DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

WATER-SUPPLY PAPER 232

UNDERGROUND WATER RESOURCES OF CONNECTICUT

BY

HERBERT E. GREGORY

WITH

A STUDY OF THE OCCURRENCE OF WATER IN CRYSTALLINE ROCKS

BY

E. E. ELLIS

WASHINGTON
GOVERNMENT PRINTING OFFICE
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ILLUSTRATIONS.

INTRODUCTION.

The study of the ground water of Connecticut, the results of which are presented in the following pages, was begun in 1903 with the collection and examination of well and spring records and was continued at intervals during 1904 and 1905. During the autumn of 1905 E. E. Ellis cooperated with the author in general investigations, and also made a study of the water in the crystalline rocks. In addition to the report on the special work assigned to him, Mr. Ellis has prepared parts of the chapters on occurrence and recovery of ground water, on character of water, and on well construction and has assisted in compiling data and in preparing illustrations.

For information regarding chemical analyses thanks are due to Prof. Herbert E. Smith, of New Haven, and Mr. George H. Seyms, of Hartford.

The writer wishes to express his great indebtedness to the well drillers of the State, who have freely given much valuable information regarding the occurrence and recovery of ground water. An unusual amount of carefully collected data has been furnished by Messrs. C. L. Grant, of Hartford; F. A. Champlin, of East Longmeadow, Mass.; C. L. Wright, of New Haven; R. L. Waterbury, of Glenbrook; H. B. King, of Hartford; and S. B. Hamilton, of Melrose, Mass.

UNDERGROUND WATER RESOURCES OF CONNECTICUT.

By Herbert E. Gregory.

CHAPTER I.

GEOGRAPHY.

TOPOGRAPHY.

GENERAL RELATIONS.

In its physiographic relations Connecticut is part of the New England plateau, which is characterized by complex groupings of hills composed of igneous and metamorphic rocks; by a few broad valleys cut in softer and less resistant rock material; and by many narrow valleys intrenched in the plateau, and in the main occupied by important watercourses. Other topographic features date from the advent of the great ice sheet of Pleistocene or "Glacial" time, which completely remodeled the New England landscape, accentuating or subduing the previous topography and originating new land forms. The plateau is, however, so dissected as to present the appearance of a region of hills, valleys, and narrow plains, differing in extent and outline.

Viewed as a whole, the surface of Connecticut is a plateau sloping gradually from Cornwall and Goshen southeastward to the Sound. There are no high precipitous mountains or sharply cut canyons, but nevertheless the topography is rugged beyond the average of regions of slight elevation and great physiographic age. High cliffs and rock walls are exhibited in the trap of the central lowland and along certain streams in the highlands, but the hilltops are on the whole rounded and the ridges show a tendency to a north-south alignment. The character of the relief and the prevalence of a north-south arrangement of the hills are well shown by the railroad map of the State, some of the lines occupying north-south valleys, and others crossing the ridges. The Highland division of the New York, New Haven and Hartford Railroad goes through the narrow defile at Bolton Notch, over the pass at Terryville, through the tunnel at Newtown, traversing 119 miles from Putnam to Danbury, though the direct distance between these points is but 89 miles. Likewise the Central New England Railway, running westward from Hartford, requires 67 miles of track to reach the New York state line, a distance of 44 miles, and crosses the Highlands at Norfolk Summit, an elevation of 1,298.58 feet. Norfolk, 2 miles farther west, with an elevation of 1,210.7 feet, is the highest railroad station in the State. The "Air Line" of the New York, New Haven and Hartford Railroad from Willimantic to Middletown is a short and direct east-west route, but its construction required expensive cuts and fills and bridges, and the grades are unsuitable for heavy traffic. On the other hand, the Northampton division of the same railroad, extending northward from New Haven to the Massachusetts line, is but 1 mile longer than the distance as measured on a map; and the Hartford division, which traverses the lowland from New Haven to Thompsonville, exceeds a direct line by only 2 miles. Even in the heart of the highland areas, the Central Vermont Railway crosses the State in a north-south direction along the winding courses of Shetucket and Willimantic rivers with but 8 miles of track more than the direct distance. In fact, if a railroad were to be constructed from Putnam in a straight line westward across the State the difficulties of operation would be scarcely less than those encountered in truly mountainous districts.

PHYSIOGRAPHIC FEATURES.

Physiographically, Connecticut may be divided into the western highland, occupying that portion of the State west of a line running from New Haven to North Granby; the eastern highland, between Rhode Island and a line through Somers, Rockville, Glastonbury, Middletown, and Branford; and the central lowland, occupying the remainder of the area. (See fig. 1.) These three provinces have characteristic groupings of topographic features which have a direct bearing on the water resources of the State and which have been the controlling factors in its settlement and industrial history.

THE HIGHLANDS.

Western highland.—The western highland increases in elevation from the Sound northward and contains areas of considerable size over 1,000 feet in height. In Barkhamsted the plateau reaches an elevation of 1,400 feet, in Colebrook of 1,500 feet, in Goshen and Cornwall of 1,600 feet, and in Norfolk of 1,700 feet, and it culminates in Bear Mountain, Salisbury, at 2,355 feet. The plateau terminates abruptly on the east and at certain points, as Compounce Pond, the rise from the lowland is precipitous. Differences in elevation and in character and prominence of rock outcrops and the presence of numerous valleys of widely varying depth, width, and extent, give the highlands an appearance of great complexity. They are not, however, a "region of disorderly hills," but have been controlled in topographic development by geologic forces whose influence was felt throughout southern New England. It was noticed by Percival[a] that the highlands "may both be regarded as extensive plateaus,"

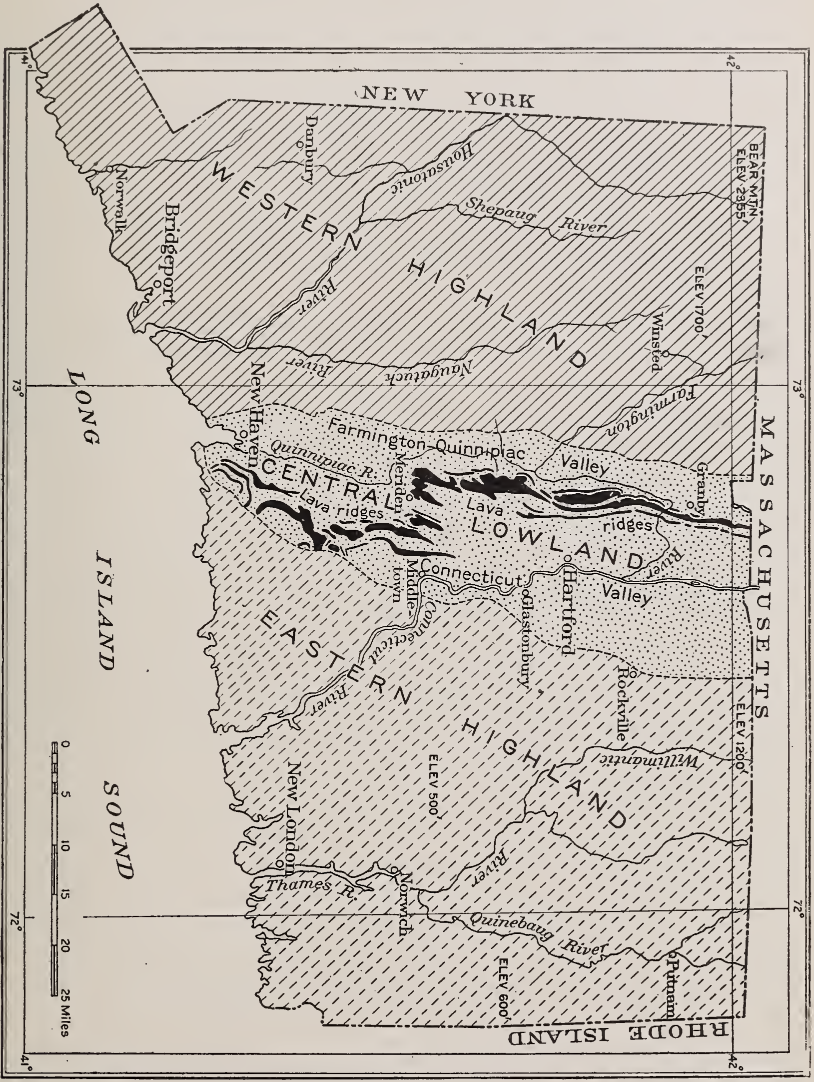

FIGURE 1.—Map of Connecticut, showing physiographic provinces.

which "present, when viewed from an elevated point on their surface, the appearance of a general level, with a rolling or undulating outline, over which the view often extends to a very great distance, interrupted only by isolated summits or ridges, usually of small ex-

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[a] Percival, J. G., Report on the geology of Connecticut, 1842, p. 477.

tent." A good view from any exposed point in the highlands confirms this impression of a plateau surface rather than a confused mingling of hills. As concisely stated by Professor Rice:[a] "If we should imagine a sheet of pasteboard resting upon the summits of the highest elevations of Litchfield County and sloping southeastward in an inclined plane, that imaginary sheet of pasteboard would rest on nearly all the summits of both the eastern and the western highlands." Certain mountains project above the general level of the plateau and many valleys are cut below it. Owing to the resistant character of the rocks composing them, Great Hill, Cobalt, 700 feet; Lantern Hill, Mystic, 520 feet; Mount Horr, Canton, 880 feet; Mount Prospect, Litchfield, 1,365 feet; Mount Haystack, Norfolk, 1,680 feet; and other points stand out as prominent landmarks above the general surface at their base.

The origin of the highland plateau is revealed by an examination of the composition and structure of its basement rock, which clearly shows that the surface as it now exists is not the result of accumulation of sediments of great thickness. The bed rock of the highlands is not sedimentary nor horizontal, but is metamorphic and igneous rock which has been folded and twisted and injected, and which could have been formed only at a great depth below the earth's surface. Mountains have been removed from western and eastern Connecticut, and the remaining rocks, with their bewildering complexity of structure, are but the stumps of old land masses which have been sawed horizontally across by the agents of erosion. If the present valleys were filled and a few projecting hills cut down the conditions of Cretaceous time would be restored and the highlands would appear as a plain—the result of long-continued, ceaseless activity on the part of rain, frost, and streams.

Eastern highland.—The counterpart of the western highland is found in the eastern part of the State, but the eastern highland represents much less contrast in relief and does not attain such altitudes. Practically all the prominent hills and ridges in this province are under 700 feet in height, and only in the towns along the Massachusetts line is an elevation of 1,000 feet attained, the culminating points being Rattlesnake Hill, Somers, 1,080 feet; Bald Mountain, Somers, 1,120 feet; Soapstone Mountain, Somers, 1,061 feet; Hedgehog Hill, Stafford, 1,180 feet; Bald Hill, Union, 1,286 feet; Stickney Hill, Union, 1,220 feet; Lead Mine Hill, Union, 1,140 feet; Snow Hill, Ashford, 1,213 feet; and Hatchet Hill, Woodstock, 1,040 feet.

Valleys in the highlands.—The valleys in the highlands are those which have been cut since the formation of the peneplain (see p. 33), and their character is determined by the rocks which they traverse and by the age and size of the streams which have occupied them.

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[a] Rice, W. N., and Gregory, H. E., Manual of Connecticut geology, 1906, p. 20.

The western highland is traversed by two well-marked valleys—those of Housatonic-Norwalk and Naugatuck-Still rivers, which inclose a rectangle of the highest land within the State. These valleys are intrenched 400 to 600 feet in the plateau and, although not occupied by continuous streams, they constitute the only feasible lines of communication between the northern and southern parts of the western highland. The two valleys are connected by the gorgelike trough of the Housatonic, which cuts through the rock ridges with a fall of 10 feet per mile. The Housatonic Valley at Danbury and at Canaan and the Naugatuck-Still Valley at Winsted widen into undulating plains. The Farmington Valley through the highlands is a gorge less than 1,000 feet in width below Riverton, and still narrower at Hartland, where it is sunk 600 feet below the plateau, and at Satans Kingdom it is barely 200 feet wide. Nearly all the minor streams of the western highland are intrenched in fairly narrow valleys, except the Pomperaug, which meanders freely over a miniature lowland on Triassic sediments.

In the eastern highland the valleys entering the lowland are mostly short and narrow and of high gradient. One important valley gorge, now occupied by Connecticut River, leads from the central lowland southeastward to the Sound. The Thames Valley is a fiord to Norwich. Its eastern branch, the Quinnebaug, is a steep-walled valley to South Canterbury, above which it widens into a plain through Plainfield, Killingly, and Putnam. The Shetucket-Willimantic Valley is broad and open through most of its course, as are also its northern branches, which divide the highland into segments.

The floor of the highland valleys is bed rock, till, or stratified drift, no stream having entirely removed the cover of glacial drift along its path. Some streams, in fact, like the east branch of the Farmington, flow through almost their entire courses without reaching bed rock.

A glance at the topographic map shows that the chief valleys trend either north and south or northwest and southeast. For example, the Housatonic from Gaylordsville to Derby, the Connecticut from Middletown to Lyme, the Farmington from Colebrook to Farmington, and the Shetucket and many valleys of lesser size are alike in their north-south alignment. The upper Connecticut, the Willimantic, the Mount Hope, Little River (Windham County), and several minor streams trend in a common direction. There is nothing in the nature of the rock which accounts for the common alignment of these two groups of valleys and, if only present geologic conditions are taken into account, the southeasterly courses of the Housatonic below New Milford and of the Connecticut below Middletown are anomalous, for these rivers leave well-developed valleys of limestone and sandstone and cut their way through the most resistant gneisses and schists. There seems no escape from the conclusion that they established their courses on an ancient coastal plain which sloped to the southeast. As a result of the uplift and consequent erosion, the strata forming the plain have been removed, but the streams have maintained their original directions, cutting valleys deep into the rocks of the plateau. (See p. 19.)

It has been shown by Hobbs[a] that the main valley lines of the State coincide in direction with five prominent systems of joints and faults and there is doubtless some genetic relationship between the joints and the trend of trough lines.

CENTRAL LOWLAND.

Extent and character.—The central lowland differs from the highlands in altitude, character of bed rock, drainage, and types of hills and valleys. In extent it is coincident with the larger of the two areas of Triassic sediments within the State. Except in the lava ridges, the altitude of the lowland averages about 100 feet and only in the region south of Middletown does it exceed 500 feet. As viewed from the highlands—for instance, at Bald Mountain, Somers, or Box Mountain, Bolton, from Bristol, or from the ridges near Canton—the lowland surface appears as a plain from which rise ridges of lava. The edges of the highland areas, as viewed from the lowland, present abrupt walls, as seen in Southington and Somers, or steeply rising slopes. In Glastonbury, Middletown, and Branford the lowland merges imperceptibly into the highland.

Lava ridges.—The most marked topographic feature of the lowland and, in fact, of the entire State, is the series of basalt ridges which extend from North Granby to East Haven. As far south as Meriden the ridges form a continuous line of elevation broken only by gaps and passes. From the Hanging Hills this ridge line passes by a series of rough steps to Beseck Mountain and thence continues southward as Totoket and Saltonstall ridges.

The most prominent parts of this ridge system are Peak Mountain, 665 feet; Talcott Range, the highest point of which is 960 feet; Rattlesnake Mountain, 750 feet; Ragged Mountain, 754 feet; Hanging Hills, 700 to 1,000 feet; Lamentation Mountains, 654 and 725 feet; Higby Mountain, 920 feet; Beseck Mountain, 840 feet; Pistapaug Mountain, 640 feet; Totoket Mountain, 780 feet; Saltonstall Ridge, 240–245 feet. The culminating point is West Peak, Meriden, 1,007 feet, which is fully up to the level of the highlands and furnishes a magnificent view of the Farmington-Quinnipiac Valley and the Wolcott Plateau beyond. The ridge of lava faces westward as a bold escarpment, but slopes gently to the east, where it merges into the lowland floor. Breaks through the ridge formed by streams or by faults furnish passes for railroads at Tariffville, New Britain, Meriden, and Baileyville.

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[a] Hobbs, W. H., River system of Connecticut: Jour. Geology, vol. 9, 1901, pp. 469–485.

Farmington and Connecticut valley lowlands.—The central ridge of lava forms a conspicuous and effective line of demarkation between the two parts of the central lowland—the Connecticut Valley and the Farmington-Quinnipiac Valley.

The Connecticut Valley area from Thompsonville to Middletown is practically a plain of drift and till 5 to 10 miles in width and with differences in elevation of less than 200 feet. South and west of Middletown the valley area passes by gradual stages into the eastern highland and the central ridges. The elevations in the Connecticut Valley lowland are drumlins and other glacial deposits and till-covered sandstone knolls. The streams tributary to the Connecticut are ditches cut into glacial deposits. The Scantic, Podunk, Hockanum, and others seldom reveal rock floor; Stony Brook (Suffield) is the type of a few streams which have cut through the drift to the sandstone below.

The Farmington-Quinnipiac Valley extends from New Haven northward across the State and is bounded on the west by the steep edge of the western highland and on the east by the broken wall of the central ridge. It is occupied by three rivers—the Farmington, Quinnipiac, and Mill (New Haven)—all of which, in common with their tributaries, flow almost entirely on glacial drift. From the floor of the Farmington-Quinnipiac Valley rise a number of trap hills which break the continuity of the plain. The most prominent of these are the Barndoor Hills, 600 to 700 feet; Mount Carmel, 737 feet; West Rock, 405 feet; and East Rock, 359 feet. The level, drift-filled floor of this valley lowland, together with the slight difference in elevation between New Haven and the Congamuck ponds, made the valley an attractive route for a canal, which was built in 1829 and was later succeeded by the Northampton Railroad.

COAST LINE.

The coast line is much indented and presents a multitude of bays, headlands, points, inlets, and marshes. Rock islands occur in groups, as at Norwalk and off Branford, or are scattered irregularly along the shore. Westward-moving tides and currents have built innumerable beaches, bars, and spits along the coast, thus greatly modifying its original outline. The character of the coast is due to the fact that the land has been depressed, allowing the sea water to enter the old valley now constituting Long Island Sound and to drown the irregular southern edge of the denuded peneplain.

DRAINAGE.

Connecticut is drained largely by streams which rise within its borders. Only two streams of large size—the Connecticut and the Housatonic—carry water from lands beyond the State, and the

Massachusetts section of the Housatonic serves but a small area. The three main river systems are the Housatonic, the Connecticut, and the Thames, which drain, respectively, 1,272, 1,443, and 1,164 square miles, or altogether 78 per cent of the surface.

Of the streams which enter Long Island Sound independently—the Byram, Mianus, Mill (Stamford), Norwalk, Saugatuck, Mill (Fairfield), Poquonock, Wopowaug, West, Mill (New Haven), Quinnipiac, Hammonassett, Niantic, Mystic, Pawcatuck, and certain smaller ones—the Quinnipiac, 35 miles long, is the only one over 20 miles in length, and all have small drainage basins.

In a number of places the divides between adjoining drainage areas are ill defined and a few stream systems coalesce. Thus the limestone valley extending from New Preston to Bedford, N. Y., an area of slight relief, is drained by five streams that have independent outlets to the sea—the Mianus, Norwalk, Saugatuck, Housatonic, and the Croton (a tributary to the Hudson). Likewise the Quinebaug, Bigelow Brook, the Natchaug, and the Shetucket together form a closed ring of water surrounding ten towns in the northeastern part of the State.

The lower ends of the streams entering the Sound are drowned, and the tides, 4 to 7 feet in height, reach up these streams to a greater or less distance. For example, the Connecticut is tidal to Hartford, 44 miles; the Thames to Norwich, 15 miles; the Housatonic to Derby, 11 miles; the Quinnipiac to Quinnipiac, 10 miles. Accordingly the lower reaches of the streams along the coast line are of no value for water supplies.

The streams of the highlands have steep gradients and their flow is interrupted by numerous waterfalls and rapids. This is particularly true of the streams entering the central lowland and of small streams in general. Thus, the Farmington from Cold Spring, Mass., to New Hartford falls 29.76 feet to the mile; the Shepaug descends at the rate of 30.5 feet to the mile, making one drop, at Bantam, of 108 feet in less than three-quarters of a mile; Moodus River falls 350 feet in 2 miles. Even the Housatonic falls 3.5 feet to the mile from Stratford to Shepaug; 10.2 feet to the mile from Shepaug to a station 1.8 miles above Cornwall bridge; 19.4 feet to the mile from this last-named point to Falls Village; and 9.2 feet to the mile from Falls Village to Ashley Falls, one-half mile north of the Connecticut boundary line. The descent of the Housatonic is accomplished by stretches of gravelly rapids alternating with reaches of relatively quiet water, but at New Milford, Bulls Bridge, and Falls Village there is an abrupt drop over rock ledges. At Falls Village the combined height of the falls is about 100 feet.[a]

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[a] Porter, Dwight, Report on water power of the region tributary to Long Island Sound: Tenth Census, vol. 16, 1885.

The streams of the lowland area have slight fall and in some places are aggrading their valleys. The Scantic, Hockanum, Farmington, Pequabuck, Mill (New Haven), Farm, and others are sluggish streams which meander freely. The Quinnipiac, with a drainage basin of 156 square miles and a length of 35 miles, falls 5 feet to the mile from Plantsville to New Haven. The Connecticut has a fall of only 0.6 foot to the mile from Enfield Rapids to Hartford; and from Hartford to Saybrook no fall whatever. The entire fall of Connecticut River in crossing the State in the lowlands is about 30 feet, as compared with the fall of Housatonic and Willimantic-Shetucket-Thames rivers in the highlands—650 and 600 feet, respectively. There are, however, many waterfalls and rapids of considerable size and great picturesqueness along the streams of the central lowland.

Lakes, swamps, and salt marshes occupy 145 square miles of the State, the topographic map showing 1,026 lakes, the largest of which is Lake Bantam, with an area of 1.56 square miles, or 999 acres. Swamps are even more abundant than lakes, and if the smaller, partly drained ones are taken into account they number several thousand. The importance of these water bodies is evident. They furnish supplies for cities, add greatly to the beauty of the landscape, and are particularly effective in controlling the drainage, serving as reservoirs to retard the escape of rainfall and thus preventing destructive floods.

A glance at the map of Connecticut will show that the drainage is to the southeast and that the streams flow in accord with the general slope of the plateau, but even a superficial glance reveals the fact that not all the larger streams are in the prominent valleys and that many occupy positions where the bed rock is unfavorable for valley development. The Connecticut, for instance, instead of following the sandstone to New Haven, leaves the lowland at Middletown and turns abruptly into the crystalline rocks of the highlands, through which it has cut a deep gorge. Likewise the Housatonic, which follows a limestone valley down to Still River, turns southeastward across rugged crystalline rocks instead of continuing in the valley indicated by rock structure. The same is true of a number of smaller streams. Anomalies of another class are illustrated in the arrangement of certain smaller streams whose direction and grade, as well as character of valley, are entirely out of accord with the present topography. For example, Still River at New Milford and a stream of the same name at Winsted flow in a direction contrary to the slope of their valleys and enter their master streams by dropping over falls. The Farmington follows the slope of the ancient peneplain from Colebrook River to Farmington, there turns northward, cuts through a trap ridge at Tariffville, and finally reaches the Sound after flowing a distance of 103 miles instead of the necessary 64 miles to New Haven or 74 miles by way of the Connecticut at Middletown.

Without going further into detail, it may be stated that the characteristic features of the present drainage are due to two main causes. First, the streams were established on a peneplain during Cretaceous time and followed the slope to the south and southeast regardless of the character of the underlying rocks. The Connecticut, Housatonic, and other streams have maintained this inherited position. Second, the entire drainage of the State has been modified by glaciation. The courses of some streams have been reversed, other streams have been cut in two, and still others have been entirely obliterated or are represented by lakes and swamps. In fact a widespread rearrangement of streams as to direction and grade has been brought about.

FORESTS.

The distribution of forests in the State follows closely the subdivisions into highland and lowland areas. The eastern and western highlands are largely forest covered, and in recent years the forest areas have been encroaching on the agricultural districts. In the central lowland the soil, transportation facilities, and nearness to market render agriculture more remunerative, and the forests are represented by small, scattered wood lots. Taken as a whole, Connecticut is a well-timbered country, 39 per cent of its area being covered with trees.

CLIMATE.

METEOROLOGICAL DATA.[a]

Sixteen climatological stations are maintained by the United States Weather Bureau in Connecticut—at Bridgeport, Canton, Colchester, Cream Hill, Danielson, Hartford, Hawleyville, New Haven, New London, North Grosvenordale, Norwalk, Southington, Storrs, Torrington, Voluntown, and Waterbury. In Falls Village, Middletown, South Manchester, Wallingford, and West Simsbury record is kept of rainfall and temperature.

The following tables and figures 2, 3, and 4 present data collected at three selected stations; one in the eastern highland—Storrs, at an elevation of 640 feet; one in the central lowland—New Haven, elevation 25 feet; and the third in the western highland—Cream Hill, elevation 1,300 feet. The tables for the New Haven station give records of rainfall, temperature, humidity, and wind velocity, which are controlling factors in ground-water supply.

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[a] From United States Weather Bureau records.

Precipitation (in inches) at Storrs, 1897–1906.

[Elevation, 640 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1897	3.84	3.40	3.66	2.37	4.44	2.79	12.24	5.23	1.39	0.92	7.14	5.61	53.03
1898	4.70	4.03	3.00	4.44	3.81	2.48	6.24	5.87	2.22	6.18	6.11	1.96	51.13
1899	3.70	3.97	6.30	2.20	1.27	3.72	5.55	3.27	3.31	1.54	2.10	2.14	39.13
1900	3.42	7.31	6.73	2.67	4.91	4.32	2.76	2.03	2.27	3.00	6.79	2.22	48.43
1901	2.17	1.05	7.18	9.51	6.30	1.96	5.54	7.58	4.33	1.97	3.04	9.55	60.18
1902	2.53	5.11	6.35	3.88	1.59	3.24	7.48	2.17	7.05	5.68	1.10	5.86	53.75
1903	3.79	5.18	7.09	2.81	.50	9.24	4.56	4.52	1.81	2.79	1.95	4.27	48.51
1904	4.55	2.80	3.31	6.40	1.96	2.53	1.85	6.00	4.71	2.19	1.47	2.42	40.19
1905	3.57	1.21	3.45	2.87	.90	4.53	1.77	2.63	5.79	2.57	2.73	4.12	36.14
1906	3.16	2.68	5.46	4.40	5.87	2.18	5.03	2.16	2.05	4.85	2.39	2.80	43.63
Mean	3.54	3.67	5.25	4.16	3.15	3.70	5.30	4.15	3.49	3.17	3.48	4.10	47.16

	Winter.	Spring.	Summer.	Fall.
Mean for season	11.31	12.56	13.15	10.14

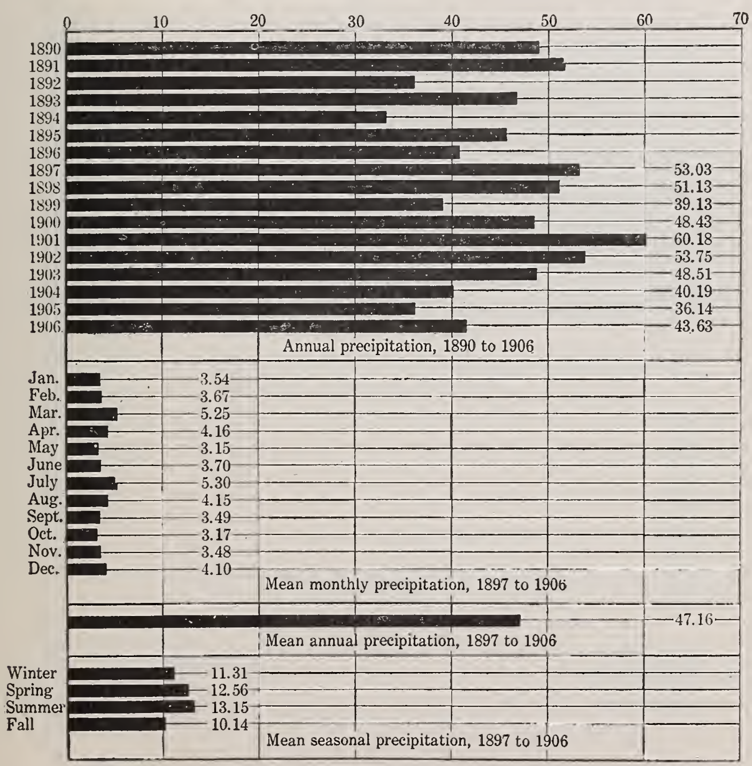

FIGURE 2.—Diagram showing precipitation, in inches, at Storrs.

Precipitation (in inches) at New Haven, 1897–1906.

[Elevation, 25 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1897	3.85	2.00	3.66	2.44	5.03	2.47	10.63	6.81	2.42	1.25	5.72	5.61	57.80
1898	4.90	4.55	2.54	4.43	8.03	.21	5.03	6.65	2.30	7.22	5.69	2.11	53.66
1899	4.33	3.39	7.28	1.79	5.52	2.59	4.17	.65	3.33	1.78	1.89	1.56	35.28
1900	3.60	6.39	4.21	1.95	3.30	1.79	2.28	.90	2.10	2.03	4.14	2.14	34.83
1901	1.38	.54	5.80	9.03	6.38	.25	4.40	6.92	5.70	2.95	1.61	7.65	68.81
1902	1.83	3.58	4.63	3.40	1.61	4.35	3.26	2.14	5.84	6.41	.79	6.49	44.33
1903	3.17	3.98	5.09	2.61	.31	7.41	2.17	6.96	2.20	2.94	1.85	2.53	41.22
1904	2.78	2.52	3.28	6.64	2.94	2.46	2.08	6.27	4.96	2.21	1.95	3.64	41.73
1905	4.14	2.06	2.96	3.42	1.18	5.87	2.86	7.20	5.07	2.21	1.53	4.83	43.33
1906	3.20	2.45	5.67	4.48	4.75	5.14	5.62	1.13	4.82	7.44	2.42	4.18	51.30
Mean	3.32	3.15	4.51	4.02	3.91	3.25	4.25	4.56	3.87	3.64	2.76	4.07	45.31

	Winter.	Spring.	Summer.	Fall.
Mean for season	10.54	12.44	12.06	10.27

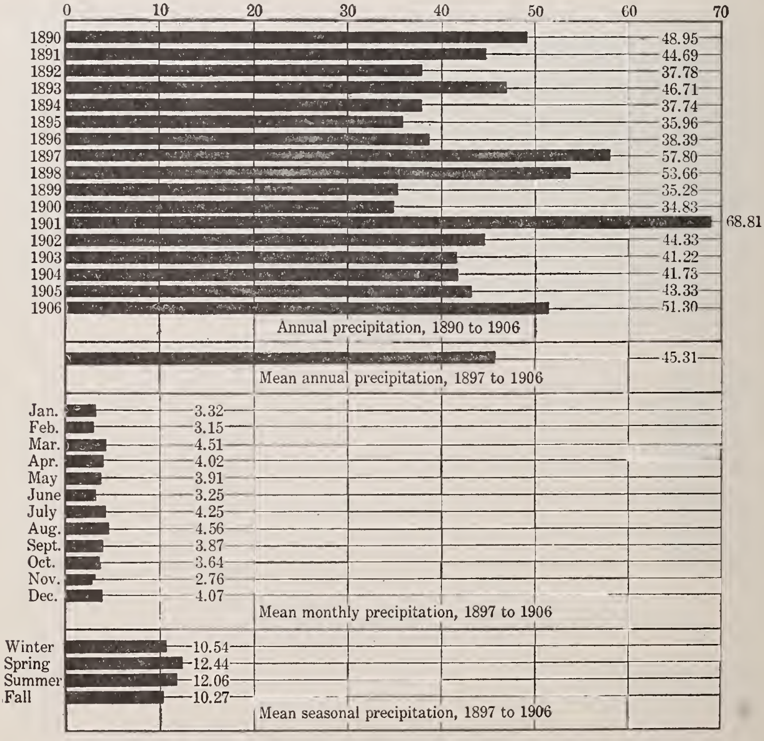

FIGURE 3.—Diagram showing precipitation, in inches, at New Haven.

The average precipitation at New Haven for thirty years ending December 31, 1903, was as follows:

Average precipitation at New Haven for thirty years ending December 31, 1903.

	Inches.
January	4. 03
February	4. 02
March	4. 51
April	3. 45
May	3. 71
June	2. 97
July	5. 01
August	4. 81
September	3. 66
October	4. 28
November	3. 73
December	3. 79
Annual	47. 97
Mean for season:	
Winter	11. 84
Spring	11. 67
Summer	12. 79
Fall	11. 67

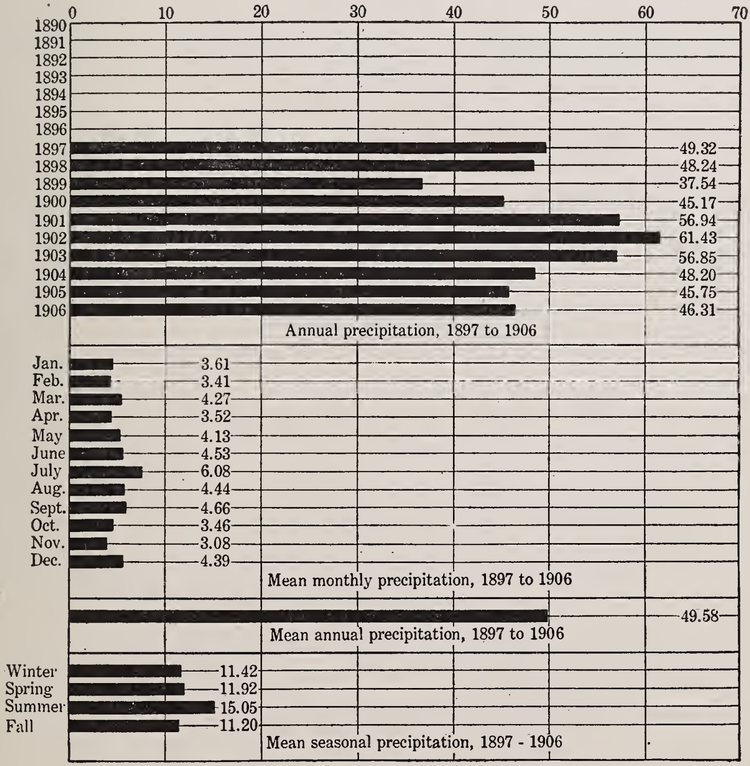

Figure 4.—Diagram showing precipitation, in inches, at Cream Hill.

Precipitation (in inches) at Cream Hill, 1897–1906.

[Elevation, 1,300 feet.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1897	3.54	2.21	2.09	3.16	4.22	5.15	9.71	5.28	2.85	1.04	5.54	4.53	49.32
1898	3.52	3.68	2.37	4.31	6.70	2.87	1.79	6.77	4.25	3.35	6.46	2.17	48.24
1899	3.47	4.13	5.84	1.47	1.75	3.39	6.70	1.11	4.21	1.67	1.59	2.21	37.54
1900	2.82	5.97	3.84	1.95	5.13	4.42	6.09	2.18	1.75	2.73	5.29	3.00	45.17
1901	1.52	.84	7.33	6.83	6.90	1.69	4.57	6.97	4.52	4.37	3.26	8.14	56.94
1902	3.26	4.90	4.68	4.76	2.99	5.06	9.40	4.70	7.83	5.42	.75	7.68	61.43
1903	3.93	4.97	4.94	3.20	1.39	9.74	4.07	5.65	2.85	6.39	3.10	6.65	56.85
1904	4.69	3.13	4.46	3.12	4.28	3.52	6.15	3.89	7.90	2.71	1.24	3.09	48.20
1905	6.91	1.68	3.12	2.74	2.35	3.90	5.83	4.71	6.83	2.90	2.19	2.59	45.75
1906	2.41	2.55	4.06	3.67	5.61	5.60	6.47	3.14	3.58	4.02	1.36	3.84	46.31
Mean	3.61	3.41	4.27	3.52	4.13	4.53	6.08	4.44	4.66	3.46	3.08	4.39	49.58

	Winter.	Spring.	Summer.	Fall.
Mean for season	11.41	11.92	15.05	11.20

The average precipitation recorded at ten stations in Connecticut for the years 1893–1903 is as follows:

Average precipitation at ten stations in Connecticut, 1893–1903.

	Inches.
January	4.28
February	3.94
March	4.23
April	3.53
May	4.03
June	2.95
July	4.42
August	4.30
September	3.34
October	4.04
November	4.48
December	3.44
Annual	46.98
Mean for season:	
Winter	11.66
Spring	11.79
Summer	11.67
Fall	11.86

Monthly and annual temperature (°F.) at Storrs, 1893–1903.

[Elevation, 640 feet.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Mean	24	24	36	46	56	64	69	68	61	50	38	30	47
Highest monthly mean	28	28	43	48	60	68	72	70	64	54	44	33	....
Lowest monthly mean	17	19	29	42	54	59	65	62	56	45	34	23	....

	Winter.	Spring.	Summer.	Fall.
Mean for season	26	46	67	50

Monthly and annual temperature (°F.) at New Haven, 1873–1903.

[Elevation, 25 feet.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Mean	28	29	35	46	58	66	72	70	64	53	41	32	50
Highest monthly mean	37	36	45	52	64	71	76	73	70	58	47	39	....
Lowest monthly mean	20	20	27	39	51	61	68	65	59	48	34	26	....

	Winter.	Spring.	Summer.	Fall.
Mean for season	30	46	69	53

For thirty-one years the highest temperature at New Haven was 100°, in September, 1881, and the lowest was 14° below zero, in January, 1873.

Monthly and annual temperature (°F.) at Cream Hill, 1897–1907.

[Elevation, 1,300 feet.]

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Mean	23.1	22.0	32.9	44.0	56.0	64.0	69.4	66.6	61.4	51.0	36.7	26.0	46
Highest monthly mean	30.2	26.6	39.2	45.4	59.0	66.0	72.1	70.6	64.6	54.6	42.4	29.7	....
Lowest monthly mean	17.3	16.3	26.0	40.6	53.8	60.0	66.1	61.2	58.6	47.6	32.2	21.4	....

	Winter.	Spring.	Summer.	Fall.
Mean for season	23.7	43.3	66.7	49.7

Mean relative humidity (per cent) at New Haven, 1901–1906.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1901	72	62	74	77	79	70	80	83	80	76	67	77	75
1902	70	69	76	69	65	71	77	75	84	78	79	72	74
1903	71	73	78	65	65	82	73	79	79	79	68	69	73
1904	72	67	72	70	69	75	75	77	80	68	72	70	72
1905	68	63	71	66	71	74	76	81	80	71	67	70	72
1906	74	69	69	63	70	75	82	81	77	76	67	72	73
Mean	71	67	73	68	70	75	77	79	80	75	70	71	73

	Winter.	Spring.	Summer.	Fall.
Mean for season	70	70	77	75

Mean relative humidity (per cent) at New Haven for fifteen years ending in 1903.

Time.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
8 a. m.	74	73	71	74	77	78	80	80	78	76	75	76	76
8 p. m.	71	72	69	74	76	78	78	80	76	74	72	72	74

Average velocity (miles per hour) and direction of wind at New Haven, 1900–1905.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1900—Vel.	10.1	11.3	10.6	9.5	9.1	8.8	8.1	7.1	8.1	9.0	10.7	8.9	9.3
Dir.	N.	W.	N.	N.	SW.	SW.	SW.	SW.	SW.	N.	N.	SW.	S.W
1901—Vel.	9.9	11.2	11.0	13.3	9.8	7.8	6.8	6.9	7.1	8.6	10.2	10.4	9.4
Dir.	N.	NW.	NW.	NE.	S.	S.	SW.	S.	SW.	N.	NW.	N.	N.
1902—Vel.	9.8	13.0	11.4	9.9	9.2	8.4	7.2	7.2	8.4	8.2	9.4	10.8	9.4
Dir.	NW.	W.	N.	S.	SW.	SW.	SW.	NW.	N.	.N	N.	N.	N.
1903—Vel.	10.2	10.0	9.5	11.7	8.0	8.5	7.8	7.3	7.9	11.3	8.4	10.9	9.3
Dir.	N.	W.	NE.	N.	S.	NE.	SW.	N.	SW.	N.	N.	W.	N.
1904—Vel.	10.3	10.6	10.1	10.7	8.2	8.2	8.2	7.7	8.3	9.5	9.0	10.7	9.3
Dir.	N.	N.	NW.	NW.	S.	S.	S.	S.	N.	N.	NW.	N.	N.
1905—Vel.	11.2	10.7	8.2	10.1	9.0	7.8	7.8	7.9	8.3	8.6	9.8	9.7	9.1
Dir.	N.	W.	N.	NW.	S.	S.	S.	SW.	N.	N.	NW.	SW.	N.
Mean—Vel.	10.3	11.1	10.1	10.9	8.9	8.3	7.7	7.4	8.0	9.2	9.6	10.2	9.3
Dir.	N.	W.	N.	N. NW.	S.	S.	SW.	S. SW.	N. SW.	N.	N. NW.	N.	N.

	Winter.	Spring.	Summer.	Fall.
Mean for season—Vel.	10.5	10.0	7.8	8.9
Dir.	N.	N.	S. SW.	N.

Prevailing winds at New Haven for thirty-one years.

January	North.
February	North.
March	Northwest.
April	Northwest.
May	South.
June	South.
July	South.
August	South.
September	Southwest.
October	North.
November	North.
December	North.
Annual	North.

SUMMARY.

The foregoing tables indicate that the climate of Connecticut possesses both continental and oceanic features directly related to the highlands and to Long Island Sound. The winters are long and severe; the summers are short, beginning abruptly in June and passing gradually into winter through autumn. Areas of high and low barometer which affect the weather of the State pass to the north down the St. Lawrence Valley, along the coast or directly across the State. Precipitation is uniformly abundant, and excessively dry years are unknown. There has been little change in the annual amount of rain for one hundred years, and the variation in seasonal amount is slight. (See figs. 2 to 4.) In fact, Connecticut may well serve as a type of uniform, evenly distributed rainfall of ample amount, in contrast with regions of seasonal rains and great annual variation.

