebbles. Among its numerous pebbles and bowlders red quartzite and greenstone are common, together with dark decomposing granite. In some portions of the county the Kansan drift is but a few feet thick; in other places it measures at least 80 feet.

The post-Kansan deposits consist in part of a yellowish and a grayish loess, between which in some places lies a clayey deposit (gumbo), which appears to be a loess modified by deposition in water.

The different depths of drift make it evident that from the southern and eastern parts of Jackson township a large buried valley extends southeastward across Squaw township and northeastward across Jefferson township, with branches extending eastward to near Indianola and northeastward to the southwest corner of Greenfield township. Another buried valley underlies the central part of Linn township, whence it extends east into Greenfield township and also southwest and northwest. The area covered with thick drift suggests an outlet to the northwest, but deeper preglacial valleys suggest an outlet to the northeast through Greenfield township.

UNDERGROUND WATER.

SOURCES.

In former years wells on the uplands very commonly ended in a gumbo, or modified loess, which is found almost universally throughout the upland in the central portions of the county, 15 to 20 feet below the surface. During the drouth of 1894, however, these wells were sunk beneath this deposit or its yellow equivalent to a sand which is generally found next beneath. Wells that are not over 30 feet deep are so constructed that they receive both the surface ground water and water from the sand below.

At a depth of about 30 feet throughout the uplands and of somewhat less in the bottom lands lie deposits of sand and gravel which are the common source of water supply throughout the county. In the central part of the county this deposit is in part post-Kansan and in part gravel (with bowlders) left after erosion of the Kansan surface. In other portions of the county, especially the southern and western parts, where the Kansan and all above it are thin, the sand is Aftonian. Along the river valleys the thick deposit of sand penetrated by wells 12 to 18 feet deep is Aftonian.

In the southern and western parts of the county wells 100 feet deep pass through the Nebraskan drift into preglacial sands and soils. In general these preglacial deposits lie at depths varying from the level of the streams to 60 feet below this level. In the upland, bored wells are ordinarily used, in the river valleys driven wells are very satisfactory.

The Simpson college well, which is 112 feet deep, ends in the bottom of deposits of old soil 25 feet deep. In testing this well it was first pumped for 49 hours at the rate of 840 gallons an hour, the pumping lowering the water 81 feet. This continued pumping merely drained away the surface water, for the water rose thereafter within 30 feet of the surface. In the final test, after 17 hours of continuous pumping with a four-inch pump worked by a 2½ horsepower gasoline engine, the water was reduced to a level 99 feet below the surface, the water toward the last lowering very slowly. Three days later it had risen within 34 feet of the surface of the ground. The greatest quantity of the water came through the gravel at the base of the Aftonian. The rest came in slowly from above.

In the eastern half of the county the Carboniferous strata lie so near the surface that they are penetrated by many wells. Some of these extend into the Carboniferous for only a foot or two, just far enough to form a basin to hold water that comes in from the upper aquifers. In some the water enters from the shale. The wells that penetrate the shale more than a foot or two are dug by hand or drilled, the shale being so dense that it is bored by a well auger only with extreme difficulty. The general dryness of the shale makes such a formation one into which it is not advisable to penetrate; the sandy phases are bearers of good water, but the quantity is generally too small to supply a good stock well. Sulphur water characteristic of all wells that penetrate the Coal Measures corrodes metal receptacles and is unacceptable for kitchen and laundry use, and therefore presents a serious difficulty in all deep wells. Such water is not generally harmful, though it is laxative. To some people the taste is unpleasant.

Several wells that are 100 to 200 feet deep extend into the Coal Measures. Only two are flowing wells, both of them on low ground in the northeastern part of the county near the small anticline which runs northwest and southeast just east of Ford. Throughout most of the county the strata dip very slightly to the west or are horizontal, and the surface is so high that deep flowing wells are not obtainable.

Only two wells in the county reach below the Pennsylvanian; one is said to penetrate two feet and the other 38 feet into the Saint Louis. In all near-by counties deep wells have been sunk, but with results too unsatisfactory to be encouraging.

*Typical well records in Warren County**

Locality.	Depth in feet. (Remarks.)	Log in Feet.
T. 77 N., R. 25 W. (Linn).		
SE. ¼ SE. ¼ sec. 7	116 On upland.	Soil, 2; loess and clay, yellow, pebbles (post-Kansan and Kansan), 73; clay, blue, (Nebraskan), 16; shale yellow, with white sand (Des Moines), 20-25.
SE. ¼ SE. ¼ sec. 15	40 On upland.	Soil, 4; loess and clay, yellow, pebbles below (post-Kansan), 16; clay, blue, pebbles (Kansan), 15; weathered stone, sand, gravel, 1; shale, clayey (Des Moines), 4.
SE. ¼ SE. ¼ sec. 27	51 90 feet below upland.	Soil, 2; clay, yellow (post-Kansan and Kansan), 20; sand (Aftonian), 29.
NE. ¼ SW. ¼ sec. 28	170 90 feet below upland.	Soil, 3; loess and clay, yellow, pebbles in lower part (post-Kansan and Kansan), 27; clay, blue, pebbles (Nebraskan), 20; sand and clay (subglacial), 15; coal, 3½; shale with 3 thin layers of coal, 101½.
NW. ¼ SW. ¼ sec. 30	116 On upland.	Soil, 2; loess and clay, yellow (post-Kansan and Kansan), 48; clay, blue (Nebraskan), 50; sand, dark gray (subglacial), 16; solid rock (Des Moines).
NW. ¼ NW. ¼ sec. 32	50 135 feet below upland.	Soil, yellow clay, blue clay (post-Kansan and Kansan), 40; gravel (Aftonian), 10. Ends in gravel 10 feet below bed of North river.
T. 77 N., R. 24 W. (Part of Greenfield).		
SW. ¼ NE. ¼ sec. 1	268 10 feet below upland.	Soil, 2½; loess and clay, yellow (post-Kansan and Kansan), 10; clay, blue, gravel and bowlders (Kansan and Nebraskan), 78; shale, clayey, sandy (Des Moines), 178.
SW. ¼ SW. ¼ sec. 5	36 On upland.	Soil, 2; loess and clay, yellow (post-Kansan and Kansan), 6-7; clay, blue, pebbles (Kansan), 26; sandstone (Des Moines), 1½.
SW. ¼ SE. ¼ sec. 13	71 On upland.	Soil, 1; clay, reddish, a little gravel (post-Kansan and Kansan), 30-40; clay, blue, pebbles (Kansan), 15-20; black dirt with old logs (Aftonian), 2; sand, fine, white, 8.
NW. ¼ NW. ¼ sec. 22	90 5 feet above flood plain.	Soil washed in, and loess, 40; clay, yellow, gravel and calcareous concretions (Kansan), 4-5; clay, blue, stiff, pebbles, 1½; gravel, fragments of limestone (Aftonian), 1-1½; clay, black, sand layer at 75 feet (Nebraskan and subglacial), 42. Bottom 65 feet below bed of North river.

*Interpretations by the writer.

Typical well records in Warren County.—Continued*

Locality.	Depth in feet. (Remarks.)	Log in Feet.
T. 77 N., R. 23 W. (Allen; parts of Lincoln, Palmyra and Richland.)		
NW. ¼ NE. ¼ sec. 6	68 On upland.	Dug 40 years ago, 30; clay, dark blue, small pieces coal (Kansan), 30; gravel underlain by white sand (Aftonian), 8; quicksand.
SE. ¼ SE. ¼ sec. 9	220 35 feet below upland.	Soil, 1½; loess and clay, yellow (post-Kansan and Kansan), 30; shale to 175 feet, then sandstone (Des Moines), 188½.
NW. ¼ NW. ¼ sec. 16	300 On upland.	Soil, 3; loess and clay, yellow (post-Kansan and Kansan), 3; quicksand, whitish (Aftonian), 10-12; clay, blue (Nebraskan); shale, sandstone, etc. ("mineral" water), (Des Moines).
NW. ¼ SW. ¼ sec. 23	351 15 feet below upland.	Soil, 4; loess and clay, yellow (post-Kansan and Kansan), 15; clay, blue (Kansan), 11; sand and gravel (Aftonian), 8; shale, clayey, sandstone, etc. (soft water) (Des Moines), 313.
T. 77 N., R. 22 W. (Parts of Richland and Palmyra).		
SE. ¼ SE. ¼ sec. 13	28 On upland.	Soil, 1; loess and clay, yellow (Kansan), 1-2; sand, red, no pebbles (Aftonian), 4; clay, blue, no pebbles (Nebraskan), 8; sand (subglacial), 2; shale, clayey, blue (Des Moines), 11.
NE. ¼ NE. ¼ sec. 29	42 On upland.	Soil, 2; loess and clay, yellow, no pebbles (post-Kansan and Kansan), 28; sand (Aftonian); shale, clayey, blue; coal, 12.
T. 76 N., R. 25 W. (Jefferson).		
NE. ¼ NE. ¼ sec. 1	120 5 feet below upland.	Soil, 2½; loess and clay, yellow, 6 in. sand at 14 feet (post-Kansan, Kansan and Aftonian), 17½; clay, blue, roots and fragments of wood at 100 feet (Nebraskan), 96; sandy material (subglacial), 4; (Des Moines).
SW. ¼ NE. ¼ sec. 5	119 On upland.	Soil, 2; loess and clay, yellow and brown (post-Kansan and Kansan), 25; gravel and sand (Aftonian), 4; clay, blue, pebbles (Nebraskan), 75; sand and clay, brown, hard (subglacial), 13.
SW. ¼ NE. ¼ sec. 16	100 10 feet below upland.	Soil, 3-4; loess and clay, yellow, no pebbles, (post-Kansan and Kansan), 16-17; clay, blue (Kansan and Nebraskan), 72; sand, white (subglacial), 6-8.
NW. ¼ SW. ¼ sec. 34 (a)	106 40 feet below upland.	Soil, loess and yellow clay (post-Kansan and Kansan), 35; clay, blue (Nebraskan), 60; sand, gray (subglacial), 5, like old soil, 6.
T. 76 N., R. 24 W. (Parts of Lincoln and Greenfield).		
SW. ¼ NE. ¼ sec. 5	111 On upland.	Soil, 2; loess and clay, yellow (post-Kansan and Kansan), 40; clay, blue (Nebraskan), 64; sand and gravel, wood (subglacial), 5.
SE. ¼ NW. ¼ sec. 5	105 5 feet below upland.	Soil, 3½; loess and clay, yellow (post-Kansan and Kansan), 26½; sand with wood (Aftonian), 10; clay, blue, some wood (Nebraskan), 50; gravel and sand, fine, gray (water) (subglacial), 15.
NE. ¼ SW. ¼ sec. 10 (b)	30 On upland.	Soil, 1; loess and clay, yellow, no pebbles (post-Kansan), 16; clay, yellow, pebbles (Kansan), 5; shale clayey, blue (Des Moines), 8.
SW. ¼ SE. ¼ sec. 18	113 10 feet below upland.	Soil, 2-3; loess and clay, yellow (post-Kansan and Kansan) 15; clay, blue, pebbles (Nebraskan), 85; sand and mud (subglacial), 10; Des Moines shale.

*Interpretations by the writer.

a Reported by J. C. Nash, driller.

b Personal inspection.

Typical well records in Warren County.—Continued*

Locality.	Depth in feet. (Remarks.)	Log in Feet.
SW. ¼ SE. ¼ sec. 24	112 Simpson College well. On upland.	Soil, black, 2; loess, yellow, blue below, then a blue, modified loess (gumbo), then grayish blue sandy loess; no effervescence, 28; sand, yellowish and gray (subloessial), 2; clay, with pebbles, bowlders, and lime concretions, yellowish brown 1 foot, then grayish blue 17 feet, then bluish black 36 feet (Kansan), 54; deposit, black, soil planes and minute partings of vegetation, no wood, few pebbles (Aftonian), 25; pebbles from Nebraskan, 1; Des Moines.
T. 76 N., R. 23 W. (Parts of Lincoln and Palmyra).		
NW. ¼ NE. ¼ sec. 1	35½ On upland.	Soil and subsoil, 6; loess, yellow above, blue below (post-Kansan), 20; sandstone (Des Moines), 3; shale, clayey, blue, 6; sand and black clayey shale, ½.
SW. ¼ NW. ¼ sec. 9 (*a*)	52 On upland.	Soil, 2; loess, yellow, (post-Kansan), 36; clay, yellowish, pebbly, (Kansan), 10; sand (Aftonian and subglacial), sandstone below (Des Moines), 4.
NW. ¼ SE. ¼ sec. 17	120 On upland.	Soil, 2-3; loess, yellow, 26; sand (post-Kansan), 1; clay, blue, lighter below, pebbles and wood (Kansan), 88; shale, gray (Des Moines), 2.
NW. ¼ SW. ¼ sec. 21	14½ 10 feet below upland.	Soil, 2½; loess and clay, yellow, some pebbles (post-Kansan and Kansan), 4-5; clay, blue, with pebbles, 4; shale, blue and black, 4 inches coal, fire clay, shale, sandy (Des Moines), 4.
NW. ¼ SE. ¼ sec. 29	41 On upland.	Soil, 3; loess, yellow (post-Kansan), 4; changes into sand, somewhat clayey, some pebbles and loose rock, 24; shale, part clayey, part sandy (Des Moines), 10; sandstone.
NW. ¼ NE. ¼ sec. 32 (*a*)	100 20 feet below upland.	Soil, 2; loess, yellow (upper loess), 14-16; loess, gray (lower loess) (post-Kansan), 14; clay, reddish yellow, pebbly (Kansan), 6-8; clay, blue (Kansan and Nebraskan), 56; sand, gray, beneath clayey old soil (subglacial), 4.
T. 76 N., R. 22 W. (Union, parts of Palmyra and Lincoln).		
Sec. 5 (*b*)	367½ Low ground.	Soil, 4; clay, yellow (post-Kansan and Nebraskan), 20; shale and sandstone, 4 seams of coal (Des Moines) 305½; limestone (Saint Louis), 38.
SW. ¼ NW. ¼ sec. 16	65 On upland.	Soil, 4; loess and clay, yellow (post-Kansan), 4-5; clay, red and blue, streaked with sand (Kansan), 15; sand (Aftonian), 1½; clay, blue streaks, pebbles, (Nebraskan), 2; clay, blue, pebbles (Nebraskan), 12-15; coal, fire clay, shale, blue, clayey, 23½.
SW. ¼ SW. ¼ sec. 28	39 On upland.	Soil, 2-3; loess and clay, yellow, no pebbles in upper part (post-Kansan and Kansan), 19; clay, light brown, stratum of gravel, water (Aftonian), 5; clay, light brown (Nebraskan), 12; coal.
T. 75 N., R. 23 W. (Jackson).		
SE. ¼ SE. ¼ sec. 3	117 On upland.	Soil, 3; loess and clay, yellow, mottled with blue (post-Kansan and Kansan), 15; sand (Aftonian), 1½; clay, yellow above, changing to blue and black at depth of 45 feet (Nebraskan), 37; clay, bluish black, 61; subglacial blue sand. Soft water rises 22 feet.
NW. ¼ NW. ¼ sec. 4	346 On upland.	Soil, 1½; loess and clay, yellow (post-Kansan and Kansan), 21½; coarse sand and gravel (Aftonian), 5; clay, blue, sand, pebbles and bowlders (Nebraskan), 52; Carboniferous, mostly shale, 3 feet coal at 255 feet depth, 266.

*Interpretations by the writer.

a Reported by J. O. Nash, driller.

b Reported by A. G. West, Runnells, Iowa.

Typical well records in Warren County.—Continued*

Locality.	Depth in feet. (Remarks.)	Log in Feet.
NE. ¼ NE. ¼ sec. 23	130 On upland.	Soil, 2; loess and clay, yellow, mottled blue below (post-Kansan and Kansan), 22; sand, little water (Aftonian), 2-3; clay, dark blue, hard, fragments of wood like black walnut at 80 feet depth (Nebraskan), 100; coarse sand (subglacial), 3-4 (water not very hard, rose 20 feet).
T. 75 N., R. 24 W. (White Oak).		
NW. ¼ NE. ¼ sec. 18	138 On upland.	Soil, 1; loess and clay, yellow, no pebbles (post-Kansan and Kansan), 34; clay, blue, pebbles; wood and shell 90 feet from surface (Nebraskan), 103.
NW. ¼ SE. ¼ sec. 20	150 On upland.	Soil, 1½; loess and clay, yellow, pebbles and streaks of sand (post-Kansan and Kansan), 48½; clay, blue (Nebraskan), 100; sand, fine, blue (subglacial).
SW. ¼ SW. ¼ sec. 32	60 On upland.	Soil, 1-1½; loess and clay, yellow, no sand or gravel to depth of 23 feet (post-Kansan and Kansan), 33½; sand and gravel (Aftonian), 1-2; clay, yellow (Nebraskan), 4; clay, blue, no pebbles, 20.
NW. ¼ SE. ¼ sec. 36	20 On upland.	Soil, 1; loess and clay, pebbles below (post-Kansan and Kansan), 8-10; shale, clayey, blue, sandy partings (Des Moines), 9.
T. 75 N., R. 23 W. (Otter).		
NW. ¼ NE. ¼ sec. 2	25 On upland.	Soil, 1; loess, yellow, no pebbles (post-Kansan), 2-3; shale, brownish and blue, 1 foot coal at 21 feet, sandstone (Des Moines), 21.
NE.¼ NW.¼ sec.8.(*a*)	214 10 feet below upland.	Soil, 2; clay, yellow, pebbles (Kansan), 23; shale, clayey, blue above, various Des Moines strata below, 189.
NW. ¼ SW. ¼ sec. 36	210 Prospect hole on upland.	Soil, 2; loess and clay, yellow, some pebbles below 15 feet (post-Kansan and Kansan), 32; Des Moines strata, 176.
T. 75 N., R. 22 W. (Belmont).		
SE. ¼ SE. ¼ sec. 13	15 30 feet below upland.	Soil, 5; shale, clayey, blue (Des Moines), 10; coal.
Ne. ¼ SE. ¼ sec. 26	33-35(*b*) On upland.	Soil, 2; loess and clay, yellow, pebbles below 18-20 feet (post-Kansan and Kansan), 24; sand, yellow, gravel (Aftonian), 1; clay, blue, pebbles (Nebraskan), 6-8.
T. 74 N., R. 25 W. (Virginia).		
NW. ¼ NW. ¼ sec. 1	140 110 feet below upland.	Soil, 3; clay, yellow, pebbles, lime concretions (post-Kansan and Nebraskan), 22-27; clay, blue, bowlders and some sand, 110-115. Ends in blue sand (subglacial) 55 feet below river; abundant soft water.
NE. ¼ NE. ¼ sec. 2	150 115 feet below upland.	Soil, 3; loess, yellow (post-Kansan), 6; sand (Aftonian), ½; clay, yellow, pebbles, (Nebraskan), 22; dark blue, gritty in places (Nebraskan), 100-125; shale, blue 70 feet below river (Des Moines).
SE. ¼ SE. ¼ sec. 4	68 On upland.	Soil, 2½-3; loess and clay, yellow (post-Kansan and Kansan), 15; gravel (Aftonian), 2; sand, hard, white, 2; clay, yellow, streak of blue (Nebraskan), 6; clay, blue, a few pebbles 1 inch in diameter, 40; shale (Des Moines).
NW. ¼ NW. ¼ sec. 31	255 On upland.	Soil, 2½; loess and clay, yellow (post-Kansan and Kansan), 27½; sand and gravel, cemented (Aftonian), ½; clay, yellow (Nebraskan), 38; clay,dark blue, some grit, 175; coal-like material, rotten, soft mud, water (subglacial), 1½-2; shale, clayey, red (sulphurous water, pumped out in ½ hour) (Des Moines), 8-10.

*Interpretations by the writer.

a 4-inch well, all cased. Water rose 100 feet, but was pumped out by a machine in an hour. Water roily, not used. Driller, D. A. Jemison, Ackworth, Iowa.

b A well close by reaches Carboniferous at about this depth.

Typical well records in Warren County.—Concluded*

Locality.	Depth in feet. (Remarks.)	Log in Feet.
T. 74 N., R. 24 W. (Squaw).		Soil, 2; loess and clay, yellow, sandy (post-Kansan and Kansan), 21; sandstone (Des Moines), 9.
NE. ¼ NE. ¼ sec. 12	32 On upland.	Soil, ½; loess and clay, yellow (post-Kansan and Kansan), 19; sand, old timber and black sand at bottom (Aftonian), 48.
SE. ¼ NE. ¼ sec. 17	68 On upland.	Soil, 2½; loess and clay, yellow; pebbles below 8-10 feet (post-Kansan), 15½; sand, a little water, 1; clay, gray, changing to blue below (Kansan), 11; clay, blue, pebbles, 12; clay, black, soft like old soil, sticks size of fingers (Aftonian), 4; clay, bluish black, stiff, a few pebbles, washed from Nebraskan (Aftonian), 26; sand and gravel (Aftonian), 1½; shale, clayey, blue (Des Moines), 1.
NW. ¼ NW. ¼ sec. 30	74½ On upland.	
T. 74 N., R. 23 W. (Liberty).		
SW. ¼ NW. ¼ sec. 4	20 100 feet below upland.	Soil, 1; sandstone, (Des Moines) 19.
SW. ¼ NW. ¼ sec. 18	38 100 feet below upland.	Soil, 2; clay, with gravel, lime concretion, traces of coal (post-Kansan and Kansan), 10-12; shale, clayey, blue (Des Moines), 22; limestone, 2½; coal, ½.
NW. ¼ NW. ¼ sec. 36	60 On upland.	Soil, 2½; loess and clay, yellow (post Kansan and Kansan), 22½; sand and gravel (Aftonian), 5; clay, blue, pebbles, bowlder 18 inches in diameter (Nebraskan), 30, water hard, but good.
T. 74 N., R. 22 W. (Whitebreast).		
SE. ¼ SE. ¼ sec. 3	40 40 feet below upland.	Soil, 2; clay, yellow (Kansan), 18; sand (Aftonian), 16; gravel and sand (Aftonian), 4; sandstone.
SE. ¼ SE. ¼ sec. 19	26 On upland.	Soil, 4-5; clay, yellow (post-Kansan and Kansan), 6-7; sand (Aftonian), 2; clay, blue and gray, pebbles (Nebraskan), 10; sand (preglacial), 3.
SW. ¼ NW. ¼ sec. 36	32 On upland.	Soil, 2-3; loess and clay, yellow (post-Kansan and Kansan), 19; sand, yellow (Aftonian), 3; shale, sandy, blue (Des Moines), 8.

*Interpretations by the writer.

WAYNE COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

The surface of Wayne county consists of a plain which has been carved by postglacial erosion into an intricate system of sharp valleys and ravines. Along the principal divides still exist broad strips of the undissected plain over which the railways have been constructed and upon which, as a consequence, the villages have been built.

The bedrock belongs to the Pennsylvanian series of the Carboniferous and consists of shale and thin strata of sandstone and limestone. Upon the rock rests a thick accumulation of glacial materials, at least the upper part of which belongs to the Kansan drift sheet. Widely spread over the drift is a veneer of loess or grayish blue clay resembling loess.

Below are given several sections, as reported, of the drift and upper part of the Pennsylvanian.

Sections at Corydon.

[Sec. 19, T. 69 N., R. 21 W.]

	Thickness.	Depth.
Shaft No. 1..	Feet	Feet
"Drift"	267	267
Sandstone	14	327
Sandstone	6	300
Shale, sandy	12	812
Limestone	6	318
Shaft No. 2.		
"Drift and secondary drift"	301	301
Shale, argillaceous	12	313
Sandstone	14	327
Shale, sandy	15	342
Shale, argillaceous	30	372
Limestone with clay partings	20	392
"Crushed limestone with rotten coal"	12	404
Shaft No. 3.		
"Drift"	297	297
"Irregular layer of rotten sandstone"	1	298

Section at Humeston

[Humphrey Creamery well.]

	Thickness.	Depth.
	Feet	Feet
Soil and clay	50	50
Clay, blue	330	380
Quicksand	20	400
Seam containing coal.		
Shale and soapstone	100	500
Rock entered.		

UNDERGROUND WATER.

SOURCES.

In Wayne county the water is generally obtained from wells dug or bored from 25 to 50 feet into the drift. In years of normal rainfall, most of these wells receive enough seepage for household use and stock farms, but in dry years many of them fail. Ponds made by throwing dams across small ravines serve as an additional supply for live stock on many farms.

The loosely aggregated and somewhat gravelly drift that furnishes the seepage for the shallow open wells gives place downward to a more compact and impervious bowlder clay, below which there is a possibility of obtaining water from (1) beds of sand or gravel at the base of the drift or between two sheets of bowlder clay; (2) strata of sandstone or limestone in the Pennsylvanian series; and (3) different sandstones and limestones at still greater depths. Such prospecting of the deeper parts of the drift as has been done at different times has not been very successful. This is attributed by drillers to the absence of sand or gravel deposits, but it may be due more largely than is realized to the leakage caused by the many deep valleys, whereby porous beds are drained or their heads so much reduced that the water will not flow rapidly into the drill holes. Neither is the Pennsylvanian satisfactory as a source of water. In its several hundred feet of thickness, certain water-bearing strata are nearly always encountered, but these are usually so thin and imperfectly porous and so completely incased by thick impervious beds of shale that their supply is small. Moreover, the water from these strata is objectionably rich in sulphates and frequently also in hardening constituents and iron.

At the creamery of J. L. Humphrey, Jr., at Humeston, a four-inch well was drilled to a depth of 384 feet, and was finished with a six-foot strainer in a bed of sand. It appears that the sand eventually entered the well and shut off the water. A second well, five inches in diameter at the top and four inches at the bottom, was later drilled to the depth of 501 feet, but it seems that no additional supply was found and the same bed of sand was utilized. The water is reported to be hard and ferruginous and to have a laxative effect, which is no doubt due to a large content of sulphates. The section as reported suggests that the sand bed lies at the base of the drift, but the data are too indefinite to allow any positive statement. The water appears to have the chemical character of that found in the Pennsylvanian strata.

One of the deepest wells reported in the county is one drilled at Corydon, in 1903, for E. A. Rea. It goes to a depth of 834 feet, ends in rock, and is said to have passed through water-bearing beds at about 75 feet, 300 feet, and 440 feet below the surface and also near the bottom. It is cased with 6¼-inch and 5-inch pipe to a depth of 610 feet, and has 20 feet of 4¼-inch casing at about 700 feet and 50 feet of 3-inch casing at the bottom. With a pump drawing from a depth of 692 feet (578 feet below the water level) the well was successfully tested, immediately after it was completed, at the rate of 20 gallons a minute for 7½ hours continuously. At the time it was visited, however, it was for some reason not in condition to yield water.

In 1911 the town put down a drill hole to 1,240 feet, at which depth the well was stopped, as its capacity amounted to but 20 gallons a minute. The elevation of the curb is about 1,110 feet.

The log of the hole, so far as kept, is as follows:

Driller's log of well at Corydon.

	Thickness.	Depth.
	Feet	Feet
Unknown	610	610
Shale, sandy	53	663
Sandstone; some water	68	731
Flint	11	742
Sandstone	6	748
Limestone	35	783
Soapstone	22	805
Limestone	2	807
Soapstone	3	810
Limestone	278	1,088
Soapstone	57	1,145
Limestone	15	1,160
Shale, blue	15	1,175
Limestone	65	1,240

The following samples of the drillings were submitted:

Record of strata in well at Corydon.

	Thickness.	Depth.
	Feet	Feet
Sandstone, fine, grains imperfectly rounded; and limestone, light gray, rapid effervescence	6	748
Chert, white, and limestone, blue-gray		770
Limestone, drab, fine granular; moderately rapid effervescence	2	807
Chert, blue-gray, and limestone of same color, rapid effervescence		810
Limestone, light gray, soft; rapid effervescence	14	835
Limestone, brown, hard; with brown flint	6	841
Limestone, blue-gray, soft; in flaky chips	4	854
Limestone, gray, soft, cherty		875
Shale, blackish, bituminous	3	898
Limestone, cream-colored, macrocrystalline; much white chert		906
Limestone, light blue-gray; with white chert	7	925
Limestone, light yellow, macrocrystalline; rapid effervescence	3	928

In this section, the base of the Pennsylvanian may be drawn at 731 feet from the surface, 379 feet above sea level. The shales from 1,088 to 1,175 feet are comparable in position to shales at Centerville which are referred to the base of the Mississippian and, like them, include an intercalated limestone. The shales at Centerville, however, lie somewhat lower than those at Corydon. Whether the footing of the drill hole is in the Devonian or in the Mississippian, it is certain that it was not carried far enough to reach the Silurian water bed tapped at Centerville, to say nothing of the Ordovician sandstone aquifers. If the shales referred to are the same as those of the basal Mississippian at Centerville the Silurian sandstones would have been encountered within 250 feet of the bottom of the well. The general dip of the strata would indicate a probable depth from the surface to the Saint Peter sandstone of about 2,050 feet. But the upwarp of the Ordovician strata in southeastern Iowa and northeastern Missouri may extend farther to the west than is now supposed and the Saint Peter may lie 200 feet higher than the estimate.

The 501-foot well at Humeston is reported to have cost $850 and the pump for it $150. The Corydon well is reported by Mr. Rea to have cost $3,000 and the pump $450. All things taken into consideration, the prospects for water below the bowlder-clay are not encouraging. The meager yield and poor quality of water that are to be expected, together with the uncertainties involved, would not seem to warrant the necessary expense except perhaps where urgent necessity exists.

HEAD.

The surficial drift layer is so imperfectly pervious that the water level conforms closely to the surface, the water in a shallow upland well commonly standing high above a near-by valley. But the head from the lower aquifers approximates more closely to the valley level. In the deep well at Corydon the water rises to a level 114 feet below the surface or to a point about 990 feet above the sea; and in the deep creamery well at Humeston it rises to a point about 100 feet below the surface, perhaps not far from 1,000 feet above the sea. At Seymour (NW. ¼ NW. ¼ sec. 24, T. 68 N., R. 20 W.) a flowing well 87 feet deep discharges water rich in sulphates at the rate of about a gallon a minute. In a deep valley west of Lineville and south of the state line a well that ends in the Pennsylvanian once overflowed. (See "Decatur County", p. 945.)

CITY AND VILLAGE SUPPLIES.

Corydon.—The Rea well at Corydon (population, 1,669) has in the past supplied a small private system of waterworks consisting of a tank on a tower connected with a few hundred feet of mains.

In December, 1912, the city well (see page 1001) was being pumped two nights a week, six hours a night, and was furnishing 40 gallons a minute. A tank holding 75,000 gallons and a reserve cistern of 50,000 gallons capacity hold an abundance of water and service connections were being made. The water is beneficial in its effects upon the health of its users.

Minor Supplies.—Aside from the plant at Corydon, Wayne county has no system of waterworks, although it contains several villages of considerable size. The problem of procuring a satisfactory public supply is difficult. Shallow wells yield supplies that are too small and unreliable; deep drilling is expensive, involves considerable uncertainty and, at best, will furnish water that is objectionable because of its mineralization; and reservoirs in which the wash from rains is collected are likely in the course of time to receive poor care, so that the water will be unfit for drinking or household use.

Though it is not generally possible to extract much water from a single shallow well, a much larger quantity could be obtained from a series of such wells. A large number of these could be bored at a moderate cost and they could all be connected at the bottom with horizontal pipes, so that a pump operating at one would draw from all. (See p. 947.) It seems probable that adequate supplies for most of the villages could in normal years be obtained in this way, but a shortage might occur in seasons of drought.

CHAPTER XIV.

UNDERGROUND WATERS OF THE NORTHWEST DISTRICT.

INTRODUCTION.

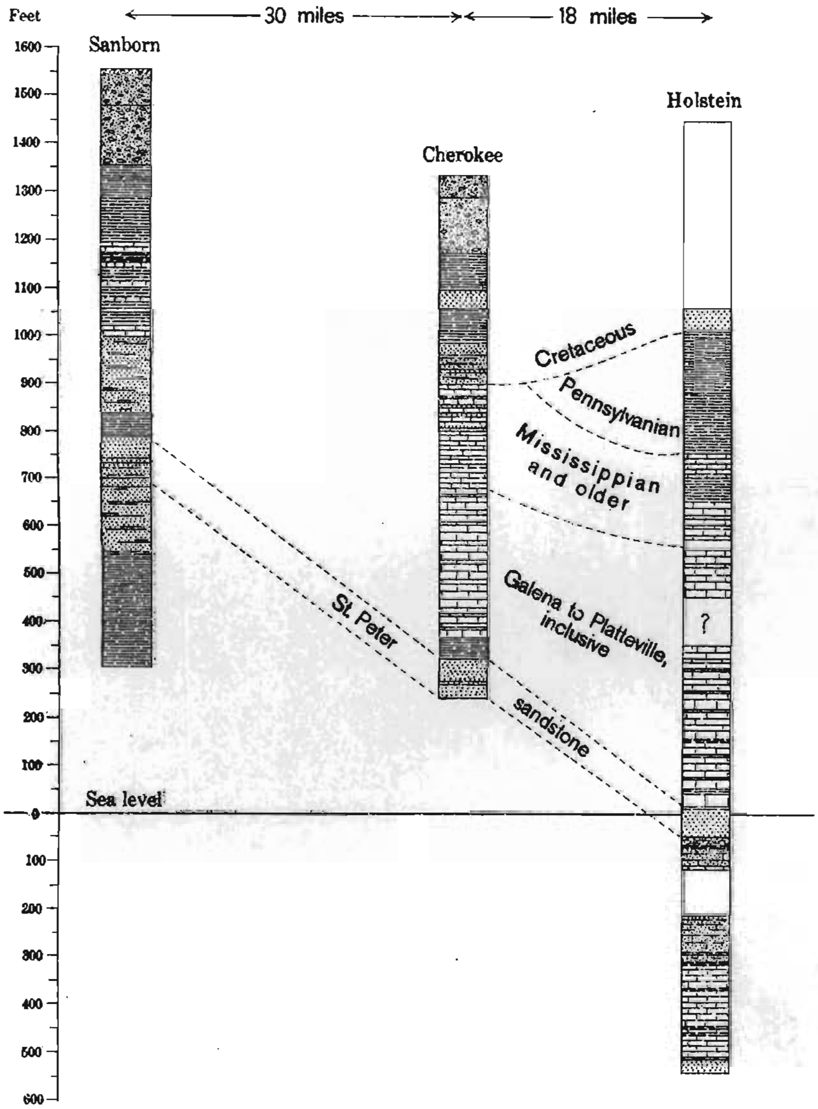
BY W. H. NORTON.

The northwest district includes nineteen counties—Buena Vista, Calhoun, Carroll, Cherokee, Clay, Crawford, Dickinson, Emmet, Ida, Lyon, Monona, O'Brien, Osceola, Palo Alto, Plymouth, Pocahontas, Sac, Sioux and Woodbury. Over this area the heavy mantle of drift has in few places been cut through by stream erosion and rock outcrops are rare. Below the clays and sands of the drift lie the shales and soft sandstones of the Cretaceous, which rest with marked unconformity on older terranes. The Carboniferous strata, on whose beveled edges the Cretaceous formations in most places rest, are prevailingly shaly, and the shales of these two series of rocks can be distinguished with difficulty when they are ground to powder by the drill. Another unconformity probably separates the Carboniferous from the older formations of the Paleozoic. The earlier Paleozoic strata strike northeast and southwest and dip southeast, the younger giving place westward to more ancient rocks.

From Emmetsburg to Fort Dodge the Saint Peter sandstone descends 874 feet in 48 miles, or at the rate of a little more than 18 feet to the mile. (See Pl. XVI, p. 814.) From Sanborn to Cherokee and Holstein its dip is 16 feet to the mile. (See Pl. XVII.) From Holstein to Dunlap, if the formation is rightly distinguished at Dunlap, its dip is somewhat less than 10 feet to the mile.

In the extreme northwest sections of Lyon county the Sioux quartzite outcrops. This is the most ancient rock exposed to view in Iowa and is referred to the Algonkian. Its surface sinks rather steeply toward the south and east from its outcrops in Lyon county.

On the whole, conditions appear to be somewhat favorable for artesian wells over a large part of northwestern Iowa. The successful well at Jefferson, just southeast of this area, suggests that deep wells in the southeastern counties might obtain satisfactory supplies. The deep wells at Sanborn, Cherokee and Holstein (Pl. XVII) carry the favorable forecasts to the counties of the second tier east of Missouri river, where the Ordovician and Cambrian sandstones may be found within drilling distance of the surface and will probably yield sufficient water for municipal supplies. A deep well at Emmetsburg, in the northeastern part of the district, was not successful. For the western tier of counties the forecast is far less favorable (pp. 1007). The Saint Peter and the subjacent formations enter northwestern Iowa from the east under their normal facies. At Holstein, where the drill hole was sunk about 550 feet below the summit of the Saint Peter, the samples preserved from below that formation indicate about 200 feet of the arenaceous dolomites of the Prairie du Chien stage, underlain by about 250 feet of the Saint Lawrence formation and 35 feet of sandstone referable to the Dresbach, the latter extending to the bottom of the well. At Le Mars (Plymouth county) the deep well affords no evidence of the strata penetrated between the base of the Cretaceous at 810 feet above sea level and the pre-Cambrian gneiss at 215 feet above sea level, except two sandstones reported at about 400 and 300 feet above sea level. (See Pl. VI, p. 310.) If the upper of these sandstones is the Saint Peter, the combined thickness of the subjacent terranes to the base of the Cambrian is only about 200 feet. At Sanborn (O'Brien county) a sandstone is reported at 787 feet above sea level, and below this lie nearly 450 feet of "shales, blue and green, mixed with sandstone" and "shales, green and white." This sandstone may be the Saint Peter or the Jordan, the shaly nature of the subjacent bed rather favoring the latter reference. At



GEOLOGIC SECTION BETWEEN SANBORN AND HOLSTEIN, IOWA
By W. H. Norton

Printed page faces p. 1006

Sioux City (Woodbury county) minute-grained, calciferous sandstones and marls, prevailingly glauconiferous, extend from the fundamental schists upward for about 250 feet. These have the appearance of the Saint Lawrence formation. At 155 feet above sea level occurs a white sandstone which, like that at Sanborn, may be either the Saint Peter or the Jordan.

Of the formations above the Saint Peter, the Decorah shale and the Platteville limestone cross the entire eastern area of northwestern Iowa in full force and continue at least as far west as Cherokee. They are succeeded upward by heavy dolomites, which no doubt include the Galena, and may also include the Maquoketa and formations of Devonian and Silurian age. These dolomitic beds measure about 300 feet at Cherokee and may exceed 500 feet at Holstein. At Sanborn they are not mentioned in the driller's log, but at Sioux City dolomites, largely cherty, occupy at least 300 and possibly 400 feet of the section above the Ordovician and Cambrian sandstones and glauconiferous shales. Though these dolomites at Sioux City may belong to the Prairie du Chien stage, their reference to the higher terranes is more in accordance with the supposed general stratigraphy of the area. At Jefferson all the samples of drillings for 650 feet above the shale of the Platteville and the Decorah shale are of dolomite or magnesian limestone. These limestones carry artesian water in other districts of Iowa, but practically nothing is known of their capacities here.

In the counties bordering on Missouri river, so much difficulty is felt in making artesian forecasts that general statements must suffice. The chief water-bearing strata are hundreds of miles from their nearest outcrops in the state in the eastern counties bordering Mississippi river, and though they have been carefully traced from one deep well to another far to the west the deep wells of western Iowa are so few, and so little is known of them that the line of stepping stones is so broken that little more than general stratigraphic considerations remain for guidance and support. Fortunately artesian water may be found in the Cretaceous sandstones under the drift, so that the question of a deeper supply is not so pressing as it otherwise would be.

In Lyon, Sioux and Plymouth counties the Sioux quartzite and pre-Cambrian schists underlie the region at depths rapidly increasing southward and eastward. Unquestionably above these pre-Cambrian rocks lie the older Paleozoic rocks, but their lithologic nature is largely a matter of conjecture and it is possible that in these counties they contain few or even no beds so constituted as to carry artesian water in considerable quantities. At Sioux City, for example, the well of the Sioux City Water Company penetrated the Paleozoic rocks to a depth of at least 700 feet, but failed to find artesian water in paying quantity. The deep well at Hull found water below 700 and 800 feet, and the supply was stated to be unlimited, but Mr. Meinzer was informed that the casing of the well had been cut at about 350 feet from the surface and that most of the water of the well came from this horizon in the country rock, a statement which finds some support in the head of the well as compared with those of other wells in the Cretaceous of the vicinity. The texture of the saccharoidal sandstones found at Hull at 755 feet to 1,263 feet would allow them to yield copiously, but at Hull they are interbedded with impervious sills. Outside the area of these igneous intrusions, an area that is probably small, these sandstones, if not indurated, may yield artesian water. Thus wells drilled below the Dakota sandstone in these three counties may be considered experimental. The geologic conditions are not strongly adverse to such experiments, but the two or three deep wells already sunk do not encourage them.

In Woodbury and Monona counties the Paleozoic rocks are no doubt thicker than they are in the northern counties bordering the Big Sioux and the possibility that they may include water beds is greater. The general geology of the deeper strata, so far as it can be inferred, is somewhat encouraging to deep-well digging in eastern Monona and Woodbury counties, but all artesian wells must be largely experiments and can not be definitely recommended. The lower Paleozoic water beds, if found, should occur at Onawa above 600 feet below sea level or within 1,650 feet of the surface, and a well of this depth should be sufficient to test possibilities at this station.

BUENA VISTA COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY AND GEOLOGY.

The surface of Buena Vista county consists essentially of a gently undulating drift plain containing numerous undrained depressions, the largest of which is occupied by Storm Lake. This plain ranges in altitude from less than 1,300 feet above sea level, in the southeast, to more than 1,500 feet in the vicinity of Alta. The only striking break in the topography is caused by Little Sioux river, which enters from the north and flows westward near the county line for some miles, occupying a gorge-like valley over 150 feet deep.

Beneath the thick and continuous mantle of glacial drift lies a stratified series of shales, sandstones and limestones, supposed to be Cretaceous in age. (See Pl. VI, p. 310.)

UNDERGROUND WATER.

SOURCES.

The water supply of Buena Vista county is drawn chiefly from alluvial deposits, the surficial portions of the glacial drift, sand in the deeper portions of the glacial drift, and Cretaceous sandstone. The alluvial deposits are practically confined to the valley of the Little Sioux in which they supply shallow wells; the surficial portions of the drift are penetrated by several thousand shallow bored wells, most of which yield only small supplies and many of which fail in dry seasons; the sand deposits in the deeper portions of the drift are reached by many drilled wells; and the Cretaceous strata have apparently been entered in a few places. Beneath these formations are other water-bearing formations not yet reached by the drill in this county, but some knowledge as to what is to be expected from these sources can be gained from the deep wells in the surrounding towns of Mallard, Emmetsburg, Sanborn, Cherokee and Holstein.

The only source of water below the surficial deposits and within reach of ordinary drilling consists of beds of incoherent sand. In times of severe drought the shallow wells on many farms failed and wells were drilled to these beds of sand, but they proved so unsatisfactory that most of them have been abandoned and reliance again placed upon shallow wells. The water is under low head, is highly mineralized, and is separated from the fine-grained and incoherent sand with great difficulty. Screens of fine mesh have been used, but the sand packs around these and becomes firmly cemented by precipitates from the water, and thus effectually closes the inlets, compelling the substitution of new screens or the abandonment of the wells. This incrustation has given so much trouble in so many wells that it has been generally concluded that the deeper sand strata are not practicable sources of water supply. These deeper sources are, however, greatly needed, and much of the failure in the past has been due to improper methods of drilling and finishing the wells. For the most part, two-inch "tubular" wells have been sunk and the pump valves have been fitted into the casing itself. For several reasons (see pp. 219-226) wells of this type are ill adapted to the conditions found in this region. Six-inch wells should be drilled and fitted with independent pumps. Then if the water is lifted slowly—for example, at the rate at which a windmill operates—the suction will be slight and regular, and in many wells screens can be dispensed with. But even where screens are found necessary, they are likely to last longer, and they can be drawn up with less difficulty through the large casing.

HEAD.

In general the water does not rise so near the surface in the deepest drilled wells as in those that end at higher levels. Owing to the indefinite character of the well data it is impossible to state to what extent the wells having low head are to be correlated with the Cretaceous sandstone and those having a higher head with the drift, but it seems evident that water from the Cretaceous rises to approximately 1,200 feet above sea level and water from most of the moderately deep drift beds rises much higher. In the following table the wells of the first group are believed to have a head of about 1,200 feet and those of the second group a higher head, but the head of the farm wells is uncertain because the surface altitude is not definitely known.

Head of water in and near Buena Vista County.

Location	Altitude of surface above sea level	Depth of well	Height to which the water rises	
			Above or below surface	Above sea level
Group 1.	Feet	Feet	Feet	Feet
Fonda (Pocahontas county)	1,234	331	+ 14	1,220
Aurelia (Cherokee county)	1,387	301	—190	1,197
Peterson (Clay county)	1,238	90	— 30	1,208
T. 90 N., R. 35 W. (Newell):				
Newell	1,264	285	— 65	1,199
T. 93 N., R. 36 W. (Lee):				
S. ½ sec. 2		417	—160	
NE. ¼ sec. 5		320	— 60	
T. 92 N., R. 38 W. (Elk):				
SE. ¼ sec. 34		338	—285	
T. 91 N., R. 38 W. (Nokomis):				
SE. ¼ sec. 28		330	—270	
SE. ¼ sec. 35		360	—300	
T. 90 N., R. 38 W. (Maple Valley):				
SW. ¼ sec. 1		350	—290	
SW. ¼ sec. 25		360	—280	
SE. ¼ sec. 29		300	—240	
Group 2.				
Rembrandt creamery well	1,335	280	— 65	1,270
T. 93 N., R. 35 W. (Poland):				
Marathon village well	1,394	161	— 74	1,320
T. 91 N., R. 37 W. (Washington):				
SE. ¼ sec. 30		216	+	

CITY AND VILLAGE SUPPLIES.

Alta.—The public water supply of Alta (population, 959) is pumped from two dug wells, 80 feet deep, one eight feet and the other three feet in diameter. It is distributed by gravity from a tank elevated upon a tower. About 9,000 gallons are said to be used daily and this is nearly the maximum yield of the wells. The inhabitants rely chiefly on shallow bored wells, many of which yield small and uncertain supplies.

Marathon.—The following section of the village well at Marathon (population, 532) was furnished by the driller:

Section of village well at Marathon.