The relation of temperature to ground-water problems is shown by the fact that percolation through sand is nearly twice as rapid at 100° F. as at 50°, and, accordingly, the amount of rainfall absorbed by the ground is subject to large monthly and seasonal variation. The proportion of the total precipitation found in the ground at each month in the year is given in the following table:[a]

Humidity of the ground.

Month.	Per cent at—			Month.	Per cent at—		
	1 foot.	2 feet.	3 feet.		1 foot.	2 feet.	3 feet.
January	89	95	98	July	20	15	10
February	76	82	88	August	32	28	22
March	66	72	77	September	44	40	34
April	54	57	65	October	57	52	48
May	44	45	48	November	66	64	67
June	32	30	30	December	82	74	83

SURFACE WATER SUPPLY.

SOURCE AND CHARACTER.

Of the water which falls as rain, a part is evaporated, another part enters the ground, and a third part goes directly into streams and is thus carried to the sea. The amount of water which is carried by streams has been approximately determined (see tables below), but there are no records of the amount evaporated, and accordingly the proportion of the rainfall absorbed by rocks and soils, and therefore available for springs and wells, is unknown. However, the amount evaporated is certainly small and, for rough calculations, the total rainfall may be divided into that which enters the ground (ground water) and that which is carried in streams (run-off).

The relation of rainfall to run-off can not be stated definitely, because several factors of unknown value are included. The rate of precipitation, the topography of the surface, the texture of the soil, and the structure of the rocks are all to be considered. The presence of lakes and swamps along the stream's course and on its catchment area modify the surface run-off, and a large but unknown amount of ground water enters streams and lakes without reaching the surface. For instance, Lake Saltonstall has a small drainage area—4 square miles—and should receive 4,000,000 gallons of water a day. It actually receives, however, a much larger amount than can be accounted for by ordinary surface drainage and is presumably fed by subterranean springs and ground-water seepage.

The presence of forests affects the relation of rainfall to run-off by increasing and regulating the flow of ground water. Deforestation

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[a] Sherman, Connecticut Almanac, 1885, p. 39.

promotes evaporation, increases the run-off, and tends to produce seasons of flood.

The general run-off of streams in the eastern part of the United States is 0.05 to 0.5 cubic foot per square mile per second, and streams tributary to Long Island Sound carry 17½ to 27½ inches of rainfall out of an annual total of 40 to 52 inches.[a] Variation in annual run-off is indicated by the record of Connecticut River, which shows the ratio of the run-off for a dry year to be 94 per cent of an average year's flow.

QUANTITY AVAILABLE.

The rivers whose discharge and run-off records are given below were chosen as typical Connecticut streams and fairly represent prevailing conditions. The Shetucket is a stream of the eastern highland, established on gneiss and schist. The Connecticut drains the sandstone lowland, and the Housatonic flows for a large part of its course above Gaylordsville in a limestone valley. The run-off record is compared with the rainfall record of the meteorological station nearest the point where the discharge is measured.

Discharge and run-off of Shetucket River at Willimantic April 4, 1904, to January 1, 1907.

Date.	Discharge (second-feet).			Run-off.			Rainfall at Storrs (inches).
	Maximum.	Minimum.	Mean.	Per square mile (second-feet).	Depth (inches).	Relation to rainfall (per cent).	
1904.							
April 4	4,420	758	1,784	4.50	4.51	70.4	6.40
May	2,350	385	920	2.32	2.68	136.7	1.96
June	555	84	326	.823	.918	36.3	2.53
July	345	84	221	.558	.643	34.8	1.85
August	930	126	373	.942	1.09	18.1	6.00
September	2,930	66	428	1.08	1.20	25.5	4.71
October	930	207	396	1.00	1.15	52.5	2.19
November	990	150	381	.962	1.07	72.8	1.47
December 1–17, 28–31	3,755	126	831	2.10	1.64	67.7	2.42
1905.							
March	3,865	275	1,937	4.89	5.64	163.5	3.45
April	4,195	510	1,254	3.17	3.54	124.0	2.87
May	706	275	455	1.15	1.33	147.8	.90
June	1,560	66	565	1.43	1.60	35.3	4.53
November	555	207	364	.919	1.03	37.7	2.73
December	2,930	555	902	2.28	2.63	63.8	4.12

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[a] Porter, Census for 1880, vol. 16, pt. 1.

Discharge and run-off of Connecticut River at Hartford January 1, 1871, to January 1, 1886.

[Drainage area, 10,234 square miles.]

Date.	Discharge.			Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.	Per square mile (second-feet).	Depth (inches).	Relation to rainfall (per cent).	
1871	87,460	5,520	17,433	1.70	21.11	56.2	37.70
1872	98,100	6,250	19,335	1.89	26.71	56.6	46.71
1873	109,800	5,390	23,061	2.25	30.62	69.9	43.85
1874	134,000	5,210	23,340	2.28	30.81	71.4	43.24
1875	90,100	5,700	18,114	1.77	23.95	55.6	43.07
1876	120,800	5,360	22,080	2.15	29.15	60.6	48.18
1877	128,200	5,700	16,683	1.63	22.09	51.5	42.92
1878	89,350	5,350	20,766	2.02	27.51	54.7	50.20
1879	116,400	5,550	18,852	1.84	24.91	52.6	47.24
1880	65,550	5,200	13,720	1.34	18.25	45.6	40.02
1881	74,000	5,250	18,026	1.76	23.88	51.0	46.93
1884	74,700	5,150	19,861	1.94	23.65	60.4	45.15
Period	134,000	5,150	19,157	1.87	25.10	57.0	44.53
1885.							
January	65,550	17,000	34,661	3.38	3.89	93.9	4.14
February	23,200	10,500	14,711	1.44	1.50	51.4	2.92
March	16,400	7,600	11,706	1.14	1.32	89.6	1.47
April	88,600	13,100	26,250	2.56	2.86	102.4	2.79
May	63,700	10,250	25,869	2.52	2.91	119.7	2.43
June	27,900	5,800	10,785	1.06	1.28	40.0	3.20
July	10,500	6,000	7,909	.77	.89	25.0	3.56
August	18,000	5,300	9,148	.89	1.03	12.8	8.06
September	13,100	6,000	8,105	.79	.88	47.8	1.84
October	21,350	6,750	10,084	.98	1.13	24.0	4.72
November	78,200	12,400	33,067	3.23	3.60	69.3	5.20
December	35,400	10,000	21,005	2.05	2.36	72.0	3.29
Year	88,600	5,300	17,775	1.73	23.65	54.3	43.62

Discharge and run-off of Housatonic River at Gaylordsville, 1901–1903 and 1906.

[Drainage area, 1,020 square miles.]

Date.	Discharge (second-feet).			Run-off.			Rainfall (inches).
	Maximum.	Minimum.	Mean.	Per square mile (second-feet).	Depth (inches).	Relation to rainfall (per cent).	
1901	14,300	303	2,216	....	29.65	52.1	56.94
1902	31,000	525	2,920	2.861	38.62	62.9	61.43
1903	25,700	550	3,006	2.946	39.65	69.8	56.85
1906.							
January	3,170	938	1,800	1.76	2.03	84.2	2.41
February	4,630	788	1,630	1.60	1.67	65.5	2.55
March	10,000	1,130	2,910	2.85	3.29	81.0	4.06
April	8,930	2,460	4,780	4.69	5.23	142.5	3.67
May	5,060	1,090	2,110	2.07	2.39	42.6	5.61
June	2,370	928	1,630	1.60	1.78	31.8	5.60
July	2,120	421	984	.965	1.11	17.2	6.47
August	1,310	347	818	.802	.92	29.3	3.14
September	876	296	554	.543	.61	17.0	3.58
October	2,220	296	861	.844	.97	24.1	4.02
November	1,980	550	992	.973	1.09	80.1	1.36
December	1,440	686	958	.939	1.08	28.1	3.84
The year	10,000	296	1,670	1.64	22.17	47.9	46.31

POPULATION AND INDUSTRIES.

The physiographic division of Connecticut into highland and lowland areas has been a controlling factor in determining the settlement and character of life of the people of the State. The bulk of the population at the present time is grouped in three areas:

First, the central lowland, containing the towns of New Haven, Hartford, Middletown, New Britain, Meriden, etc., in which 39 per cent of the entire population of the State is located. This region was first settled in 1637 and the population has increased gradually from that date. The favorable conditions of the lowland area are the fertile soil, which is readily tilled, and the ease of establishing lines of communication by wagon roads, canals, and railroads.

Second, on the shores of Long Island Sound, where are located Norwalk, Stamford, Bridgeport, New London, and other towns, which together have a population of 199,719, or 22 per cent of the total.

Third, in the highland valleys, where Waterbury, Winsted, Willimantic, and many smaller towns are located and where 26 per cent of the population reside. The original attractions of these places were the water power and ease of communication along valleys. Collinsville is typical of many small villages that have been built up about a factory whose location was determined by excellent water power.

The towns of the State outside of these three groups have attracted but 13 per cent of the population. The soil is thin but of fairly good quality. The roads have steep grades and are difficult to maintain. Railroad lines enter the highlands only along the wider valleys and are at an inconvenient distance from many of the towns. Parts of Union, Hartland, and North Stonington are 10 miles from any railroad, and many farms in Killingworth, Salem, Goshen, Ashford, Canterbury, and Ledyard are nearly as inaccessible. The result is that the population of certain hill towns has actually decreased. During the decade from 1890 to 1900 ten towns out of twenty-six in Litchfield County showed a decrease in population and ten out of thirteen towns in Tolland County suffered a net loss in population of 1,400. At the present time a new era seems to be dawning for rural Connecticut, partly as a result of improved methods of farming and of the introduction of the practice of scientific forestry, but more largely owing to the fact that the farms of the highlands are being purchased for summer homes and estates. For this purpose an abundant supply of good water is essential. In fact, the water resources of Connecticut form one of its chief commercial assets, and a knowledge of their character and occurrence has become a matter of great practical importance.

CHAPTER II.

GEOLOGY.

OUTLINE OF GEOLOGIC HISTORY.

Very little is known of the early geologic history of Connecticut. It is probable that some of the gneisses and schists date from a time before any living forms existed upon the earth, but no fossils older than the Triassic have been found in the State, and it is therefore impossible to determine definitely to what age the pre-Triassic rocks belong. Their position in the time scale can, however, be determined approximately by comparing them with similar rocks in regions where their relations are known. This study of adjoining regions, taken in connection with the detailed study of the structure of the rocks themselves, indicates that the crystalline rocks of Connecticut have a long and complicated geologic history.

Pre-Cambrian rocks are represented in the State by the Becket gneiss, but no data are at hand to determine definitely the origin or age of this formation. Its component parts have been so completely altered by changes that have taken place since their deposition that all evidence of value for determining their original character has been destroyed. The character of the rocks overlying the Becket gneiss indicates that a sea extended over a large part of Connecticut during Cambro-Ordovician time and that the Stockbridge limestone and associated quartzites were deposited in that ancient water body. Such an accumulation of material implies the wearing down of land masses and suggests that lands of considerable elevation must have existed to the east of the present shore line.

The long interval between the close of the Ordovician and the beginning of the Mesozoic time has left no legible records of deposits that can be assigned to any definite geologic period. The great thickness of Devonian sediments to the west suggests a New England mountain range of considerable height which furnished material for the sedimentary strata.

One series of events, however, is abundantly attested, namely, that igneous intrusions occurred frequently in the interval between the Ordovician and the Triassic periods, resulting in the formation of numerous veins and dikes of quartz and granitic and basic rocks. The nature of these intrusive masses indicates that they have been brought to the surface by the removal of thousands of feet of sediments. The particular date of any of these igneous intrusions is unknown, but their effect is well shown, and it is not at all unlikely that part of the molten rock reached the surface and was represented by volcanic activity, all traces of which have disappeared.

The geologic records show also that at different times between the Ordovician and the Triassic there were important movements in the earth's crust which resulted in the metamorphism of all the existing rocks in the State. Just when these profound changes took place is unknown, but the rocks are believed to have been involved in the great earth movements which produced mountains at the close of the Archean, Ordovician, and Carboniferous periods.

That many changes took place in Connecticut during the time from the Ordovician to the close of the Carboniferous is shown beyond doubt by an examination of the highland areas.

These rocks are chiefly schists and gneisses, and accordingly have structures indicating that they have been profoundly changed from their original sedimentary or igneous character. The original component minerals have been rearranged, stretched, and drawn out in lines; new minerals have been produced; parts have been fused and recrystallized. Instead of horizontal layers or uniform igneous masses, we find twisted and broken rock with layers, bands, and ribbon structures in every conceivable position. This tangle of structure is further complicated by the presence of dikes, seams, and veins which have made their way into the rock at different stages of its history. In looking at this confused mass of rock which forms the Connecticut crystallines, it seems apparent that it has taken part in manifold changes which went on in the earth's crust for ages. This very complexity of structure is an important aid in determining the relative age of the rocks, for it is evident that in general the oldest rocks must have been affected by the greatest number of disturbances, and accordingly the rocks of one age may exhibit structures not found in those of succeeding ages. In the absence of other criteria the geologist is forced to fall back upon this. These rocks are like a parchment on which writing after writing has been placed at diferent times by different hands, without at any time completely erasing the previous inscriptions. Little wonder that we have difficulty in deciphering the original writing.

Such composition and structure as is described above can be produced only at very great depths in the earth (probably below 20,000 feet) where rocks are so deeply buried that, whatever the lateral stress, they will not adjust themselves by breaking, but by plastic deformation. It is therefore certain that, whatever the age of the crystallines, mountain ranges perhaps rivaling the Alps in height and ruggedness once occupied central Connecticut; and when we examine the rocks of Satans Kingdom, or the Quinnebaug Valley, or the Connecticut gorge below Middletown, or indeed any part of the area of crystalline rocks, we are studying the roots of lofty land masses composed of strata deposited during part or all of the Paleozoic era.[a]

The land at the close of the Carboniferous was probably marked by rugged topography—the hills and valleys making prominent scenic features. During Triassic time these elevations were removed and the material from the crumbling hills was built into the sandstones of central Connecticut.

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[a] Rice, W. N., and Gregory, H. E., Manual of Connecticut geology, 1906, pp. 80, 81.

The Triassic rocks are very much younger than any of the crystalline rocks exposed within the State; in fact, it is possible that no rocks were formed for a long period before the deposition of the lowest sandstone stratum. Where the ancient crystalline rocks and the Triassic rocks come into contact there is a marked unconformity, the sandstones lying upon the upturned edges of schists and gneisses of ancient time. The Triassic sandstone was deposited in water which was fresh or perhaps brackish, and a great deal of it was deposited in water which must have been shallow. The presence of animal life is indicated by the fossils found in the sandstones and shales. Skeletons of dinosaurs have been recovered and thousands of tracks of these strange animals have been found in the quarries of the Connecticut Valley. The shales at Saltonstall and Durham and elsewhere contain abundant remains of fish.

During the long time throughout which the Triassic sediments were being deposited volcanic eruptions formed widespread lava flows extending from New Haven to the northern line of the State. Outbursts of lava occurred at three different times and the fields of basalt which represent these flows are separated by considerable thicknesses of shale and sandstone, indicating periods of volcanic activity followed by long periods of quiet.

The sandstones and lavas of Connecticut were laid down in an approximately horizontal position, but at a date later than the Triassic the flat-lying beds were broken by a series of faults extending diagonally across the central lowlands. Displacement along these fault lines formed a series of giant blocks, composed of sandstone and trap, that were elevated on the west side and depressed on the east. The topographic result was a series of ridges with steep westward escarpment and gently sloping eastward face.

During Cretaceous time the entire region seems to have been worn down to a plain practically at sea level and sloping gently from northwest to southeast. Hills stood above the plain, but not to such an extent as to give the country a rugged topography. The southern part of the State at this time was probably covered with sediments deposited in a Cretaceous sea which extended to the latitude of Hartford. The result of this long period of erosion was to reduce the inequalities produced by the uplifting of the blocks of sandstone and lava and to lessen the contrast between highland and lowland areas.

Near the beginning of the Tertiary period the area now forming the State was uplifted and the streams which had been wandering across the Cretaceous plain were revived and began once more to cut their channels and to carry sediment to the sea. The result was to bring into relief all the harder and more resistant rock masses by removing the softer material. For example, in central Connecticut the areas of resistant trap stand above the sandstone plain as ridges whose length and shape had been previously determined by the direction of the fault lines. In the same way the softer Cretaceous strata along the coast seem to have been entirely removed and the less resistant limestone of the Housatonic Valley reduced to a narrow lowland. As a result of this long period of stream erosion during Tertiary time, the topography of the State acquired the larger general features of the present time.

During the Pleistocene ("Glacial") epoch the topography of Connecticut was again remodeled. The continental ice sheet which covered the northern part of America extended entirely across New England. Its thickness was great, the power urging it on was irresistible, and accordingly the landscape was molded in a characteristic manner. The loosened soil covering was removed from the rocks and the rocks themselves were reduced in height. They were grooved and scratched and polished by the pebbles embedded in the ice. A great quantity of material was removed permanently from the area and carried to Long Island. Although the larger features of the topography left by Tertiary erosion were little changed when the glacier disappeared, the details were greatly modified. Instead of the soil formed by the decomposition of the rocks, the glacier left two types of surface covering—glacial till, an unassorted and unstratified mass of rocks, bowlders, clays, and sands, differing widely in size and in composition, and stratified drift composed of layers of sands and gravel. The till came directly from the material carried by the glacier. The stratified drift was deposited by the waters from the melting ice mass. The distribution of this glacial material over the entire region modified the shape of hills, filled valleys, blocked drainage courses, rearranged stream channels, and left many depressions filled with bodies of water, so that although the main streams, like the Connecticut and the Housatonic, are now flowing in courses inherited from Tertiary time, yet the smaller streams owe their present arrangement very much to the changes produced by glaciation. Waterfalls, lakes, ponds, and swamps are also records of the Pleistocene ice invasion.

DESCRIPTIVE GEOLOGY.

INTRODUCTION.

The occurrence of ground water and the methods of its recovery are determined by the structure of the rocks, and therefore a knowledge of the character of the geologic formations of a region is essential to the well driller and to the well owner if he desires to attain satisfactory results at minimum expense. In Connecticut a well in mica schist may need to be of different construction from one in sandstone and will yield water differing in amount and in quality. Wells in till are usually shallow and of large diameter; those in stratified drift are particularly liable to contamination; those in sandstone and shale rarely yield water that is suitable for boilers. Thus in many ways the rock formations represented in the State determine the nature and value of the water supply.

In Connecticut three widely different rock groups must be taken into account by the well driller—the crystalline rocks forming the western and eastern highlands; the sandstones of the central lowland; and the deposits of sands, gravels, and clays which overlie all the rocks of the State. The sandstones, shales, and conglomerates are of Triassic age, as is shown by the numerous fossils contained in them. The gravels and other surficial deposits are of Pleistocene age. The crystalline rocks are of much greater antiquity, but owing to the absence of any definite marks of identification they will be referred to simply as pre-Triassic.

CRYSTALLINE ROCKS.

DISTRIBUTION AND CHARACTER.

With the exception of the area underlain by Triassic strata, the entire State of Connecticut is occupied by crystalline rocks of very great age. They are of two types, igneous and metamorphic, both widely different from the sediments of the valley lowlands.

Igneous rocks are those which have been molten and have solidified from cooling. They are accordingly composed of crystals, closely fitted and interlocking, instead of being made up of grains or fragments of material, as are sandstones. The many different textures shown by these igneous rocks were determined by their rate of cooling, and in accordance with this principle fine-grained granites and granite porphyry have been formed. Unchanged igneous rocks are rare in Connecticut outside of the traps of the Triassic region. They occur as veins, dikes, and small bosses, mostly of granite and related rocks. A few diabase dikes are distributed along the borders of the lowlands. The masses of unaltered igneous rock within the ancient crystalline areas are so small that it has not been found desirable to indicate them on the geologic map of the State.[a]

Metamorphic rock constitutes practically all of the crystalline areas in Connecticut. Rocks of this type have been profoundly changed from their original condition either as igneous or sedimentary. The change in some of these rocks is merely a hardening, as when shales are baked by the intrusion of a trap dike. But the metamorphic rocks of the State as a whole show much more complete alteration. Their mineralogical composition has been changed, their structure has been destroyed, and fossils which they may

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[a] Bull. Connecticut Geol. and Nat. Hist. Survey No. 7, 1907.

have formerly contained have been obliterated. The changes have been so great that the rocks bear little resemblance to their former appearance, and with some of them it is impossible to determine whether the original material was igneous or sedimentary.

The metamorphic rock masses existing within the State are crystallized limestone (marble), quartzite, phyllite, schist, and gneiss. Marble is a metamorphosed limestone, in which the grains of the original rock have been converted into crystals. Quartzite is a sandstone which has been made firm and compact by filling in the spaces between the sand grains with quartz. Phyllite is usually an advanced stage in the development of slate, which in turn is made of mud shales and related rocks. Schists and gneisses are so widespread within the State that they might be said to constitute the bed rock of the region. Twenty-three varieties of gneiss and eight varieties of schist are shown on the Connecticut geologic map. Schist is a term used to indicate the structure of the rock, not its composition, and represents an extreme stage of metamorphism in a rock which may have been originally igneous, sedimentary, or metamorphic. In schists so far has metamorphism proceeded that new minerals have been made, particularly mica, and a complete rearrangement of the mineral particles has taken place.

The value of the crystalline rocks as water carriers is determined by the facts that they are very dense, nonpermeable rocks, that structures of slatiness and schistosity are developed in them, that they are traversed by numerous joints in many directions, and that they are cut by large or small faults.

Schists are characterized by cleavage planes which enable the separation of the rock into irregular layers of small thickness. The structure which admits of the splitting of the rock in this manner is called schistosity and owes its origin to the parallel arrangement of micas and other flat minerals whereby separation takes place in one direction much more readily than in others. Schists always contain an abundance of mica, but they contain also other minerals in large amounts. Feldspar is invariably present, and a typical mica schist consists essentially of feldspar, mica, and quartz. The names hornblende schist, quartz schist, kyanite schist, etc., used in the following pages, indicate the prominence of certain minerals. Most of the Connecticut schists are believed to be the metamorphic equivalents of sedimentary rocks, the Hoosac ("Hartland") schist, for example, having previously been a series of sandstones, shales, and limestones, much like the present sediments of the Triassic belt.

Gneiss, like schist, is a term which refers only to the structure of a rock and implies the existence of a series of roughly parallel breaking planes along which the rock may be separated into slabs of various sizes. The development of schistosity is alike in gneisses and schists, but gneiss is more massive and is commonly the present equivalent of former igneous rocks. The production of gneiss from granite has taken place within the Connecticut area on a large scale. Granite masses have been stretched and squeezed so that instead of being of uniform texture and massive structure they are drawn out into sheets and definite layers. Practically all of the granite quarried within the State is granite gneiss, the gneissoid structure of which is an important factor in successful quarrying.

When schists or gneisses are exposed to the atmosphere the planes of schistosity often become definite cracks and open fissures into which water may descend and collect in amounts sufficient to supply wells or springs. It is this capacity to carry water which makes a detailed study of the structure of rocks a matter of practical importance.

JOINTS.

Rocks do not as a rule present an unbroken surface over any considerable area, but are traversed by cracks, which vary in size from those that are scarcely visible to those that are several inches in width. These cracks or "seams," as they are called by drillers and quarrymen, are technically joints. They are the results of mechanical action in rocks, which breaks them into more or less regular polygonal blocks separated by open spaces, and they are therefore of great importance when water-storage capacity is considered.

The most common type of joints includes those which are approximately vertical and cross each other at various angles, giving the rock surface the appearance of a rough screen or network. The prevalence of vertical jointing is shown by the fact that the inclination of about seventy-five measured joint planes in the Connecticut crystalline rocks was found to average 74°, forty of the joints being practically 90° from the horizontal. Another set of joints in the crystalline rocks runs more or less parallel to the surface of the rock. Some of these joints correspond to gneissoid and schistose structures, but many others represent entirely different planes of cleavage. In the gneissoid granites, as at Maromas and Glastonbury, these horizontal joints occur, but they vary considerably in their extent, number, spacing, and direction, as well as in width of opening, a variation which seems to depend primarily on the character of the rocks which they traverse. In the gneisses, particularly in gneissoid granites and granodiorites, the horizontal joints are very well developed and constitute the so-called "bedding" of the quarrymen. In the schists and the less massive gneisses horizontal jointing is poorly developed and in places even lacking. The character and number of vertical joints also depend on the nature of the rock. Certain rocks seem to be thoroughly shattered and broken by vertical joints into small wedges and blocks a fraction of an inch in diameter. Other rocks, like pegmatites, may extend for 25 to 50 feet without being marked by a prominent line of breaking. A good illustration of the difference of the jointing in two types of rock is seen in the Milford chlorite schist, where much fractured schistose and slaty varieties occur immediately in contact with fairly compact masses of altered diabase.

FAULTS.

Fractures along which more or less vertical movement has taken place are called faults and have been frequently observed in outcrops of crystalline rock. Many of the fractures extend to considerable depths and may appear on the surface as single lines or as zones of closely packed joints or of shattered rock. Much ground water may be stored in zones of faulted rock, and the open spaces afforded for the movement of water make fault lines of great value as channels for spring waters and supplies for wells.

TRIASSIC SANDSTONE AND TRAP.

DISTRIBUTION.

The Triassic rocks of the State occur in two areas—one extending from the Massachusetts line to Long Island Sound, with a breadth of about 20 miles at Thompsonville and narrowing at New Haven to the width of the harbor, the other underlying the towns of Southbury and Woodbury. Both of these areas are links in a broken chain of similar Triassic deposits which extends from North Carolina to Minas Basin, on the Bay of Fundy, a distance of 1,200 miles, and which covers altogether 10,000 square miles.

STRATIGRAPHY.

The relation between the Triassic strata and the ancient crystalline rocks is seen at Roaring Brook, in Southington, where sandstone lies unconformably upon the upturned edges of the Hoosac ("Hartland") schist. A general study of the Triassic areas of the Atlantic coast leads to the belief that the Connecticut areas are parts of a much larger expanse of Triassic rocks and that they owe their present existence to the fact that they have been dropped down as a result of faulting, and thus protected from the erosion which removed the adjoining areas exposed at higher levels.

The rock types existing in the Triassic area are two—the lavas (basalts) and intrusive sheets and dikes (diabase), rocks which are called popularly "trap;" and the sandstones, which range in texture from fine shales to extremely coarse conglomerates. The stratigraphic series in the Triassic of Connecticut consists of three lava flows with sedimentary strata below, between, and above them. Their relations are shown by the following table:

Stratigraphic succession in Triassic rocks of Connecticut.

Pre-Triassic metamorphic rocks.	Feet.
"Lower" sandstones	5,000–6,500
"Anterior"[a] (lower) trap	250
"Anterior" shales and shaly sandstones	300–1,000
"Main" (middle) trap	400–500
"Posterior" shales	1,200
"Posterior" (upper) trap	100–150
"Upper" sandstones	3,500

The "Lower" sandstone varies in texture from a fine-grained rock in the vicinity of Avon and Granby to a coarse conglomerate in which some of the pebbles exceed 2 feet in diameter. Where typically exposed in the quarries at Fair Haven the rock consists of fragments from the bordering crystalline rocks, including abundant crystals of feldspar, pebbles of quartz, fragments of porphyries, gneisses, and schists. Great variation is shown in the composition and structure of the beds, and abrupt changes in the character of the rock are observed at many places. In general the stratification is uneven and irregular, and the coarser and finer materials have rather the character of lenses than of uniform beds of wide extent.

The "Anterior" and "Posterior" sandstones contain a much larger proportion of shales than the "Lower" sandstones; in fact, shales and shaly sandstones are characteristic of these formations. In certain places, as east of Southington, an impure limestone occurs, and in a number of localities there is a slightly bituminous black shale. The stratigraphic position of the black shale is 50 to 100 feet above the "Anterior" trap sheet and at different levels between the "Main" and "Posterior" traps. The presence of these beds of shale has an important bearing on the problem of water supply. (See p. 109.) Fossil fish have been discovered in them at Saltonstall Lake, Rocky Hill, Durham, and other localities.

The "Upper" sandstones, consisting of sandstone and shale, with conglomerate locally developed, constitute the Triassic strata east of the central trap ridge. It is in these sandstones that the quarries at Portland and Long Meadow are located. In certain localities the "Upper" sandstone has characteristic features, but as a rule it is not a distinct formation. As stated by Davis,[b] "the Anterior, Posterior, and Upper sandstones and shales are seldom distin-

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[a] Owing to the monoclinal faulting which has broken the Triassic strata into eastward-tilting blocks, the traveler going from west to east across the Connecticut lowland comes first to the lowest and oldest lava flow, next to the middle, and last to the uppermost. Hence the terms "Anterior," "Main," "Posterior," first used by Percival.

[b] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1898, p. 139.

guishable." It is also true that these three formations are practically indistinguishable from the "Lower" sandstones.

The three lava flows—"Anterior," "Main," and "Posterior"—are identical in chemical and mineralogical composition and are manifestly of closely similar origin. They are flows of basalt from unknown sources. The "Anterior" trap is broken into a series of small hills and short ridges at Saltonstall, Totoket Mountain, Lamentation Mountain, and other places, and disappears in the vicinity of "Newgate Prison," in East Granby. This trap sheet is comparatively dense, but is vesicular on the upper surface, and at Lamentation Mountain it contains an "ash bed" of fine lapilli, 30 feet thick. The "Main" trap sheet is made up of two or more flows with a combined thickness of 400 to 500 feet and constitutes the most prominent topographic feature of central Connecticut, forming the conspicuous ridges beginning at Saltonstall and extending through Meriden and Farmington and into Massachusetts, where they include Mount Tom and Mount Holyoke. The "Posterior" trap follows the "Main" trap sheet in general alignment and has similar characteristics, but at only a few places does it become an important topographic feature. An excellant view of the "Posterior" trap and the underlying sandstones may be obtained at the city quarry, Hartford, immediately adjoining the buildings of Trinity College.

In addition to the three lava flows there is a series of intrusive trap sheets and dikes composed of diabase. East and West rocks at New Haven, Gaylord Mountain, the ridges east of Canton, and the Barndoor Hills are examples.

JOINTS.

Both the sandstones and the traps of Connecticut are traversed by many prominent joints, which form reservoirs for ground water. Where exposed in quarries the sandstone is seen to be cut by numerous joints and open fissures, so that even in the most favorable localities it is impossible to quarry slabs of stone of very large size. The principal joints are nearly vertical and intersect each other at fairly wide angles, so that the finer-grained sandstone and the shale break in more or less uniform blocks. In the Hartford quarry the shale is traversed by two prominent sets of cracks, which enable the workmen to remove diamond-shaped blocks about a foot in diameter. The conglomerate, especially where it contains large quantities of quartz, exhibits much less uniformity in jointing than the finer-grained rocks. The blocks into which it breaks are wedges and rude polyhedrons of such a variety of form as to make it impossible to predict the location of definite division planes. Many of the joints in the sandstone are weathered to great depth and furnish ready passage for water. (See pp. 73–74, 111–113.)

The trap rocks are of such uniform texture and of such fine grain that the jointing is exhibited on a very elaborate scale. Usually the joints are barely visible, but in a few places they are widely open and some of them have been filled with secondary material. The intrusive traps, and some of the lava flows as well, show a decided jointing at right angles to the plane of cooling, which gives a rudely columnar structure to the rock. In the New Haven region the columns are beautifully developed at Rabbit Rock, and some of the dikes in the Fair Haven tunnel show a regular and uniform system of joint cracks.

Perhaps the most convincing evidence of the abundance and influence of joints in trap is furnished by exposed cliffs below which is a talus slope of broken trap formed by joint blocks derived from the ledge above. Practically every high trap ridge in the State is flanked by such jumbled masses of fragments, the size and shape of which is determined by the direction and spacing of the cracks in the ledge. On the exposed edges of cliffs the joints furnish ample facilities for the free circulation and storage of water. In fact, where the bed rock is trap these cracks contain almost the only water supply within reach of wells.

FAULTS.

The sandstones and lavas of the Triassic area were laid down in a horizontal position. They no longer retain that attitude, however, but dip to the east at an average angle of 15° to 20°. In a few places the strata lie practically flat, and locally the dips are as high as 40°. These dips are due to the fact that the region is crossed by a series of fault lines which have cut the strata into blocks that are tilted to the east. Faults are joints or cracks in rock along which movement has taken place and which, accordingly, disturb the continuity of the rock much more profoundly than simple joints. In the lowland area twenty-five faults have been traced which extend for 5 miles or more, and one fault extending between Hanging Hills and Lamentation Mountain extends northeast and southwest for 40 miles. Innumerable smaller faults exist and may be observed in practically every outcrop of trap or sandstone. In places they occur so abundantly and are so closely placed that the rock appears to be shattered into small fragments. The amount of slipping which has occurred along these fault planes varies from a few inches, observed in quarries and railroad cuts, to several thousand feet in the great diagonal faults which have brought the "Lower" sandstones of Lamentation Mountain up to the level of the "Posterior" trap. The uplift in most of these faults is on the east side of the fault line, which accounts for the eastward dip of the strata and for the westward-facing cliffs. If the faults extended in the direction of the strike of the strata a series of parallel ridges would be exposed, marked by prominent cliffs of erosion on the west side. But the faults have traversed the formations obliquely, most of them from northeast to southwest, with the result that the erosion has produced a series of blocks which are not in alignment but are offset to one side or the other and separated by passes and gaps and notches.

The small Triassic area in the Pomperaug Valley presents features practically identical with those in the central lowland, and therefore requires no separate description.[a]

PLEISTOCENE DRIFT.

DISTRIBUTION AND GENERAL RELATIONS.

The glacial deposits of Connecticut form a mantle covering the bed rock practically everywhere. It is doubtful if bare rock is exposed over one-tenth of 1 per cent of the surface. The drift in thickness varies from a mere film to masses 300 feet in depth which have obliterated ancient stream courses. It is not quite so thick near the Sound and on the highlands as in the major valleys, and the rock ledges are confined for the most part to the summits of ridges and projecting cliffs now partly covered with talus. The disintegrated rock material formed throughout earlier geologic ages was removed by the glaciers, so that in general the rock surface where exposed is firm. Immediately overlying the solid rock, but with a marked unconformity between, is the glacial drift. The surface material as a rule has not originated from the rock on which it rests, and it may be entirely different in composition as well as in texture. Drift fragments of gneiss may be in immediate contact with shale, and bowlders of sandstone and trap may form the soil above ledges of mica schist. The fact that the bed rock is everywhere covered with glacial drift is one of the most important factors in the underground water problem of Connecticut, for the drift acts as a reservoir to feed water into the joints and cracks of the bed rock underneath. (See p. 142.)

CHARACTER OF MATERIAL.

Two types of glacial material are exhibited in the State—till and stratified drift. The till was made directly by the glacier and consists of deposits which are characteristic and quite unlike those made by water or wind. Glacial ice does not sort material, and the result is that till is composed of bowlders, sands, clay, and pebbles of all sizes, confusedly intermingled; and the same outcrop may show a heterogeneous lot of bowlders mixed with finely ground

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[a] For a complete discussion of the faults of the Woodbury-Southbury region see Hobbs, W. H., Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 3, 1901, pp. 7–162.

clay and sand. The bowlders may be securely bedded in rock flour in such a manner as to form "hardpan," which is scarcely less friable than artificial concrete and which furnishes little access to water; or the whole mass may be composed of bowlders and sand with large spaces between the fragments. Ordinarily the till is spread more or less uniformly over a region with a thickness depending on the character of the underlying topography, but here and there it is built into mounds (drumlins) which have been overridden by the ice, much as sand bars are formed in rivers.

Most of the rock fragments composing the till have not been rounded by water, and although much worn they are subangular and in many places polished and grooved and striated. The innumerable bowlders strewn over the surface of the State, built into fences, or used for foundations are parts of the till left by the retreating glacier.

Stratified drift consists of rounded fragments of sand and gravel deposited by water from the melting ice and differs little in appearance from deposits made by rivers or by the ocean. It differs from till in being stratified—that is, it is arranged in layers of fine and coarse material; and although the original fragments are the result of the grinding action of the ice sheet, the present position and structure of the drift are due to glacial waters. Stratified drift usually forms sand plains, and is confined chiefly to valleys and lower levels. Certain long winding ridges of stratified drift, indicating the channels of preglacial streams, are called eskers, and in some places the stratified drift takes the form of knobs, short ridges, and kettle holes, which are due to water action under conditions of confinement.

CHAPTER III.

OCCURRENCE AND RECOVERY OF GROUND WATER.

CIRCULATION OF GROUND WATER.

THE WATER TABLE.

The term "ground water" is used in referring to water supplies obtained from wells or springs, in contrast with those derived from streams and lakes. The ground water represents that part of the rain or snow which penetrates into the soil, while the remainder of the precipitation is delivered directly to surface streams, evaporated, or absorbed by vegetation.

The clearest conception of the circulation of ground waters may be obtained by considering the material in which they occur to be of a uniform character. Every one is familiar with the fact that a hole dug in the sandy beach of the sea or of a lake will fill with water to the level of the sea or lake water, and in a sea-beach hole the level of the water will lower as the tide goes out. As holes or wells are dug at greater distances from the shore and at higher elevations the level of the water in the wells is found to rise above that of the surface of the lake, river, swamp, or other body of water with which the comparison is made. The height to which the water will rise at any point in the ground is known as the height of the water table at that point. The water table therefore represents the upper limit of a zone saturated with water, above which the ground is relatively free from water except immediately after rainfall. It is the surface of the sea of ground water, and it is also called the "ground-water level."

The water table has a surface rising and falling with the land surface, but with smaller differences of elevation. The water has the highest elevation on the hills and the lowest in the depressions, but stands farthest from the surface of the ground on the hills and rises nearest to the surface in the depressions; where these are deep enough it reaches the surface to form swamps, lakes, and streams. Where the ground is perfectly level and uniform in character the level of the water table is uniform, but where changes occur in the surface elevation the water flows from the higher to the lower points, and there is thus a constant movement of the ground water from the hills toward the valleys. With surface waters this movement is unrestrained and the water immediately runs off the hills; but the movement of ground waters is very slow, owing to the frictional resistance to the passage of the water through the small openings of the soil and rock. This slowness of movement makes possible the existence of shallow dug wells on hills, and it is also the cause of the constancy of flow of streams and springs throughout the year. If the ground water moved as freely as the surface water the streams would have exceedingly large flows immediately after heavy precipitation and would be dry in the intervals between rains.

MOVEMENT OF GROUND WATER.

The movement of ground water is due to the force of gravity, and accordingly tends to take a vertical direction. After a rainfall the water absorbed by the ground gradually percolates downward through the soil until it reaches the water table, where the motion of the sea of ground water instead of being vertical is mainly in the same direction as the slope of the surface. This slowly moving body of ground water finally comes to the surface. Some of it emerges as springs or as a succession of small seepages along the banks of streams, but a considerable proportion of it probably enters streams and lakes below the water level. The general directions of flow of ground water and the manner in which streams are supplied are indicated in figure 5.

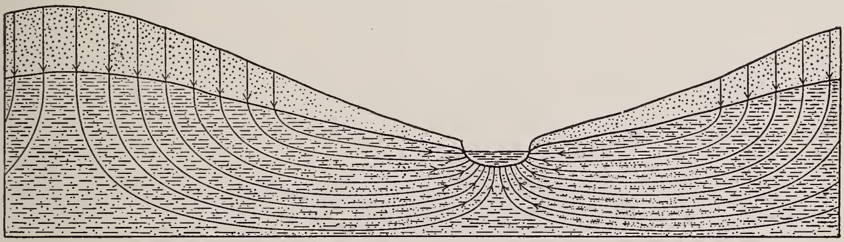

FIGURE 5.—Diagrammatic section illustrating seepage and growth of streams. Lines with arrows are lines of flows.

Although the circulation of ground water is in a general way as stated above, it happens that natural conditions rarely afford a uniform material in which the level of the water table may be predicted at any point. The ground is nearly everywhere made up of materials varying in character and offering different degrees of resistance to the circulation of water. In Connecticut the ideal conditions are most nearly realized in some of the flat sandy plains of the Connecticut Valley.

POROSITY.

The circulation of water in any material is directly dependent on the amount and character of the openings in that material, and these openings may be in the form of small pores, of long flat joints or other fractures, or of irregular rounded and tubular openings varying in size.

All rocks are composed of masses of separate particles or grains which do not touch each other at all points, small irregular openings occurring between the grains. This pore space, called "porosity," varies greatly in different materials and is largest in rocks that are composed of rounded grains laid down under water and least in rocks that have solidified from a molten condition. The porosity of a rock is expressed as a percentage of the entire volume. If 100 cubic feet of sandstone can absorb 20 cubic feet of water the rock is said to have a porosity of 20 per cent.

The following table gives the percentage of pore space and the amount of water absorbed per cubic foot by various sorts of rocks:

Porosity of different rocks.

Rock.	Percentage of pore space.	Water absorbed per cubic foot (quarts).
Sandstone	4.81	2–6
Do	28.28	
Limestone	.14	$\frac{1}{4}$–$1\frac{1}{4}$
Do	13.36	1–5
Marble	.184	
Do	3.578	
Granite	.969	$\frac{1}{100}$–$\frac{1}{4}$
Do		
Slate	.099	
Do	.304	
Chalk		4–8
Sand		8–10
Clay		10–12

These figures represent the ordinary limits of the porosity of the rocks and are derived from different sources.

PERMEABILITY.

The permeability of a rock is a measure of its ability to transmit water and is the most important factor in determining its value as a source of water supply. Permeability is dependent on the amount and character of porosity and on the existence of other openings, such as joints and other fractures and the small openings formed by escaping gas in certain lava flows.

In order that water may readily pass through a rock it is necessary that the openings be of appreciable size and have good connection with one another. In openings of small size the flow of water is strongly opposed by friction and by the attraction between the sides of the openings and the water, which in very small openings is sufficient to cause all the water to adhere to the sides as if glued. The effect of small size of openings is well shown by clays such as the brick clays of the Connecticut Valley, which may absorb water equal to 40 per cent of their weight, indicating a high porosity, but which allow water to pass through only with extreme slowness. In clays the constituent particles are so small and of such angular shape that the individual pore spaces are exceedingly minute, though in the aggregate of considerable volume. In sandstones the openings are so large as to allow relatively rapid flow. In general the size of the pores and consequently the permeability decrease with decrease in size of grain. Slichter [a] has made the following calculations, based on experimental work, of the velocity and amounts of ground water passing through materials of different grades.

Velocity of ground water in materials of different grades, pressure gradient 10 feet to the mile.

Material.	Diameter (millimeters).	Distance traveled per year.	
		Miles.	Feet.
Fine sand	0.2	0.010	52.8
Medium sand	.4	.041	216.0
Coarse sand	.8	.16	845.0
Fine gravel	2.0	1.02	5,386.0

Flow of ground water in materials of different grades through a bed of vertical cross section 200 by 1,000 feet, sloping 10 feet to the mile.

	Cubic feet per minute.
Fine sand	5.5
Medium sand	22
Coarse sand	87
Fine gravel	546

These determinations assume a uniform size of grain, a uniform porosity of 32 per cent, and a temperature of 50° F.

The law of flow through homogeneous porous materials is that the quantity of flow varies as the square of the size of the soil grain, other factors being constant. This law is based on the assumption that the grains are unconsolidated, but in all sandstones there is more or less cementing material which binds the grains together and necessarily decreases the amount of pore space. The more highly cemented the rock the less the porosity, although the cementation itself is an indication of former free circulation, as it is due to the deposition of mineral matter from water. Other factors influencing the amount of flow are variations in porosity and in temperature.[b] The flow at 70° F. is about double that at 32° F., owing to the fact that the viscosity of water decreases rapidly with rise in temperature.

The influence of joints and other fractures is of increasing importance as the porosity and size of the pore openings decrease, and in thoroughly crystalline rocks the only water circulation of consequence is through fractures. The rapidity of flow through joints is

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[a] Slichter, C. S., Motions of underground waters: Water-Supply Paper U. S. Geol. Survey No. 67, 1902, pp. 29, 30.

[b] Slichter, C. S., op. cit., p. 25.

not known, but it is undoubtedly much greater than through the pores. Owing to the differences in the permeability of rocks water has decidedly different rates and amounts of flow in adjacent materials. The main flow of water is confined to the most permeable formation, other conditions being equal.

Most underground waters yielding supplies of economic importance are under more or less modified artesian conditions; that is, they follow definite inclined channels or zones, inclosed by material more impermeable to water than that carrying the water, and rise to some extent above the level where they are struck.

ARTESIAN CONDITIONS.

The term artesian was originally applied only to wells which yielded a flow of water rising above the surface of the ground, but it is now frequently used for any water that will rise above the point where it is struck, indicating that it is under pressure or head. The ideal conditions for artesian circulation are two inclined layers of impervious material inclosing a layer of permeable material saturated with water for which there is no escape below the point where the water-bearing material is tapped. If the upper impervious layer is then penetrated in some manner, as by a drill hole, so that the saturated layer is entered at some point below the level at which the water naturally stands, the water will rise in the drill hole to a height determined by and nearly equal to the level at which the water stands in the water-bearing material. Figure 6 represents the conditions under which flowing wells may occur and under which the water will rise under artesian pressure to a certain level, but will not reach the surface.

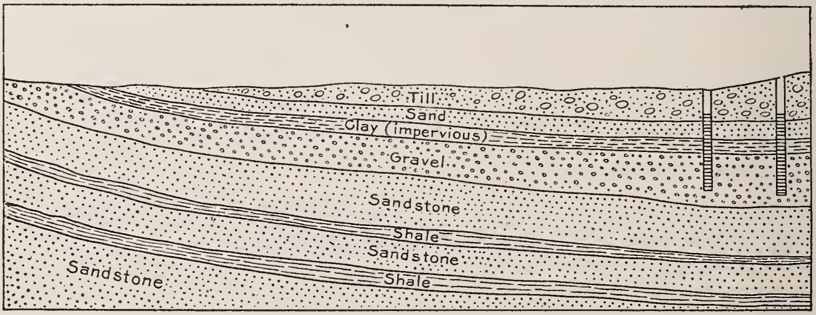

FIGURE 6.—Diagram illustrating artesian conditions where water does not rise to the surface.

The level to which water will rise in the well will always be somewhat lower than that of the water table in the permeable material, owing to the loss of head due to friction during the passage of the water to the well, and this difference in level will increase with increase of distance from the source of supply.

The conditions on which artesian flow depends may be summarized as follows:

1. A porous and permeable stratum capable of absorbing and transmitting large quantities of water. In certain localities planes of fracture may transmit the water rather than a porous stratum.

2. Relatively impervious materials above and below, preventing the escape of water from the porous stratum. Such conditions might be realized by a bed of sandstone between two beds of shale or by a layer of sand resting on massive granite and overlain by clay.

3. An exposure of the porous stratum where it may absorb water supplied either by direct precipitation or by percolation of waters falling on porous material above.

4. An inclination of the water-bearing stratum so that gravity may force the water down and produce an artesian head. This inclination may be due to the manner of original deposition, but is ordinarily caused by a displacement of the strata after deposition.

5. A lack of easy escape for the water at lower points than that where the porous material is penetrated, as the artesian head would be lost if the water had such escape.

6. A sufficient precipitation and absorption to keep the porous material saturated and maintain the artesian head.

Although these conditions are partly realized at many places in Connecticut, they are generally modified by many factors. In the Connecticut Valley the relatively porous sandstone has a marked dip to the east, and it is not uncommon to find a stratum of sandstone confined between two layers of shale. However, these rocks are intersected by so large a number of fractures that the water which can not pass through the fine pores of the shale leaks through the jointed material, destroying the artesian head. At many places in Connecticut a number of springs occur in a relatively straight line, indicating the existence of a fracture plane along which waters are escaping from confinement below. The artesian waters, instead of coming to the surface through artificial wells, are escaping through the openings furnished by nature. Fuller [a] has shown that artesian conditions may occur in such uniform materials as sand, owing to the overlapping of the elongated sand grains.

The fact that the ground water is in a state of continual motion, as shown by various experimental methods, implies that there must be some escape for the water at lower levels than that where it enters. Such natural escape may occur in a variety of ways. In a material of uniform nature, as sand, the surfaces of streams, lakes, and swamps represent the level of ground water at that point and the escape is due to slow seepage. Bodies of water fed in such a way are extremely

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[a] Fuller, M. L., Water-Supply Paper U. S. Geol. Survey No. 145, 1905, p. 41.

variable, increasing and decreasing in amount as the water table rises and falls, owing to varying weather conditions. The way in which such streams are fed is indicated in figure 5.

SPRINGS.

A large amount of the escaping ground water emerges at the surface in the form of springs that are usually rather constant in the amount of flow throughout the year. Such springs may represent an escape of artesian waters through fissures, as stated on page 49. Commonly they owe their existence to the presence of a stratum of pervious material overlying an impervious layer (fig. 7). The water penetrating the pervious layer is prevented from moving downward through the impervious layer, whose slope it follows until it finally emerges at the surface at the contact of the two layers.

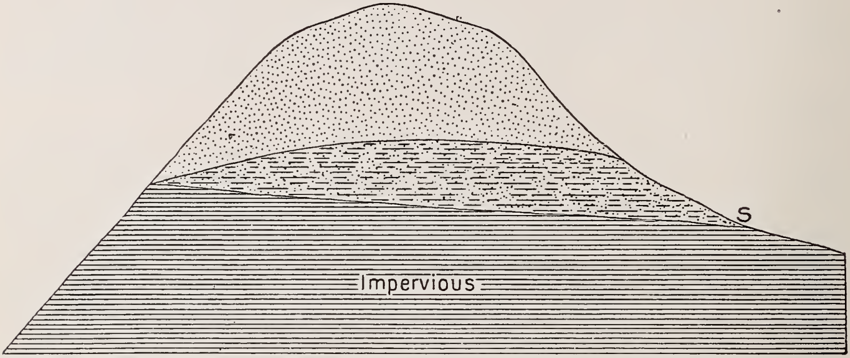

Figure 7.—Diagram showing formation of a spring at the outcrop of an inclined impervious stratum. S, Spring.

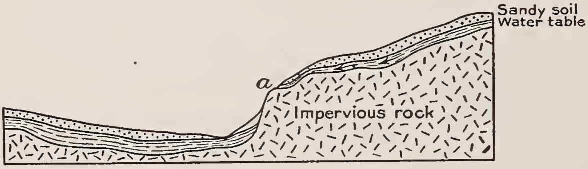

Figure 8.—Diagram illustrating manner in which spring may form at contact of soil covering and impervious rock below, when soil is removed by erosion. *a*, Point of emergence of the spring.

Figure 8 represents a type of spring in which the top of a hill is capped by a layer of sandy soil resting on impervious rock. The ground water follows the rock surface until some opportunity is afforded for escape, when the water will emerge as a spring.

Figure 9.—Diagram illustrating manner of formation of spring at contact of pervious formation and impervious formation when dissected. A, C, Impervious shale beds; B, porous water-bearing sandstone; M, top of saturated zone; X, point of emergence of spring.

Figure 9 represents the conditions where erosion has cut through the porous stratum and into the impervious layer, affording an easy escape for the ground waters. These diagrams represent two of the numerous ways in which springs may occur. Springs are usually seen issuing as streams rather than as a continuous seepage, both because the stream springs are more conspicuous and because if there is any considerable opening such as a joint crack the water will tend to concentrate in this open channel where the frictional resistance is least.

AMOUNT OF GROUND WATER.

It must be clearly understood that the amount of ground water is limited, as it depends on the amount of precipitation which is absorbed by the ground. The amount that escapes in the form of springs, though also dependent on the amount of precipitation, varies relatively less than the precipitation. The amount of precipitation, however, is variable, a dry season being marked by a lowering of the water table and a wet season causing a corresponding rise. The effect of these changes is always marked in shallow dug wells of the ordinary type, the water rising nearly to the top in winter and spring, whereas the same wells will be nearly or quite dry during the latter part of the summer. Springs also are affected to a certain extent by such seasonal changes, but the effect is relatively small as compared with wells. Variations in the level of the water table are also caused by barometric fluctuations, but though these variations may be sufficient to affect the amount of flow of

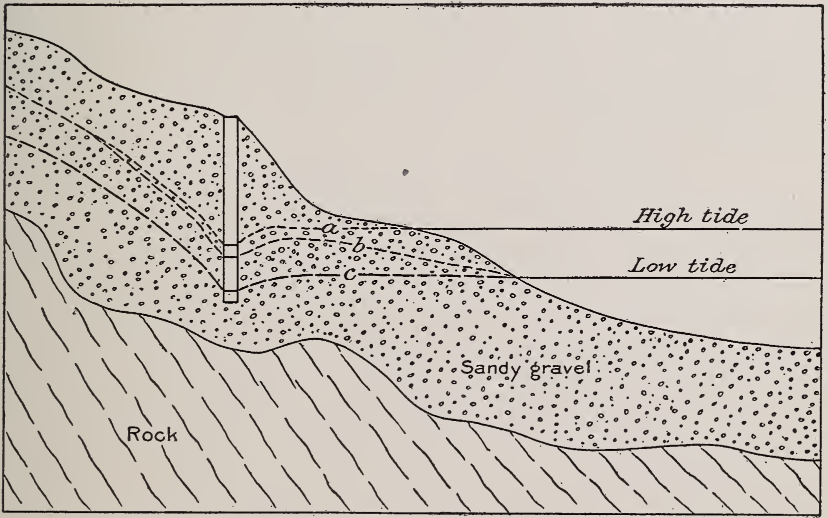

FIGURE 10.—Diagram illustrating effect of tides on water table. *a*, Normal water table at high tide; *b*, normal water table at low tide; *c*, depressed water table during a dry season.

springs, as shown by F. H. King,[a] they cause no permanent effect on the water supply. In wells near the coast fluctuations of the water table with the rise and fall of the tide are common, as the height of the sea water at high tide gives a slope to the water table differing from the slope at low tide. This is shown in figure 10.

Neighboring wells will usually affect one another, as water can ordinarily be pumped from the wells faster than it can be supplied by the water-bearing material, and the water table is therefore depressed for a varying distance around the wells, so that heavy pumping of one well will cause the lowering of the water level in an adjacent well deriving its supply from the same source. It is not uncommon for an artesian well which had previously given a good flow to lose its flow entirely on the sinking of another well which happened to give an easier escape for the underground waters. As a rule the flow of artesian wells decreases with the lapse of time and the head gradually lowers, indicating that the well is exhausting the supply faster than it is renewed by precipitation, or, in other words, that the water table in the water-bearing material is undergoing continuous depression.

TEMPERATURE OF GROUND WATER.

When the water enters the ground it has a temperature corresponding to that of the atmosphere, but as it percolates downward it is affected by the temperature of the ground and within a very short distance from the surface acquires the temperature of the material through which it is passing. In any region there is a certain depth at which the temperature is constant throughout the year and is practically the same as the mean annual temperature of the region. In Connecticut this depth is 50 to 60 feet, and the mean annual air temperature is 47°, so that waters at about 50 feet below the surface will have this temperature. Most of the Connecticut well waters come from much shallower depths, and consequently have temperatures above or below this average, depending on the season of the year.

Below the level of constant temperature there is a fairly uniform increase of temperature with increase of depth, amounting to about 1° F. for every 60 feet of depth. It is a common belief that the deeper the well the colder will be the water, but it will be readily seen that on this basis beyond a depth of 50 feet the deeper the well the warmer will be the water. This statement corresponds to the facts shown by the deep drilled wells of Connecticut, although in such waters there is a small change of temperature during the rise of the water to the surface.

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[a] Movements of underground water: Nineteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1899, pp. 75–77.

CONTAMINATION.

From what has been stated above, it is evident that ground water does not exist in pools or cavities in the rock and is not stationary. It has a movement in a definite direction, which can be determined for any given place. A velocity as high as 100 feet in twenty-four hours has been measured, but the common rates, even in sand, are only from 2 to 50 feet a day. (See p. 47.) The fact of the movement is undisputed and has an important bearing on health, for disease germs may be carried by water wherever it travels. No kind of rock or soil is proof against the transmission of ground water containing pollution. Fuller [a] has shown that water may traverse several miles of crystalline rock and may carry contamination through that distance. In a settled community too much emphasis can not be placed on the necessity of locating wells in positions where they are not liable to infection. The only safe way is to treat ground water as if it were a surface stream. No one would use water from a river a short distance below points of contamination, and no one should use water from wells where the downward slope of a ground-water table is such that the water might carry infected material. (See pp. 171–172.)

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[a] Fuller, M. L., Bull. Geol. Soc. America, vol. 16, 1905, p. 372.

CHAPTER IV.

GROUND WATER IN THE CRYSTALLINE ROCKS OF CONNECTICUT.

By E. E. Ellis.

INTRODUCTION.

The laws governing the occurrence of ground water in unconsolidated material and in porous sedimentary formations are now generally understood, but little has been written concerning the sources of supply for wells in the so-called crystalline rocks. The term "crystalline rocks" is used for those rocks whose component grains have crystallized into their present relative positions, in contrast with the sedimentary rocks, which were laid down under water and generally consist of fragments of older rocks mechanically arranged. Under the head of crystalline rocks two main types may be distinguished—(1) igneous rocks, such as granite, diabase, gabbro, etc., which were once in a molten condition and which crystallized and hardened on cooling; (2) metamorphic rocks, such as schists and gneisses, which were originally either sedimentary or igneous but have been altered by metamorphic processes to their present form.

Connecticut offers an exceptionally good field for an investigation of ground water in the crystalline rocks, as more than two-thirds of the State is underlain by rocks of this type (see fig. 11) and a large number of wells have been drilled in this area.

LITERATURE.

It seems necessary to dwell on the theoretical principles involved in the occurrence of ground water in crystalline rocks more largely in this paper than is customary in a report on underground water resources, because of the scarcity of previous information on these points. Accordingly a summary of the most important articles which have been written on such occurrences is here given. Many of these articles are contained in the discussions of the relation of circulating waters to ore deposits and to metamorphic changes. The principles involved, however, have been deduced for water circulation in general, both in rocks permeable because of their porosity and in rocks giving opportunity for circulation only through fracture planes; the latter type corresponds to the crystalline rocks under discussion. The theory as stated by Van Hise[a] considers that there

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[a] Van Hise, C. R., A treatise on metamorphism: Mon. U. S. Geol. Survey, vol. 47, 1904.

are two general zones of water circulation—a zone below the level of ground water, where all openings in the rocks are filled with water, and a zone above the level of ground water, where the openings are but partly filled. He considers the extreme possible depth of circulating waters to be about 10,000 meters, which is the limit at which open fractures may exist. The circulating waters are considered to enter the earth's crust at many points and as, owing to the force of gravity, they work downward, they tend to seek larger and larger channels, which offer less resistance to their flow, and finally to converge in some large channel and emerge at the surface at some point lower than that where they entered. Gravity is considered to be the primal force in producing this circulation. The chief objection to this theory has been the assumption of a saturated zone below a certain level. Similar theories have been less fully brought out by Daubrée, and by De Lapparent.

Certain general statements regarding the occurrence of water in crystalline rocks and the procuring of water from joint planes are given by M. L. Fuller.[a]

In a paper on the water resources of a crystalline area in New Hampshire and Maine, George Otis Smith[b] has discussed the manner of occurrence of water in these rocks. He considers that the movement of the water is confined to stratification partings, joint openings, and less continuous passages, the main circulation being along master joints which are nearly horizontal. The circulation is slow owing to the constricted nature of the openings, and the water supplying wells is contributed from distant areas and is confined largely to trunk channels. The occurrence of certain flowing wells is attributed to constriction and cementation in the upper portions of the fractures, giving opportunity for hydrostatic pressure.

J. A. Holmes[c] describes the occurrence of water supplies from the contact of fresh rock and the decomposed portion above in the crystalline rocks of North Carolina, but considers the undecomposed rock to be an uncertain source of supply.

The only published discussion of well supply in the crystalline areas of Connecticut is by H. E. Gregory,[d] who gives certain statistics regarding the wells in this area.

A number of records of wells drilled in crystalline rocks in New Jersey, Pennsylvania, New York, and Connecticut are given in the water reports of the New Jersey Geological Survey.

A. Daubrée,[e] in a treatise on subterranean waters, has paid particular attention to various types of fractures that offer passage to

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[a] Occurrence of underground waters: Water-Supply Paper U. S. Geol. Survey No. 114, 1905, pp. 28–29, 39.

[b] Water resources of the Portsmouth-York region, New Hampshire and Maine: Water-Supply Paper U. S. Geol. Survey No. 145, 1905, pp. 120–128.

[c] Notes on the underground supplies of potable waters in the south Atlantic Piedmont plateau: Trans. Am. Inst. Min. Eng., vol. 25, 1896, pp. 936–947.

[d] Underground waters of Connecticut: Water-Supply Paper U. S. Geol. Survey No. 114, 1904, pp. 78, 79.

[e] Les eaux souterraines, 1887, pp. 150–157, 271–277.

water. In considering rock fractures in relation to circulating waters he distinguishes three classes—"leptoclases," or small discontinuous fractures such as occur in basaltic structure, dividing the rock into comparatively small fragments; "diaclases," characteristic of all rocks and dividing the rock into polyhedrons by their mutual intersections; and "paraclases," which represent such continuous fractures as faults. The diaclases or joints are considered as planes extending in many places more than 300 feet laterally, and a joint series may extend with the same mean orientation for many miles. Their vertical extent is variable. In discussing the occurrence of water in crystalline rocks Daubrée notes the irregularity of occurrence and the general feebleness of springs from such rocks. He then states that however unimportant the movements of water may be near the surface, water-bearing fractures are still less accessible with depth, because they are less numerous and have tighter walls, and cites the experience of engineers in piercing the St. Gothard tunnel as proof. He also describes a series of three lava flows near Catania, which have absorbed an entire river into their fractures.

Nordenskiöld[a] has described a series of wells sunk at seven localities in Sweden on islands of igneous rocks such as granite, diorite, etc. These wells all obtained fresh water at a depth of 100 to 120 feet, and he considers the supply to be derived from horizontal fractures caused by the daily variations in temperature. He considers the most favorable localities to be where vertical joints are lacking, but does not account for the origin of the fresh water.

DISTRIBUTION AND CHARACTER OF THE CRYSTALLINE ROCKS IN CONNECTICUT.

The general distribution of the crystalline rocks in Connecticut is shown on the map (fig. 11), where the State is seen to be divided into three sections, consisting of two areas of crystalline rock separated by an area of sandstone and trap which occupies a general depression between the higher crystalline rocks. The crystalline areas are well drained, although here and there lakes of glacial origin occur, and the stream waters contain unusually small amounts of mineral matter. The softness of the water has been an important factor in determining the location of many of the great woolen mills throughout the State.

ROCK TYPES.

The three types of crystalline rocks that cover the greater part of Connecticut beyond the limits of the central Triassic area are granite, gneiss, and schist, although near the western portion of the State there is a considerable area of dolomitic limestone largely changed to mar-

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[a] Sur une nouvelle espèce de puits dans les roches granitiques de la Suède: Compt. Rend. Acad. Sci., vol. 120, 1895, pp. 857-859.

ble. There are also several areas of more or less schistose quartzite. Cutting these formations are many masses of pegmatite and a few dikes of diabase or trap rock, and in the central Triassic area the trap occurs both as dikes and as surface flows standing in high hills and ridges above the general central plain.

Granite.—There are many varieties of granite throughout the State, but they may all be distinguished by the characteristic granitic texture. The rock which throughout this discussion is considered as granite is in reality a granite gneiss—that is, a granite which has been subjected to metamorphism and has thereby acquired a gneissoid structure. The original granite nature is clearly evident and as granite is a more popular name, this term is retained in the discussion, although on the map the designation granite gneiss is used.

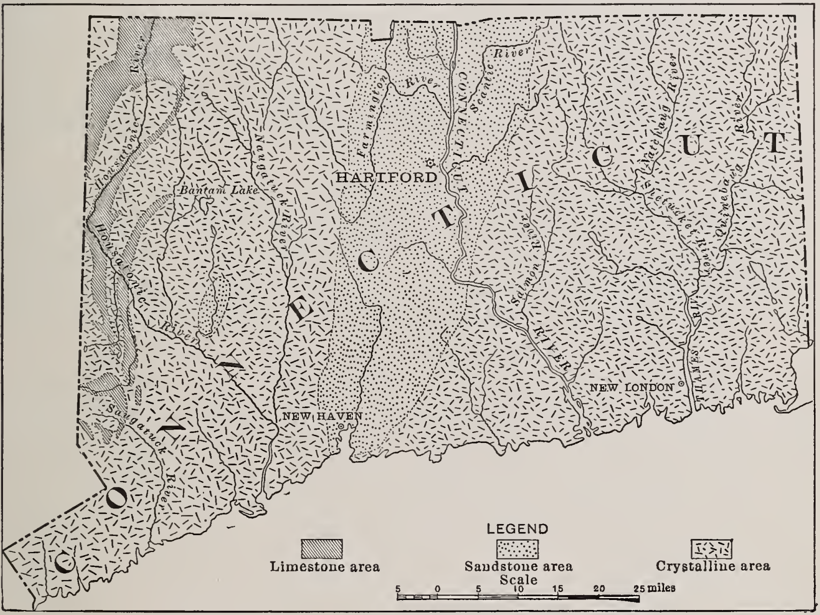

FIGURE 11.—Map showing areas of limestone, sandstone, and crystalline rock in Connecticut.

The rock is composed mainly of grains of quartz, feldspar, and mica, which are of fairly uniform size and easily distinguishable from one another. The rock is massive and will split about as readily in one direction as in another, except in joint planes. Locally schistose and gneissose phases occur even in a typical granite, giving one direction of easy fracture in the plane of schistosity. The main granite area is in the southern portion of the State and extends along or near a large part of the shore line.

Along the coast from the New York state line to Bridgeport is an area of somewhat similar rock called granodiorite. This rock resembles granite but contains a much larger proportion of the black mica (biotite). At many places in this area it is highly schistose and may be split much more readily in one plane than in others.

Gneiss.—The gneiss is a more variable rock than the granite, presenting very different characteristics even in adjacent areas and lacking the uniformity of texture of the granite. It may be distinguished by its banded or streaked appearance. It contains a large amount of feldspar and usually a considerable proportion of black mica or black amphibole, which, being present in greater amounts along certain lines than along others, gives the rock an appearance of alternating darker and lighter streaks. In some of the rock these streaks are developed into even bands from one-half inch to 3 feet in width, which continue for several hundred feet with variations of less than an inch in thickness. The most conspicuous area of gneiss is in the southeastern and eastern part of the State. Another large area consisting mainly of schist injected by granitic material occurs in the vicinity of Waterbury.

Schist.—Although schist usually contains a large amount of quartz and feldspar its most conspicuous constituent is mica, which on casual inspection appears to constitute the bulk of the rock. A careful examination will show that these mineral particles are much longer than they are wide and thick and that their longer axes lie in the same direction. This is the direction of schistosity or rock cleavage, and the rock splits along this plane much more readily than in any other direction. Wherever there is an exposure of schist the tendency of the rock to split along the plane of schistosity together with the high angles at which these planes usually stand gives a jagged and serrated appearance to the rock surface. The parting plane is usually rather uneven, but in certain types of schist it is very smooth and shows a shining surface in the sunlight. Schist of this type called phyllite, is too fine grained to distinguish the separate constituent particles and closely resembles slate, being in fact, intermediate between a slate and a schist. Certain of the chloritic schists of Connecticut assume a similar aspect. Though nearly all the Connecticut crystalline rocks are characterized by the presence of garnet, this mineral reaches its largest and best development in the schists.

The greatest development of the schists is beyond the western border of the Triassic area and in the area running from Middletown to the northeast corner of the State.

Quartzite schist.—There are several areas of an extremely quartzose schist in the northeastern and northwestern portions of the State. This rock is composed entirely of quartz grains and is supposed to represent a quartzite completely metamorphosed to a schist. In the western part of the State recementation appears to have taken place, resulting in an extremely indurated rock more nearly resembling a true quartzite.

Pegmatite.—Traversing many of these rocks are dikes and irregular masses of pegmatite, which are white or very light in color and consist in great part of large crystals of white or pink feldspar with quartz and in places bunches of broad-leaved mica. This rock is usually called "feldspar" by drillers and quarrymen.

Trap rock.—The trap rock is familiar to nearly everyone, and is easily distinguished by its dark color and fine-grained and compact texture. It occurs in the crystallized rocks as intrusive masses or dikes of material which has been thrust into older rocks. The external appearance of these dikes in the highland areas is closely similar to that of the traps of the lowland, and in composition the two rocks are identical.

Limestone.—The limestone is softer than any of the other rocks considered; it may be readily scratched by a knife and will usually effervesce when acid is applied. It is ordinarily white or gray in color, and is the only rock considered in the present discussion which may be definitely classed as of sedimentary origin without careful study. It is usually dolomitic—that is, it contains a considerable proportion of magnesium carbonate and in many places has been metamorphosed to a genuine marble.

DRILLING PRODUCTS.

The marked characteristics of these rocks give equally characteristic products in drilling. In many places the drill will yield fragments that are large enough to show the general texture of the rocks. In others the drillings will all be in the form of rock dust. In general the granite drillings are even grained, with a large proportion of the white or pink minerals, quartz and feldspar, and the same character and color of material will be maintained for a number of feet. Gneiss gives a somewhat similar product but as a rule has a larger proportion of biotite (black mica) and the character of the drillings changes rapidly, usually every few inches. Schist is generally softer and more readily drilled than either granite or gneiss, and the drillings contain a conspicuous amount of mica which occurs in larger particles than the other minerals. As in granite, the drillings maintain a fairly uniform appearance. The phyllite is usually a hard rock to drill, owing to its fineness of grain and the nearly vertical position of its cleavage at many places. Trap rock is considered the most difficult rock to drill, because of its hardness; it is readily distinguished from the other types. Limestone drillings are ordinarily white, and may be tested by adding acid or strong vinegar, which will produce an effervescence, owing to the escape of carbon dioxide.

DRIFT.

Although in some places, particularly in the southern part of the State, the rocks above described are exposed at the surface, they are in large part covered with glacial deposits—till and stratified drift. The till occurs as a relatively thin layer over the rock surface both in valleys and on hills, and the valleys are filled with heavy deposits of stratified sand, gravel, and clay deposits resting upon the till and tending to form a flat valley floor. At many places the till has been eroded and the stratified deposits rest directly on the rock. The till deposits on the hills average about 15 feet in thickness, varying where present up to 60 feet or more; the valley deposits at many places are over 100 feet thick and average about 36 feet, although varying within very short distances owing to the irregularities of the underlying rock surface. These averages are made from the well records in the crystalline areas.

In general, therefore, the hills have a configuration corresponding rather closely to that of the underlying rock surface, the minor irregularities of which are masked by the overlying drift. On the other hand, the valley bottoms are flat and a decidedly different topography would be shown if the sand and gravel deposits were removed. The general relation of the glacial deposits to the underlying rock and to each other are indicated in figure 23.

CONDITIONS AFFECTING OCCURRENCE OF WATER IN CRYSTALLINE ROCKS.

INTRODUCTION.

The occurrence of water in crystalline rocks is necessarily unlike that in most kinds of water-bearing sedimentary rocks, owing to the great difference of texture in the two types. In unmetamorphosed sedimentary rocks the pore space is usually large, running above 20 per cent of the total volume in many sandstones and locally above 40 per cent. This means that such rocks will absorb an amount of water equal to one-fifth or even two-fifths of their entire volume. In the crystalline rocks there is little pore space between the constituent grains, which have crystallized into their present relative positions and therefore closely interlock with one another. Few of the granites have a porosity exceeding 1 per cent, and the average is 0.5 per cent or lower.[a] In gneissoid granites the proportion of pore space is about the same, and in slates it is less, averaging 0.45 per cent or lower. Although in many limestones the porosity runs above 10 per cent, their metamorphosed equivalents—the marbles—have a porosity about equal to that of granite.

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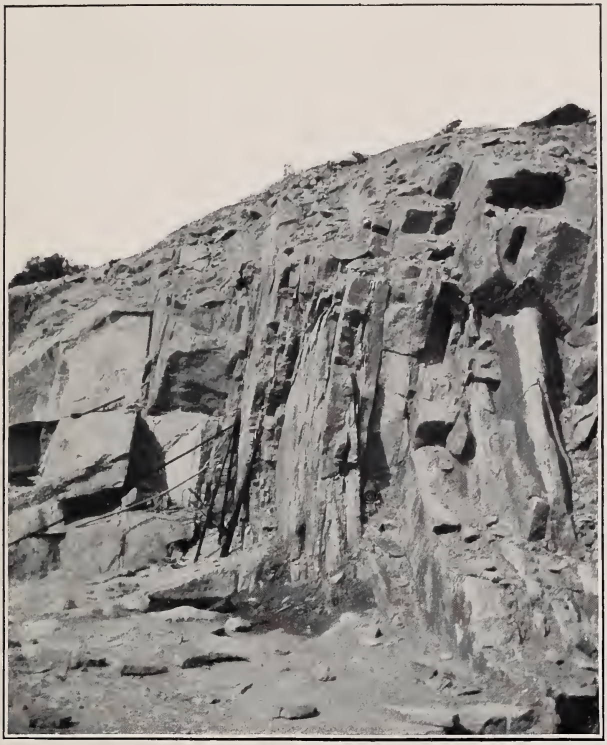
[a] Buckley, E. R., Building and ornamental stones of Wisconsin: Bull. Wisconsin Geol. Survey No. 4, 1898, p. 374.



A. VERTICAL JOINTS IN GRANITE.

B. HORIZONTAL JOINTS IN GRANITE.

In such rocks as these, which absorb less than 0.5 per cent of their volume of water and contain less than 1 per cent of uniformly distributed pore space, the pores are mainly of subcapillary size and, though admitting water, allow little and exceedingly slow transmission. In many of the sedimentary rocks, on the other hand, the openings between the grains are of capillary or supercapillary size and give ready transmission to circulating waters. Therefore in the crystalline rocks the only circulation of water which has sufficient rapidity of movement to be of value as a source of well supply must be through joints and fractures developed subsequent to the crystallization. (See fig. 12.)

JOINTS.

A joint in rocks may be defined as an opening or fracture of great length and depth as compared with its width. Joints are produced by mechanical action which causes the rock to break into more or less regular blocks after it has hardened. They are usually attributed to some dynamic force that brings about movements in the earth's crust. They are ordinarily called seams or cracks by drillers.

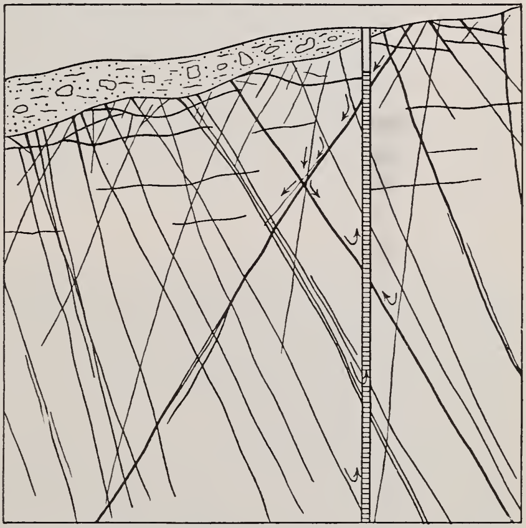


FIGURE 12.—Diagram illustrating the manner in which a well obtains water by cutting joints.

Vertical joints.—The most common type of joints comprises those in planes approximating a vertical position. (See Pl. I, *A*.) Though there are many joints within 2° or 3° of verticality, the greater number deviate considerably from this position. A large number of measurements were made on the inclination of this type of joint in the crystalline areas of Connecticut, the average inclination of a series at any exposure being taken rather than a number of measurements on separate joints at the same exposure. The mean inclination, as shown by 75 observations, was 74° from the horizontal. In only four observations did the inclination run below 40°, in 14 it was between 40° and 70°, in 17 between 70° and 80°, and in 40 between 80° and 90°. It is evident that in the Connecticut crystalline rocks the main jointing is between 70° and 90°. In several of the places where lower inclinations were observed the jointing was parallel to some structure plane in the rock.

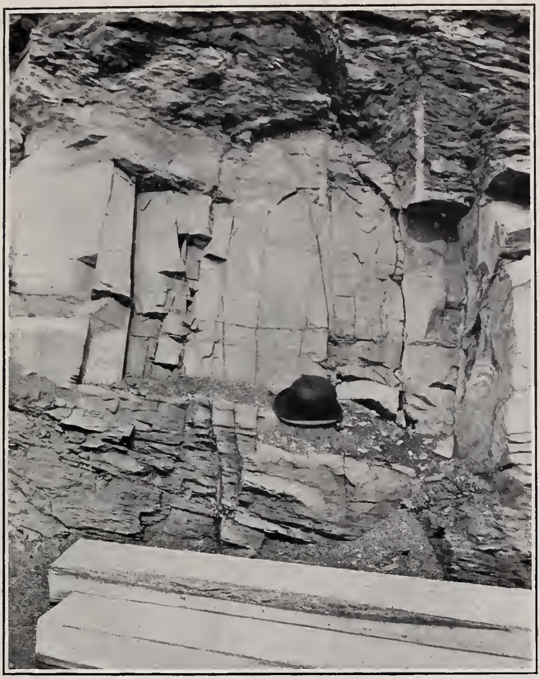
Horizontal joints.—In many of the rocks there is another set of joints which are very distinct from those of the vertical type, both in their degree of inclination and in their general nature. This set occupies an approximately horizontal position, in few places pitching more than 20°, and as a rule much less than this. (See Pl. I, *B*.) In general this joint structure follows the surface configuration of the rock, but here and there it pitches at a low angle in an opposite direction to the slope of the hillside. In the most extreme cases of deviation from a horizontal position this jointing was found to be approximately parallel to planes of schistosity in the rock. This is well shown in the lower of the two gneissoid granite quarries near Maromas.

In the further discussion of jointing, the names vertical jointing and horizontal jointing will be used for these two main types.

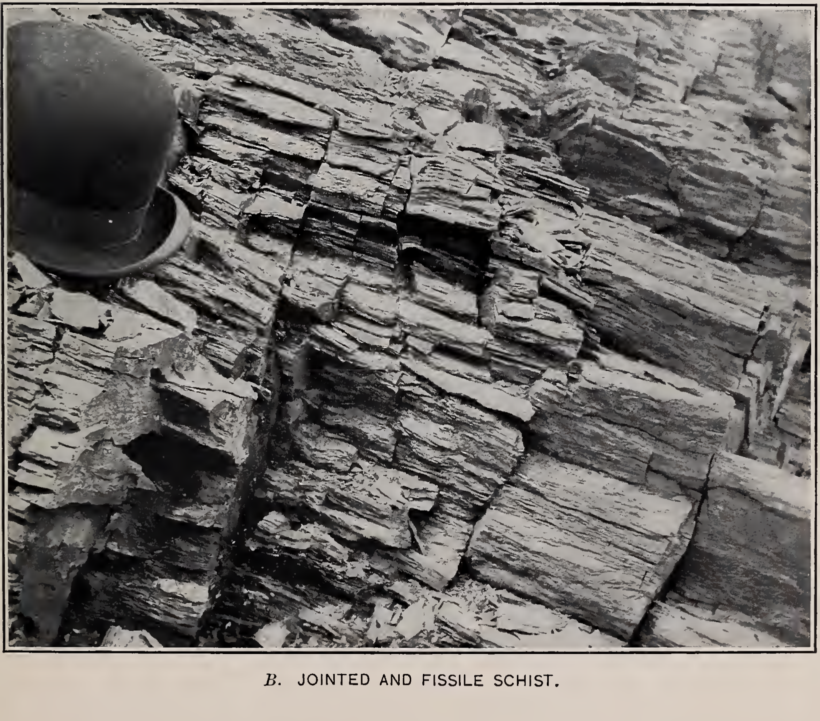
Relation of rock type to jointing.—Both vertical and horizontal jointing are present in all the crystalline rocks, but occur in greatly varying degrees of development in the differing types. The horizontal joints are typically developed in the massive granites, where they are commonly very regular. They form the most striking feature of quarries in such rocks and constitute the plane of separation called ''bedding'' by the quarry men. In the gneissoid granites these joints are developed equally well, but their direction is determined by the gneissoid structure in some places where that lies at a low angle to the horizontal.

In the typical gneisses the joints are irregular and uncertain and occur only near the surface; in the schists they are usually lacking, although here and there irregular and discontinuous fractures may be seen running in a nearly horizontal plane. Where such horizontal fractures occur in schists they are usually near the surface and very open.

The vertical jointing is not confined to any particular rock type, but is developed throughout all consolidated formations, both sedimentary and igneous. The degree and nature of the development, however, vary not only with varying rock types, but also to a great extent in rocks of the same type in different localities. This difference of development at the contact of rocks of two distinct types may consist of a mere tightening or closing of the joint on passing into the second rock, or of a difference in the number of the joints in the two rocks, indicating that some joints have stopped at the contact lines. Numerous instances of the former difference have been noted in the studies of ore bodies, and a good example on a small scale, typifying both differences, may be seen in the railroad cut just west of the station at West Haven, Conn. Here lenses and streaks of extremely schistose and slaty rock occur with similar layers of compact diabase several feet in thickness. The diabase is completely traversed by



A. JOINTS IN SCHIST AND METAMORPHOSED DIABASE.



B. JOINTED AND FISSILE SCHIST.

joints and seams, some of which stop abruptly at the contact with the schistose rock, while those which continue across the schist are relatively tight. A similar occurrence on a larger scale may be seen on the north bank of Housatonic River, 3 miles above Derby, where a schist lies above a heavy pegmatite. It is impossible with present evidence to say what will be the rule in this respect at the contact of a schist and a granitoid rock, but it seems probable that in most such places the joints will become tighter and less numerous in passing from a granitoid to a schistose rock. (See Pl. II, *A*, *B*.)

Joint direction.—Any individual joint maintains a fairly constant direction with a few small curves, and here and there the same directions of prominent jointing will remain fairly constant over a considerable area, as shown by the observations of Hobbs[a] in the Pomperaug Valley, where he found four major directions of jointing. Where there is a particularly well-developed joint set the series may maintain the same general direction for long distances.

In a series of observations throughout the crystalline areas of the State it was found by the writer that a much larger proportion of joint systems ran in a northwest–southeast direction than in one northeast and southwest. However, for particular localities the direction of jointing can be determined only by local observations.

Structure planes.—Of secondary importance to the joints as regards water supply is the presence of structure planes, such as schistosity and gneissoid banding in the rocks. In rocks exhibiting these features there has been more or less fracturing parallel to the structure planes, which have an average inclination much lower than the joints. The planes of schistosity dip at all angles, but for any single formation there is usually some dip which is more constant than others. Observations on these formational dips in Connecticut show them to be quite as commonly below 45° from the horizontal as above that angle, whereas, as previously shown, most of the joints, exclusive of the horizontal joints, have greater dips than 75°.

The fracturing parallel to the schistosity may consist of rather widely spaced and relatively open fractures or of small discontinuous breaks an inch or less apart, producing a structure known as fissility. Whatever the nature of these fractures, they will average a lower inclination than joints, although in some rocks, as in the chlorite schist and phyllite west of New Haven, they are nearly vertical.

Variation in jointing.—In the schists and similar rocks, with a marked schistose structure, such as the schistose granodiorite along the coast east of Greenwich, there is usually one direction or system of jointing that is more prominent than any other. This main system

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[a] Hobbs, W. H., The Newark system of the Pomperaug Valley, Connecticut: Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 3, 1901, pp. 7-162.

is, as a rule, accompanied by a wider spaced and less well developed series of joints intersecting the main series at high angles. In the schistose granodiorite the jointing is well developed, rather closely spaced, and very uniform in direction. In the schists the joints maintain a fairly uniform trend, but are commonly very tight, and in much of the rock die out within short distances. In most exposures one or two distinct series of joints can be distinguished, and many small irregular fractures connecting the main joints occur near the surface, but disappear at relatively shallow depths.

In the granitoid rocks the vertical joints are generally more open and continuous than those in the schistose rocks, but usually lack their characteristic regularity of arrangement in series and are ordinarily more widely spaced. Although in many of these rocks there is one set of joints with a general parallel direction, even in the joints which may be classed in the same series there may be a variation of 10° to 20° in direction, and other vertical joints may intersect these with no regularity of arrangement with reference to each other. This is the usual occurrence of jointing in the Connecticut crystalline rocks of this class, but in certain places two, three, or even four distinct sets of joints may be distinguished.