	Thickness.	Depth.
	Feet	Feet
Soil and yellow clay; blue clay	70	70
Sand	10	80
Clay, blue	70	150
Sand	11	161

The water is reported to rise within 74 feet of the surface, or 1,321 feet above sea level, and the well has been pumped continuously for eight hours at the rate of 100 gallons a minute. The waterworks consist of an air-pressure system with one and one-eighth miles of mains, six fire hydrants, and 17 taps. Only a small portion of the people use the public supply and only about 2,000 gallons are consumed daily.

Newell.—The public supply for Newell (population, 728) is pumped from a drilled well, 285 feet deep, into an elevated tank, from which it is distributed by gravity through approximately one mile of mains. There are 14 hydrants. The daily consumption of water is estimated at 12,000 gallons.

Sioux Rapids.—The public supply of Sioux Rapids (population, 868) is obtained from a well 10 feet in diameter and 27 feet deep, sunk into the gravel of the river bottom. The water is pumped to an elevated tank from which it passes to the mains. There are 15 fire hydrants. The average daily consumption is reported to be about 30,000 gallons.

Storm Lake.—The public supply of Storm Lake (population, 2,428) is taken from the lake, from which it is pumped into a standpipe and is thence carried by gravity through about five miles of mains to 28 fire hydrants. The water is used extensively in boilers and for various other purposes and is led through private pipe lines to several farms near the city. The culinary supplies are obtained chiefly from shallow private wells.

According to Norton a deep well drilled at Storm Lake would first pass through the drift clays and sands, then through heavy beds of Cretaceous shales and sandstones, and possibly through still lower shales of the Coal Measures (Carboniferous), below which it would have a long run through limestones. After penetrating the shales of the Platteville limestone (which may need casing) the drill would enter the Saint Peter sandstone at about 120 feet above sea level, or about 1,300 feet below the surface. To obtain the largest yield the well should be sunk to about 1,700 feet below the surface, at which depth it should tap the Jordan sandstone, if that formation preserves its identity so far to the west. It will then have penetrated the dolomites and sandstones of the Prairie du Chien stage which separate the Saint Peter and the Jordan. On account of the high surface elevation, no flow can be expected, but the water should rise within pumping distance.

CALHOUN COUNTY.

BY W. J. MILLER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

Calhoun county presents a level surface over which many ponds are scattered. The only important stream that modifies this flat topography is North Raccoon river, which cuts across the extreme southwest corner of the county, receiving from the north Camp and Lake creeks, much smaller streams.

Wisconsin drift covers the entire region, resting on the Kansan drift, which presumably also extends throughout the county. Except in a narrow strip on the eastern edge of the county occupied by the Des Moines stage (Carboniferous), the drift rests on Cretaceous rocks.

The drift deposits lie horizontally on the rocks, which in turn either lie flat or dip slightly eastward. (See Pl. VI, p. 310.)

UNDERGROUND WATER.

SOURCES.

In Calhoun, as in the neighboring counties, there are two important water beds in the drift, one at the base of the Wisconsin drift and the other at the base of the Kansan drift. A large number of wells obtain good supplies of hard water from the drift and are as a rule so satisfactory that comparatively few wells go into the rock formations below.

The available data show that the sand or gravel at the base of the Wisconsin drift has not been struck at a depth of less than 45 feet and that in many localities it is more than 160 feet below the surface, the most common depths being 70 to 90 feet. Though most of the wells of the county derive water from this source, it does not everywhere yield water and in places the supply is not satisfactory. The sand or gravel lying at the base of the Kansan drift almost invariably affords a good supply of water, seemingly unaffected by the seasons. Well records show that this aquifer has not been struck at a depth of less than 108 feet or more than 280 feet, the most common depth being from 200 to 230 feet. Occasionally a good water supply is obtained from local sandy layers in one of the blue clays. Some deep wells have obtained water from shales, sandstones, and limestones of the Cretaceous and older rocks.

Only two flowing wells have been noted in this county, one near Somers and the other near Lohrville. Both are situated near small streams or slough bottoms. The horizon from which the water comes is not known.

SPRINGS.

Springs of any consequence are very scarce in Calhoun county. A few seep from the drift along the sloughs.

CITY AND VILLAGE SUPPLIES.

Lake City.—The public water supply of Lake City (population, 2,043) is taken from two wells 229 feet deep. The water is pumped to a standpipe and distributed under gravity pressure of 30 pounds to 172 taps. About 35,000 gallons are used daily by 600 people. The water is hard. (See analysis of water from deep well of Chicago & North Western Railway Company, page 178.) The driller's log of these wells shows the following section.

Driller's log of Lake City well.

	Thickness.	Depth.
	Feet	Feet
Soil, black	4	4
Clay, yellow	20	24
Clay, blue	36	60
Sand (water)	6	66
Clay, blue	20	86
"Hardpan"	6	92
Clay, hard	18	110
Clay, yellow; hard blue clay; fine sand (water)	119	229

The chief water beds of the Iowa artesian system lie deep below Lake City, the uppermost, the Saint Peter sandstone, hardly less than 300 or 350 feet below sea level, or from 1,550 to 1,600 feet below the surface. As the Paleozoic limestones overlying the Saint Peter yield more or less water a well 1,700 feet deep might obtain an adequate supply, but to get the largest supply a well 2,000 feet deep may be necessary and any contract for a deep well should provide for a depth of 2,200 or 2,300 feet.

In sinking such a well below the drift the drill will pierce Cretaceous and Carboniferous shales. The quality of any waters found in accompanying sandstones should be tested, as they may be so heavily impregnated with various mineral substances as to make it desirable to case them out. In the Mississippian limestone and the dolomites which extend thence downward to the shales of the Platteville limestone some water of fair quality should be had under good head; but the main supply is to be looked for in the Saint Peter sandstone and the creviced dolomites and porous sandstones underlying it.

Lohrville—The town well of Lohrville (population, 674), 180 feet deep, furnishes a good supply of hard water. The water is pumped to a tank, from which it is distributed under gravity pressure of 35 pounds through one-fourth mile of mains to 20 taps and five fire hydrants. About 3,100 gallons are supplied daily to 100 persons. No log is available.

Manson.—The public supply of Manson (population, 1,236) is obtained from a well 1,250 feet deep, put down in 1905 by J. F. McCarthy, of Minneapolis. (See Pl. VI, p. 310.) The well is cased with 10-inch pipe to 290 feet, 8-inch pipe to 834 feet, and 6-inch pipe to 1,250 feet. The curb is 1,245 feet above sea level and water stands 25 feet below curb. The tested capacity, original and present, is 300 gallons a minute. Water comes from 1,250 feet (according to another report from 1,050 feet) and from other depths unrecorded. The temperature of the water is 56° F. The water is pumped through three miles of mains to 25 fire hydrants and 75 taps. Domestic pressure is 50 pounds and fire pressure 80 pounds. About 400 persons are supplied daily. The daily consumption is 30,000 gallons. The water is said to be soft.

Driller's log of Manson city well (Pl. VI, p. 310).

	Thickness.	Depth.
	Feet	Feet
Soil and yellow clay	23	23
Clay, blue	187	210
Gravel and water	3	213
Clay, blue	97	310
Shale or slate; some hard; some soft; some red	740	1,050
Sandstone	170	1,220
Shale, red	30	1,250
Granite-like rock.		

A citizen of the town asserts that no rock of any kind was struck until the drill reached a depth of 1,050 feet, when it entered porous sand rock, from which water flowed in immense volume. Another citizen who had much to do with the well attempts to support the theory that this sandstone is the Saint Peter by stating that it was "as hard as flint and as white as snow, and ground up into fine dust or powder." The driller states that he believes "that it was the true quartz rounded white sand rock."

Literally construed this log would revolutionize the current conception of the deep geology of the region. Although but 18 miles distant from Fort Dodge, Manson is reported to find a heavy sandstone 600 feet higher than the first sandstone at Fort Dodge—the Saint Peter. The Saint Peter undoubtedly rises from Fort Dodge toward Manson, but according to the average dip from Cherokee to Fort Dodge the Saint Peter would not be encountered at Manson within 1,500 feet of the surface —450 feet below the summit of the sand rock of the Manson well.

If there are no local sharp deformations of the deep-lying strata in this region the aquifer at Manson is Silurian or Ordovician (Galena). Dolomites from these formations are not infrequently termed sand rock, because of the sparkling crystalline sand to which they are crushed by the drill. The description of the Manson water bed as "a rock hard as flint" in no way fits the Saint Peter, which is uniformly one of the softest of rocks, but seems to point to cherty layers that occur in both the Silurian and the Galena.

As to the granite-like rock at the bottom of the well, it is improbable that any deformation exists in this area sufficient to bring the floor of crystalline rocks so near the surface. The sample of this granite submitted for examination was a granitic pebble of glacial drift, about three inches in diameter.

The Manson well, with its exceptionally large supply of water of unusual softness and high head and its exceedingly peculiar log, emphasizes the need and value of keeping samples of the cuttings at frequent intervals as the well is drilled. There are few localities where the lack of such information is more severely felt.

If the well should fail and repairs should prove ineffectual, a larger supply may be obtained by sinking the well deeper. Assuming an uninterrupted dip of the terranes from Cherokee to Fort Dodge, the Saint Peter sandstone lies about 250 feet below the bottom of the drill hole. Drilling not only to the Saint Peter but also to the sandstones of the Prairie du Chien stage and the Jordan sandstone should give an inexhaustible supply within 1,900 feet of the surface.

Pomeroy.—The public supply of Pomeroy (population, 815) is obtained from a well 149 feet deep, from which it is pumped by direct pressure (air) through 1½ miles of mains serving 40 taps and 20 fire hydrants. The domestic pressure is 40 pounds and fire pressure 60 pounds. About 300 persons use the city supply. The daily consumption is 9,000 gallons. The water is rather hard. The strata penetrated by this well are indicated by the following log:

Driller's log of Pomeroy town well.

	Thickness	Depth
	Feet	Feet
Soil, black	3	3
Clay, yellow	12	15
Clay, blue	20	35
Sand (some water)	1	36
Clay, blue	45	81
Clay, yellow	15	96
Clay, blue	36	132
Sand and gravel (water)	17	149

Rockwell City.—Rockwell City (population, 1,528) owns two deep wells—one 1,475 feet deep and the other 950 feet deep. The latter well, which until recently supplied the town and two railways, is 12 inches to 6¼ inches in diameter and is cased with 10-inch pipe to 264 feet, 8⅝-inch pipe to 355 feet, and 6¼-inch pipe to 490 feet. The water stands 200 feet or more below the curb and has been pumped at rate of 105 gallons a minute. The well was completed in 1904 by J. P. Miller & Company, of Chicago.

The water is pumped to a standpipe, from which it is distributed under gravity pressure of 40 pounds domestic and 75 pounds fire through 2.6 miles of mains to 70 taps and 19 fire hydrants.

Driller's log for city deep well No. 1 at Rockwell City.

	Thickness.	Depth.
	Feet	Feet
Drift	264	264
Shale and streaks of rock, caving	91	355
Lime, hard, and shale, caving	135	490
Lime, hard	160	650
Lime, shaly	200	850
Lime, hard	91	941
Shale, sandy, to bottom of well	9	950

The deeper well was completed in 1910. The geologic section, so far as it can be made out from the samples saved, is as follows:

Record of strata, city deep well No. 2, Rockwell City.

	Thickness.	Depth.
Quaternary (161 feet thick; top, 1,223 feet above sea level):	Feet	Feet
Soil	2	2
Clay, yellow, sandy	20	22
Till, blue	133	155
Till, light yellow	6	161
Carboniferous:		
Pennsylvanian (160 feet thick; top, 1,062 feet above sea level)—		
Shale, dark drab	90	251
Sandstone, white; grains very imperfectly rounded; calcareous cement; much pyrite	3	254
Shale, blackish	50	304
Shale, dark drab, pyritiferous	5	309
Shale, light drab	12	321
Mississippian (499 feet thick; top, 902 feet above sea level)—		
Dolomite, dark buff, with finely disseminated white silica in granules; also dolomite, blue-gray, hard, compact, in larger chips	194	515
Dolomite, dark, buff, coarse crystalline-granular	85	600
Shale, light blue, calcareous but nonmagnesian, pyritiferous; also much buff and drab dolomite, in chips	220	820
Devonian and Silurian (160 feet thick; top, 403 feet above sea level):		
Limestone or dolomite; rather slow effervescence; light buff, fine crystalline-granular, in small chips	73	893
Dolomite, light yellow-gray; in sand	7	900
Dolomite, buff; in small chips; crystalline-granular	80	980
Limestone, dark blue-gray; slow effervescence; rather small argillaceous residue; some hard green shale and well rounded grains of quartz, at		980
Ordovician:		
Galena dolomite and Platteville limestone (492 feet thick; top, 243 feet above sea level)—		
Dolomite, brown, crystalline	50	1,030
Dolomite, brown, fine-grained, compact	110	1,140
Dolomite, light blue-gray, saccharoidal, cherty	50	1,190
Dolomite, light yellow, in fine crystalline sand	75	1,265
Dolomite, buff, granular crystalline	30	1,295
Dolomite, cream-colored, in fine sand	43	1,338
Limestone, whitish, rapid effervescence	75	1,413
Shale, greenish, facies of the Decorah	59	1,472
Saint Peter sandstone (5 feet penetrated; top, 249 feet below sea level)—		
Sand, white, with much brown bituminous shale in drillings	5	1,475
Shale		

Analyses of drillings from city deep well No. 2, Rockwell City.

	Depth of sample in feet		
	515-600	1190-1202	1265-1295
$CaCo_3$	56.583	69.608	57.742
$MgCo_3$	41.189	21.416	32.187
SiO_2	0.857	6.987	6.841
Fe_2O_3 and Al_2O_3	0.877	1.893	3.140
H_2O	0.109		
	99.615	99.904	99.910

[1]Made in chemical laboratory of Cornell College, Iowa.

It had been estimated that the Saint Peter sandstone would be found at 300 feet below sea level (1,525 feet below the surface). In May, 1910, this formation was reached at 1,472 feet below the surface.

Somers.—The Chicago Great Western well at Somers (population, 169) has a depth of 1,483 feet and diameters of 12 inches to 152 feet, 10 inches to 200 feet, 8 inches to 339 feet, and 6 inches to bottom; casing to 660 feet. The curb is 1,157 feet above sea level, and the head 60 feet below the curb. The capacity is 100 gallons a minute. The water comes from 1,000 to 1,200 feet (small amount) and from 1,470 feet (main flow). The well was completed in 1904 by C. A. Stickney of St. Paul. Two sets of samples of the drillings have been examined, one having been sent to the United States Geological Survey at Washington and one directly to the senior writer by a contractor. The two are conflicting and several of the labels are evidently incorrect:

Record of strata in railway well at Somers.

	Depth in feet.
Till (U. S. Geol. Survey sample): Limestone, yellow; slow effervescence; hard, dark drab; calcareous and siliceous shale, all in fine sand	60
Limestone, gray; slow effervescence	60
Till, blue (U. S. G. S.)	78
Till, blue (U. S. G. S.): Limestone, light buff; slow effervescence; much white chert	106
Shale, dark, carbonaceous (U. S. G. S.); limestone, crystalline, light yellow-gray, hard; slow effervescence	155
Shale, blue (U. S. G. S.); limestone, light buff, hard; slow effervescence	210
Shale, dark drab, carbonaceous (U. S. G. S.); shale, blue, noncalcareous, pyritiferous, minutely arenaceous	220
Dolomite, buff, porous, crystalline, in sand at 508, 520, and	566
Limestone, gray, cherty; slow effervescence	680-689
Dolomite, crystalline; gray; much white and gray chert and some rather fine rounded grains of quartz sand	1,315
Dolomite, buff; much white chert	1,320
Dolomite, drab and white; a few grains of quartz sand	1,335
Dolomite, buff; with white chert	1,340
Dolomite, light yellow-gray (U. S. G. S.); shale, dark drab, black when wet, apparently from Coal Measures and evidently misplaced	1,345
Dolomite, white, crystalline; in fine sand	1,350
Dolomite, buff	1,355
Dolomite, white and gray; 1,360 and	1,365
Dolomite, light gray; with white shale	1,370
Dolomite, light yellow	1,375

Record of strata in railway well at Somers—Continued.

Dolomite, gray (U. S. G. S.); limestone, light yellow, rapid effervescence, compact, earthy luster; some lithographic with conchoidal fracture, probably misplaced	1,380
Dolomite, light yellow, crystalline	1,385
Dolomite, light gray (U. S. G. S.); drab till, evidently misplaced	1,390
Marl, light pinkish yellow; large residue of cryptocrystalline and crystalline quartz particles	1,395
Dolomite, buff; cherty, at 1,400, 1,410, and	1,415
Dolomite, light and dark gray	1,420
Marl; as at 1,395 feet	1,425
Dolomite, white, gray, and buff, some chert; 6 samples	1,430-1,470

It may be added that the driller who had charge from 660 feet to the completion of the well reports that for this distance the drill appeared to be working in one solid mass of hard "lime rock." The dolomites from 1,315 to 1,470 feet evidently belong to the Galena. (See Fort Dodge section p. 918.

WELL DATA.

The wells listed in the following table may be considered typical for the county:

Typical wells of Calhoun County.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
Frank Casey	4 miles southwest of Manson.	162		Sand	20	Bored well, 12 inch. Black soil, 3; yellow clay, 22; sand (some water), 6; blue clay, 129; sand and water, 2; no rock.
G. Haney	2 miles north of Rockwell City.	125		do	40	Bored well, 22 inch. Black soil, 3; yellow clay, 15; blue clay, 106; sand and much water, 1; no rock.
Sam Ness	3 miles northeast of Somers.	300	230	Sandstone	90	Black soil, 4; yellow clay 20; blue clay, 106; gravel, (no water), 5; blue clay, 93; sand, 2; sandstone (water at bottom), 70.
Henry Arnold	2½ miles east of Manson.	196		Sand and gravel.	60	Black soil, 3; yellow clay, 17; blue clay, 60; sand (no water), 8; blue clay, 107; sand and gravel and water, 6; no rock.

Typical wells of Calhoun County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
Charles Dunnonn	1½ miles south of Manson.	223	------	Gravel ----	20	Black soil, 3; yellow clay, 15; blue clay, 60; yellow clay, 25; blue clay, 65; clay (harder), 50; "hardpan" hard clay, 1; gravel (water), 4, no rock.
J. D. Hunt------	½ mile east of Manson	198	------	------------	17	Water in rock (?) at base.
Moody & Davey	½ mile south of Jolley	145	129	Shale (?)---	22	
R. S. Middleton-	2 miles south of Lohrville.	53	------	Gravel-----	15	No rock.
George Linvillinger.	5 miles east-northeast of Lake City.	209	------	---- do ----	100	Black soil, 3; yellow clay, 10; blue clay, 62; sand and gravel (dry), 75; yellow clay, 4; sand and gravel (dry), 46; sand and gravel and water, 9; no rock.
—— Workman --	3 miles south-southeast of Lake City.	126	------	---- do ----	60	No rock.

CARROLL COUNTY.

BY W. J. MILLER AND W. H. NORTON.

TOPOGRAPHY.

Carroll county is divisible into two topographic provinces by a line extending from the northwest to the southeast corners. The line of separation is, however, not sharp. The southwestern area is made up of low rounded hills and intervening valleys like those in Crawford county, to the west, and is crossed by the high land of the Iowa divide. It is cut by many small streams, of which Brushy creek, on the east side, is the largest. The northeastern area is primarily a flat country, poorly drained except in the vicinity of the main waterways and showing only very broad, gentle undulations; North Raccoon river crosses its northeastern corner and Middle Raccoon river flows along its western border. Branching streams are few.

GEOLOGY.

The loess covers half of the county, but thins eastward. In the southwestern half of the county it rests everywhere on Kansan drift. Wisconsin drift extends over all of the northeastern half and causes the level land of that region. The Kansan drift, under the loess or under the Wisconsin, is spread over the whole county. The drift is exceedingly thick in the western part along the Iowa divide and gradually becomes thinner toward the east. Rocks of Cretacous age, lying flat or dipping very gently eastward, everywhere underlie the Kansan drift. (See Pl. XI, p. 458.)

UNDERGROUND WATER.

SOURCES.

At least three well-defined water horizons are found in the drift deposits of Carroll county—one in sand or gravel just below the loess at depths ranging from 10 to 50 feet below the ground surface; one in sand and gravel beneath the Wisconsin drift at depths ranging from 70 to 150 feet; and the third in sand or gravel just below the blue clay of the Kansan at depths ranging from 150 feet to 400 feet. The beds at the last-named horizon are the most widespread, persistent, and satisfactory, almost everywhere yielding water in large supplies, unaffected by seasons. The greatest depths to water are found in the western part of the county along the Iowa divide, where the drift is deepest. In some wells water has been struck in sandy layers within the blue clays of either the Wisconsin or the Kansan drift.

Little is known regarding the sources of water in the rock formations underlying the drift, but a few wells have been drilled through the thin Cretaceous beds, and derive their water from the Upper Coal Measures (Missouri stage).

In the loess-covered southwestern half of the county many dug wells obtain water from the sands and gravels below the loess and below the blue clay of the Kansan. In the northeastern half of the county, where Wisconsin drift overlies the

Kansan, many drilled wells obtain water at the base of the Wisconsin and at the base of the Kansan.

In the northeastern area, especially toward the east side of the county from Lanesboro southward to Coon Rapids, the drift deposits, like the ground surface, slope gradually downward from the Iowa divide, and low ground along the stream courses affords conditions favorable for flowing wells. A number of such wells are found along North Raccoon river or Middle Raccoon river and its tributaries and on low land near them, where the head of water is great enough to cause overflow. The gathering ground for this water is probably on the higher land farther west. The water in most of these wells is thought to come from gravel under the blue clay of the Wisconsin at depths ranging from 25 to 130 feet according to location. Along Willow creek, in the extreme southeastern part of the county, flowing wells are easily obtained at depths ranging from 25 to 40 feet.

SPRINGS.

In the eastern part of the county along the principal stream bottoms, such as North Raccoon river and Middle Raccoon river, are many small springs, most of them from the Wisconsin drift.

CITY AND VILLAGE SUPPLIES.

Carroll.—Carroll (population. 3,546) is supplied from three wells 113, 116, and 120 feet deep. The water is pumped to a standpipe, whence it is delivered by gravity through 4½ miles of mains to 38 fire hydrants and 300 taps. Three thousand people use 150,000 gallons daily. The domestic pressure is 85 pounds and the fire pressure 100 pounds.

The drilling of a deep well at Carroll (elevation, 1,251 feet) is not discouraged, but it should be definitely understood that the quantity and quality of the water in the deeper rocks are not certain. Some water will be found in the drift, in the sandstone interbedded with the heavy shales of the Cretaceous and the Pennsylvanian, and in the underlying Mississippian limestones. Water should also occur in the dolomites (Galena), hundreds of feet thick, that intervene between the Mississippian and the Decorah shale. If the general attitude of the deep strata assumed for western Iowa prevails here, and there is no local deformation, the Saint Peter sandstone lies about 400 feet below sea level, or 1,650 feet beneath the surface.

For a town the size of Carroll a well should be sunk through the Saint Peter and the underlying creviced dolomites and porous sandstones, which as a rule yield far more generously. When the drill reaches any considerable thickness of glauconiferous shales or marls, drilling should be stopped. The water may be expected to belong to the sodic sulphated class. If the upper waters from the Cretaceous and Carboniferous are admitted to the well the water will probably be distinctly more highly mineralized.

Minor supplies.—Small village supplies are summarized in the table below:

Minor supplies in Carroll County.

Town	Nature of supply	Pumping system	Distribution	Pressure		Mains	Fire hydrants	Taps	Persons supplied	Daily consumption
				Domestic	Fire					
				lbs.	lbs.	Miles				Galls.
Coon Rapids	Well 90 feet deep.	Steam pump, double acting.	Gravity from tank.	40	(?)	1	15	40	850	12,000
Glidden	2 wells 122 and 132 feet deep.	Gasoline engine and deep well pump.	Direct (air) pressure. *a*	20-70	70	1⅓	12	140	700	30,000-40,000
Manning	17 driven wells with sand points. *b*.	Steam pump, double action.	Gravity from tank.	60-80	80+	1.1	18	161	1,200	30,000

a One tank in reserve for fire.
b One well dug for fire only.

WELL DATA.

The following table gives data of typical wells in Carroll county:

Typical wells of Carroll County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
J. Shrower	2 miles east of Arcadia.	400	360	Sandstone	— 75	Drift, 360; sandstone, 40.
Town	Glidden	122		Sand	— 76	Soil, and yellow clay, 40; blue clay, 50; sand, 32; no rock.
Mrs. C. J. Brown	7 miles southeast of Glidden.	175		Gravel and sand.	— 80	20 foot bed water-bearing sand at bottom. Gasoline engine pumps 90 gallons a minute. No rock.
O. C. Dutton	5 miles south, 2 miles east of Glidden.	426	175			Unsuccessful well. Black soil, yellow clay, blue clay, gravel (no water), 175; sandstone, 25; shale (hard and black) and sandstone layers, 218; coal, 8.
Chas. Stuteman	5½ miles north, 2 miles west of Glidden.	316		Gravel	— 4	Flows through pipe out of side of well. No rock.
M. J. Hieres	1 mile northwest of Carroll.	435		Sand and gravel.	—100	8-foot sand bed at bottom. No rock.
W. Anderson	5 miles northeast of Arcadia.	400	(?)	Sandstone or cemented sand		
H. Eklers	6 miles south of Arcadia.	400+		Sandstone		Sandstone or consolidated sand.
Chicago & North Western Ry.	Carroll	158		Sand		Steam pump for railway. No rock.
Mr. Kelly	3 miles south of Lanesboro.	70		Gravel	—+	Flows at elevation of several feet. Yellow clay and pebbles, gravel, 20; blue clay, 35; sand, gravel (water), 15; no rock.
Y. Moore	2 miles northeast of Lidderdale.	248		Gravel and sand.	— 40	No rock.
Mr. Arneal	¾ mile west of Lidderdale.	238		Sand	— 40	Do.
G. W. Stout	Coon Rapids	250		Sand or sandstone.	—190	Do.

CHEROKEE COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

Cherokee county occupies a gently undulating upland plain, most of which is more than 1,300 feet above sea level and a part more than 1,400 feet. Intrenched in this upland is the valley of Little Sioux river, whose flood plain throughout most of its course is less than 1,200 feet above the sea.

The upland surface is covered by a thick layer of glacial drift, whose upper portion is somewhat yellowish and gravelly, but whose deeper portions consist chiefly of a denser and darker bowlder clay. In the valleys water-laid deposits of gravel, sand, and clay are found at the surface. Below the glacial drift is a stratified series of soft blue shale and poorly cemented sandstone, supposed to be Cretaceous in age, and below this are older sedimentary formations. (See Pls. VI, p. 310; XVII, p. 1006.) The Cretaceous strata have apparently been entered by the drill in a number of wells, and the underlying older formations have been deeply penetrated at the Hospital for the Insane at Cherokee, in a well sunk from the upland level to a depth of 1,070 feet.

UNDERGROUND WATER.

SOURCES.

The water supplies are derived from the alluvial sand and gravel, glacial drift, Cretaceous sandstones, and pre-Cretaceous sandstone (deep well at Hospital for the Insane).

The alluvial sands and gravels are practically restricted to the valley of the Little Sioux, where they yield copious quantities of water, which is of excellent quality where the wells are protected from pollution.

The clay and gravel that constitute the upper layers of glacial drift are tapped by several thousand shallow wells and furnish nearly all of the water used for culinary, stock, or other purposes on the extensive upland tracts. The abundance and permanence of the supply from this source vary with different localities according to the amount of gravelly material and the depth at which it is found and also according to the topographic relations that determine the ease with which the water may be drained from these porous beds. Where conditions are favorable the supply is ample at all seasons, but where they are adverse serious difficulty is experienced during dry years. The wells are generally sunk in low places, the conditions being so local that radical differences are found in different parts of the same farm. The water is hard, but is otherwise generally of good quality.

A small number of drilled wells end in sand and gravel at or near the base of the drift, and most of these wells are giving satisfactory service. In some localities, however, water-bearing deposits have not been found in the deeper portions of the drift.

Only a few wells extend to the Cretaceous. Some of these are successful, but in others there is difficulty in separating the water from the fine incoherent sand. The water from this source rises to about 1,200 feet above sea level. Thus on the uplands it remains 200 feet, more or less, below the surface, but in the Little Sioux valley in some places it overflows. It should not be supposed that because flows are obtained in the valley they can also be obtained by deep drilling on higher ground.

HEAD.

The following table gives approximate data as to the head of the water in some of the deepest wells in the county:

Table showing head of water in Cherokee County.

Description	Altitude of surface above sea level	Depth	Height to which the water rises	
			Above or below surface	Above sea level
	Feet	Feet	Feet	Feet
Aurelia village well	1,387	301	—190	1,197
Group of farm wells near Aurelia	1,390[a]	300-375	—190[a]	1,200[a]
Three Cherokee city wells	1,180[a]	165-200	+0	1,180
Two hospital wells at Cherokee	1,350[a]	343	—150	1,200[a]
Group of wells between Cherokee and Quimby	1,190-1,200	100	+0 to —10	1,190

[a]More or less.

CITY AND VILLAGE SUPPLIES.

Aurelia.—The well which furnishes the public supply of Aurelia (population, 625) is 301 feet deep and ends in sand from which water rises within 190 feet of the surface, or very nearly 1,200 feet above the sea. It has been tested at 50 gallons a minute. The water is lifted from the well into a cistern from which it is pumped into two air-tight tanks and thence distributed by air pressure through more than a mile of mains to 14 fire hydrants and 23 taps. A small portion of the people use the water, and it is reported that about 6,000 gallons are consumed daily.

Cherokee.—About half of the people of Cherokee (population, 4,884) are supplied from the city waterworks and the other half from private wells, most of which are shallow. The public supply is obtained from three flowing wells 165 to 200 feet deep, situated in the valley and apparently ending in sandy Cretaceous strata. The artesian head is about 1,180 feet above sea level. The water is allowed to discharge into an underground reservoir from which it is pumped into a standpipe and distributed through the mains by gravity. There are 40 fire hydrants and approximately 400 taps and it is estimated that 115,000 gallons of water are consumed daily.

At some date preceding 1890 a deep well was drilled at Cherokee in the center of the town. The following record is given by Todd:[1]

[1]Todd, J. E., proc. Iowa Acad. Sci., vol. 1, pt. 2, 1892, p. 14.

Old city well at Cherokee.

	Thickness.	Depth.
	Feet	Feet
Pleistocene, or unknown	800	300
Limestone, light blue	400	700
Shale, blue, or soapstone	260	960

Well No. 1 of the State Hospital for the Insane has a depth of 1,070 feet. The curb is 1,338 feet above sea level and the head 150 feet below curb. The tested capacity is 60 gallons a minute. Water was found at 240, 435, 470, and 725 feet (rising within 180 feet of the curb), and from 1,012 feet to the bottom (rising within 150 feet of the curb). Date of completion, 1902.

Driller's log of State Hospital well No. 1, at Cherokee.

	Thickness	Depth
	Feet	Feet
Loam, black	4	4
Clay, light yellow	36	40
Clay, dark yellow	20	60
Clay, blue-gray; gravel	20	80
Clay, light blue; gravel	40	120
Clay, dark blue	10	130
Clay, blue-gray; gravel	30	160
Clay, dark blue	80	240
Quicksand	15	255
Gravel	5	260
Quicksand	10	270
Clay, gray-blue	10	280
Clay, pink and blue	10	290
Clay, blue-gray	50	340
Clay, dark blue	15	355
Sandrock	20	375
Slate	10	385
Slate, pink	15	400
Gravel	5	405
Slate, gray	5	410
Slate, pink and red	20	130
Limestone, gray	20	450
Slate, gray	20	470
Limestone	10	480
Slate, light	10	490
Limestone	15	505
Sandrock	5	510
Slate	15	525
Sandrock	10	535
Limestone, crevice of 10 feet at 735 feet	430	965
Slate	50	1,015
Sandrock	55	1,070
Shale, soft, crumbling		

Record of strata in State Hospital well No. 1, at Cherokee (Pl. VI, p. 310; Pl. XVII, p. 1006).

	Thickness.	Depth.
Quaternary (160 feet thick; top, 1,338 feet above sea level):	Feet	Feet
Soil	10	10
Clay, pale yellow, calcareous; with sand and small pebbles; a till, 2 samples	20	30
Clay; as above, with flakes of drab siltlike clay, the dark color disappearing before blowpipe	10	40
Till, yellow; slightly darker than at 10 feet; calcareous	10	50
Till; as at 30 feet	10	60
Till, greenish drab, calcareous	10	70
Till, blue	10	80
Till, drab	10	90
Clay, fine, yellow-drab, dense; nodules of lime; limestone pebbles numerous; drillings contain pebbles of northern drift, and soft, lignitic coal; 3 samples	30	120
Clay, drab, dense; reddens before blowpipe; destitute of pebbles; calcareous, gritty	10	130
Clay; as at 90 feet	30	160
Cretaceous (275 feet thick; top, 1,178 feet above sea level):		
Shale, dark drab, gritty; few if any pebbles present; very slightly calcareous; in tough cemented masses; 8 samples	80	240
Sandstone, fine, green-gray	15	255
Sandstone, coarse, yellow	5	260
Sandstone, fine, yellow	10	270
Sandstone, light gray, fine, argillaceous	10	280
Shale, light gray, noncalcareous, gritty	10	290
Shale, drab; in molded masses with no cuttings of fissile shale; gritty, practically noncalcareous; less argillaceous than Maquoketa and Pennsylvanian shales; 10 samples	65	355
Sandstone, light gray, fine; grains but slightly rounded; mostly of clear quartz, 4 samples	20	375
Sandstone; as above, somewhat argillaceous	5	380
Shale, white, highly arenaceous; grains minute; noncalcareous	10	390
Shale, ocher-yellow; as above	5	395
Shale; as at 380 feet	5	400
Sandstone, yellow, coarse, argillaceous	5	405
Shale; as at 380 feet	10	415
Sandstone, fine, brown	10	425
Shale, pink, noncalcareous	5	430
Shale, yellow-gray	5	435
Carboniferous (Mississippian) (220 feet thick; top, 903 feet above sea level):		
Chert, white	5	440
Limestone, dark and light drab; granular-crystalline, rather soft; rapid effervescence; in flaky chips	10	450
Limestone, gray, argillaceous; minute fragments in the midst of powder; large quartzose residue with some chert	10	460
Shale, blue, calcareous	10	470
Limestone, dark drab, hard, crystalline; moderately slow effervescence	5	475
Limestone, earthy; light yellow-gray; rapid effervescence; in large flakes	5	480
Sandstone; grains irregular in form, varying widely in size, mostly of clear quartz, but some of reddish cryptocrystalline silica; considerable shale	5	485
Limestone, light gray, nonmagnesian, fine-grained; much sand and shale; 3 samples	15	500
Sandstone, grains subangular	5	505
Limestone, light yellow and drab; nonmagnesian	5	510
Sandstone, gray; grains irregular, mostly of clear quartz, but some green and red	5	515
Shale and limestone; large fragments of green shale; small chips of limestone with quartz sand	10	525
Sandstone, gray; as at 510 feet	10	535
Chert, white, and some light gray nonmagnesian limestone	5	540
Limestone, light gray; brisk effervescence; soft; with considerable chert; 3 samples	15	555
Limestone, light gray; moderately effervescent	10	565
Limestone, dark drab, argillaceous, soft; in large flakes; brisk effervescence; cherty	10	575
Limestone, dark brown, cherty	10	585
Limestone, dark brown; moderate effervescence; some chert	10	595
Limestone, gray, cherty; moderate effervescence	5	600
Limestone and chert; drillings largely quartz sand, probably from above	10	610
Limestone, drab; effervescence slow; cherty	15	625
Limestone, blue-gray, highly argillaceous	5	630
Limestone, brisk effervescence; granular drillings consist largely of fine quartz sand	25	655

Record of strata in State Hospital well No. 1, at Cherokee (Pl. XVII).

	Thickness.	Depth.
	Feet	Feet
Ordovician:		
Galena and Platteville limestones (360 feet thick; top, 683 feet above sea level)—		
Limestone, magnesian; in fine powder; 4 samples	20	675
Dolomite, blue gray; some chert in places; 54 samples	285	960
Dolomite and shale	5	965
Shale, blue; 9 samples	50	1,015
Saint Peter sandstone (55 feet thick; top, 323 feet above sea level)—		
Sandstone, white; 5 samples	20	1,035
Sandstone; no samples	35	1,070
Prairie du Chien stage—		
Shale (Shakopee), soft; no samples.		

Analysis of drilling at 765 feet.[a]

$CaCO_3$	50.29
$MgCO_3$	41.47
SiO_2	4.92
Fe_2O_3	.89
Al_2O_3	.67
H_2O	2.68
	100.92

Well No. 2, at the State Hospital for the Insane, located 80 feet from well No. 1, has a depth of 343 feet and a diameter of 12 inches; 12-inch casing to 335.5 feet. Water enters between 330 feet and the bottom. The maximum daily yield is reported to be 125,000 gallons. The well was drilled a few months after the completion of well No. 1. Its water is said to be much the better, but it contains sediment which varies considerably in quality from time to time. For weeks together the water will remain so clear that it can be used in the pipes and flush tanks of the institution without trouble and for all domestic purposes; it may then suddenly become so filled with silt as to wear the pump leathers and deposit sediment in the flush tanks, and a week or two of pumping may be required to clear it.

Marcus.—The public supply of Marcus (population, 896) is derived from two dug wells, each 10 feet in diameter and 20 feet deep; they seem to furnish an adequate and dependable supply. The waterworks include 1 1-3 miles of mains, with which are connected 16 fire hydrants and 67 taps. It is estimated that the water is used by approximately one-third of the population.

[a]Made in chemical laboratory of Cornell College, Mount Vernon, Iowa.

CLAY COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY.

Clay county is bordered on the east by a belt of high land characterized by irregular morainic topography, with numerous lakes, ponds, swamps, and sloughs. Farther west the surface is more gently undulating and somewhat better drained.

Little Sioux river flows irregularly southward through the central part of the county; after crossing the southern boundary it turns northwestward, reenters the county, and cuts across the southwest corner. Its valley is wide and shallow in the north, but becomes deeper and narrower downstream.

The highest parts of the county are along the east and west margins, where the general altitude is between 1,400 and 1,500 feet above sea level; the lowest point is where the Little Sioux crosses the west boundary, below the village of Peterson, at an altitude of scarcely more than 1,200 feet.

GEOLOGY.

The surface deposits of Clay county comprise outwash materials and bowlder clays. The outwash materials consist of stratified gravel and other sediments. They occur along Little Sioux river and are well developed in the vicinity of Spencer. The bowlder clay, which has an average thickness of several hundred feet, is yellow and gravelly near the surface but denser and darker at greater depths. Interbedded with it are a few lenses of sand and gravel.

Beneath the bowlder clay there is a stratified series of soft shales, limestones, and sandstones of probable Cretaceous age.

The following is the driller's log of the deep well of D. C. White:

Section of deep well of D. C. White at Webb.

	Thickness.	Depth.
	Feet	Feet
Clay, yellow, etc.	40	40
Clay, blue	145	185
Sand	8	188
Clay, blue	38	228
Clay, yellow	34	260
Clay, dark blue	90	850
Clay, light blue, and sand	97	447
Quicksand and gravel	4	451
Limestone and sandstone	99	550
Soapstone.		

UNDERGROUND WATER.

SOURCES.

The horizons from which water is taken may be grouped as outwash sands and gravels, surficial portions of the glacial drift, sand and gravel deposits in the deeper portions of the drift, and Cretaceous sand strata.

In the valley of Little Sioux river, and also in a rather extensive low-lying area associated with Little Sioux and Ocheyedan rivers east of Spencer, outwash deposits furnish an abundant and permanent water supply to very shallow driven wells. Elsewhere most of the supply is obtained from shallow wells bored or dug into the upper part of the unstratified glacial drift, from which they receive seepage.

The drilled wells, which constitute a very small percentage of the total number, are supplied from deeper horizons that probably belong to the drift, although the sections of only a few wells were obtained. In depth they range from less than 100 feet to at least 550 feet. In the Little Sioux valley, especially in the lower portion, the water in these wells rises nearly to the surface, but on the uplands it remains at considerable depths. Thus in the village well at Peterson, situated in the valley, the water comes within 30 feet of the surface, whereas in the deep well of D. C. White at Webb it stands 180 feet below the surface, though in both wells it rises to approximately the same level, about 1,200 feet above the sea.

The deepest water-bearing formations have not been reached by the drill, but successful deep wells have been sunk at Emmetsburg and Mallard, about 12 miles east of the east boundary. (See pp. 1071 and 1072.) In Clay county the head of the water from these deep formations would probably not be higher than in the deepest wells already drilled. At Spencer the surface elevation is 1,315 feet above sea level and the deep water would probably not rise higher than 1,200 feet.

CITY AND VILLAGE SUPPLIES.

Peterson.—The village well at Peterson (population, 480) is 90 feet deep, the last 20 feet being in sand and gravel. It is pumped at 20 gallons a minute and is giving satisfactory service. The water is lifted into a surface reservoir on the top of the valley cliff and thence distributed by gravity. There is a small system of mains with five fire hydrants and 20 taps. The average daily consumption probably does not exceed 1,500 gallons.

Spencer.—The public supply of Spencer (population, 3,005) is obtained from three 16-foot wells, one 40 feet, one 16 feet, and one 8 feet in diameter, dug in outwash sand and gravel. The wells will fill within 5 feet of the top and furnish 1,000 gallons of water a minute. The water is pumped to an elevated tank and distributed through 4½ miles of mains to 21 fire hydrants and about 200 taps. Approximately 1,000 people are supplied, and 100,000 gallons are consumed daily.

CRAWFORD COUNTY.

BY W. J. MILLER.

TOPOGRAPHY AND GEOLOGY.

Crawford county lies just west of the Iowa divide and its principal drainage slope is toward the southwest. The surface is made up of low rounded hills, the rolling contours being somewhat more pronounced in the western portion than in the eastern. The region is thoroughly dissected by many branching streams, the largest of which, Boyer river, flows across the county from northeast to southwest. Soldier river and its branches flow across the northwestern part.

Both the loess and the Kansan drift are well represented, the combined thickness on the Iowa divide being 450 to 550 feet, much above the average for the state. Both the loess and the Kansan are spread over the entire county. Over much of the county the Kansan drift rests on rocks of Cretaceous age, chiefly sandstones. In places, however, heavy limestones, probably of Missouri age, immediately underlie the glacial deposits. Except for variations in the thickness, the drift deposits are horizontal. The Cretaceous rocks probably dip slightly westward; the older rocks lie nearly flat or dip slightly eastward. (See Pl. XI, p. 458.)

UNDERGROUND WATER.

SOURCES.

The water supply of Crawford county is largely obtained from shallow dug wells and the supply in general is not altogether satisfactory, because many of the wells are affected by the seasons and fail altogether in times of extreme drought.

There are two important water horizons in the drift deposits. One is found in sand or gravel just below the loess and is reached by wells that range in depth from a few feet to 75 feet, depending on the thickness of the loess; this is the so-called "first water" level. The second horizon is found in sand or gravel just below the blue clay of the Kansan drift. Though much more satisfactory than the first, comparatively few wells extend to it, as it lies 140 to 500 feet below the surface, the greater depth being in the eastern portion of the county. Wherever tapped, however, it yields a never-failing supply. A few wells obtain a good water supply from local layers of sand or gravel within the blue clay, but as a rule these layers are either dry or yield little water, and in some of them the water is so heavily charged with decomposing organic matter as to give off a disagreeable odor.

A few wells have passed through drift deposits into the underlying Cretaceous sandstones or Missouri limestones. Most of the deeper rock wells are in the eastern part of the county.

SPRINGS.

Springs are not common in this county. Small springs or seepages from the drift are found along the chief stream courses.

CITY AND VILLAGE SUPPLIES.

Denison.—Denison (population, 3,133) draws its supply from two wells 25 feet deep, which it pumps by steam, delivering the water by gravity from a standpipe with a pressure of 45 to 90 pounds. There are 6½ miles of mains, 42 fire hydrants, and 600 taps. Three thousand people use the water, consuming 98,000 gallons daily. The supply is apt to run short in dry weather.

According to Norton, any deep well forecast for Denison must be based on the supposed general succession of formations deeply buried below the surface and pierced by no wells within scores of miles. Whether the Saint Peter sandstone extends this far west is uncertain though probable. The drill may be expected to pass first through heavy Pleistocene deposits of stony clays and sand and gravel beds and through heavy Cretaceous and Pennsylvanian shales with some sandstones; below these beds it will find Mississippian limestones, probably in part cherty. These limestones may be expected to rest on dolomites of uncertain age, accompanied by much argillaceous limestone and considerable shale. It is quite possible that the shale of the Platteville will be found to rest directly on the arenaceous dolomites of the Prairie du Chien stage at about 200 feet below sea level; or the latter may be absent and the Ordovician sandstones may not be found higher than about 1,350 feet from the surface. From a level about 1,350 feet below the surface the drill will very probably pass through several hundred feet of sandy dolomites and sandstones which carry water; and a well 1,500 or 2,000 feet in depth is not likely to fail of moderate success. Water will not flow from these deep formations but should rise within pumping distance.

Minor supplies.—The following table summarizes minor village supplies.

Minor supplies.

City or town	Nature of supply	Pumping system	Distribution	Pressure: Domestic	Pressure: Fire	Mains (miles)	Hydrants	Taps	Persons supplied	Daily consumption	Remarks
				lbs.	lbs					gals.	
Arion	Well 40 feet deep.	Gasoline engine	Gravity from reservoir on high hill.	100	100	$\frac{1}{2}$	(?)	(?)	---	------	Good supply.
Charter Oak	10 driven wells and 1 dug well (22 feet deep).	Steam pump, duplex.	Gravity from tank.	50-60	90	2	---	---	800	------	Good supply.
Dow City	Dug well	Gasoline engine	Direct air pressure.	-----	---	$\frac{1}{8}$	---	---	---	-----	Plant recently installed
Manilla	2 wells 64 and 68 feet deep.	Steam pump, compound.	Gravity from tank.	25-40	---	2	26	65	300	9,000	Good supply.
Schleswig	Dug well 30 feet deep.	Gasoline engine	Direct air pressure.	70	100	1	8	40	150	18,000	Shortage in dry weather
Vail	8 driven wells and 2 dug wells 30 feet deep.	Gasoline engine and windmill.	Gravity from tank.	65	--	1.7	22	80	200	8,000-10,000	Good supply.

WELL DATA.

The following table gives data of typical wells in Crawford county:

Typical wells of Crawford County.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
G. Schelon	1 miles south of Charter Oak.	104	------	Gravel	— 46	Dug well. No rock.
H. Planggie	3 miles west of Charter Oak.	104	------	---- do	— 72	No rock.
Chas. Reynolds	8 miles west of Dow City.	325	------	Sand	—265	Abandoned on account of quicksand. Yellow loam (water toward bottom), 45; bluish black clay (bad odor), 50; blue clay, 216; "hardpan," 4; sand (water), 10; no rock.
Mr. Dunham	1½ miles northwest of Dunlap	264	------	Sand and gravel.	—224	No rock.