The limestones of the State are even more irregularly fractured than the granites and the fracturing is usually so close as to prevent the use of the rock as building stone. Joints cut these rocks at all angles, and the general shattering has produced more open space than in any other type of rock which might be classed as crystalline.

No general conclusions on the occurrence of vertical joints in the crystalline areas of Connecticut will hold for every portion, as there is great variation in their occurrence within short distances, even in the same formation. On the other hand, the horizontal joints have a very uniform mode of occurrence for all the granitoid rocks. They are approximately parallel to the rock surface, except where influenced by local factors such as structure planes, and are spaced at fairly uniform distances from one another. They are everywhere curved or wavy and intersect one another at varying intervals, dividing the rocks into a series of approximately horizontal wedges with curved faces. The principal variation is in the closeness of these intersections. In some places the horizontal joints intersect one another every 20 or 30 feet; in others they run parallel to one another for 100 feet or more. In general the horizontal jointing is more regular, though not necessarily better developed, where the amount of vertical jointing is small. A good example of this may be seen in the gneissoid granite quarry at Monson, Mass., where there is an excellent parallel horizontal jointing but vertical joints are almost lacking and except at the immediate surface are filled with vein material.

FAULTS.

Faults may be considered as extreme types of joints in which there has been movement of one wall of the joint plane past the other. The work of Hobbs, Davis, and others has shown that there has been a considerable amount of faulting in Connecticut, and it is not uncommon to find strongly marked shear zones, indicating slipping in the crystalline rocks. These are rather rare phenomena, however, and are seldom encountered in well drilling; accordingly they will be treated simply as special cases of jointing. They are probably very important as channels for spring waters, although it is extremely difficult and generally impossible to ascribe any particular spring to a fault plane.

CIRCULATION AND STORAGE OF WATER.

The circulation of water in the crystalline rocks, being confined to openings of the sort discussed in the foregoing pages—that is, those having great length as compared with their thickness—is necessarily limited by the abundance of these planes of parting, by their degree of opening, and by their intersection of one another; and there are many modifying factors, such as local entrance conditions for surface waters, local textural variations in the rock, intrusions and inclusions of other rocks, and the restraining effect of overlying glacial drift.

INFLUENCE OF JOINTS AND OTHER OPENINGS.

Spacing of vertical joints.—The vertical joints, which are the important water carriers, have no regularity of spacing even in the same rock. These joints are much more closely spaced in natural outcrops, owing to the influence of weathering, and in railroad cuts where there has been heavy blasting than in quarries where the natural conditions prevailing in the rock below the surface are exhibited. In such natural exposures the spacing of joints was found to vary from a fraction of an inch up to 200 feet or more. The extremely close jointing occurs only in sheeted or shear zones which vary from a few inches to 2 feet in width, and these sheeted zones are a considerable distance from one another. Instances of such close sheeting as to give a spacing of 1 inch are exceptional, and are found in relatively few exposures. The same general occurrence on a larger scale, however, is typical of vertical jointing. In every quarry observed in Connecticut where jointing is developed over a considerable area the joints were found to be much more closely spaced at certain points than at others, constituting a series of zones of close jointing separated by intervals in which the distances between joints are much greater. These zones of close jointing vary from 1 foot to 15 feet in width and the joints making up the sheeted areas are spaced from 3 inches to

2 feet apart. Purington[a] describes a similar but more regular occurrence in a Colorado mine where, along the side of a drift, fissures 30 feet apart become nearer and nearer together until they are only 3 or 4 inches apart, forming a sheeted zone, beyond which the intervals gradually increase.

A number of observations on joint series in the Connecticut crystalline rocks indicate that at the places where jointing is well developed the average spacing is between 3 and 7 feet. It is very difficult to form an estimate of the average spacing for all rocks, however, for in some localities, as in the quarries at Monson, Mass., and Sterling, Conn., there are exposures of several acres where the rock has been quarried, and not more than three or four open joints can be distinguished in the entire quarry, giving a spacing of at least 100 feet. Here and there older joints may be distinguished which have been filled with vein material, but these can yield no water under present conditions.

If it were supposed that all the vertical joints were placed in parallel planes, both major and minor series, it is probable that the average spacing would not be less than 7 feet to a depth of 50 feet from the surface. The average spacing between vertical joints of the same series for the crystalline rocks, exclusive of trap and limestone, is more than 10 feet for this same zone of 50 feet from the surface, as shown by field observations, and the study of well records indicates that this is not far from the average spacing for all joints to a depth of 100 feet.

Spacing of horizontal joints.—The horizontal joints present much greater regularity of spacing than the vertical joints. They are apparently surface phenomena and diminish in number rapidly with increasing depth; it is probable that they do not exist at a depth of 200 feet. For the first 20 feet below the surface these horizontal joints average 1 foot apart, for the next 30 feet they average between 4 and 7 feet, and for the next 50 feet they are much more widely spaced, being from 6 to 30 feet or more apart.

Continuity of horizontal joints.—The length of individual horizontal joints rarely exceeds 150 feet, but owing to their intersection of one another they may constitute a continuous opening several hundred feet long, which would have the form of a curved sheet approximately parallel to the hill slope, each lower sheet having less curvature than the one above. They are probably better developed on the hills than in the valleys, as the pitch of the joints is usually less than the slope of the surface, which consequently cuts across the joints. Moreover, as they are more widely spaced with depth the horizontal joints that cross the valleys are widely spaced.

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[a] Purington, C. W., Preliminary report on the mining industries of the Telluride quadrangle, Colorado: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 765-769.

Continuity of vertical joints.—There are two directions in which vertical joints may have great length—vertically, or along their dip, and in the direction in which they cut the surface. No mathematical relation between these two directions has been determined, but it has been assumed in the study of ore deposits that a fracture will have about as great extent along the dip plane as along the strike plane.[a] The degree of continuity is very uncertain owing to the difficulty of direct observation on either the entire length or the depth of any joint, and to the fact that a joint may exist with its two sides so closely pressed together that the fracture is not apparent to the naked eye. It is certain that some joints are far more continuous than others and that many die out within very short distances both vertically and laterally. Faults have the greatest continuity and may extend for several miles across the country, or even for tens of miles. The sheeted zones of closed jointing are probably almost as continuous as faults, and their dimensions should be measured in hundreds of feet. Where there is a well-defined series of parallel joints the prominent joints may extend for several hundred feet, while the minor intersecting joints will be much shorter.

Fissility and schistosity openings.—The circulation of water as determined by structure planes has not been discussed up to this point because the evidence is not as clear as in the case of joints. Although it is probable that the absorptive capacity of a schist would be greater than that of a slate, owing to the larger size of the grains, the porosity would still be too small to allow any circulation in the pores. In a crumpled schist there are probably small openings between the folded laminæ, but these must be discontinuous and would not allow sufficiently rapid circulation for well supply. However, there are nearly everywhere fractures of considerable extent parallel to the schistosity, but with much less regularity of occurrence than the joint planes in the same rock. These fractures also are much less continuous than joints and die out within short distances.

In such discontinuous fractures the circulation would be comparatively slow, but sufficient for well supply. Small springs issue from such fractures at many places, as along the east bank of Connecticut River above Hadlyme Landing. These fractures are much more numerous near the surface, particularly where the dip of the schistosity is in a low plane, and become tighter and less abundant with increasing depth.

Intersection of fractures.—It has been shown that the main circulation of water available for well supplies in crystalline rocks is along jointing planes, and it will be shown later that some joints carry a

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[a] Ransome, F. L., Economic geology of the Silverton quadrangle, Colorado: Bull. U. S. Geol. Survey No. 182, 1901, pp. 61, 62.

greater amount of circulating water than others. It is evident that the intersection of joints with one another is a very important factor in determining the degree and direction of the underground-water circulation.

The manner of occurrence of joints indicates that such intersection may be found in every possible direction, but that there will be much better connection in some of them than in others. In the granitoid rocks, where the vertical joints have little regularity of arrangement and therefore intersect one another at many points, and where the horizontal joints are nearly universal, there is a thorough connection between the various fractures of the upper zone in which the horizontal joints occur. In the schists and schistose gneisses, in which the joints are usually more regular in arrangement and in which the horizontal joints are poorly developed, the connection between the various joints is less complete. In these schistose types, as in the granitoid rocks, there are invariably cross joints connecting the main systems, but they are commonly considerable distances apart and are tighter than the main joints, so that the opportunity for lateral transmission of water from one joint to another parallel joint is less than for longitudinal transmission along the main joints. The connection of the small and discontinuous fractures in the planes of schistosity is much poorer than that of the joints.

Opening of joints.—The degree of opening between the walls of joints is exceedingly variable and very difficult to measure. At the immediate surface many joints have an opening of half an inch to 2 inches, or even much greater. This wide opening is due to various weathering and mechanical agencies, which act only near the surface, and consequently is not found at depths below which these agents act. In an artificial cut, such as a quarry wall, many of the joints which may be open half an inch at the surface are too tight to admit a knife blade at a depth of 25 feet.

The joints at 30 feet below the surface may have only one-twentieth the opening that they have at the surface, but the same proportionate tightening will not continue at lower depths, although it is certain that the greater the depth the greater must be the tendency of joints to close, owing to increased pressure and to the smaller opportunity for lateral expansion below the level of minor topographic relief.

The closing with increasing depth is, of course, a measure of the vertical continuity of the joint, and it seems very probable that there is a direct relation between vertical and longitudinal continuity. Accordingly there is a great variation in the depths at which different joints close; the smaller joints close at moderate depths, but the larger joints continue to varying greater depths according to their importance.

If the above statement holds true, the closing of the joints produces not only a tightening with increasing depth, but also a decrease in number or a widening of the space between joints. This principle applied to the vertical joints is closely analogous to the tightening and increase of spacing of the horizontal joints with increasing depth, which may be observed at nearly any granite quarry, although the causes producing the two types may be different.

The application of this principle in the drilling of wells is of the utmost importance, as it is frequently asserted that water can always be obtained by going deep enough, whereas the deeper the well the less the chance of striking fractures, which are the only passages permitting water transmission in crystalline rocks. It is evident that, owing to the closing with depth, there will be a much greater circulation in the upper half than in the lower half of any individual joint.

Though many of the joint openings are supercapillary in size, most of them are probably of large capillary size. The upper limit of capillary sheet openings is about one one-hundredth of an inch, which gives an opening of appreciable size, but in a freshly quarried wall the greater proportion of the joints have manifestly less width than this. A rough estimate of the degree of opening of joints may be made from the yield of wells in the crystalline rocks, which average about 17 gallons a minute, although the greater number give less than 15 gallons a minute. The average well intersects between three and four joints, and this number of saturated joints would supply much more than the average yield of the wells if the openings were appreciably larger than capillary size. These openings, however, must be toward the upper limit of capillarity in order to yield 10 to 15 gallons a minute. Some wells undoubtedly pass through openings of much greater width than 0.01 inch, and nearly every well driller can cite several instances when his drilling tools have suddenly dropped several inches. Although the driller usually considers the sudden fall of the tools to indicate an open crevice, the probability is that no actual open space exists, but that a fracture has been encountered in which decomposition has softened the rock walls to such an extent that the material offers little or no resistance to the heavy drill. Nearly every quarry in the crystalline areas of Connecticut gives examples of such decomposed strips bordering joints, but such an occurrence as an opening wider than a fraction of an inch in crystalline rocks, except at the immediate surface, is practically unknown to quarrymen.

It is probable that openings of considerable size occur along fault planes, but faults are relatively few as compared with joints, and there is small chance of a drill hole penetrating them. Some of the wells of larger capacity may derive their water from such fault openings, although more probably it comes from a closely sheeted zone.

Number of contributory joints.—The number of fractures supplying water to a single well varies greatly in different wells. In some wells the greater part of the water appears to come from a single opening; in others the water comes in slowly from a large number of openings. In the average well there are from one to four horizons at which the principal supplies of water are obtained, although the yield from one of them is usually greater than that from all the others together. This is particularly true of the wells from 200 to 300 feet deep, in which the principal source is usually very close to the bottom of the well.

From the character of the fractures in the varying rocks it seems probable that the wells in gneiss and the deeper wells in granite derive their main supplies from one or two comparatively large openings, but that in the more schistose rocks the fractures contributing water are more numerous but less open. In the upper portions of the wells in granite the horizontal joints contribute a series of small supplies below the point where the water level is struck.

If an average inclination of 70° from the horizontal and an average spacing of 10 feet is assumed for the vertical joints for the upper 200 feet of rock, each well 200 feet in depth would intersect seven joints. This is probably not far from the average for all the wells, exclusive of the small and discontinuous fractures near the surface. Below 200 feet the average number of joints intersected would be somewhat decreased for the next 100 feet and greatly decreased at lower depths than 300 feet. It is evident that in some localities the joints are much more closely spaced than in others, that locally they are highly inclined and elsewhere lie at low angles, and that all these factors modify the number of fractures which a well intersects.

WATER LEVEL.

If the fractures were all equally open and had complete connection with one another, there would be a zone of saturation in the crystalline rocks and the upper surface or water table of this saturated zone would follow rather closely the shape of the rock surface, as in sand or other homogeneous porous material. Under such conditions the water in adjacent wells should rise to the same level. In homogeneous sands the upper limit of the saturated zone is called the water table. In describing the occurrence of water in joints the term "water level" will be used to indicate the upper limit of the saturated portions of the joints.

Observation shows that the fractures are of greatly varying degree of opening, and that although most of them are connected with one another in some way the connection is much better in some places than in others. It is to be expected that under such conditions water will rise to different heights, even in joints which are close together, when there is no connection or very poor connection between them. As a typical instance of such variation may be cited the wells drilled for the Fitch Home for Soldiers at Noroton Heights, Conn. One well was drilled to a depth of 425 feet in the bottom of a small valley, resulting in a flow of 4 gallons a minute that rose more than 7 feet above the surface. A second well was drilled 130 feet away and at an elevation only 4 feet higher, to a depth of 503 feet, and in this well the water rose only within 15 feet of the surface. Both wells passed through about 12 feet of hardpan. The difference of pressure head in these wells, only 130 feet apart but evidently deriving their water from different fractures, is therefore more than 18 feet. Both these wells give heavy yields on pumping and the pumping of the second well does not affect the flowing well, although it lowers the level of the water in an old drilled well higher on the hillside. Similar occurrences have been noted at other places, even in wells less than 100 feet deep.

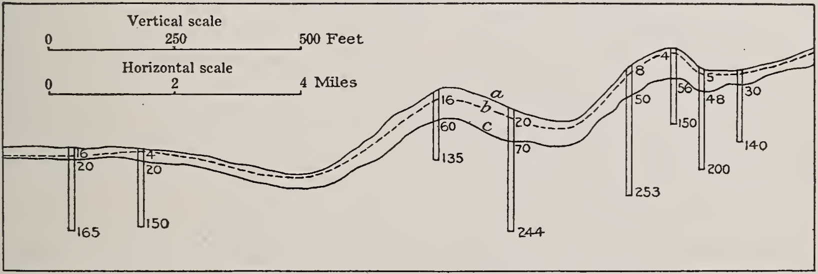

FIGURE 13.—Sketch showing relation of water level to topography. *a*, Surface of ground; *b*, line indicating height at which water stands in wells; *c*, rock surface.

Although there are local irregularities in the water level in the crystalline rocks, such as that just described, the general surface of the saturated zone still follows the topography, as is shown by the heights at which the water stands in the various wells. (See fig. 13.) The following table indicates the relation of the level at which the water stands in the wells to the surface of the rock:

Relation of water level in wells to surface of rock.

Position.	Number of wells averaged.	Percentage with water level—		
		Below rock surface.	Above rock surface.	Even with rock surface.
Hills	42	61.9	26.2	11.9
Valleys	24	12.5	87.5	0
Slopes	35	48.5	40.0	11.5

It is thus evident that on the hills the water tends to stand below the rock surface, but that in the valleys it is under sufficient hydrostatic head to rise above the rock surface and under favorable conditions to cause flowing wells.

At many places on the hills the tendency of the water level in the crystalline rocks to stand lower than the rock surface gives rise to an unsaturated zone immediately below the drift, although the lower portion of the drift itself may be completely saturated and furnish excellent supplies for comparatively shallow dug wells of large diameter. The existence of such an unsaturated belt is believed to be due to the facts that the movement of water in certain places is more rapid through the upper fractured portion of the rock where the joints are open than through the relatively small capillary openings of the drift and that the water, having opportunity to escape from the rock crevices at some point lower than the entering point, is carried away down to a certain level faster than it is furnished. In some localities, however, where the fractures do not allow escape at lower levels, the water table of the drift and of the rock may be the same; that is, in wells deriving water from rock seams the water may rise to the same level as in open wells in the drift above. However, owing to the generally rapid movement in fracture planes the general water level tends to approach a flatter plane in crystalline rocks than in porous materials like sand, where there is greater frictional resistance to water flow and where the effect of capillary flow is greater.

The term "water level," as used in reference to the depth below the surface at which water stands in the openings of crystalline rocks, in its broad sense, implies a surface with much smaller differences of elevation than the water table of a sandstone area having similar topographic relief, but with much greater minor irregularity, owing to the great variation in the water channels. The larger fractures extending for long distances usually have some outlet to the surface, but in many of the smaller joints the water passes from one joint to another with no surface outlet. The fast flow in the larger joints lowers the level of the water in these and connected joints below that in neighboring unconnected joints having poorer outlets. Even in a connected series the water level will have different heights in joints of varying opening, owing to the faster flow in the more open joints, where friction is less.

DIRECTION OF CIRCULATION.

The movement of water entering any joint above the point where it is saturated with water will be mainly vertical along the dip or inclination of the joint. The circulation below the water level in any joint is both vertical and lateral. The lateral motion, along the strike of the joint, predominates, owing to the fact that the length of the outlet or outlets for any particular joint is much smaller than the total length of the joint. Any connected series of joints there will manifestly have a very complex circulation, but the main circulation will be toward and along the fractures having the largest openings and the nearest outlets, and in these fractures the general movement will be in the direction in which the land slopes.

DECOMPOSITION AS A MEASURE OF CIRCULATION.

The relative importance of various joints in the water circulation is indicated by the decomposing effect of the water on the walls of the fracture planes. The oxidizing surface waters carrying carbon dioxide and organic acids naturally react on the minerals in the rock walls, the action being indicated in some places by a mere reddish-brown staining of the joint sides and here and there by a breaking down of the mineral particles, giving rise to a disintegrated border along the joint plane. There is a great difference in the amount of this weathering, even in joints which may be adjacent members of the same series, indicating that some joints are heavier water carriers than others of the same age, probably owing to greater opening and in some of them to better entrance conditions. The areas of greatest decomposition are along the sheeted zones, and next along the most continuous vertical joints, and in these fractures the weathering extends down to the limit of observation, with no apparent change. In the minor joints the weathering effects are less conspicuous and usually appear to the observer as mere discolorations, extending from half an inch to 3 inches or more on each side of the joint plane and becoming less marked with increasing depth.

As a rule the horizontal joints of the granitoid rocks show less weathering than the minor vertical joints. Though usually discolored and weathered near the surface, the walls of these joints are commonly unaltered at a depth of 20 feet. However, where the horizontal joints are cut by a prominent weathered vertical joint, the weathering effect extends along the adjacent horizontal joints to a very marked degree, diminishing in amount with increasing distance from the vertical joint. This feature is well shown in the granite gneiss quarry of the Rhode Island Brown Stone Company, 1½ miles west of the railway station at Oneco, Conn. At this quarry a heavy discoloration extends along the flat joints for a distance of 25 feet from a vertical joint, gradually diminishing in intensity. Occasionally a flat joint is found which is weathered throughout its exposed length. (See Pl. III, *B*.)

In the sheeted zones it is common to find a strip of disintegrated material from 1 to 6 inches in thickness and in the large single vertical joints similar but narrower bands of disintegrated rock occur.

Through such material as this a large amount of water can pass with comparative ease.

If the degree of decomposition along joint planes is taken as a criterion of the amount of circulation along the joints it would appear that the circulation is mainly along the large vertical joints, next along the minor vertical joints, and in small amounts along the horizontal joints. Although this statement is probably true as to the proportionate amounts of circulation it does not mean that the unweathered vertical or horizontal joints are dry. The probability is that the lower horizontal joints are saturated with water, but that owing to the relatively flat planes in which they lie and their tendency to tighten at their intersection with one another, the water has a very feeble circulation.

The horizontal joints are probably much younger than the vertical joints and weathering has had less time in which to act, but the fact that some are weathered more than others indicates that even in these joints, which are manifestly of the same age, some offer better conditions than others for water circulation.

STORAGE OF WATER.

The wells in the crystalline area of Connecticut are remarkably constant, showing little variation in yield or depth of water, either annually or through a period of years. In some the yield has increased since the well was drilled and in a few it has decreased, but most of the wells have shown no appreciable change. The level to which the water rises in the wells shows nearly as great constancy as the yield, although in the shallower wells the water level varies somewhat with seasonal variations in rainfall, and in some of the deeper wells a lowering of water level has been noticed in unusually dry years. These fluctuations are most conspicuous in wells of small yield. In nearly all wells the water level is lowered to a greater or less extent on pumping, until by this lowering a sufficient increase of head is obtained to give an increased rapidity of flow, which will furnish a yield equal to that pumped out. When the pump is stopped the water will gradually, or in some wells very rapidly, rise again to its normal level. Minor fluctuations are probably more common than is reported, as changes in level are not readily noticed in covered wells. However, it is evident that there must be a very constant supply of underground water to maintain so constant a level in the wells.

The total average yearly rainfall in Connecticut is 46.89 inches, rather uniformly distributed throughout the year, and this uniformity of precipitation will, under natural conditions, with no artificial removal of water, give a fairly constant level for ground water in the rocks. If 25 per cent of this amount of rainfall is assumed to be absorbed by the rocks—undoubtedly a considerably higher percentage than is actually absorbed—the total amount absorbed by an area of rock 100 feet square is 9,768 cubic feet, or 73,260 gallons. A well pumping 15 gallons a minute, which is about the average yield of wells in the Connecticut crystalline rocks, would draw out this amount in 81.4 hours. A well of this capacity pumping for 300 days during the year for one hour a day would withdraw an amount of water equal to 25 per cent of all the water falling on an area within a radius of 108 feet around the well. Probably 10 per cent of the precipitation more nearly represents the proportion absorbed by the rock than 25 per cent, and if so a well pumping at the rate above indicated would draw all the water on an area more than twice as great. When it is considered that some wells are pumped at the rate of 30 gallons a minute for ten hours a day throughout the year, it is evident that a single well may drain a very large area of all the water it absorbs.

With an average spacing for all fractures of 5 feet and an average opening of 0.01 inch, the saturated fractures in 1,000,000 cubic feet of rock, equivalent to a depth of 100 feet for a surface area 100 feet square, would hold 833 cubic feet of water, which a well with a capacity of 15 gallons a minute could pump out in seven hours if there were no renewal of the supply.

These figures are sufficient to indicate that the area contributing to any one well must be very large to maintain a constant level for the water in the well. Owing to the shape of joints and the manner in which they intersect one another this contributing area will be in the form of a number of long and comparatively narrow intersecting belts, and the well will draw water from very long distances. Wells on islands surrounded by salt water have been successful in obtaining supplies of fresh water, but they are usually moderate in yield and frequently somewhat contaminated by salt water, so that as a general rule fresh water obtained in these locations consists of that which has fallen on the island itself. Fuller,[a] however, cites a well on Fishers Island, 3 miles from the Connecticut coast, that penetrated 281 feet of unconsolidated gravel, sand, and clay in which salt water was found, and obtained fresh water in the crystalline rock below. No outcrops of crystalline rock occur on this island, and it seems clear that the fresh water must have come through the joint openings from the mainland 3 miles away. The water is evidently held in the rock openings by the restraining covering of clay above the rock.

As the head in all the wells is fairly constant, it is evident that the yield in any well is proportional to the number and opening of the fractures contributing water. As the heaviest yields are derived from the most open joints, and as these joints are the most continuous

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[a] Fuller, M. L., Geology of Fishers Island: Bull. Geol. Soc. America, vol. 16, 1905, p. 372.

(see pp. 66–67), the following relation holds: The yield of water from a joint is proportional to its continuity, which depends partly on the number of intersecting joints and which consequently determines the area contributing to the wells. If this relation is true, and the yield is proportional to the contributing area, it follows that there will be no permanent change of head in the well until the amount withdrawn by the well is greater than the annual absorption of rainfall throughout the contributing area. This statement may be made in another way: When a small amount of water is pumped from a well the contributing area is small, but as larger amounts are pumped the contributing area is increased and the more remote connecting joints give their contribution to adjust the difference of level caused by the tendency toward depressions of the water level in the immediate vicinity of the well. Owing to frictional resistance to flow there will, of course, be some depression at this point, but it is probably relatively small. When the amount withdrawn by the well annually is greater than the amount annually absorbed by the contributing area the water level in each connecting joint is lowered and a permanent lowering of the water level results. As any lowering of the water level means a loss of head for the well, and as the head determines the rapidity of flow into the well, it is evident that when the water level is lowered the yield of the well will immediately decrease.

TABULATED WELL RECORDS.

The following tables, with the notes succeeding them, comprise the information obtained regarding the wells in the crystalline rocks. Logs of four of these wells are shown graphically in figure 14.

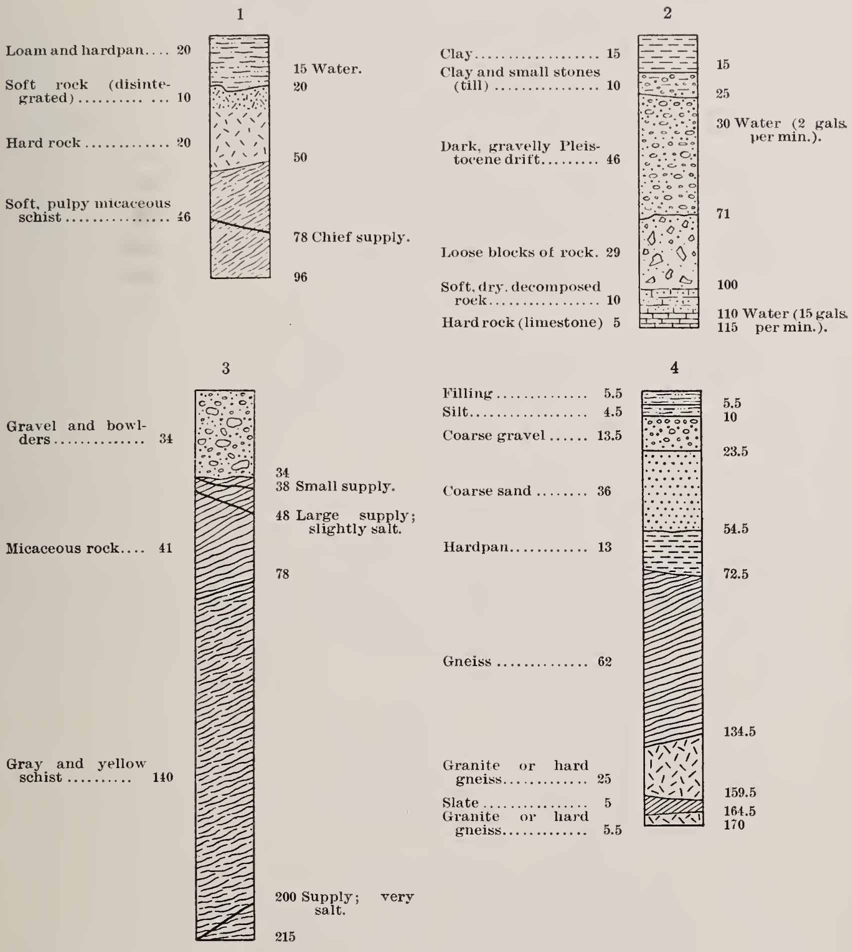

FIGURE 14.—Logs of wells in crystalline rocks. 1, Well of Thomas Fogarty, Ansonia; data furnished by C. F. Underwood. 2, Well of Miss E. O. Wheeler, Sharon; data furnished by A. J. Corcoran. 3, Well of Atlantic Starch Works, Westport. 4, Well of Sidney Blumenthal Company, Shelton; data furnished by the company.

Records of wells in crystalline rocks of Connecticut.

No.[a]	Town.	Locality.	Owner.	Topographic position.	Depth to rock.	Depth of rock.	Depth of well.	Depth of principal source.	Depth to water.	Variation of water level.	Yield per minute.	Diameter.	Temperature.	Quality.	Use.	Rock in which well is drilled.	Cost per foot.
					Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Galls.*	*In.*	° *F.*				
1	Ansonia		Ansonia O. and C. Co.	Valley plain			209	209	20		16	8			Bleaching	Granite or granodiorite.	$5.00
*2	do		Thos. Fogarty	Hill	20	76	96	78	15		20	7		Med. hard.	General	do	4.50
3	do	Woodbridge Hill.	Mrs. Gilbert	do	10	90	100				Small.					Phyllite	
4	Barkhamsted		C. H. Tiffany	do			15	14½	6	Seasonal to 0.		33	45	Soft	Domestic	Schist or gneiss.	
5	Bethany		Arthur Doolittle				25	20	12		[b] 1,000			do		Slate	3.00
6	do		Albert Hosely	Slope			68			Seasonal	3	6		do	Domestic, stock.	Granodiorite.	
*7	do		H. F. Peck	Ridge	14	36½	50½	50½	16	do	3	6	48	Hard	Domestic	do	
8	Branford	Stony Creek	E. H. Coe	Shore, elevation 8 feet.			20		7	do					do	Granite	
9	do	do	Jas. S. Elton	Island	2	148	150			Pumps dry	[b] 250					do	
*10	do		J. C. Anderson	Island, elevation 6 feet.	2½	92	94½		10		Good.					Gneiss	
11	do	Short Beach	J. D. Welch	Slope, elevation 20 feet.	13	87	100	94	13	Constant	6	6		Hard	Stock, lawn	Gneissoid	5.00
12	Bridgeport		Hartman Brewing Co.	Valley plain	90	165	255		35			10	51	do	Brewing, condensing, washing.	Schist or granodiorite.	
13	do		do	do	11½	40	15½		15	Constant	35	6	51	Med.	Brewing, washing, boiler.	do	4.00
14	do		A. Städtler	Hill	8	69	77	80	30	do	15	6		do	Drinking	do	6.50
15	do		Naugatuck Valley Ice Co.	Valley plain	42	648	690	120	18		8	8	52	Hard	Condensing.	Granodiorite.	
16	do		do	do	42	108	150				0			do	do	do	
17	do		do	do	42	8	50				10			do	do		
*18	Bristol		New Departure Mfg. Co.	Valley	50	265	315	75–150	12	Pumping lowers to 80 feet.	20	8, 6	54	Soft	Boilers	Granite	
19	Brooklyn		Church of Sacred Heart.	Slope			106	106	28		12	6		Hard	Drinking, boiler.	Gneiss	3.00
20	Canaan	Falls Village	Dwight E. Dean		50	105	155		50	Constant	10	5		Med.	Domestic	Limestone	2.00

21	Chatham	EastHampton.	Lake View Cemetery Assoc.	Hill	8	27	35	35		Seasonal	Small.			Hard	Watering	Schist or granite.	
22	do.	do.	Mrs. S. B. Childs.	do.	13	162	175	174	2	Slight seasonal.		60		Med. soft.	Domestic	do.	5.00
23	do.	do.	N. N. Hill		6	48	54		4		3+	6		Hard	General	do.	5.00
24	do.	do.	D. A. Rich	Slope	6½	42	48½		7		½	6		Soft	Domestic	do.	5.00
25	do.	do.	Chas. Lucas	do.			38	35						do.	do.	do.	
26	do.	do.	Center School district.	Slight elevation.	1	29	30	25	18	Seasonal		6		Hard	General	do.	4.00
27	do.	do.	N. N. Hill Brass Co.	Stream bed	6	121	127	40	4		10+	6		Iron	General, factory.	Schist	3.25
28	do.	do.	A. N. Conklin		7	23	30	20	3			36		Hard	Domestic	Schist or granite.	3.35
29	do.	do.	F. S. Hall		22	14	36	28	22		⅚					do.	
30			Mrs. I. H. Stone.	Hill	0	142½	142½	142½	50		10	6		Med. soft.	Domestic	Gneiss	
31	Colchester		Dr. E. B. Craigin.	Hilltop	16	185	201	185	9		7	6		Iron		Schist	
32	do.		Danl. W. Williams.	Slope			81					6		do.	Stock	do.	
33	do.		Chas. N. Taintor	Hill	10	92	102	90	12	Siphoned and constant.		6 6		Iron, soft.	Domestic, stock.	do.	3.50
34	Colebrook		H. D. Northrop	do.	10	67	77	First at 55.	17		2½	6		Med	do.	Gneiss	4.50
35	Coventry	Mansfield Depot.	Dr. F. E. Johnson	Plain	10	30	40	40			Small.	6	50	Soft	Stock	Schist	
36	Danbury		Geo. N. Frost	Slope	1½	44½	46	44	16		3	3	50	do.		Granodiorite or gneiss.	
37	do.		Chas. H. Brundage.	do.	6	48	54	51	18	Constant	Good.	4	51 48	do.	Domestic	Gneiss	
38	do.		do.		0	68	68	62	15		Very large.			do.	Stock	do.	
39	do.		District school		3	69	72				Large.			do.	General	do.	
40	do.		V. B. Buck	Hill	4	108	112		30		Good.	6		do.	Domestic	do.	
41	do.		G. H. Knapp	Hill slope	6	65	71	71	6		Fair.	4	54	do.	do.	do.	
42	do.		Leonard Salmons	Plain	12	40	52		12		Small.	4	50	Hard	do.	do.	
43	do.		Alexander Turner		30	152	182		20			6		Soft	Domestic, garden.		5.00
44	Darien		Geo. P. Brett	Hilltop	50	180	230	220	20	Constant	20	6		Hard	Domestic	Granodiorite.	
*45	do.	Noroton Heights.	Fitch Home for Soldiers.	Small Valley	13	490	503	400	15		26	8	56		General	Gneiss	
*46	do.	do.	do.	do.	12	413	425	335–425	Flows+7	Pumping lowers to 80 feet.	4 flowing, 50 pumping.	8	53		do.	do.	
47	do.		Dr. Delafield				126		18		10	6				Granodiorite.	
48	do.	Noroton	William Zeigler	Island	Small.		200				Poor.			Salty		Gneissoid granite.	

[a] Additional details concerning wells marked * are given on pp. 90–91.

[b] Per day.

Records of wells in crystalline rocks of Connecticut—Continued.

No.	Town.	Locality.	Owner.	Topographic position.	Depth to rock.	Depth of rock.	Depth of well.	Depth of principal source.	Depth to water.	Variation of water level.	Yield per minute.	Diameter.	Temperature.	Quality.	Use.	Rock in which well is drilled.	Cost per foot.
					Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Galls.*	*In.*	*°F.*				
49	Darien	Noroton	William Zeigler	Island	Small		1465				3			Brackish.		Gneissoid granite.	
50	Derby		Derby and Ansonia Brewing Co.	Valley plain	80	85	165				30	6				Granite	
51	East Haddam	Hadlyme	H. Weinstein	Slope	30	70	100	99	30		1	6		Hard	Domestic	Schist	
52	do	do	Allen Willey	do	3	57	60	55			Small.	6		Soft	Drinking	do	
53	do	Moodus	F. B. and S. P. Clark.	do	4	36	40				Good.			Hard	Domestic	do	
54	do		Geo. Wykes	Hill	0	100	100	75	53	Pumping lowers.	1½	6	40	Soft		do	
55	East Haven	Fair Haven	Andrew Holleran				66½				5	4		Med.	General		
56	East Lyme	Niantic	Andrew Champion.	Coast, elevation 10 feet.	39	29	68	65	5	Constant	20	6			Domestic	Granite	
57	do	Crescent Beach	Atwood Collins	Plain	28	66	94	80	20		2½				do	Gneiss	
58	Easton		E. F. Wheeler	Hill	11	114	125	110	30	Slightly affected by pumping.	15	6	50	Soft	Sold	Granite, schist.	$4.75
59	Essex		Essex Wood Turning Co.	River flat			212							Salty			
60	Fairfield	Southport	J. H. Perry	Small elevation	10	158	168	160	10		3	5		Hard	Domestic	Schistose gneiss.	3.00
61	do	do	Miss Frances Wakeman.	Hill			190		10	Constant				Soft	do	do	
62	do	Greenfield hill	S. Pease		9	13	22	18	4			36		do	do		
63	Franklin	Yantic	G. E. Starkweather.	Slope			12	10				48		do	do	Schist or gneiss.	
64	Greenwich	Sound Beach	A. A. Marks	Slope, elevation 30 feet.	0	20	20	18	3	Seasonal				do	Boiler	Granodiorite.	
65	do		Emil L. Boas	do	65	235	300	240			12	8		Med.	Domestic, garden.	Granite	
66	do		Mrs. A. W. Mansfield.	Hill	2½	117½	120	50	8		30	6		Iron	Domestic	Granodiorite.	
67	do		H. O. Havemeyer	do	35	140	175	150	50	Constant	50	6	55		General	do	7.00
68	do		Wm. S. Todd	Slope	10	133	143		10	Lowers		6		Soft	Domestic, stock.	Granite	
69	do		John Mahar	Slope	22	178	200	160	Flows.		Pumps 70					Granodiorite.	
70	do		Jaynes Parh	Base of hill	8	52	60	48	Flows.					Soft		do	

71	Greenwich	Sound Beach	E. C. Benedict		0	225	225				37			Brackish.		Granodiorite.	
72	do		do		0	265	265							do		do	
73	do		E. W. Bullinger		4	249	253				1						
74	Griswold	Glasgo	J. G. Bill	Hill	6	56	62	60	22		12	6	50	Hard	Domestic	Gneiss or gabbro.	
*75	do	Jewett City	Aspinook Co	do			30 60		12–20		*a* 10			Soft	Drinking, washing, bleaching.	Gneiss	(*b*)
76	Groton	Eastern Point	J. Hunt Smith	Elevation 20 feet.	9	55	64	50	40	Said to vary with tide.		6			Domestic	Granite	
77	do		Thos. W. Avery	Hill	20	95	115	100	30	Rapidly lowered.	Poor.	6	50			do	
78	do	Eastern Point	do	do	15	45	60	40	10	Lowered to 35 feet.	Good.	6			Domestic	do	
79	do	Mystic	Miss Alice Damon.	do	12	74	86	86	6		2½	6		Med.	General	Granitic gneiss.	$4.00
*80	do	do	Oral school	do	20	528	548		10		21(?)				do	do	
81	do	do	Benj. Barrows	do	0	30	30		8		2						3.00
*82	do		J. F. & N. D. Sevin.	Slope, elevation 100 feet.	12	38	50	28–40	6		4	6		Med. hard.	Domestic	Granite	4.50
83	do		Capt. T. Hamilton.	Hill			290	280	30			6		Soft	do	do	5.75
84	do		C. H. Marquardt	do			100	90	30			6	45		General	do	6.00
85	do		G. W. Maxley	do	25	30	55		40	Pumps dry		6		Soft	Domestic	do	
86	do		Florence S. Kilern.	Coast plain			43		8			6		do	do	do	5.00
87	Guilford	Leete Island	Fred Butler	Hill	6	60	66	60	25	Pumping lowers.		6		do	Drinking	do	4.00
88	do	do	R. M. Leete	Slope	12	50	62	60	20	do	1	6	48	Med. hard.	General	do	3.75
89	do	Sachem's Head	N. E. Wordin	do	11	36½	47½	47	½	do	8	6	52	Hard	do	do	5.00
90	do	do	do	do	4	52	56	52	4	Pumping does not lower.	10+	6	52	do	do	do	5.00
91	do	do	F A. Cummings	Hillside	1½	45½	47	45	35			6		Soft	Domestic	do	
92	do	do	Mrs. G. B. Mitchell.	Near shore	2	68	70		4		¼					do	
93	do	do	Eng. Fish	do	6	211	217		5		35			Salt		do	
94	do	do	do	do	0	43	43		8		1½					do	
95	Haddam	Higganum	E. L. Webb	Hill	3	57	60	30	28		Good.	6		Hard		Trap dike.	
96	Hebron	Turnerville	Edw. W. Bill	do	16	85	101	65	6		60	6		Hard, iron.	Domestic, stock.	Schist	4.00
*97	Huntington	Shelton	Sidney Blumenthal Co.	Valley	73	97½	170½									Granite and gneiss.	
98	do	do	Oscar Wright		25	76	96	96			8					50 feet phyllite slate, 21 feet granite.	

a Average.

b Total cost, $1,597 for nine wells.

Records of well in crystalline rocks of Connecticut—Continued.