Typical wells of Crawford County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
W. Butterworth	Dow City	82	------	Sand	—76	Do.
McCaffrey Bros.	6 miles north of West Side.	662	350	Sandstone	—365	Yellow loam and blue clay, 35; sand and blue clay, 45; sandstone, limestone, sandstone (water), 812.
Henry Munt	Denison	180	------	Sand	------	Unused on account of lack of water. No rock.
Jonathan Miller	7 miles northeast of Denison. SW. ¼ sec. 16 Milford Tp.	492	460		------	Loess, 20; till, bowldery, 55; blue clay, bowldery, 385; limestone, blue-gray, 30.
D. C. Franklin	3½ miles east of Denison.	404	380	Sandstone	30+	Sandstone at 380 feet.
J. Barnhoff	4½ miles southeast of Vail.	572	552	do	—360	Loess, 20; clay, blue and yellow, pebbly, 80; blue clay, 100; "potter's clay," 350; sandstone, gray, 22½.
George Span	6 miles northwest of Denison.	85	------	Sand	— 35	Water has bad odor. Auger was lifted by water. No rock.
Town	Manilla	68	------	Gravel and sand.	— 12	Pumped by steam. No rock.
Clayton Baker	4 miles north of Manilla.	515	------	do	—260	Yellow clay, 75; sand (water) 2; blue clay and pebbles, 408; "hardpan," 20; sand and gravel (water), 10. One of the deepest drift wells in Iowa. No rock.
Henry Naeve	1 mile east of Schleswig.	393	------	Sand	—323	No rock.

DICKINSON COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY AND GEOLOGY.

Dickinson county is wholly drift-covered. Its topography ranges from gently undulating in some localities to irregularly morainic in others. The surface is imperfectly drained, and the county contains several large lakes, such as Spirit, Okoboji, and Silver lakes, besides innumerable smaller lakes, ponds, and swamps. According to railway surveys the altitude is 1,469 feet above sea level at Lake Park, 1,413 feet at Spirit Lake, 1,441 feet at Milford, and 1,417 feet at Terrill.

The glacial drift is so thick in this region that the drill has very seldom reached the soft blue shale and white sand of the Cretaceous upon which the drift is supposed to rest in all parts of the county. In the following approximate section of the deep well drilled for the Chicago, Rock Island & Pacific Railway at Lake Park the drift probably extends to the depth of 250 feet:

Section of deep railway well at Lake Park.

	Thickness.	Depth.
	Feet	Feet
Soil, yellow clay, blue clay, black and yellow clay	250	250
Shale, clay, sand, etc.	554	804

UNDERGROUND WATER.

SOURCES.

The outwash deposits have small distribution but exist to some depth in the valley of the Little Sioux, where they are filled with excellent water that is recovered chiefly by means of driven wells. On account of the lack of drainage the upper part of the drift is usually saturated nearly or quite to the surface, and hence most of the wells are very shallow. At some distance below the surface the bowlder clay is compact and impervious, but at certain horizons it includes sand and gravel that are charged with water under pressure. The wells that extend to these artesian aquifers have a much more copious and reliable supply than the shallow seepage wells.

In the deepest wells, especially in those which penetrate the stratified formations below the drift, the artesian pressure is not sufficient to raise the water near the surface, and the pumping lift is therefore much greater than in the shallow seepage wells or in the wells that stop in deposits of sand and gravel at depths of 100 to 200 feet. At no point in the county are there prospects of obtaining flows by deep drilling, the water from deep sources probably everywhere remaining far below the surface. Conditions in wells in surrounding counties make it improbable that water will rise higher than 1,200 feet above sea level, which would be between 200 and 300 feet below the surface in most localities.

In the deep well at Lake Park, the section of which is given above, the water is reported to stand about 300 feet below the top of the well, or about 1,170 feet above sea level. This well is unsatisfactory because the head is low, the water is highly mineralized, and fine sand enters the well and impairs the pump. The water is not used in locomotives.

CITY AND VILLAGE SUPPLIES.

Lake Park.—The waterworks in Lake Park (population, 552) consist of an air-pressure system with about half a mile of mains, nine fire hydrants and eight taps. The two wells upon which the system depends are both unsatisfactory. One is six feet in diameter and fifty feet deep and has a yield which varies greatly with the season, but is always small. The other is a six-inch drilled well that ends at 98 feet in fine sand which tends to clog the screen and thus shut out the water. At the time the plant was visited the maximum combined yield of the two wells was very small.

Spirit Lake.—The city well at Spirit Lake (population, 1,162) ends at about 100 feet in a bed of fine sand from which the water rises within 50 feet of the surface. This well furnishes the entire public supply, but when pumped at 300 gallons a minute it soon shows signs of exhaustion. The water is lifted into a surface reservoir from which it is forced by direct pressure through 1¼ miles of mains. There are 15 fire hydrants. A considerable portion of the people are supplied from this source.

Spirit Lake is 1,413 feet above sea level. According to Norton, after passing through the thickened drift of the moraine on which the town is situated, the drill will encounter shales and then enter sandstones of the Cretaceous, from which a large supply of water may be drawn. Should it be thought advisable to sink the well deeper dolomitic limestone will next be encountered, and at a depth of 600 to 700 feet the Saint Peter sandstone may be expected. A six-inch well 700 or 800 feet deep will test the capacity of this sandstone and if the yield is inadequate it can then be determined whether a sufficient increase can be obtained by reaming the hole to 8 or 10 inches, whether the well should be sunk deeper in exploration, or whether a small group of six-inch wells, of 700 or 800 feet depth, would be preferable. The water of the Saint Peter should be of excellent quality, belonging to the calcic-magnesic alkaline class but containing no large amount of mineral matter.

EMMET COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY AND GEOLOGY.

Most of Emmet county consists of a gently undulating and poorly drained drift plain interspersed with numerous lakes and ponds. West Fork of Des Moines river flows through the western part, where it has developed a rather wide flood plain. Westward from this river the altitude increases rapidly and the topography becomes irregular and morainic.

The surface formation consists of glacial drift, except in the valley of the Des Moines, which is partly filled with outwash and alluvial deposits. Beneath the drift is a thick series of shale, sand, and sandstone which is not known to outcrop in the county and whose age therefore remains a matter of conjecture. It is probably Cretaceous, but may be in part older, and it rests upon a limestone formation which is believed to belong to the Mississippian series.

The general character of the Cretaceous (?) shale and sandstone is indicated by the driller's logs of the well on the property of Mrs. Allen, in Estherville, and of the village well at Ringsted.

Section of well of Mrs. Allen, Estherville.

	Thickness.	Depth.
	Feet	Feet
Gravel	15	15
Clay, blue, and sand	195	210
Shale, blue	77	287
Hard quartz rock	½	287½
Sandstone, white (entered).		

Section of village well at Ringsted.

	Thickness.	Depth.
	Feet	Feet
Clay, blue	147	147
Shale, sandy	3	150
Sand, blue, and gravel	10	160
Sand, yellow	38	198
Clay and shale	42	240
Sand and shale	60	300
Shale, white	12	312
Shale, dark, sandy	8	320
Shale, sandy	44	364
Limestone (entered)	136	500

In the Estherville well the formations recorded below a depth of 210 feet are probably Cretaceous; in the Ringsted well the Cretaceous apparently begins at a depth of 147 feet. The limestone in the Ringsted well is undoubtedly Paleozoic and is probably Mississippian.

UNDERGROUND WATER.

SOURCES.

The water supply of this county is derived from outwash and alluvial sands and gravels, glacial drift, sand and sandstone strata (Cretaceous?), and limestone (Mississippian?).

The outwash and alluvial sands and gravels, which are practically restricted to the valley of Des Moines river, are very porous and are so situated that they are filled with water nearly to the surface. Hence they constitute a very accessible source of supply and are tapped by numerous driven wells. The conditions, however, are such that contamination may easily occur, especially in a large settlement such as Estherville. The water is somewhat less mineralized than that from other aquifers.

Outside of the valley of the Des Moines the water supply is drawn chiefly from the glacial drift, though some of the deepest wells extend into the underlying stratified formations. The drilled wells differ greatly in depth and also in the height to which the water rises. In the vicinity of Estherville they range in depth from less than 100 feet to at least 446 feet, 160 feet perhaps being an average; in the vicinity of Gruver they range from 75 feet or less to 275 feet or more, most of the wells near Ryan and Swan lakes being less than 100 feet deep and those near the village of Gruver averaging deeper; in the vicinity of Armstrong they range from about 75 to 250 feet, 135 feet perhaps being an average. In many of the two-inch tubular wells much trouble is caused by the incrusting of the sand screens, but this difficulty can be largely overcome by drilling wells of greater diameter and using independent pumps. (See p. 219.)

In the Allen well at Estherville the water rises within 120 feet of the surface, or approximately 1,180 feet above sea level, and the well has been pumped at about 30 gallons a minute. In the deep well at Ringsted the water rises within 76 feet of the surface and is not greatly lowered when pumped at 40 gallons a minute. It is reasonably certain that below the limestone penetrated in the Ringsted well are older sandstones which would yield large amounts of water that would rise to a level 1,100 to 1,200 feet above the sea, but would probably not come nearer the surface than the water in the deepest wells that thus far have been drilled.

CITY AND VILLAGE SUPPLIES.

Armstrong.—The village well at Armstrong (population, 586) is 160 feet deep and ends in a bed of fine sand. The water stands 68 feet below the surface, or 1,172 feet above the sea, and pumping at 50 gallons a minute is reported not to lower it greatly. It is lifted from the well into an elevated tank from which it is forced by gravity through one mile of mains to 24 fire hydrants and about 40 taps. It is estimated that about 200 people are supplied and 7,000 gallons of water are consumed daily. The rest of the population depend on shallow private wells.

Estherville.—The people of Estherville (population, 2,404) depend for their domestic supplies on private wells, most of which are shallow. The public supply is taken from the river and is not considered safe for domestic uses, though it is employed in large quantities for other purposes. There is a rather extensive system of mains with 24 fire hydrants. The pressure is applied directly by the pumps.

According to Norton a deep well at Estherville (elevation, 1,287 feet) would reach the base of the Cretaceous at 300 to 400 feet from the surface and would then enter Paleozoic dolomites. From these it would pass into the heavy blue and green shales of the Decorah and Platteville formations. The Saint Peter sandstone should be reached about 800 feet above sea level, or about 500 feet below the surface, but it may lie 100 or 200 feet deeper. In exploration the well may be drilled a few hundred feet deeper than the above estimate but should be stopped when the drill strikes heavy glauconiferous shales indicating the Saint Lawrence horizon, the Algonkian (?) red shales, or crystalline rocks, such as granite, quartzite, or schists.

Ringsted.—The waterworks in Ringsted (population, 313) consist of an air-pressure system. Water is obtained from the deep well already described (p. 1043). Most of the people still use private wells.

IDA COUNTY.

BY W. J. MILLER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

Ida county, lying well west of the flat country of the Wisconsin drift, is characteristically hilly, the western portion being a little more rugged than the eastern. The region is thoroughly dissected by many branching streams. The principal one, Maple river, enters from the northeast and leaves at the southwest. Little Sioux river cuts across the extreme northwest corner and Soldier river rises in the southern part.

The Kansan drift extends over the whole county and is completely covered by the loess. The total thickness of these two formations is unusually great, being in places almost 500 feet. The drift rests directly on rocks of Cretaceous age.

Except for local variations in thickness the drift deposits lie nearly horizontal. Of the underlying rock formations the Cretaceous beds are thought to dip noticeably to the west; the still older rocks are nearly horizontal or show a slight easterly dip. (See Pl. XVII, p. 1006.)

UNDERGROUND WATER.

SOURCES.

The most clearly defined water horizon is at the base of the Kansan. The source of the water in many wells, however, is within the loess. Very little can be said about the water of the older rock formations, as but one well is known to extend into them.

So far as existing wells are concerned, the most important source of water in the county is either within the loess itself or in sands or gravels at its base. By far the greater number of farm wells in Ida county are dug and are only from 15 to 30 feet deep. A few bored wells reach a depth of 50 to 100 feet. The dug wells are especially likely to be unsatisfactory in very dry seasons, because their water often either greatly diminishes or fails altogether.

Although but few wells in the county reach it, the most persistent and satisfactory aquifer at a moderate depth consists of the sands or gravels at the base of the Kansan. The available well records indicate that this aquifer lies 300 to 480 feet or more below the surface and seldom fails to yield a large supply of good water. Locally good supplies of water are obtained from sand beds in the blue clay. The well at Holstein (2,004 feet deep) is the only one known to enter the older formations to any extent.

SPRINGS.

Springs are of little consequence in Ida county, though small seepages occur here and there along the low valley lands.

CITY AND VILLAGE SUPPLIES.

Battle Creek.—The town water supply of Battle Creek (population, 527) is taken from 10 drilled and driven wells, ending in gravel at depths ranging from 42 to 48 feet. The wells yield a good supply of medium hard water which is distributed by gravity (domestic pressure 35 pounds, fire pressure 80 pounds) through somewhat more than a mile of mains to 30 taps and 13 fire hydrants. About 150 people use the city water. The daily consumption is estimated at 6,000 gallons.

Holstein.—The city well (Pl. XVII) at Holstein (population, 936) is 2,004 feet deep and is 8 inches to 4 inches or less in diameter; it is cased with 8-inch pipe to a depth of 387 feet, 5-inch pipe to 722 feet, and 4-inch pipe to 1,465 feet. The original head was 270 feet below the curb; in 1908 the head was 300 feet below the curb. When drilling reached a depth of 1,500 feet a 26-hour test pumped 75 gallons a minute without lowering the water; on completion the well yielded 60 gallons a minute; in 1908, 75 gallons a minute. Water came from 390 feet in quicksand, from 1,200 feet, and from "below 1,500" feet; at 390 feet it stood 200 feet below the curb, at 900 feet 365 feet below the curb, at 1,590 feet 325 feet below the curb, and on completion 270 feet below the curb. The well was put down by J. P. Miller & Company of Chicago, in 1897.

The water is pumped to a steel tank and is forced under gravity pressure of 40 pounds (domestic) or 100 pounds (fire) through 2½ miles of mains to 53 taps and 19 fire hydrants. The city water is used by about 300 people. The daily consumption is estimated at 9,000 to 12,000 gallons. The water is hard.

Record of strata in Holstein city well, based on driller's log (Pl. XVII, p. 1006).

	Thickness.	Depth.
	Feet	Feet
Clay	390	390
Quicksand	50	440
Carboniferous:		
Pennsylvanian (?)—		
Shale	260	700
Mississippian (?) and Devonian (?)—		
Limestone	50	750
Shale	50	800
Limestone	80	880
No samples; limestone	20	900
Ordovician:		
Galena dolomite to Platteville limestone—		
Dolomite, gray; much chert and some rounded moderately coarse grains of quartz sand	100	1,000
No samples; limestone (?)	100	1,100
Limestone, magnesian, or dolomite; brown, with about 2 feet of red shale at 1,300 feet; shale noncalcareous, highly arenaceous, with coarse, imperfectly rounded grains of limpid quartz	300	1,400
No sample	37	1,437
Shale, dark greenish gray, slaty, noncalcareous; caving badly after drill had penetrated the underlying sandstone	8	1,445
Saint Peter sandstone—		
Sandstone; described as white, clean, very soft, and caving; called by driller Saint Peter	40	1,485
Prairie du Chien stage—		
Limestone (?), marly, arenaceous; described by driller as a "sandy rock which wears the drill"; sand grains brought in slush bucket; other drillings very light and float up on water; rock drills about 1 foot an hour and does not cave	35	1,520
Shale, red; "at about 1,520 red marl was coming in and could not tell much about the formation from there down to 1,890 feet, as it was caving very badly all the way, and caved more or less from there down to 2,000 feet"		1,520
Sandstone; fine-grained, blue-gray, dolomitic cement		1,575
Sandstone and dolomite; quartz sand, considerable red shale and some green shale from above, and a little gray siliceous dolomite		1,670
Chert, dark reddish brown, ferruginous; in small chips, slightly arenaceous, with minute particles of crystalline quartz; as similar chert and reddish argillaceous powder are found in nearly all the drillings below, this may have fallen in from 1,520		1,700
Sandstone and chert; sandstone, fine-grained, in detached grains of clear quartz; many imperfectly rounded and minute white cuttings, showing quartz particles in dolomitic cement; chert dark, brown, ferruginous, dolomitic		1,720
Marl; in buff, slightly concreted masses; dolomitic, arenaceous, and argillaceous; quartz grains moderately fine; many imperfectly rounded; red chert, as above, with a few chips of yellow siliceous dolomite		1,740
Shale, blue, plastic, calcareous	5	1,755
Marl; chiefly quartz sand, with dolomite, yellow-gray, and white, soft, glauconiferous; some red chert		1,760
Marl, gray, dolomitic		1,775
Shale, blue, plastic, calcareous		1,785
Dolomite, gray, highly siliceous; microscopic particles of crystalline quartz, glauconiferous; considerable fine quartz sand		1,795
Marl or calciferous argillaceous sandstone		1,805
Dolomite, hard, dark gray, saccharoidal, possibly from above		1,810
Marl, arenaceous		1,815
Shale, blue, calcareous, slightly glauconiferous, minutely quartzose	2	1,827
Shale, green, hard, fissile, slightly calcareous	15	1,915
Dolomite and shale; dolomite, saccharoidal, mottled greenish gray and pink, interlaminated with hard green calcareous shale; quartzose and glauconiferous, in large chips		1,920
Marl, arenaceous, with fine rounded grains; chips composed largely of quartzose particles	10	1,930
Cambrian (?):		
Dresbach (?) sandstone—		
Sandstone, yellow, saccharoidal, soft; rounded grains of about 0.5 millimeter	41	1,971

Ida Grove.—Two wells, each 24 feet deep, furnish Ida Grove (population, 1,874) with a fairly good supply of hard water. The water is pumped by steam and is distributed by direct pressure (70 pounds domestic and 125 pounds fire) through 1¾ miles of mains to 200 taps and 20 fire hydrants. About 700 peoply use the city water. The daily consumption is estimated at 45,000 gallons.

The success of the deep well at Holstein, 10 miles north of Ida Grove, is distinctly encouraging. The succession of rocks is probably the same at both places, but any given formation or water bed may be expected to lie about 100 feet deeper at Ida Grove than at Holstein. Thus at Ida Grove (elevation above sea level, 1,225 feet) the Saint Peter sandstone will be found at about 100 feet below sea level, or 1,325 feet below the surface. The drill may fail to strike the water vein reached at Holstein at 259 feet above sea level in Galena dolomite, but it may find other water-bearing crevices in this formation. Sufficient water may probably be found about 300 feet below sea level (somewhat more than 1,500 feet below the surface), but if not, drilling may be continued to about 1,900 feet to tap the lowest sandstone found at Holstein. The fact that Ida Grove stands more than 200 feet lower than Holstein not only brings the deep formations somewhat nearer to the surface, but also gives a higher head to the artesian water, which should come within 50 or 100 feet of the curb. In quality the water may be expected to be rather high in sulphates, but to be well within the limits of potability. The waters found above 700 feet should be carefully tested for quality, and possibly should be cased out on account of excessive mineralization.

WELL DATA.

Information concerning typical wells in Ida county is presented in the following table:

Typical wells of Ida County.

Owner	Location	Depth	Source of supply	Head below curb	Remarks
		Feet		Feet	
Mislow Bros.	5½ miles east of Ida Grove.	210	Gravel and sand.	160	No rock.
M. Martin	4 miles southwest of Ida Grove.	115	do	40	Water bed at 81 feet. No rock.
A. Harper	2 miles southeast of Ida Grove.	215	do	115	Black loam, 4; yellow clay, 40; sand and clay and some water, 70; gravel and water, 3; yellowish clay and sand, 85; gravel and water, 13; no rock
W. K. Van Wayne	4 miles north of Ida Grove.	300	do		No rock.

LYON COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY AND GEOLOGY.

Lyon county is much better drained than the counties farther east. The gently undulating upland, whose general altitude is more than 1,400 feet above sea level, is somewhat dissected by water-courses that lead to Big Sioux river, which forms the west boundary of the county and occupies a well-defined valley about 200 feet deep.

The following geologic section is revealed in outcrops and wells:

Glacial outwash and recent alluvium (in the valleys).

Loess (on the uplands).

Glacial drift.
Cretaceous shales and impure limestones.
Cretaceous sandstone (Dakota).
Sioux quartzite.

The Cretaceous formations outcrop in Big Sioux valley south of Lyon county and are penetrated in many drill holes in this county. The Sioux quartzite outcrops in small areas in the extreme northwestern part of the state and probably underlies the entire county, though its surface is so irregular that within a short distance from an outcrop it may lie several hundred feet below the surface and hence it is not generally encountered even in the deepest wells.

UNDERGROUND WATER.

SOURCES.

On the uplands the shallow wells end in glacial drift, the depth to the Dakota sandstone is relatively great, and the water from all deep formations remains far below the surface when tapped by wells; in the valleys the shallow wells end in alluvial and outwash sand and gravel, the depth to the Dakota sandstone is not great, and the water from deep sources rises nearly to the surface. The valleys include only a small portion of the total area and grade into the uplands along the minor streams.

All the geologic formations except the loess and the Cretaceous shale will yield some water, but those most heavily drawn on at present are the glacial drift and outwash gravel. The latter is found in the principal valleys, where it furnishes large quantities of good water to shallow wells and constitutes the source from which all public supplies are obtained; the glacial drift everywhere underlies the upland, where it yields most of the private supplies on farms and in villages remote from streams. The loosely consolidated beds of drift near the surface are commonly saturated and yield a certain amount of water to shallow bored and dug wells; and seams of sand and gravel embedded in the impervious blue bowlder clay at greater depths contain water under considerable pressure, which is recovered by means of bored and drilled wells. The deep drift water is notably harder and more ferruginous than the water in the valley gravels. The Dakota sandstone contains a large store of mineralized water and supplies a few of the deepest wells. It is very imperfectly cemented and gives some trouble because of the tendency of its fine sand to rise with the water, especially when rapid pumping is attempted. The Sioux quartzite yields small supplies to wells in South Dakota and Minnesota, the water occurring in joints and also in the less cemented portions of the rock, but on account of the expense and difficulty of drilling through this formation, it is properly avoided in Iowa as much as possible. In some parts of the county water-bearing beds may exist between the Dakota sandstone and the Sioux quartzite, but, so far as known, no such beds have yet been reached by the drill.

In all sections of the county most of the wells are bored and commonly range between 15 and 50 feet in depth, but there are also many drilled wells between 70 and 500 feet deep, wells 150 to 160 feet deep being common east of Rock Rapids and wells of 190 to 300 feet west of that city. The difficulty with fine sand can to some extent be overcome by drilling wells of larger diameter and using independent pumps that will allow the water to flow into the wells under uniform pressure. (See pp. 219-226.)

The water from the Dakota sandstone is lifted by artesian pressure to approximately 1,225 feet above sea level, which brings it nearly to the surface in the Sioux valley but leaves it about 100 feet below the surface at Rock Rapids and more than 200 feet below on much of the uplands. According to railway surveys, the altitude of Beloit, in the Sioux valley, is 1,242 feet above sea level; of Rock Rapids, in the valley of Rock river, 1,345 feet; of George, in the valley of Little Rock river, 1,377 feet; and of Granite, Larchwood, and Inwood, all upland towns, 1,407 feet, 1,426 feet, and 1,473 feet, respectively. Drilling below the Dakota sandstone is not advised in this county, because it is improbable that much would be gained in quantity or quality of water or in artesian pressure. The Sioux quartzite would probably be encountered before the drill reached a depth of many hundred feet.

Near the Chicago, Rock Island & Pacific Railway station at Lester there is a 10-inch well, 70 feet deep, from which the water rises above the surface and flows several gallons a minute.

CITY AND VILLAGE SUPPLIES.

Alvord.—The village well at Alvord (population, 283) is eight feet in diameter and is sunk to a depth of thirty feet into the gravel of the creek valley, obtaining great quantities of good water.

The waterworks system consists of an air pressure tank with about half a mile of mains, eight fire hydrants, and eight taps. Only a few homes have service connections and the consumption is small.

Doon.—The village well at Doon (population, 581) is 10 feet in diameter and 28 feet deep and ends in gravel, from which a large amount of relatively soft water can be drawn.

The distribution system comprises an elevated tank, about a mile of mains, 12 fire hydrants, and 42 taps. Perhaps 200 people are supplied, and approximately 7,000 gallons are consumed daily.

Rock Rapids.—The public supply of Rock Rapids (population, 2,005) is derived from a well 18 feet in diameter and 20 feet deep ending in the valley gravels.

The waterworks consist of a standpipe with about three miles of mains, 28 fire hydrants, and 250 taps. It is reported that a majority of the people are supplied and that about 30,000 gallons of water are consumed daily.

MONONA COUNTY.

BY W. J. MILLER.

TOPOGRAPHY.

Topographically, Monona county is clearly divisible into two portions. The western third is occupied by the Missouri river bottom, where the land is low, very level, and much of it swampy. Little Sioux river and its West Fork flow along the eastern border of this lowland. The eastern two-thirds of the county is characteristically very hilly and rugged. Important river channels are cut in the hill country by Soldier river, by Maple river and by Little Sioux river. The hilly and the lowland regions are sharply separated.

GEOLOGY.

Of the upper or surface formations three types are to be found. The lowland region is covered by alluvial or river deposits, consisting of sands, gravels, and clays. The hilly region is completely covered by the loess except locally where the principal streams have cut through it. Below the loess, in the hilly portion, comes the Kansan drift. The Kansan drift and the loess have been practically all removed by erosion over the lowland area.

Of the old rock formations both the Cretaceous system (shales and sandstones) and the Pennsylvanian series (shales, sandstones, and limestones of the Missouri stage) are represented. The Missouri stage immediately underlies the alluvial deposits in the southern half of the river-bottom area; and the Cretaceous spreads over the remainder of the county.

Along the river bottom the alluvium rests directly upon the older rock formations. So far as known all the strata of the county are in a general way horizontal.

UNDERGROUND WATER.

SOURCES.

The sand and gravel layers of the river bottom afford an abundance of water. In the hilly country water is found in sand or gravel below the loess and in sand or gravel below the blue clay of the Kansan drift. Important water beds are doubtless present in the older rock formations, although little is known about them, as but two wells in the county are known to have extended into these formations.

By far most of the water of the county is obtained from shallow dug or driven wells, but the supply is often not as constant or satisfactory as it is in central Iowa, and in particularly dry seasons is considerably affected. The water, as a rule, is of good quality but hard.

Practically all of the water in the river-bottom district is derived from sand or gravel beds in the alluvial deposits. There is no single clearly defined water-bearing stratum of widespread extent, the alluvial deposits being very local. Nearly all the wells in this district are driven and range in depth from 15 to 80 feet, the average depth being about 30 feet. The head usually responds more or less to the rise and fall of water in Missouri river. In the region around Onawa the water in the deeper wells (60 to 80 feet) is heavily charged with oxide of iron. This water seems to come from under a hard yellow clay or "hardpan" whereas the water above the "hardpan" is softer and free from iron oxide.

In the hilly loess-covered region many of the dug wells extend into water-bearing sand or gravel below the loess, the depth to this so-called "first-water" level being between a few feet and 100 feet. Generally the water supply is not large and fluctuates according to seasons, even failing in some very dry seasons.

A larger and more constant supply of water is to be found in the sands or gravels beneath the blue clay of the Kansan drift. Well records show that this aquifer has been struck at depths ranging from 35 feet along the stream bottoms to a maximum of 300 feet or more on high ground in the eastern part of the county, but comparatively few wells reach it. Some wells appear to derive water from sand layers within the blue clay.

A few drilled wells enter the deeper rock formations. Satisfactory records, however, are lacking to show the source of water in these wells.

PROVINCES.

Monona county may be divided into two underground-water provinces—the river bottom, on which the water is found in the alluvial deposits and also in the deep-lying rock formations, and the eastern hilly region, where the water occurs in sand or gravel beneath both the Kansan drift and the loess and also probably in the deep rock formations.

At least two flowing wells are known to derive their water from the older rocks below the alluvial deposits. One of these wells, 863 feet deep, is at Onawa, and flows a large stream under considerable head. The other, more than 400 feet deep, is near Blencoe. A very general record of the Onawa well shows the source of water to be in limestone. No record of the Blencoe well could be obtained. The head of water is sufficient to permit an overflow on the lowland only.

Some flowing wells are known in the drift along the Maple river bottom near Castana. The river has here cut through the loess, and a well extending 30 to 40 feet downward into the blue Kansan clay strikes a bed of gravel with water under sufficient head to cause an overflow in the river bottom.

SPRINGS.

Springs of small size are numerous along stream courses where the bottom of the loess is exposed. The water emerges from the sand or gravel below the loess, as along Maple river in the vicinity of Castana. Thus these springs furnish examples of natural flow from the so-called "first-water level."

CITY AND VILLAGE SUPPLIES.

Onawa.—The Onawa city supply is drawn from a flowing well 863 feet deep and is forced by direct pressure by two steam duplex pumps through two-fifths of a mile of mains to 18 fire hydrants and 42 taps. Domestic pressure is 40 pounds and fire pressure 100 pounds. The supply is sufficient, but constant pumping is necessary. The water is hard. It is used by 200 people.

The well has a depth of 863 feet and a diameter of 12 to 8 inches; casing to 563 feet. It is located on the river bottom. The head is 15 feet above curb, and the flow 75 gallons a minute. Water beds were struck at 863 and 300 feet. Driller, J. H. Shaw of Sioux City; date of completion, 1905.

Driller's log of city well at Onawa.

	Thickness.	Depth.
	Feet	Feet
Dark loam and clay	50	50
Gravel, coarse	80	130
Clay, blue, or shale	14	144
Sandstone, soft	4	148
Shale, blue	16	164
Sandstone, hard Shale Clay or shale, soft; thin layer	16	180
Shale	100	280
Limestone (small flow of water)		300
Shale		350
Limestone with flow increasing to bottom of well		

The first limestone, at 300 feet, is probably at the base of the Pennsylvanian and the summit of the Mississippian.

Minor supplies.—Minor supplies are summarized in the table below:

Minor supplies in Monona County.

Town	Nature of supply	Pumping system	Distribution	Pressure		Length of mains	Fire hydrants	Taps
				Domestic	Fire			
				Lbs.	Lbs.	Miles		
Castana	Well 66 feet deep	Gasoline engine.	Direct air pressure.	40	40	0.7	12	40
Mapleton	12 driven wells 20 feet deep.	Steam duplex pump.	Gravity or direct.	70	160	2	16	92
Ute	Wells (driven) 60 feet deep.	Gasoline engine.	Gravity	38	38	1½	14	80 or 90

Minor supplies in Monona County—Continued.

Town	Persons supplied	Daily consumption	Remarks
		M gals.	
Castana	350	8	Ordinarily sufficient, but hard.
Mapleton	400	15	Fair supply, but hard. Deep well contemplated.
Ute	450		Good supply, but hard. New mains being laid.

WELL DATA.

The following table gives data of typical wells in Monona county:

Typical wells of Monona County.

Owner	Location	Depth	Depth to rock	Source of supply	Head above or below curb	Remarks
		Feet	Feet		Feet	
Robert Seton	5 miles southeast of Onawa	64		Sand	— 8	Driven well. No rock.
Town	Onawa	863	130	Limestone	+ 15	Flowing well, 75 gallons a minute; pumped by steam for city purposes.
Dr. Creik	Castana	115		Gravel and sand	— 60	No rock.
Narcross Mill	do	45		do	+	Flowing drift well. No rock.
Mrs. Janess	1 mile east of Ticonic.	150	130	Drift sand	— 40	20 feet of dry shale below water bed.
Mr. Cloud	4½ miles south of Mapleton.	52		Gravel	— 34	No rock.
R. Perkins	Ute	265		do	—100	Do.
F. Shanahan	3 miles south of Ute.	58		do	— 44	4 foot open bricked well. No rock.
Chicago & North Western Ry.	Onawa	85		do		Steam-pumped for locomotives. No rock.

O'BRIEN COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY.

The surface of O'Brien county consists, essentially, of a gently undulating plain which in most of the county is more than 1,400 feet above sea level and in the north-central part reaches an altitude of more than 1,500 feet. Little Sioux river, which crosses the southeast corner of the county, has cut a deep trench into this plain and flows at a level of only a little more than 1,200 feet above the sea. The smaller streams have not yet dissected the plain to any great extent, but occupy broad, shallow, and rather indefinite valleys through which they habitually meander lazily.

GEOLOGY.

The entire county is underlain by an accumulation of glacial drift, which was found to be 200 feet thick at Sanborn and which apparently is of considerable thickness at all points beneath the uplands. The upper portion of the drift consists of a loose, gravelly, more or less yellowish clay, but the greater part is a compact blue bowlder clay, containing in some localities embedded sheets and lenses of sand and gravel. In the principal valleys porous, gravelly water-laid deposits lie at the surface.

Below the drift are strata of soft blue shale, soft white sandstone, impure limestone, etc., the shale being much the most abundant. At least the upper of these strata are supposed to belong to the Cretaceous system. (See Pl. XVII, p. 1006.)

The following sections show to some extent the character of the drift and of the underlying stratified formations. Both are reported by the drillers and are in part approximations.

Section of Chicago, Milwaukee & St. Paul Railway well at Sanborn.
(*See Pl. XVII, p. 1006.*)

	Thickness	Depth.
	Feet	Feet
Clay, yellow	75	75
Clay, blue	125	200
Shale, blue	160	360
Shale, blue and green, with strata of limestone	200	560
Sandstone, soft, white, with some shale	155	715
Shale, gray, and streaks of rock	50	765
Sandstone, white	45	810
Shale, blue and green, mixed with sandstone	200	1,010
Shale, green and white	246	1,256

Section of village well at Sutherland.

	Thickness	Depth.
	Feet	Feet
Clay, yellow	50	50
Clay, blue	110	160
Sand and clay	30	190
Sand	20	210
Gravel, fine	2	212

UNDERGROUND WATER.

SOURCES.

At present nearly the entire water supply of the county comes from the upper part of the drift and the gravel deposits in the valleys. The upper part of the drift is sufficiently porous to furnish a slow seepage to dug or bored wells but can not always be relied on in dry seasons. At greater depths the drift consists chiefly of impervious blue bowlder clay, from which no water can be procured. Many deposits of water-bearing sand or gravel embedded in this blue clay form a reliable and satisfactory source of supply, but unfortunately such deposits are not everywhere found. In some wells, therefore, the drilling has been carried through the entire thickness of the drift and a certain amount of the soft bluish shale, and the wells have been finished in sandy strata which are apparently Cretaceous in age. These deep wells, as also some of the deepest drift wells, have not proved satisfactory because the water is highly mineralized and generally remains so far below the surface that the lift is great and because the fine incoherent sand in which they end is usually troublesome. Hence many of them have been abandoned and supplies from very shallow sources have again been resorted to, with the result that in seasons of drought there is on many farms a shortage in water for stock. Some farmers have dug large open wells in low-lying and poorly-drained localities where the supply from the surficial deposits is not readily affected by drought, and a number have extended pipe lines from these wells to the barnyards where the water is wanted. In many places such an arrangement is more satisfactory than a deep sand well would be. For suggestions in regard to finishing sand wells see pages 219-226.

CITY AND VILLAGE SUPPLIES.

Hartley.—The village well at Hartley (population, 1,106) is 130 feet deep and has been tested at 30 gallons a minute. The water is pumped into an elevated tank from which it is distributed through the mains by gravity, only about 2,500 gallons being used daily. The total length of mains is about half a mile, and there are eight fire hydrants and 17 taps.

Paullina.—In Paullina (population, 796) the public supply is drawn from a shallow dug well which will supply 300 gallons a minute. The water is lifted into an elevated tank and thence distributed by gravity through 1¾ miles of mains to 18 hydrants and 93 taps. A large portion of the people are supplied, and it is estimated that approximately 6,000 gallons are consumed daily.

Primghar.—The public supply at Primghar (population, 733) was formerly obtained from a drilled well 420 feet deep, in which the water stood about 250 feet below the surface. This well proved so unsatisfactory that it has been abandoned for a dug well 15 feet in diameter and 15 feet deep, which ends in gravel with the water normally standing only six feet below the surface. The water is stored in a cylindrical air-tight tank from which it is forced through the mains by compressed air. The system is not extensive and supplies only a small portion of the population.

In the vicinity of Primghar a number of wells go to depths of about 100 to 140 feet, the water rising within 50 feet of the surface. They all end in sand or gravel, and most of them are giving satisfactory service. As examples of this group of wells may be mentioned those of G. B. Slocum (SE. ¼ sec. 25, T. 96 N., R. 41 W.), George Ward (NE. ¼ sec. 24, T. 95 N., R. 41 W.), L. Strangland (NW. ¼ sec. 19, T. 95 N., R. 40 W.), F. Scac (NW. ¼ sec. 6, T. 95 N., R. 40 W.), and the Chicago, Rock Island & Pacific Railway (at Calumet).

Among the deeper wells in the same vicinity may be mentioned the old village well at Primghar, which is 420 feet deep; a well on the County Farm (N. ½ sec. 5, T. 95 N., R. 40 W.), which is 408 feet deep; a well in the SE. ¼ sec. 1, T. 95 N., R. 41 W., which is 414 feet deep; a well in the NE. ¼ sec. 1, T. 95 N., R. 40 W., which is 370 feet deep; and a well in the SE. ¼ sec. 33, T. 96 N., R. 40 W., which is 380 feet deep. These wells end in fine-grained incoherent sand which causes trouble, and the water in them remains about 225 to 275 feet below the surface. Some of them have proved so unsatisfactory that they have been abandoned. In the abandoned Primghar village well the water is said to stand 250 feet below the surface (about 1,250 feet above sea level).

Sanborn.—The public supply of Sanborn (population, 1,174) is obtained from two dug wells, one of which is 56 feet and the other 62 feet deep. They end in gravel and yield about 60 gallons a minute. There are an elevated tank, about two miles of mains, and about 200 taps. The average daily consumption is estimated at 16,000 gallons.

The railway well at Sanborn (see p. 1060 for section) goes to a depth of 1,256 feet, piercing the entire thickness of the Cretaceous and probably extending far into the subjacent Paleozoic formations. (See Pl. XVII.) The diameter is 8 inches to 436 feet, 6 inches to 721 feet, 4½ inches to the bottom; casing to 815 feet. The curb is 1,552 feet above sea level and the head 350 feet below curb. Water comes from 494, 503, 633, and 857 feet; capacity, 100 gallons a minute. Driller, S. Swanson, Minneapolis. Date of completion, 1896. The water in this well contains a large amount of mineral matter.

In some drilled wells about 150 feet deep in the vicinity of Sanborn the water rises within less than 100 feet of the surface. In a few between 300 and 400 feet deep the water remains farther below the surface.

Sheldon.—The public supply for Sheldon (population, 2,941) is drawn from shallow deposits of gravel, sand and clay which are tapped by two wells 18 feet in diameter and 26 feet deep, two other wells 12 feet in diameter and 14 feet deep, and about 1,100 feet of tile laid 14 feet below the surface. There are an elevated tank, six and one-quarter miles of mains, 35 fire hydrants and 238 taps. Approximately 1,000 people are supplied and 70,000 gallons of water are consumed daily, but most of the inhabitants still depend on shallow private wells.

In the vicinity of Sheldon several wells have been sunk to beds of fine sand at depths of 300 to 350 feet, and in these the water rises within 200 feet of the surface, or perhaps 1,225 feet above sea. In one well, which was sunk to a depth of 470 feet, the water is reported to remain 350 feet below the surface.

Sutherland.—The public supply at Sutherland (population, 664) is derived from a well 212 feet deep (see p. 1060 for section). The water rises within 50 feet of the surface, and the well has been pumped at 100 gallons a minute. The waterworks consist of an air-pressure system. Nearly all the inhabitants have private wells, and the consumption of the public supply probably does not exceed an average of 2,000 gallons a day.

OSCEOLA COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY AND GEOLOGY.

The northeastern part of Osceola county is occupied by a pronounced morainal belt of Wisconsin drift. In this area the drainage is very imperfect, lakes, ponds and swamps being interspersed in the most chaotic manner among irregular gravelly hills, mounds and ridges. Here, also, is found the highest land in Iowa, the culminating point probably being Ocheyedan Mound, a massive accumulation of glacial material which stands in prominent relief on the plain southeast of the village of Ocheyedan and reaches an altitude of approximately 1,670 feet above sea level.[1] Bordering this morainic belt on the southwest and sloping gently away from it is a plain underlain by a sheet of gravelly glacial outwash material which apparently thins out as the distance from the moraine increases and eventually, in the southwestern part of the county, gives way to the attenuated deposit of yellow claylike loess which is generally spread over the older drift sheets throughout the state.

Below the surface deposits lies a thick bed of glacial drift which consists in the main of a matrix of compact blue clay in which bowlders and pebbles are promiscuously embedded. At depths of several hundred feet occurs soft blue shale with some interbedded strata of fine-grained sand or sandstone which are believed to be Cretaceous in age. In no place in the county has this shale and sandstone series been found at or near the surface, and in only a few of the deepest wells has it been penetrated by the drill.

UNDERGROUND WATER.

SOURCES.

The glacial-outwash material is largely so gravelly and porous that it is well adapted for absorbing and yielding water, and in the belt in which it occurs it supplies many shallow wells. Where the deposit is thin, however, or is so situated that it is readily drained, its supply is liable to fail in seasons of prolonged drought. In the morainic belt the material near the surface is also somewhat porous, being more or less gravelly and not closely packed together, and, owing to the general absence of deep drainage channels, these semiporous deposits are saturated nearly to the surface, and hence supply water to wells that are

[1] Macbride, T. H., Ann. Rep. Iowa Geol. Survey, vol. 10, 1900, p. 195.

dug or bored a short distance into them. In the deeper portions of the drift are found beds of sand and gravel which are generally filled with water under sufficient artesian pressure to flow into the wells rapidly, the yield being only slightly affected by variations in rainfall.

The Cretaceous sand strata supply a few of the deepest wells, but up to the present time they have proved of little value as water horizons. As nearly as it is possible to interpret the well data in terms of geologic formations, it seems that the most satisfactory drilled wells are those which end before penetrating the Cretaceous rocks. Little is known about the water-bearing formations below the Cretaceous, but the evidence at hand indicates that nothing would be gained, either in the quality of the water or in the artesian head, by drilling to these formations. On account of the high surface altitude the water from any of the lower horizons would remain several hundred feet below the surface.

The wells of the county can be grouped, rather arbitrarily, into four classes, as follows: (1) Wells that are dug, bored, or driven into the outwash gravels or upper loosely aggregated accumulations of glacial drift to a depth slightly below the normal ground-water level, and that depend on the seepage from these materials. This class includes perhaps four-fifths of the wells of the county. (2) Wells that are bored to depths of about 50 to 150 feet and reach beds of water-bearing sand or gravel or at least extend far enough below the ground-water level not to fail in dry seasons. (3) Wells that are drilled to depths between 75 and 225 feet, extending to deposits of sand or gravel from which the water rises under artesian pressure. These wells are tightly cased and depend entirely on the water-bearing beds in which they end; they are relatively few in number but have several advantages over the other types which recommend them for general use. (4) Wells drilled to greater depths and also tightly cased to the bottom. They are for the most part less satisfactory than the shallower drilled wells because they end more commonly in fine sand (probably Cretaceous) that interferes with the pump, limits the yield, and frequently fills the well, and their water is generally harder and more ferruginous and remains at greater depths below the surface. The difficulty with the sand can in a measure be overcome by drilling wells of larger diameter and using independent pumps.

CITY AND VILLAGE SUPPLIES.

Ashton.—The village well at Ashton (population, 518) is six inches in diameter and 65 feet deep and is cased to the bottom. It ends in a bed of sand from which the water rises to the surface, and it is reported to have been tested at 800 gallons a minute. The water is pumped into an air-tight tank from which it is forced through the mains by compressed air. Nearly all the inhabitants have shallow private wells and make small use of the public supply.

Sibley.—The waterworks at Sibley (population, 1,330) are supplied from a well 16 feet in diameter and 26 feet deep; they comprise an elevated tank, about three miles of mains, and about 25 fire hydrants. The average daily consumption is estimated at 11,000 gallons. The well furnishes sufficient water for present demands but is liable to fail in dry seasons.

Sibley is 1,502 feet above sea level. According to Norton, its high elevation and its nearness to the old land of pre-Cambrian crystalline rocks seen in the outcrop of Sioux quartzite a few miles west render the success of an attempt to obtain artesian water from the Ordovician and Cambrian water beds problematic. Beneath the exceptionally heavy drift of this region—reported at Ollendorff as 515 feet thick—the drill will find thick beds of the Cretaceous, comprising the shales and marls of the Colorado group and the underlying Dakota sandstone—the last furnishing an abundant supply of water. Whether the Saint Peter sandstone extends this far to the west and north is unknown. According to the general lie of the formations, it should be found, if at all, within 600 or 800 feet from the surface, the depth depending not so much on the dip of the strata as on the depth to which the upturned edges of the gently inclined strata were worn down during the erosion periods before the Cretaceous submergence and on the thickness of the Cretaceous beds and drift deposited upon them.

PALO ALTO COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY.

West Fork of Des Moines river flows diagonally through the central part of Palo Alto county, occupying a wide but shallow alluvium-filled valley, on either side of which extends a monotonous and poorly drained drift plain. Westward from the valley this plain rises considerably, so that along the west margin of the county it is decidedly higher than elsewhere.

GEOLOGY.

The glacial drift rests upon a series of soft shales and poorly cemented sandstones believed to be Cretaceous in age, beneath which lie limestones and other indurated Paleozoic formations. Both the glacial drift and the Cretaceous rocks seem to thin out somewhat toward the southeast corner of the county, thus allowing the Paleozoic limestones to come relatively near the surface. (See Pl. XVI, p. 814.) The following well records throw light upon the geologic section of this region.

Section of abandoned city well at Emmetsburg.

	Thickness.	Depth.
	Feet	Feet
Soil, yellow clay, gravel	25	25
Clay, blue	20	45
Sand gravel, and yellow clay	5	50
Clay, blue	65	115
Gravel and sand	2	117
Clay, blue	88	205
Hardpan	½	------
"Quicksand"	60	------

Section of Chicago, Milwaukee & St. Paul Railway well at Emmetsburg.

	Thickness	Depth
	Feet	Feet
Drift, etc.	225	225
Incoherent sandstone	109	334
Shale, red	22	356
Dolomite	32	388
Shale, sandstone, limestone, etc.	484	872

Section of village well at Ayrshire.

	Thickness.	Depth.
	Feet	Feet
Soil, yellow clay, sand and blue clay	160	160
Sand	2	162
Clay, blue, with sand	58	220
Shale	80	300
Sand, with seams of shale	73	373
Shale, red (entered)	-------	-------

Section of village well at West Bend.

	Thickness.	Depth.
	Feet	Feet
Clay, yellow and blue	81	81
Sand, fine, white, and blue clay	22	103
"Flint"	½	103½
Sand (entered)	7	110½

Section of the abandoned village well at West Bend.

	Thickness.	Depth.
	Feet	Feet
Drift (similar to above section)	94	94
Sand	112	206
"Red marl"	20	226
Chert, etc.	43	269
Sandstone, etc.	23	292
Limestone	89	381
Shale, blue (entered)	-------	-------

The "quicksand" in the first Emmetsburg well, the incoherent sandstone in the second, the 73-foot bed of sand in the Ayrshire well, and the 112-foot bed of sand immediately below the drift at West Bend apparently represent the Cretaceous—probably the basal Cretaceous deposit. In each of the three localities this formation rests upon a bed of red shale which may be the red shale formations found in the vicinity of Fort Dodge. According to the section, the thickness of the glacial drift is a little over 200 feet at Emmetsburg, about 220 feet at Ayrshire, and approximately 100 feet at West Bend.

UNDERGROUND WATER.

SOURCES.

The water supply of Palo Alto county is drawn from outwash and alluvial deposits, glacial drift, Cretaceous sand or sandstone, Mississippian (?) limestone, and older formations.

The outwash and alluvial deposits, which are virtually confined to the valley of Des Moines river, furnish water freely to shallow wells, and this water is generally not so hard as that from other sources. Outside of the valley most of the supply is obtained from the upper part of the drift or from beds of sand that lie at greater depths between deposits of bowlder clay, but many drilled wells end in the Cretaceous sand. In the southeastern part of the county a few end in the underlying limestone, and two—the railway well at Emmetsburg and the village well at Mallard—draw from still deeper sources.

The drilled wells have the greatest average depth on the high ground along the west margin of the county. Thus in the southern part of Lost Island township and the northern part of Highland township they are commonly about 300 feet deep; in the western part of Silver Lake township many are about 250 feet deep; and in Booth township depths up to 377 feet were reported. In Vernon township depths of 250 to 300 feet are also common, but in general throughout the central and eastern parts of the county the depths are less. In the vicinity of Cylinder 100 feet is perhaps an average, and near the river many drilled wells end at considerably less than 100 feet.

Much difficulty has been experienced in finishing wells in the Cretaceous sand strata. This difficulty and its remedies are discussed on pages 219-226.

HEAD.

The depth at which the water stands in the wells varies with the altitude of the surface, being generally greatest in the deep wells in the western tier of townships, in many of which it stands from 100 to 175 feet below the top of the well, and least in the valleys and other low-lying areas farther east, where it may rise nearly to the top or in a few localities may flow. In the railway well at Emmetsburg the water rises within 33 feet of the surface, or 1,197 feet above the sea, and in the abandoned city well it rose within 40 feet of the surface, or 1,197 feet above the sea. At Cylinder it rises within 12 feet of the surface. Between Ruthven and Emmetsburg several flowing wells that end in the glacial drift evidently derive their head from the high area immediately west. Another group of flowing wells, apparently supplied from Cretaceous sand, is found in the valley of Prairie creek in the vicinity of West Bend. To judge from the 1,050-foot well at Mallard and other deep-well data, no additional head would be gained by drilling to formations below the Cretaceous.

CITY AND VILLAGE SUPPLIES.

Ayrshire.—The village well at Ayrshire (population, 337) is 373 feet deep, ends in Cretaceous sand, and has been tested at 120 gallons a minute. (See p. 1068 for section.) The waterworks, which consist of an air-pressure system, are not yet extensively used.

Emmetsburg.—In Emmetsburg (population, 2,325) it is estimated that about 1,600 people are supplied from the city waterworks. The public supply is taken from a dug well, 13½ feet in diameter and 25 feet deep, and the system consists of a standpipe, more than eight miles of mains, 37 fire hydrants, and 320 taps. The average daily consumption is approximately 40,000 gallons.

The Chicago, Milwaukee & St. Paul Railway well (Pl. XVI, p. 814) has a depth of 874 feet and a diameter of six inches. The curb is 1,230 feet above sea level and the head 33 feet below the curb. The water comes from the Saint Peter sandstone, the water of the Dakota sandstone having been cased out. Driller, W. E. Swan.

Driller's log of railway well at Emmetsburg.

	Thickness.	Depth.
	Feet	Feet
Soil	5	5
Clay, yellow	16	21
Clay, blue	204	225
Sand, dark	30	255
Sand, gray	79	334
Marl, red	22	356
Limestone, broken	10	366
Limestone, sandy	22	388
Shale, black	4	392
Limestone	30	422
Shale, gray	15	437
Limestone, magnesian	224	661
Shale, gray	65	726
Shale, blue	30	756
Sandstone, white	110	866
Granite	8	874

Record of strata of railway well at Emmetsburg (Pl. XVI, p. 814).

	Thickness.	Depth.
	Feet	Feet
Quaternary (225 feet thick; top, 1,230 feet above sea level):		
Soil	5	5
Clay, bright yellow, calcareous; with drift pebbles	16	21
Clay, blue, pebbly; more strongly calcareous than above	204	225
Cretaceous:		
Dakota sandstone (109 feet thick; top, 1,005 feet above sea level)—		
Sandstone, moderately coarse, gray; mostly of clear quartz, but contains many grains of pink and dark gray quartz, jasper and flint	30	255
Sandstone, very coarse; similar in composition to the above; sample contains fragments of fine white kaolinic clay	79	334
Carboniferous (Permian?):		
Clay, fine, bright red; slightly sandy, noncalcareous	22	356
Undifferentiated strata:		
Dolomite, hard, gray and buff; fossiliferous; fragment of impression of one valve of a square shouldered brachiopod; rough; subcrystalline	32	388
Shale, blue	4	392
Dolomite, light buff; the larger part of the sample consists of sand as at 225 feet	30	422
Shale, light blue, soft, calcareous	15	437
Ordovician:		
Galena limestone (224 feet thick; top, 793 feet above sea level)—		
Limestone, magnesian, gray	50	487
Dolomite, light buff, soft	90	577
Limestone, magnesian, hard, gray	104	661
Platteville limestone (95 feet thick; top, 569 feet above sea level)—		
Shale, blue, soft, highly calcareous	65	726
Shale, as above but darker and less calcareous	30	756
Saint Peter sandstone (110 feet thick; top, 474 feet above sea level)—		
Sandstone; grains of clear quartz, smooth, well rounded, mostly 0.55 to 0.7 millimeter in diameter	110	866
Prairie du Chien stage—		
Shakopee dolomite—		
Dolomite, light gray, subcrystalline	8	874

Graettinger.—Most of the people of Graettinger (population, 556) get their water from shallow wells that end in alluvial deposits, but perhaps one-fifth are supplied from the public waterworks, which include an elevated tank and a short system of mains. An abundance of water for the public supply is obtained from a dug well sunk 28 feet into alluvial deposits.

Mallard.—The waterworks at Mallard (population, 331) are supplied from a well 1,050 feet deep. (See Pl. XVI, p. 814.) There are an elevated tank, one-fourth mile of mains, four fire hydrants, and six taps. The average daily consumption is estimated at 3,000 gallons.

The well has a diameter of eight to four and one-half inches, casing to 1,000 feet. The curb is 1,228 feet above sea level and the head 66 feet below curb; capacity, 76 gallons a minute. Water was struck at 260 feet in fine sand, and again at 1,000 feet in white sandstone. Driller, Swanson, of Minneapolis. Year completed, 1903.

Record of strata in Mallard city well (Pl. XVI, p. 814).

	Thickness.	Depth.
	Feet	Feet
Drift	380	380
Unknown	119	499
Limestone, argillaceous	11	510
Sandstone	90	600
Shale, blue, calcareous	45	645
Dolomite and limestone	100	745
Limestone with seams of shale	30	775
Dolomite	25	800
Limestone	80	880
Shale, light colored, calcareous	30	910
Limestone	20	930
Shale, blue, calcareous (Platteville)	60	990
Shale, hard, calcareous	20	1,010
Sandstone, white, noncalcareous (Saint Peter)	40	1,050

Ruthven.—The waterworks at Ruthven (population, 655) are supplied from a dug well, 20 feet in diameter and 20 feet deep. The water is pumped into an air-tight tank, from which it is forced by air pressure through about half a mile of mains to seven fire hydrants. The water is very little used except for fire extinction. There are many shallow private wells from which the domestic supplies are obtained.

West Bend.—The public supply at West Bend (population, 679) comes from a 110-foot flowing well. (See p. 1068 for section.) The water will rise three feet above the surface, or 1,156 feet above the sea. It overflows at the surface at the rate of several gallons a minute, but is drawn down to 30 feet below the surface when pumped at 100 gallons per minute. It is lifted into an elevated tank and distributed by gravity through about a mile of mains to 10 fire hydrants and 20 taps. About 100 people are supplied and approximately 2,500 gallons are used daily.

An old city well at West Bend has a depth of 381 feet and a diameter of six inches to 284 feet and four and one-half inches to bottom. The curb is 1,197 feet above sea level and the head 31 feet below the curb. The water is from 290 to 381 feet; capacity, 20 gallons a minute. The well was completed in 1895 by C. P. Thomas, of West Bend, and was abandoned some years later on account of the insufficiency of its supply.

Record of strata in city well No. 1 at West Bend.

[Based on driller's log.]

	Thickness.	Depth.
	Feet	Feet
Quaternary:		
Soil	5	5
Clay, yellow	16	21
Clay, blue	41	62
Sand and gravel	9	71
Clay, blue, and hardpan, blue	23	94
Cretaceous:		
Sand, yellow	112	206
Marl, red	20	226
Carboniferous (Mississippian):		
Chert, white, slightly pyritiferous; some fine green clay	43	269
Sandstone, in fragments of limpid quartz, with considerable chert, and some blue-gray limestone	23	292
Dolomite, white, somewhat arenaceous	6	298
Limestone, blue-gray	4	302
Dolomite or magnesian limestone, blue, crystalline	4	306
Dolomite, crystalline, light blue-gray, blue-gray and yellowish; 3 samples	25	331
Dolomite, blue and light gray, hard, compact, finely crystalline, argillaceous; 2 samples	8	339
Limestone, from light yellowish to dark blue-gray; often mottled; in thin flakes; soft, earthy luster	11	350
Limestone, brown and buff, soft and argillaceous at 350 feet; crystalline and cherty below; 3 samples	12	362
Limestone, magnesian, gray, hard, compact; some shale; 3 samples	19	381
Shale, blue.		

PLYMOUTH COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

The upland surface of Plymouth county consists of a gently undulating prairie which descends gradually toward the southwest and is trenched by a number of valleys that trend southwestward, their direction no doubt being determined by the original upland slope. Big Sioux river, which occupies a rather wide valley, forms the west boundary of the county.

The surface deposits consist of alluvial and outwash deposits, loess, and glacial drift. In the Sioux valley, in Sioux and Plymouth counties, a series of Cretaceous rocks, consisting of shale and impure limestone (Benton), and sandstone (Dakota), is exposed. Between the glacial drift and the underlying Cretaceous lie sands of doubtful age.[1] (See Pl. VI, p. 310.)

UNDERGROUND WATER.

SOURCES.

Water in Plymouth county is derived from alluvial and outwash sand and gravel, glacial drift, sand of uncertain age, and Cretaceous limestone and sandstone.

The alluvial and outwash sand and gravel are confined to the principal valleys, where they constitute a valuable source of supply. The glacial drift, which has a much wider distribution, is relied on chiefly in the upland districts and furnishes most of the water used in the county. A number of drilled wells end in sand which lies at or near the base of the drift and may, at least in some places, be identical with the sand deposit of uncertain age in the Sioux valley between the Cretaceous deposits and the drift.

[1]Bain, H. F., Rept. Iowa Geol. Survey, vol. 8, pp. 326, 327.

The Cretaceous limestone crops out near Akron, where it gives rise to strong springs. It also supplies a number of drilled wells in the western part of the county. Though drillers do not recognize it farther east, it seems probable that if they would watch for it after the drill had penetrated shale, they would find it more widely distributed than it is at present known to be, and might find it a valuable source of water. No screens would be required in wells ending in this formation, and its depth is not great.

The Dakota sandstone outcrops in the Sioux valley in the southwestern part of the county, where it supplies many drilled wells. The head of the water lowers toward the outcrops, as is shown by the fact that at Hull, Sheldon, and Primghar the water rises to about 1,225 feet above sea level; at Hawarden to 1,150 feet; at Le Mars to 1,142 feet; and at Hinton to only 1,120 feet. In some sections of the county the water remains so far below the surface that it will perhaps never be extensively utilized, but in other parts it rises nearer to the surface and would be a valuable and reliable source of supply if it were not for the sand which tends to rise in the wells. Another disadvantage is the hard and ferruginous character of the water.

In the northeastern part of the county nearly all farm wells are bored or dug, are very shallow, and are commonly situated on low ground. Farther east and south most of the wells are drilled and many end in the Dakota sandstone at depths of 100 to 200 feet. In the Sioux valley driven wells about 25 feet deep are widely used.

SPRINGS.

Many rather large springs emerge along Big Sioux river, the water in most of them coming from the limestone that outcrops in the valley. One spring of local note about a mile south of Akron yields several hundred gallons a minute; another occurs four and one-half miles north of Akron, along the river.

CITY AND VILLAGE SUPPLIES.

Akron.—The public supply of Akron (population, 1,130) comes from eight driven wells, each 24 feet deep. The water is pumped into a reservoir on the top of the valley cliff and is thence distributed by gravity pressure through about one and one-half miles of mains to nine fire hydrants and 62 taps. The average daily consumption is approximately 15,000 gallons.

Kingsley.—The public supply of Kingsley (population, 977) is furnished by three dug wells, each 16 feet in diameter and 20 feet deep. The water is pumped into an elevated tank and thence distributed by gravity through one and one-half miles of mains to 24 fire hydrants and 63 taps. It is reported that about one-third of the population are supplied and that approximately 6,000 gallons of water are consumed daily.

Le Mars.—The waterworks in Le Mars (population, 4,157) are owned and operated by a private corporation. The water is obtained from 22 driven wells and is pumped directly into a system of mains about 12 miles long, which is tapped by 94 fire hydrants and about 850 service connections. It is estimated that approximately 750,000 gallons are consumed daily.

A well at Le Mars (Pl. VI, p. 310), owner unknown, has a depth of 1,560 feet, starting at an elevation of 1,275 feet above sea level.

Record of strata in deep well at Le Mars.[a]

	Thickness.	Depth.
	Feet	Feet
"Soil"	7	7
"Clay, yellow"	13	20
"Clay, blue"	44	64
"Sand and gravel"; hardened above	27	91
"Soapstone and slate"	89	180
"Sandstone, clays, and some lignites; in alternating strata"	138	318
"Sandstone; with some shale"	147	465
Sandstone, micaceous; of broken grains; noncalcareous		860
Sandstone; as above, many grains pink, reddish and yellow		960
Gneiss (?); constituents of orthoclase, quartz, and muscovite; reddish in mass		1,060
Gneiss (?); chiefly feldspar and mica		1,325
Schist, micaceous; brown in mass		1,560

The base of the Cretaceous may be placed at a depth of 465 feet, or 810 feet above sea level. The floor of crystalline rocks was unquestionably reached at 1,060 feet, or 215 feet above sea level. The sandstone at 960 feet may be compared in the num-

[a] Strata below 560 feet were determined by the writer; all other statements are taken from Todd, J. E., Proc. Iowa Acad. Sci., vol. 1, pt. 2, 1892, p. 14.

ber of pink, reddish, and yellow grains to the sandstones at Hull, which are found associated with intrusive sheets of quartz porphyry and may be pre-Cambrian in age.

A drill hole owned by C. R. Woodward (section 15, T. 92 N., R. 45 W.) east of Le Mars has a depth of 381 feet.

Record of strata in Woodward drill hole near Le Mars.

	Thickness.	Depth.
	Feet	Feet
Drift	25	25
Clay, bluish black, with bituminous matter and gypsum	25	50
Bituminous matter and gypsum	10	60
Soapstone and clay, organic matter colored by iron oxide and carbonate of lime and magnesia	19	79
Sandstone, very hard, ferruginous, slightly calcareous	3⅔	83
Calcareous sandstone, iron oxide; first seam of lignite, 1 inch; also sulphate of magnesia	2½	85½
Stone, arenaceous, chalky, calcareous; marly partings contain nearly pure calcium carbonate	7½	93
Marl, calcareous	1	94
Calcareous fragments	1	95
Slate, rotten, bituminous, calcareous	6	101
Slate, slightly calcareous	11	112
Shale, calcareous	1	113
Slate, rotten, bituminous; and shale	12	125
Soapstone and slate	6	131
Shale, calcareous	1	132
Shale, calcareous and siliceous	5	137
Shale	8	145
Shale, very hard	1	146
Limestone, in bands; hard, bituminous	12	158
Slate, bituminous, and shale, with streaks of coal and limestone	4	162
Shale; hard slate and shale; wind veins blow sand out of top of well	13	175
Slate and shale; with limestone bands and openings	4	179
Conglomerate, hard	2	181
Sandstone, hard, ferruginous, calcareous, with slate streaks	6	137
Sandstone, reddish brown, ferruginous	8	195
Rotten siliceous rocks, slate and blackjack	6	201
Slate and fire clay, with streaks of hard coal	4	205
Sandstone, micaceous, with streaks of fine clay	6	211
Fire clay and slate	4	215
Sandstone, hard, micaceous	5	220
Slate, bituminous	2	222
Upper coal	2½	224½
Fire clay, ½, and sandstone, 1	1½	226
Sandstone, dark; organic matter	5	231
Shale, bituminous	3½	234½
Coal	1½	236
Fire clay, fine coal	1	237
Soapstone and slate; limestone and coal streaks	5	242
Shale, arenaceous; coal in streaks	⅔	242⅔
Black oxide of iron (magnetic), hard, solid	6	248⅔
Same; with soapstone	4	252⅔
Gypsum and soapstone	6	258⅔
Soapstone, hard, ferruginous, with gypsum	4½	263⅓
Coal and slate	½	263⅚
Slate and fire clay; pyrite	4⅓	268
Soapstone	15	283
Chert	½	283½
Soapstone	16½	300
Slate, bituminous; with pyrite	6	306
Slate, bituminous, siliceous; with pyrite	9	315
Slate, fine-grained; with pyrite	8	323
Sandstone, brown, ferruginous; streaks of coal and slate	11	334
Sandstone, brown, ferruginous; with heavy spar		
Shales, quartz crystals	6	340
Shale, ferruginous, calcareous	10	350
Quartz rock and spar	14	364
Sandstone, ferruginous; with fluorspar	6	370
Shales, siliceous, with streaks of carbonaceous matter	6	376
Coal (solid vein)	5	381

All these strata are referred by Bain to the Cretaceous, although he would entertain the theory of a Pennsylvanian outlier in which the drill was still working at the bottom of the drill hole.

Remsen.—The waterworks in Remsen (population, 1,076) draw from two dug wells a supply which, though not great, is sufficient for the present requirement of approximately 13,000 gallons a day. There are an elevated tank, about a mile of mains, 15 fire hydrants, and 22 service connections.

POCAHONTAS COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY.

The surface of Pocahontas county is a monotonous, slightly undulating, poorly drained drift plain which has been modified to a minor extent by stream erosion. It rises gradually toward the west.

GEOLOGY.

The glacial drift appears to have a thickness of approximately 200 feet in the western part of the county, but it becomes thinner toward the east and especially toward the northeast, where in certain localities it is very attenuated, the underlying rock coming to the surface in at least one place.

Cretaceous deposits, consisting chiefly of beds of loose sand, lie below the drift in perhaps all parts of the county except in a small irregular area in the northeast, where the drift rests upon limestone of Mississippian age. (See Pl. XVI, p. 814.) The Cretaceous deposits are not known to outcrop anywhere in the county, though they are constantly encountered in drilling, but Mississippian limestone is exposed in the quarry near the railway northeast of Gilmore and perhaps elsewhere. It is not improbable that remnants of the Pennsylvanian also exist in the county.

The small area in which the limestone is near the surface and the Cretaceous deposits are absent occupies the northern and eastern parts of Clinton township (T. 92 N., R. 31 W.) and some adjoining territory. Its margin passes through the village of Gilmore, northwestward to a point west of Rolfe, and thence turns northeast. Along this margin the limestone surface descends with relative abruptness, passing beneath the Cretaceous accumulations to depths that are never reached in ordinary wells. In Gilmore this limestone surface was found to drop 80 feet between two wells 150 feet apart, and other similar evidence suggests that in some localities there may be a buried limestone escarpment.

UNDERGROUND WATER.

SOURCES.

The glacial drift, the porous Cretaceous sand strata, and the fissured Mississippian limestone are all three drawn upon for water. The first supplies numerous shallow wells, in many of which the yield is small and easily affected by drought; the second contains an abundance of good water, but yields it with difficulty because of the sand (for remedies, see pp. 219-226); the third has a large supply of water and is very satisfactory throughout the small area over which it lies sufficiently near the surface to be reached in ordinary drilling operations.

Near Fonda the drilled wells have an average depth of perhaps 200 feet, though some extend to more than 300 feet; near Laurens they range from less than 100 feet to approximately 375 feet and average perhaps 250 feet; near Pocahontas they average about 200 feet, but some are much deeper; near Palmer their average depth is between 100 and 200 feet; and near Rolfe they range from about 60 to 300 feet and average about 140 feet.

Two of the deepest wells in the county are the Chicago, Rock Island & Pacific Railway well at Laurens, which is reported to enter sand at 190 feet and to end in sandstone at 490 feet, and the old Blanden well, in regard to which no information was obtained.

HEAD.

The water remains farthest below the surface in wells on the relatively high area in the northwest and comes nearest to the surface in those on the lower ground in the southeast, where indeed in the valley of Lizard creek several flows have been struck. Relative to sea level, however, the water rises highest in the northwest area and remains lowest in the northeast, where it is drained from the limestone into the Des Moines valley. These conditions are shown in the following table, which is based on wells that end in the lower part of the drift or in the subjacent sandstone or limestone:

Head of the water in Pocahontas County.

Location	Altitude of surface above sea level	Height to which the water rises	
		Below surface	Above sea level
	Feet	Feet	Feet
Laurens	1,312	— 65	1,247
Fonda	1,234	— 14	1,220
Havelock	1,232	— 25	1,207
Pocahontas	1,225	— 20	1,205
Palmer	1,244	— 30	1,214
Lizard creek		+	
Rolfe	1,160	— 40	1,120
Gilmore	1,207	—100	1,107

DRAINAGE WELLS.

In the area of limestone wells a number of small swamps on the drift surface are being drained downward through wells into the underlying limestone. This method of drainage is of course possible only in areas where the head of water from the limestone is considerably lower than the ground-water table of the drift, but because of the leakage from the limestone in the valley of Des Moines river this is here the usual condition. Drainage wells have not proved entirely successful because of their rapid deterioration, which is probably due to the sediment that is carried into them with the water. Wells discharging into the sand strata have been less successful than those which empty into limestone, because the pores between the grains of sand are much smaller than the crevices in the limestone, and hence they conduct the water away less freely and are more easily choked with sediment.

CITY AND VILLAGE SUPPLIES.

Fonda.—The village well at Fonda (population, 978) ends in sandstone at the depth of 331 feet. It has been tested at the rate of about 400 gallons a minute. The water rises within 14 feet of the surface, or approximately 1,220 feet above sea level. It is pumped into an elevated tank from which it is distributed by gravity through about three miles of mains to which are attached 16 fire hydrants and 95 taps. It is estimated that about 600 people are supplied, and that 50,000 gallons of water are consumed daily.

Section of village well at Fonda.

	Thickness.	Depth.
	Feet	Feet
Soil and yellow clay; clay, blue	197	197
Sand and gravel	23	220
Clay, hard, blue, with gravel	53	273
Sandstone	7	280
Shale, blue and red; limestone, sandstone, etc.; sandstone (entered)	51	331

Beneath the strata penetrated in the village well, sandstones and shales of the Pennsylvanian may be expected, and shales which will merge into the great dolomitic series extending with little interruption to the shales of the Platteville immediately overlying the Saint Peter sandstone. Norton's estimate places the Saint Peter somewhat more than 1,300 feet below the surface. No flow can be expected, but by casing out the upper waters a less heavily mineralized supply than the present could, according to Norton, be obtained.

Gilmore.—The village of Gilmore (population, 689) has a public well but no waterworks. The well is 244 feet deep and enters limestone at the depth of 200 feet.

Laurens.—The village well at Laurens (population, 817) is 229 feet deep; the beds for the first 190 feet are reported to consist mainly of clay and for the last 39 feet of sand. The water rises within 65 feet of the surface, or 1,247 feet above sea level, and has been pumped at the rate of 35 gallons a minute. It is raised into an elevated tank, whence it is distributed by gravity through about a mile of mains to six fire hydrants and about 40 taps. It is estimated that 200 people are supplied, and that 12,000 gallons of water are consumed daily.

Pocahontas.—Perhaps one-third of the people of Pocahontas (population, 987) use water from the public supply, and the rest depend on private wells, many of which are shallow. The village well ends in sandstone at the depth of 248 feet, and has been pumped at the rate of 150 gallons a minute. The water rises within 20 feet of the surface, or about 1,205 feet above sea level. The waterworks consist of an air-pressure system with nearly two miles of mains, to which are attached 18 fire hydrants and about 40 taps. The average daily consumption is reported to be approximately 20,000 gallons.

Section of village well at Pocahontas.

	Thickness.	Depth.
	Feet	Feet
Clay	120	120
Sand	108	228
Soft sandstone (entered)	20	248

Rolfe.—The village well at Rolfe (population, 954) is 108 feet deep, all but the first eight feet of which is in limestone. The water stands 40 feet below the surface, or 1,120 feet above the sea, and has been pumped at 40 gallons a minute. It is lifted into an elevated tank from which it is distributed by gravity through a system of mains, about 7,000 gallons being used daily.

SAC COUNTY.

BY W. J. MILLER.

TOPOGRAPHY AND GEOLOGY.

Sac county may be divided into eastern and western topographic provinces. The eastern province is covered by Wisconsin drift and shows the generally level surface characteristic of that deposit. North Raccoon river flows through it in a southerly and southeasterly direction, cutting its valley to a considerable depth below the general level. The western province is loess-covered and is distinctly more hilly than the eastern. Boyer river flows across it from north to south. The western boundary of the Wisconsin drift practically constitutes the drainage divide in this part of the state and it is a region of unusually high land.

Of the drift formations, the Kansan extends over the entire county, being overlain by the Wisconsin in the east and by the loess in the west. Rocks of Cretaceous age may be found beneath the drift in all parts of the county.

The drift deposits are in general horizontal, and the older rock formations lie either flat or dip slightly eastward.

UNDERGROUND WATER.

SOURCES.

There are two important water horizons in the drift, one at the base of the Wisconsin and the other at the base of the Kansan. A large number of wells sunk to these horizons furnish a good supply of water of excellent quality except for its hardness. The Cretaceous and older rocks afford a third source of water.

Over the whole county the most certain and satisfactory aquifer in the surface deposits is the sand or gravel at the base of the Kansan drift. The drift is unusually deep over the region and this aquifer is known to be at a maximum depth of at least 480 feet, and has nowhere been struck at a depth of less than 130 feet. As a rule it lies deeper in the western part of the county because of the greater thickness of the drift there. In some wells, as in the abandoned wells at Odebolt and Schaller, water from this deposit is so highly mineralized and so full of organic matter as to be unfit for use.

In the eastern or Wisconsin drift-covered region an important water bed is the sand or gravel at the base of the Wisconsin. This aquifer ranges in depth from 50 to 100 feet, but in many places is missing. A few wells obtain a fair supply of water from local sand or gravel pockets within the blue clays of the Kansan or the Wisconsin drift.

In the western or loess-covered region water is obtained in some places from a sandy layer within or at the bottom of the loess. Many shallow wells derive water from this source, but the supply is often seriously affected by varying seasons.

As compared with the counties of central Iowa, Sac county contains but few "rock" wells. Such wells receive their water mostly from Cretaceous sandstone.

PROVINCES.

Sac county may be divided into two underground-water provinces—the eastern or Wisconsin drift-covered area and the western or loess-covered area. The chief difference between the two is that in the former there are two clearly defined water horizons, one at the base of the Wisconsin and the other at the base of the Kansan; whereas in the latter there is but one, at the base of the Kansan.

A few flowing wells are to be found in the eastern province. These wells, south of Sac City, are on low ground along a tributary of North Raccoon river, where the head is great enough for overflow. Good well records are not available, but it is thought that the water comes from the important aquifer at the base of the blue Kansan clay.

SPRINGS.

Some springs of large size are found along North Raccoon river, the most noteworthy ones being those leased by Sac City for a water supply. Other springs occur along the river, such as that on the William Harrold farm across the river from Sac City and a so-called "sulphur" spring on the M. Judd farm, two miles south of Sac City. All these spring waters are heavily charged with carbonate of lime and are locally called "petrified" springs because their waters incrust objects thrown into them. Some smaller springs or seepages are found along other stream courses.

CITY AND VILLAGE SUPPLIES.

Sac City.—The water supply of Sac City (population, 2,201) is drawn from springs. The water is led into a tank whence it is pumped by steam to a standpipe. The direct and gravity pressure is 80 pounds. There are three miles of mains, 27 fire hydrants, and 327 private hydrants. About 1,800 people use the water, which is plentiful but hard.

The springs, which are four in number, are located along a small branch of North Raccoon river about one mile north of the city. They emerge from the slope of the branch, the water apparently coming from a gravel layer in the yellow Wisconsin clay. The flow is about 1,000 barrels a day, the supply being only slightly diminished in very dry weather. The temperature of the water ranges from 52° to 56°. The water incrusts boilers considerably. Each of the four springs has been carefully cleaned out, built up with cement tiling, and is kept covered and locked. A pipe leads from each spring into a four-inch main which in turn extends about three-fourths of a mile southward to a reservoir at the pumping plant. From the reservoir the water is pumped into a standpipe.

The well of the Chicago & North Western Railway has a depth of 379 feet. It was completed before 1900 by William Burge, of Lisbon, Iowa.

Driller's log of well at Sac City.

	Thickness.	Depth.
	Feet	Feet
Till, yellow	15	15
Sand and coarse gravel, mixed	12	27
Clay, blue; mixed with cobble stones	85	112
Sand, gray and fine (water bearing)	5	117
Clay, blue; mixed with coarse gravel	77	194
Sand, gray; fine, ending coarse (water bearing)	8	202
Gumbo, hard, black; will not mix with water; will burn	3	205
Clay, dark blue and varying to a light color, but the last 5 feet mixed with coarse gravel and very hard	133	338
Coal, burns well	1	339
Hard substance; coal churned with it, so could not tell what it was	3	342
Clay, hard, blue, and gravel mixed	5	347
Sand, blue, fine at top, coarse at bottom; full of water; water rose 230 feet in pipe and the sand forced up 100 feet	6	353
Sandstone, compact, hard	8	361
Coal	1½	362½
Sandstone, light	14½	377
Slate	2	379

Sac City is 1,196 feet above sea level. Its artesian forecast by Norton is rather favorable on the whole, although a well tapping the chief water beds of the Iowa artesian system must necessarily be a deep one. The drift with its clays and sands may be expected to be thick, and below it occur various strata of Cretaceous and Carboniferous age, chiefly shales. Limestones and dolomites of the Mississippian and lower terranes extend with some interruptions of shaly beds for more than 700 feet to the shale of the Platteville. This green shale, which in many places is fossiliferous, caps the Saint Peter sandstone, which should be here found at 100 to 200 feet below sea level, or 1,300 to 1,400 feet below the surface. For a town as large as Sac City the drill hole should be carried a few hundred feet deeper, or to 1,600 or 1,800 feet, in order to tap the large supplies usually to be found in the dolomites and sandstones underlying the Saint Peter. The contract should be drawn for several hundred feet more than the most liberal estimate of needed depth, but drilling should be stopped on reaching the glauconiferous shales of the Saint Lawrence formation. Casing may be needed in the shales of the Carboniferous, the Cretaceous, and the Platteville, and also in the Maquoketa shale, should this formation extend so far to the west; but below the Pennsylvanian the drill hole will be mostly in solid limestone to the Platteville, which immediately overlies the Saint Peter.

Water may be expected but can not be assured in the different limestones, especially in the Mississippian and Galena, but the chief supply will come from the Ordovician and Cambrian sandstones.

Minor supplies.—Minor water supplies in Sac county are summarized below:

Minor supplies in Sac County.

Town	Nature of supply	Pumping system	Distribution	Pressure		Length of mains	Fire hydrants	Taps	Persons supplied	Daily consumption	Remarks
				Domestic	Fire						
				lbs.	lbs.	Miles				Thousand gals.	
Early	Well 15½ feet deep.	Gasoline engine and windmill.	Gravity	35	+ 35	1	11	40	200	+ 4.0	Good supply of medium hard water.
Odebolt	2 wells 25 feet deep.	Steam engine.	do	48	100	1½	---	100	300	18.0	Good supply of hard water.
Schaller	Well 12 feet deep.	Steam pump	do	40	+ 40	2	12	30	175	9 to 15	Fair supply of medium hard water.
Wall Lake	Well 25 feet deep.	Gasoline engine, Triplex pump.	do	37	------	2½	12	140	750	51.0	Good supply of medium hard water.

WELL DATA.

The following table gives data of typical wells in Sac county:

Typical wells of Sac County.

Owner	Location	Depth	Depth to rock	Source of supply	Head	Remarks: (Logs given in feet)
		Feet	Feet			
A. J. Masteller	Southwest of Sac City.	180	------	Sand	— 90	Yellow clay, 25; blue clay, 25; black mud with very bad odor, 22; dry sand, blowing out air, 58; blue clay, 44; sand and water, 6.
F. H. Woods	1½ miles west of Sac City.	203	------	Sand and gravel.	----------	

Typical wells of Sac County—Continued.

Owner	Location	Depth	Depth to rock	Source of supply	Head	Remarks: (Logs given in feet)
Town	Odebolt	25		Sand	— 5	Open well, steam pump.
Town	Odebolt	356		Sand		Soil and muck, 10; sand and gravel, 1; blue clay, 80; yellow clay, with bowlders at bottom, 50; blue clay, with streaks hardpan and gravel, also struck "sea mud," 192; sand and water, 23.
Mrs. O. M. Hopkins	5½ miles east of of Wall Lake.	62		Gravel	— 30	
Chas. Hecthner	7 miles southeast of Sac City.	80		do	— 15	Bored, 2 feet tiling.
Walter Snecring	5½ miles east of Sac City.	84		do	— 25	Do.
Dan Rowe	5½ miles southwest of Sac City.	57		Sand and gravel.	+	Bored well, 2 feet tiling. Flows 1½-inch stream.
Geo. Speck	2½ miles north of Early.	350		do	—240	
C O. Porter	6 miles southwest of Schaller.	432		do	—266	Black soil, 4; yellow clay (some gravel), 75; sand, 2; blue clay and some gravel, 272; dry sand, 18; ocher clay and blue clay, 19; hardpan, 12; sand and gravel (water), 30.
J. C. Bodine	5 miles southeast of Schaller.	402		Sand	— 68	
F. Fravert	3½ miles north of Odebolt.	129		Gravel	— 40	
Mrs. E. Murrey	Schaller	351	345	Shale (?)	—242	Black soil, 4; yellow clay, 70; dark (blue) clay, 50; yellow clay and blue clay, 216; hardpan, 5; shale (water), 6.
C. N. Search	2 miles south of Nemaha.	400	390	Sandstone	—140	Pumped by windmill and gas engine. Yellow clay (some gravel), 30; blue clay, 70; sand and some water, 15; yellow clay, 45; blue clay, 230; sand rock and water, 10.
Frank Smith	4 miles north of Early.	480	468	(?)	—240	Water bed unknown, contains pyrites.
W. D. Holdridge	9 miles southeast of Early.	260	240	Sand	—140	Yellow clay, 40; blue clay 60; yellow clay and sandy layers, 60; blue clay, 75; sand and water, 6; shale, 18; coal, 1⅓.
City	Wall Lake	16		do	—6&—16	Maximum yield 147 gallons per minute; decreased account sand.
Chicago & North Western Ry.	Auburn	124	116	Sandstone		

SIOUX COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

The gently undulating upland surface of Sioux county is trenched by the valleys of several southwestward-trending streams leading to Big Sioux river, whose deep and wide valley forms the west border of the county. The uplands are underlain by glacial drift with a thin veneer of loess, and the principal valleys contain deposits of glacial outwash and recently formed alluvium. Beneath the drift and the valley deposits lie Cretaceous shales, sandstones, and impure limestones, some of which are exposed in the Big Sioux valley farther south.

UNDERGROUND WATER.

SOURCES.

The water supply is obtained from glacial outwash and recent alluvium, glacial drift, Cretaceous strata above the Dakota sandstones, Dakota sandstone, and lower formations.

The glacial outwash consists in large part of beds of coarse clean sand and gravel which, because of their great porosity, their favorable situation for receiving drainage and seepage from the uplands, and the impervious formations beneath them, contain a large and permanent store of water, of high value by reason of its abundance, its excellence, and the ease with which it can be obtained. Although this outwash occurs over only a small part of the county, the water is largely available for municipal supplies, because most of the cities and villages are located near streams. Though normally of good quality especial precautions are necessary to prevent its pollution, because, in most cases, the city is built on the valley slope which drains into the valley flat where the well is located.

The glacial drift furnishes most of the water used in the county and is relied on almost exclusively in the upland districts. Many bored wells end in the surficial portion of the drift, from which they derive supplies that are small in amount and that frequently fail completely in dry seasons. Deeper bored or drilled wells, however, reach seams of sand and gravel in the lower portions of the drift and thus tap water that is under considerable artesian pressure. Unfortunately in some parts of the county these deeper water-bearing beds are not found in the drift.

The deepest drilled wells penetrate the Cretaceous formations and are supplied from the Dakota sandstone, or perhaps in some places from higher sandstones or limestones. The Dakota contains large and permanent supplies but the water is hard and ferruginous and the sand causes trouble by entering the wells, especially if the latter are of the small "tubular" type or are pumped rapidly. In the northeastern part of the county the water rises to about 1,225 feet above sea level. In the creamery well at Hull it rises to 1,228 feet and in the deep wells at Primghar (O'Brien county) to about 1,225 feet. Farther southwest the head is lower, evidently because of outcrops of the formation in this direction and consequent leakage. At Hawarden the water rises apparently to only 1,150 feet above the sea, and at Le Mars to only 1,142 feet; farther southwest it remains still lower. In the northeastern part of the county the level to which water from this formation rises is about 200 feet below the upland surface. In the valley of Big Sioux river the artesian head is only slightly below the flood-plain surface but there is no evidence that flows can anywhere be obtained.

The only well known to penetrate formations below the Dakota is the deep well at Hull, which obtained unfavorable results.

CITY AND VILLAGE SUPPLIES.

Alton.—The waterworks at Alton (population, 1,046) are supplied from large open wells sunk 20 feet into the saturated materials in the valley of Floyd river. Until recently the supply has not been adequate but a large new well has been dug which will probably yield more than sufficient to meet present demands. The system consists of a standpipe, two miles of mains, 20 fire hydrants, and approximately 100 taps. A large proportion of the inhabitants use the public supply.

Granville.—The village well at Granville (population, 400) is four feet in diameter and 40 feet deep. The waterworks consist of an elevated tank with a short system of mains and three fire hydrants. The water is used almost exclusively for fire protection, the domestic supply being drawn from numerous private wells.

Hawarden.—The public supply of Hawarden (population, 2,107) is derived from sixteen two-inch driven wells 23 feet deep, which penetrate a layer of alluvial gravel. The water is pumped directly from these wells into about two miles of mains, with which are connected 16 fire hydrants and 159 taps. Approximately 800 people are supplied, the average daily consumption being about 50,000 gallons.

Hull.—The waterworks at Hull (population, 658) consist of a tank elevated upon a tower and one-fourth mile of mains with four fire hydrants. Little use is made of the water. The city well is 1,263 feet deep, and the diameter is ten to six inches. The well is cased to 800 feet, and the water is reported to come in part from about that depth and in part from 340 feet, where the casing is said to have been opened. The curb is 1,433 feet above sea level, and the water stands at 230 feet below the surface, or about 1,205 feet above the sea, which is nearly the level to which the water from the Dakota sandstone rises in this vicinity. The supply is "abundant," the capacity being 29 gallons a minute. Temperature 58° F. The well was completed in 1892 by Rodgers & Ordway, of St. Paul, and was repaired in 1907 by inserting 306 feet of new casing.

Little is known of the sequence of strata except that the drift extends to at least 190 feet and that at 755 feet there begins a succession of alternating beds of sandstone and quartz porphyry whose record is given by Beyer.[1]

[1]Ann. Rept. Iowa Geol. Survey, vol. 1, p. 168, 1893.

Description of strata below 755 feet in city well at Hull.

	Depth in feet.
Quartz porphyry, compact, olive-green	775-800
Sand rock, fine-grained	800-802
Quartz porphyry	802
Sandstone, coarse-grained	825
Quartz porphyry	832-840
Sandstone, fine-grained	840-860
Conglomerate	866
Sandstone, fine-grained	880-900
Quartz porphyry; the drillings contain also angular fragments of quartz	900-930
Sandstone, fine-grained	930
Pebbles, waterworn; fine sand adhering	930-935
Quartz porphyry, decomposing	935-940
Quartz porphyry, perfectly fresh	944
Quartz porphyry, decomposing	949
Quartz porphyry	975-990
Sandstone	990
Quartz porphyry	1,194-1,220
Sandstone, fine-grained	1,228

The entire section is regarded as pre-Cambrian.

Ireton.—The waterworks at Ireton (population, 631) are supplied from four wells three feet in diameter and 12 feet deep. The water is pumped by a windmill from the wells into a reservoir, and by an engine from the reservoir into an elevated tank. About a mile of mains supplies 12 fire hydrants. The water is not considered fit for domestic use, and the people depend largely on rain water, which is stored in cisterns.

Orange City.—Until recently the public supply for Orange City (population, 1,374) was taken from a drilled well 215 feet deep, but difficulty with the screen made it necessary to abandon the well, and two shallow dug wells, whose combined yield is only about 4,500 gallons a day, were temporarily brought into service. There is an elevated tank and about a mile of mains with nine fire hydrants and 28 taps.

A deep well was sunk in 1911 for city supply to a depth of 562 feet, by G. L. Savidge, of Sioux City. The diameters are eight inches to 331 feet and six inches thence to the bottom. Water was found at 300 feet and in sandstone from 410 to 562 feet. The head is 25 feet below the surface. The pumping capacity at completion is stated to have been 20 gallons a minute. It is also stated that the well "will hold out at 75 gallons." The cylinder is placed at 321 feet below the surface of the ground. The well is cased with eight-inch casing to a depth of 331 feet, below which is 144 feet of six-inch and 110 feet of four and one-half inch casing, 60 feet of each of the latter sections being perforated with one-half inch holes to admit water. No packing was used. The cost of drilling was $2 a foot. Unfortunately it proved impossible even with the cooperation of the town officials to secure any samples as the drilling progressed or any accurate log. A sketch of the well made by the driller indicated the following sequence:

Log of well at Orange City.

	Thickness	Depth
	Feet	Feet
Unknown, probably largely drift	331	331
Rock	8	339
Clay, blue	? 73	? 412
Sandstone; not very much water	30	442
Clay	70	512
Sandstone, white, soft	50	562
Clay, blue.		

Rock Valley.—The village well at Rock Valley (population, 1,198) is 10 feet in diameter and 30 feet deep, ends in gravel, and has been tested at 300 gallons a minute. The waterworks include an elevated tank, one and one-quarter miles of mains, 18 fire hydrants, and about 80 taps. Approximately 400 people, or one-third of the population, use the water, an average of 25,000 gallons being consumed daily.

WOODBURY COUNTY.

BY W. J. MILLER AND W. H. NORTON.

TOPOGRAPHY.

Woodbury county may be divided into two topographic provinces—the Missouri river bottom, which occupies the western side of the county, and the rugged highland region, which extends eastward from the Missouri river bottom. The line of separation between the two is rather sharp, the flat swamp lands of the river bottom coming abruptly against the characteristically very rugged hilly region.

The largest stream in the county is Little Sioux river, which flows across the eastern end. West Fork of Little Sioux river flows across the central portion of the county from north to south. Both these streams have numerous branches which greatly dissect the region.

GEOLOGY.

Of the drift formations, the Kansan and the loess are both well represented, each extending over the whole county except along the Missouri river bottom, where both are mostly eroded away. Clays and soft sandstones of Cretaceous age lie immediately beneath all of the drift, and good exposures may be seen along Missouri river. As far as known, all the geologic formations of the county lie approximately horizontal.

UNDERGROUND WATER.

SOURCES.

Water is obtained by shallow wells from the alluvium of the Missouri river bottom and from the loess. Deeper wells strike the aquifer beneath the Kansan or the Dakota sandstone. A well at Sioux City extends far into the Algonkian.

Except in and about Sioux City, most of the wells of the county are shallow surface wells, though there are a few deeper drilled wells. The numerous wells furnish a good supply of water, which is almost always hard.

In the drift deposits there are two water horizons—one in sand or gravel below, or sometimes within the loess, and the other in sand or gravel below the blue Kansan clay. The combined thickness of the Kansan and the loess is much less in Woodbury county, as a rule, than in the next county to the east (Ida), and these water horizons are proportionately nearer the surface. The loess appears to range in thickness from nothing to 60 or 70 feet, and most of the wells of the county are shallow (20 to 80 feet) dug wells, whose water comes from the loess itself or from sand or gravel just below it. Many of these shallow-well supplies fluctuate according to seasons.

A much more clearly defined and persistent water horizon is that of the sand or gravel at the base of the Kansan, although comparatively few wells are deep enough to reach it, its depth ranging from less than 100 feet along stream bottoms to 300 feet in the high land. Locally, water-bearing sands may be struck within the blue clay itself.

Along the Missouri river bottom many shallow driven wells are obtained by going from 15 to 45 feet in the alluvial deposits, in which many sand or gravel layers are charged with water. The head of water in the wells generally responds to the rise and fall of water in Missouri river itself.

The Cretaceous rocks below the drift or alluvial deposits contain some important water-bearing beds, especially in the vicinity of Sioux City. The rocks and soft sandstones yield large supplies of water in numerous places at depths ranging from a few feet to 500 feet.