No.	Town.	Locality.	Owner.	Topographic position.	Depth to rock.	Depth of rock.	Depth of well.	Depth of principal source.	Depth to water.	Variation of water level.	Yield per minute.	Diameter.	Temperature.	Quality.	Use.	Rock in which well is drilled.	Cost per foot.
					Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Galls.*	*In.*	*°F.*				
99	Killingly	Danielson	S. C. Hutchins				50 80		0		4			Hard	General	Gneiss	
100	Madison		G. A. Wilcox	Rockyhill	8	55	63	63	8	Seasonal	Good.	6		Hard, iron.	Domestic, heating.	do	$5.00
101	do	North Madison	J. Heinemann	Hill	4	68	72				Large.	6		Soft	Domestic	Granite	
102	Mansfield	Storrs	Connecticut Agricultural College.	do	9	841	850	800	36	Pumping lowers slightly.	40	6	52	do	do	Schist	8.00
103	Middletown	Higganum	Inocente Tolette	do	18	132	150	125	8	Pumps dry.		6		do	do	Granite	4.00
104	Milford	Naugatuck Junction.	Chas. G. Root		30	45	75		30			6		Hard	do	Phyllite	
105	do	Naugatuck	J. O. R. Sheridan	Flat	0	43	43		6		1				General	Granodiorite.	
106	Monroe	Stepney Depot.	A. B. Curtiss	Slope	7	32	39		12	Constant		4		Soft	Domestic	Schist	
107	Montville	Uncasville	Mrs. E. R. Burchard.	do	20	80	100		15	do				Hard	do	Gneiss	
*108	do		Jacob Irons	do	2½	50	52½		2			6				do	
109	New Canaan		T. W. Hall	Hilltop	20	145	165	125	18	Constant	25	6	50	Hard	General	Granite	5.00
110	do		A. J. Gray	Slope	54	50	104		30	do	7	6	1	do	Manufacture of mineral waters.	do	5.75
111	do		B. Fischer estate	Ridge			130						50	do	Domestic	do	5.00
112	do		L. P. Child	Hill			156		64	Constant	15	6		do	General, greenhouse.	do	
113	do		L. D. Alexander	Ridge	35	215	248	240	15	Pumping lowers.	Good.	5	50	Soft	Domestic	do	
114	do		C. F. Diefenteler		60	93	153	153	18	Pumping lowers to 50 feet.	20					do	
115	do	New Canaan	Sturgis Coffin	Hill	56	94	150		4		18	6				do	
116	do	do	Mrs. W. E. C. Bradley.	do	50	203	253		8		40	6				do.[a]	

117	do	do	Dr. P. H. Williams.	do	48½	151⅓	200		5	Pumping lowers to 80 feet.	2	6				do	
118	do	do	Mr. Taggart	Slope	65¾	87¼	153		20		70	6				Redgrowth	
119	do	do	Miss C. A. Bliss	Hilltop	20	130	150		4		40	6				Granite	
120	do	do	Theodore Terrill	do	14	172	186		9		6					do	
121	New London		Consolidated Street Ry. Co.	Elevation 2 feet	60	73	133		2			6		Saline		do	
122	New Milford		H. H. Hartwell	Slope	5	60	65	60	5		1½	4	48	Hard, iron.	Domestic		
123	do		Mrs. O. W. Hoyt	do	22	38	60	55	25	Seasonal	2	4	51	Soft	do	Granite	
124	do		Henry S. S. Kinnlin.	Hill	5	57	62	40	10			5		Hard	do	do	4.00
125	do		W. D. Black	do			250				Good.				do	Limestone	
126	do	Boardman	Benj. Houghtailing.	Valley	13	44	57		30		3	3	51	Hard	do	do	
127	do	do	New England Lime Co.	Slope	5	45	50		7	Constant	Good.					do	
128	Newtown		C. G. Morris	Hill			20		4–20	Dries in summer.		36		Hard		Granodiorite.	
129	Norfolk		A. P. Curtiss		30	78	108		11	Constant	15	6		Soft	General	Gneiss	3.00
130	do		R. C. Burr		49	17	66		15		15				do	do	3.00
131	North Canaan	East Canaan	A. A. Lawrence		18	19½	37½	30	15			40	44	Hard	do	Limestone	
*132	Norwalk	South Norwalk	Jos. Himmel	Island, elevation 8 feet.			125	20	8		20			Salty	Not used	Granite	5.00
*133	do	do	Norwalk Iron Works Co.	Valley	80		260	60	6			8		Hard	Drinking	do	
134	do	do	Meeker Union Foundry Co.	Valley, elevation 4 feet.			107	100	5		Good.	6	45		Drinking, boiler.	do	4.00
135	do		Joseph Burns	Valley			247		10		25	6		Salty	Cooling	do	
136	Norwich		Ulmer Tannery Co.	do	20	95	115	80	15		10	6		Soft	None	Gneiss	
137	do		Montville Street Ry. Co.	Foot of hill			200	190	10				52		Boiler		5.00
138	do		Frich Co	do	0	265	265	170	100		10			Hard	None	Gneiss	6.00
139	do	Taftville	P. Dion	Hill	11	42½	50½		30			6		do		do	
140	do	do	Jos. Coron	do	0	75	75		15	Seasonal		6		Soft	Domestic	do	
141	do	do	Anthony Murphy	Hillside	2	101	103	60	16	Constant	6	6				do	
142	do	Norwichtown	Harriet M. Howland.	Hill	80	125	205		10	Pumping lowers 6 feet.	8½	8		Soft		Gneiss, gray blue slate.	
143	Orange	West Haven	Ridgely Larkin	Slope, elevation 30 feet.	20	54	74	74	10		5	6		do	Domestic	Chlorite schist.	
*144	do	Woodmont	John W. Merwin	Hill	13	237	250	230	50		Good.	6		Hard	Drinking	do	
145	do	do	J. I. Doolittle	Plain	1	56	57	30–35	Few feet.		Small.	6		Very hard.	do	Phyllite	4.50
146	Plainfield		J. C. Noyes	Slope	10	90	100	40	18	Pumping lowers.		6		Hard	Domestic	Gneiss	
147	do	Moosup	All Hallows Church Corp.	do			117							do	General	do	

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a No water above 150 feet.

Records of wells in crystalline rocks of Connecticut—Continued.

No.	Town.	Locality.	Owner.	Topographic position.	Depth to rock.	Depth of rock.	Depth of well.	Depth of principal source.	Depth to water.	Variation of water level.	Yield per minute.	Diameter.	Temperature.	Quality.	Use.	Rock in which well is drilled.	Cost per foot.
					Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Galls.*	*In.*	°*F.*				
148	Plainfield	Moosup	W. H. Wilson	Hill	15	18	33	30		General		8		Hard, iron.	General	Gneiss or schist.	$7.00
149	do	Central Village	G. P. Borjerson	do	3	52	55							Hard	do	Gneiss	
150	do	do	Torrey Bros	Valley	12	43	55	40	10	Constant	20	6	52	Hard, sulphur.	Drinking	do	
151	do	do	Plainfield Woolen Co.	Stream bed	30	132¾	162¾	160	20		20	6		Hard	General	do	2.75
152	do	Wauregan	John A. Baton				53½		Flow.		18			Med	Domestic, cattle.	do	
153	Plymouth	Terryville	Terryville Water Co.	Stream bed	30	70	100	100	Flows+3		30	8	50	Hard	Domestic	Schist	6.00
154	Pomfret		Mrs. M. V. Clark	Slope	18	592	610	600	25		12	6		Hard, sulphur.	Domestic, greenhouse.	Quartzite schist.	5.00
155	do		Wm. G. Jennings	Hill	98	7	105		43		5				General	do	
156	do		do	do	84	28	112		30		6				do	do	
*157	Putnam	Putnam Heights.	Mrs. R. P. Danielson.	do	55	365	420	55	20	Seasonal	2	6	51	Soft	do	do	
158	do	do	Dr. E. M. Harris	Slope	18	627	645		4		4	6		Hard	Domestic, stock.	do	
159	do		G. A. Pettis	Hill slope	18	94	112	110	30			6		do		Gneiss	3.00
160	Redding	Redding Ridge	Julia H. Sanford		7	78	85	65	20		Large.	6		Hard, iron.	Domestic	Schist	4.00
161	do	do	Lester Peck		52	96	148	138	15		30	6			General, stock.	do	3.00
162	Roxbury		Herman Behr & Co.	Hill			486				Dry.	6¼				Garnetiferous schist.	
163	Salisbury		Geo. E. Quaile	do	10	205	215	200	30	Varies	Large.	6	45	Iron	Domestic	Limestone.	
164	Saybrook	Deep River	W. W. Jennings		30	48	78	68	2	Varies, occasionally flows.	Large.	6		Soft	do	Schist or gneiss.	4.50
165	Seymour		O. E. Hurlburt	Hill			88	88	20		4	6		do	do	Granite	
166	do		Mrs. J. W. Spencer.	do	22	52	74	70	12		2½	6	47	do	do	do	3.50
167	do		Catherine R. Warner.	do			280				Failure.	6				do	

168	do		Jas. Swan	Slope			280	60	12		40				General	do	
169	Sharon		C. A. Low	Hill	25	146	171		20			6		Hard	Domestic, garden.		
*170	do		Miss E. O. Wheeler.	Slope	100	15	115	110	70		15			Very hard.	Domestic	Limestone	
171	Sherman		Geo. A. Barnes	do	12	58	70	50	20		Good.	4		Soft		Gneiss	
172	Sprague	Baltic	N. R. Garden	Hill	3	38	41	15–25	3			120				do	
173	do	do	St. Mary's R. C. Society.	Slope			175		Flows.		9	6		Hard	General	Schist or gneiss.	4.00
174	do	do	Dr. S. Bouvier	do	27	31	58	56	2	Constant	12			Soft		Gneiss	
175	do	Hanover	Angus Park	do	30	50	80	75	30	do	2	6		do	Domestic	Schist or gneiss.	4.50
*176	Stafford	West Stafford	Ralph Brown	do	21	26	47	47	22			4	50	do	do	Schist or granite.	5.00
177	Stamford		H. S. Cammann	Hill			177	177	15	Pumping lowers to 30 feet.	50	6		do	do	Grano-diorite.	
178	do		Patrick Boyle	Plain, elevation 20 feet.			102			Pumping lowers.	Good.	6		do	do	do	
179	do		Dr. A. J. Givens		30	382	412				Very poor.					Paro-diorite	
180	do		Clendenin Echert		25	161	186		52		70			Soft		do	
181	do		Diamond Ice Co.	Shore	50	120	170				15		52	Med. hard.		Grano-diorite.	
182	do		do	do	50	42	92				200			do		do	
183	do	Sound Beach	Mr. Dobbs	Slope			70			Pumping lowers to 50 feet.	20					do	
184	Stonington		Mrs. J. R. Chesebro.	Slope, elevation 30 feet.	3	98	101	78	29		1½	6	50	Hard	Domestic	Granite	
185	do		Atwood-Morrison Co.		28	143	171	30	15		11	6		Salty		do	
186	Thompson		J. M. Chapin	Hill	7	45	52	40	7	Pumping lowers.	15	6		Hard	General	Gneiss	3.00
187	do		J. N. Kingsbury	do	15	60	75		12–18		15	6		do	Domestic	do	
189	do		Chas. E. Olney	do	13	37	50	15–40	4	Seasonal	2	6		do	Bathing	do	
190	do		N. B. Ream				310		25	Pumping lowers slightly.	40	6		Iron	Domestic	do	
191	do		John H. Wilkes	Hill			60		10		3	6		Hard	Stables	do	2.20
192	do	North Grosvenordale.	Grosvenor Dale Co.	Valley	15	275	290		4	Pumping lowers.	60	8 6		do	Drinking	do	
193	do	do	Mauritz Nelson	Slope	0	53	53	33		Dries.	2	6		do	General	do	
194	do	Willsonville	Jos. Brault	Hill	7	39	46		10		6	6			do	do	4.00
195	Torrington		S. A. Hermann	do	35	79	114	112	6	Constant	10	6	50	Med. soft, iron.	Cooking, stock.	Granite	3.00
196	do		Excelsior Needle Co.	Valley	43	540	583	500–583	8	Pumping lowers to 250 feet.	25	6		Hard	Drinking	do	

Records of wells in crystalline rocks of Connecticut—Continued.

No.	Town.	Locality.	Owner.	Topographic position.	Depth to rock.	Depth of rock.	Depth of well.	Depth of principal source.	Depth to water.	Variation of water level.	Yield per minute.	Diameter.	Temperature.	Quality.	Use.	Rock in which well is drilled.	Cost per foot.
					Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Galls.*	*In.*	*°F.*				
197	Torrington	......	Thos. J. Stone	Valley plain	23	75	98	65	8	Lowers to 30 feet.	16	6	......	Soft	Manufacturing mineral waters.	Granite	......
198	...do	......	Torrington Mfg. Co.	Valley	50	54	104	90	9	......	20	6	55	......	Factory, drinking.	...do	......
199	Trumbull	......	N. B. Curtis	Small elevation	18	32	50	48	8	Seasonal	......	6	......	Hard	Domestic	Schist or granodiorite.	$4.00
200	...do	......	E. S. Fairchild	Ridge	30	45	75	50	0	Pumping lowers to 40 feet.	Good.	6	......	Soft	Domestic, boiler.	...do	......
201	...do	......	Thos. L. Wade	Slope	16	69	85	75	25	Pumping lowers.	......	6	......	...do	Domestic	Schist or gneiss.	4.00
*202	Vernon	Rockville	B. L. Burr	Hill	6	54	60	58	46	...do	Good.	6	......	...do	Drinking	Gneiss	......
203	...do	...do	Horace G. Holt	......	25	7	32	......	......	......	......	6	......	Hard	...do	...do	2.50
204	...do	Talcottville	Talcott Bros	Slope	97	230	327	......	32	Pumping lowers.	7	......	......	......	Domestic	...do	......
205	Voluntown	......	John N. Lewis	...do	17	33½	50½	50	13	Constant	10	6	44	Soft	General	Granite	......
206	...do	......	...do	Flat	......	......	50	49	13	...do	15	6	......	...do	Domestic	...do	3.00
207	Washington	......	Dr. H. H. Hartwell.	Slope	5	60	65	......	5	......	2	......	48	......	......	Schist	......
208	Waterbury	......	Waterbury Brass Co.	Valley	80	80	160	160	13	Pumping lowers somewhat.	150	8 6	......	Hard	Drinking, general.	Gneissoid schist.	4.00
209	...do	......	Platt Bros	...do	10	74	93	80	8	Pumping lowers.	......	6	54	...do	Cooling	...do	......
210	...do	......	Valentine Bohl Co.	Slope	60	120	180	......	9	Constant with slow pumping.	35	6	52	Med	...do	...do	......
211	...do	......	Waterbury Machine Co.	Valley	48	141	189	185	30	Constant	20	6	52	Hard	Drinking, washing.	...do	......
212	...do	......	Jean Jacques	...do	0	65	65	55	2	Pumping lowers.	4	6	50	Soft	Manufacturing ginger ale.	...do	......
213	...do	......	Waterbury Mfg. Co.	Slope	20	330	350	300	3	......	3½	8 6	......	......	Drinking	Granite	3.00

214	do		Franklin H. Kalbfleisch Co.		50	36	86	27	27	Pumping lowers 2 feet.		6	52–55	Hard	Cooling	do	
215	do		W. P. Jarrett	Hill	14	23	37		7		1				General	Gneiss, schist.	
216	do		do	do	10	32	42		7		1				do	do	
217	do		do	do	14	48	62		4		1				do	do	
218	do		do	do	20	11	31		11		4				do	do	
219	Waterford	Pleasure Beach	John O. Enders	Plain, elevation, 80 feet.	18	100	118	80	16	Pumping lowers.	6½	6		Soft	do	Granite	
220	do	do	Booth Bros	Plain	17	63	80			do		5			Boilers	do	
221	do		Fred C. Crowell	Slope	7	36	43	13	11		Good.	6		Hard	General	do	
222	do		Maj. H. A. Hull	Hill	58	15	73	40	12	Constant		6		Soft	do	Gneiss	
*223	do		Angeline W. Hill	do	6	45	51	35	26		Large.	6		do		do	
224	Westbrook		Mrs. J. H. Ripley	do	0	87	87			Pumps dry	Small.	6		Iron	Domestic	do	
225	do		A. C. Knothe	do	10	90	100		60		5	5		Soft	do	do	
226	do		R. H. Stannard	do	3	47	50	45 50	4			6				do	
*227	Westport		Atlantic Starch Works.	Valley	34	181	215	48 200		Pumping lowers to 15 feet.	60	8 6	50	Hard	Factory (not boilers).	do	
228	do	Greens Farm	Dr. Graham Hammond.		30	118	148	20			5					Schist	
229	do	Saugatuck	A. W. Smith	Hilltop	15	79	94	35	30		15	6	54		None	do	
230	Wilton		J. C. Berringer		16	10	26		10	Seasonal		36		Soft	Domestic	Granodiorite.	
231	Winchester	Winsted	L. J. Comstock				102		Flows		2½	6		Med	Domestic, stock.		
232	Windham		Holland Mfg. Co.	Valley	5	95	100		4	Pumps dry		6				Gneiss	
233	Woodbridge		Geo. D. Watrous	Hill			75		15		Small.	6			Domestic	Phyllite	
234	do		Edwin Judge	Valley	0	15	15	12	7	Seasonal		24		Hard	do	Slate, schist	
235	do		Wm. Peck	Hill	15	15	30		10	do		48		Soft	do	Slaty schist	
236	do		W. J. Lum	Slope	20	44	64	54	12		1½	6		do	Domestic, stock.	Chlorite schist.	2.35
237	do		J. T. Newton	do	9	141	150		Flows 1½	Slight seasonal.		6	52		Sale	do	

Additional records of wells in crystalline rock of Connecticut.

[Furnished by C. L. Grant.]

No.	Town.	Locality.	Owner.	Depth of well.	Depth to water.	Yield per minute.	Probable rock in which well is drilled.
				Feet.	*Feet.*	*Gallons.*	
1	Andover		R. P. Chapman	60	38		Schist.
2	Bolton		Mrs. M. C. Baker	105	11	28	Granite.
3	Branford	Stony Creek	Wm. F. Clark	60	28		Do.
4	do	do	Maltby, Stevens & Maltby	30	7		Do.
5	Bridgeport		Hutchinson, Pierce & Co	325	24	25	
6	do		Naugatuck Valley Ice Co	200	18	24	
7	do		F. Armstrong	135	3		
8	Bristol		Bristol Brass & Clock Co	100		30	Do.
10	Brooklyn		Brooklyn Cemetery	70	45		Gneiss.
11	do		S. H. Bowen	40	0	11	Do.
13	Canton	Collinsville	H. P. Chandler	20	1	18	Granite.
14	do	do	H. P. Reichert	30	10	3	Do.
15	Coventry	South Coventry	C. E. Rood	44	20		Gneiss.
16	do	do	Thos. Joyce	95	40	6	Do.
17	do	do	Martin Hughes	36	2		Do.
18	Griswold	Jewett City	A. Brown	40	30		Do.
19	do	do	Chas. Meech	57	0		Do.
20	Groton		Mrs. J. E. Keeney	51	15	6	Granite.
21	Mansfield		Edwin Reynolds	40	4	6	Schist.
22	Milford		W. M. Merwin & Sons	93	3	35	Do.
23	do		Chas. Coupland	90	9	7	Do.
24	do		D. E. Smith	58	21		Do.
25	do		Mrs. E. P. Smith	35		12	Do.
26	do		J. W. Kelly	100	24	18	Do.
27	Naugatuck		C. H. Hoffman	25	12		Granodiorite.
28	do		Olaf Swanson	31	18	3	Do.
29	New Canaan		Mrs. A. M. Bradley	253	11	40	Granite.
30	New London		N. L. Brewing Co	60	Flows.	110	Do.
31	Norwich		Thames Iron Works	61	5	30	Gneiss.
32	do		do	124	4	110	Do.
33	do		N. D. Sewin	50	3	4	Do.
34	do	Norwichtown	M. Cryer	30	12	7	Do.
35	Old Lyme	Lyme	R. S. Griswold	23	8		Granite.
36	do	do	do	42	20		Do.
37	Plainfield	Wauregan	Wauregan Mills Co	45	10		Gneiss.
38	do	do	do	158		40	Do.
39	do	do	Henry Woods	33	21		Gneiss or gravel.
40	do	do	Charles Carter	29		18	Do.
41	do	do	Nelson Willett	63	14	16	Do.
42	do	do	J. W. Atwood	55	20	18	Do.
43	do	Moosup	W. H. Wilson	36	0	5	Schist or gneiss.

44	do	do	Joseph Potwin	175	56	8	Do.
45	do	do	do	89	24	12	Do.
46	do	do	do	125	35	10	Do.
47	do	do	Benj. Lamont	60	12		Schist, gneiss, or gravel.
48	do	do	E E. Salisbury	33	7	3	Do.
49	do	do	Rev. J. A. Creeden	29	1	18	Do.
50	do	do	J. A. Paine	40	14	3	Do.
51	do	do	Henry Daggett	60	5	5	Do.
52	Pomfret		Mrs. Gertrude Vinton	70	666	1	Do.
53	Seymour		Tingue Mfg. Co	129	34	60	Granite.
54	do		do	80	11	60	Do.
55	do		Joseph Reigel	110	29	11	Granite or schist.
56	do		Patrick Ryan	17	1	33	Do.
57	do		Jas. Swan	57	10	6	Do.
58	Stamford		Dennis Beach	130	11	25	Do.
59	Sterling		G. Anderson	45	15	9	Do.
60	Thompson		Henry Elliott	46		2	Do.
61	Vernon	Rockville	N. E. Engineering Co	80		25	Gneiss.
62	Waterbury		Wm. H. Smith	160	14	35	Gneiss or schist.
63	do		Mr. Fitzsimmons	60	28	5	Do.
64	do		Waterbury Clock Co	500	29	7	Do.

NOTES.

2. Penetrated 20 feet of loam and hardpan, 10 feet of soft rock, 20 feet of hard rock, and 46 feet of soft pulpy micaceous rock. Water was obtained in the soft micaceous rock. (See fig. 14.)

7. Dug and blasted 28 feet and drilled 22½ feet. Passed through 2 feet of loam, 12 feet of till with a 1-foot layer of iron-cemented material, 14 feet of disintegrated rock, and 22½ feet of hard rock.

10. Water salty on first being pumped but becomes fresh with continued pumping.

18. In drilling, considerable amounts of water were encountered in the sand and gravel above the rock. This water was cased out and a small amount was found at a depth of 25 feet in the granite, and additional supplies, increasing in small amounts, were found down to a depth of 150 feet. Below this point no new supplies were encountered, although the total depth of the well is 315 feet. The material penetrated was as follows: Sand and gravel, 50 feet; granite, 100 feet; clay and gravel (probably disintegrated rock marking a shear zone), 20 feet; soft white micaceous rock followed by granite varying in hardness every few feet (probably gneiss).

45 and **46.** Maj. William Spittle has furnished the following information: One well was drilled to a depth of 425 feet through 12 feet of clay till and 413 feet of granitic rock, of nearly the same character for the entire depth, probably a gneissoid granite. Water first began to flow over the surface at 335 feet from the top and continued to increase slowly in the amount of flow and in the height of the rise above the surface with increasing depth. At present the water will rise at least 7 feet above the surface of the well in a ¾-inch pipe. In five months' continuous flowing the volume of water decreased from 4 to 3 gallons a minute. When pumped the well yielded 50 gallons a minute and the water level was lowered to 80 feet below the surface and remained steady. The second well was sunk 130 feet away and at an elevation 4 feet higher to a depth of 503 feet. This well yields 25 gallons a minute, but the water stands at a level 15 feet below the surface. The pumping of the second well did not affect the yield of the first.

75. Mr. H. B. King has furnished information regarding five wells drilled for the Aspinook Company at Jewett City. They are from 15 to 100 feet apart and from 30 to 60 feet in depth, all penetrating 6 to 8 feet of sand and gravel. They are located on a hillside at varying elevations. These wells each average 20 gallons a minute and are all connected to a siphon which conducts the water to the mill at an elevation about 75 feet lower than the wells. Two of these wells, 15 feet apart, affect each other's yield, but the remaining wells are apparently independent of one another.

80. A small stream of water was encountered at 83 feet from the surface, and at 180 feet a stream of 1 gallon a minute; below this there was no increase in supply to a depth of 530 feet.

82. At a depth of 32 feet this well yielded 1 gallon a minute and at 38 feet 4 gallons a minute. The last 10 feet of the well gave no increase of supply.

97. Filling, 5.5 feet; silt, 5 feet; coarse gravel, 13.5 feet; coarse sand, 36 feet; hardpan, 13 feet; gneiss, 62 feet; granite or hard gneiss, 25 feet; slate, 5 feet; granite or hard gneiss, 5.5 feet. The total depth of the well is 170.5 feet. (See fig. 14.)

108. On the slope of a hill near the base of which are numerous springs. The water is siphoned from the well to tenement houses below. In dry seasons the level of water in the well drops 2 feet.

132. Drilled on a small island in Long Island Sound. A trace of fresh water was obtained at 125 feet, hut the remaining supply was salty.

133. Fresh water was obtained at a depth of 60 feet, evidently from gravel deposits, but salt water was encountered in the rock seams below this point. The well was plugged below 60 feet and the fresh water from the gravel is utilized.

144. No water was found in the first 100 feet. In the next 70 feet a small amount was obtained, possibly 40 gallons a day, and the water stood at a level 107 feet below the surface. The well was drilled to a depth of 250 feet and an excellent supply obtained at 230 feet below the surface. Information furnished by H. B. King, the driller.

157. The water comes from the contact of the overlying clay and the solid rock. No water was found in the rock, which is a quartzite schist, although 365 feet of rock were penetrated.

170. The following log is furnished by the driller, A. J. Corcoran: Solid clay, 15 feet; clay and small stones (till), 10 feet; dark gravelly material, 46 feet; loose blocks of rock, 29 feet; soft and dry decomposed rock, 10 feet; hard rock, 5 feet. A small yield of water, 2 gallons a minute, was found at a depth of 30 feet, but no more was encountered until the last 5 feet of hard rock was penetrated, when a supply of 15 gallons a minute was obtained. (See fig. 14.)

176. Water was found in the superficial drift, but was lost on encountering a dry seam in the rock.

202. A good supply of water was obtained at a depth of 25 feet, but this flowed off at 45 feet, and when water was struck again at 60 feet it rose to this point and flowed off in the open rock seam.

223. At 35 feet the well pumped 100 gallons an hour and the water rose within 16 feet of the surface. A second and very large supply was encountered at a depth of 51 feet and the level of the water dropped to 25 feet below the surface.

227. Penetrated 34 feet of gravel and bowlders and 41 feet of micaceous rock, in which a little fresh water was found at 38 feet below the surface and a large flow of slightly salt water at 48 feet below the surface. The rest of the well was through a rock described as gray and yellow sandstone (probably schist). At 200 feet very salt water was encountered, but this is held back by a plug. (See fig. 14.)

PRACTICAL APPLICATIONS.

PERCENTAGE OF FAILURE OF WELLS.

Wells in crystalline rocks are unlike most other wells, in that it is impossible to predict their success or failure, even when numerous wells have been sunk previously in the same locality. For this reason a well driller will rarely guarantee to obtain water from such a well, although occasionally water is guaranteed and an additional price per foot charged to offset the driller's risk of failure.

When a well is considered a failure the fault lies either with the quality or with the quantity of the water obtained. It is a very exceptional well in which no water supply is obtained in the rock. Nearly all wells encounter some water in the surface material above the rock, but it is common for the drill to penetrate 30 or 40 feet of rock, and occasionally even 100 feet, without obtaining enough water in the rock to keep the drillings wet, so that water must be poured in at the top to allow the drilling to continue. Although no satisfactory data are at hand regarding the number of wells which have failed to obtain any water, it is certain that the number is very small. Among 237 wells only 3, or 1.25 per cent, are recorded as obtaining no water. Drillers are naturally averse to giving information regarding unsuccessful wells which they have sunk, but the available information indicates that, though dry wells are uncommon, there are a considerable number of wells in which the yield of water has been less than 2 gallons a minute. For certain purposes, such as manufacturing, this small supply would be considered a failure, but for domestic use where the water is obtained by a hand pump or windmill a supply of this amount is generally sufficient. Among 134 wells whose yield is known, only 17, about 12.5 per cent, furnish less than 2 gallons a minute. It is probably a conservative estimate to state that not less than 90 per cent of the wells sunk in the crystalline rocks have given supplies of sufficient amount for the use required.

The greater number of unsuccessful wells in regard to quality are located along the coast or on tidal rivers, where the well supplies are affected by sea water. When a well is within a few hundred feet of salt sea water, it sometimes happens that salty or brackish water is obtained, although perfectly fresh water is yielded by other wells in similar locations. Six wells are recorded in which the water has been contaminated in this way and others, regarding which definite information is lacking, are known to have been failures for the same reason. It is certain that a large percentage of wells near salt water have yielded brackish water and any well sunk in rock on a small island or within 500 feet of the sea is likely to afford an unsatisfactory supply. As nearly as can be estimated from present information, the chances of failure for such wells are between one in four and one in three.

When there is a choice of several locations, the well should be as far as possible from the sea and at as high elevation as convenient. Several wells that have been ruined by the entrance of salt water are situated on old salt marshes or on filled ground that is but slightly elevated above tide level. In the quarry at Millstone Point, near New London, which is about 150 feet from the sea, brackish water enters through the horizontal seams in the upper part of the quarry wall nearest the Sound. The rock outcrops in the sea and the open seams have abundant opportunity to absorb salt water.

VARIATIONS IN YIELD AND DEPTH.

The depths and yields of wells vary widely within very small areas. When considered collectively, as in the table on page 102, it is seen that there is an average increase in the amount of water obtained with increase in depth of the wells. It is often found, however, that of two wells sunk within 100 feet of each other in the same kind of rock, one will obtain a plentiful supply of water while the other may be sunk to twice the depth and obtain only one-tenth the amount. This is a typical case which nearly every Connecticut well driller will present in one form or another when information regarding his drilling experiences is requested.

This variation within short distances is due to the varied occurrence of the water-bearing fractures considered on the previous pages. One well may be sunk in a portion of the rock in which the fractures are numerous and closely spaced or it may intersect a large open fracture; the second well, only 100 feet away, may be located in an area of widely spread fractures or it may intersect only fractures with closely compressed walls and consequently can obtain only a meager water supply. Owing to the general steep pitch of joint planes, there would be little chance of two wells intersecting the same fracture, although they might possibly intersect connecting fractures and in this way affect each other's yield. Even where two wells intersect connecting fractures at the same depth, the yield of the two wells would probably be different, owing to differences in the opening of the fractures.

LIMIT OF DEPTH FOR WELLS IN CRYSTALLINE ROCKS.

Although the well records given on pages 78–89 show that supplies of water have been obtained at all depths from 15 feet to 800 feet, the largest percentage of failures is among the wells more than 400 feet in depth. The reasons for the increasing probability of failure with increasing depth are indicated in the discussion of joints (pp. 61–64), where it is shown that increased depth means a decrease in number and a tightening of joints. Increased depth usually means an increase in the cost per foot, as drilling is necessarily slower and consequently more expensive at considerable depths. Owing to the great length of rope and the necessity of waiting for the recoil of the stretched rope fewer blows can be struck per minute and there is also greater danger of losing the drilling tools.

In view of the increasing cost and the decreasing probability of finding water-bearing seams with increasing depth, and of the great variation in water-bearing fractures within very short distances, it seems manifest that if a well is unsuccessful within a certain depth the best policy is to abandon the well and start a new one at some distance from the first. In one place a well was abandoned in this manner and a second and successful one sunk by simply turning the rig around and drilling a hole less than 20 feet away. It is always preferable, however, to move as far away from the first well as possible.

In deciding at what depth an unsuccessful well should be abandoned a number of factors must be taken into consideration, but an estimate that will prove of value may be made from the available well records. The table on page 100 shows that the average depth of the wells varies considerably for different rocks. The average depth in rock of 163 wells is 88.8 feet and the average total depth, including the surface material overlying the rock, is 108.4 feet. About 90 per cent of the wells are under 300 feet in depth and 82 per cent under 200 feet. In many of the wells which have gone below 250 feet the main supply and in several the entire supply has come from seams less than 250 feet in depth. From a study of the recorded wells it would appear, therefore, that if a well has penetrated 250 feet of rock without success the best policy is to abandon it and sink in another location. For wells in granodiorite, which have been successful at an average greater depth than in other rocks, this depth might be somewhat too small, but for wells in other rocks it is possible that a maximum depth of 200 feet should be adopted.

The wells that penetrate 200 feet or less of rock show a rather regular increase in yield of water with increasing depth, but in deeper wells than this the tendency is toward a smaller average yield owing to the failure of many of the wells. The average yield of 123 wells in the crystalline rocks is 12.7 gallons a minute, and as their average depth is 108 feet the cost of the average well for this yield of water at $4.25 a foot is $459.

QUALITY OF WATER.

A general discussion of the chemical composition of well waters and a number of analyses of well waters derived from crystalline rocks may be found on pages 166–168, 176–179. The general quality of water from these rocks is excellent and they are well adapted to boiler use.

TEMPERATURE OF WATER.

The temperature of the water is entirely dependent on the depth from which it comes. In wells less than 50 feet deep the water will show variations in temperature agreeing in a modified form with the seasonal changes. In wells more than 50 feet in depth the temperature of the water increases at the rate of about 1° to every 60 feet of depth. The average temperature of the water of 49 wells in the crystalline rocks is 50.5° F. The average annual temperature of Connecticut is 47° F.

LOCATION OF WELLS.

So many factors are involved in considering the location of a well that it is impossible to lay down any set rule for choosing a location. Before sinking a well it is always advisable to find out what wells have been sunk in the vicinity and what success they have had. The list of well records on pages 78–89 gives all the information at hand, although there are probably as many more wells in Connecticut regarding which no information has been obtained.

In localities where, owing to limited space or other factors, there is only one place where a well can be sunk, the only questions to be considered are the possibility of obtaining a satisfactory supply and the probable cost. For such wells the information embodied in this report should be of considerable value.

Where there is a choice of situations for the well the following points should be considered. The well should be as far removed from contaminating influences as possible. This is particularly important for wells near sea water. (See p. 174.) It is better to sink the well where there is a heavy covering of surface material rather than on a bare rock ledge. If there are rock exposures near by, a study of the joints may be of assistance in locating the well so as to intersect possible water-bearing fractures.

The Aspinook Company, at Jewett City, has adopted a very successful scheme which doubtless could be used in many other places. The mill is located below a hill and a series of wells were sunk on the hillside at a considerable elevation above the mill. The water is obtained by means of a siphon and a very considerable pumping expense is thus saved. The same method has been adopted for individual wells elsewhere and has proved satisfactory.

In order that a siphon may be used, the water level must be not more than 30 feet from the surface and the lower end of the siphon pipe or the escape valve must be at an elevation lower than the water level. The average depth from the surface of the ground to the water level in the recorded wells is 19 feet on hills and 15 feet on slopes. The water level will of course lower to some extent when water is drawn out and the degree of lowering will be proportional to the volume of water removed, but in many wells the lowering will not be sufficient to affect the use of the siphon. The greatest certainty of success will be on hillsides where there is a covering of clay or hardpan and where there are no outcrops of rock showing above the surface at elevations lower than the top of the well.

The wells located on hills average less in cost than those in valleys, owing to the greater depth of the valley wells, as shown in the table on page 102; but the average yield of wells on hills and in valleys is nearly the same.

CONSTANCY OF YIELD.

The wells appear to maintain a remarkably constant yield from year to year. Although the drilling of wells in the crystalline rocks is a comparatively new venture and almost all of these wells have been sunk in the last three years, no well in which water was obtained has failed to yield a supply on continued use. In very shallow wells dry seasons have marked some decrease in supply, but the decrease has been small and only temporary. In a number of wells the supply has increased after continued pumping, probably owing to the removal of material lodged in the rock crevices, which are cleaned out by the running water.

In some wells supplies obtained at short distances below the surface have been lost with deeper sinking, an open dry crevice struck at a lower level allowing the water to run off. Such occurrences are unusual and are found at relatively shallow depths. During the drilling of any well it is usual to find a number of fractures supplying water. Often the water derived from small sources will stand at a certain level in the well and when the main supply is struck will rise or fall, depending on the height at which the water stands in the main crevice. There will of course be an equalizing between the various supplying fractures. If the well penetrates one saturated fracture in which the water stands at 10 feet below the top of the well and a second fracture in which the water stands at 30 feet below the top, the water level in the well will occupy an intermediate point somewhere between 10 and 30 feet below the surface.

FLOWING WELLS.

The question is often asked regarding the possibility of obtaining flowing wells in Connecticut. A number of flowing wells have been obtained in the sandstone area in the central and northern portions of the State, but a flowing well in crystalline rocks is a very unusual occurrence. Information has been obtained regarding six wells in the Connecticut crystalline areas in which the water has maintained a constant flow over the top for some time and several wells are known in which the water has flowed over the surface for a few minutes but has eventually lowered to a level below the mouth of the well.

The occurrence of flowing wells is therefore common enough to demand an explanation. Four of these wells have been personally visited and the position of the others is known approximately. Each of the wells is located on the side slope of a hill or in a small valley where there is a considerable elevation back of the well. One well at Greenwich is on a very gently sloping surface so that it appears to be at the top of the hill, but in reality the ground rises gradually to an elevation at least 40 feet higher than the well. All the wells are in markedly glaciated areas, where there is a considerable thickness of clay till overlying the rock, and there are no neighboring rock outcrops except at one flowing well called the Buttress Dyke Spring, near New Haven. This well is in an area of schistose rock where the hill back of the well exhibits numerous outcrops, but there are no rock ledges showing at elevations lower than the well.

From the study of the individual wells and of the general occurrence of water in rock fractures, it is concluded that the artesian conditions

A. FLOWING WELL AT NOROTON HEIGHTS.

B. WEATHERING DUE TO GROUND WATER IN GRANITE QUARRY.

giving rise to flowing wells in Connecticut are due solely to the capping of clay till above the rock and that this capping is sufficiently impervious to prevent the water escaping from the rock crevices, at least with sufficient freedom to destroy the artesian head. The water occupying the rock seams is under hydrostatic pressure owing to its confinement on the sloping hillside, and, an easy escape being offered by the open well, the water rises to the surface. It is probable that the joints that give rise to the flowing wells are more nearly at right angles to the slope of the hillside than parallel to it. The same conditions might arise where the joints have a pitch parallel to the surface slope and a very low inclination, but the pitch of most of the joints is so steep that they would intersect the surface so near the well as to give little or no head to the water.

As far as water supply is concerned, flowing wells need not be considered as of any particular importance in Connecticut. In the first place it is impossible to predict that a well will flow, even though the most favorable location be chosen. At Noroton Heights two wells were sunk within 150 feet of each other in the same kind of location, one of which flowed 7 feet above the surface, while in the other the water rose only within 15 feet of the top. Second, the flow at each of the flowing wells has been small, from 1 to 4 gallons a minute. This supply is too small for the use made of it at most of the wells and pumping machinery has been installed. The wells have yielded unusually large supplies when pumped, but the level of the water has sunk to a considerable distance below the surface. It is not known whether the wells would again flow if pumping were stopped. (See Pl. III, *A*.)

It is probable that in the wells which flowed for only a few minutes after being struck the water then found an escape through open dry fractures in the upper portion of the well, as the water level dropped to several feet below the surface.

WELLS IN VARYING ROCK TYPES.

A study of joints and other rock fractures indicates that these structures vary with varying rock types, and as the water supply of wells is directly dependent on the fractures it is to be expected that there will be corresponding variations of supply in the wells in the different rock varieties. These variations are discussed below. The records on which the discussion is based are not as complete as might be desired, but are sufficiently numerous to have considerable weight.

Wells in granite.—It has been shown that the fractures particularly characteristic of granite masses are the nearly horizontal joints which in general run parallel to the surface of the ground. These joints are manifestly of considerable importance in the transmission and storage of water, but it is doubtful whether they are sources of large supply to wells. In granite quarries where the horizontal joints are well developed, the greater portion of the water entering the quarry comes through these flat joints. Owing to their parallelism to the surface these joints are not in a suitable position to receive water from the material overlying the rock, and must get their main supply of water from that descending through the vertical joints. In the quarry walls the largest amount of water escapes and the heaviest decomposition of the rock occurs near the major vertical joints, indicating that the vicinity of such joints is the place of greatest water circulation.

As a well sunk in granite must pass through a large number of horizontal seams, which are far more abundant in the upper 50 feet of rock than in the next 50 feet, it would appear that if these seams were saturated and could yield good water supplies the granite wells should furnish unusually large supplies at comparatively shallow depths.

The records show, however, that the wells in granite yield about the same as those in gneiss and schist, and that although their average depth is 10 per cent less than that of the wells in gneiss it is slightly greater than the average of the schist wells. The natural inference to be drawn is that though the number of contributing fractures to any one well is much greater in granite than in the other two main rock types, the total yield of the well is no greater than the amount furnished by the vertical joints to the horizontal joints.

In granite the vertical joints are more irregular and probably more widely spaced than in the other rock types, but they are well connected with one another by the intersecting horizontal joints. The contributing area to a granite well should occupy a space with an approximately uniform radius around the well.

Wells in schist and gneiss.—Little difference can be distinguished between the occurrence of joints in schist and that in gneiss, and in fact the two rocks grade into each other so completely that it is in some places difficult to say whether a rock is a schist or a gneiss.

The marked development of horizontal joints characteristic of granite is lacking in these rocks, and the more regular character of the vertical joints tends to produce a different manner of circulation through the rock. A single well, instead of drawing water from an area surrounding it on all sides, will draw from long distances through the feeding fractures and the vertical fractures connecting with them.

The wells in schist and gneiss have nearly the same average yield, but those in gneiss average 15 per cent deeper than those in schist. It is possible that the supply for the wells in schist comes not only through the joints but also through fissility openings or small fractures parallel to the schistosity. Such fractures are common near the surface, and owing to their inclination might well absorb considerable volumes of water. Because of the small size and lack of continuity of these openings they would yield water very slowly to the well, but might give an important amount in the aggregate. The derivation of a supply through such openings, which would have their greatest development near the surface, would account for the relative shallowness of wells in schist.

That fractures parallel to the schistosity may be important carriers of water is well shown on the east bank of Connecticut River above Hadlyme Landing, where there is a long exposure of fissile schist and a number of small springs issue from partings parallel to the schistosity.

Wells in quartzite schist.—In the northeastern portion of the State there is an important development of a rock which is a schist but is unlike most of the schists of Connecticut and will be treated separately. This rock is an altered quartzite and consists very largely of quartz grains with a very small percentage of other minerals. No study was made of the fractures in this rock, but information has been obtained regarding five wells which were drilled in it, three of which are more than 300 feet in depth and one more than 200 feet. In each one the supply has been very small and unsatisfactory. Though the number of these wells is small, the evidence indicates that the rock is a very unreliable source of water supply and that the fractures are few or poorly developed.

Wells in phyllite.—Near Woodbridge and at Woodmont several wells have been drilled in a greenish slaty rock or phyllite in which the supplies have proved very unsatisfactory. The cleavage of the rock is nearly vertical, causing difficulty in drilling, and most of the fractures appear to be filled by some cementing mineral matter. The wells that have been drilled in this rock are comparatively shallow, but the water obtained has been so universally poor that the probability of getting a satisfactory supply appears to be very slight.

Wells in limestone.—Comparatively few wells have been drilled in the limestone area in the western part of the State, where springs are so numerous as to constitute far the most important source of water supply. The limestone itself is largely recrystallized and changed to a marble. It is dolomitic in part, but unlike many dolomites is compact and contains very little pore space.

The fracturing is very thorough and in fact so complete that it has been found impossible to obtain blocks for building purposes large enough to warrant quarrying. The limestone is traversed throughout by irregular fractures which divide it into a series of comparatively small blocks. Solution is very effective in limestone, as the calcium carbonate constituting the bulk of the rock is readily soluble in water containing carbon dioxide. No large solution caverns, such as are typical of many limestones, have been found in the Connecticut limestones, but the fractures generally have decomposed borders several inches wide and are sufficiently enlarged to offer easy passage to water.

Wells should be very successful in this rock, but because of its highly fractured condition water passes through it rapidly and the level of the water in the wells will probably be at a greater distance below the surface than in rocks of other types.

Wells in granodiorite.—In the vicinity of Stamford and Greenwich the wells drilled in schistose granodiorite have met with a considerable degree of success. The rock outcrops in this area show a well-developed and rather closely spaced jointing which is nearly at right angles to the schistose structure of the rock. There is no apparent reason why the wells in this rock should differ from those in schist and gneiss, but the average depth and average yield are much greater. It is possible that especially large supplies have been required in this locality and that for this reason the smaller supplies in the upper portion of the rock have been insufficient and the wells have been drilled until a large supply was struck.

STATISTICAL TABLES.

TABLE 1.—*Yields of water at varying depths in the rock below the covering of surface material.*

["Vol."=average yield in gallons per minute; "No."=number of records from which the average is taken.]

Depth in feet	0–30		30–50		50–70		70–90		90–110	
	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.
Schist	3.2	2	......	......	9.5	4	21.6	3	22.1	6
Granite	7	1	6.7	9	9.8	5	20.5	2	14.4	8
Gneiss	1	1	11.9	13	12.4	14	7.6	7	5.5	2
Granodiorite	......	......	......	......	......	......	8.0	......	0	1
Quartzite schist	......	......	......	......	......	......	6.0	1	......	......
Average	3.6	4	9.75	22	11.3	23	12.4	14	15.2	17

Depth in feet	110–200		200–300		300–400		400–500		500–650	
	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.	Vol.	No.
Schist	8.5	2	......	......	......	......	0	1	......	......
Granite	13	5	16	3	0	1	50	1	......	......
Gneiss	8.3	8	33.0	2	22.0	2	......	......	14.0	2
Granodiorite	46.0	6	10.7	3	2	1	......	......	......	......
Quartzite schist	......	......	0	1	2	1	......	......	7	2
Average	20.2	21	16.7	9	11.5	4	26.0	5	5.2	4

NOTE.—The information at hand shows no relation between the depth of the surface drift and the yield or success of wells.

TABLE 2.—*Yield of wells more than 400 feet deep, with reference to topographic position.*

Location.	Depth in feet.	Yield (gallons per minute).
Valleys	583	25
	690	[a] 10
	503	26
	425	50
Hills	850	40
	548	Poor.
	420	2
	486	Dry.
Slopes	610	12
	645	4
Island	1,465	[b] 3

[a] All water obtained at 120 feet.

[b] Salty.

TABLE 3.—*Average yield of wells in various locations.*

Location.	Average yield (gallons per minute.	Number of records.
Valleys	24.4	18
Hills	20.6	27
Slopes	8.7	25
Plains	18.8	9

TABLE 4.—*Relation of average yield of wells in various topographic locations to average yield of wells in any rock type and in any location.*

[Yield in gallons per minute.]

Rock.	Location.	Relation of average yield of wells in any location to average yield of all wells in same kind of rock.			Relation of average yield of wells in any location to average yield of all wells in same kind of location.		
		Average yield for location.	Average yield for rock type.	Difference.	Average yield for location.	Average yield for all in similar location.	Difference.
Granite	Hills	9.3	17.4	− 8.1	9.3	20.6	−11.3
	Slopes	10.3	17.4	− 7.1	10.3	8.7	+ 1.6
	Valleys	21.7	17.4	+ 4.3	21.7	24.4	− 2.7
Schist	Hills	26.5	17.0	+ 9.5	26.5	20.6	+ 5.9
	Slopes	4.7	17.0	−12.3	4.7	8.7	− 4
	Valleys	10.0	17.0	− 7	10	24.4	−14.4
Gneiss	Hills	21.8	17.0	+ 4.8	21.8	20.6	+ 1.2
	Slopes	10.1	17.0	− 6.9	10.1	8.7	+ 1.4
	Valleys	24.3	17.0	+ 7.3	24.3	24.4	− .1
Other crystalline rocks	Hills	24.7	26.4	−11.7	21.7	20.6	+ 1.1
	Slopes	2.2	26.4	−24.2	2.2	8.7	− 6.5
	Valleys	42.5	26.4	+16.1	42.5	24.4	+18.1

TABLE 5.—*Relation of level at which water stands in wells in various locations to surface of rock which marks bottom of overlying drift.*

Rock.	Location.	Percentage of wells in which water level is below rock surface.	Percentage of wells in which water level is above rock surface.	Percentage of wells in which water level is even with rock surface.
Granite	Hills	37	50	13
	Valleys	11	89	0
	Slopes	41	50	8
	Plains	50	50	0
Schist	Hills	62.5	37.5	0
	Valleys	0	100	0
	Slopes	50	33	17
Gneiss	Hills	69	21	10
	Valleys	22	78	0
	Slopes	44	36	20
	Plains	0	50	50
Granodiorite	Hills	71	0	29
	Valleys	0	100	0
	Slopes	60	40	0
	Plains	33	67	0

NOTE.—A summary of the results for all wells may be found on page 133.

TABLE 6.—*Average depth and yield of wells in varying rock types.*

Rock.	Depth of surface material.		Depth in rock.		Total depth.		ield.	
	Feet.	Number of records.	Feet.	Number of records.	Feet.	Number of records.	Gallons per minute.	Number of records.
Granite	20.6	45	100.5	45	122.5	54	13.0	35
Gneiss	16.3	69	112.6	70	131.4	73	12.3	50
Schist (other than quartzite schist)	13.7	23	96.0	23	109.7	23	13.9	16
Granodiorite	24.1	15	138.5	15	156.6	19	33.0	13
Quartzite schist	32.5	3	411.0	3	443.5	3	7.25	3
Phyllite (slate)	14.4	5	80.2	5	93.8	5	Very poor.	5

TABLE 7.—*Average depth from surface to water level in the well.*

Location.	Depth to water.	Number of records.
	Feet.	
Hills	19	76
Valleys	11	30
Slopes	15	44
Plains	8	30

TABLE 8.—*Average depths, in feet, of surface material, of rock, and of the entire well for the records at hand, exclusive of wells more than 400 feet in depth and of wells known to be dry.*

Location.	Average depth of surface material.	Average depth in rock.	Average total depth.	Number of records.[a]
Valleys	36	104.5	140.5	26
Hills	17	94.0	111.0	67
Slopes	21	79.4	100.4	54
Plains	10	74.0	84.0	16

[a] Average depth of surface material based on only 122 records.

NOTE.—Average total depth of all these wells is 108.4 feet.

It is clearly shown in Table 1 that there is an increase in the average yield of wells with increase in depth to a certain point, beyond which the average yield tends to decrease, owing mainly to the larger proportionate number of the deep wells that prove to be failures. The table also indicates that most of the wells are between 30 and 200 feet in depth. The wells in granite are evenly distributed over a considerable range in depth, but most of the wells in gneiss are shallow, 70 per cent being less than 100 feet deep. The wells in granodiorite whose records are available are mostly in the schistose area near Stamford, and the data indicate that in this rock good supplies of water are obtained at considerable depth.

Table 8 indicates that the impression of well drillers that wells obtain water at shallower depths on hills than in valleys is borne out by the facts, but that the greater part of the difference is due to the heavier deposits of surficial drift in the valleys. On the other hand, it is shown in Table 3 that the average yield of wells in valleys is somewhat greater than that of wells on hills. If there were any relation between the yield of wells and their topographic situation it would seem that wells located on slopes should give an average yield intermediate between that of the wells on hills and that of the wells in valleys. On the contrary, the wells on slopes average a yield less than half of that for either of the other locations and the wells on slopes are also the shallowest of the three groups.

Table 5 shows that the ground water in wells in granite has an occurrence differing from that in the other rock types, the position of the water level with reference to the rock surface being the reverse in wells on hills and slopes to that in the other rocks, though in the wells in valleys the same relation is shown by all rock types.

CHAPTER V.

GROUND WATER IN TRIASSIC SANDSTONES AND TRAPS.

INTRODUCTION.

The bed rock of Connecticut, as is shown on the map (fig. 11), consists of two main types, widely separated in character and age—the pre-Triassic metamorphic crystalline rock and the Triassic sandstone, conglomerate, shale, and lava. In the sedimentary rocks and traps of the Triassic area the water occurs in four situations—within the rocks themselves, in bedding planes, in joints, and along fault lines.

WATER WITHIN THE ROCKS.

CONDITIONS OF OCCURRENCE.

No rock is so dense as to exclude water entirely. However firm and compact it may appear to be, there are spaces between the individual grains and crystals, of capillary size and larger, which, though invisible, allow access and movement of water. Though it is true that all rocks possess a capacity to hold water, yet the amount of available space varies within wide limits, in accordance with the character of the rock. In the crystalline rocks, composed of closely interlocking crystals, there is small space for water, and the densest known granite (from Montello, Wis.) has an average porosity of only 0.237 per cent, or about 1 part in 400. In sand the pores may constitute 30 to 40 per cent of the volume; in sandstone, 20 per cent or more. The sedimentary formations of Triassic age in Connecticut include sandstone, conglomerate, and shale, all of which have relatively large water capacity.

WATER IN SANDSTONE.

The prevailing sedimentary rock in Connecticut is sandstone, which varies in texture from coarse to fine and in color from chocolate brown to reddish brown, with local green and buff tints. Commercially the rock is known as ''brownstone,'' and the quarries of Portland, Long Meadow, and other places have furnished a great amount of it for building purposes. The large outcrops of sandstone in Connecticut are generally not homogeneous, presenting as a rule wide variation in grain, conformity, order of stratification, and relative amounts of the component strata. Overlapping lenses of sandstone, conglomerate, and shale, rather than uniform beds of sandstone, make up the formation. In one of the quarry pits at Portland four types of rock are sufficiently distinct to be separated for commercial purposes.

The Triassic sandstone of Connecticut consists of quartz, feldspar (in many localities kaolinized), biotite, muscovite, and garnet, with fragments of chlorite schist, mica schist, gneiss, and granite. The cement which holds the grains together and gives color to the rock is partly a film of iron oxide surrounding the grains and partly fine clay.

Sandstone in general has great water-holding capacity, and the Connecticut varieties form no exception. A sample from the Portland quarry which was dried carefully and then immersed in water for three months was found to have increased in weight during that time from 150 to 154 pounds,[a] an absorptive ratio of about one-fortieth of the weight of the specimen examined. The amount of water absorbed was about 2 quarts for every cubic foot, equivalent to 88,502,857 barrels for a square mile of rock 200 feet deep. This is sufficient water to form a lake 1 mile in diameter and 50 feet deep.

In spite of its capacity for holding such enormous quantities of water, the exposed portions of the sandstone usually appear dry. In railroad cuts and on cliffs the water is not seen to ooze out of the rock nor to form a film over its surface. It is only in artificial openings, such as wells, that the water drips from the rock itself. This absence of water on the face of a natural rock outcrop does not indicate that the rock is not saturated at a short distance back of the face, for the water within the rock would naturally seek a lower level of escape through some bedding plane or fracture nearer the base of the hill. In several localities springs issue from crevices immediately above which the rock is practically dry. In such localities the water table is depressed at the point of leakage.[b] (See fig. 15.) The depth to which saturated sandstone extends varies with the topographic location and character of the rock, but is in few places more than a few hundred feet. Wells are reported where the rock was so dry between depths of 200 and 300 feet that water had to be pumped into the hole to enable the drill to perform its work.

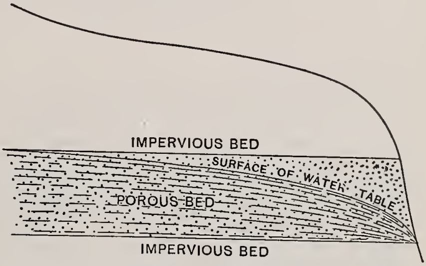

FIGURE 15.—Diagram illustrating depression of water surface at point of leakage in sandstone.

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[a] Stone, vol. 9, 1894, p. 20.

[b] Fuller, M. L., Water-Supply Paper U. S. Geol. Survey No. 110, 1905, p. 98.

WATER IN CONGLOMERATE.

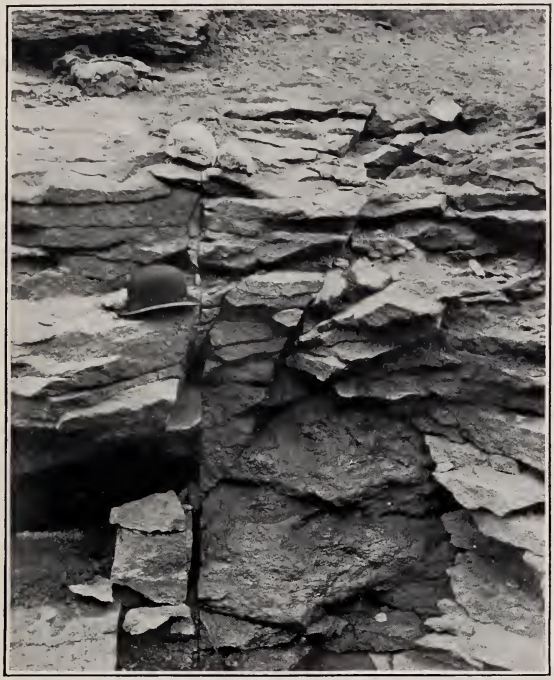
Interbedded with the sandstones are lenses and short layers of conglomerate, and at several localities, as in the vicinity of New Haven and elsewhere along the Triassic border, this rock occurs in great abundance. The pebbles in the conglomerate average from 1 to 5 inches in diameter, but reach extremes of more than 2 feet. Conglomerate is cemented gravel, and the pebbles of which the Triassic conglomerate of Connecticut is composed are crystals of quartz, feldspar, and mica, together with partly rounded fragments of schist, gneiss, porphyries, granite, and pegmatite. The pebbles, large and small, lie in a matrix of sandstone. The cementing material and coloring matter are identical with those of the sandstones, except that there is perhaps a smaller amount of clay.

The conglomerate contains within itself abundant water, as its pore space is relatively large, but, like the sandstone, it seems to give up its water readily to joints and other large openings and to be relatively dry at great depths. The deep wells in the Connecticut Triassic area which have been failures—the Northampton well, 3,700 feet deep; the Westfield well, 1,100 feet; the Forestville well, 1,290 feet; and the Winchester Arms Company well at New Haven, 4,000 feet—are in the conglomerate. The easterly dip of the conglomerate along the west side of the Triassic area suggests conditions favorable for flowing wells, especially as the upturned edges of the strata are in a position to receive the water from the Western Highlands and to carry it eastward into the ground. These favorable conditions are, however, offset by the lack of continuity in the rock strata due to the presence of joints and faults. (See pp. 133–135.)

WATER IN SHALES.

The shales of the Connecticut Valley, popularly called "slate," do not cover wide areas to the exclusion of other rocks, but occur as beds or lentils interstratified with the sandstones, conglomerates, and lavas which make up the Triassic of the State. Typical shales are layers of mud that have become consolidated by the addition of cementing material and by the pressure of overlying rock masses. The fragments of which they are composed are largely grains of quartz, feldspar, and mica, either fresh or partly disintegrated, and the layers into which a shale outcrop is divided are usually but a fraction of an inch thick.

Pure mud shales contain a large amount of water, but the pore spaces are so small that they retain it with great tenacity and wells sunk in unbroken shale beds of homogeneous structure remain as holes with moistened sides but with an amount of water insufficient for practical purposes. The Triassic shales, however, are not homo-



A. VERTICAL AND HORIZONTAL JOINTS IN SANDSTONE.

B. VERTICAL AND HORIZONTAL JOINTS IN TRAP.

geneous layers of compressed mud and silt, but thin beds of shale alternating with sandstone, and much rock which passes for shale or "slate" is in reality a very fine grained sandstone of large water capacity. Furthermore, the shale contains some small lenses of lime and gypsum, possibly also salt, which are readily dissolved and leave channels and pipes through which ground water may circulate with great freedom. The shales are furthermore broken by joints and faults of sufficient extent to permit the passage of water. These characteristics make the Triassic shales of scarcely less value than the sandstone as sources of water, although the quality of the water is usually inferior. The chief importance of clay shales, however, is not as a water carrier, but as a confining layer in the midst of more porous material which serves to collect and transmit the water, giving rise to springs and determining favorable locations for wells. (See p. 109.)

WATER IN TRAP.

There are two chief types of trap rocks in the Connecticut Valley—extrusive volcanic rocks (basalt) and intrusive rocks (diabase)—but considered in regard to their water-bearing capacity they may be treated as one. Except for the amygdaloid cavities in the lavas, filled with fresh or decomposed calcite, zeolites, etc., the traps are exceedingly dense, and the interlocked crystals of feldspar and pyroxene afford practically no access to surface waters. That ground water does not penetrate these rocks is clearly shown by the presence of unaltered anhydrite and bitumen at depths less than 30 feet from the surface. Moreover, the topographic form of the trap ridges prevents their absorption of surface waters. They project high above the surrounding plain and slope in two directions, and the rain that falls on them is hurried to the lowlands in streams. In fact, the lower slopes of the lava ridges furnish favorable catchment areas for surface waters, which are utilized by Hartford, New Britain, Meriden, and New Haven for city water supplies. Under the most favorable conditions the traps contain within themselves probably less than one-half of 1 per cent of their weight of water, and therefore may be disregarded as water reservoirs. (See Pl. IV, *B*.)

WATER IN BEDDING PLANES.

CONDITIONS OF OCCURRENCE.

The sandstone, conglomerate, and shale of Connecticut, although differing markedly in texture, in extent and uniformity of bedding, and in structural relations, are alike in being water-laid deposits. They constitute a series of parallel strata separated by more or less definite bedding planes, whose location, extent, and character exert a predominant influence on the water supply of the State. If the strata composing the Triassic were all of one type and homogeneous the ground water would be uniformly distributed, but owing to the different degrees of permeability possessed by the sandstone and shale the water tends to concentrate along definite horizons. For example, a bed of impervious shale overlain by sandstone allows water to accumulate in the upper strata. The water occupying the spaces between the sandstone grains will find it easier to move along the bedding plane than to penetrate the shale, and if the plane is exposed on a hillside or in an artificial opening a stream or seepage of water will likely be developed. (See fig. 5.) Shale is the most impervious rock in the sedimentary series and sandstone the most pervious, and together they form the best reservoirs, but water will occupy the bedding plane between sandstone and lava, or between sandstone and conglomerate, or between two beds of the same strata. The bedding planes are not usually actual cavities visible to the eye, but rather planes of parting through which water moves by capillarity. In some places, however, the solvent action of water operating for thousands of years has widened the cracks to a fraction of an inch, and in a very few localities definite stream channels several inches in height have been developed through which water pours as small-sized rills.

That water occupies these bedding planes in large amount is abundantly shown by direct observation and by the experience of well drillers. In one of the Portland quarries, where pits 200 feet in depth have been opened "water everywhere emerges from along the bedding planes, especially along the shaly partings, where, dripping down, it darkens the quarry walls over large surfaces."[a] In 1906 an exposed rock wall 75 feet in height in this quarry showed water entering from the bedding planes in large amounts, but none coming from the joints or oozing from the rock surface. In dozens of springs within the sandstone area the water issues from the contact between strata of varying texture and composition.

The experience of well drillers leads to the same conclusion. C. L. Wright, of Augurville, who has sunk many wells in the sandstone, finds that the water comes from "flat seams"—that is, bedding planes at the "juncture of firmer rocks overlain by loose-textured rocks"—and that water frequently passes from these planes as a "sheet extending entirely across the drill hole." A. A. Murray, of Middletown, reports that the largest amount of water "is to be encountered in hard rock directly at its contact with shale." In the vicinity of Hartford, according to C. L. Grant, the "usual water horizon is in the sandstone directly above the shale."

That water circulates freely along definite bedding planes is shown by the manner in which wells that are located in proximity tend to influence one another. For example, five wells of the Electric Light

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[a] Stone, vol. 9, 1898, pp. 42–43.

Company in Hartford, sunk in sandstone and shale to a depth of 200 to 225 feet and situated 40 to 50 feet apart, are all affected when water is pumped from any one, apparently because they draw their water from the same bedding plane. Other interesting evidence of the presence of water in bedding planes and its movements along these planes is furnished by two wells at the sanitarium 2½ miles northwest of Wallingford. One of the wells became contaminated by gasoline from a buried tank, and shortly afterward the other, 225 feet distant in the direction of the slope of the rock, became contaminated also. The polluted water had apparently traveled down the tilted bedding plane between sandstone layers.

Another proof of the circulation of water along bedding planes is found in the fact that the rock bounding these planes is decomposed by the action of chemicals carried by subterranean waters. In quarries and railroad cuts where these bedding planes are exposed they usually appear as lines or zones of discolored rock, but in many places there is a distinct layer of leached and disintegrated material that has formed in place by slowly moving ground water charged with carbon dioxide and other chemical reagents.

BLACK SHALE.

Probably the most impervious rock within the Triassic area is the black bituminous shale which occurs as a member of the ''Posterior'' sandstones. (See p. 39.) In the vicinity of Hartford this shale has been penetrated by wells at a number of localities and at different depths, and it rarely fails to define a water horizon of great importance. The logs of wells shown in figures 16 and 17 were furnished mainly by C. L. Grant and demonstrate two interesting facts—(1) that the water-bearing strata may be shale, as in the Newington, Allyn House, and Goodwin Park wells; or sandstone, as in the Bloomfield wells; or conglomerate, as in the Windsor street well; and (2) that the typical posterior black shale, unmixed with sandy layers, is a water-confining bed of exceptional impermeability, even where only 10 feet in thickness. The well of F. C. Dininy obtains its principal water supply at 256 feet below the surface and little water was encountered at a greater depth.

WATER IN JOINTS.

VERTICAL AND HORIZONTAL JOINTS.

As explained on pages 37–38, all rocks are traversed at relatively short intervals by cracks or seams which serve to mark the rock surface into polygons and break it up into blocks of various sizes. These are the joints in rocks, and their presence and distribution are important factors bearing on the water supply of Connecticut.

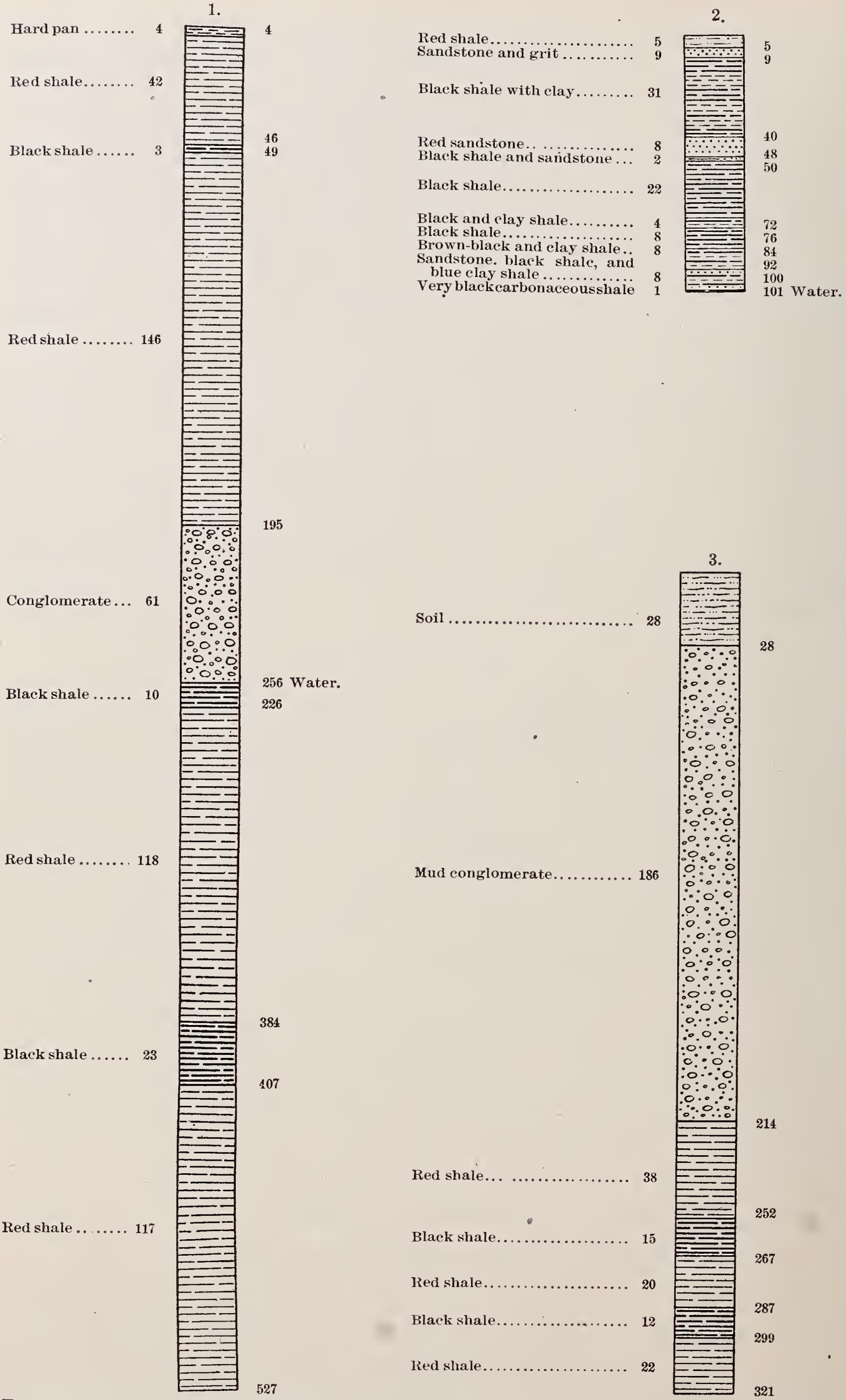

FIGURE 16.—Well logs showing influence of Triassic black shale in determining water horizons. 1, Well of F. C. Dininy, Windsor street, Hartford; water stands at 95 feet when well is pumped; yields 40 gallons a minute at 150 feet. 2, Well of H. C. Douglass, Bloomfield; flows 2 feet above surface; data furnished by owner. 3, Allyn House well, Hartford.

The joints in Triassic sandstone, conglomerate, and shale intersect at various angles, both in the vertical and in the horizontal plane, and many of the blocks which they bound are wedges of large or small size. Numerous measurements of the inclination of joint planes show that they stand commonly at high angles approaching the vertical. In the Fairhaven tunnel the prominent joints dip between 65° and 86° S. In the railroad cut north of Yalesville and in several other localities the dip of the main joints is less than 10° from the vertical. Approximately three-fourths of the conspicuous joint planes noticed at sixteen localities in Triassic sedimentary rocks are between 70° and 90° from the horizontal. There are, however, numerous fractures which are nearly or quite parallel to the planes of stratification and which serve to break the rock into still more irregular and indeterminate fragments. These horizontal joints are in many places approximately parallel to the surface of the ground, and where they cross the bedding planes it is usually at an angle of less than 25°.

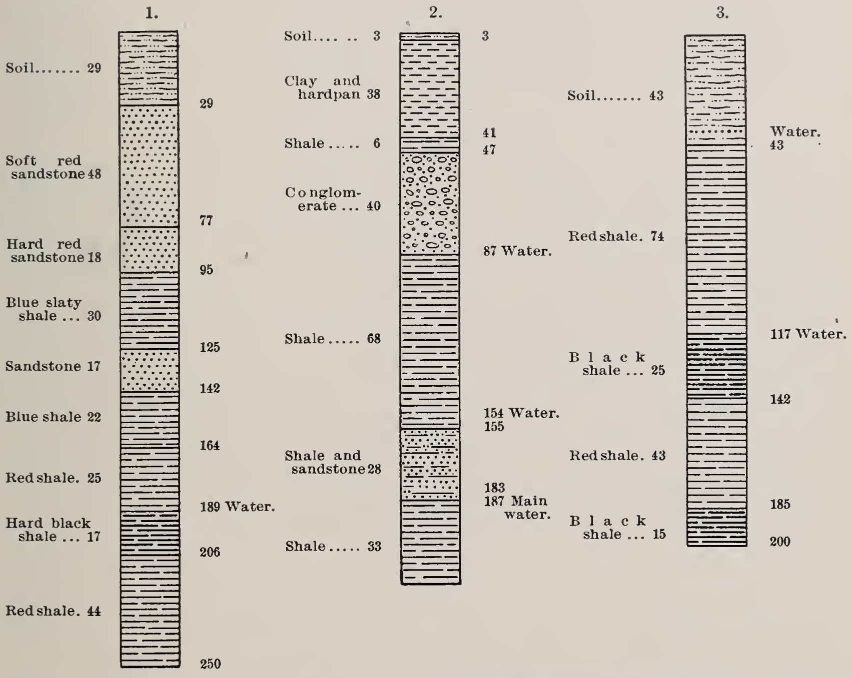

FIGURE 17.—Well logs showing influence of Triassic black shale in determining water horizons. 1, Flowing well at Goodwin Park, Hartford. 2, Well of L. A. Storrs, Bloomfield. 3, Well of Dr. A. B. Johnson, Newington; yields 40 gallons a minute.

Joints, both vertical and horizontal, are more common and more conspicuous and intersect at a larger number of angles in conglomerate and coarse sandstone than in shales. In fact, large regular blocks of conglomerate are quarried in very few places within the State.

In the sandstone quarries the joints are fairly regular and evenly spaced. In the long exposure of shaly sandstone in the gorge at South Meriden vertical joints are rare. Near Mill Rock joints in fine sandstone start, branch, and die out within a few inches, and in a number of localities joints traversing sandstone and conglomerate stop abruptly on reaching a stratum of shale. (See below.)

DIRECTION AND CONTINUITY OF JOINTING.

In the Portland quarry the prominent joints run N. 50° E., N. 60° E., N. 75°–85° E., and N. 20° W.; in the vicinity of New Haven the chief joints extend east and west, N. 70°–80° W., N. 20° W., N. 15°–20° E., and N. 50° E.; at West Granby, N. 80° W., N. 35° W., N. 10° E., and N. 20° E.; at West Cheshire, N. 80° W., N. 50°–60° W., N. 30° W., N. 10° E., and N. 55°–60° E. In the Pomperaug Valley Hobbs[a] found four major directions of jointing—N. 34° W., N. 5° W., N. 15° E., and N. 54° E. Although these uniform joint directions indicate some cause operating throughout the Triassic areas, there are many local variations, and in each region prominent cracks occur which do not correspond with the more common joints. For practical purposes each locality must be studied separately.

Some of the more prominent joint planes have been traced on the surface for several hundred feet and from the top to the bottom of the deepest quarry and railroad cuts. A few doubtless extend parallel to fault lines for some thousands of feet. Most of the joints observed, however, appear as open cracks for distances rarely exceeding 50 feet, though they may extend for great distances, both vertically and horizontally, as invisible parting planes.

SPACING OF JOINTS.

In the outcrops of sedimentary rock examined there was found great irregularity in the number and distribution of joints. In places the joints are 50 to 60 feet apart; elsewhere ten to twenty joints occupy 50 feet of wall space. In most large outcrops there are zones along which joints are crowded at intervals of less than an inch, and on weathered surfaces and in cuts where blasting has been carried on the rock is shattered into fragments a few inches in thickness by a multitude of intersecting joints. Outcrops of red and black shale occur in which the horizontal joints have separated the rock into chips or flakes that could be removed with a shovel. It is evident that in such rock ground water would circulate freely and be stored in large quantities. In the Portland quarries the main sets of vertical joints are 30 feet or more apart; at the north end they are 35 to 100 feet apart; and nowhere in the quarry were joints of the

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[a] Hobbs, W. H., Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 3, 1901, p. 100.

same series observed nearer than 7 feet from each other. In the railroad tunnel at Fairhaven the larger joints are about 25 feet apart and converge at low acute angles and branch out. At Pine Rock and West Rock the joints of all kinds average about five to a linear yard. The spacing of joints and their angle of inclination are the factors which determine the number contributory to a well.

Both vertical and horizontal joints are wider, more numerous, and more closely spaced near the surface than farther down. In one quarry observed by the writer the upper 30 feet of wall had nearly twice as many horizontal joints as the second 30 feet. The effect of joints is to greatly favor the absorption of water, but this must be a surface phenomenon, as the joints die out with increasing depth. In Connecticut large open joints are probably rare at depths exceeding 200 feet.

OPENING OF JOINTS.

Some joints at the earth's surface and probably all joints at considerable depths are tightly closed and are more nearly planes along which the rock might be broken than open cracks. Many joints, however, are a fraction of an inch wide, some are 1 inch to 2 inches wide, and in the Blakeslee quarry horizontal joint zones 3 to 4 inches wide are found. One crack in this quarry which is 2½ inches in width at the top was so narrow at the bottom that a sheet of note paper could not be inserted. Many joints exposed in quarry walls are filled with decomposed rock through their extent, and experience in well drilling proves that decomposition extends to considerable distances and serves to enlarge cracks to an important degree. (See pp. 73–74.) Where two joints intersect or where one crosses a bedding plane a channel may be developed by removing the disintegrated rock which forms the boundary planes. (See fig. 18.) In one of the Portland quarries the water enters in good-sized streams from vertical joints to an amount estimated at 250,000 gallons daily. Such freedom of circulation would account for the water-laid sand found in joints at Hartford 20 feet below the surface. Numerous small joints, however, furnish more abundant and uniform water supply than a few large open fractures.

JOINTS IN TRAP.

The direction, continuity, and inclination of cracks in the trap of the Triassic area are essentially the same as in sandstone. Exposures of trap rock are invariably characterized by well-developed vertical joints intersecting one another in all directions in vertical planes and dividing the rock into a series of polygonal blocks. This type of jointing undoubtedly is more conspicuous in exposures than it would be in unweathered ledges, yet the structure is developed in deeply buried rock and occasions trouble in drilling, owing to the breaking off of angular blocks that wedge the tools.

The opening of joints in trap and their value as reservoirs are practically the same as in the denser crystalline rocks described in Chapter IV (pp. 54–103).

WATER ALONG FAULT LINES.

Faults in rock are joints or cracks along which the strata have moved up or down or sidewise. The amount of displacement may be a fraction of an inch or thousands of feet, but as a rule there is a complete break in the continuity of the strata and a more or less open crack to mark the line of rupture. Few faults are single clean-cut breaks; more commonly they consist of a number of breaks that result in shattering the rock along a line some feet in width, forming a zone of material arranged as a confused mosaic of loose or cemented fragments.

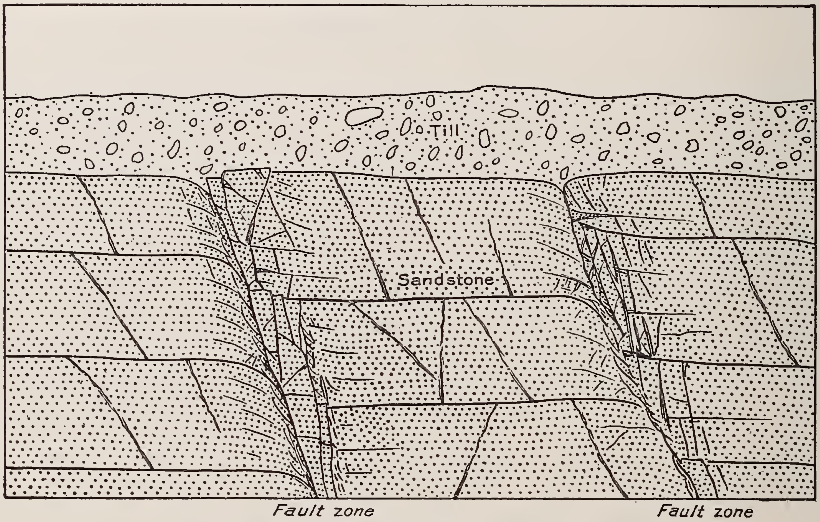

FIGURE 18.—Sketch showing fault zones in sandstone.

The structure of fault zones is favorable for the absorption of large quantities of ground water, which may be readily recovered. (See fig. 18.) Many springs in Oregon, the hot springs of the southern Appalachians, Saratoga Springs, etc., are located along faults, and the character of their waters is due to the great depths from which they come. The relation of springs to fault lines is a well-known phenomenon in Connecticut and some striking instances have been described by W. H. Hobbs.[a] At one place in the Pomperaug Valley eight springs occur within a distance of 60 rods, all located on a single

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[a] Twenty-first Ann. Rept. U. S. Geol. Survey, pt. 3, 1901, pp. 91–93.

fault line. Near South Britain a number of springs are located at the intersection of two or more fault lines.[a] Where fault lines are exposed in cuts and quarries the circulation of water in them is shown by actual seepage, by growth of plants, and by a zone of decomposed rock, formed by the solvent and oxidizing power of the ground water carrying carbon dioxide, etc., in solution. The relation of faults to water supply is well illustrated in the Middlesex quarry. Here the principal water carrier is an oblique fault zone 6 inches to 1 foot wide, which not only absorbs much water from the earth's surface but is also the main artery receiving supplies from bedding planes one-fourth to one-half inch wide. This fault contains probably 15 per cent of open space available for water storage.

Examples of wells located on faults are those of the Hartford Light and Power Company and of Armour & Co. at Hartford. The wells at the New York, New Haven and Hartford power house and the Berlin Brick Company and the Yale Brick Company's works, Berlin Junction, and at Hotel Russwin, New Britain, are advantageously located near fault zones.

RECORDS OF WELLS IN TRIASSIC SANDSTONES, CONGLOMERATES, AND SHALES.

The records of wells on the following pages have been selected to show the conditions controlling the recovery of ground water in the Triassic sediments of Connecticut.

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[a] Water-Supply Paper U. S. Geol. Survey No. 67, 1902, p. 80.

Records of wells in sandstone and other Triassic rocks of Connecticut.

No.[a]	Town.	Village.	Owner.	Topographic position.	Depth to rock.	Depth in rock.	Depth of well.	Depth to principal source.	Depth at which water stands.	Variation of water level.	Yield per minute.	Diameter of well.	Temperature.	Character of water.	Use.	Cost per foot.	Remarks.
					Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Galls.*	*In.*	° *F.*			*Dolls*	
*1	Avon		Mrs. J. B. Hadsell.	Plain	70	30	100	75	23	Pumping lowers.	1	6		Hard	Domestic		
2	Berlin		C. M. Jarvis				224		46		Good.	6		do	do	2.35	Watercomesfrom shale.
3	do		G. H. Sage	Hill	75	75	150	148	50			6		do	do	2.75	
4	do		J. B. Smith				201		50		6	6		do	do	2.00	
5	do	Berlin	F. L. Wilcox				220	220	50		40	8			General	3.40	
6	do		Geo. Arthur	Hill	60	55	115		20		10				do	2.00	
7	Bristol	Forestville	M. McCormick	do	4	47	51		26		1				do	2.50	
8	Bloomfield		H. C. Douglas	Slope	5	96	101		+ 2		8	6		Hard	Medicinal		Flowing well. Water comes from black shale. (See analysis, p. 177.)
9	Chatham	East Hampton	F. S. Hall		22	14	36	28	22		¾	6		do	Domestic	3.30	
10	Cheshire		Cheshire Coal and Feed Co.		35	7	42	42	14		60	6		do		2.30	Probably from surface material at contact with rock.
11	do		R. H. Morgan	Slope	11	180	191		17		4	6	52	do	Green-houses, domestic.	2.15	
*12	do		S. A. Bronson		12	313	325		35		25	6					
13	do		Frank Ives		12	24	36	33	2		20	6					
14	do		Mr. Williams		5	83	88	35 40 85	8		6	6					
15	do	West Cheshire	Ball and Socket Manufacturing Co.	Valley			150	146	19	Not lowered at 30 gallons.	+30	6	55		Factory, boiler.	2.00	Water found in "gray" rock. (See analysis, p. 177.)
16	Durham	Durham Center.	Henry Burchel	Slope	18	40	58	43	8	Pumping lowers and lower in summer.		6		Hard	Domestic		Water comes from seam in rock.
17	do		Albert Eich	Stream bed.			980?		Flows.					do	Domestic, stock.		When allowed to flow this well dries up three other wells within a quarter-mile radius.
18	East Hartford	Burnside	Mr. Hanson	Flat	15	33	48		15		12				General	2.25	
19	do	do	J. M. Mohrs	do	17	34	51		15		2				do	2.20	
20	do	do	P. Donohue	do	30	46	76		31		60				do	2.00	

21	do	do	East Hartford Manufacturing Co.				398		Flows.		Very large.			Hard			
22	East Haven		G. E. Poirot	Hill	½	99½	100		28		2½				Domestic		Passes through trap rock.
23	do		C. M. Finch	Slope	7	48	55	50	15		6½				do		
*24	do	Morris Cove	Rev. W. Roberts	Hill	17½	54	71½		22		2½			Medium	do		
25	East Windsor	Broadbrook	Jos. Morton	Flat	60	26	86		48		32				General		
*26	do	Melrose	F. Gowdy	Hollow	60	250	310		4		80				do	2.00	See analysis, p. 177.
27	do	do	E. M. Granger		135	135	270		80		22					2.00	
28	do	Warehouse Point.	Biard Daniels Co.	Flat	17	385	402		10		120					1.75	
29	do	Windsorville	Edw. Miller	Hill	9	209	218		43		12				General	2.00	
30	do	do	John Colman	do	87	30	117		47		40					2.00	
31	Ellington		John Thompson	do	15	42	57		11		50						
32	Enfield	Hazardville	J. W. Copley	Slope	10	31	41	41	10		40	6	47	Soft	Domestic, stock.	1.80	10 feet lower in summer of 1900.
33	do	do	E. C. Allen		40	67	107		20	Constant	25	6	48	Hard	Domestic	2.00	
34	do	do	Wm. Smith	Plain	52	58	110	108	28		15	6	50	Soft	Domestic, stock.		
35	do	do	Justin Bardwell	do	15	26	41		5		28	6		do	General	1.50	
36	do	do	E. King	Flat	4	44	48		5		50				do		
37	do	do	G. Reynolds	do	90	15	105		15		22						
*38	do	Thompsonville.	Connecticut Valley Brewing Co.		12	40	52		7	Pumping lowers 8 feet.	31	6	51	Hard	Boilers		
40	do	do	Issac Allen		17	50	67	45, 67	22	Lowers 15 feet in dry weather.	Good.	6	52	Medium.	Domestic		
41	do	Hazardville	Frank Olmstead	Flat	38	67	105		13		15				General		
42	do	do	Willis King	do	15	23	38		23		1				do		
43	do	do	do	Hill	40	33	73		36		6				do		
44	do	do	Harry Bridge	do	15	31	46		12		50						
45	do	do	Mrs. M. Fox	do	17	32	49		19		29						
46	do	do	Robt. Horthorn	do	25	35	60		10		15						
*47	Glastonbury		C. N. Carter	Valley	150½	74½	225	210–225	30	Constant		2		Soft	Domestic		
48	Hamden	Mount Carmel.	H. D. Clark	Plain	28	32	60	50	Flows, 2+.	Pumps down to 6 feet.	15	6		Medium.	do	2.50	Well flows in wet seasons but not in dry.
49	do	do	A. Woodman		12	58	70		14		9	6			do		
50	do	do	F. S. Brockett	Plain	35	7	42	37	28	Constant	15	6	42	Soft	do		Probably from gravel.
51	do	do	Phelps Montgomery.	Slope	3	77	80	33 60 78	18	Pumping lowers to 26 feet.	15						Sandy till and red sandstone to one-fourth mile south of a trap mountain.
52	do		W. W. Terrell	do	8	35	43		15	Varies with wet and dry season.		6	48	Hard	Domestic	2.00	
53	do		I. V. Cook	Plain			116	80	30	Constant		6	50	Soft	do	1.50	

a Additional details concerning wells marked * are given on pp. 124–126.