PROVINCES.

Woodbury county may be divided into two underground-water provinces—the Missouri river bottom, where many shallow wells derive water from Cretaceous sandstones, and the larger province east of the river bottom, where water is obtained largely from the loess and the Kansan drift and where a few deeper wells obtain water from the Cretaceous rocks. No flowing wells have been noted in the county.

SPRINGS.

Many small springs emerge from the loess or the Kansan drift along the main stream courses.

CITY AND VILLAGE SUPPLIES.

Sioux City.—Sioux City (population, 47,828) draws its supply from two groups of wells. The water is pumped by steam and is distributed under gravity and direct pressure of 110 pounds. The wells at the Main Street station are 97 in number, comprising 90 driven wells from 90 to 100 feet deep and seven drilled wells more than 300 feet deep. Those at the Isabella Street station are 19 in number, one drilled to a depth of 371½ feet, and 18 driven to between 75 and 78 feet. The wells yield a good supply of medium hard water; 1,680,000 gallons are used daily. There are 58 miles of mains, 325 fire hydrants and 4,500 taps.

The drilled well at the Isabella Street Station has a diameter of 10 inches. The water heads 24 feet below curb.

Record of strata in city waterworks' well, Sioux City.

[Based on driller's log.]

	Thickness	Depth
	Feet	Feet
Pleistocene:		
Sandy clay	35	35
Fine gravel and water	13	48
Cretaceous:		
Gray shale or clay	32	80
Sandstone, fine-grained, light colored, and water	36	116
Sandstone, yellow; with layers of shale	20	136
Shale, pink and blue	11	147
Shale, gray and blue	21	168
Sandstone, coarse	67	235
Sandstone, finer, light gray	27	262
Pyrite and lignite	31	293
Sandstone, fine, light gray	2	295
Sandstone, white, fine-grained	19	314
Sandstone, darker and coarser	33	347
Sandstone, coarse; limestone fragments	11	358
Sandstone, etc., as above but coarser	3	361
Sandstone, very coarse; water	10	371

The well of D. A. Magee has a depth of 2,011 feet and a diameter of 6 inches to 1,270 feet; casing, 6 inches to 444 feet and 230 feet of four inch casing, place not reported. The curb is 1,125 feet above sea level and the head at curb. Water beds lie at 65 feet (drift gravel), at 120 feet (yielding 120 gallons a minute), at 570 feet (heading 12 feet below the curb), at 1,250 feet (flowing 3 gallons a minute), and at 1,480 feet (pre-Cambrian). The discharge is 6 gallons a minute; temperature, 70° F. The well was completed in 1882 by Marrs & Miller, of Chicago.

The water of the well is strongly mineralized, containing large amounts of the sulphates of calcium, magesium, and sodium, and has been sold for medicinal purposes.

Driller's log of Magee well (Sioux City Waterworks Company) at Sioux City.

	Thickness	Depth
	Feet	Feet
Soil and clay	60	60
Gravel	25	85
Shale	54	139
Sand, white	2	141
Sandstone, brown	34	175
Sandstone, white	100	275
No samples	155	430
Sandstone, gray	110	540
Sand and limestone	30	570
Limestone, gray	50	620
Sand and limestone	35	655
Limestone, white	100	755
Sand, light colored	30	785
Limestone, gray	20	805
Shale	98	903
Limestone	10	913
Shale	12	925
Limestone	10	935
Shale	5	940
Limestone	5	945
Shale, sandy	35	980
No samples	50	1,030
Limestone	70	1,100
Shale	60	1,160
Shale and limestone	30	1,190
Limestone, gray	60	1,250
Marl, red; with sand	5	1,255
Sandstone, porous (Saint Peter)	15	1,270
Sand and marl	25	1,295
Marl, sandy	20	1,315
Sandstone, micaceous. very hard; crevice giving water	165	1,480
Sandstone, brown, micaceous; and lime, very hard	380	1,860
Limestone, light colored	5	1,865
Sandstone and lime, very hard	146	2,011

Record of strata in Magee well (Sioux City Waterworks Company) at Sioux City.

	Depth in feet.
Cretaceous:	
Sandstone, light yellow; of fragmental quartz grains	210
Undetermined Paleozoic:	
Dolomite, light yellow-gray; much fissile, green shale, in rounded lumps, and some quartz sand, both probably from above	530
Sandstone and limestone; mostly quartz sand, grains of moderate size, imperfectly rounded; also considerable limestone, light yellow-gray, in small fragments, chips of hard crystalline gray dolomite, and shale as above	540
Dolomite, gray; in sand; drillings largely chert	645
Dolomite, light buff; in sand, drillings chiefly white pyritiferous chert	780
Cambrian:	
Sandstone, bluish gray, argillaceous, pyritiferous, slightly calcareous; grains microscopically fine, subangular, 2 samples	840-855
Sandstone, white; some grains rounded and polished but most of them broken	970
Dolomite, highly arenaceous; embedded grains rounded, pyritiferous, and glauconiferous; pyrite in minute nodules	1,000
Sandstone, calciferous, pyritiferous, glauconiferous	1,010
Sandstone, light gray; grains minute, not rounded	1,030
Sandstone, gray, calciferous; many rounded grains	1,035
Sandstone, medium dark blue-gray, calciferous; grains minute; glauconiferous	1,070

Record of strata in Magee well (Sioux City Water Works Company) at Sioux City, Iowa—Continued.

Sandstone, highly calciferous, gray; minute angular particles of quartz, highly glauconiferous, with considerable green shale	1,160
Pre-Cambrian:	
Schist, soft, fine-grained; speckled with white and dark green-gray; so friable that a microsection could not be obtained; when pulverized it is seen to be composed of quartz and chlorite	1,260
Schist or gneiss; contains quartz, feldspar, white and pink feldspar, black ferromagnesian mica; and a translucent apple-green mineral, probably chlorite; 2 samples	1,320-1,850
Schists or gneisses, gray, brown, and black; micaceous, usually with biotite; much hornblende, 32 samples; at 1,860-1,865 samples are chiefly feldspar and quartz	1,727-2,000

The well of the Sioux City Brewing Company has a depth of 215 feet.

Record of strata in well of Sioux City Brewing Company.

	Thickness	Depth
	Feet	Feet
Clay, brown, difficultly friable	30	30
Shale, dark drab; carbonaceous inclusions from 30 to 56 feet; minutely quartzose from 56 to 98 feet	68	98
No record	6	104
Sandstone, yellow; grains little rounded, seldom exceeding 0.4 millimeter in diameter	21	125
Sandstone, as above, but coarser; largest grains 1 mm. in diameter	15	140
Shale, drab, calcareous	75	215

Minor supplies.—The following table summarizes the smaller supplies of Woodbury county:

Village supplies in Woodbury County.

City or town	Nature of supply	Pumping system	Distribution	Domestic pressure	Fire pressure	Length of mains	Fire hydrants	Taps	Persons supplied	Daily consumption	Sufficiency of supply	Quality
				lbs.	lbs.	Miles				1,000 gallons		
Anthon	98-foot well.	Gasoline engine.	Gravity	------	------	------	----	----	----	--------	Good supply.	Hard.
Correctionville.	18-foot well.	Electric motor; duplex pump.	-- do --	45	100	$1\frac{1}{4}$	20	50	350	75-90	---- do ----	Do.
Moville	32-foot well.	Gasoline engine	-- do --	42	------	$\frac{3}{8}$	----	51	420	15.3	Fairly good supply.	Medium hard.
Sloan	13 driven wells.[1]	Steam pump.	-- do --	------	12	$\frac{1}{2}$	8	----	----	--------	Good supply.	Hard.

[1]For fire use only.

WELL DATA.

The following table gives data of typical wells in Woodbury county:

Typical wells of Woodbury County.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
H. Dolan	5 miles northeast of Smithland.	24		Sand	147	No rock.
Oscar Button	1½ miles north Smithland.	120		do	70	Do.
Town	Anthon	98		Gravel and sand.	20	Gas engine pump. Black soil, 4; yellow clay and some gravel, 20; gravel and water, 20; bluish black clay, 20; gravel, sand, lignite, and water, 34; no rock.
Henry Hein	4 miles northwest Correctionville.	400	350+	Sandstone	200	Yellow clay (gravel toward bottom), 35; blue clay, 250; gravel and water, 25; blue clay, 30; sand and shale, 52; sandstone (hard and white) and water, 8.
B Delmater	1½ miles southwest Correctionville.	337	302	do	200	
Hans Lahan	4 miles southeast Correctionville.	285	240	do	210	Yellow clay with gravel at bottom, 40; blue clay, 200; shale, sandstone and water, 45.
—— Margeson	7 miles west Moville	175	155	do	95	
City	Sioux City	371½	136	Coarse sand.	24	Well not now used but will be cleaned and used again.
Chicago, St. Paul, Minneapolis and Omaha R.R. shops	do	72-75		Gravel	28	3 wells driven along river bottom. Filling, 12; black soil, 3½; blue clay and yellowish sandy clay, 38; gravel and water 20-22, blue clay, no rock.
Cudahy Packing Co.	do	355	170	Sandstone	19	Air lift. Gravel, 30-40; light colored clay; white sandstone, 170; shale or clay, 202; sandstone, 205; white chalk rock, 300; sandstone (water), 325; light colored shale, 350; shale, 355.
Logan Park Cemetery.	3 miles north of postoffice, Sioux City	120	110	do	60	Black soil and water, 40; blue clay, 47; sand and water, 3; yellow clay, 25; sandstone (soft), and water, 10; blue clay.
Macx Dreyfus	4 miles east of postoffice, Sioux City.	87	80	Shale	80	Gas engine. Feed yard.
Harriford Produce Co.	Sioux City	120		Gravel	20	Steam pump. Cold storage. Alluvium, 35; fine sand, 15; blue clay, 6; fine gravel, 14; hard blue clay, 4; coarse gravel, 2; clay and gravel alternating (water in last gravel layer), 44; no rock.
Town	Sloan	30		Sand	5-10	Driven; steam pump. No rock.

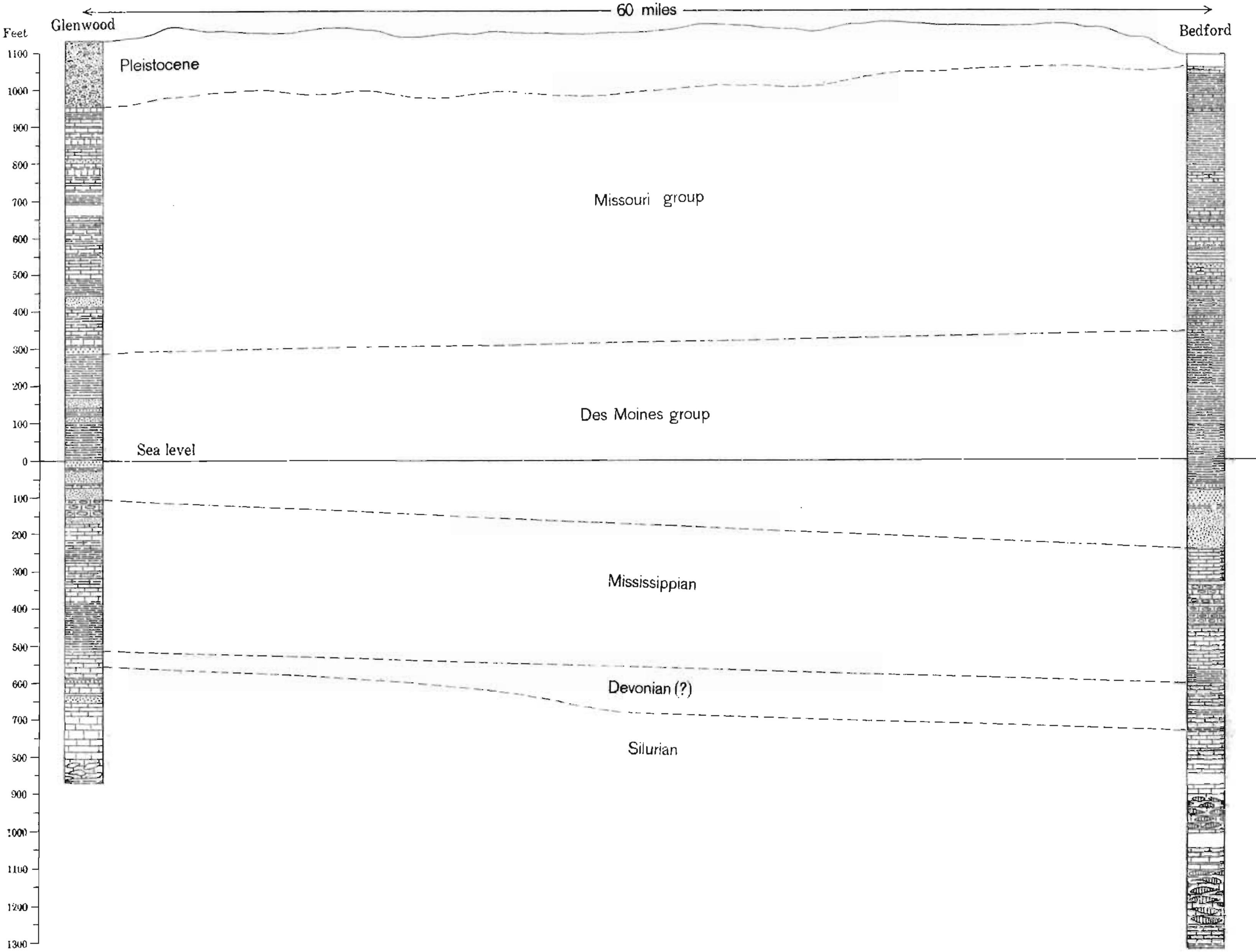
CHAPTER XV.

UNDERGROUND WATERS OF THE SOUTHWEST DISTRICT.

INTRODUCTION.

BY W. H. NORTON.

The southwest district includes eleven counties—Adams, Audubon, Cass, Fremont, Harrison, Mills, Montgomery, Page, Pottawattamie, Shelby and Taylor. Over the northern counties the Cretaceous deposits lie immediately below the drift; over the remaining counties the drift is underlain by the Missouri stage of the Pennsylvanian series. At Atlantic the Pennsylvanian shales, limestones, and sandstones are 725 feet thick and extend to 300 feet above sea level, where they give place to highly cherty limestones of the Mississippian series. At Council Bluffs, however, a distinct upwarp reduces the thickness of the Pennsylvanian to about 500 feet. At Glenwood the base of the Pennsylvanian can not lie more than 1,235 feet below the surface, 103 feet below sea level; at Bedford it occurs 1,340 feet below the surface or 242 feet below sea level; in the section of the drill hole at Nebraska City, Nebraska, it is placed at 90 feet below sea level. (See Pl. XVIII.) At Clarinda a drill hole 1,002 feet deep failed to reach it. The map showing the elevation of the base of the Pennsylvanian (fig. 7) indicates a gentle downwarp whose axis extends from Polk county to Fremont county. If this interpretation of the data at hand is correct, the Pennsylvanian series on the uplands near the Missouri state line may attain a thickness of about 1,400 feet.



GEOLOGIC SECTION BETWEEN BEDFORD AND GLENWOOD, IOWA
By W. H. Norton

THE NORRIS PETERS CO., WASHINGTON, D. C.

Printed page faces p 1100

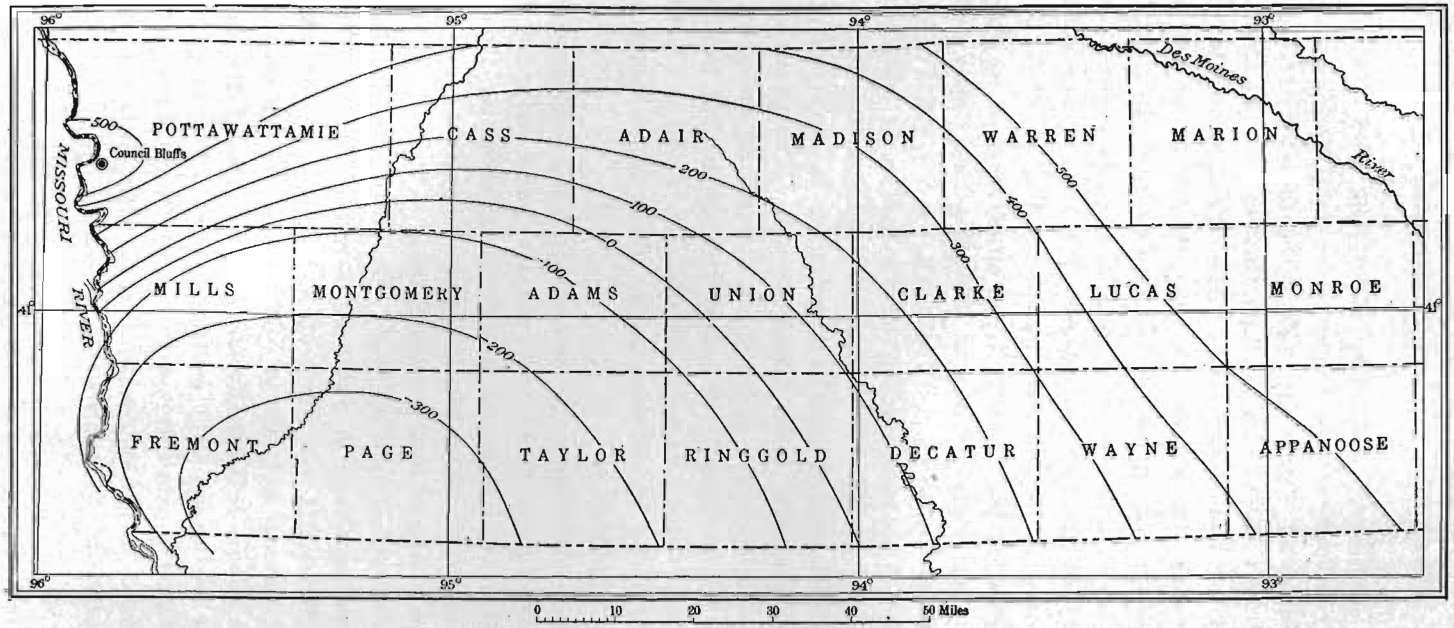


Figure 7.--Map showing by contours the elevation of the base of the Pennsylvanian in parts of southwest and south-central Iowa.

Of the Paleozoic terranes underlying the Pennsylvanian series very little has been disclosed by deep wells. At Bedford the Mississippian series appears to be at least 300 feet thick, not including a basal shale which is probably Kinderhook but which may be Devonian. Below the shale are about 200 feet of argillaceous limestones, red or pink in the lower portion, which rest on water-bearing dolomites and anhydrite marls that continue to a depth of at least 2,400 feet from the surface. Like the gypseous beds of eastern Iowa, they are referred to the Silurian. At Glenwood the succession is similar. Below the sandstone at the base of the Pennsylvanian lie the cherty limestones and basal shales of the Mississippian, resting on water-bearing dolomites. At Dunlap, on the north line of this area, a deep well reached the Mississippian at 569 feet above sea level, and at 416 feet below sea level a calciferous sandstone or arenaceous dolomite which may be referred either to the Saint Peter or to some lower terrane. The presence at 194 feet below sea level of a green shale resembling the green shales of the Platteville favors the latter reference; but the fact that the dolomite intervening between the shale and the supposed Saint Peter is not arenaceous lends some countenance to the former hypothesis.

At Lincoln, Nebraska, the State well, 2,463 feet deep, left the Pennsylvanian at 40 feet above sea level and entered the Saint Peter at 827 feet below sea level, the intervening strata being largely magnesian limestones. The southwest strike of the Saint Peter mapped for southwestern Iowa (Pl. I) thus appears to continue into Nebraska. On the other hand, there is in south-central Iowa a south-southwest strike of the Saint Peter into Missouri. In the deep well at Forest City, Missouri, the Pennsylvanian extends to 760 feet below sea level and the base of the shales referred to the basal shales of the Mississippian in the Nebraska City section lies at 1,181 feet below sea level, according to the interpretation of the Missouri geologists. The Paleozoic terranes reach their greatest known depths in territory adjacent to southwestern Iowa.

All of the facts at hand support the theory graphically shown in Plate I that the deeper Paleozoic strata of southwestern Iowa form a trough whose axis extends southwestward from Des Moines. Just where the axis of the trough crosses the southern boundary of the state is unknown. The fact that the base of the Mississippian is lower at Bedford than at Nebraska City leads to the inference that the axis may lie as far east as Page or Taylor county. The great thickness of the Silurian at Bedford leads to the same conclusion. If at Bedford the distance from the base of the Mississippian to the Saint Peter is as great as at Nebraska City, the Saint Peter would be reached at Bedford at about 2,000 feet below sea level. The hypothetic contours of the summit of the Saint Peter in southwest and south-central Iowa have been drawn by spacing the rise of the Saint Peter from its assumed depth at Bedford to Nebraska City, Dunlap, Des Moines, Pella, and Centerville, assuming some increase in steepness toward the southwest.

The water-bearing beds of the drift and of the Cretaceous are described in the reports of the individual counties of this district.

The sandstone at the base of the Pennsylvanian series will afford moderate supplies of water which in the deeper valleys may rise near the surface. The Mississippian limestones supply moderate quantities of water at Council Bluffs, Logan, and probably at Woodbine, where they lie from 600 to 900 feet below the valley levels.

The magnesian limestones referred to the Silurian yield copious supplies of heavily mineralized water. At Glenwood the water is used for city supply; at Bedford it is not fit to drink. The quality of the water is probably best in the northern counties of the area, where the strata stand the highest. At Nebraska City there is a large flow of fresh water from the dolomites underlying the Kinderhook; at Council Bluffs dolomites referred to the Silurian yield copiously, and these and subjacent dolomites should afford generous supplies for scores of miles up the Missouri valley and the valleys of its tributaries. Water may possibly be found in the Saint Peter (Pl. I), but the depth to this formation is great—over most of the district too great for profitable drilling—the casing out of the mineralized waters of the Carboniferous is difficult, the quality of the water of the Saint Peter is uncertain, and on the uplands the head of the water would be low. In the northern tier of counties the Silurian and Ordovican water beds are within a not excessive distance of the surface. At Logan, for example, whose elevation is 1,033 feet above sea level at the Illinois Central Railroad station, the Saint Peter should be found about 1,650 feet below the surface or about 650 feet below sea level. A well 2,250 feet deep would thoroughly test the capacities of the chief water beds associated with the Saint Peter. Water may be expected here in heavy arenaceous dolomites probably of Ordovician age. The capacity of the present well at Logan, which draws its supply from the Mississippian series, would no doubt be greatly increased if it were deepened to reach the horizons which furnish the main supplies at Council Bluffs. At Harlan the Saint Peter is estimated at about 1,900 feet from the surface and the required depth for a deep well would range from 2,000 to 2,500 feet At Audubon the Saint Peter will probably be found about 2,000 feet below the surface.

Information of great value in interpreting the geology of southwestern Iowa is afforded by a drill hole sunk in 1911 and 1912 in search for oil and gas at Nebraska City, Nebraska, by Ingersoll Brothers, of Pittsburgh, Pennsylvania. Through the efiorts of Dr. George L. Smith, of Shenandoah, Iowa, who has long studied the geologic problems of this section of the state, a log made out with special care was secured and a number of samples of the drillings were submitted for examination.

Driller's log of boring at Nebraska City, Nebraska.

	Thickness	Depth
	Feet	Feet
Soil	4	4
Limestone	4	8
Shale	25	33
Limestone	2	35
Shale, red	5	40
Shale, blue	15	55
Shale, red	5	60
Shale, blue	22	82
Limestone	5	87
Shale, blue	32	119
Red rock	6	125
Sandstone	2	127
Shale, blue	73	200
Limestone	9	209
Shale, black	6	215
Limestone, blue	5	220
Limestone, white	30	250
Limestone, blue	15	265
Shale, black, with oil	2	267
Limestone, white	15	282
Shale, blue	8	290
Limestone, white	45	335
Shale, blue	2	337
Limestone	17	354
Shale, blue	2	356
Shale, black	9	365
Limestone	15	380
Sandstone with mineral water, artesian	35	415
Shale, blue	20	435
Limestone, white	20	455
Red rock	3	458
Shale, black	10	468
Limestone	25	493
Shale, blue	15	508
Sandstone, with artesian mineral water	12	520
Shale, black	10	530
Limestone, white	40	570
Red rock	5	575
Limestone, bottom sandy, with water	40	615
Shale, blue	2	617
Limestone, white	60	677
Shale and limestone	5	682
Shale	3	685
Limy shale	5	690
Limestone	10	700
Shale, black	10	710
Sandstone, limy	15	725
Limestone	25	750
Limestone, blue	10	760
Shale, limy	25	785
Sandstone, very hard	8	793
Limestone	20	813
Sandstone	5	818
Limestone, very hard	5	823
Shale	10	833
Limestone	10	843
Shale, blue	20	863
Wanting	17	880
Limestone, blue	20	900
Shale, blue	25	925
Shale, black	15	940
Limestone, white	20	960
Shale, red	60	1,020
Rock, hard, flinty	4	1,024
Soapstone, white	5	1,029
Sandstone, white; with big flow of water, saline between 1,040 and 1,050; passing gradually into limestone below	21	1,050
Limestone, cherty; with several small layers of shale toward bottom, none over 2 feet thick	190	1,240
Shale, blue; in last 50 feet hard thin shells of pyrite	200	1,440
Unknown, hole caving badly	20	1,460
Shale, white; casing set here	1	1,461

Drillers log of boring at Nebraska City, Nebraska—Continued.

	Thickness	Depth
Sand, white	4	1,465
Sand, and lime, brown; big flow of fresh water rising within 100 feet of surface	48	1,513
Sand, gray	4	1,517
Lime and sand, white	82	1,599
Shale, green and black	6	1,605
Limestone, sandy, white	65	1,670
Shale, green-blue	5	1,675
Limestone, brown; show black shale	13	1,688
Limestone, brown; turning to white	38	1,726
Limestone, buff, sandy	35	1,761
Sandstone, white, hard, sharp	56	1,817
Limestone, white	5	1,822
Limestone, brown	30	1,852
Limestone, white	153	2,005
Limestone, white, sandy	24	2,029
Shale, black	2	2,031
Limestone, white, sandy	6	2,037
Limestone, white	6	2,043
Limestone, blue, white, sandy	17	2,060
Limestone, white	42	2,102
Limestone, dark, and shale	59	2,161
Limestone, shaly, dark; showed some sand	113	2,274
Limestone, buff; showed some mineral	35	2,309
Limestone, blue, hard	38	2,347
Limestone, brown, very hard	18	2,365
Limestone, white	137	2,502
Limestone, blue, white, sandy; drills into chips and cuts steel badly	22	2,524
Limestone, white, sandy, medium hard	20	2,544
Limestone, white	10	2,554
Limestone, blue-white and darker, hard	13	2,567
Limestone, blue-white, sandy	13	2,580
Limestone, black, hard	3	2,583
Limestone, dark, very sandy	22	2,605
Limestone, dark	14	2,619
Limestone, brown, sandy	44	2,663
Shale, black; alternating with limestone shells; wet sample gives odor of petroleum	24	2,687
Limestone, brown, very hard	15	2,702
Limestone, gray, sandy, very hard	17	2,719
Limestone, blue, very hard	7	2,726
Limestone, brown, very hard	25	2,751
Limestone, blue-white, hard	3	2,754
Shale, black and blue; with shells, alternating hard and soft, fossiliferous		

Description of strata of boring at Nebraska City, Nebraska.

Carboniferous:	Thickness	Depth
Pennsylvanian (1,020 feet thick; top, 930 feet above sea level)—	Feet	Feet
No samples	1,020	1,020
Mississippian (420 feet thick; top 90 feet below sea level)—		
Chert, white, sparingly pyritiferous; in large fragments; 1 fragment of nonmagnesian, light gray-brown, fine crystalline-granular, compact limestone, and 1 diorite pebble from drift; 1 sample	220	1,240
Shale, light blue, plastic, argillaceous; somewhat calcareous, fine-grained, massive; some fragments of light blue, finely arenaceous laminated shale, laminae ⅟ inch thick	200	1,440
Devonian and Silurian (720 feet thick; top, 510 feet below sea level):		
Dolomite; in fine yellow powder, crystalline grains; very small admixture of minute grains of quartz	20	1,460
Limestone, magnesian; or dolomite; effervescence moderately slow; buff in mass, in fine sand and powder; some minute quartz grains; 4 samples	35	1,495
Dolomite, light brown; in fine sand; a little chert, at		1,500
Limestone, magnesian; or dolomite; dark buff; moderately slow effervescence; in fine crystalline sand, at		1,515
Limestone, magnesian; or dolomite; as above; 1 sample		1,540
Shale, hard, light blue-green, and darker, blue-gray; slightly calcareous, at		1,665
Limestone; in light buff powder, rather brisk effervescence; with minute grains of quartz and cryptocrystalline silica; 3 samples, at		1,770

Description of strata of boring at Nebraska City, Nebraska—Continued.

	Thickness	Depth
	Feet	Feet
Limestone, magnesian ; or dolomite; light buff; in sand; effervescence rapid at first, then slow; more or less residue of irregular and broken minute grains of quartz and cryptocrystalline silica; 3 samples, at		1,840
Dolomite, light buff, cream color, and whitish; in fine crystalline sand; residue of minute, irregular grains of quartz and flakes of crytocrystalline silica; in some samples large residue of cryptocrystalline silica; 1 sample contains fragments of hard, granular-crystalline vesicular dolomite; cavities drusy; 8 samples	27	2,012
Dolomite, light buff and light brown, in sand and powder; highly cherty below 2,060; 7 samples	130	2,160
Orodovician:		
Maquoketa shale (114 feet thick; top, 1,230 feet below sea level)— No samples	114	2,274
Galena dolomite (480 feet thick; top, 1,344 feet below sea level)—		
Limestone, light gray and whitish, minutely granular-crystalline; oxidized on surface to buff; rather slow effervescence; contains minute cubes of pyrite and some gray chert, in chips; also limestone, soft, buff, minutely crystalline-granular; rather rapid effervescence at first immersion, but crystalline grains attacked rather slowly; considerable blue-gray flint in fine sand; fragment of pygidium of trilobite noted on one chip of same; much shale (2,274 feet) caving from above; blue-green, hard, fissile, noncalcareous, nonarenaceous, nonglauconiferous	35	2,309
Chert, blue-gray, mottled, and light buff; in small chips; a little soft crystalline-granular limestone, buff, of rather rapid effervescence; some hard green and gray fissile shale and pyrite	4	2,313
Dolomite, light gray, highly cherty, pyritiferous; some minute irregular grains of quartz; in fine sand, at		2,322
No samples	43	2,365
Dolomite, light buff, crystalline, granular, vesicular; in places cherty; in fine sparkling sand; 5 samples	159	2,524
Dolomite, buff and gray, cherty; a little hard fissile greenish shale, somewhat calcareous; 2 samples	51	2,575
No samples	45	2,620
Dolomite, buff, impure, considerable microscopic siliceous and argillaceous residue. (Described by driller as "alternating layers of lime and dark shale")	24	2,644
Dolomite, dark buff, crystalline, granular; in sand; 3 samples	46	2,690
Limestone, mottled buff and gray, compact; rapid effervescence; pyritiferous; 2 samples	64	2,754
Decorah shale (top, 1,824 feet below sea level)—		
Shale, dark green, hard, fissile, fossiliferous; Stictoporella angularis and Dalmanella subaequata var. minneapolis, identified by Ulrich.		

On March 25, 1912, the drillers reported that after passing through 29 feet of the Decorah shale the drill entered at 2,783 feet from the surface a white sandstone 64 feet thick, evidently the Saint Peter. The Platteville limestone unexpectedly is absent. The summit of the Saint Peter here lies at 1,853 feet below sea level. The Saint Peter was found to be underlain by red rock and shale 22 feet thick, and this in turn rested upon sandstone. The Saint Peter and the strata below it were found to be dry.

Analysis of drillings from 1,982 to 1,993 feet.[a]

$MgCO_3$	36.63
$CaCO_3$	47.00
$FeCO_3$	2.38
SiO_2	13.97
	99.98

[a]Made in chemical laboratory of Cornell College, Iowa, under direction of Dr. Nicholas Knight.

Omitting the silica, which occurs largely as chert, it will be noted that the percentages of magnesium carbonate and calcium carbonate are respectively 42.5 and 54.6, or nearly those of these constituents in dolomite.

The first 1,020 feet of the boring is clearly Pennsylvanian. The age of the large body of limestone between 1,020 and 1,240 is of special importance. In reamings there was found a fossil identified by the late Dr. Samuel Calvin as a thick, short-hinged variety of *Spiriferina kentuckiensis*, a species most common in the Pennsylvanian, but not unknown in the Mississippian. Reference of the bed to the Mississippian is favored by the occurrence of entirely similar thick cherty limestones at about the same horizon at Bedford and Glenwood. At Nebraska City they underlie the shales of the Des Moines stage and are with little doubt the westward extension of the cherty limestones of the Mississippian of southeastern Iowa. The absence of any body of cherty limestone of like thickness in the Missouri stage in Iowa makes for the same reference. Assuming, then, that the limestone in question is Mississippian, it will be noted that the Pennsylvanian section at Nebraska City is almost wholly of the Missouri stage, the Des Moines stage having thinned to a few feet of shale at base. The same assumption gives the summit of the Mississippian at Nebraska City as 90 feet below sea level, practically the same as at Glenwood, and 150 feet higher than at Bedford. The base of the Coal Measures at Lincoln, Nebraska, is about 100 feet higher than at Nebraska City. Apparently then the floor of the Coal Measures lies nearly horizontal over this area with the axis of the slight syncline lying between Bedford and Missouri river.

On the other hand, Dr. George L. Smith, of Shenandoah, Iowa, who has given much study to the Missouri stage of southwestern Iowa, finds a considerable dip southward along Missouri river, a dip of at least 400 feet from the railway bridge at Plattsmouth to Nebraska City, and largely on this account he is convinced that the limestone in question is the Bethany limestone.

Beginning at 1,240 feet the drill passed through 200 feet of shale. This is correlated with the 130 feet of shale immediately beneath the Mississippian limestone at Glenwood and with a much thinner shale at the same horizon at Bedford. It may be referred to the Kinderhook, but in part may be Devonian. On the other hand, if the cherty limestone overlying the shale is the Bethany limestone, this shale represents the Des Moines stage. Unfortunately no succession of samples of the shales were saved, so that their lithologic affinities are unknown. When the well had reached a depth of 1,330 feet, the driller described this shale as light blue and states that "in places it gets sandy and hard, but is practically one body of shale so far as we have gone." At 1,385 feet the same description, practically, is given. There is no evidence of the alternations in color which are common in the Des Moines.

From 1,440 to 2,160 feet the drill continued in magnesian limestones and dolomites. This body of limestone, 720 feet thick, nowhere so far as the drillings are in evidence carries gypsum or anhydrite as at Bedford and Glenwood. At 1,460 feet a parting of one foot of shale is recorded and at 1,665 another parting less than 10 feet in thickness.

This body of limestone is assigned to the Devonian and Silurian without any attempt to draw a division line between them. The base also of the Silurian is in doubt, for the reference of the strata between 2,160 and 2,274 feet to the Maquoketa shale rests only on the statement of the driller's log, reporting here "alternating limestone and shale." From 2,274 to 2,754 feet extends an unbroken body of limestone and dolomite, which may be assigned to the Galena dolomite, since it overlies a shale which extends from 2,754 to 2,783 feet, and which contains fossils proving it to be the Decorah. In the Decorah shale, at 1,824 feet below sea level, a definite and certain geologic datum is evident.

As the drill hole was sunk as an oil prospect no quantitative or qualitative tests were made of the waters found at different horizons. To 400 feet the hole was dry. From the Pennsylvanian water-bearing beds were reported from 400 to 415 feet, from 508 to 520 feet, and at 615 feet. Small flows occurred also in the same terrane between 615 and 900 feet at intervals not exceeding 50 feet. A larger flow of salty water was encountered at the summit of the Mississippian at 1,040 feet. These waters rose slightly above the surface and yielded not to exceed two gallons a minute. They are described by Dr. George L. Smith as bitter, saline, purgative, and unpotable. At 1,050 feet casing was placed which shut them out, and all waters below this depth are said to be fresh. Between 1,461 and 1,480 feet, a flow was reached in the limestones underlying the shale referred by the writer to the Kinderhook, but which is the apparent equivalent of that at Forest City which the Missouri geologists have placed with the Devonian. This flow is described by the drillers as "immense;" at least it was not lowered by them in their work. The temperature is said to have been colder than spring water; the head was 125 below the surface. A measurement was kept of the height of the water in the drill hole, but no changes occurred below 1,480 feet to indicate that other veins had been reached. Below that level, however, the bailer brought up water which after going through the cold water of this flow was still a little warm.

ADAMS COUNTY.

BY HOWARD E. SIMPSON.

TOPOGRAPHY.

Adams county comprises a portion of the old drift plain which slopes from the crest of the Mississippi-Missouri divide southwestward toward Missouri river. Though well up on the slope the plain is maturely dissected and thoroughly drained by the numerous tributaries of Nodaway river. The larger streams flow through broad, flat, preglacial valleys which are carved deeply into the underlying rocks and are partly refilled by drift and alluvium.

GEOLOGY.

The drift mantles all the country rock to depths of 15 to 150 feet, and is in turn overlain by the loess. Broad strips of alluvium, consisting of sands, gravels, and clays overlain with fine silt, border the larger streams, and sands and gravel fill the valleys beneath to a depth in many places of 40 feet.

In the northwest corner of the county the drift is underlain by heavy beds of soft, porous, brown sandstone—the Dakota sandstone of the Cretaceous. Over all the rest of the county the Dakota is missing and the drift is directly underlain by the Missouri stage (Carboniferous), which consists chiefly of heavy beds of hard limestone, alternating with shales and, rarely, a thin seam of coal. Below, these rocks grade into those of the Des Moines stage. The limestone decreases, whereas the shale, sandstone, and coal increase. The whole has a thickness of several hundred feet.

UNDERGROUND WATERS.

SOURCES.

The alluvial sands and gravels afford a plentiful supply of water to inexpensive driven wells ranging in depth from 15 to 50 feet. Most of the wells of the county, however, obtain their water from the drift. Many very shallow wells, 15 to 20 feet deep, are scantily supplied by surface waters seeping through the porous loess, and others reach the sandy layers which lie beneath. The water in all of these wells is scanty and is subject to pollution from organic matter washed in from the surface.

As the quantity of ground water near the surface has decreased as a result of more perfect drainage and the cultivation of the land, it has been found necessary to sink many of the wells into the sands and gravels which usually lie at the base of the drift and which furnish good water freely and permanently. These wells are lined with 18-inch tiling and will probably prove the best source of supply for upland farms over all the limestone region. Other wells obtain an ample supply in the local sandy layers above the base of the drift.

The Dakota sandstone yields the best and purest water obtainable in the county. Unfortunately, this soft sandstone underlies the drift only in the northwestern corner of the county, and in some places it is too thin to furnish water abundantly. The water is only moderately hard and is free from undesirable minerals. It makes an excellent domestic and stock water. The limestones and shales of the Missouri stage underlie the entire county, but because of their compact texture they afford only a scanty supply of hard water, and are penetrated only by wells which fail to find a suitable supply in the drift. Fortunately, this failure is rare, for though the limestone beds between shaly layers in many wells yield a supply of good hard water, several holes drilled to depths of 200 to 500 feet have been abandoned because of scantiness of supply. In such wells waters from the drift may be combined with those from the limestone by puncturing the casing opposite the higher beds. In the coal-prospect hole drilled at Carbon heavy water-bearing sandstone was found at a depth between 700 and 800 feet. The hole was 873 feet deep and, except for 16 feet of drift, was entirely in Pennsylvanian strata. The sandstone lenses, however, lie so deep and their occurrence is so uncertain that drilling for them is not warranted except where artesian wells are sought.

No flowing wells of importance are reported. A few weak flows are obtained on low ground, one such being on the farm of J. Mercer (sec. 28, T. 71 N., R. 33 W.).

SPRINGS.

Several good stock springs flow from margins of Dakota sandstone on the sides of the Nodaway river valley, typical ones being found on the farms of Joe Houcks and Peter Curry, one mile and three miles, respectively, north of Carbon. Other springs from sandy layers of drift occur at different points in the county, but none are important sources of water supply.

CITY AND VILLAGE SUPPLIES.

Corning.—Corning (population, 1,702)has one well, 169 feet deep, extending 131 feet below the alluvial deposits of East Nodaway river into the shales and limestones of the Missouri stage. The well yields a scanty supply of hard water and is unused. A large open well sunk on the river bottoms 38 feet to bedrock is walled with brick laid in mortar. This well is 25 feet in diameter and furnishes the present town supply. The water comes in at the bottom from gravels overlying bedrock, stands at a level varying from 3 to 28 feet below the curb, and may be entirely withdrawn by heavy pumping. Two steam pumps having a capacity of 10,000 gallons each force the water into an elevated tank, from which it is distributed under gravity pressure of 60 pounds through five miles of mains to 27 hydrants and many private taps. Driven wells, ranging in depth from 30 to 100 feet, are common on the bottoms while most wells on the slopes and in higher portions of the city are dug or bored. All these wells are in drift, and many of them draw from sands immediately overlying bedrock.

Prescott.—Prescott (population, 426) has a small public supply for fire protection. The water is obtained from shallow wells and distributed through a few hundred feet of mains to three or four hydrants located on the principal street.

Most of the wells at Prescott are bored and lined with tile to depths ranging from 15 to 40 feet. The alluvial and subloessial sands furnish the water. On uplands the wells extend to the deeper drift sheets.

Minor supplies.—At Nodaway 30-foot sand points are common on all of the lower lands. Wells on uplands are bored 50 to 200 feet in drift. Near Carbon 40-foot points obtain plenty of water in the Nodaway bottoms. In Nodaway valley, outside the alluvial belt, all 50-foot wells find abundant water in the drift. At Brooks and Nevinville wells range in depth from 20 to 70 feet, many being 35 feet deep. Mount Etna gets its water supply from driven and bored wells ranging in depth from 16 to 50 feet and averaging 30 feet. A clay overlies the water-bearing sandstone.

WELL DATA.

The following table gives data of typical wells in Adams county:

Typical wells in Adams County.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
		Feet	Feet		Feet	
J. A. Mason	NE.¼ sec 5, T. 71 N., R. 35 W.	276	150	Sandstone (Dakota)	106	Yield 3 gallons per minute for one-half day without lowering. Drift (Pleistocene), 150; sandstone (Dakota), 40; shales and limestone (Missouri), 86.
W. C. Day	NE.¼ sec. 2, T. 72 N., R. 35 W.	403	68	do		A little water in Dakota sandstone, none below. Abandoned. Drift (Pleistocene), 68; sandstone (Dakota), 6; shale and limestone (Missouri), 329.
Corning	River bottoms	169	38	Limestone (Missouri)	30	6-inch drilled well cased to rock; put down for city supply but unused on account of hardness and scantiness. Alluvium, sand and gravel (Pleistocene), 38; shales and limestone (Missouri), 131.
Corning	Corning	85	35	Gravel	3 to 28	Chief city supply; diameter, 24 feet. Soil and loam, 8; gumbo, 8; blue clay, 10; gravel, 12; limestone.
Bros.	River bottoms	38	38	do		

AUDUBON COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY AND GEOLOGY.

Audubon county comprises an upland that is dissected by several rather wide alluvium-filled valleys and numerous ravines.

The generalized upland section as reported by R. S. Gransbury, driller at Exira, is as follows:

Yellow clay containing lime concretions and pebbles with hardpan and a little sand near the bottom.
Light blue clay.
Hardpan.
Blue-black clay.
White hardpan.
Yellow hardpan.
Yellow and white cemented sand.
Limestone, shale and sandstone.

The interpretation of this section seems to be as follows: The yellow clay is loess and weathered Kansan drift; the light blue clay is unweathered Kansan; the blue-black clay is Nebraskan and the overlying hardpan, Aftonian; the white and yellow hardpan and subjacent cemented sand are Cretaceous and the series of limestone, shale and sandstone is Pennsylvanian. The Cretaceous hardpan is said to be between one and 20 feet in thickness, and the cemented sand has about the same range but averages less than 10 feet. The Cretaceous deposits have not been found in all parts of the county. Drillers report them best developed near the eastern margin and generally wanting in the vicinity of Audubon and farther north. They consider them most likely to be reached by wells on the divides between the principal drainage lines, which condition indicates that the present streams follow in general the courses of the preglacial streams where the Cretaceous was submitted to the most severe erosion in the period before the drift was deposited. The cemented sand is found at depths of 300 feet and more on the highest ground and at correspondingly less depths on lower ground near the valleys.

UNDERGROUND WATER.

SOURCES.

Water can be obtained from the alluvium, the drift and associated deposits, the Cretaceous sandstone, and the lower formations. Of the lower formations the Upper Carboniferous strata are predominantly nonwater-bearing, but their deeper beds are likely to furnish at least small amounts of water. Still lower formations yield larger supplies.

Though the Cretaceous sandstone yields more freely than any of the drift deposits, its water is under little pressure and flows into the wells at only a moderate rate, and must be lifted a great distance to be brought to the upland level. Two wells, reported by E. L. Gransbury as ending in the "cemented sand," may be cited as typical:

The well of F. Hays, located in sec. 13, T. 79 N., R. 34 W., has a depth of 340 feet and a diameter of 3 inches. Its water bed is 6 feet thick, and its head is 290 feet below the surface. Continuous pumping at the rate of 3 gallons per minute lowers the water level 20 feet. The water is hard and ferruginous.

The well of George McClain, located in sec. 35, T. 79 N., R. 35 W., has a depth of 218 feet and a diameter of 3½ inches. Its water bed is 5 feet thick, and its head 148 feet below the surface. Pumping at the rate of 6 gallons a minute lowers the water level 20 feet.

Many wells drilled to the Cretaceous on ridges in this and adjacent counties in years of extreme drought have on the return of more normal conditions been abandoned on account of difficulties arising from the depth, low head, mineralized water, and the incrusting of the sand screens. Two-inch tubular wells are not so successful as wells of larger diameter with independent pumps. In many places larger wells can be finished without screens by sand pumping and putting down fine gravel which tends to keep back the sand.

Most of the wells at present in use are of the shallow bored and dug types, are located on the lowest ground feasible, and depend on a slow seepage from the drift. They are fairly satisfactory except in dry years or where large supplies are required. Much of the difficulty resulting from inadequate yield could be overcome if, instead of a single hole, a series of holes were bored. (See page 947.)

In the valleys generous supplies can commonly be obtained by sinking inexpensive open or driven wells into the stream deposits. This source is utilized largely in settlements located along streams.

CITY AND VILLAGE SUPPLIES.