Records of wells in sandstone and other Triassic rocks of Connecticut—Continued.

No.	Town.	Village.	Owner.	Topographic position.	Depth to rock.	Depth in rock.	Depth of well.	Depth to principal source.	Depth at which water stands.	Variation of water level.	Yield per minute.	Diameter of well.	Temperature.	Character of water.	Use.	Cost per foot.	Remarks.
					Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Galls.*	*In.*	*°F.*			*Dolls*	
54	Hamden		W. C. Mansfield	Slope			55	40	15	Varies with wet and dry season.	2			Hard	Domestic, barn.	2.00	
55	do		C. L. Wright	do	8	38	46	28	12		6			do	Domestic, lawn.	1.50	
56	do		B. A. Davis				140		17		Large.			do		2.00	
57	do	Whitneyville	Morris Steinert		4	119	123		20		10	6			Domestic		
58	do	do	F. D. Grave		0	140	140	130	34	Pumping lowers 20 feet.	15	a8			do		
59	do	do	W. F. Downes		7	43	50	35	3	5		6		Hard	General	2.50	Water destroys solder in copper tank.
60	do	do	H. R. Stadtmiller.	Slope	0	85	85		22	Pumping lowers to 40 feet.	8	6	45	do		5.00	
61	do	do	C. E. Langdon	Ridge	8	82	90	40	35	Varies 10 feet with dry and wet season.	6	6	45	Soft	Domestic		
62	do	do	New Haven Country Club.	Hill			196	190	30		Good	6		do	General	2.00	
63	do	do	F. D. Putnam	Slope	12	153	165	164	20	Constant	+15	6		do	House, barn.	3.00	
*64	Hartford		Mrs. Samuel Colt	do			1,250					6					
65	do		Hartford Rubber Works Co.	Valley	190	160	350		18	Constant	45	6	54	Hard	Drinking		
66	do		D. F. Burns	Slope	40	223	263	+200	Flows.	Pumping lowers.	30	6	53		Ice machine, general use.	2.00	
67	do		Y. M. C. A	Valley	52	148	200	175	50		+25	6					
68	do		Keney Park	Slope	58	142	200	166	Flows 9+.		14	6	51	Hard	Used to supply lake.	2.00	
69	do		Goodwin Park	Foot of hill.			251		Flows +31.		Flows 1⅓.		53	do	Drinking	2.00	Water of black shale horizon. (See analysis, p. 177.)

70	do		Joseph Dart	Hill			74	69	Flows 0.	Constant	Flows ⅔.			Hard and sulphur.	Drinking, stock.		
71	do		Francis Parsons	do			136		86		3			Hard	Domestic	2.25	
72	do		J. A. Pilyard	do	150	55	205	190	52		60			Sulphur	Manufacturing, bakery.	2.00	
73	do		F. C. Rockwell				206	206	15					Hard			
*74	do		Capewell Horsenail Co.	Plain	12	238	250		12					do		1.60	See analyses, p. 177.
75	do		H. C. Long	Hill	15	26	41		25		23		50		Domestic, stable.	3.00	
76	do		Armour & Co	Flat	0	430	430		1		100			Hard	Cooling		
77	do		Kelly Bros	do	32	143	175		15		60			do	Washing stone.		
78	do		Atlantic Screw Co.	do	22	218	240		12		35			do	General		
*79	do		Hartford Light and Power Co.				620				125	12					
*80	do		New England Brewing Co.				462				350	10		Hard			
*81	do		Armour & Co				420			Flows	150	6					
*81½	do		Hubert Fischer Brewing Co.				500				75	8		Hard	Cooling		See note on p. 81.
82	do		Brady Bros		33	244	277				25	6			Bottling		Water becomes cloudy at times.
83	do		W. C. Wade		12	113	125		13		200		54	Hard	Cooling		
84	Manchester	South Manchester.	Harry Bowers	Flat	20	47	67		21		24				General		
*85	do	do	Cheney Bros	Valley	12	445	457	400	Flows 15+.	Constant	205	[b] 2	54	Hard	Washing silks.	(c)	See analysis, p. 177.
86	do	do	M. S. Chapman		20	205	225		Flow.		30	6		do	Fish ponds.		
87	do	do	do		20	105	125		Flow.		11			do	do		
88	do	do	do		20	55	75		Flow.		2½			do	do		
89	do	do	do		20	55	75				None.			do	do		
90	do	North Manchester.	F. J. Sharp		19	81	100		1		10			do			
*91	do	do	American Writing Paper Co.				300		Flows.		Flows, 12.			do			
92	do		Clayton Grant	Slope	16	87	103	100	50	Constant		6		do	Drinking		
93	Meriden		H. L. Aubrey	Plain			100	35	20		Large.	8		do	Laundry	3.00	
94	do		T. P. Lyon	do	30	46	76	70	6			6				2.50	
95	do		Meriden Brewing Co.				279		18		60	8		Hard	Brewery		
96	do		Meriden Bronze Co.				300				100	8		do			
97	do		Foster-Merriam Co.		100	200	300		0		100	8			Factory		

[a] For 2 feet 6 inches.

[b] 8 inches for 385 feet; 6 inches for 75 feet.

[c] $3.50 for 8-inch; $2.75 for 6-inch.

Records of wells in sandstone and other Triassic rocks of Connecticut—Continued.

No.	Town.	Village.	Owner.	Topographic position.	Depth to rock.	Depth in rock.	Depth of well.	Depth to principal source.	Depth at which water stands.	Variation of water level.	Yield per minute.	Diameter of well.	Temperature.	Character of water.	Use.	Cost per foot.	Remarks.
					Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Galls.*	*In.*	° *F.*			*Dolls*	
98	Meriden		J. G. Schwink, jr.	Slope			80		15	Constant	Large.	6		Hard	Stock	2.00	
99	do.		D. L. Bishop	Flat			102	102	19		30	6		Soft	General	2.20	
*100	do.	Meriden	Edward Miller & Co.				(*a*)				10–80	8		Hard	do.		
*101	do.	do.	International Silver Co.		100	460	560		5			6		Very hard.	Too hard for boilers.		
102	do.	do.	Meriden Curtain Fixture Co.		50	255	305				25	6					
*103	Middlefield		G. W. Durkee	Hill	70	15	85	80	40	Pumping lowers 12 feet.	Large.	6	52	Soft	Domestic, stock.	2.00	
104	do.		O. N. Miller	Plain	5	320	325		60			6		do.	Domestic	2.25	
105	Middletown		A. W. Budde	Slope	40	70	110	70	35			6	50	Hard, iron.	do.	1.50	
106	do.		Connecticut Hospital for Insane.	Hill	70	138½	208½	190				4	45	Soft, iron	Drinking		
107	do.		Goodyear Rubber Co.	Slope	40	156	196	130	Flows, 2+.	Pumping lowers.		6		Hard	Cooling		
108	do.		Portland Silk Co.	Plain	50	71	121	120	Flows.			6				2.30	
109	do.		Russell Manufacturing Co.	Stream bed.	30	120	150	130	Flows, 3+.		5	6		Soft	Drinking	2.00	
110	do.		B. F. Turner	Terrace, plain.	25	35	70	70	20	Constant	Good.	5		do.	Domestic	2.00	
111	do.		R. Kennedy	do.	50	200	250	240	10	Pumping lowers.	Good.	10		Iron		2.00	Water level sinks 2 or 3 inches in dry weather.
112	do.		L. D. Brown & Son Co.	Slope	40	252	292		45	Pumping lowers 30 feet.	80	6		Hard	Drinking	2.00	See analysis, p. 177.
*113	do.		Wilcox, Crittenden & Co.	do.	15	785	800	40	12–25		(2) Small.	6		Soft	Abandoned		
114	New Britain		A. J. Sloper	Hill			75	47	15	Constant	45 Large.	3		Medium.			Became contaminated with use.
115	do.		Landers, Tracy & Clark.	(*b*)	40	202	242	100	14	Pumping lowers	9	6		Hard			Water said to be in rock of slaty nature in trap.
*116	do.	New Britain	Hotel Russwin				152		9		Large.						

117	New Haven		New England Dairy Co.			1	157½					6			General, boiler.		See analysis, p. 177.
118	do		Seamless Rubber Co.				160				10	8			Factory purposes, cooling, general.		
*119	do		Winchester Repeating Arms Co.				4,000				Dry.	8					
120	do		J. E. Heaton	Slope	0	101	101	4			1½	6			Domestic		
121	do		L. Simons		6	91	97		20		1	6			do		
122	do		H. B. Ives		26	59	85	1	12			6			do		
123	do		St. Francis Orphan Asylum.		6	236	242		3		3				General		
124	do		W. P. Blake	Slope	3	147	150		25		30	6			Domestic		
125	do		G. H. Gill		12	90	102		16		30+	6			do		
*126	do		Hoyt Beef Co.	Flat	264	308	572		10		7	6			General		
127	do	New Haven	Lavigne Automatic Machine Co.			53	42	95			13	6					
128	do	Fair Haven	New Haven Iron and Steel Co.		119	406	525		10		1	6			General		
129	do		Housatonic Manufacturing Co.		32	168	200		25		10	6					
130	do	Fair Haven	J. R. King			203	203			Pumping does not lower.	40	6		Soft			No water above 100 feet.
131	do		Jos. Kegelmeyer	Plain	8	123	121	80	20		Good.	6				2.00	
132	do		Frank Brazos	do	70	57	127		48			6		Iron	Drinking	1.80	
133	Newington	Elm Hill	F. B. Wischek	Slope			75	17	13		3	6		Hard, iron.		2.00	
134	North Branford.	Northford	Mrs. T. H. Smith.	Hill			50	23	(c)			6				4.00	
135	do	do	Chas. Foote	Slope	1	99	100	98	(d)			6		Soft		2.00	
136	do	do					100					6					
137	North Haven	Montowese	T. Bishop		20	44	64		18		3	6					
138	do	do	do		20	62	62		18		2	6					
139	do		Wm. Dickerman.	Hill	0	140	140		50		2½	6					
140	do		A. F. Austin	do	0	50	50	20	30			4		Hard	General		
141	do		do	do	4	50	54	44	10	Constant	Large.	6		do	do		
142	do		C. W. Turner	Slope			96	70	70		Good.		(e)		Domestic	2.00	
143	do	Clintonville	J. E. Brockett	Plain	30	59	89	79		Constant	Good.	6		Hard	Domestic, stock.	2.00	
144	do		M. N. Wooding	Hill	15	15	30	24	10	Varies in season.		6		do		2.00	
145	do		G. O. Munson	Slope			75	50	10	Constant		6		Soft	Domestic	1.50	
146	do		E. A. Potter	do	46	24	70							Hard	do	2.00	
147	do		H. R. Smith	Hill			140	130	10	Pumping lowers.		6			General	2.00	

a 5 wells, 250 feet.

b Swampy ground.

c Flows in wet season.

d Varies seasonal, 20 to 45

c Top 56, bottom 50.

Records of wells in sandstone and other Triassic rocks of Connecticut—Continued.

No.	Town.	Village.	Owner.	Topographic position.	Depth to rock.	Depth in rock.	Depth of well.	Depth to principal source.	Depth at which water stands.	Variation of water level.	Yield per minute.	Diameter of well.	Temperature.	Character of water.	Use.	Cost per foot.	Remarks.
					Ft.	*Ft.*	*Ft.*	*Ft.*	*Ft.*		*Galls.*	*In.*	*° F.*			*Dolls*	
148	North Haven		I. L. Stiles & Son Brick Co.	Flat	50	70	120		30			6			General, boilers.		
149	Orange	West Haven	Mrs. E. Rogers	Hill	6	45	51				1½	6			Domestic		
150	Plainville		J. N. Bishop	Slope	6	46	52		40			6		Soft			
151	Rocky Hill		W. E. Pratt	Hill			56	54+½	28		1	6		Very hard.	Domestic	3.00	14 feet of soil, 36 feet of trap, 1½ feet of sedimentary rock.
152	Simsbury		Westminster School.	do			212		87	Constant	17	4	54	Soft	Drinking, washing, boilers.	3.00	See analysis, p. 177.
153	Somers	Somers Station	W. Prentice	Flat	52	18	70		30		50				General		
154	do	Somersville	Somerville Manufacturing Co.	do	60	26	86		20		20				do		
155	do	do	S. Anderson	do	83	11	94		20		7				do		
156	do	do	R. Delaney	Hill	55	15	70		37		2				do		
157	do	do	C. Doothy	do	20	13	33		10		5				do		
158	do	do	S. Ledgere	Flat	53	15	78		15		30				do		
159	do	do	S. Anderson	Hill	82	12	94		30		25				do		
160	do	do	W. Hemingway	Flat	13	29	42		18		50				do		
161	do	do	W. Billings	do	2	78	80		24		15				do		
162	Southington	Milldale	M. S. & C. T. Co.	Valley			200	150	20	Varies with season.		6		Hard	Boilers		
*163	South Windsor.	Wapping	C. M. Johnson	Flat	84	34	118	35	30		½	8		Soft	Domestic		
164	do	do	B. F. Nichols	Slope	60	20	80	80	36					Hard			
*165	Suffield		Suffield Water Co.	Hill	67	163	230	230	70		300	6	50	do	Town supply.		See analysis, p. 177.
*166	do		do	do	67	170	237	237	80			4		do	do		
167	do		Chas. Spencer	do	6	39	45		35		7				General		
168	do		Chas. Bissell	do	25	75	100		25		40				do		
169	do		S. A. Kent	do	90	169	259		18		100				do		
170	do	West Suffield	Terrett House	Flat	15	60	75		12		50				do		
171	do	do	Clara Loomis	do	5	120	125		17		8				do		
172	do	do	J. Gregg	do	8	123	131		24		10				do		
173	do	do	J. Noble	do	20	80	100		24		30				do		
174	do	do	W. Noble	do	3	59	62		24		14				do		
175	do	do	Sam Barr	do	50	50	100		20		40				do		
176	do	do	W. H. Hastings	do	135	50	185		Flows.		15				do		

177	do	do	Geo. Peckham	do	84	81	165		13		25				do		
178	Wallingford		G. D. Hall	Slope			67				Small.	4			Stock		
179	do		City of Meriden	Plain			105	80	80			6			Domestic, stock.	2.50	
180	West Hartford	Elmwood	N. E. Goodwin	Hill	55	45	100	30	30		8	6		Hard	Domestic	3.00	
181	do		Whitlock Coil Pipe Co.	Small hill.	60	137	197		25			6		do	Boiler		
182	do		Paul Thompson	Slope	20	20	40		30		Good.	2		do	Domestic	2.50	
183	do		St. Mary's Home	do			200	200						Soft	Stock, lawn		
184	do	Buena Vista	W. E. Howe	Hill			62				2			Hard	Domestic		
185	do		H. O. Griswold		10	142	152		15	Lowered pumping to 112 feet.		6					
186	Westersfield		C. L. Grant, C. I. Allen.	Hill			192		85		7	6		Hard	Stock	3.00	
187	do		. L. Grant, E.S. Goodrich.	do			82		62		12	6		do	Domestic		
*188	Windsor	Rainbow	Wm. L. Bidwell	Knoll	70	61½	131½		26	Pumping lowers.	½	6	50	do	do		
189	do		H. J. Fisk	Hill			135	135	40	Constant	2	6		do	General	2.00	See analysis, p. 177.
*190	do	Windsor	Windsor Water Co.		123	263	386		40	Pumping lowers 5 feet.	30	6					
*191	do	Wilson Station.	Christianson Bros.				113				50	6					
192	do	Windsor Heights.	Dr. H. J. Fisk				135				Small.			Medium hard.			
193	Windsor Locks.		J. O. R. Sheridan.	Hill	90	110	200		30		45				General	2.00	

NOTES.[a]

1. Passed through 20 feet of gravel, 25 feet of quicksand, 25 feet of gravel and hardpan, and 30 feet of red shale, in which the water was obtained. The water comes in slowly and carries fine sediment.

12. A little water was obtained at a depth of 50 feet and the water rose within 12 feet of the surface and remained at this level until a large supply was struck at a depth of 325 feet, when the water level lowered to 35 feet below the surface.

24. Passed through 17½ feet of soil and through 54 feet of trap ending in a hard red rock, probably sandstone. The source of the water is at the contact between the trap and the sandstone.

26. This well was drilled through sandstone into trap rock and the water enters above the trap.

38. This well is 52 feet deep and 6 inches in diameter, 40 feet of its depth being in the rock. The water rises within 7 feet of the top, a good many feet above the level of Connecticut River, which is only a stone's throw away. The pump raises 31 gallons a minute, which lowers the well 8 feet, but no farther. The water is moderately hard, has been used in boilers, and keeps a uniform temperature of 51° F. the year round.

47. Soil and sand, 20 feet; blue clay, hard and dry, 30 feet; clay and red quicksand, 10 feet; fine red quicksand, very shifting and hard packed, with a thin layer of saturated gravel at 118 feet from the surface, 60 feet; quicksand, 30 feet; gravel, 8 inches; sandstone, varying in hardness at different depths, 74½ feet. The water stood at 8 feet below the surface in the first soil and sand stratum but dropped to 30 feet below the surface after the 30-foot layer of clay was penetrated.

64. This well was drilled in 1863 by Col. Samuel Colt and flowed until 1898, when a well was drilled 1,000 feet farther north and the Colt well stopped flowing the next day.

74. This well was drilled by C. L. Grant, who furnished the following data: Depth, 250 feet; diameter, 8 inches. The well is in rock and flows. Elisha Gregory, a well driller of New York City, states in his "Torpedo circular" that the well was torpedoed by him at a later date and that as a result the yield was increased from 15 to 35 gallons a minute. It is reported that the quality of the water was injured by the process. Inquiry at the office of the company shows that at last accounts the water was not used for anything, so heavily is it charged with mineral matter. For analysis see table on page 177.

79. The 620-foot well of this company gives a more copious supply of water in rainy than in dry weather. The water contains too much calcium sulphate for boilers but is used for condensers. This well is said to have diminished the yields of four wells, each about 200 feet in depth, sunk for the same company.

80. It is stated that 400 gallons a minute have been pumped from this well without making any apparent impression on the water level. The well is 462 feet deep.

81. Depth, 420 feet. The water flows 1 inch over the top of the pipe when allowed to stand, which brings the water level above a large part of the neighboring land. The ordinary yield is 150 gallons a minute, the well being pumped continuously.

†81½. Depth, 500 feet; diameter, 8 inches. The water rises to the surface of the engine-room floor, and is pumped at the rate of 75 gallons a minute. The well is drilled in the "Upper" sandstones, but unquestionably pierces the "Posterior" trap sheet, which outcrops at no great distance to the west.

85. The water in this 457-foot well will rise 15 feet above the top and yield 205 gallons a minute at the surface. Pumping 600 gallons a minute for ten hours lowered the water level to 12 feet below the surface, where it remained constant.

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[a] Descriptions of wells marked "†" are taken from Water-Supply Paper 110.

†91. Depth, 300 feet; diameter, 4 (?) inches. The water flows over the top of the pipe at a rate of probably 10 to 12 gallons a minute. The water is hard and is used for drinking purposes only. The well lies entirely in the rock, which, in the stream near by, is seen to be rather loose in texture and to be filled with fragments of the crystalline rocks of the neighboring eastern highland.

†100. There are on the premises of this company five artesian wells, all 8 inches in diameter, from 250 to 300 feet deep, and bored into red sandstone, which at this place lies from 6 to 10 feet below the surface of the ground. The yield was measured when they were first bored, and varied in the different wells from 10 to 80 gallons a minute. The supply thus measured was obtained by means of an ordinary suction pump, which, operated at the rate named, lowered the water about 25 feet below the surface—as low as it could be pumped with that form of apparatus. A few years ago a system that works by compressed air and forces the water from depths of 70 to 90 feet was installed. This apparatus gave a very greatly increased output, which now supplies all the needs of the company. The water from these wells is all discharged into one large cistern, from which it is circulated through the factory. It is not easy to determine exactly the amount of water used, but it is estimated as between 75,000 and 100,000 gallons a day of ten hours. A much larger quantity than this could be obtained if needed. The water is satisfactory for manufacturing purposes except for use in boilers.

101. A well 560 feet deep, penetrating 9 feet of soil, 18 inches of gravel, 90 feet of quicksand, and 459½ feet of rock.

103. Drilled through 24 feet of clay, 20 feet of sand, 8 feet of clay, 50 feet of sandstone.

113. Depth, 500 feet. At a depth of 40 feet in sandy shale the well gave a small flow and drained an old dug well, 25 feet deep, in similar material. The well passed through about 300 feet of sandstone above bluish sandy shale and through a soft carbonaceous shale at about 400 feet. The well then passed through conglomerate and ended in blue clay shale. No water was struck below 40 feet and the flow ceased after a charge of nitroglycerine was fired in the well.

†116. Depth, 152 feet; depth of water when lowest, 130 feet, but if the well is a allowed to stand the water flows at the level of the engine-room floor, which is 10 feet below grade. The ordinary consumption is fully 10,000 gallons a day. The water can be used for all purposes. The well penetrated 140 feet of sandstone, etc., without finding enough water to keep the drill wet, but at that depth the drill became jammed in what appeared to be a crack about 2 inches wide, and an ingress of water followed the loosening of the drill. The apparent breadth of the crack may in reality be due rather to the presence of soft, decomposed rock along the joint plane than to an actual opening of the size indicated.

119. Drilled by the company in 1893, but no water was obtained except from surface seepage. It is 4,000 feet deep.

126. Depth, 572 feet. Penetrated 264 feet of quicksand and clay, the clay occurring mainly in small layers but with one 25-foot stratum above the rock.

163. Passed through 6 feet of loam, 76 feet of sand, 2 feet of gravel, and 34 feet of sandstone.

†165 and **166.** Town water supply of Suffield, owned by Paulus Fuller. No. 165 is 230 feet deep and has a diameter of 6 inches; No. 166 is 240 feet deep and has a diameter of 8 inches. The two wells together pump at the rate of 300 gallons a minute into a standpipe containing 293,000 gallons. The water rises within about 60 feet of the surface and is rather highly mineralized. It can be used in boilers, however, but gives some scale. The wells enter rock about 10 feet below the surface.

188. Depth, 131½ feet. Passed through 70 feet of soil, consisting of light sandy soil, light gravel, coarse gravel, and hardpan, and penetrated 61½ feet of soft red sandstone. The water naturally stands at 26 feet below the surface, and on being pumped out to a depth of 75 feet gave the following flows, as recorded by Mr. Bidwell:

Depth (feet).	Water rose (feet).	Time (hours).	Feet per hour.
75	5	¼	20
64	3.5	¼	14
	11.5	1	11.5
	18.5	2¾	6.7
52½	4.5	½	9
48	2.5	1	2.5

†**190.** Depth, 386 feet; depth of water, 326 feet; diameter, 6 inches. The pump yields 30 gallons a minute, which lowers the water 5 feet. The well passed through sand, 17 feet; clay, 56 feet; hard red gravel, 50 feet; the remainder in sandstone with the exception of two layers of "slate." Four analyses of the water have been made, according to which it ranges from moderately hard to excessively hard. It would seem that the water is free from organic impurities, but shows sulphate of lime to the extent of 590 parts to the million. It is extremely hard to the soap test. When first drawn the water is said to give off a strong odor of hydrogen sulphide.

†**191.** Depth, 113 feet; diameter, 6 inches; yield, 50 gallons a minute. Drilled in the bottom of an old open well and lies in the rock. The water is good only for drinking and garden use. It is said that when the well was first drilled the water had a very strong odor, which disappeared after the well had been used awhile. Data furnished by King & Mather.

Additional records of wells in the sandstone area of Connecticut.

[These wells were drilled by C. L. Grant, who has furnished the records. They presumably derive their water from sandstone, though a few may be in trap.]

No.[a]	Town.	Locality.	Owner.	Depth of well.	Depth to water.	Yield per minute.
				Feet.	*Feet.*	*Gallons.*
1	Berlin		New York, New Haven and Hartford R. R.	300	22	120
2	do		Berlin Brick Co	60	11	
3	do		do	70	8	
4	do		Yale Brick Co	100	19	11
5	Bloomfield		Mrs. A. S. Sage	86	18	14
6	do		M. J. Bradley	47	12	8
7	do		Grover Brown	31	17	13
8	do		Mrs. G. A. Cadwell	61	61	8
9	Farmington		Mrs. E. A. Smith	290	50	20
10	do		T. H. & L. C. Root	190	55	3
11	do		Lewis A. Storrs	208	41	25
12	do		Frank Hotchkiss	100	29	40
13	Hamden	Whitneyville	John H. Burton	50	10	15
14	do	do	W. F. Downer	67	27	7
15	do	do	Edw. Davis	56	9	10
16	do	do	Geo. W. Ives	65	13	8
17	do	do	Mr. Johnson	58	25	30
18	do	Mount Carmel	A. E. Woodruff	50	12	7
19	do	do	Chas. Wheeler	50	17	8
20	do	do	Sylvester Peck	36	21	6
21	do		Newton Archer	38	18	
22	do		Wm. Benham	68	28	3
23	Hartford		Hartford Woven Wire Mattress Co.	246	16	10
24	do		Retreat for Insane	180	24	20
25	do		W. C. Wade	125	11	50
*26	do		Ropkins & Co. Brewery	200	0	60
27	do		Long Bros	200	11	29
28	do		H. E. Patten	110	10	150
29	do		Hartford Light and Power Co	200	2	120
30	do		do	228	1½	150
31	do		do	201	1½	120
32	do		do	200	0	150

[a] For additional details, see page 128.

Additional records of wells in the sandstone area of Connecticut—Continued.

No.	Town.	Locality.	Owner.	Depth of well.	Depth to water.	Yield per minute.
				Feet.	*Feet.*	*Gallons.*
33	Hartford		Herold Capitol Brewing Co	300	Flows.	250
34	do		Allyn House	318	25	50
35	do		Geo. M. Brown	240	25	45
36	do		Brady Bros	159	15	15
37	do		D. F. Keenan	140	29	10
38	do		Keney Park	170	32	16
39	do		Hotoph & Carlson	155	25	12
40	do		Frank S. Tarbox	57	9	5
41	do		do	67	19	2
42	do		E. G. McCune	110	23	12
43	do		Geo. F. Hubbard	37	0	7
44	do		do	62	22	14
45	do		Thos. E. Moore	60	20	3
46	do		W. S. Mather	37	0	....
47	do		Wm. O'Brien	50	20	11
48	do		Addison & Impey	63	27	8
49	do		Johnson & Weeks	49	20	11
50	do		Wm. Rogers	110	75	5
51	do		Peter Peterson	50	10	9
52	do		A. Hepburn	50	11	8
53	do		C. L. Bailey	48	21	11
54	do		H. G. Abbey	35	17	7
55	do		Andrew Nason	28	12	5
56	do		B. L. Chappell	50	16	12
57	do		Geo. E. Hurd	50	11	8
58	do		M. H. Erickson	37	13	10
59	do		Dr. W. Crane	60	30	2
60	do		C. A. Green	50	12	6
61	do		E. B. Jerrum	50	15	11
62	do		O. Bengston	50	10	8
63	do		F. H. Seymour	70	30	8
64	do		Geo. J. Maher	65	18	13
65	do		A. M. Weber	75	25	5
66	do		R. Balinson	53	5	9
67	Middletown		A. B. Calef	75	40	....
68	New Britain		W. E. Bradley	40	18	....
69	do		Dennis & Co	195	12	40
70	do		A. B. Johnson	200	38	32
71	do		do	60	7	12
72	do		J. P. Curtis	250	13	10
73	do		Wm. Derby	80	49	6
74	do		A. W. Stanley	237	18	5
75	do		Coburn Land and Lumber Co	173	1	47
76	New Haven		Geo. W. Ives & Son	50	Flows.	....
77	do		do	200	3	10
78	do		A. B. Hendryx	254	....	65
79	do		Lion Brewery	103	....	60
80	do		National Wire Co	300	12	58
81	do		do	245	112	45
82	do		H. H. Olds & Co	75	35	....
83	Newington		Center school district	67	18	20
84	do		E. E. Pimm	24	15	5
85	do		Mrs. S. F. Robbins	91	28	12
86	do		Newton Osborn	159	....	18
87	do		J. G. Paradise	73	21	12
88	North Haven		F. L. Stiles	83	14	35
89	do		I. L. Stiles & Son	102	6	30
90	Plainville		John Coughlin	28	2	....
91	do		N. Terrell	50	12	8
92	dc		P. Horan	48	22	....
93	Rocky Hill		J. K. Green	25	....	4
94	Simsbury		W. L. Cushing	212	125	17
95	do	Tariffville	Connecticut Tobacco Corporation	331	36	30
96	do	do	Mrs. G. C. Willoughby	61	34	4
97	Southington		D. Green	66	24	5
98	do		Ætna Nut Co	....	....	....
99	Suffield		E. A. Fuller	40	6	6
100	do		Dr. M. T. Newton	63	14	10
101	do		A. C. Harmon	45	6	3
102	do		David Guy	48	18	3
103	do		Second Baptist Church	60	13	4
104	do	West Suffield	Frank S. Root	135	9	12
105	Wallingford	Yalesville	G. I. Mix & Co	100	6	40
106	do	do	J. H. Yale	67	45	....
107	do	do	C. W. Michaels	90	118	....
108	do	Quinnipiac	C. T. Stevens	40	Flows.	4
109	West Hartford		Jas. Thompson	110	15	23
110	do		E. C. Wheaton	135	20	35
111	do		Mrs. Kate Gallagher	53	9	3

Additional records of wells in the sandstone area of Connecticut—Continued.

No.	Town.	Locality.	Owner.	Depth of well.	Depth to water.	Yield per minute.
				Feet.	*Feet.*	*Gallons.*
112	West Hartford....	....	Geo. V. Brickley.................	30	15	12
113	.....do............	....	L. N. Burt......................	52	13	6
*114	.....do............	....	P. H. Reilly......................	175	15	40
115	.....do............	....	D. F. Crozier.....................	100	13	30
116	.....do............	Elmwood........	Mrs. E. W. Talcott...............	51	23	8
117	.....do............	.....do............	Jas. H. Waldron..................	195	39	6
118	Wethersfield......	....	J. H. Rabbett....................	30	2	12
119	.....do............	....	Rev. Lynch.......................	70	30	35
120	Windsor...........	....	C. D. Reed.......................	101	12	18
121	.....do............	Poquonock.......	Connecticut Valley Tobacco Co..	150	100	4

NOTES.

26. Depth, 200 feet; diameter, 6 inches; yield, 60 gallons a minute. The ordinary yield of the well is 25 gallons a minute and it flows if left standing. The water is too hard for boilers.

114. Sunk in the "Posterior" trap sheet, which at this locality is comparatively thin. The thickness of the trap has not been determined, but at least two-thirds, and possibly three-fourths, of the depth of the well must be in the "Posterior" shales which underlie the sheet, and it is very probable that the water does not come from the trap at all, but from the underlying shale.

WELLS IN TRAP.

Owing to the rugged topography of the main trap ridges few houses are built on them and consequently few wells have been drilled in rock of this character. In the vicinity of Hartford there are several wells which have been sunk directly into trap and obtain yields of 2 or 3 gallons a minute. The greater number of successful wells in rock of this type pass entirely through the trap and obtain their supplies from the underlying sandstone or shale.

All exposures of trap show an extraordinary development of jointing, and in cliffs, as at East Rock and West Rock in New Haven, the vertical joints cut the formation from top to bottom and usually show weathering, indicating the past action of water. In large trap exposures it is unusual to strike streams of water, which are so characteristic of the quarries in crystalline rocks, although it is said that in one of the Hartford quarries two days after a heavy rain water will begin to seep out of the joints at the base.

The field evidence indicates that the chances are small for obtaining water by drilling on the higher parts of the trap ridges, as the rock is so completely fractured at the surface as to allow the water to pass through and escape at lower levels, and at a short distance below the surface the joints are too tight to admit water in quantity. On such ridges, however, supplies may generally be obtained by shallow dug wells in the overlying drift.

Some interesting wells in trap have been described[a] by M. L. Fuller and W. H. C. Pynchon, as follows:

W. E. Pratt [*Rocky Hill*].—This well is located in the thin "Posterior" sheet of trap. It was drilled in the bottom of an old open well, 20 feet deep, which entered the rock for a distance of 6 feet. From this point the well was drilled 30 feet through trap, when it broke into the underlying sedimentaries, which it pierced to the depth of 1½ feet. This well therefore gives a section of 14 feet of soil, 36 feet of trap, and 1½ feet of sedimentary rock—a total depth of 51½ feet. This brings the bottom of the well about 50 feet above the surface of Connecticut River, which flows by it only a few hundred feet eastward. The diameter of the well is 6 inches and the maximum amount of water obtainable is a little less than 1 gallon a minute. The well pumps dry in thirty minutes. The water is fair for drinking, but is excessively hard.

J. K. Green [*Rocky Hill*].—Depth of well, 26 feet; depth of water, 25 feet; diameter, 6 inches; yield not given. The well is in trap rock. Data by Grant.

Hotel Russwin [*New Britain*].—The depth of the well is 152 feet, and the depth of the water at the lowest 130 feet, but if the well is allowed to stand the water flows at the level of the engine-room floor, which is 10 feet below grade. The ordinary consumption is fully 10,000 gallons a day. The water is very pure and can be used for all purposes.

[*Wells at Cedar Mountain.*]—The wells * * * at Cedar Mountain, southwest of Hartford, * * * are on the property of Dr. Gordon W. Russell, who sunk the wells largely as an experiment and who has shown much interest in scientific matters. The mountain is a part of the ridge of the "Main" trap sheet, and has a maximum elevation of about 360 feet above the sea. Its western face is very steep, dropping 250 feet to the plain within a distance of two-fifths of a mile, and is actually precipitous near the summit. The eastern face slopes more gradually, dropping about 120 feet to the valley occupied by shales, about three-fifths of a mile distant. It is in all a typical trap ridge.

Well A is an ordinary open well and was dug to supply the needs of the farmhouse. It was opened 9 or 10 feet to the rock, but the water became shallow in summer. It was then sunk 1 or 2 feet into the loose, greatly jointed surface trap and has since given an abundance of water for domestic uses. The supply, however, fluctuates regularly with the wetness or dryness of the season. From the well mouth the mountain side with its drift covering rises steadily for two-fifths of a mile to the west till it reaches the crest, which is about 100 feet above the well. The supply is clearly the surface water contained in the soil and in the heavily jointed upper surface of the trap, the source also of a little stream which lies a little farther up the ridge.

Well B is located about 200 feet south of well A. It passes through 9 feet of soil and then through about 290 feet of trap rock, at which point the string of drilling tools wedged fast, possibly along a joint plane. The well is 6 inches in diameter. On illuminating it brightly for a considerable depth by light reflected from a mirror, it appeared that no water came into it except from the shattered upper surface of the trap sheet, as in well A. The drill had not entered the underlying sediments when the well was visited in 1902, notwithstanding the fact that the bottom of the well was much below the level of the western plain.

Well C is located about three-fourths of a mile farther south and a little farther east than the other two wells. It has a depth of 103 feet. It was thought from the residue brought up by the sand bucket that the well entered the sedimentary beds below, but in view of the record of well B and the thickness of the "Main" sheet this is extremely doubtful. Water was struck at a depth of 38 feet from the surface in a joint, the yield being 32 gallons an hour. At the present depth the well is capable of giving 90 gallons an hour, the water probably coming through joints from a level below the well bottom

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[a] Water-Supply Paper U. S. Geol. Survey No. 110, 1905, pp. 88, 89, 100, 101, 103.

and rising to within 25 feet of the surface. During the drilling light was reflected down the bore and water was seen coming in through the trap, and in the opinion of the driller, Mr. H. B. King, of Hartford, from the downhill side. However this may be, we have here a well near the summit of the mountain whose bottom is above the level of the lowlands on either side, with water coming in through the trap and rising to a point about 175 feet above the plain three-fourths of a mile to the west and about 70 feet above the valley one-fourth of a mile to the east. The top of the well is about 280 feet above sea level.

PRACTICAL APPLICATIONS.

YIELD OF WELLS.

The sedimentary rocks of Connecticut possess large storage capacity between strata, in joints, along faults, and within the rocks themselves, and it is but rarely that a well sunk into sandstone, conglomerate, or shale does not obtain water from one or all of these sources in sufficient amount for domestic purposes. No enormous supplies running into thousands of gallons a minute, such as are obtained elsewhere in the United States, are found, and in some parts of the State difficulty has been experienced in obtaining sufficient supplies for large manufacturing plants. Wells in sandstone offer the best chances for large supplies, shale coming second, and conglomerate third. A few wells in conglomerate at New Haven encountered dry rock from top to bottom of the drill hole. One well on George street, 500 feet deep, obtained no water after passing through the cover of glacial drift, and another well remained dry to a depth of 4,000 feet. Such wells should not be abandoned "without a thorough test of every water horizon, however small. The casing, if possible, should be raised above the level of the water-bearing bed, a pump inserted, and the supply measured. When it is impossible to remove the casing, it can be destroyed at the water horizon by a shot of nitroglycerine, which will also at the same time tend to loosen up the surrounding rock and increase the flow. Supplies have frequently been developed at horizons which were not at first thought worthy of testing and which were originally drilled through without stopping and cased off."[a] Of the 194 wells recorded on pages 116–123, only 11, or 5.6 per cent, failed to obtain 2 gallons a minute, the minimum amount desired for domestic purposes. Drillers are naturally averse to reporting well failures, yet considering the number of successful wells of which no records are available the above percentage is probably close to the facts.

The average yield of 112 wells in sandstone reported in the tables is 27½ gallons a minute, the largest being 350 gallons and the smallest two-thirds of a gallon. The 107 wells included in the supplementary list furnished by C. L. Grant (pp. 126–128) have an average yield of 26 gallons. As a rule, the well that encounters the largest number of joints and bedding planes has the largest supply of water, and there

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[a] Water-Supply Paper U. S. Geol. Survey No. 110, 1905.

is, therefore, an increased yield with increased depth. This statement, however, is true only for wells less than about 300 feet in depth (see below), and many exceptions are to be noted. A well which strikes a favorable bedding plane between sandstone and shale, or drains water from a contact of trap and sandstone, or strikes a fault zone may yield large amounts at slight depths. In fact, the water moves so freely through the rock that wells sunk to lower levels or located more advantageously may drain a neighboring well, thus making it useless. (See pp. 108–109.)

The abundant and uniformly distributed rainfall of Connecticut (see p. 24) and the freedom of circulation of ground water in the Triassic sediments account for the slight variation in yield throughout the year. Few drilled wells in rock show seasonal variations. A few record a decrease in summer; in several others the supply has increased since the wells were dug. Mr. Grant is of the opinion that "in general, the wells in the Triassic area have increased their flow with age." This seems to be due to the enlargement of seams and joints caused by the washing out of the decomposed rock ("clay"). "Water from black shale," says Mr. Grant, "clears up in about two hours, but that from red shale remains cloudy for a week or two." In many wells the water has become clearer as the years have passed. The height at which water stands in the well is also remarkably uniform.

DEPTH OF WELLS.

Two geologic myths seem to have attained the dignity of facts in the popular mind; one is that ore veins increase in richness with increasing depth, the other that water is more abundant and of better quality in proportion as it comes from greater depth. So far as Connecticut's water supply is concerned, the facts are not in accord with popular opinion. Though water is drawn from sandstones at all depths between the surface and 800 feet, yet the greatest number of failures are in wells exceeding 400 feet in depth. The reason for decreased supply at greater depth is the decrease in the number of joints and the tightening of both joints and bedding planes. The average depth of 287 wells, including the three deepest, one of them 4,000 feet, is 144 feet. At $2.26 a foot, which is the average cost of 67 wells, the cost of the average well is $335.44. The depth to the principal water horizon is even less than the depth of the wells. In 63 wells with an average depth of 127 feet the principal source of water was 97 feet below the surface. The depth to the surface of the water in 144 wells in sandstone averages 23 feet. Of the 314 wells recorded in sandstone, shale, and conglomerate, 75 per cent are less than 200 feet deep, 90 per cent less than 300 feet, and only 5.6 per cent more than 400 feet; 47 per cent, including some of the best wells in the Connecticut Valley, are less than 100 feet deep.