Audubon.—The city waterworks of Audubon (population, 1,928) are at present supplied from 5 shallow wells located in the creek valley. The principal well is 27 feet in diameter and 35 feet deep, and receives its water from sand and gravel near the bottom. The wells fill within 15 feet of the surface, and are frequently pumped at the rate of 10,000 gallons an hour for 5 consecutive hours. The water has a large amount of permanent hardness, as is shown by the analysis (p. 202). Boring was at one time carried to a depth of 95 feet and ended in dark blue clay without water. The distributing system comprises an elevated tank and about 2 miles of mains, with 125 taps. The average daily consumption is 30,000 gallons.

Exira.—The village well at Exira (population, 787) is sunk in the river bottom to a depth of 28 feet, the last 2 feet of which is in gravel. It is 10 feet in diameter, is cased with brick, and fills with water within 8 feet of the surface. Approximately 8,000 gallons are used each day, but the well would easily provide several times this amount. When the waterworks were installed, a series of 2-inch wells were driven to the same bed of gravel, but were not as satisfactory as the large well used at present. The waterworks include a standpipe, three-fourths mile of mains, 10 fire hydrants, and about 35 service connections. The water is said to be very hard and is used by only a small portion of the inhabitants.

Kimballton.—The village of Kimballton (population, 271) has a system of waterworks which draws from a well and includes one-fifth mile of mains, 4 hydrants, and 12 taps.

CASS COUNTY.

BY HOWARD E. SIMPSON AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

Cass county is near the southwest corner of the state, well up the western slope of the Missouri-Mississippi divide.

Topographically it is a drift plain, sloping gently southwestward, cut in every direction by the channels of minor streams. Nishnabotna and Nodaway rivers flow southwestward across it in wide, deep, preglacial valleys, which they have cut in the underlying rock and recut in the soft drift cover. The upland slopes to the north and east grade into gently rolling prairies; those to the south and west show more complete dissection and more mature drainage than those on the eastern side of the divide.

In the valleys of Nishnabotna and Nodaway rivers the drift rests on Carboniferous strata, here chiefly a series of heavy shales alternating with thinner beds of hard limestone (Missouri stage). Over a large part of the county the drift rests on Cretaceous sandstone, known as the Dakota, which rests unconformably on the Carboniferous. On the uplands the drift has an average thickness of perhaps 200 feet, and consists of heavy beds of till overlain by a comparatively thin mantle of loess. Heavy deposits of sand and gravel are found in the bottoms of the larger valleys.

UNDERGROUND WATER.

SOURCES.

The water-bearing beds utilized in Cass county are the alluvial sands and gravels, loessial sands, drift sands, the Dakota sandstone, and the limestone of the Missouri stage.

In few parts of Iowa can so satisfactory supplies of water be obtained at so slight cost as in the gravel-filled valleys of the southwestern part of the state. The sands and gravels that fill the valley bottoms of Nishnabotna and Nodaway rivers and their larger tributaries to depths of 50 to 100 feet afford an inexhaustible supply of good water at depths ranging from 20 to 100 feet. The water is generally obtained by driving 1¼-inch pipe shod with a three-foot point covered with No. 60 gauze mesh. The expense of such a well complete, with pump, is $15 to $25. Rarely is the sand so fine as to fill the point and thus destroy the well. When it does, the pipe may be drawn, the point cleaned, and the whole again driven.

On the uplands, especially in the eastern part of the county, where the loess is comparatively thin, many shallow wells obtain water from sands under the loess. In the western part, where the loess is thicker, many wells do not pass through the loess, but depend entirely on the slow seepage from this porous clay. Wells in the loess and its underlying sands are very likely to be contaminated by drainage from the surface.

In all parts of the county an excellent supply of water may be obtained from the gravels at the base of the drift at depths of 100 to 225 feet. The head is relatively low but strong. Many wells obtain a scant but wholesome supply from seepage and from local sand layers that lie at different depths within the till. Where cultivation and artificial drainage have lowered the ground-water level, dug wells have been dug deeper, and bored wells filled with large tiling or sewer pipe extending down to lower gravels of the drift are very common. The gravel between the drift sheets also yields water.

The Dakota sandstone is an aquifer of the first order and rarely fails to yield excellent water at depths ranging from 150 to 300 feet.

The limestone of the Missouri stage affords a scant supply of hard water that is seldom utilized. It is important only on the slopes of the larger valleys, where the Dakota sandstone has been eroded away. It is rarely reached within 250 feet of the surface.

CITY AND VILLAGE SUPPLIES.

Anita.—The public water supply of Anita (population, 1,118) is obtained from a 207-foot well, which draws excellent water from the Dakota sandstone. It is somewhat hard and is said to pit the boilers. The water is pumped by gasoline engine into elevated tanks, from which it is delivered over the entire town under direct pressure of 50 pounds.

Atlantic.—The public supply of Atlantic (population, 4,560) is owned by the city. It is drawn from 30 drilled and driven wells, ranging in depth from 52 to 86 feet and in diameter from four to six inches, located in the "bottoms" of Nishnabotna river. The drilling is done inside a tube, the well being pumped out and the tube driven a few inches or feet at a time until it reaches a suitable aquifer, into which drilling is continued a foot or two to form a collecting pocket. A Cook strainer is pushed to the bottom and fixed on the end of the driven pipe. The wells are connected with T's to air chambers and so connected in groups and series that any individual or group may be cut off, the caps may be removed, and the sand pumped out at will. One of the 30 wells never produced at all, and this well and two others whose casings were broken in cleaning have been cut off.

The water-bearing bed, a sharp white sand with some gravel, lies 50 to 86 feet below the surface. Above it are many layers of clay silt alternating with beds of sand and gravel, some of which are water bearing. Several years ago fifty three-inch drive points penetrating some of these gravel layers were utilized, but they were abandoned on account of the insufficiency of the supply. The series could be pumped dry in about one hour.

When not pumped the water in the present wells ordinarily stands 13 feet below the surface, but the level varies with weather and rainfall. The wells respond within 24 hours to heavy rainfall or rise of river near by, but the water level lowers much more slowly than it rises. Under emergency pumping the water level has been lowered to 28 feet below the surface.

The water in these wells is distributed by direct pressure through 13 miles of mains to 104 fire hydrants and more than 1,200 taps. Four-fifths of the inhabitants of the city are supplied. The daily use is 500,000 gallons; the daily capacity of the plant is 2,500,000 gallons. The water pumped at night in excess of that used overflows into a reservoir where it is held in reserve for emergency. In case of fire the water from this pond is forced directly into the mains and the pressure is raised from 80 to 155 pounds. The contamination of the city mains with stale water from the pond is the unsatisfactory feature of this otherwise excellent system.

The water has been used in boilers and for manufacturing purposes by the Chicago, Rock Island & Pacific Railway, the electric light company, laundries, canning factories, starch factory and others, and, is on the whole, very satisfactory. It precipitates, on standing, a small quantity of the red sediment that is commonly found in drift-gravel waters, and some firemen find it helpful to use a small amount of boiler compound.

A prospect hole, drilled in 1888 by Rust Artesian Well Company of Ithaca, New York, for the Atlantic Coal & Mining Company, goes down 1,310 feet. The elevation of the curb above sea level is 1,150 feet. No record was preserved of water-bearing beds, as the contract required a dry hole at all times. It is said that drilling was stopped because the pressure became so great that it caused the casing to collapse. The hole is situated a short distance east of the railway station.

Samples of the drillings of this boring were placed at the disposal of the Iowa Geological Survey by Seth Dean of Glenwood. In the following record of strata determinations those in quotations are supplied by Mr. Dean; those marked with a star are from the manuscript record of Mr. E. H. Lonsdale.

Record of strata in deep well at Atlantic.

	Thickness	Depth
	Feet	Feet
Pleistocene (no sample)	125?	125?
Carboniferous:		
Pennsylvanian (725 feet thick; top, 1,025 feet above sea level)—		
"Shale, blue"	35	160
"Shale, gravelly"	35	195
"Shale, red and blue, gravelly"	5	200
"Limestone, gray, sandy"	15	215
"Shale, red and blue, with soapstone"	5	220
"Shale, gravelly"	5	225
"Shale purple, dark drab and green, fine, unctuous; with pebbles (five limestone, one vitreous sandstone, one coal)"	35	260
"Shale, gravelly"	50	310
"Clay, mottled red and blue"	30	340
"Shale, blue"	15	355
"Shale, red and blue, with gravel"	5	360
"Shale, blue, with slate"	5	365
"Sandstone and shale"	50	415
"Slate, black; soapstone, blue and green"	5	420
Shale, varicolored, green and reddish; fissile, practically noncalcareous	10	430
"Sandstone"	5	435
"Shale"	15	450
"Shale and limestone"	15	465
"Shale, varicolored, green and reddish; fissile, practically noncalcareous"		
"Clay and soapstone"	15	480
"Sandstone"	25	505
"Shale, blue"	12	517
Shale, dark gray, very finely laminated, somewhat calcareous	23	540
"Sandstone, or sandy limestone"	10	550
Shale, dark gray	15	565
Shale, dark brown-gray, noncalcareous, arenaceous, pyritiferous	20	585
Sandstone, brown, highly ferruginous	5	590
"Sandstone"	10	600
"Shale, sandy"	30	630
"Sandstone, very fine"	30	660
"Shale and slate"	15	675
Shale, iron gray finely laminated, noncalcareous	10	685
"Sandstone, white, very fine"	10	695
*Clay, blue, with gravel	15	710
*Shale, sandy	15	725
*Sandstone	5	730
Shale, finely arenaceous, ocherous; some black	10	740
Shale, black, carbonaceous	10	750
*Shale, blue, and slate	10	760

Record of strata in deep well at Atlantic—Continued.

	Thickness	Depth
	Feet	Feet
*Shale, yellow, gravelly	40	800
Sandstone, gray, of finest grain, with much black shale; samples at 800 and 815	25	825
*Limestone sandy	5	830
*Sandstone, brown	5	835
*Sandstone, gray	15	850
Mississippian (420 feet thick; top, 300 feet above sea level)—		
Limestone, white, nonmagnesian; white chert constitutes the bulk of the sample	35	885
Limestone, blue-gray, argillaceous; quartzose residue, with large fragments of dark shale; probably from above	75	960
Limestone, yellow-gray; sample chiefly dark brown flint with some chalcedonic silica; a very little quartz sand	5	965
Flint, brown-gray, calcareous; some chalcedonic silica; much shale in fragments	10	975
Flint, gray and black chalcedony; drusy quartz; some shale	5	980
Flint, brown, calcareous; some chalcedony; a little shale	5	985
Flint and chalcedony; 5 samples; drillings largely milk-white, translucent chalcedony, with brown calcareous flint and some limestone	45	1,030
Limestone, nearly white; much white chert; 2 samples	15	1,045
Chalcedony and flint; drillings remaining after original washing made up of chalcedonic silica and blue-gray and yellow siliceous fragments which effervesce in cold dilute hydrochloric acid, but do not disaggregate; pure limestone practically absent	30	1,075
Shale and flint; shale, blue-gray, somewhat calcareous	5	1,080
Limestone, soft, light yellow-gray; with silica as above, and some fragments of shale; 4 samples	40	1,120
Limestone, brown; much white chert	5	1,125
Limestone, lighter colored; drillings chiefly chert; only finest sand is limestone and even this is siliceous	5	1,130
Limestone, light yellow, nearly pure; considerable shale in small fragments	5	1,135
Limestone; as above; much chalcedony and chert	5	1,140
Limestone, white, chalky, and light yellow	5	1,145
Chert; drillings of chert and chalcedony; at 1,145 feet a few rounded grain of crystalline quartz and particles of fine-grained sandstone; 4 samples, all of which in mass effervesce freely in acid	25	1,170
Flint; black, yellow, and red flint and jasper, with sand of rounded grains of quartz; fragments of limestone, chert, and chalcedony	10	1,180
Limestone, blue-gray, cherty, and argillaceous	10	1,190
Chert, white and brown; some shale in sample	10	1,200
Limestone, cherty; gray in mass	25	1,225
Limestone; siliceous material constitutes one-tenth of sample by weight	20	1,245
Chert and shale, buff; chert effervescent; shale pink, in fine grains, but slightly calcareous	10	1,255
Limestone, highly arenaceous and siliceous; chert and chalcedony; two-fifths of sample by weight insoluble	5	1,260
Sandstone, highly calciferous; limestone arenaceous; quartz in minute angular particles; white and yellow-gray; 2 samples	10	1,270
Devonian ? (40 feet penetrated; top, 120 feet below sea level):		
Shale, fine, light gray, calcareous	15	1,285
Limestone, cream-yellow, rather hard; in angular sand	25	1,310

Griswold.—The town of Griswold (population, 949) is supplied from a 200-foot drilled well which draws its water from drift within 70 feet of the surface. A standpipe is used for storage and the water is distributed through $1\frac{1}{4}$ miles of mains at pressure varying from 35 to 100 pounds.

Lewis.—The water supply of Lewis (population, 603) is chiefly from wells ranging in depth from 40 to 70 feet. The public supply is drawn from a dug well seven feet in diameter and 68 feet deep, in which the water stands 50 feet below the surface. The well ends in sand and gravel overlain for almost the entire depth by clay. The water is distributed from an elevated tank under direct pressure of 43 pounds through nearly one mile of mains.

A well drilled on a valley slope in 1900 as a prospect for coal and artesian water passed through seven feet of Dakota sandstone, probably the edge on the valley side, and continued down through Coal Measures to a depth of 562 feet, where it was abandoned. An excellent spring flows from the sandstone outcrop in the bluffs bordering Nishnabotna river and furnishes water for drinking and bathing at a summer resort established by Mr. D. W. Woodward.

Marne.—At Marne (population, 266) domestic wells are sunk 30 to 60 feet to sand layers in the drift. Many of the stock wells, demanding a larger supply, are sunk to the lower gravel layers, about 200 feet. The city well supplies an elevated tank from which water is distributed by direct pressure of 25 pounds for fire, street, and domestic purposes.

Massena.—At Massena (population, 490) there are few deep wells, most of the people relying on bored wells 20 to 60 feet deep. The city has no other supply than that afforded by open cisterns and hand pumps.

WELL DATA.

Information in regard to some of the typical wells in Cass county is presented in the following table:

Typical wells of Cass County.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
T. 76 N., R. 35 W. (Franklin).		Feet	Feet		Feet	
R. R. Bell	SW.¼ sec. 24	189		Sand	179	Upper water bed at 40.
T. 76 N., R. 37 W. (Washington).						
W. B. Berry	NE.¼ sec 7	226		Fine sand	150	Very hard water.
W. J. Copeland	SE.¼ sec. 11	150		Drift sand		
Julius Kirkpatrick	NE.¼ sec. 10	180		do	130	
T. 74 N., R. 37 W. (Pleasant).						
Town of Griswold.	Griswold	100	100	"Blue rock"	70	Valley.
Town	do	200	70	Drift sand		No water below drift
T. 75 N., R. 36 W. (Bear Grove):						
Sam Deverns	6 miles south of Atlantic.	365	100	No water		In limestone and shale.
T. 76 N., R. 36 W. (Grove).						
F. C Schain	SE.¼ sec. 29	110		Drift sand	30	Good strong well.
Bert Frost	NE.¼ sec. 19	218		Sand	163	
Polk Byrd	NE.¼ sec. 6	150	124	Sandstone (Dakota).		Drift, 124; white sandstone, 4; red sandstone, 18; shale, 4.
C. V. Wilder	5 miles south of Atlantic.	128	128	Drift sand and gravel.		Abundant water in sand and gravel over limestone.
T. 77 N., R. 35 W. (Benton).						
Thomas Kelly	4 miles southeast of Braydon.	295	245	Sandstone (Dakota).	220	Strong well, good water.
T. 77 N., R. 37 W. (Brighton).						
L. S. Allen	NW.¼ sec. 30	247	234	do	166	Limestone (Missouri) at 247 feet.
T. 77 N, R. 36 W. (Pymosa).						
Winfield Wilbur	7 miles north of Atlantic.	283	250	Sandstone (Missouri).	200	Water in crevice of limestone.
T. 75 N., R. 34 W. (Massena).						
W. S. Shields	NW.¼ sec. 32	324	178	No water		In limestone (Missouri).
T. 74 N., R. 34 W. (Victoria).						
John Holste	NE.¼ sec. 20	240	207	do		Do.
T. 77 N., R. 34 W. (Grant).						
Town	Anita	207	171	Sandstone (Dakota).	171	Hilltop; Pleistocene, 171; Dakota sandstone, 36; limestone (Missouri) at 207 feet.
T. 75 N., R. 37 W. (Cass).						
Town	Lewis	562	70	Limestone (Missouri).		Hillside: Pleistocene, 70; Dakota sandstone, 7; Carboniferous, 485. Water in limestone at 82. Abandoned because of caving; drilled for coal.

FREMONT COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY.

Fremont county is divisible into two distinct physiographic provinces: (1) The uplands, consisting of rugged hills and ridges separated by innumerable sharp ravines, and (2) the lowlands, consisting of broad valleys with flat, monotonous bottoms that include nearly one-half of the county's area. Between Missouri river, which forms the west boundary, and the abrupt margin of the uplands, stretches a flood-plain belt nearly six miles in average width; and the valleys of both forks of the Nishnabotna are also in most places several miles wide.

GEOLOGY.

The bedrock, composed of alternating strata of shale and limestone belonging to the Missouri stage (Pennsylvanian), was at one time deeply buried under glacial drift which seems to include two distinct till sheets—a lower, dark, dense bowlder clay (Nebraskan) and an upper yellow and pale blue crumbling bowlder clay (Kansan). In certain localities beds of sand and gravel are also found between the two sheets, at the base of the drift, and perhaps at other horizons. Since its deposition much of the drift has been removed by erosion, for not only were countless ravines and gullies carved out of this material in the upland areas, but the wide, deep valleys were also excavated in it.

After weathering and dissection had progressed far, the region was mantled with yellow homogeneous silt known as loess, which, according to Udden,[1] has an average thickness in Mills and Fremont counties of about 60 feet and which along the ridge border-

[1]Udden, J. A., Geology of Mills and Fremont counties; Ann. Rept. Geol. Survey Iowa, vol. 13, 1902, p. 167.

ing the Missouri valley attains a maximum thickness of 100 to 150 feet. Since the loess was deposited it, too, has been vigorously attacked by stream erosion.

In the valleys the rivers have laid down considerable quantities of alluvium, which consists largely of fine silt derived from the loess, but which includes also beds of sand and gravel, especially at some depth below the surface.

UNDERGROUND WATER.

SOURCES.

In this region much of the drilling into bedrock has been done for the purpose of finding coal, and such explorations for water as were made have generally yielded unfavorable results. At Hamburg a hole was drilled into the Missouri strata to a depth of 180 feet, according to current reports, without finding water, and there are other indefinite reports of unsuccessful wells sunk into the upper part of this series. The deep wells at Glenwood (see p. 1137) discovered supplies in formations far below the surface.

On the lowlands hard but otherwise satisfactory water is obtained without difficulty from beds of alluvial sand and gravel that lie at very moderate depths and from which the water rises nearly or quite to the surface. The driven wells, which are here in common use, are inexpensive and fairly satisfactory, although some trouble is caused by the incrusting of the screens.

On the uplands supplies are obtained principally from the seepage out of the loess and glacial drift. Water-bearing deposits of sand and gravel exist in certain localities but seem to be too largely wanting to be generally relied upon. The loess is homogeneous in texture and so constituted that it allows the water to percolate through it very slowly. Hence, where it is thick its lower portion is saturated even on hills and ridges near deep valleys, and if wells are sunk into this saturated zone they receive a sure though meager seepage supply, the amount varying with the area of the infiltration surface, which, of course, depends upon the depth and diameter of the well. The glacial drift, especially in its upper layers, behaves in a somewhat similar manner, but since it is more heterogeneous in its structure it is also more diverse in its water-bearing capacity.

An ordinary dug well which extends through loess or drift to a short distance below the water level will usually furnish enough water for the small demands of a household, but will seldom supply a windmill continuously, and will frequently prove inadequate for stock farms. The yield can be indefinitely augmented by increasing the number of wells or projecting drifts out from the bottom of a well, the best method probably being to bore with a well auger a sufficient number of holes, perhaps 25 feet apart, and to connect the latter at the bottom with small pipes placed in holes bored with a link auger. (See p. 947.) The difficulty of obtaining enough water from these sources for municipal supplies is illustrated by the experience at Tabor and Sidney. but the solution here also seems to consist in increasing the infiltration surface.

Throughout the uplands many ravines and valleys have been cut below ground-water level and hence receive a slow seepage which gives rise to rivulets and creeks that are extensively utilized for stock and domestic supplies. Numerous springs also issue at the base of the cliff along the east margin of the Missouri valley.

CITY AND VILLAGE SUPPLIES.

Hamburg.—In Hamburg (population, 1,817) the public supply has in the past been obtained from (1) a huge dug well situated at the edge of the valley and ending in fine sand, and (2) a spring which issues from the cliff that borders the valley. The total daily yield from these two sources is reported to be only about 20,000 gallons a day, which has not been enough to meet the demands. A system of two-inch driven wells is to be installed at a point farther from the cliff, where the alluvium is thicker and yields more freely.

The water is pumped into a large cement reservoir situated on the loess ridge back of the city, 170 feet above the valley, and is thence distributed through two or three miles of mains to 22 fire hydrants and about 110 taps.

Sidney.—In Sidney (population, 1,019), located in the upland area, several unsuccessful attempts have been made to obtain an adequate supply for the public waterworks. There are two dug wells, one 15 feet in diameter and 55 feet deep, the other six feet in diameter and 58 feet deep, both ending in a bed of fine sand and connected at the bottom by a drift. The normal water level is said to be 20 to 25 feet below the surface, but the wells fill to a depth of less than 10 feet in 24 hours and together furnish only about 15,000 gallons a day. Two holes were also drilled to bedrock, at about 200 feet, without finding water except in a small amount at 80 feet. The waterworks include a standpipe and about two miles of mains with 15 fire hydrants and 40 taps.

Tabor.—Tabor (population, 909) is on the upland nearly 300 feet above the Missouri valley. Its public supply is taken from a dug well 12 feet in diameter and 114 feet deep. The first 80 feet appears to consist of loess and the rest of yellow "joint clay," which is probably drift. The clay in the last two feet is somewhat sandy. The well receives seepage from all levels below about 40 feet and will fill within this distance of the surface. Its yield has not been definitely ascertained, but it is apparently small, though adequate for present needs. The water is only moderately hard and is considered otherwise good. The system of waterworks consists of two compression tanks, about one-half mile of mains, seven fire hydrants, and 31 taps.

Thurman.—Thurman (population, 336), like Hamburg, is located at the foot of the Missouri valley cliff and gets most of its water supply from the alluvium. The waterworks, which are owned by a private company, depend on a four-inch well that ends with an eight-foot screen at the depth of 92 feet. The water rises within about 30 feet of the surface and has been pumped for long periods at the rate of approximately 20 gallons a minute without noticeable effect. There is less than a mile of mains, with eight fire hydrants and 12 taps. The pressure is obtained from a storage reservoir on the bluff about 100 feet above the village. The water is good, though somewhat hard, and it is estimated that an average of 7,000 gallons is consumed daily. The village well has about the same depth as the one that supplies the waterworks, but most of the private wells are driven to depths of only 15 to 30 feet.

HARRISON COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

A striking contrast to the rugged and thoroughly dissected upland that occupies most of this county is presented by the broad expanses of flat, swampy lowland formed by the Missouri valley in the western part, and by its largest branches, which extend diagonally southwestward across the county. This entire region is underlain by Pennsylvanian rocks (Upper Carboniferous), which consist essentially of a succession of shales and limestones, aggregating several hundred feet in thickness. These rocks outcrop at a few points and have been pierced by the drill at Logan, Woodbine, and Dunlap. Over an indefinitely known area, especially in the northeast, they are covered by Cretaceous sandstone and shale; elsewhere they are overlain directly by glacial drift or alluvial deposits. The drift comprises two sheets, the dark Nebraskan below and the lighter Kansan above, separated in some localities by Aftonian gravel. On the weathered surface of the Kansan till rests a thick cover of loess-like clay. In the lowlands the alluvial deposits of clay, sand, and gravel are extensively developed.

UNDERGROUND WATER.

SOURCES.

Ground-water supplies in Harrison county are derived from alluvial deposits, loess, drift and associated gravels, Cretaceous rocks, and lower rock formations.

The deeper formations reached in the public wells at Logan, Woodbine, and Dunlap have a certain value for municipal and other supplies but they are not entirely satisfactory in either the quantity or quality of water that they yield. The Pennsylvanian strata, though not totally destitute of water-bearing members, are generally so disappointing that it is not advisable to penetrate them unless it is the intention to drill to the lower aquifers.

A few wells in this region probably draw water from Cretaceous deposits. In some wells shale or "soapstone" was found below the drift, and beneath the "soapstone" a bed of sand or sandstone saturated with water; other drilled wells have not passed through shale, but have been finished in sand or sandstone at depths ranging from a hundred to several hundred feet —most commonly about 250 feet; still others have entered shale and limestone of the Pennsylvanian series without finding a satisfactory water-bearing bed. The drilled wells are two to six inches in diameter and are mostly finished with sand screens. Wells of small diameter are, however, not adapted to the conditions found in the uplands, both because of the limitations in yield and because of the rapidity with which their screens become incrusted. Cretaceous wells and other drilled sand wells should have a diameter of four or six inches.

In the uplands the two principal water horizons above the Cretaceous are at the contact zone between the loess and the Kansan and in the Aftonian gravel between the two drift sheets. Neither of these generally supplies water readily enough for drilled wells, although they furnish a satisfactory yield for bored wells. The upper of the two beds is characterized by white calcareous accumulations of "chalk," so commonly found near the bottom of the weathered zone of the Kansan drift, and also by sandy and gravelly seams that are frequently cemented into a "hardpan." The water which percolates slowly downward through the loess saturates the sandy and gravelly material at this level and is hindered from descending farther by the impervious unweathered drift. The Aftonian gravel is only vaguely recognized in wells and, indeed, is reached in few. Where sufficiently developed it ought to furnish more water than any deposit at a higher level.

In the lowlands generous supplies of hard but otherwise good water are obtained by means of inexpensive wells, the best type of which are driven or drilled and end in screens. The most copious yield is secured from the coarsest materials and these are most common near the bottom of the alluvial filling, but the amount of dissolved iron is generally greater in this deeper water than in that near the surface because it is less accessible to the oxygen of the atmosphere. The water from all parts of the alluvium rises within a few feet of the surface and can be pumped at small cost by means of suction pumps. Examples of large supplies obtained from this source are afforded by the railway and city wells at Missouri Valley and the railway well at Dunlap. The wide distribution and great importance of the alluvium as an aquifer will be realized when it is remembered that the Missouri Valley wells are located on the Missouri bottoms six miles from the river, and that the Dunlap well is located near the northeast corner of the county, many miles from where the Boyer valley opens into the Missouri.

CITY AND VILLAGE SUPPLIES.

Dunlap.—The public supply of Dunlap (population, 1,155) is obtained from a well 1,535¾ feet deep, six and one-fourth inches in diameter, cased to 400 feet. The curb is 1,151 feet above sea level; original and present head, 47 feet below curb. The tested capacity is 80 gallons a minute. The well was completed in 1887 by J. P. Miller & Company, of Chicago, and was repaired about 1903 by inserting smaller casing. The strata penetrated are indicated by the following section:

Record of strata in Dunlap city well (Pl. XI, p. 458).

	Depth
Pleistocene:	Feet
Unknown	0-50
Sand	50-70
Gravel; pebbles of northern drift and sand	70-95
Gravel; pebbles of northern drift, at	150
Cretaceous and Carboniferous (Pennsylvanian) (307 feet thick (minimum); top, 926 feet above sea level):	
Shale, drab	225
Shale, pink, at	300
Sandstone, grains varying widely in size and imperfectly rounded, at	392
Shale, dark drab, at	400
Shale, black, noncalcareous, at	450
Shale, pink and purplish, at	480
Carboniferous (Mississippian) (288 feet thick; top, 619 feet above sea level):	
Limestone, white, soft, chalky; with gray-green shale at	532
Limestone, white, hard; of finest grain, at	600
Limestone, light yellow-gray, cherty, at 650 and	703
Limestone, gray, finely crystalline; fracture subconchoidal, at	797
Devonian (?) Silurian and Ordovician (715¾ feet penetrated; top, 331 feet above sea level):	
Limestone, magnesian or dolomite, brown and buff; 3 samples, at 820, 875 and	890
Shale, light green-gray, calcareous; 2 samples, at 970 and	980
Limestone, magnesian, light yellow-gray, and shale, green; all in concreted powder, at	1,006
Limestone, highly argillaceous, yellow; in almost white powder; 3 samples, at 1,020, 1,050 and	1,093
Shale, gray-green, calcareous, at	1,150
Limestone; as at 1,010 feet; 2 samples, at 1,184 and	1,241
Shale, bright green, noncalcareous, at	1,295
Dolomite, buff, pyritiferous, slightly arenaceous, at	1,375
Dolomite, buff; much chert carrying disseminated crystals of pyrite; a few grains of limpid quartz, some of which are rounded; a little chalcedonic silica, at	1,400
Dolomite, highly arenaceous; or calciferous sandstone; grains varying in size, many coarse, imperfectly rounded, at	1,517
Dolomite, white; in fine powder, with arenaceous rounded grains, quartzose and cherty residue; at bottom of well, at	1,535¾

The arenaceous dolomite at 1,517 feet possibly represents the Saint Peter, but it is also possible that the Saint Peter is absent, and that the shales and clayey limestones from 1,010 to 1,295 belong to the Platteville, and the dolomite from 1,375 down to the Shakopee.

The samples are said to have been taken at every "change" of rock.

The water is lifted into a standpipe and thence distributed by gravity through one-half mile of mains. It is used by a small proportion of the people and the daily consumption does not exceed 10,000 gallons. The water is very hard. Large supplies of less mineralized water are available in the valley at no great depths below the surface.

The Chicago & North Western Railway well at Dunlap is sunk into the stream deposits of Boyer river valley. The section is as follows:

Section of Chicago & North Western Railway well at Dunlap.

	Thickness	Depth
	Feet	Feet
Clay, sandy	20	20
Sand	12	32
Sand, coarse (water bearing)	23	55
Clay, blue (entered).		

This well is 12 inches in diameter and ends with a 14-foot screen. With the suction pipe extending 40 feet below the surface, it is reported to be pumped at the rate of 300 gallons a minute and to furnish about 100,000 gallons daily.

Logan.—The public waterworks at Logan (population, 1,453) were until recently supplied from two wells—a shallow open well and a deep drilled well—both located in the valley. The open well is 20 feet in diameter, is cased with brick, and ends at a depth of 32 feet in a bed of sand resting upon rock. It fills with water within about 10 feet of the surface but its yield is not great. The water is hard, though otherwise good.

The public supply is used by most of the inhabitants, and the daily consumption is estimated at 30,000 gallons. The pressure is secured from a reservoir located on the upland. The supply for the Illinois Central locomotives is taken from large dug wells in the valley.

The drilled well is 840 feet deep, 10 to six inches in diameter, is cased with 30 feet of eight-inch pipe to rock, and 570 feet of six-inch pipe, heads 30 feet above the curb, and has a natural flow of 13 gallons a minute. The water bed is shale at a depth of 650 feet. The well was drilled in 1902 at a cost of $2,000. The water is called "mineral." It is generally liked by the people and is said to be soft and wholesome and to have a mild laxative effect.

Fortunately for the interests of science one of the citizens of Logan, Mr. C. N. Wood, obtained at his own expense from the drillers a fairly complete set of samples of the drillings, and submitted them to the Survey for examination. The following table presents the interpretation of the samples:

Record of strata in city well No. 1 at Logan.

	Thickness	Depth.
Carboniferous:		
Pennsylvanian—	Feet	Feet
Unrecorded	22	22
Limestone, blue-gray, earthy, soft, and light buff, harder; in large chips; rapid effervescence	12	34
Shale, greenish, practically noncalcareous; some yellow and red shale; chips of light yellow limestone; in molded masses	8	42
Shale, copper-red, calcareous; a few cuttings of limestone	18	60
Limestone, light yellow and blue-gray, compact; and sandstone, micaceous, fine-grained, light blue-gray	10	70
Shale, drab and blue or greenish gray	40	110
Limestone, grayish buff, very fine-grained, compact; smooth fracture; fossiliferous; in large flakes	5	115
Limestone; as above, with greenish crystalline limestone and some reddish clay staining surfaces of limestone cuttings	10	125
Shale, red and greenish, hard, calcareous, in cuttings, some limestone chips	5	130
No samples	25	155
Shale, blue-gray and drab; some yellow limestone cuttings; some fine-grained greenish laminated sandstone	10	165
Limestone, blue-gray, close-textured, earthy; in rather large chips; fossiliferous; with some reddish brown shale from above (?)	4	169
No sample	15	184
Limestone, highly argillaceous, blue-gray, earthy, soft	6	190
Shale, highly calcareous; in chips; cemented by rusted iron cuttings, evidently from tools dropped in the well	15	205
Shale, reddish	40	245
Shale, black, coaly	15	260
Shale, light greenish gray, somewhat calcareous, plastic; in molded masses	15	275
Limestone, dull luster, light gray	5	280
Shale, drab, fissile, calcareous; some limestone cuttings	6	286
Shale, dark drab and green-gray, hard, fissile, calcareous	4	290
Sandstone, gray, micaceous, fine-grained; grains imperfectly rounded	15	305
Shale, yellow, plastic; in molded masses; a little ocherous limestone	20	325
Limestone, yellow, argillaceous; in fine cuttings; fragments of joints of crinoid stems; chips of shale of various colors	25	350
Shale, orange and other colored, plastic	50	400
No samples	155	555
Mississippian—		
Limestone, drab, argillaceous, slightly gritty; much translucent milky-white chalcedonic silica; in small cuttings; some grains of crystalline quartz	5	560
Limestone, gray; in fine sand; much chalcedony; some quartz grains imperfectly rounded	20	580
Limestone, gray, yellow-gray, and light drab; fine crystalline-granular; some white cryptocrystalline silica and some shale in powder and small cuttings	5	585
Limestone, light buff in mass; fine crystalline-granular; some cryptocrystalline silica and some quartz sand	10	595
Limestone; as above; and some white; in coarse sand	15	610
Limestone, whitish and light yellow-gray; some rounded quartz grains	10	620
Limestone; as above; a very little cryptocrystalline with white silica and some quartz sand	15	635
Limestone, pure white, fine-grained	20	655
No samples	(?)	(?)
Limestone, blue-gray and light yellow-gray; in fine sand, sample labeled "to 770"	(?)	770
Limestone, white; in fine meal	10	780
Limestone, light grayish white; in fine sand; this and all other limestones of the samples effervesce rapidly in cold dilute hydrochloric acid	41	821
No samples, but reported to be no change in strata	19	840

Another city well has recently been drilled at Logan. The depth is 954 feet and the diameter six inches; casing, six inches to bottom of well. The curb is 1,033 feet above sea level and the head 80 feet above curb. The flow is 200 gallons a minute, the principal supply being at 940 feet; other water beds are at 36 and 454 feet. The well, which cost $5,000, was drilled by L. E. Nebergall, of Omaha, Nebraska, in 1911.

Missouri Valley.—The public supply of Missouri Valley (population, 3,187) is obtained from four six-inch wells located a short distance from the margin of the valley. The wells pass through clay, "hardpan," etc., and end with 10-foot to 14-foot brass screens at a depth of 85 feet in a bed of gravel from which the water rises within four to five feet of the surface.

By means of a suction pump at the surface, the wells are usually made to yield 550 gallons a minute, but they are reported to have been pumped for 17 hours continuously at about 600 gallons a minute. The water is rather hard and in time seals the screens with chemical precipitates. A dug well with a group of sand points was at first installed but was not so satisfactory as the wells now in use.

The water is stored in a large cement reservoir on the top of the bluff and is delivered under considerable pressure through about six miles of mains to 60 fire hydrants and 500 taps. It is used by a large proportion of the people, the average daily consumption from November 1, 1908, to November 1, 1909, having been 170,500 gallons.

The Chicago & North Western Railway owns two wells, about 25 feet apart, sunk through the alluvial deposits to a depth of 90 feet and finished with screens in a bed of gravel that is said to rest on rock. The water rises within five or six feet of the surface, and the pump cylinders are placed 14 feet below the surface, with suction pipes extending lower. According to the man in charge, nearly 200,000 gallons of water are taken from these wells every day.

Persia.—The waterworks at Persia (population, 358) consist of a tank elevated upon a tower and connected with about one mile of mains. The supply is at present drawn from a well four feet in diameter, sunk about 50 feet into clay from which it receives a seepage of hardly more than 2,000 gallons per day. A hole bored to a depth of over 100 feet discovered a bed of quicksand at about 60 feet which yielded only a small amount of water. There is, however, little question that an adequate supply for the waterworks can be obtained without deep drilling.

Woodbine.—The public supply of Woodbine (population, 1,538) is derived (1) from an 840-foot flowing well whose small natural flow (12 gallons a minute) is augmented perhaps threefold when an air lift is applied; and (2) from a dug well, 18 feet in diameter and 26 feet deep, which ends in a bed of sand and gravel but does not seem to furnish much water. The deep well, which was put down by J. Shaw in 1905, is 12 to six inches in diameter. Altogether about 25,000 gallons of water are consumed each day, requiring the operation of the air lift for six hours. The waterworks include a standpipe and about three miles of mains. The deep water is said to be very hard and to produce much scale in boilers.

No record of the strata has been preserved, but the succession is probably closely that of the Logan deep well (p. 1134) and the water bed is Mississippian.

MILLS COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

The surface of Mills county consists of hilly upland areas separated by broad tracts of flat lowland through which the principal streams meander. The unconsolidated deposits consist of glacial drift, loess, and alluvium; the bedrock, to a depth of 670 feet in the deep well at Glenwood (Pl. XVIII), consists almost exclusively of alternating strata of shale and limestone belonging to the Missouri stage of the Upper Carboniferous. In some localities thin beds of sandstone, referred to the Cretaceous, lie between the Missouri strata and the drift.[1]

[1]Udden, J. A., Geology of Mills and Fremont counties: Ann. Rept. Iowa Geol. Survey, vol. 13, 1902, p. 161.

UNDERGROUND WATER.

SOURCES.

The thick Missouri stage contains so little water, and that little is so highly mineralized, that wells should not be sunk into it unless it is intended to go to great depths for artesian supplies, as in the Glenwood wells (p. 1139). Ordinarily, water must be obtained either from surface sources or from the deposits above the Missouri. The lowland and upland ground-water conditions differ radically. In the lowland areas abundant quantities of hard but otherwise good water are obtained by driving inexpensive points to beds of alluvial sand and gravel at slight depths; in the upland areas more meager amounts of equally satisfactory water are obtained from large wells dug or bored into the loess or drift. In the former areas large supplies can be developed by driving a sufficient number of sand points, connecting the wells at the top, and drawing from all simultaneously; in the latter it is difficult to obtain large supplies, but the yield can be increased indefinitely by expanding the infiltration surface. In some localities layers of sand or sandstone (either Aftonian or Cretaceous) are encountered and copious supplies obtained, but such water-bearing layers are not everywhere found.

SPRINGS.

Springs are abundant in Mills county. Seeps which give rise to rivulets occur in many of the deep ravines that have been cut into the uplands below the surficial water level, and many springs also issue from the cliffs bordering the main valleys, the water coming from Aftonian gravel, from the base of the drift, or from more or less porous materials at other levels.

CITY AND VILLAGE SUPPLIES.

Glenwood.—The public supply of Glenwood (population, 4,052) is pumped from a deep-drilled well (Pl. XVIII), which has a depth of 2,000 feet and a diameter of 10 to four and three-fourths inches, cased to 1,773 feet. The curb is 1,132 feet above sea level. The original head was 171 feet below curb; head in 1909, 180 feet below curb. The original tested capacity was 60 gallons a minute; tested capacity in 1896, 83 gallons a minute; tested capacity in 1908, 108 gallons a minute. The well was completed in 1891 at a cost of $7,265 by the American Well Works Company, of Aurora, Illinois.

Character of water in Glenwood city well.

	Depth of water bed	Head below surface
	Feet	Feet
Fresh	154	------
Salt	716	176
Salt	825	15
Fresh	1,008	40
Fresh	1,210	126
Fresh	1,668	100
Fresh	1,794	40
Fresh	1,836	171

The following data concerning pumping tests have been supplied by Seth Dean: On January 28, 1890, the pump was started at 10 a. m., pumping 50 gallons per minute. The temperature of the water rose from 60° F. at 10.15 a. m. to 66° at 11.30 a. m., to 68° at 12 M., and to 69° at 3.15 p. m.

A second test was made July 26 and 27, 1892, after the salt water had been cased out. The pump was started at 4.30 p. m., pumping 60 gallons a minute. The temperature of water rose as follows: 4.50 p. m., 60°; 5 p. m., 62°; 5.40 p. m., 66°; 6 p. m., 69°; 8.17 p. m., 72°; 2.45 a. m., 72½°; 9.45 a. m., 72½°; and 11 p. m., 72½°. Probably the gradual rise in temperature is caused by the increasing proportion of water drawn from the lower vein.

The well was repaired about 1904 by replacing some joints of casing, but without effect on the discharge. The cylinder (not more than six inches in diameter) is set about 280 feet below the curb. The pump is run continuously 16 hours a day, at a speed of 16 to 17 revolutions a minute; running the pump faster does not increase the yield.

Record of strata in city well at Glenwood (Pl. XVIII, p. 1100).

	Thickness.	Depth.
Quaternary (175 feet thick; top, 1,132 feet above sea level):	Feet	Feet
Soil	2	2
Loess	152	154
Gravel and coarse sand (water bearing)	6	160
Sand, coarse	5	165
Till, yellow; greenstone, and other pebbles	10	175
Carboniferous:		
Pennsylvanian—		
Missouri stage (670 feet thick; top, 957 feet above sea level)—		
Limestone, soft, light and darker gray, cherty	2	177
Limestone, dark blue, argillaceous, pyritiferous	10	187
"Shale, black, carbonaceous"	1½	188½
Clay, blue, shaly	6½	195
Shale, iron-gray	8	203
Limestone, gray; earthy luster	24	227
Shale, dark blue-gray, fissile; disks of crinoid stems and fragments of a Productus	5	232
Limestone, gray; luster, earthy; compact, moderately hard; with crinoid stems, echinoid spines, and fragments of brachiopods	8	240
Shale, black, carbonaceous	4	244
Limestone, soft, yellow-gray, with Fusulina	13	257
Shale, blue	7	264
Limestone, light yellow, fossiliferous	9	273
Shale, dark red	16	289
Limestone, brecciated; sample consists of two large unfractured masses of very hard limestone breccia; limestone gray or reddish; matrix greenish gray and argillaceous, but hard	25	314
Sandstone	9	323
Limestone, argillaceous, bluish gray	17	340
Shale, blue	2	342
Limestone, compact	5	347
Shale, greenish gray, arenaceous, calcareous	3	350
Limestone, hard, gray; highly cherty at 358 feet	13	363
Shale, hard, greenish gray, highly calcareous	10	373
Limestone, light greenish gray, highly argillaceous	5	378
Limestone, light yellow-gray, compact, fine-grained	18	396
Shale, black, carbonaceous; and greenish gray, hard	9	405
"Marl, white"	2	407
Limestone, hard, gray	8	415
Shale, gray; and limestone, argillaceous	4	419
Shale, varicolored	19	438
Limestone, gray, close textured	18	456
Limestone, hard, blue, highly argillaceous; crinoid stems and fragments of brachiopods	11	467
Shale, black, carbonaceous; impure gray limestone	3	470
Sandstone	6	476
Limestone, white and light gray, close textured; earthy luster	15	491
Slate, black	5	496
Limestone, yellow-gray, fossiliferous, crystalline to earthy	12	508
Shale, dark and greenish gray; with Chonetes	11	519
Limestone, light yellow-gray, soft, fossiliferous	10	529
Shale, green, calcareous	21	550
Limestone, white, soft, crystalline to earthy	20	570
Shale, gray, highly calcareous, fossiliferous	10	580
Shale, black, carbonaceous, dark drab	15	595
Limestone, white and light colored; in places fossiliferous, with 1 foot of "coal?" at 612 feet, and brown chert at 635 feet; 9 samples	43	638
Shale, varicolored, arenaceous; with minute angular particles of limpid quartz; 2 samples	47	685
Sandstone, greenish gray, close and fine-grained, argillaceous and calcareous; some siliceous limestone, hard, subconchoidal fracture; with much shale at 706 and 711 feet; vein of salt water at 716 feet	35	720
Coal and black shale	1	721
Shale, blue	4	725
Limestone, gray, hard; fracture subconchoidal; close textured; fossiliferous and flinty at 732 feet; 4 feet of blue shale at 730 feet	15	740
Slate	12	752
Limestone, arenaceous	3	755
Shale, dark blue, calcareous; and black, carbonaceous	3	758
Sandstone, dark brownish gray; calcareous; ferruginous; argillaceous; fossiliferous, with Chonetes and other brachiopods	6	764
Limestone, lighter yellow-gray; highly fossiliferous in places; shale at 783 feet	27	791

Record of strata in the city well at Glenwood—Continued.

	Thickness.	Depth.
	Feet	Feet
Shale, black, slaty	2	793
Shale, gray	7	800
Limestone with shale	15	815
"Shale, blue with sandstone band"	10	825
Sandstone, fine gray, micaceous; vein of salt water	20	845
Des Moines stage (390 feet thick; top, 287 feet above sea level)—		
Shales; some fossiliferous, in places carbonaceous; mostly noncalcareous; of various colors; limestone at 868 and 885 feet, and 956 feet; coal at 956 feet; pyrite at 901 feet; 17 samples	117	962
Limestone	3	965
Sandstone and shale, fossiliferous	24	989
Sandstone, gray, soft, argillocalcareous, fine-grained	9	998
Shale, hard, brittle, noncalcareous, green and brown	10	1,008
Sandstone, gray, water bearing	17	1,025
Shale, hard, brittle; of various bright colors; finely laminated; fracture splintery; noncalcareous	20	1,045
Shale, arenaceous	36	1,081
Shale, black, carbonaceous	7	1,088
Fire clay, gray; in molded masses	6	1,094
Shale, black and gray; some sandstone	8	1,102
Limestone	3	1,105
Shales, varicolored, hard, brittle, noncalcareous	23	1,128
Sandstone, fine-grained; with shale; 2 samples	22	1,150
Shale; mostly black, brittle, splintery	10	1,160
Sandstone; 4 samples	30	1,190
Shale, black, hard, fissile	5	1,195
Chert, gray, with shale, limestone, and sand	10	1,205
Sandstone, gray; grains of moderate size; imperfectly rounded; 2 samples	30	1,235
Mississippian—		
Chert; with limestone, chalcedonic silica, and quartz sand; the latter sometimes seem embedded in the chert; 5 samples	45	1,280
Sandstone, argillaceous; in dark gray powder	20	1,300
Chert; with chalcedony; limestone, and at 1,305 feet much shale; 5 samples	70	1,370
Shale, highly calcareous; in blue-gray concreted powder; residue after washing, pyritiferous chert, quartz sand; a little glauconite, and nonmagnesian limestone; 3 samples	35	1,405
Limestone, cherty, argillaceous; blue-gray; 3 samples	60	1,465
Limestone, gray; 2 samples	45	1,510
Shale, highly quartzose and calcareous, in light blue-gray powder; 3 samples; quartz particles minute	90	1,600
Shale, green, massive	44	1,644
Limestone; in flakes; some light yellow-gray; some soft and white; nonmagnesian; compact; some chert at 1,649 feet	24	1,668
Limestones, magnesian, or dolomites, crystalline; drab, buff and brown; largely in sand; effervescence slow; 4 samples	41	1,709
Limestone, brown and gray; considerable green shale at 1,720 feet	24	1,733
Limestone, magnesian; or dolomite, brown, roughly crystalline; 4 samples	32	1,765
Sandstone, gray; grains of limpid quartz imperfectly rounded, with some crystals	19	1,784
Limestone, magnesian; or dolomite, buff and yellow; 3 samples	28	1,812
Limestone, somewhat magnesian; moderately rapid effervescence; in brown and buff crystalline sand; 2 samples	20	1,832
Limestone, magnesian; and dolomite, crystalline, vesicular, brown and buff	68	1,900
Dolomite, light yellow-gray, cherty; 3 samples	24	1,924
Dolomite, greenish gray; argillaceous residue	6	1,930
Dolomite, light gray; much gypsum; water bearing	8	1,938
Gypsum; in light yellow concreted powder; now highly indurated	3	1,941
Dolomite, gray; flakes of gypsum and selenite; 4 samples	39	1,980
Limestone, gray, somewhat magnesian, seleniferous, argillaceous	10	1,990
Shale, soft, greenish, calcareous	5	1,995
Dolomite, gray; in powder; highly seleniferous	5	2,000
Shale, hard, green, very slightly calcareous.		

The distribution system consists of two standpipes and about three miles of mains with 16 fire hydrants and 146 taps. The water is rich in sulphates and chlorides, but is freely used for drinking and culinary purposes and is also employed in several stationary boilers with fairly satisfactory results. It is estimated that 50,000 gallons are consumed in an average day, which requires the operation of the pump during a large part of the time.

The supply for the State Institution for Feeble-minded Children at Glenwood was formerly obtained from a well 1,910 feet deep which was similar to the city well. The curb is 980 feet above sea level; casing, 8 inch to 822 feet, 7 inch to 1,011 feet, 6¼ inch to 1,103 feet, 5 3-16 inch to 1,515 feet, and 4½ inch to 1,640 feet; casing perforated at 1,450 and 1,600 feet. The original head was five feet below curb; head at present, 10 feet below curb. Temperature, 66° F. The well was completed in 1897 at a cost of $4,800 by F. M. Gray, of Milwaukee.

The driller's log, which evidently does not record all the strata passed through, is as follows:

Driller's log of well No. 1 of the Iowa Institution for Feeble-minded Children at Glenwood.

	Thickness.	Depth.
	Feet	Feet
Drift	35	35
Limestone	5	40
Shale, black		45
Limestone, blue	20	65
Limestone	10	100
Shale, red	30	140
Limestone	40	200
Shale		256
Shale, red	10	280
Limestone	15	305
Shale, black	20	340
Shale, blue	30	360
Limestone	10	430
Shale, black	5	445
Rock, soft, white	4(?)	475
Shale, blue	20	479
Shale, red	30	499
Limestone	10	529
Shale, black, coaly	1	549
Sandstone	7	550
Sandstone, with salt water	7	575
Shale, blue	10	625
Limestone	5	640
Limestone with pyrite (approximate base of Missouri in city well)	2	655
Shale, green	10	690
Shale, red		715
Miner's slate	10	732
Soapstone	10	780

Drillers log of well No. 1 at Glenwood—Continued.

	Thickness	Depth
	Feet	Feet
Miner's slate with pyrite		820
Shale, sandy, with salt water		865
Sandstone	5	990
Limestone		1,010
Sandstone		1,032
Sandstone (approximate base of Des Moines in city well)	10	1,065
Limestone, brown	12	1,103
Quartzite, red	3	1,115
Limestone, magnesian	23	1,198
Limestone, gray	64	1,226
Sandstone, white	5	1,351
Soapstone	20	1,410
Soapstone (approximate base of Mississippian in city well)		1,460
Limestone	20	1,509
Limestone, gray		1,535
Soapstone	8	1,580
Soapstone	2	1,600
Limestone, sandy	50	1,700
Gypsum	2	1,750
Limestone, gray	30	1,772
Limestone, bastard		1,850
Limestone, hard, gray		1,896
Bottom of well		1,910

The first water bed was struck at 570 feet. The water was salty and stood at six feet below the curb. The capacity was about 30 gallons a minute. At a depth of 1,008 feet another water bed was found, whose water rose within 60 feet of the surface and yielded 75 gallons a minute. At a depth of 1,160 feet the water rose to the surface and 70 gallons a minute were pumped. At a depth of 1,356 feet the water fell to six feet below the curb. Water was also found at depths of 1,668 and 1,836 feet and at the latter depth stood five feet below the surface and was pumped at the rate of 70 gallons a minute.

During the early part of the winter of 1897 a pump was placed in the well and operated by electric motors. These proving unsatisfactory, a Fairbanks-Morse steam pump was installed in 1900, the cylinder being placed 500 feet below the curb. Breakage of the rods necessitated frequent repairs, and in August, 1901, the working barrel worked loose and dropped to the bottom of the six-inch casing. On August 22, 1901, the cylinder was replaced at a depth of 100 feet, but 10 minutes pumping lowered the water below the foot valve. When the cylinder was placed 163 feet below the surface, pumping 20 strokes to the minute lowered the water below the foot valve in one hour; pumping at 13 strokes to the minute the pump delivered 40 gallons of water a minute. Early in September the cylinder was set at 228 feet below the surface; by running the pump at 18 strokes a minute for 10 hours 54 gallons of water a minute were obtained, but at the end of this period the water stood below the foot valve. From this date until March, 1902, the well was used only to supply drinking water, the general supply being taken from Keg creek. In March and April, 1902, it was found that 54 gallons a minute could be obtained by operating the pump at 19 strokes a minute. On May 5, the cylinder having again worked loose, it was reset 266 feet below the surface. During the summer the pump delivered 45 to 50 gallons a minute, according to the conditions of the leathers and the length of time the pump was run. In February, 1903, a new and larger cylinder, 5¾ inches in diameter, with a discharge pipe six inches in diameter, was set 294 feet below the surface. At 18 strokes to the minute this cylinder gave 50 to 75 gallons of water a minute up to January, 1906, with the following interesting exceptions: On June 13, 1905, the water began to fall noticeably. The leathers were found in fair condition. The failure continued until on July 20 no water could be pumped. On August 1 the yield was but five gallons a minute and the water contained a large amount of sediment. At the same time the city well of Glenwood was able to furnish but a small supply of water. After August 4, however, no sand or sediment was noted in the well, and running 10 hours a day the pump delivered about 60 gallons a minute. In January, 1906, it was found that with a stroke of 18 a minute and running continuously for 24 hours a yield of 50 gallons was obtained.

With the exception of a period of some six weeks in 1905, maximum pumping did not exhaust the supply, and the pump was run in 1906 for 24 hours a day. The needs of the institution, however, had become much larger than the well could supply. Furthermore, the well became infected with the germs of typhoid fever. Water taken directly from the discharge pipe was found by the State bacteriologists to contain the colon bacillus in large quantities and to have been contaminated by surface drainage, evidently through corroded or otherwise leaky casings. The location of the well is favorable for such contamination.

It was decided to sink an additional well to the water bed at about 1,000 feet to obtain a larger supply and to shut out the surface water finding access to well No. 1 by recasing it to 120 feet. The second well was carried to a depth of 975 feet and was then abandoned. It had a diameter of 15 to 6 inches; casing, 15-inch to 124 feet, 12-inch to 557 feet, 10-inch to 769 feet, 8-inch to 860 feet, and 6-inch to bottom. The curb was 1,060 feet above sea level. The log follows:

Driller's log of well No. 2 of the Institution for Feeble-minded Children at Glenwood.

	Thickness.	Depth.
	Feet	Feet
Clay, yellowish	10	12
Clay, reddish, very hard and dry	13	25
Clay, yellowish as from 2-12	20	45
Clay, dark yellow, moist; easy to dig	50	95
Gravel, and fine white sand, water	5	100
Limestone, white; under which was 2 inches of yellow clay	1	101
Shale, blue-black	29	130
Limestone, white, very hard	2	132
Shale, black	5	137
Limestone, blue, hard	10	147
Shale, black	5	152
Limestone	23	175
Shale, blue	20	195
Limestone, white	20	215
Clay shale, red	15	230
Shale, white slate	35	265
Limestone, hard, gray	30	295
Limestone, hard	15	310
Shale, blue	10	320
Limestone, very hard	25	345
Gravel and shale	10	355
Limestone, soft	5	360
Shale, red	25	385
Limestone, white	25	410
Shale, blue	10	420
Limestone, hard	10	430
Shale and lime	5	435
Shale, blue	5	440
Slate and lime	25	465
Slate, blue	10	475
Limestone	40	515
Lime and shale	10	525
Slate and shale	35	560
Limestone, blue	5	565
Shale	15	580
Shale, blue	30	610
Coarse sand and limestone	10	620
Slate, black, white, and red	15	635
Shale	35	670
Limestone, soft	5	675
Sandstone; salt water rising to 175 feet below curb	30	710
Shale, blue	30	740
Slate, black	10	750
Shale, blue, and sand	30	780
Shale, black	60	840
Shale, blue, and slate	20	860
Shale and limestone	30	890
Shale	20	910
Shale, dark, and 1 foot of limestone	25	935
Clay, red, and some limestone	15	950
Sand	5	955
Shale, dark blue	20	975

Because of the failure to obtain a sufficient amount of water in well No. 2 to supplement that of the first well, the second was also abandoned and a supply found in shallow wells on the Missouri river flood plain about 2½ miles from the institution.

Though no pumping tests seems to have been made of the capacity of well No. 2, there is little or no doubt that sufficient water was not obtained. The drilling was stopped at 85 feet above sea level, and the water beds of the sandstone at the base of the Pennsylvanian were not reached in well No. 1 until the drill had gone 28 feet below sea level. Had the well been drilled 113 feet deeper probably 75 gallons a minute would have been obtained from this sandstone.

Water for the institution is now obtained from a system of eight 6-inch driven wells in the Missouri valley about one mile east of Pacific Junction. The eight are spaced about 26 feet apart, and end with 8-foot screens in alluvial sand, at a depth of 32 feet. The casings are all connected at the top, and the water, which normally stands about 7½ feet below the surface is drawn by two duplex suction pumps 4 feet below the surface. The pumps are usually operated at the rate of 450 gallons a minute without producing any noticeable effect upon the supply. The water is only moderately hard but contains an undesirable amount of dissolved iron that is successfully removed by aeration.

Hastings.—The Chicago, Burlington & Quincy Railroad well at Hastings (population, 393) is 24 feet deep and apparently ends in the alluvium of the valley. It is said to yield about 32,000 gallons in eight hours.

Malvern.—The public supply of Malvern, (population, 1,154) is drawn from 14 driven wells located in the valley only slightly above the level of Silver creek. Some of the wells are three inches and others four inches in diameter. They pass through about 24 feet of soil and clay and end with 3½-foot screens in a bed of sand, reported to be fine-grained and between 2 and 13 feet in thickness. It seems that the yield, which was originally not great, has decreased gradually by the incrusting of the screens until the entire system will not yield over 100 gallons a minute when pumped continuously. A dug well which was 22 feet deep and ended at the top of the sand stratum, was originally used but was abandoned for the present system because of its meager yield. It is also reported that the Chicago, Burlington & Quincy Railroad at one time drilled to a depth of about 300 feet without success.

The waterworks consist of an elevated tank and approximately four miles of mains, with 18 fire hydrants and about 65 taps. The average daily consumption is reported to be 9,000 gallons.

Pacific Junction.—The Chicago, Burlington & Quincy Railroad has a pumping station in the valley between Pacific Junction and the asylum wells. The water is drawn by suction from six four-inch driven wells 35 feet deep. The pump usually lifts about 200 gallons a minute, which amount the wells are reported to yield except during very low water in the summer.

MONTGOMERY COUNTY.

BY HOWARD E. SIMPSON.

TOPOGRAPHY.

Montgomery county lies near the extreme southwest corner of Iowa. Its surface is an old drift plain carved into broad parallel ridges and valleys by the streams that flow across it in a direction slightly west of south, toward the Missouri. The broad, flat bottoms of the valleys and the mature dissection of the ridges indicate that a long time has elapsed since the whole was a broad level plain sloping in the direction now followed by the master streams. These streams, Walnut, East Nishnabotna, Tarkio, and West Nodaway rivers, and their tributaries thoroughly drain the county, so that it contains no standing surface water.

The drift thickly covers the entire county except some areas in the large valleys whose bottoms are filled with sand and gravel and silt and on whose sides it has been here and there eroded away, exposing the bedrock beneath. That this till is very old may be inferred from the facts that it is deeply leached, that many of its igneous bowlders are entirely disintegrated by weathering, and above all that its surface is maturely dissected. Well records do not indicate its division into Kansan and Nebraskan, as they do in counties north and east; whether the drift is Kansan or Nebraskan has not been positively determined. The uplands are mantled with fine grayish yellow loess that is characteristic of the Missouri valley region.

GEOLOGY.

The bedrock immediately below the drift on the uplands and ridges is the soft, porous Dakota sandstone (Cretaceous). This is wanting in all the river valleys, the pre-glacial streams which occupied these having cut deeply into the shales and limestones of the Missouri stage (Pennsylvanian), which lies just beneath. The result is that sandstone under the uplands alternates with shale and limestone under the valleys in parallel belts running almost north and south across the county. This fact, together with the presence of heavy alluvial deposits over the shale and limestone, is of prime importance in a consideration of underground water in this county. The strata of the county dip slightly west of south.

UNDERGROUND WATER.

SOURCES.

The most clearly defined water-bearing beds are the alluvial sands beneath the valleys and the Dakota sandstone beneath the uplands. Together these afford an abundant supply of good water for most of the county. Besides these the entire county is underlain by the drift and limestone horizons. Only on upland slopes that are not underlain by sandstone nor overlain by alluvium and in places where, owing to deep dissection, the drift is well drained, is there lack of good underground water in Montgomery county.

Most important of all aquifers are the deep beds of sands underlying the till of both the first and the second bottoms of each of the several rivers. These afford an inexhaustible supply of water at depths of 20 to 100 feet over belts ranging in width from a few hundred yards to 2½ miles and extending across the county from north to south. The water is medium hard and locally carries sufficient iron compounds in solution to form a red precipitate on standing, yet it is on the whole very wholesome where not contaminated by organic matter as in towns and cities.

Water is generally obtained from this bed by means of driven wells sunk at very slight cost. Ordinarily there is sufficient clay above the sands to seal out immediate surface waters and prevent contamination. In the cities and towns, however, a large amount of sewage enters through the cesspools dug into or through the surface soil and clay and through open wells which mingle surface waters and the sand waters. Pollution may be easily determined by analysis, and where found all private shallow wells should be closed and the public supply taken from some point above the city and free from contamination.

Over the uplands many shallow wells obtain a supply for domestic use or for small farms from the waters that gradually seep through the porous surface clay, the loess. The lower portion of the loess generally consists of fine sands, and these are the more common sources of supply for wells 10 to 20 feet deep. Loess wells are usually of the dug type and are unsatisfactory, as their supply greatly diminishes or fails entirely in dry seasons.

In recent years bored wells drawing on the sands and gravels at or near the base of the drift are replacing the shallower wells. These wells range in depth from 30 to 75 feet and obtain a larger and purer supply. A few wells obtain a supply from local lenses of sand or gravel in the bowlder clay.

Where found beneath the uplands the soft brown sandstone immediately under the drift is a most excellent aquifer, the purest and best. It ranges from a few feet to a hundred feet in thickness and is found at depths ranging up to 150 feet. Only on the margins of the uplands is it inadequate. When this water is obtained care should be taken to case out all others.

The limestone of the Missouri stage is everywhere present under the sandstone or directly under the drift and affords a very scanty supply of hard water. This should be sought only when higher beds fail or are contaminated. Failure to procure ample supply from higher sources will rarely occur except on the lower upland slopes and uplands in the western edge of the county—that is, where the drift is deeply eroded and well drained and is neither overlain by alluvium nor underlain by sandstone. In such places it will probably be necessary to utilize waters from all sources by casing to limestone and by puncturing the casing opposite each horizon.

PROVINCES.

Montgomery county comprises several underground-water provinces. The first, or valley bottoms, consists of the first bottoms, the part now flooded in times of high water, or the flood plain; and the second bottoms, the terraces of the old valley floor, now above all ordinary floods and occupied by splendid farms and in many places by towns and villages. The second bottoms vary in width from a few hundred yards to two or three miles. On them the entire supply of water comes from driven, dug, or bored wells, which draw water from the alluvium. In the deeper portions, where silt is underlain by heavy beds of sand, driven wells are chiefly used, and such wells should be used wherever possible, as they prevent the mingling of surface waters with the supply used. In cities and towns on the bottoms care should be taken to determine by frequent analysis whether such wells are contaminated, and if contaminated, the private wells should be closed and free public water provided from a location above the town or from some source too deep for contamination.

The higher uplands underlain by sandstone constitute the second province. These are not all continuous or even connected, but this sandstone is one of the best aquifers in the state.

Most wells in this region are shallow and obtain water from the drift, but where a large, pure, and permanent supply is desired the sandstone is sought.

The third province, that of the limestone, occupies the higher lowlands and the lower uplands of the western edge of the county and lies in general on the slopes between the other two. Though the limestone is everywhere present, it is sought only where the alluvial and sandstone aquifers are wanting and where the drift is so broken and dissected as to be thoroughly drained. The limestone is a last resort and the water is frequently so scanty as to require a careful combining of the waters of all beds to make the supply sufficient, when the quality may not be satisfactory.

The shales of the Des Moines stage, lying underneath the Missouri stage, are very impervious and therefore dry in this part of the state.

FLOWING WELLS.

Several small flowing wells have been reported, the aquifers of which are the drift or the Dakota sandstone. The best is that of A. Monson on very low ground in NE. ¼ sec. 19, T. 72 N., R. 36 W. At a depth of 50 feet it obtains a fairly good flow from a conglomerate layer of the Dakota sandstone. Another well, drawing its supply from drift sands, is on J. P. Maben's farm near the center of sec. 21, T. 72 N., R. 36 W. Water flowed for a time from the tubular well on the farm of J. R. Jones (NE. ¼ sec. 16, T. 73 N., R. 39 W.), but soon ceased. The source is unknown. A flow was also struck in the 35-foot test hole put down on the slope 15 feet south of the new city well at Red Oak. This comes from the Dakota sandstone. A flow was not obtained, however, in the larger well. Small flows may usually be found in Dakota sandstone on low slopes. These may be of value in a small way for stock wells, and may be classed as artificial springs. No important flows can be expected from shallow wells.

SPRINGS.

Where the deeper valleys cut through an excellent aquifer, such as the Dakota sandstone, and leave it exposed over the valley sides, a number of excellent springs are found. Some are of the usual drift variety and are formed at outcropping edges of sand and gravel beds in the heads of ravines and on valley sides. The stronger, however, come from Dakota sandstone where it overlies the shales and limestones of the Missouri stage, and flow perennial streams of pure, cold water. The best known of this class are the "Sand Springs" just south of Red Oak (N. ½ sec. 33, T. 72 N., R. 38 W.).

CITY AND VILLAGE SUPPLIES.

Elliott.—All wells at Elliott (population, 528) are driven, the average depth being 30 feet. A good cover of soil and clay overlies the sand, which occurs at a depth of about 20 feet. The valley bottom in which such wells may be obtained is three-fifths mile wide. On the uplands beyond, wells are bored, dug, or drilled. Most common are the wells bored 60 to 80 feet to sand and gravel and lined with 12 to 18 inch sewer pipe. Others penetrate the sandstone.

The public supply is obtained from a battery of twelve two-inch drive points connected in series by four-inch pipe to a 12-horsepower gasoline pump with a capacity of 200 gallons a minute. Mains 900 feet long connect the pump with five hydrants. The system is used only for fire protection, when a pressure of 20 pounds is obtained.

Red Oak.—Drive points are the common wells on the lowland portion of Red Oak (population, 4,830), the usual depth being 25 to 40 feet, though a few reach 60 feet. On the upland portion tubular wells are in very general use. The water heads 10 to 12 feet below the surface; in wet weather four feet below.

A section is as follows:

Section of well at Red Oak.

	Depth in Feet.
Soil	1-6
Gumbo	6-10
Clay, yellow	10-20
Sand, ferruginous (first water)	20-25
Clay	
Gravel (second water)	40-50

Villisca.—Driven wells on lowlands all about Villisca (popuation, 2,039) find sheet water in sand at 15 to 35 feet. On the higher land wells 35 feet deep in alluvium or drift obtain an abundance of water. Few deep wells are reported. Sheet water in sand would probably not be found in Jackson township except in the western tier of sections.

The public supply is obtained from a spring well at the bottom of the slope between the town and the river. This well is a large, square hole 20 feet deep walled with rock, pointed up with mortar, and roofed over. From this a tile extends into the source of a spring which is evidently in the drift of the hill. The water is pumped into a tank by a triplex electric engine having a capacity of 100,000 gallons a day. A steam pump of equal capacity is held in reserve in such a way as to give gravity pressure of 55 pounds on the main business streets and 68 pounds at the plant. In case of fire 125 pounds direct pressure by electric and steam pumps may be obtained. Mains 2¾ miles long connect with 22 fire hydrants and about 120 taps, supplying one-tenth of the people.

A small tank is maintained for the city electric light pumping plant and for street-sprinkling. It draws its supply from the river, since the city water scales boilers badly and is low in dry seasons.

In emergency the tank supply may be cut off and after the well is drained the river may be drawn upon for unlimited supply. This has, however, been found necessary but once or twice in the history of the plant.

The water is so unfit for domestic use and unsatisfactory for boiler purposes and the supply furnished in dry seasons is so scant that a new system is contemplated.

WELL DATA.

The following table gives data of typical wells in Montgomery county:

Typical wells of Montgomery County.

Owner	Location	Depth	Depth to rock	Source of supply	Head below curb	Remarks: (Logs given in feet)
T. 73 N., R. 36 W. (Douglas).						
		Feet	Feet		Feet	
R. W. Corbin	SE. ¼ sec. 8	220	50	Coal (Missouri)	160	
W. Gardner	NE. ¼ sec. 17	210	149	Limestone (Missouri).	150	Hard water.
T. 73 N., R. 37 W. (Pilot Grove).						
Mrs. G. Halbert	N. ½ sec. 11	180	100	Sandstone (Dakota).	160	Fine water.
S. Tripp	SW. ¼ sec. 26	278	100			No water; limestone well.
T. 73 N., R. 38 W. (Sherman).						
J. W. Griffith	1 mile northwest of Stennett.	178	27			Do.
D. L. Rush	NW. ¼ sec. 27	270	40			Do.
D. W. Brick	W. ½ sec. 7	50	40	Sandstone (Dakota).		Plenty of water.
J. E. Good	NW. ¼ sec. 21	161		Sand and gravel.	81	No rock.
T. 73 N., R. 39 W. (Lincoln).						
J. H. Arkin	NE. ¼ sec. 12	160		do	140	Do.
T. 72 N., R. 39 W. (Garfield).						
Mrs. M.E.Tolman	SE. ¼ sec. 26	245		Sand	100	Plenty of water. No rock.
G. W. Buchanan	NW. ¼ sec. 35	175		Sandstone (Dakota).	75	Strong well; no rock.
T. 71 N., R.39 W. (West).						
T. G. Haag	NW. ¼ sec. 1	140		do	115	Strong well.
J. Larsen	NW. ¼ sec. 3	177		do		Plenty of water.
J. E. Frank	S. ½ sec. 14	125	60	do		Soft water.
T. 71 N., R. 38 W. (Grant).						
S. Anderson	SW. ¼ sec. 22	175	90	do		
T. 72 N., R. 38 W. (Red Oak).						
J. A. McLean	SE. ¼ sec. 15	212		do		
T. 72 N., R. 36 W. (Washington).						
A. Monson	NE. ¼ sec. 19	50		do		Flowing well.

PAGE COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY.

Page county is crossed by several streams, all of which meander through wide, flat-bottomed valleys that are nearly parallel and have a general southward or slightly southwestward trend. The two largest are Nodaway and East Nishnabotna rivers. Between the valleys extend intricately dissected upland belts having a relief of about 200 feet.

GEOLOGY.

The entire county is underlain by the Missouri stage (Pennsylvanian), which consists essentially of shale with numerous thin strata of limestone and a few coal seams. The total thickness of the series, as determined by deep drilling at Clarinda apparently is nearly 700 feet. (Pl. XVIII, p. 1100.) Below the Missouri is the Des Moines, another thick series belonging to the Pennsylvanian and consisting predominantly of shale, but differing from the Missouri chiefly in containing less limestone and more sandstone.

The upper surface of the Missouri stage lies for the most part below the valley level and is encumbered with a heavy deposit of glacial detritus, out of which the valleys have been excavated, and the hill topography of the interstream belts, with their 200 feet of relief, more or less, has been carved. At a number of places a thin layer of sandstone has been found between the glacial drift and the shale or limestone of the Missouri stage, and this is considered by Professor Calvin as probably Cretaceous.[1]

The upper surface of the drift is thoroughly weathered and is widely overspread with a few feet of loess. The broad val-

[1]Calvin, Samuel, Geology of Page County: Iowa Geol. Survey, vol. 11, 1901, p. 439.

leys are filled with alluvium, in some localities to depths of more than 50 feet. The alluvium, especially near the top, consists chiefly of fine-grained loesslike sediments, but it also includes beds of sand and gravel.

UNDERGROUND WATER.

SOURCES.

The alluvial deposits are the most reliable source of water in Page county. They are very important, not only because they occur over a considerable part of the county, but also because they are available to the principal cities and villages. They furnish the public supplies at Clarinda, Shenandoah, and Essex, the locomotive supplies for both the Wabash and the Chicago, Burlington & Quincy Railroad companies, the hospital supplies at Clarinda, the industrial and domestic supplies in essentially all the valley towns, and the domestic and stock supplies on a large number of farms.

The bulk of the alluvium consists of clay and silt that will not yield water, and much of the rest consists of fine sand that gives up its water slowly, but fortunately there also exist, commonly at considerable depths, beds of gravel, through which the water percolates more freely. A large number of the private wells end in sand and provide only scanty supplies, but where the demands are greater, as for public and industrial uses, the gravel beds are utilized, although even these are sharply limited in their yield. It needs to be said, however, that the small capacity of both private and public wells is, to a certain extent, due to the chronic clogging of the screens by fine sediment and by precipitates from the water.

For domestic and stock purposes, driven wells are largely employed. A pit is commonly dug nearly to the water level and the pump cylinder is placed at the bottom, where it will be protected from frost. Many pits are sunk some depth below the water level, so that the water rising in the driven wells overflows into the pit, from which it is pumped. The manifest advantage of such an arrangement is that a reserve of water accumulates during the intervals that it is not drawn upon, and hence water can at times be pumped more rapidly than the rate at which the well will yield. A serious disadvantage of such an arrangement, or of any that establishes communication between the well and pit, is that the water is always in danger of contamination, especially in the settlements, where cesspools and privies are in common use.

In the upland areas, between the streams, the ground-water conditions are more precarious. The drift contains beds of sand and gravel, but if these lie above the valley level then they have been drained of their water wherever they are widely distributed and are freely porous. If the drill or auger penetrates to the valley level it may perhaps discover a stratum of drift sand or of Cretaceous sandstone filled with water, but it is more likely to encounter the shale and limestone of the Missouri stage, which is an unpromising source of water, as to both quantity and quality. The imperfectly porous parts of the drift, such as are commonly found in the uncompacted upper portion, do not readily lose their water by leakage into the valleys, and hence it is that in spite of their meager yield they are relied upon for supplies on most of the upland farms. Many of the shallow wells in the hilly areas are in large ravines, where the prospects of procuring sufficient seepage are better than on valley sides or hilltops.

SPRINGS.

The leakage from the sandy and gravelly seams in the drift produces numerous springs, some of which are found in the smaller draws well toward the tops of the divides. The water from the drift, especially from its upper part, is, like that from the alluvium, of good quality except that it is hard.

CITY AND VILLAGE SUPPLIES.

Clarinda.—The public supply at Clarinda (population, 2,832) is drawn from five six-inch wells, all of which are situated in the valley and end with screens in a nine-foot bed of gravel that lies below about 50 to 60 feet of clay and sand and rests upon shale. The water is hard but otherwise good. It rises within about 20 to 30 feet of the surface, and the wells will furnish an average of about 50 gallons a minute each. It is reported that either of the two wells at the Lee electric light plant, situated 75 feet apart, will yield 100,000 gallons in 24 hours, but that together they will yield only 130,000 gallons. The aquifer seems to be entirely reliable and not to be affected by dry seasons, but the wells deteriorate rapidly and must be renewed every few years. A system of small driven wells, previously used for the public supply, was not satisfactory.

The water is pumped by the Electric Light Company into a standpipe, from which it is carried to the consumers by gravity. About 175,000 gallons are used daily.

At the State Hospital for the Insane three six-inch wells start from slightly higher ground than the city wells and go to a depth of 77 feet, evidently ending in the same bed of gravel below alluvial clay and sand above Carboniferous shale. The gravel is here said to be a little over seven feet thick. The three wells are reported to have a maximum capacity of 106,000 gallons, 96,000 gallons, and over 100,000 gallons, respectively, in 24 hours. The average daily consumption is about 110,000 gallons. The water is considered excellent for drinking and for general domestic use and serves very well for boilers, though it is somewhat hard.

A boring at Clarinda was carried to a depth of 1,002 feet in search of coal. Water flowed from the boring for a short time during the progress of the work. The driller's log, which seems to have been carefully kept, contains 40 entries, including records of shale of various kinds, limestone, marl, and coal. The drill seems to have passed from the Missouri stage into the Des Moines at about 700 feet, but apparently did not reach the Mississippian.

An accurate and detailed log (109 entries) of a diamond drill hole at Clarinda, 840 feet deep, is published by the Iowa Geological Survey.[1] From this log and an inspection of the core, Leonard places the base of the Missouri stage at about 715 feet.

[1]Iowa Geol. Survey, vol. 12, pp. 29-31.

The driller's log first mentioned is given below:

Driller's log of coal prospect at Clarinda.

	Thickness.	Depth.
	Feet	Feet
Clay and gravel	50	50
Shale, with thin streaks of rock	50	100
Shale, brittle	20	120
Marl, black	5	125
Shale, black	20	145
Shale, blue	5	150
Limestone	5	155
Shale, light	15	170
Limestone, very hard	25	195
Shale	20	215
Soapstone, changing to shale	85	300
Limestone	20	320
Shale, black	20	340
Marl, red	4	344
Soapstone, impure, red	36	380
Shale, blue	120	500
Limestone	20	520
Shale	72	592
Shale	28	620
Stone, dark colored	10	630
Shale	30	660
Coal, impure	8	668
Limestone	11	679
Rock and shale	21	700
Coal	5	705
Shale	5	710
Shale	10	720
Shale and coal	9	729
Shale	11	740
Shale	80	820
Coal	5	825
Limestone	5	830
Shale, black and blue	20	850
Slate and shale	35	885
Slate, gray	5	890
Shale, white	5	895
Shale	41	936
"Drift"	4	940
Shale, blue and black	48	988
Soapstone	14	1,002

Coin.—The Charles Schick well at Coin (population, 591), a prospect hole for gas and coal, has a depth of 888 feet, casing from 800 feet to bottom. Salty water is said to flow from well. Below a depth of 62 feet the rocks penetrated probably belong to the Pennsylvanian series.

Driller's log of Charles Schick well at Coin.

	Thickness.	Depth.
	Feet	Feet
Material containing wood, at		45
Gravel	2	62
Limestone, very hard	2	64
Limestone and black shale, alternating every 2 to 4 feet		
Caving rock and water, at		190
Shale and coal blossom	12	217
Limestone	8	225
Coal	2	227
Shale and limestone, alternating every 2 to 4 feet	153	380
Shale, black, tarry	4	384
Shale, etc.; rapid alternations	456	840
Coal and slate	9	849
Stopped drilling to case well on account of caving; casing broken and tools lost; well abandoned, at		888

Essex.—The public supply at Essex (population, 776), as at Clarinda and Shenandoah, is drawn from alluvial gravel. A six-inch well passes through 40 feet of clay and sand and ends with a six-foot strainer in a bed of gravel from which the water rises to a level 12 feet below the surface. According to estimates made the maximum yield does not greatly exceed 20 gallons a minute. The water is reported somewhat hard but otherwise good. It is stored in two compression tanks, from which it is delivered by air pressure through over a mile of mains to 12 fire hydrants and 41 taps. It is used by perhaps one-fifth of the people, who consume approximately 4,000 gallons daily.

Shenandoah.—The city waterworks at Shenandoah (population, 4,976) are supplied from one 10-inch and six six-inch wells, which pass through about 45 feet of alluvial clay and sand and end with screens in a bed of gravel. The water level fluctuates somewhat but is commonly about 16 feet below the surface. The casings of the seven wells are connected with a pump placed in a pit approximately at water level, and this pump draws by suction from all the wells simultaneously at the rate of about 200 gallons a minute, which approaches the maximum capacity of the system. It is probable that this small yield is largely due to the deterioration of the six-inch wells, which have been in service for a period of years. Before the wells at present in use were put down, a series of small driven wells was used.

The water is pumped into a standpipe from which it is distributed through 9 or 10 miles of mains to a large number of fire hydrants and taps. It is extensively utilized for domestic purposes and is also used in the locomotives on the Wabash Railroad. The total daily consumption is about 125,000 gallons.

The well of M. W. Smith in the NW. 1/4 sec. 21, T. 69 N., R. 39 W., is 710 feet deep and four to two inches in diameter. It is cased to rock. The curb is 1,024 feet above sea level and the head is above the curb. The flow is now 1,000 gallons a day, but was greater, the yield having diminished. The water is salty and is used for stock. The well was completed in 1887.

POTTAWATTAMIE COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY.

Most of Pottawattamie county consists of an upland carved by stream erosion into innumerable steep hills and ravines, but Missouri river, which forms the west boundary of the county, and Nishnabotna river and other affluent streams, which cross the county in a southwest direction, occupy wide valleys whose broad, flat, monotonous bottoms are in striking contrast to the rugged topography of the uplands.

GEOLOGY.

The region is underlain by Pennsylvanian strata, consisting chiefly of shales and limestones that outcrop at several localities but are commonly buried under 100 to 200 feet of unconsolidated materials of Pleistocene and more recent age. At a few points in the eastern part of the county a Cretaceous formation, mainly sandstone, has been found in exposures and wells[1] between the Pennsylvanian and Pleistocene series. On the uplands the Pleistocene consists in downward succession of loess, yellow clay somewhat resembling loess, Kansan drift, Aftonian

[1]Udden, J. A., Geology of Pottawattamie County: Ann. Rept. Iowa Geol. Survey, vol. 11, 1901, p. 233 et seq.

gravels, and Nebraskan drift. The numerous wide valleys all contain thick deposits of alluvium.

The deep geology of the western part of the county, near Council Bluffs and Omaha, Nebraska, has been almost entirely unknown. A very few samples of the drillings of the deep well of the Willow Springs distillery at Omaha, examined by Norton in 1896, showed that a magnesian limestone series begins about 1,055 feet from the surface, or about sea level, and continues thence to the bottom of the boring at a depth of 1,780 feet, interrupted, so far as shown by the samples, only by a thin shale at 1,250 feet and a white sandstone at 1,430 feet. The logs of several wells at Council Bluffs and Omaha are on record but are vague and contradictory. The great depth of the Pennsylvanian in southwestern Iowa has led to a belief that at Council Bluffs, as at places farther to the east and south, the Coal Measures might well extend down to sea level.

The drillings at Miller Park, Omaha, and at Fort Crook (see pp. 1172-1176) agree in testifying that at about 550 feet above sea level there begins a series of limestones and cherts, 500 feet thick, containing in many places milk-white translucent chalcedony. In view of its nature and its thickness this series can hardly be attributed to any higher terrane than the Mississippian. At least this hypothesis seems preferable to the hypothesis that the Des Moines stage changes from clay shales to limestones of Mississippian facies on nearing Missouri river at this latitude.

Apparently, then, there is in this area a rather sharp upwarp that brings the Mississippian floor of the Coal Measures 650 feet higher at Omaha than at Glenwood, 18 miles to the southeast, so that they have a dip of 36 feet to the mile. The southward dip is corroborated by the testimony of well drillers, who report a much greater dip.

The heavy shales of the Kinderhook stage, which are regarded as the base of the Mississippian at Glenwood, are absent at Omaha and Council Bluffs, so that it is difficult to draw any line of separation between the Mississippian and the Devonian, and it is quite possible that more or less of the limestones assigned to the former really belong to the latter. The thickness of the Mississippian is not excessive, for at Glenwood it measures somewhat more than 400 feet. At Logan, also, farther north, where it should be thinner, the Mississippian extends from at least 478 feet above sea level to 212 feet above sea level, giving a minimum thickness of 266 feet. The Mississippian at Logan, however, may begin 150 feet higher up, there being a gap in the record; moreover, its lower limit does not seem to have been attained.

At about 50 feet above sea level at Fort Crook a series of dolomitic limestones begins. At 70 feet above sea level at Miller Park, Omaha, dolomites are first encountered, although limestones, more or less magnesian, are found 100 feet higher. These magnesian limestones and dolomites are the uppermost beds of a thick series of rocks that are widely spread over western Iowa and eastern Nebraska. They probably represent different formations, but in the absence of fossils any identification or even demarcation seems impossible. In exception, it may be noted that a thick body of magnesian limestone and dolomite occurring at Glenwood and at Bedford well up toward the summit of the series may be referred with some confidence to the Salina (?) formation of the Silurian, on account of its content of gypsum and anhydrite. In the Council Bluffs section these minerals are absent, and the upper beds may be assigned to the Silurian solely on account of their place in the series.

At Fort Crook the magnesian series is interrupted by limestones of slight magnesian content from 1,070 to 1,125 feet. At 1,220 feet (150 feet below sea level) occurs a hard, bright green shale interbedded with dolomite, the whole being 30 feet thick. All limestones below this shale are thoroughly dolomitized. At 1,340 feet (270 feet below sea level) they are slightly arenaceous. At the Willow Springs distillery, Omaha, a white sandstone occurs about 400 feet below this. At Miller Park, Omaha, a red arenaceous shale with thin layers of sandstone intervenes at 75 feet below sea level. This may represent the hard green shale found in the Fort Crook well at 150 feet below sea level.

The formation to which the dolomites below the green and red shales belong is quite uncertain. In facies they resemble the dolomites of the Prairie du Chien stage except in their generaly non-arenaceous nature. But the Silurian dolomites at Bedford are of great thickness. The drill was still in them at 2,400 feet, which would give them a minimum thickness of 575 feet. There seem, therefore, to be no data by which the lower limit of the Silurian dolomites at Council Bluffs can be drawn.

It would not be inconsistent with some of the data to refer the bright green and the red sandy shales found from 75 to 150 feet below sea level to the base of the Platteville. This would imply an upwarp of the lower Paleozoic in the Council Bluffs area of far greater steepness than any known in the state. It would correspond with the already inferred upwarp of the Mississippian floor of the Coal Measures, but it would be considerably steeper, lifting the Saint Peter about 1,000 feet higher than the general stratigraphy would indicate. At Lincoln, Nebraska, where the Saint Peter is fairly well identified in the State well, it occurs nearly 900 feet below the summit of the magnesian limestones, and if the green shale at Fort Crook at 150 feet below sea level marks the top of the Saint Peter, it occurs at but 100 feet (or at most at but 200 feet) below the same datum, although the Mississippian has thinned out to the west from Omaha to Lincoln. For this reason it would seem somewhat more probable that the Saint Peter lies below the lowest terranes pierced by the Omaha wells.

UNDERGROUND WATER.

SOURCES.

Water is found in (1) the alluvium; (2) the loess, drift, and associated deposits; (3) the Cretaceous deposits, and (4) the lower formations.

In the lowland tracts water can be secured from alluvial sand or gravel in sufficient quantities for all ordinary purposes. When not polluted this water is of good quality, though it contains rather large amounts of calcium and magnesium. Driven wells are in common use and the water rises nearly or quite to the surface.

Two 12-inch wells drilled in the Missouri valley at Council Bluffs for the Chicago & North Western Railway have the following section:

Section of Chicago and North Western Railway wells at Council Bluffs.

	Thickness.	Depth.
	Feet	Feet
Clay, soft, yellow	24	24
Mud, soft, gray	20	44
Sand, soft, gray, muddy	20	64
Sand, gray	16	80
Sand, coarse, and gravel	16	96

These wells were finished with 10-inch screens in the basal sand and gravel from which the water rose within 10 feet of the surface, and was lowered 15 feet 4 inches by pumping 300 gallons a minute for nine hours.

The loess and the upper part of the bowlder clay are slightly porous and contribute a slow seepage to dug or bored wells sunk below the ground-water level. Beds of sand and gravel are numerous. The Aftonian gravel appears to be widely distributed, and in some places attains considerable thickness. Along the cliffs north of Council Bluffs, where it is especially well developed, it gives rise to numerous good springs. According to Andrew Graham, Park Commissioner, 31 springs in this vicinity, presumably all issuing from the Aftonian, together yield 1,250,000 gallons a day. Sand and gravel also occur in certain localities between the drift and the bedrock.

Most of the water in the numerous sand and gravel deposits is not under much pressure and generally does not flow readily into drilled wells of small diameter, though it may constitute a very satisfactory source for large bored wells. The difficulty with many of the bored wells is that they fail to reach water because well augers can not bore into gravels that are firmly cemented, as they are in many places. In seeking municipal, industrial, or stock supplies in the upland regions, explorations should if necessary be carried to the Pennsylvanian strata, which can easily be recognized.

The conditions found in drilling in Fairmont Park, on the loess-covered uplands at Council Bluffs, may be regarded as typical. The first hole was sunk through 125 feet of loess and bowlder clay, two feet of yellow sand, and finally through about 13 feet of red or yellow rock, stopping at 140 feet (about at the valley level) without water. The second hole was started on ground about 20 feet lower than the first and was carried through about 100 feet of loess and bowlder clay, two feet of gravel, eight feet of red or yellow rock, and 155 feet of rock, consisting of alternating shale and limestone strata. Finally, at a depth of 265 feet, it was abandoned, for it did not find sufficient water to supply a well of small diameter, although in the first 100 feet there were seeps that would probably have sufficed for a well of large diameter. The third hole was started on ground perhaps 110 feet higher than the first and was sunk to a depth of 280 feet. Near the bottom the drill passed through two feet of brown sandstone, 10 or 15 feet of yellow clay, and three feet of clean white sand and gravel, ending in a few feet of red or yellow rock. The water from the sand and gravel rose about 40 feet in the well, and with the cylinder at the bottom it can be pumped at about six gallons a minute. It is apparently of good quality. A fourth hole encountered six feet of sandstone instead of two, and four and one-half feet of gravel instead of three; its maximum yield is eight gallons a minute instead of six.

Locally, the Cretaceous sandstone will yield freely, but it is so generally absent that for the county as a whole it is not of much consequence.

The deep beds, which have been tapped by a number of wells in Council Bluffs and Omaha, yield moderate amounts of water rich in sodium sulphate. Between them and the water-bearing beds that are nearer the surface lie several hundred feet of Pennsylvanian strata, which are unpromising as a source of water, although a few wells seem to draw from them.

The thick body of limestones referred to the Mississippian carries artesian water at several levels. In the Missouri valley at Council Bluffs small flows may be expected at depths between

620 and 740 feet and stronger flows between 800 and 815 feet (245 to 235 feet above sea level).

The magnesian limestones and dolomites referred to the Silurian (often called sand rock in drillers' logs because of the sharp sparkling crystalline sand to which they are crushed by the drill) are tapped by most of the artesian wells of the area. Water is found in them at 950 to 1150 feet below the Missouri bottoms at Council Bluffs.

Other water is found in deeper dolomites referred with great uncertainty to the Silurian. Like the water from the Silurian dolomites at Bedford, these deeper waters are highly mineralized. These beds are the source of the main water at Fort Crook (1,560-1,580 feet) and were tapped also at Willow Springs Distillery (1,600-1,700 feet).

CITY AND VILLAGE SUPPLIES.

Avoca.—The public supply at Avoca (population, 1,520) is derived from four five-inch driven wells which stand 30 feet apart on the Nishnabotna bottoms and end at a depth of 28 feet with six-foot screens in a 13-foot bed of sand and gravel, from which the water rises within a few feet of the surface. The combined yield of the four wells was roughly estimated at 250 gallons a minute. The water is hard and the screens become incrusted in about two years. Before the present wells were put down a less successful system of small sand points was used. The water is pumped by the Electric Light Company into a standpipe and is delivered through about 4½ miles of mains to approximately 100 buildings. It is used by one-third of the people and 25,000 gallons are daily consumed. Water for the boilers at the electric light plant and mill is drawn from the river; that for the railway locomotives is taken from a large dug well on the river bank; that for the boiler at the brick yard is drawn from rain water stored in a cistern, and that for the canning factory is taken from a well similar to the village wells.

Carson.—Carson (population, 640) is located at a place where the Nishnabotna valley is greatly constricted, apparently owing to outcropping bedrock. The waterworks, which are in private ownership, draw from a dug well about six feet in diameter and 40 feet deep that extends largely through fine sand from which the water is with difficulty separated. The yield is between 10 and 15 gallons a minute. The supply is pumped by water power into a small tank on high ground and distributed by gravity through a system of mains with limited service. The railway locomotives are supplied from a well that is similar to that at the waterworks.

Council Bluffs.—Water at Council Bluffs (population, 29,292) is obtained from four distinct sources: (1) Missouri river, which supplies the public waterworks and most of the railway companies, and furnishes the most satisfactory boiler water; (2) alluvial sand and gravel, which in the valley yields generous quantities of hard water that is widely used for a variety of purposes; (3) loess and drift materials, which on the uplands furnish meager supplies of good water that must generally be lifted from near the bottoms of the wells, as at Fairmont Park; and (4) rock formations at greater depths, which provide moderate amounts of sodium-sulphate water that in some cases rises above the valley level. The deep water is used at the State School for the Deaf and at several industrial establishments, but it is avoided for locomotive boilers.

For the public supply the water is lifted from the river by a centrifugal pump into sedimentation basins and thence elevated by duplex pumps into a storage reservoir, from which it is distributed by gravity. The system consists of about 34 miles of mains with 288 fire hydrants and 4,500 service connections. The water is widely used by the people and by the railway companies, and approximately 2,500,000 gallons are consumed daily.

Well No. 1 of the School for the Deaf is 1,012 feet deep and 3 inches in diameter. The curb is 1,010 feet above sea level. The original head was 50 feet above curb, but the present head is only 10 feet above. The original discharge was 50 to 60 gallons a minute; the discharge in 1889 was 11 gallons a minute; the discharge in 1908 was three gallons a minute and the present pumping capacity is 15 gallons a minute. The well was completed in 1885. In 1894 several hundred feet of new casing was inserted, with the effect of temporarily increasing the flow. This well now flows into an artificial pond and furnishes auxiliary supply for fire protection.

Record of strata of well No. 1 at School for the Deaf, Council Bluffs.[a]

	Thickness	Depth
	Feet	Feet
Shale, red, calcareous	280	280
Shale, lavender-colored, noncalcareous	10	290
Shale, bluish, calcareous; some small chips of limestone	35	325
Shale, dark gray, fine-grained, slightly micaceous, noncalcareous	25	350
Shale, blue, tough, calcareous	5	355
Shale, blue, calcareous; some chips of limestone	45	400
Shale, light gray to green, pyritiferous; a few chips of limestone	70	470
Shale, reddish brown, calcareous	30	500
Shale, dull red, siliceous, noncalcareous; 2 samples	100	600
Shale, blue-gray, very weakly calcareous; 2 samples	90	690
Sandstone, white, transparent; quartz grains rather sharp; some calcareous particles	55	745
Limestone, white; much quartz sand	15	760
Shale, greenish; some fragments of limestone; calcareous, slightly pyritiferous	50	810
Sandstone, fine, calciferous	20	830
Limestone, dark, mixed with some shale and sand	30	860
Sandstone, very fine; some calcareous grains	60	920
Shale, green-gray, slightly calcareous	60	980

a From descriptions of drillings by J. A. Udden and by a member of Iowa Geological Survey.

Well No. 2 at the School for the Deaf has a depth of 1,080 or 1,100 feet and a diameter of 6¼ inches to 482 feet, 5½ inches to 618 feet, and 4 inches to bottom. The casing is 4-inch pipe to 482 feet. The original discharge was 40 gallons a minute; discharge in 1908, 6 gallons; pumping capacity, 30 gallons a minute. Date of completion, 1889. The well is pumped and furnishes 35,000 gallons a day.

Log of well No. 2, School for the Deaf, Council Bluffs.

	Thickness	Depth
	Feet	Feet
Surface material	90	90
Shale	300	390
Sand	80	470
Limestone	100	570
Shale	250	820
Limestone	100	920
Sandstone	40	960
Limestone	50	1,010
Sandstone	30	1,040
Shale	35	1,075
Sandstone	25	1,100

The Geisse Brewery well is 1,114 feet deep and nine to three inches in diameter. The curb is 1,047 feet above sea level and the original head was 55 feet above curb. The original discharge was 175 gallons a minute. The water comes from limestone. Date of completion, 1886(?).

The well of the Chicago, Milwaukee & St. Paul Railway, at the roundhouse, is reported to be 750 or 860 feet deep. The curb is 980 feet above sea level and the present discharge 3½ gallons a minute. A gradual lessening of flow has been noted. No pumps are used. Driller, W. H. Gray & Brother, Chicago.

Driller's log of well of Chicago, Milwaukee and St. Paul Railway.

	Thickness	Depth
	Feet	Feet
Drift	70	70
Limestone	100	170
Shale	480	650
Sandstone	100	750

The J. G. Woodward & Company candy factory well was 830 feet deep. It obtained a flow of 15 gallons a minute from water bed at 725 feet, which had decreased to 5 gallons a minute by 1904. The well was deepened in 1904 to 847½ feet and the flow increased to 12 gallons a minute. Water at present is pumped at the rate of 60 gallons a minute with cylinder 140 feet below surface. Date of completion, 1901.

The Bloomer Ice & Cold Storage Company well is 1,280 feet deep and 12 to 8 inches in diameter. The head is 80 feet above curb. A slight flow of ferruginous water at 700 feet was cased out, the main flow coming from 1,000 to 1,100 feet. The original discharge was 105 gallons a minute; the discharge in 1909 was 75 gallons a minute; the temperature was 62° F. The well was completed in 1906 at a cost of $5,500, by L. E. Nebergall, of Omaha.

The owner of the well states (from memory) that limestone was struck at 95 feet, beneath three or four feet of blue shale. A coal seam two or three inches thick was found at about 700 feet, with shale above and below it, and a very coarse conglomerate gravel with flattened pebbles at about 1,100 feet. From 1,150 feet to the bottom the well is in limestone.

Omaha, Nebraska, and adjoining towns.—Some assistance in the interpretation of the difficult section at Council Bluffs is afforded by records of wells at Omaha, Lane, and Fort Crook, Nebraska. These records were collected by James H. Lees, Assistant State Geologist of the Iowa Geological Survey, and by correspondence.

Driller's log of Riverview Park well at Omaha, Nebraska.

	Thickness	Depth
	Feet	Feet
Drift	94	94
Limestone	70	164
Shale	10	174
Limestone	86	260
Caving shale; streaks of limestone	87	347
Limestone	48	395
Streaks of lime and shale, caving badly, at		400
Caving shale to		569
Lime and shale	41	610
Sandy shale, caving badly in places	132	742
Limestone	108	850
Shale, caving considerably	149	999
Limestone, with streaks of shale caving badly	101	1,100
Limestone	58	1,158
Sandstone	72	1,230
Shale streak, at		1,233
Limestone; streaks of shale	147	1,380

Log of Young Men's Christian Association well, Omaha, Nebraska.

[Elevation of curb, 1,070 feet above sea level.]

	Thickness	Depth
	Feet	Feet
Earth	102	102
Limestone	198	300
Shale, red and black	200	500
Limestone	20	520
Shale, black	50	570
Limestone	170	740
Shale and limestone	50	790
Limestone	284	1,074
Sandstone	60	1,134

Log of Booth Fisheries Company's well, Omaha, Nebraska.

[Elevation of curb, 1,045 feet above sea level.]

	Depth
	Feet
Loam and clay	40
Clay, blue, struck blue rock	50
Bedrock	61
Shale	78-88
Limestone and shale	93
Shale	98

Log of Booth Fisheries Company's well—Continued.

	Depth
	Feet
Shale; trace of red rock	115
Clay, blue; trace of red rock	125
Rock	130
Limestone, 180 and	200
Clay, blue	210
Shale, red, 260 and	280
Clay, blue, 290 and	315
Shale, gray	370
Shale, red	380
Shale, red and gray, 400 and	410
Shale	412
Shale, reddish	420
Rock	428
Shale, red, and clay	440
Shale, gray	520
Limestone	550
Limestone and clay; a small overflow	620
More water	740
Limestone	792
Limestone; more water	805
Through limestone; more water	812
Shale; flow 46 gallons a minute	815
Limestone, milky	850
Bad cave	950
Limestone, hard; water somewhat milky; 60 gallons a minute	970
Hard rock; 67 gallons a minute	1,047
Bottom of well (flow of 110 gallons a minute)	1,094

Log of Union Pacific Railway well, Lane, Nebraska.

[Curb, 1,091 feet above sea level.]

	Thickness	Depth
	Feet	Feet
Clay, sandy	50	50
Sand	2	52
Shale, blue	53	105
Limestone	45	150
Shale, black	13	163
Limestone	20	183
Shale	2	185
Limestone	15	200
Shale	2	202
Limestone	48	250
Sandstone	4	254
Limestone	7	261
Shale	159	420
Limestone	295	715
Shale	10	725
Limestone	10	735
Shale	15	750
Limestone	10	760
Shale	6	766
Limestone	146	912
Shale	8	920
Limestone	26	946
Shale	4	950
Limestone	41	991
Shale	9	1,000
Limestone	318	1,318
Shale, blue	67	1,385
Limestone	33	1,418
Shale	7	1,425
Sandstone	8	1,433
Shale	10	1,443
Sandstone	9	1,452
Shale	16	1,468
Sandstone	12	1,480
Limestone	90	1,570
Sandstone	12	1,582
Limestone	8	1,590
Sandstone	18	1,608
Limestone	104	1,712
Shale, green	12	1,724
Sandstone	105	1,829

Record of strata of deep well at Fort Crook.

[Furnished by Frank Phillips, Government engineer.]

	Thickness	Depth
	Feet	Feet
Unrecorded	65	65
Sand, coarse	4	69
Sand; gravel up to three-fourths inch diameter; pebbles of quartzite, greenstone, granite, etc.	6	75
Till, blue; small pebbles, some of coal; facies of Kansan drift	28	103
Gravel; up to 1 inch diameter; well rounded; cuttings of gray crystalline limestone; rapid effervescence in cold dilute hydrochloric acid	10	113
Limestone; as above, some grayish white fossiliferous cuttings	2	115
Limestone, light yellow-gray; rapid effervescence; subcrystalline; Fusulina cylindrica	7	122
Limestone, gray-white; in small chips	12	134
Limestone, blue-gray, soft, earthy; large irregular chips, fossiliferous; crinoid stems and joints and Fusulina cylindrica; some shale	4	138
Limestone; gray, subcrystalline, encrinital; some green shale	2	140
Limestone, green-gray, hard, fossiliferous; rapid effervescence	13	153
Shale, black, fissile	5	158
Limestone, grayish white, encrinital; in flaky chips	22	180
Shale, black	15	195
Limestone, light gray, earthy; some black shale from above	5	200
Limestone, white, fossiliferous; in large flaky chips; some blue shale	13	213
Shale, green, small particles of white limestone	8	221
Limestone, gray and white, soft, earthy	9	230
Limestone, blue-gray, fossiliferous, compact	10	240
Shale, red, slightly calcareous	60	300
Sandstone, blue-gray, fine-grained, micaceous, calciferous, in chips; some red shale	27	327
Limestone, blue-gray, highly argillaceous; some pyrite	13	340
Limestone, blue-gray; shale, black, reddish, and yellow; fragments of Productus	5	345
Limestone, cream-colored, earthy; rapid effervescence	10	355
Limestone, light gray, earthy	5	360
Shale, black, coaly	5	365
Shale, light green, calcareous	15	380
Shale, blue, calcareous, plastic	5	385
Sandstone, dark blue-gray, calcareous, micaceous, laminated, fine-grained; in chips	5	390
Limestone, light buff and gray; rapid effervescence; blue shale	10	400
Shale, varicolored, blue, gray, yellow, red	70	470
Shale, gray; some coal; in thin flakes	30	500
Sandstone, light gray, micaceous; grains minute and highly irregular in shape; in fine sand	10	510
Limestone, sandstone, and shale; limestone and sandstone in fine sand;, shale, black, fissile, in flakes of some size and perhaps from above	37	547
Chert, white	3	550
Chert, white, and limestone; some sand and shale	15	565
Limestone, light buff and white; chert; some sand in drillings, rapid effervescence	10	575
Limestone, light buff and white; rapid effervescence; chert; some sand	5	580
Limestone, white and gray; rapid effervescence; some chert and chalcedonic silicia	10	590
Chert and chalcedony; some limestone, of rapid effervescence; 3 samples	50	640
Limestone, light gray; rapid effervescence, chalcedony and chert; all in fine sand; all samples below the sandstone at 500 contain more or less quartz sand of irregular and minute grains	18	658
Chert, white and gray; limestone, light gray; limestone, in sand, chert in large chips	26	684
Limestone, white and light gray, compact; rapid effervescence; some chert	6	690
Limestone, light gray and white; some laminated, compact; rapid effervescence; some crystalline, darker; some chert	40	730
Limestone, white and light gray, macrocrystalline, soft, fossiliferous	32	762
Limestone, compact, white, rather soft; rapid effervescence; larger part of water-worn chips of shale of various colors and some gray sandstone, both evidently from above	8	770
Limestone, white and light gray; in small flaky chips	23	793
Sandstone, light gray; grains diverse in size and irregular in shape; considerable white limestone; all in fine sand; 2 samples	65	858
Shale, blue, plastic	8	866
Limestone, light gray; rapid effervescence; sample consists of limestone, some quartz sand and chert, and black shale and pyrite; all in fine sand	6	872
Limestone, white, soft and dark gray, subcrystalline, hard; in flaky chips	15	887
Limestone, light gray, dense; in small angular cuttings	13	900
Limestone, light gray; rapid effervescence; some chert	26	926

Record of strata in deep well at Fort Crook—Continued.

	Thickness	Depth
	Feet	Feet
Limestone (?), cuttings of limestone, chert, shale of all colors, and grains of quartz; probably due to caving	24	950
Limestone, light buff, some white; considerable chert and quartz sand in drillings	30	980
Chert, blue, mottled; limestone of rapid effervescence; some quartz sand	20	1,000
Limestone, light buff; much blue chert; slow effervescence, indicating large content of magnesia	4	1,004
Limestone, light gray and white, compact; in flakes, rapid effervescence	11	1,015
Limestone, light buff and light gray, subcrystalline; effervescence slow; some particles rapid	3	1,018
Dolomite, dark brown, crystalline; in sharp sand; effervescence slow	37	1,055
Dolomite, light buff; in fine sand	3	1,058
Dolomite; as at 1,055 feet	2	1,060
Shale, blue, plastic, calcareous	5	1,065
Dolomite, light buff	5	1,070
Limestone, buff, en-mass; rapid effervescence; much white and light gray limestone; some black shale and quartz sand; resembles upper limestones	10	1,080
Limestone, dark and light gray; rapid effervescence; in minute cuttings; black shale from above	45	1,125
Dolomite, light buff; in finest crystalline sand, without shale, and with negligible quartz sand; 3 samples	95	1,220
Shale, bright green, hard, noncalcareous, nonarenaceous; in sand; many chips of dolomite	30	1,250
Dolomite, gray; in finest sand; 2 samples	90	1,340
Dolomite, white; in finest sand (see analysis below); some quartz sand in drillings, grains fairly well rounded, some with secondary enlargements; many broken; quartz sand from 5 to 10 per cent of drillings	120	1,460
Dolomite, light gray and whitish; in finest sparkling crystalline sand, almost free from quartz sand	100	1,560
Dolomite, white, macrocrystalline; in coarse sand	20	1,580
Dolomite, light buff; cherty in fine sand practically free from quartz	185	1,765

Analyses of drillings from deep well at Fort Crook, Nebraska.

[Made in chemical laboratory of Cornell College, Mount Vernon, Iowa.]

	1,018 feet	1,340 feet	1,580 feet
Silica (SiO_2)	5.41	17.92	11.46
Iron (FeO)	1.37	1.23	2.60
Water (H_2O)	2.26	2.08	2.01
Calcium (CaO)	26.20	19.64	20.73
Magnesium (MgO)	21.06	20.65	22.73
Carbon dioxide (CO_2)	43.73	38.18	41.21
	100.03	99.70	100.74

A complete set of samples of the drillings taken from the deep well in Miller Park, Omaha, was preserved by the drillers, J. P. Miller & Company, of Chicago. The surface at the well as reported by the city engineer is 1,007 feet above sea level. The depth to the principal water bed is 810 feet; another water bed is at 1,150 feet. The natural flow is about 150 gallons a minute; temperature, 60° F.

Record of strata in deep well at Miller Park, Omaha, Nebraska.

	Thickness	Depth
	Feet	Feet
Silt, light greenish yellow, calcareous, argillaceous; mainly fine, angular quartzose particles; some hard chips of white limestone, at	----------	50
Limestone, light blue-gray, and light yellow, earthy, subcrystalline; rapid effervescence in cold dilute hydrochloric acid; in large cuttings	11	70
Shale, red, according to label	10	75
Limestone, white, soft, earthy; in large chips	15	90
Limestone, white, soft; in thin flakes; with green shale	10	100
Limestone, white, earthy	10	110
Limestone, white and light gray, compact, fine-grained, earthy; in flaky chips	20	130
Shale, blue; and limestone, white, soft, earthy, blue-gray, fossiliferous	15	145
Shale, red; and limestone, light blue-gray, hard, fine-grained; some lithographic with conchoidal fracture, some partly crystalline	10	155
Limestone, blue-gray and pinkish, earthy; some fine-grained, conchoidal fracture; reddish shale	10	165
Limestone, drab, conchoidal fracture; reddish and greenish shale	10	175
Shale, drab, argillaceous; calcareous nodules	10	185
Shale, red	10	195
Shale, blue	10	205
Shale, blue, plastic	40	245
Shale, blue, plastic, calcareous	10	255
Limestone, gray; in fine angular sand	10	265
Shale, red; some green plastic shale	10	275
Shale, blue, plastic, slightly calcareous	10	285
Limestone, blue-gray, fossiliferous; crinoid stems; in small chips in mass concreted with drab and black shale	10	295
Shale, blue, plastic; two samples	20	315
Limestone, buff; in fine angular sand	10	325
Shale, black	10	335
Shale, red; some green, at	----------	335
Shale, green and purple; some hard silico-calcareous cuttings	10	345
Limestone, gray; some pinkish; a little flint, with yellow, green, and reddish shale	10	355
Shale, reddish and yellow; and sandstone, blue-gray, fine-grained	10	365
Limestone, gray; in fine angular sand, at	----------	385
Shale, greenish yellow, three samples	30	415
Shale, blue, plastic	20	435
Shale, blue, somewhat calcareous	10	445
Shale, black and yellow-green	10	455
Shale, black and reddish	10	465
Limestone, white and gray; some white chert	10	475
Chert and limestone, white and gray	10	485
Limestone, blue, highly argillaceous, hard and white, saccharoidal; some chert	10	495
Limestone, white and light gray; much white chert	20	515
Limestone, light gray; in fine sand; with powder of shale in light blue-gray concreted masses	10	525
Chert and chalcedonic silica; much black, drab, and reddish shale from cave	20	545
Shale, drab; gray limestone and chert	10	555
Limestone, medium dark blue-gray, dense, earthy; in rather large chips; some flint and crystalline quartz, apparently geodic; also blue shale	10	565
Limestone, light yellow-gray; some greenish gray; in fine sand, at	----------	565
Chert, light gray, in small chips; a little limestone of same color	10	575
Chert, gray; a little light gray or whitish limestone	10	585
Chert, gray, drab, and white; a little chalcedonic silica and gray limestone	20	605
Limestone, light gray; much chert; some fine grains of clear quartz, partly rounded	20	625
Limestone, light gray and yellow; considerable chert and bluish chalcedony and some quartz grains	10	635
Shale, blue and light green; in molded masses; small, hard, dark blue-gray nodular masses at 635 feet; calcareous and argillaceous	50	685
Limestone, light yellow-gray; and hard, blue, argillaceous	10	695
Limestone, light yellow-gray, dense, fine-grained; in flaky cuttings	10	705
Limestone, white, soft, earthy; some hard, crystalline; with rare fragments of crinoid stems, white and bluish white chert, and small quartz crystals; in medium sized chips	10	715
Limestone, cream-colored, hard, fine-grained; in coarse meal	10	725
Limestone, white and light gray; soft; in small flakes	10	735
Limestone, light yellow-gray	10	745
Limestone, white and light gray; two samples	20	765
Limestone, white and cream-colored; dull luster; in flakes; soft	20	785
Limestone, white, subcrystalline; in sand; minute rounded grains suggest oolitic or foraminiferal tests; with shale, green, noncalcareous	10	795

Record of strata in deep well at Miller Park—Continued.

	Thickness	Depth
	Feet	Feet
Limestone, gray, of rapid effervescence; some subcrystalline limestone of slow effervescence. Latter is the first limestone whose slow effervescence indicates any considerable magnesian content; shale green, practically noncalcareous; in chips	10	805
Limestone, white and yellow-gray; with chert, and some quartz sand; and shale, green, pyritiferous; in chips	10	815
Limestone, white; rapid effervescence; with shale in chips; much fine quartz sand; shale from 785 to 825, probably due to caving	10	825
Limestone, white and light yellow, crystalline; effervescence rather slow; with shale; blue-gray, highly pyritiferous	10	835
Limestone, white or light yellow-green, crystalline, and in part saccharoidal; much blue-gray noncalcareous shale	10	845
Limestone, buff; slow effervescence; much white chert; fine cuttings	10	855
Limestone, gray; with white chert; effervescence slow; in fine cuttings	10	865
Dolomite or magnesian limestone, light gray; in very fine crystalline powder; slow effervescence; two samples	20	885
Limestone, light brown; moderately slow effervescence; in crystalline sand; a few fine rounded grains of quartz	10	895
Limestone, brown; in sand; effervescence rather rapid	10	905
Limestone, light yellow, crystalline; some of moderately slow and some of rapid effervescence	10	915
Limestone, light yellow-gray, subcrystalline; in fine cuttings; effervescence rapid	10	925
Limestone, light yellow and brown, crystalline; effervescence moderately slow	10	935
Dolomite or magnesian limestone, buff, crystalline, compact; effervescence slow; in small cuttings; three samples	30	965
Dolomite or magnesian limestone, crystalline, cherty, light gray; slow effervescence; two samples	30	995
Limestone, light gray and yellow; in fine sand; effervescence moderately slow	10	1,005
Limestone, light gray, blue-gray and drab; hard; effervescence rather slow; much quartz sand of rounded grains	10	1,015
Limestone, light gray; rather slow effervescence, cuttings of hard, white calcareous shale; all in sand; four samples	40	1,055
Shale, bright green, hard; in small chips; calcareous; with limestone, buff; effervescence rather slow; some calcite; in fine sand	10	1,065
Shale, green, plastic, in molded masses but with individual fissile fragments embedded; calcareous	10	1,075
Shale; as at 1,065 feet; some chips of light gray limestone; rapid effervescence	10	1,085
Limestone, buff; some mottled with drab, rather slow effervescence; some green shale	20	1,105
Dolomite or magnesian limestone, clean, bright yellow, fine, crystalline, granular; effervescence slow; with embedded minute ill-rounded grains of silica; a little white chert; two samples	20	1,125
Limestone, light yellow and whitish; moderately rapid effervescence; much green shale; all in fine sand; two samples	20	1,145
Sandstone, white, fine; well rounded grains of crystalline quartz; some pink limestone of rather rapid effervescence	20	1,165
Limestone, pinkish and light buff, subcrystalline; moderately rapid effervescence; some gray, of much slower effervescence; in chips; and shale, dark red, very slightly calcareous, arenaceous; in chips; and sandstone, of grains as above, with dark red matrix of shale	10	1,175
Limestone, light gray; rapid effervescence; some white chert; and sandstone, of fine well rounded grains	10	1,185
Dolomite or magnesian limestone, light blue and yellow-gray, compact, with white chert; effervescence slow; some quartz sand and green shale, probably from above; eight samples	84	1,269

Driller's log of Miller Park well, Omaha, Nebraska.

	Thickness.	Depth.
	Feet	Feet
Clay, soft	30	30
Hardpan and gravel	40	70
Hard limestone	25	95
Shale and streaks of limestone	12	107
Limestone	13	120
Shale	5	125
Limestone	10	135
Shale, red	40	175
Limestone, hard	5	180
Shale, blue	45	225
Limestone	5	230
Limestone, hard	3	233
Shale	62	295
Limestone, hard	20	315
Shale	35	350
Shale, black	15	365
Limestone	7	372
Shale, yellow, and limestone	38	410
Shale, blue	45	455
Limestone	20	475
Shale, white	12	487
Limestone	20	507
Shale, black	10	517
Limestone, hard	14	531
Shale, blue	6	537
Limestone	5	542
Shale, blue	12	554
Limestone	3	557
Shale	5	562
Limestone	23	585
Shale	5	590
Limestone	25	615
Shale	4	619
Limestone	20	639
Shale, white	33	672
Limestone, hard	48	720
Caving rock	4	724
Limestone	116	840
Sand (water bearing)	2	842
Limestone	7	849
Shale	6	855
Limestone	85	940
Shale	12	952
Limestone	108	1,060
Shale	7	1,067
Limestone, hard	8	1,075
Shale	30	1,105
Limestone	20	1,125
Sandstone	4	1,129
Marl, sandy, red	15	1,144
Limestone	125	1,269

Minden.—In Minden (population,423) there are two pumping stations each with two wells, none of which supply much water. The first well is eight feet in diameter and 40 feet deep, is cased with brick, passes through clay and gravelly streaks from which it receives seepage, and furnishes about 5,000 gallons a day. The second is 16 inches in diameter and 60 feet deep, is cased with tile, penetrates a bed of quicksand, and yields perhaps 10 gallons a minute. The two new wells at the pumping plant recently installed are 20 inches in diameter and 58 or 60 feet deep, are cased with tile, and also end in quicksand. There are a standpipe, 1½ miles of mains, 22 fire hydrants, and 41 service connections. The water is liked by the people and is widely used for domestic purposes. The average daily consumption is estimated at 10,000 gallons, which amount is now easily provided by the wells. The Chicago Great Western Railway has in the past utilized a spring and a shallow well that have not been satisfactory. It is reported that the railway company at one time drilled to a depth of several hundred feet without success. The well at the canning factory is similar to the village wells.

Neola.—The public supply at Neola (population, 926) is obtained from one five-inch and about fifteen two-inch wells that end with screens in a thick bed of alluvial sand and gravel at depths of 45 to 50 feet, from which the water rises within about 14 feet of the surface. With a suction pump placed six feet below the surface this system of wells has been made to yield 145 gallons per minute. Some of the small wells have been in service a long time and their supplies have probably been shut off or greatly diminished by the incrusting of their screens. The water is of good quality though it has considerable temporary hardness. There are two miles of mains, 24 fire hydrants, and numerous taps. The pressure is obtained from a storage reservoir situated on high ground. The water is used extensively for domestic purposes and it is estimated that 50,000 gallons are consumed daily. Both railway companies draw locomotive supplies from the valley gravels.

Oakland.—Oakland (population, 1,105) is located in the Nishnabotna valley and has a gravity system of waterworks that derives its supply from a series of driven wells that end in alluvial sand at a depth of about 22 feet.

Walnut.—In Walnut (population, 950) two wells were drilled to a depth of about 200 feet into a bed of incoherent fine-grained water-bearing sand. Numerous unsuccessful experiments were made to separate the water from the sand, but the wells were finally abandoned. At present the supply comes from a reservoir formed by damming a ravine at the south margin of the village and from four shallow wells in the same locality. Three of the wells are bored to about 60 feet, where they are said to strike gravel; the other is a dug well 10 feet square and about 30 feet deep. The supply from this system is small and precarious and is not considered satisfactory. The waterworks include a standpipe and two miles of mains. Only small use is made of the water, the consumption being perhaps not over 3,000 gallons a day.

SHELBY COUNTY.

BY O. E. MEINZER.

TOPOGRAPHY AND GEOLOGY.

Shelby county consists of a hilly but fertile loess-covered upland interrupted by several wide alluvium-filled valleys that trend southwestward. The hill topography, with a general relief of 100 to 200 feet, is carved out of a thick accumulation of glacial drift and associated deposits, below which is hidden a thin layer of Cretaceous sandstone and shale and a much thicker series of Pennsylvanian shale, limestone, and sandstone.

UNDERGROUND WATER.

SOURCES.

The water-bearing formations underlying the county are the alluvium, the loess, drift, and associated deposits, the Cretaceous sandstone, and the lower formations.

The Pennsylvanian strata will furnish little water, but moderate quantities can be secured from formations at greater depths. The Carboniferous and deeper waters are rich in sodium sulphate.

The Cretaceous beds, which consist of poorly cemented sandstone and soft shale or "soapstone," where present, lie next above the Pennsylvanian. They have apparently been reached in a number of wells, but since most of these wells are old and a large proportion have been abandoned little definite information in regard to them remains. The sandstone contains water, which, however, is not under much head and hence does not enter the wells rapidly and must be lifted from considerable depths. Moreover, the sand screens that are used readily become incrusted, shutting out the supply. From the meager data at hand it seems that the water is harder than that from more shallow sources but is less mineralized than the deeper water. In future work it should be understood that better results can be expected from four-inch and six-inch wells than from small two-inch wells, which are poorly adapted to this region.

The bulk of the county's water supply is obtained from bored and dug wells, whose advantage lies in their large circumference and resultingly extensive infiltrating surface. These wells are commonly sunk at low points into the unconsolidated materials, from which they derive meager contributions at several levels, the most water probably being obtained (1) at the contact between the loess and the subjacent gravelly and weathered drift and (2) at the contact between the two drift sheets that appear to exist here.

In the principal valleys fairly abundant supplies can be obtained by sinking inexpensive open or driven wells into the alluvial sand and gravel, and it is from this source that a large part of the water for public waterworks and locomotives is obtained.

CITY AND VILLAGE SUPPLIES.

Earling.—The waterworks at Earling (population, 323) are supplied from two pumping plants, each of which draws from two dug wells. The four wells, all situated on low ground, range in depth from 21 to 51 feet and depend chiefly on slow seepage from clay. They fill each day to a level within about eight feet of the surface and will together easily supply 15,000 gallons, which is about two and one-half times the average daily consumption at present. The water is only moderately hard and is used by nearly one-half of the people. The waterworks include a tank elevated upon a tower on high ground, one-half mile of mains, eight fire hydrants, and 40 taps.

Harlan.—The public supply of Harlan (population, 2,570) is drawn from eight six-inch wells located in the valley near the river. They extend through yellow clay, tough blue clay, and fine sand into coarse sand and gravel, in which they are finished with 12-foot screens at a total depth of 43 feet, and from which the water rises to a level 20 to 24 feet below the surface. The pump, which is in a pit eight feet below the surface and therefore has a vacuum of 12 to 16 feet before pumping is begun, has been operated rapidly enough to lift 275 gallons a minute and is usually run at the rate of 175 gallons a minute for about 18 out of every 24 hours. It is propelled by water power. The water is stored in a standpipe situated on high ground and is delivered by gravity through about four miles of mains to 41 fire hydrants and 380 service connections. It is used by most of the inhabitants and by the three railway companies. About 200,000 gallons are consumed daily, one-third of which goes to the railway locomotives. The water is only moderately hard and is fairly good for use in boilers (see p. 202 for analysis).

Kirkman.—Kirkman (population, 180) has an air-pressure system of waterworks supplied from a dug well six feet in diameter, which extends through clay to a depth of 47 feet and ends in a bed of gravel. The well fills to a level about 25 feet below the surface. It furnishes approximately 2.000 gallons a day and would yield considerably more. The water is only moderately hard and is used to some extent for domestic purposes.

Panama.—The waterworks at Panama (population, 232) consist of a gravity system with limited service supplied from a six-foot dug well that extends to a depth of 43 feet and depends on clay seepage. In the driest season the yield of this well was reduced to 2,000 gallons a day, but it normally yields several times this amount.

Portsmouth.—The public supply of Portsmouth (population, 347) is obtained from four driven wells located in the valley. They end with screens in sand and gravel at a depth of about 50 feet, the water rising within 16 feet of the surface. Two of the wells are together pumped at the rate of 50 gallons a minute by means of a suction pump at the surface. The water is lifted into a tank on the upland and is distributed by gravity through 1¼ miles of mains to 10 fire hydrants and about 30 service connections. It is used by nearly one-half of the people, and approximately 7,500 gallons are daily consumed.

TAYLOR COUNTY.

BY O. E. MEINZER AND W. H. NORTON.

TOPOGRAPHY AND GEOLOGY.

Taylor county is deeply trenched by numerous valleys that trend in general southwestward, between which are hills, ridges, and isolated tracts of comparatively level upland. The glacial drift, where not dissected, is of considerable thickness. At the bottom it is very dark, and at the top it has been colored yellow by oxidation. At intermediate horizons are found "hardpan" and a few beds of sand and gravel. The base of the drift has been so little exposed that it is not known to what extent sand exists between the bowlder clay and bedrock. Widely spread over the weathered drift is a coat of clay, rarely as much as 25 feet thick, and apparently averaging much less, which is essentially free of pebbles and grit and which is ashy and plastic at the bottom, but is generally yellow and loesslike at the surface. In some of the valleys the alluvial deposits are well developed. As far as is known, the bedrock belongs to the Missouri stage (Pennsylvanian), and consists chiefly of limestone and shale. In the section of the deep well at Bedford (Pl. XVIII, p. 1100) this stage is supposed to have a thickness of 722 feet, the total thickness of the Pennsylvanian being considered to be 1,300 feet.

UNDERGROUND WATER.

SOURCES.

Almost the entire water supply for Taylor county comes either from surface sources (streams, cisterns, and artificial "ponds") or from shallow wells sunk into the upper layer of drift or into the valley deposits. Some wells have been drilled to the deeper parts of the drift and a few into the underlying rock strata, but the information concerning such wells is exceedingly scant. Some have been finished successfully, but a large number were failures. Since no reliable and satisfactory deep-water bed has yet been discovered beneath this county, it seems advisable for domestic, stock, industrial, and even public purposes to seek to develop supplies near the surface. The method of boring a number of shallow wells of large diameter and connecting them at the bottom with drifts is being employed on stock farms with good results.

CITY AND VILLAGE SUPPLIES.

Bedford.—The supply for the public waterworks in Bedford (population, 1,883) is from several wells of large diameter, located in the valley and sunk through about 28 feet of clay into a 10-foot bed of sand that rests upon limestone. The sand is saturated with water but it is so fine-grained and incoherent that there is difficulty in separating the water from it, and the total yield of the system of wells is consequently only about 6,000 gallons a day, an amount that is entirely inadequate. The water is pumped into a standpipe and thence distributed through the mains by gravity pressure. A 2,400-foot hole was drilled at Bedford (Pl. XVIII) without finding a satisfactory supply, and plans are now being considered for further developing the supply from the bed of sand at present utilized, or for installing a filtration plant for purifying the river water. Without much doubt the yield from the sand bed could be indefinitely augmented by boring more wells or in other ways increasing the infiltration surface.

The well of the Bedford Developing Company is 2,400 feet deep and 10 inches in diameter to a depth of 2,008 feet. The curb is 1,098 feet above sea level and the head 265 feet below the curb. Water was found at 1,180 to 1,228 feet in sandstone; and water which had previously stood at 15 to 30 feet below the curb dropped to 90 feet. A strong flow of water was struck at 1,560 to 1,580 feet, water rising to a point 298 feet below the curb. Water struck at 1,920 to 2,005 feet rose to a level 284 feet below the curb and, after pumping test, to 265 feet (a pumping test at 2,009 feet gave 150 gallons a minute). Water was also struck at 2,020 to 2,168 feet. Driller, J. P. Miller Company, of Chicago; date of completion, 1909.

The water was too salty for drinking. In all tests the pumps drew fresh water for about 40 minutes until upper veins of uncertain location were exhausted. The water at 1,177 or 1,180 feet, in the basal sandstone of the Pennsylvanian, was supposed by the owners to be salty, but by the drillers the salt water was located at the 1,580-foot vein. The test at the 1,661-foot vein also brought up water not fit for any city use. In order to test the lower water beds the well was reamed to 2,008 feet and a three-inch pipe was inserted and packed to this depth. The pumping test gave 100 gallons a minute through this pipe, but the water was extremely salty. It is much to be regretted that the water of the basal Pennsylvanian sandstone was not tested as to both quality and quantity.

Record of strata of deep well at Bedford (Pl. XVIII, p. 1100).

	Thickness.	Depth.
	Feet	Feet
Pleistocene:		
Drift, no samples or record	38	38
Carboniferous:		
Pennsylvanian—		
Missouri stage (722 feet thick; top, 1,060 feet above sea level)—		
Limestone, light gray, nonmagnesian, soft; earthy luster; permeated with minute ramifying, smooth-surfaced masses of calcite	6	44
Limestone, argillaceous, light gray, soft; earthy luster; and shale, plastic	6	50
Shale, drab, unctuous, noncalcareous; 8 samples	40	90
Shale, bluish drab, calcareous	5	95
Limestone, earthy, light blue-gray	5	100
Shale, drab, calcareous; 3 samples	15	115
Limestone, light blue-gray, soft, argillaceous; with shale	5	120
Shale, drab, calcareous	5	125
Limestone and shale; limestone, soft, whitish; rapid effervescence; numerous Fusulina; encrinital; 5 samples	25	150
Limestone, light gray, soft, earthy; a little chert	5	155
Shale, greenish drab; some limestone with crinoid stems	10	165
Shale, as above; some black, carbonaceous and a little blue-gray limestone	5	170
Limestone, light brown, white, gray, hard, compact; and greenish shale	5	175
Limestone; light blue-gray, argillaceous; and light yellow-gray with crinoid fragments; greenish shale	5	180

Record of strata of deep well at Bedford—Continued.

	Thickness.	Depth.
	Feet	Feet
Limestone, yellow, gray, hard	5	185
Shale, dark brick-red, calcareous; 2 samples	10	195
Shale; greenish drab, calcareous, siliceous; and ocher-yellow, hard, siliceous, calcareous; 2 samples	10	205
Shale, hard, greenish drab; so highly siliceous with minute particles of quartz that it might be termed an argillaceous sandstone	5	210
Shale, greenish drab, plastic, pyritiferous; some hard, yellow, fossiliferous limestone	15	225
Shale, blue-drab, soft, laminated; harder siliceous layers	25	250
Shale, drab, laminated; 6 samples	30	280
Shale, drab, with some laminae of black coaly shale	5	285
Shale, green, fossiliferous	5	290
Shale, green, fossiliferous; some drab limestone and chert	5	295
Shale, hard, red; 2 samples	5	300
Limestone, hard, drab, with shale	10	310
Shale, drab, fossiliferous	10	320
Limestone, hard, fine-grained, siliceous	5	325
Limestone, yellow-gray; and white, soft; earthy luster; 3 samples	15	340
Shale, green and black, carbonaceous	5	345
Limestone, soft, yellow, macrocrystalline	10	355
Shale, drab; 5 samples	25	380
Shale, drab; some drab limestone	5	385
Shale, drab; with sand of flinty drab limestone	5	390
Shale, reddish; with dark green-gray argillaceous limestone	5	395
Shale, red; a little brown siliceous limestone	10	405
Shale, drab; 4 samples	15	420
Limestone, light yellow-gray; crystalline in sand; 4 samples	20	440
Shale, greenish drab	10	450
Limestone, light yellow-gray; much shale	5	455
Shale, greenish; some drab limestone, flinty	10	465
Limestone, light yellow-gray	10	475
Shale, drab; 4 samples	20	495
Limestone, white; large fragments of shale	21	516
Shale, drab; some black at 516, with limestone at 525; 4 samples	19	535
Limestone, white and gray	15	550
Shale, black, fissile, combustible; and hard, gray limestone	5	555
Shale, dark drab	10	565
Shale, greenish; with white limestone in concreted powder	5	570
Sandstone, white; microscopic grain; calciferous; with shale	5	575
Limestone, white and light gray	10	585
Shale, dark drab	5	590
Limestone, hard, gray, siliceous; shale	5	595
Shale, dark drab	5	600
Limestone, yellow-gray, rather hard; much shale in large fragments	15	615
Shale, dark drab; nodules and masses of gray chert	15	630
Shale, light brown, calcareous	5	635
Shale, greenish; with gray limestone and chert	5	640
Limestone, gray; much shale	5	645
Shale, drab; black at 645; gritty at 650 and 655; with limestone at 670; sandy at 670, 675, 695, 700; coaly at 705	65	710
Sandstone, fine, gray; 3 samples	15	725
Shale, dark drab; some black; fissile	10	735
Limestone, gray, finely arenaceous	10	745
Shale, drab and reddish brown; 2 samples	10	755
Limestone, light gray	5	760
Des Moines stage (580 feet thick; top, 338 feet above sea level)—		
Shale, varicolored; highly arenaceous at 765 and 770; reddish brown at 785, 790, 940 and 1,065; black at 855, 1,045, 1,055 and 1,060	400	1,160
Sandstone; drillings mostly shale	5	1,165
Shale, black	15	1,180
Sandstone, fine, white; much shale in drillings; 8 samples	40	1,220
Shale	5	1,225
Sandstone	10	1,235
Sandstone, in fine gray meal, the particles of which resemble flint macroscopically but are composed of minute quartzose grains with considerable yellow chert at 1,250, with considerable shale in all drillings; 10 samples	50	1,285
Sandstone, clean, fine, yellow-gray, composed of minute irregular grains	5	1,290
Sandstone, coarser; some grains reaching 1 mm. in diameter	5	1,295
Sandstone, green-gray, fine-grained	5	1,300
Sandstone, yellow-gray, coarser; grains irregular in shape and far from uniform in size	5	1,305
Sandstone, fine gray; shale in drillings probably from above	35	1,340

Record of strata of deep well at Bedford—Continued.

	Thickness	Depth
Mississippian (355 feet thick; top, 242 feet below sea level)—	Feet	Feet
Limestone, gray; rapid effervescence	5	1,345
Limestone, yellow-white, soft; earthy; 4 samples	20	1,365
Limestone, gray, rather hard, conchoidal fracture; lithographic texture	15	1,380
Limestone, soft, gray, earthy, argillaceous	20	1,400
Limestone; as above; and gray, fine-grained sandstone	5	1,405
Limestone, light drab, argillaceous	20	1,425
Limestone and chert; drillings largely chert and chalcedonic silica	10	1,435
Limestone, drab; less chalcedony	5	1,440
Chert, white and gray; in places brown, and limestone, often siliceous; 17 samples	85	1,525
Limestone, soft, gray, earthy; a little chert	5	1,530
Limestone, soft, white and light gray; saccharoidal; some chert	5	1,535
Chert and limestone; limestone nonmagnesian; 14 samples	85	1,620
Limestone, buff; slow effervescence; much gray chert	5	1,625
Limestone, brown; moderate effervescence	5	1,630
Limestone, brown; rapid effervescence, calcite crystals	15	1,645
Limestone, gray, oolitic; rapid effervescence; 4 samples	20	1,665
Shale, blue, fine-grained, gritless, calcareous; in concreted powder; 6 samples (Kinderhook?)	30	1,695
Devonian (130 feet thick; top 597 feet below sea level):		
Limestone, light gray; rapid effervescence	10	1,705
Limestone, light blue-gray, compact, fine-grained; in thin flaky chips	10	1,715
Limestone, yellow; in sand; rapid effervescence	15	1,730
Shale, drab, clayey, highly calcareous	5	1,735
Limestone; white and mottled gray at 1,735; gray from 1,740-1,755; buff at 1,755 and 1,760; light gray, subcrystalline, dense at 1,765 and 1,770; all of rapid effervescence	40	1,775
Shale, or highly argillaceous limestone; gray, in nonconcreted powder	10	1,785
Limestone, buff; in fine meal; rapid effervescence	15	1,800
Limestone, gray; in fine meal; rapid effervescence; argillaceous at 1,810; 5 samples	25	1,825
Silurian (575 feet thick; top, 727 feet below sea level):		
Limestone and shale; limestone, gray in meal, rapid effervescence; shale, brick-red, highly pyritiferous, in fine meal and powder not concreted; some fine ill-rounded quartz grains at 1,830; color of mass of drillings, brick-red	20	1,845
Limestone, yellow; drillings pink from admixture with fine meal and powder of red shale, probably from 1,825; limestone in meal and sand, crystalline; rapid effervescence; some irregular rounded quartz grains in drillings which also may be from above; 14 samples	70	1,915
Dolomite, dark gray; in fine crystalline meal; some calcite	20	1,935
Dolomite, buff	10	1,945
Dolomite, dark gray, argillaceous	5	1,950
Unknown; drillings washed away	20	1,970
Dolomite, light brown; in crystalline meal	7	--------
Marl, in fine white powder, not concreted; calciferous, argillaceous; large amount of anhydrite	4	2,009
Dolomite, as at 1,970; calcite rhombs and a few crystals of anhydrite	6	2,015
Dolomite, light yellow; in finest crystalline meal; numerous crystals of anhydrite	20	2,035
Dolomite, light brown; in floury meal; residue of anhydrite	35	2,070
Dolomite, light greenish gray, argillaceous; much anhydrite and dolomitic marl	5	2,075
Dolomite, light gray, less argillaceous; considerable anhydrite	10	2,085
Dolomite, bright yellow; in meal; considerable anhydrite	15	2,100
Dolomite, brown; in coarser meal	5	2,105
Dolomite, light brown; in much finer meal; anhydrite rather plentiful	------------	2,105
Limestone; somewhat magnesian, judging from effervescence; light yellow and buff; argillaceous; some anhydrite in drillings	15	2,160
Dolomite, buff; in fine crystalline, sparkling meal	8	2,168
Dolomite, light gray, argillaceous; in finest powder, not concreted	2	2,170
Dolomite; in fine brown or yellow meal, not concreted; some anhydrite	35	2,205
Anhydrite marl; in light cream-colored or whitish powder; 10 samples	55	2,260
Anhydrite marl; in bright buff powder; dolomite	20	2,280
Anhydrite marl, cream-colored; 9 samples	45	2,325
Dolomite and anhydrite; in fine buff meal	15	2,340
Anhydrite marl, argillaceous; in yellow powder	10	2,350
Shale, slightly calcareous and gypseous; in gray powder	5	2,355
Dolomite, light buff; in fine meal	5	2,360
Shale, calcareous; in gray powder	5	2,365
Dolomite; in fine buff meal	5	2,370
Limestone, magnesian, or dolomite; in gray powder and meal; residue argillaceous and cherty and with considerable anhydrite	15	2,385
Dolomite, buff; in angular sand	10	2,395
Shale, calcareous; considerable anhydrite	5	2,400

Analyses of drillings from Bedford deep well.[a]

	Depth.					
	1,830 feet	1,920 feet	2,100 feet	2,240 feet	2,300 feet	2,400 feet
$CaCO_3$	45.42	58.80	53.23	36.07	11.76	36.71
$MgCO_3$	17.32	44.18	37.33	11.63	3.12	44.75
$CaSO_4$	----------	----------	----------	32.92	76.53	5.20
Al_2O_3	1.70	----------	.78	.34	.61	.07
Fe_2O_3	11.07	----------	2.02	.82	2.72	.81
MgO	----------	----------	----------	5.10	----------	----------
SiO_2	21.30	----------	4.29	11.53	1.29	2.22
H_2O	2.05	----------	1.66	2.48	3.73	9.69
Total	98.86	----------	99.31	100.89	99.76	99.45

[a]Made in chemical laboratory of Cornell College, Mount Vernon, Iowa.