In view of these facts and in consideration of the increased difficulty and cost of deep-well construction, it is good practice to abandon a well that has not obtained satisfactory supplies at 250 to 300 feet. Two or three wells 200 feet deep could be drilled at the cost of one 500-foot well, and the prospect of obtaining water would be greatly increased. In case a well is abandoned, the new location should be as far as possible from the old. In fractured rock favorable conditions may be found a few hundred feet distant. Wells in shale may be sunk to greater depth before abandoning the site, as is indicated by the fact that of sixteen deep wells in shale two are between 100 and 200 feet deep, five between 200 and 300 feet, four between 300 and 400 feet, two between 400 and 500 feet, and three more than 500 feet.[a]

QUALITY OF WATER.

The table of analyses shows that the composition of water in Triassic strata varies greatly, for wells only a few hundred feet apart may show marked differences in mineralization. One reason for this can be traced primarily to the inclination of the strata. As the rocks dip eastward at an angle of 15° or more, the area tributary to each well is rather small; a 500-foot well, for instance, would have a supply basin of considerably less than one-sixth of a square mile. Therefore different wells are supplied from different sets of beds, which differ from each other in their composition and consequently in their effect on the water passing through them. In general, the waters of the Triassic are so highly mineralized as to be undesirable for boilers without purification, thus strongly contrasting with those obtained from wells in crystalline rock. (See p. 168.) They are not too hard for cooling, washing, and certain other manufacturing purposes, nor for domestic use. Many wells show 500 to 2,500 parts per million of dissolved solids, including not only incrusting carbonates, but also the more undesirable sulphates. The water percolating through sandstone and shale is usually harder than that in joints and in bedding planes, and water of different quality may come from each stratum.

TEMPERATURE.

The temperature of well waters is determined by the depth from which they are drawn. At depths less than 50 feet the temperature of the water will roughly vary with the temperature of the air, which for Connecticut is 45° for the spring season, 67° in the summer, 51° in the fall, and 36° in the winter.[b] Below about 50 feet the temperature increases at the rate of 1° for each 60 feet.

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[a] Water-Supply Paper U. S. Geol. Survey No. 110, 1905, p. 99.

[b] These figures are based on the mean seasonal temperatures of Storrs, New Haven, and Cream Hill, combined, for the years 1893-1903, 1873-1903, and 1897-1907, respectively, as given on pages 24, 25.

HEIGHT OF WATER IN WELLS.

Water in wells tends to reach a certain level, which remains constant with the exception of slight seasonal variations and changes produced by pumping. The height at which this water level stands depends on the character and permanency of the supply. In some wells the water stands at the rock surface, in others above or below that surface, and in a few it is under hydrostatic pressure and reaches the earth's surface as a flow. The topographic location is another factor in determining water level in wells, for, as shown in the table below, the water in valleys tends to rise above the rock floor, whereas about half of the wells on hills and slopes maintain a level within the rock. Considered as a whole, the water level in the Triassic sandstone stands 23 feet below the surface of the ground.

Height of water in wells.

Location.	Number of wells averaged.	Percentage with water level—		
		Below rock surface.	Above rock surface.	Even with rock surface.
Hills	28	46.4	50	3.6
Valleys	59	28.8	67.8	3.4
Slopes	29	48.3	44.8	6.9

FLOWING WELLS.

As stated on page 49, the primary conditions for flowing wells are (*a*) strata capable of holding large amounts of water, overlain by strata which are relatively impermeable; (*b*) outcrops of the strata where they may receive the surface water, and (*c*) a suitable dip to the rock. All these conditions are present in the Triassic areas of Connecticut. Sandstone and shale are interstratified, forming the couple which produces artesian wells in the Dakotas, New Jersey, Texas, and elsewhere. Lava flows alternate with the sandstones and shales, a condition which makes an artesian basin in parts of Idaho.[a] The edges of the water-bearing strata are well exposed, the rainfall is ample, and there is a dip to the strata of 15° or more to the southeast. Under normal conditions the Connecticut lowland would therefore form an unusually good artesian basin, and wells sunk anywhere along the western border of the Triassic area would procure large supplies, as shown in figure 19. This opportunity of obtaining artesian wells is almost entirely destroyed by two circumstances. First, the region is crossed by a series of faults and the strata are broken into huge blocks uplifted on the west side. The continuity of the water-bearing beds is therefore destroyed. But, even under these conditions, artesian

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[a] Russell, I. C., Bull. U. S. Geol. Survey No. 199, 1902, pp. 178-180.

basins of moderate extent (fig. 20) would be present were it not for the fact that the strata between the fault lines are cut by joints which run in all directions and are but short distances apart, several being present in each 100 feet (fig. 21). The continuity of the beds is thus

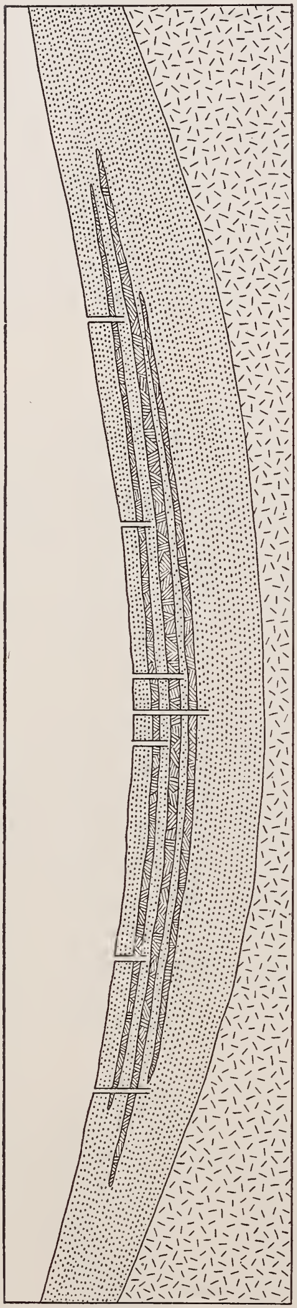

FIGURE 19.—Section of the Connecticut Triassic area as a synclinal basin—conditions favorable for artesian wells.

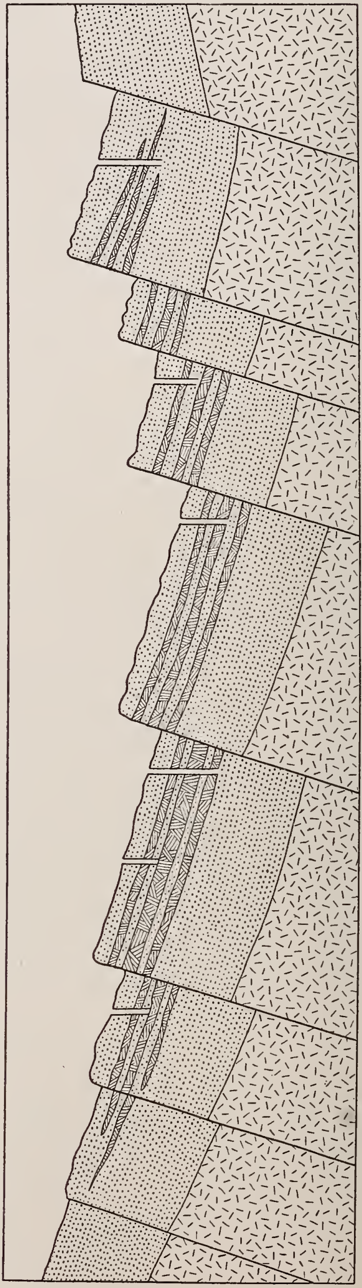

FIGURE 20.—Section of the Connecticut Triassic area as a simple faulted monocline—conditions favorable for several small artesian basins.

further disturbed and the existence of unbroken beds, either as water bearers or water retainers is made impossible. All the strata, including the lavas, have taken part in this faulting and jointing, with the result that instead of numerous flowing wells throughout the region, there are a few the waters of which rise slightly above the surface. Some of the flowing wells derive their water from local bedding planes in rock; the others from the contact of rock with the cover of glacial till.

LOCATION OF WELLS.

Two considerations will usually control the location of wells—the amount and the quality of the water desired. To insure good quality requires a location selected with reference to freedom from contamination by drainage from barns, cesspools, houses, factories, etc. High ground with a surface cover of glacial material is a better location than bare rock. A well in low ground will usually yield more water at less expense, but the danger of contamination is greater. When it is proposed to construct a well, the condition of existing wells in that vicinity or in the same rock type should be studied with care. The direction, opening, continuity, and number of joints in the rock should be observed; also the dip or inclination of the strata and the presence of beds of shale or trap.

It is to be remembered that water in bedding planes passes up as well as down an inclined surface. The usual experience, as stated by C. L. Wright, of Augerville, is to find water at less depths on eastern slopes of hills than on western slopes, because of the eastward dip of the strata. There are numerous examples of both wells and springs,

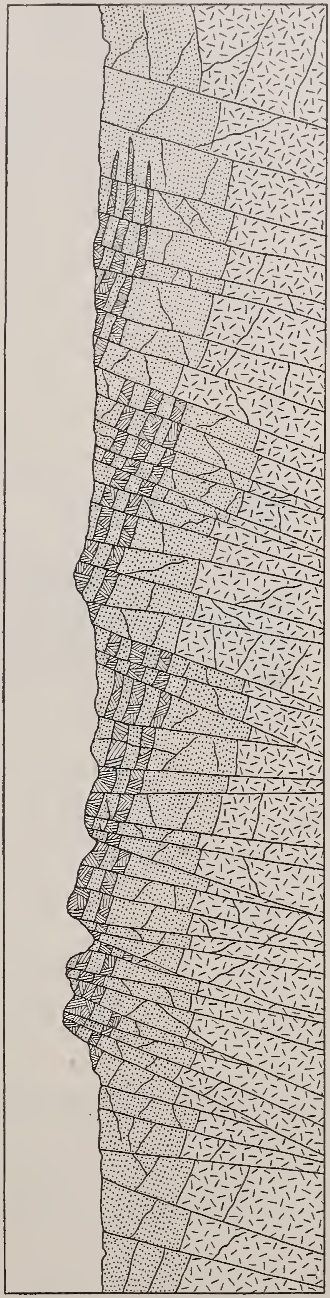
FIGURE 21.—Section showing actual condition of the Connecticut Triassic area—faulting and jointing developed to such an extent as to preclude the possibility of large artesian basins.

however, which indicate that water flows up the slope after being fed into the bedding planes by joints. A well at Thompsonville, illustrating movement of this type, is described on page 124. The water in this well is 25 feet higher than the water in Connecticut River, near by, which might otherwise be its source; the water-bearing bed does not outcrop farther east; and there seems to be no source of supply other than joints or faults. A well at the "old Talcott tower," near the edge of a 700-foot cliff, is believed to derive its meager supply from water moving up the 15° slope from the east. The hundreds of springs located along the western faces of low sandstone ridges that derive their water from a combination of joints and upward-sloping bedding planes may be illustrated by a spring on the estate of A. I. Ward, at Mount Carmel. (See fig. 22.)

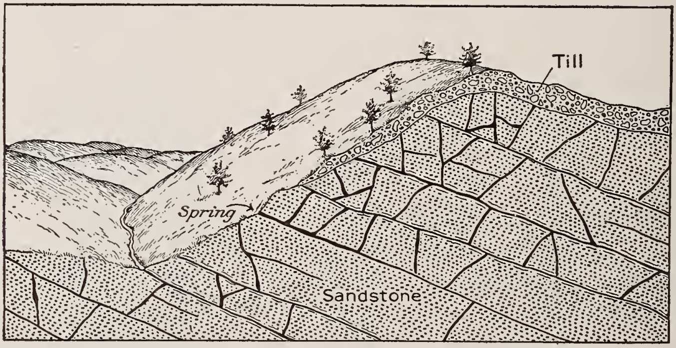

FIGURE 22.—Spring deriving its supply from joints and upward-sloping bedding planes.

STATISTICAL TABLES.

Yields of water at various depths in the rock below the covering of surface material.

"Vol." = average yield in gallons per minute; "No." = number of records from which the average is taken.]

Depth in feet.	Vol.	No.	Depth in feet.	Vol.	No.
0–30	4.7	3	110–200	27.6	53
30–50	14.8	40	200–300	56.4	41
50–70	11.1	44	300–400	40.7	7
70–90	17.7	21	400–500	185.0	6
90–110	20.3	29	500–650	40.0	5

The foregoing table requires a little explanation, especially in regard to wells more than 400 feet in depth, where the recorded yield of 185 gallons a minute does not represent a true average. This estimate is the average of the yield of five wells in Hartford and one in South Manchester, in both of which places unusual conditions prevail. Moreover, the principal source of water of these wells is at a less depth than 400 feet, so that the same yields would have been obtained if drilling had stopped at 300 to 400 feet. Considered in this light, the data from wells 400 to 500 feet in depth indicate the presence of water in bedding planes down to 400 feet and should go to swell the average yield of wells 200 to 300 feet and 300 to 400 feet deep. The figures for wells more than 500 feet in depth likewise convey a wrong impression of the relation of yield to depth. The five wells included in the table report yields of 1, 2, 7, 75, and 125 gallons a minute. In all these wells the principal source of water is less than 300 feet and in one well less than 50 feet below the surface. When these facts are taken into account the yield of wells more than 500 feet in depth drops to an average of less than 10 gallons a minute.

Average yields of wells in various locations.

Location.	Average yield (gallons per minute).	Number of records.
Valleys	64.3	6
Hills	44.4	24
Slopes	17.7	14
Plains	42.7	46

Relation of level at which water stands in wells in various locations to surface of rock which marks bottom of overlying drift. [a]

Location.	Number.	Percentage of wells with water level below rock surface.	Percentage of wells with water level above rock surface.	Percentage of wells with water level even with rock surface.
Hills	28	46.4	50.0	3.6
Valleys	8	12.5	87.5	0.0
Slopes	29	48.3	44.8	6.9
Plains	51	31.3	64.7	4.0

[a] A summary of the results for all wells may be found on p. 133.

Average depth from surface to water level in the well.

Location.	Depth to water.	Number of records.
	Feet.	
Hills	31.9	37
Valleys	16.9	10
Slopes	21.2	26
Plains	19.9	53

Average depths, in feet, of surface material, of rock, and of the entire well for the records at hand, exclusive of wells more than 400 feet in depth and of wells known to be dry.

Location.	Average depth of surface material.	Average depth in rock.	Average total depth.	Number of records.
Valleys	82.5	199.5	282.0	6
Hills	39.4	73.9	113.3	30
Slopes	20.4	95.1	115.5	22
Plains	39.3	93.8	133.1	50

NOTE.—Average total depth of all these wells is 161 feet.

CHAPTER VI.

WATER IN THE GLACIAL DRIFT.

INTRODUCTION.

Exposed rock surfaces in Connecticut are confined largely to hill summits, cliffs, river valleys, and the shore line, and their combined area probably amounts to less than one-tenth of 1 per cent of the 4,965 square miles constituting the area of the State. Where rock outcrops are absent, glacial drift forms the surface covering. The three classes of glacial material in which ground water occurs are till, stratified drift, and clay.

CHARACTER AND WATER CAPACITY OF DRIFT.

TILL.

Till varies in texture from loosely compacted bowlders a few inches to several feet in diameter to a firm, dense, securely cemented mass of small rock fragments and clay, popularly called "hardpan." The composition of an average deposit of till is shown by the following mechanical analysis of the so-called Triassic stony loam from Bloomfield:

Mechanical analysis of stony loam from Bloomfield.[a]

	Diameter of grains.	Per cent.
	Millimeters.	
Gravel	2 -1	2
Coarse sand	1 - .5	3.35
Medium sand	.5 - .25	8.60
Fine sand	.25 - .15	31.25
Very fine sand	.1 - .05	34.22
Silt	.05 - .01	4.35
Fine silt	.01 - .005	6.20
Clay	.005- .0001	6.57
Loss at 110° C		1.36
Loss on ignition		2.03

[a] Field Operations, Div. Soils, U. S. Dept. Agr., for 1899, p. 131.

The soil represented by the foregoing analysis is the fine earth after coarse gravel and bowlders, varying in size from an inch to 7 or 8 feet in diameter, have been removed. The amount of gravel and undecomposed rock invariably exceeds 5 per cent, and may exceed 50 per cent.

The heterogeneous character of till makes it impossible to estimate its water-bearing capacity for any large area. The amount of clay present, the size, shape, and composition of the constituent bowlders, and the degree of compactness vary within wide limits, and therefore determinations of absorptive ratios apply only to the sample tested. Determinations of water capacity are made still more uncertain by the presence of irregular deposits of sand and gravel included within the till. The loosely compacted till has practically the capacity of conglomerate; the "hardpan" variety is almost as impervious as shale.

A mass of till collected near Yale Field, New Haven, was found after five days of continuous drying to weigh 22 pounds. After soaking in water for one day and being allowed to drain the added water had increased its weight to 24.87 pounds, a gain of 2.87 pounds, which showed an absorption percentage of 11.55, or 3.46 quarts to a cubic foot of till. This is probably not far from the average capacity of till in Connecticut.

STRATIFIED DRIFT.

Stratified drift consists of sands and gravels with local clay bands and is composed of rounded waterworn fragments of the more resistant rocks, like granite, trap, and quartzite, together with an abundance of grains of quartz, mica, garnet, magnetite, etc. It owes its origin to streams, and especially to the water produced by the final melting of the continental ice sheet. As contrasted with till, stratified drift occurs in layers of various degrees of coarseness, depending on the velocity of the stream which deposited the débris.

It must not be supposed that the stratified drift presents uniform conditions over large areas, for there are several types of the drift, each varying in texture, structure, and topographic appearance, in accordance with their method of formation. Flood-plain deposits and terraces contain numerous fine clayey layers. Delta deposits made in bodies of standing water exhibit strata of sand, gravel, and silt inclined at various angles, and the different sets of beds contain water in different amounts.[a] The grains composing sand and gravel come into contact with one another, but are so placed that there is much unoccupied space between them. Sand is practically sandstone with cementing material removed and the water capacity proportionately enlarged. As a reservoir of ground water, stratified drift is therefore very important. Such material has been found to contain an amount of water equal to over 30 per cent of its volume.

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[a] Crosby, W. O., Water-Supply Paper U. S. Geol. Survey No. 145, 1905, pp. 177–178.

The proportions of different sizes of grains in the average sand of the New Haven plain, are shown by samples from four localities analyzed by Freeman Ward, as follows:

Size of grains in sand from New Haven plain.

Size of grains.	1.	2.	3.	4.
$\frac{1}{2}$ inch to $\frac{1}{4}$ inch	0.9	2.3	0.6	0.8
$\frac{1}{4}$ inch to $\frac{1}{8}$ inch	.7	2.7	1.6	1.6
$\frac{1}{8}$ inch to $\frac{1}{16}$ inch	1.1	10.0	5.5	6.3
Less than $\frac{1}{16}$ inch	97.3	85.0	92.3	91.3
	100.0	100.0	100.0	100.0

Rain water is freely imbibed by stratified drift, and accordingly the surface dries very shortly after showers, and this material furnishes little water to streams. The water, however, stands close to the surface and the sands of plains and kames are thoroughly saturated. On the North Haven sand plain there is "plenty of moisture a few inches below the surface, even in a protracted drought.[a]

CLAY.

The clays of Connecticut are largely the result of the deposition of fine material in lakes of glacial origin. They are accordingly stratified and usually contain layers of "strong clay" interbedded with sandy clay, quicksand, and sand of coarser textures. Clay consists of minute particles of kaolin, quartz, feldspar, mica, iron ores, etc., and when compacted under pressure these fragments are so nearly in contact as to give little pore space. However, the very small openings between the grains permit the access of much water, for each space acts as a capillary tube and the clay is expanded. The fine-grained clays, therefore, absorb and retain large amounts of water. That abundant water is present is indicated by the mud cracks in exposed clay surfaces and by the shrinkage which takes place on drying—an amount often over 10 per cent. The total amount of water in the brick clays of Connecticut is usually between 30 and 40 per cent. Most of the commercial clays of the State "contain enough water to make them highly plastic, so that they can be tempered without addition of more water."[b]

THE DRIFT AS A WATER RESERVOIR.

The mantle of glacial drift spread over Connecticut is perhaps the most important single factor in the ground-water supply of the State, because it contains abundant water in itself and controls the supply

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[a] Britton, Bull. Torrey Bot. Club, vol. 30, 1903, pp. 571-620.

[b] Loughlin, G. F., The clays and clay industries of Connecticut: Bull. Connecticut Geol. and Nat. Hist. Survey, No. 4, 1905, p. 63.

of water to the underlying rocks. The bed rock exposed on the summits and sides of hills is not in a position to absorb water. It is apparent that the greater part of any rainfall on such surfaces would run off immediately; in fact, a locality where even 2 per cent of the precipitation was absorbed by the rock would be exceptional. Even where there are wide-open cracks on the rock surface, the greater part of the water would run off before it could be absorbed by the few joints, which, not far below the surface, are so tight as to allow very slow passage to the water.

On the other hand, where the rock is covered by glacial material the water does not run off rapidly but is absorbed by layers of porous sandy soil, from which in turn a considerable portion of the precipitation passes down into the rock fractures. Numerous shallow-dug wells indicate that the lower portion of the drift is in a saturated condition, being always ready to supply water to joints or faults or bedding planes below. The saturated belt in the surface material forms a constant reservoir, kept filled by uniform precipitation, from which water is delivered to the rocks to compensate for the amount removed by springs and wells. The sandy and gravelly portions of the drift are the most important reservoirs for supplying water to rock seams, for they carry a large quantity of water and allow ready passage; the clayey till, which may hold nearly as much water, allows very slow passage. The character of the overlying drift is, therefore, by its difference in permeability, largely determinative of the amount of water supplied to the underlying rock.

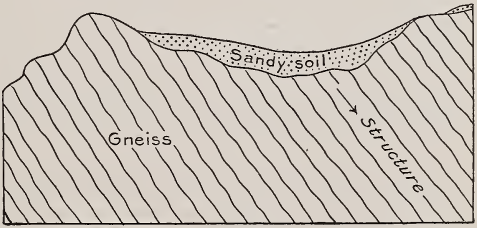

FIGURE 23.—Section of hilltop showing suitable catchment and reservoir conditions for a water supply to the rock fractures.

The condition of the rock surface is another factor in the absorption of the water. At many localities the rock is marked by minor irregularities, due to a scooping out of the rock by glacial erosion (see fig. 23), or to a dam of impervious glacial material. These small depressions in the rock serve as guiding channels to the circulation of ground water in the drift, and joints opening into these depressions have better opportunity for the collection of water than those intersecting the rock surface at intermediate and higher points. Many depressed areas which have no outlet occur in the rock. In such basins the water collects and has no escape by seepage into rock joints, and evaporation is relatively unimportant where the drift has an appreciable thickness.

Vertical joints are evidently more important than horizontal joints in giving opportunity for the entrance of subsurface water from the drift. Owing to their parallelism to the rock surface many of the horizontal joints pitch downward when they reach the ground surface and consequently do not offer good conditions for the entrance of water, although in exposures of bare rock the fractures lying at low angles tend to absorb more of the precipitation than the vertical joints.

WATER BED AT CONTACT OF ROCK AND DRIFT.

The glacial drift rests directly upon bed rock without any intervening soil or disintegrated material. (See fig. 24.) There is a sharply drawn line of contact between the till, stratified drift, or clay and the gneiss, schist, sandstone, or other rock beneath. The contact forms a water bed, the supplies from which are larger and more permanent than those of any bedding plane in the Triassic sediments or set of joints in the crystalline rocks. As shown above, the drift is filled with water, which percolates downward more rapidly than it can be imbibed by the rocks. The result is an accumulation of water at the rock surface which brings the drift to the point of saturation. In this way the layer immediately above the rock is supplied with water to 30 to 40 per cent of its volume, an amount equal to 2.24 to 2.99 gallons a cubic foot. Wells sunk to the contact of drift and rock show a large yield. Three wells, owned by the Bradley & Hubbard Manufacturing Company, at Meriden, reach rock at depths of 203, 208, and 256 feet, and have a combined yield of 100 gallons a minute.

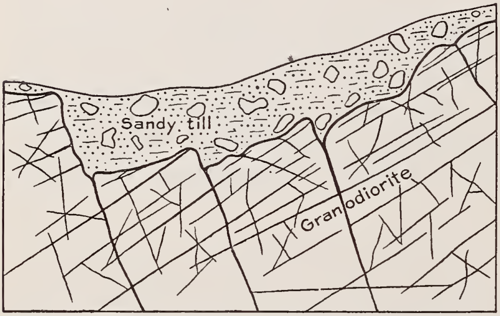

FIGURE 24.—Section showing common relation of rock surface to overlying drift.

WELLS IN TILL AND STRATIFIED DRIFT.

Probably three-fourths of all the wells in the State are shallow, open pits of large diameter, sunk in glacial material. (See fig. 25.)

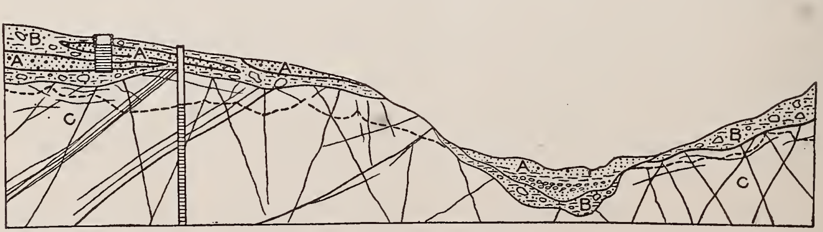

FIGURE 25.—Generalized section showing relation of rock to glacial drift. A, Layers of sand and gravel, partly saturated with water; B, bowlder clay; C, crystalline rock.

Owing to the uniform rainfall, these wells yield sufficient water for domestic purposes, but the supply is uncertain and is subject to marked seasonal and annual variation. The data collected for this report, taken in connection with investigations made by the State board of health, indicate that such wells are not to be recommended either for large yields or for unqualified purity.

WATER HORIZON.

The principal water horizons in glacial drift are the porous sandy beds confined between beds of material more or less impervious. The water-bearing layer may be sand or gravel, or even clay containing a small proportion of sand, and it may lie between layers of till and stratified drift, between different members of a stratified-drift series, or between the till and bed rock. At Stafford Springs John McCarty finds that wells in drift, which average about 20 feet in depth, are sunk through a top covering of loam, followed by 2 to 10 feet of sand and gravel, and then by a layer of hardpan 5 to 20 feet in thickness. The water comes either from the sand above the hardpan or, more commonly, from the contact between the hardpan and the underlying rock. In many places the till acts as a confining bed to retain the water stored in both sand and gravel. In fact, the hardpan variety of till exerts its chief influence as an impervious bed to limit the percolation of ground water. This relation is illustrated by the well of Mr. Coppus, at South Willington (see fig. 26), where the water enters in quantity at the junction of sand and underlying till. The most favorable water horizon, however, is in the drift, the zone lying immediately over bed rock, as explained on page 142.

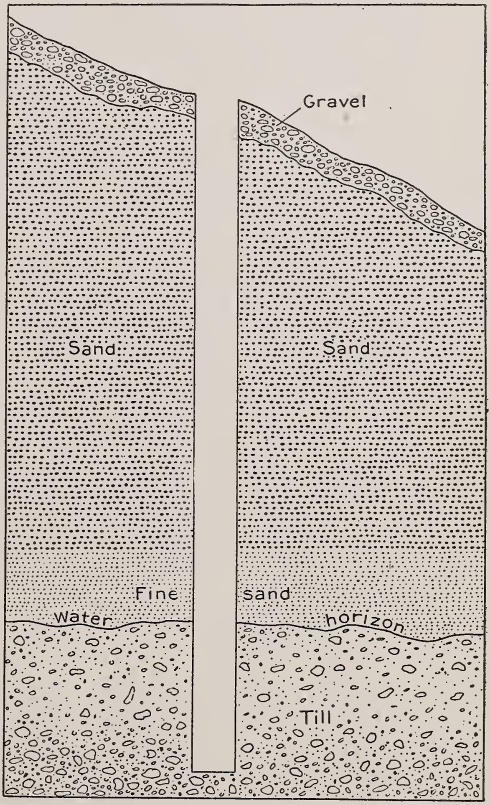

FIGURE 26.—Diagram of well at South Willington, showing water horizon at contact of till and stratified drift.

There is usually sufficient variation in the texture of the stratified drift to furnish pervious and impervious layers in contact. A slight variation in fineness of grain may be all that is necessary to concentrate the water along one plane, but the most favorable relations exist where sand overlies clay. In the brick yards at Montowese, Berlin, and North Haven water is present in quantity along the upper surface of the clay beds, and in other localities sandy layers between beds of clay furnish abundant water supplies. The whole North Haven sand plain is a good illustration of this relation. The area is underlain at a depth of 20 to 30 feet by beds of clay 5 to 20 feet thick, on top of which lie sand and gravel. Water sinks so readily into the sand that vegetation is practically absent from this area, but wells sunk to the clay bed find abundant water, and where the strata are shown in sections, as along Quinnipiac River, there is a line of springs and seepages. In certain localities the bed of clay holds the water under hydrostatic pressure, and when this cover is pierced by a well the water rises nearly or quite to the surface.

Wells sunk in till which does not contain sandy layers have no definite water horizon. In such wells the water is seen to form as a film and to drip from the surface, or to ooze out in small amounts around some of the larger bowlders. The circulation of water in such material is much retarded, and the wells are accordingly likely to vary much in yield.

DEPTH AND YIELD.

The average depth of the recorded wells in till is 24 feet, which is probably 5 feet too much, as an average for the State, because of the omission of a large proportion of shallow dug wells. The greatest depth reported is 151 feet and the least 7 feet. A few wells located at the contact of drift and bed rock flow at the surface.

The average depth of 83 wells in stratified drift is 48.3 feet, a figure probably 10 feet in excess of an average made by including several thousand shallower wells sunk in this material. The deepest well in drift is 110 feet deep and the least depth recorded is 7 feet, but the tables do not include numerous wells with depths of less than 10 feet that are known to exist.

These wells, both in till and stratified drift, probably procure all the water necessary for domestic purposes, for which they are largely used; by sinking to greater depths they could obtain much larger supplies. The average thickness of the drift cover over the sandstones is 38.4 feet and over the crystalline rocks 36 feet, an average of about 37 feet for the State. It is readily seen that the wells in till, with an average depth of 24 feet, do not penetrate to great depths in this glacial material. The wells in stratified drift are sunk deeper and take more advantage of the opportunity offered to procure large supplies from a considerable thickness of drift. In case more water is desired, it is advisable to sink a well in drift to bed rock or a few feet into the fractured upper surface of the rock itself. These are the conditions, as explained above (p. 142) under which the largest yield of water may be obtained with a minimum depth of well.

The number of wells recorded of various depths in the till and stratified drift is shown in the subjoined statement.

Depths of wells in till and stratified drift.

Depth, in feet.	Number of wells.		Depth, in feet.	Number of wells.	
	Till.	Stratified drift.		Till.	Stratified drift.
0–30	84	31	70–90	1	7
30–50	8	21	90–110		6
50–70	1	9	110–200	2	5

QUALITY OF WATER.

Till and stratified drift, alike, are composed of fragments of all sorts of rock, and it is therefore to be expected that the quality of the water should vary within wide limits, with reference to both depth and location, and that water from different depths and from different locations should be unlike in character. The waters of wells in till derived from sandstone and limestone are sure to contain compounds of calcium, magnesium, etc., making them hard, while wells sunk in drift composed of fragments of crystalline rocks are much more likely to yield soft water. Wells in till are more liable to have hard water than those in stratified drift, because the water circulates slowly and with difficulty in material of this sort and, accordingly, has an opportunity to take larger amounts of mineral matter into solution. The tables of wells in till show 45 yielding hard water, 38 soft, and 11 medium in a total of 94 wells. In stratified drift 25 wells are reported to yield hard water, 30 soft, and 4 medium out of a total of 59.

Most wells in drift, especially if they are shallow and open and of large diameter, contain impurities. Wells of this character, especially if they have been dug a number of years and are located near buildings, are so liable to contamination that an examination of the water should be made at short intervals. In thickly settled districts the water in shallow wells is often dangerous. Many wells near the beach sunk in stratified drift give brackish water, although a number of instances to the contrary may be cited. Wells in till are much less liable to contamination by salt water, and a number of such wells are located along the shore in close proximity to the Sound. Two wells at Saybrook Point are reported to contain fresh water except during dry seasons, when the water becomes low and brackish.

WATER LEVEL.

The wells in till have an average depth of 24 feet and those in stratified drift 48.3 feet so far as recorded. The average depth to water in these wells, however, is 10 feet for the till and 20.6 feet for the stratified drift. If the thousands of unrecorded wells in the State were added to the list the average distance of water from the surface would probably be still less. These figures indicate the freedom of circulation of water, especially in the stratified drift, for the principal water horizon is at a depth of 35.5 feet and the average rise of water in the well is therefore 15 feet. Unlike the wells in sandstone and crystalline rocks, the wells in till and stratified drift are subject to great variation of water level, both annual and seasonal, and sometimes daily.

The average variation of water level of wells in till recorded on pages 148–150 is 12 feet, sufficient to render many shallow wells valueless in dry seasons. Most of these wells have a regular annual period of maximum supply in late winter or spring, when they are full or overflowing. Single showers often raise the water level because of the added supply, but much more because of pressure on the air contained in the soil. Sudden rises of water in wells amounting to several feet are frequently reported, under circumstances where the rainfall could not have had time to enter the well through the drift and where the pressure of soil air was amply sufficient to account for the phenomenon. However, it is usually impossible to tell in any particular case, how much of the rise is due to infiltration and how much to the pressure applied to the air occupying the space between the grains. The wells of Sperry & Barnes, at New Haven, fluctuate in harmony with the level of water in the Sound, rising sometimes 10 inches in advance of the tide. The change in level is probably not due to the forcing of salt water toward the well, but rather to a squeezing of the fresh water from the pores of the sand, owing to the weight of the tons of water piled up on the shore.

In stratified drift the fluctuation of the water level is not so marked, owing doubtless to the greater ease of circulation in the loose-textured sands and gravels. Sudden rises, however, due to air pressure, as explained above, are reported.

The relation of rainfall to the fluctuation of water level in stratified drift is well shown by experiments conducted at the Yale Medical School, New Haven.[a] The well in which measurements were taken is sunk in sand at 146 York street, and the rain gage was located on the roof of the Medical School building on the adjacent lot, and read on the 15th of each month. As shown by the table below, the greatest depth of water at any time was 7.15 feet and the least 5.50 feet, showing a variation during the year of 1.65 feet.

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[a] Report Connecticut State Board of Health for 1889–90, p. 282.

Rainfall and variations in ground water at New Haven, 1889–90.

Month.	Rainfall.	Depth from surface to water.	Depth of water.
	Inches.	*Feet.*	*Feet.*
November	5.16		
December	6.54	21.70	7.15
January	.87	22	6.85
February	3.96	22.35	6.50
March	2.87	21.90	6.95
April	7.13	21.70	7.15
May	3.64	21.90	6.95
June	4.36	21.85	7
July	2.50	22.70	6.15
August	5.23	23	5.85
September	4.21	23.35	5.50
October	6.21	23.40	5.45
November	5.16	23	5.85
	57.84		

COST OF WELLS.

Of 82 wells in stratified drift 28 are drilled, 22 are driven, and 32 are dug. The average cost of 6-inch drilled wells is about $3.50 a foot; of 1½-inch driven wells, 70 cents a foot; and of 3-foot dug wells, $3.15 a foot.

Wells in till have an average inside diameter of 3 feet and an outside diameter of 6 feet. They are usually lined with field stone and cost an average of $3.10 a foot.

RECORDS OF WELLS IN TILL.

The following table comprises the available records of Connecticut wells in till.

Records of wells in till in Connecticut.[a]

No.	Town.	Locality.	Owner.	Diameter.	Depth.	Depth to water level.	Quality.	Use.	Cost.	Remarks.
				Feet.	*Feet.*	*Feet.*				
*1	Andover		E. D. White	7½	17	1–4		Domestic	$100	
2	do		W. Kingsbury		24	Var.	Hard	do		
3	do	Andover	—— Town	3	22	12	do	General	150	
*4	Ashford	North Ashford	George A. Keach	8	7	2	Soft	Domestic		
*5	Barkhamsted	Barkhamsted	W. F. Beach	3	16	Var.	do	Stock		
*6	Bethlehem		G. C. Stone	5	12	6+	do			
7	do		A. T. Minor	6	23		do			
8	do		F. H. Thompson	8	27	3–20	do	Domestic, stock	50	
9	Bolton		C. F. Summer		23	6+	Hard		35	
*10	do		M. W. Sperry	3½	27	10+	do	Domestic		
11	do	Bolton Center	C. M. Perry	6	18	5–10	do	do	45	
12	Canaan	Falls Village	Henry Brinton	4	16	2–8	do	do		
13	do	do	Walter Kellogg	Top, 4; bottom, 8.	22	5–16	do	do		
14	do	do	H. B. Smith	3½	18	14	do			
15	do		J. N. Van Deusen	3	16	4–10	do	Domestic	25	
16	Canton	Collinsville	S. Gibson	3	24	14		do		
17	do	do	Miss E. White	2	30		Hard	do		
18	Chaplin		C. E. Chester	3½	35	30	Soft	do		
19	Eastford	Phœnixville	M. F. Latham		30		do	do		
20	Franklin	North Franklin	A. R. Race	3½	11	7	do	do		
*21	do	do	do	10	14		do	do	53	
22	Chatham	East Hampton	H. G. Clark	4	8	5	do	do	25	
23	do	do	H. D. Chapman	3	15	Var.	do	do	75	
24	do	do	L. S. Carpenter	4	15	5	do	do	25	
25	do	do	T. S. Brown	6	22	10–16	Hard	do	40	
26	do	do	S. D. Barton	3	16	5–12	Medium	do	35	
*27	do	do	L. H. Goff	3	25	6–24	do	do	30	
28	Columbia		E. D. Dewey	Top, 2½; bottom, 4.	35	5+	do	do		
*29	do		S. D. West	4	13	3–8	Hard, iron	Domestic, stock		
30	do		H. C. Isham	3	27	12	Hard		30	
31	Eastford	Phœnixville	G. R. Dickey	3	20	4–16	do			Stoned down 3 feet.
32	Fairfield		B. F. Pease	4	12	5	Soft	Domestic		150 gallons a day; easily lowered.
*33	Goshen	West Goshen	W. H. Wadhams	2½	18	2–14	Hard	do		
34	do	do	H. G. Wright	4	15	Var.	Soft	do		
35	do		E. Carlisle	3	15		do	do		
36	do		Lyman Hall	10	20	3–13	Hard	do	75	Stoned throughout.
37	Greenwich		L. M. Close	5	18	10	do	Stock		Water comes from clay.
38	do	Stanwich	S. R. Close	4	24	Var.	Soft	Domestic		Temperature 54° F.

*39	Groton	Mystic	S. G. Fish	Outside, 8; inside covering, 3.	16	3-13	Hard	do	50	
40	do	do	C. R. Heath	2½	20	3-17	do	Domestic, stock	50	
41	Haddam		E. P. Arnold	9	8	0	do	Domestic	150	Never dry.
42	do		B. W. Kelsey		14	0	Soft	do		
43	do		E. E. Lewis	3	15	6	Hard	do		
44	Hebron	Gilead	Frederick Prentice	3	20	10-19	Soft	do		Rises in springs and lowers gradually till winter.
45	do	Hebron	F. W. Little	4	35	20		do		Rock at bottom.
46	do	Turnerville	Ben Jones	4	25	10; var.	Soft	do		Water from clay.
47	do	do	R. D. Stephens		18		do	do		
48	do	do	Edw. T. Smith	4	28	15-20	do	do		
49	do	do	Joel Jones	5	15	12	do	do		Rock at 14 feet.
50	Huntington	Shelton	A. E. Hewitt		67½	60	do	do		Water from hardpan.
51	do	do	O. J. Beard	2½	25	0-19	Hard	do		Do.
52	Lebanon		D. Blanchard	3	14	9-14	Soft			Rock at bottom; dry in summer.
53	do	Lebanon	C. H. Loomis	3	20	12	do	Domestic		
54	do	do	J. H. King	2½	19	5	Hard	do		
*55	do	do	R. E. Turner	6	28	3	Soft	do	200	
56	Litchfield	Prospect	H. S. Clark	3	17	10+	Hard	do	35	Water comes from hardpan.
57	do	do	H. N. Payne		22	8	do	do		
58	do	do	L. G. Clark	6	24	6	do	do		Do.
59	Madison		M. T. Bushnell	3	23	Var.	Soft	do		
60	do		J. Q. Buell	3	19	16	do	do		
61	do		P. P. Coe		27	5	do	do		
62	do		C. W. Scranton	3	15	3-11	Hard	Domestic, stock, irrigation.	50	Cased by tiling.
*63	do	East River	S. H. Chittenden	3	25	12-22	do	Domestic		
64	Milford		D. L. Clark	3	21	8-13	do	do	63	
65	do		E. L. Ford	3	27		Medium	do	50	
66	Montville		D. A. Botham	3½	30	10-20	Soft	do		
67	New Haven	New Haven	E. C. Hildebrand	3	14	10	do	do		
68	Newtown		L. C. Morris	3	38	10+	Hard	do	200	
69	do		Chas. Morris	3	19	4-19	do	do		Dry in summer; temperature, 46° F.
70	North Canaan	East Canaan	G. O. Dunning	2½	8	3	Medium	do	15	
71	North Branford		A. H. Hill	(*b*)	75	20	do	Stock	150	
72	North Stonington	Pendleton Hill	H. V. Baker	5	30	2-15	Soft	Domestic	50	Water comes from clay.
73	do	North Stonington	O. Chapman		17	5-15	do	do	43	
74	Norwalk	Silver Mine	C. N. Adams	6	14	6	Hard	Greenhouse		Yields 1,500 gallons daily.
75	Old Mystic	Old Mystic	S. H. Babcock	(*b*)	36			Domestic		
76	Plymouth	Pequabuck	Scott & Co.	3	25	12	Hard	Drinking		From clay; temperature, 50° F.
77	Redding	Redding Ridge	D. S. Sanford	3	20	8	do	Domestic		
78	do	do	J. B. Cornwall	4	16	8	Soft	do		From clay; water is siphoned for use.
79	Sharon	Sharon	Mrs. C. Schwab	(*b*)	150	40	Hard	Domestic, farm	450	
80	do	do	Mrs. E. C. Schwab	(*b*)	152	48	do	do	456	
81	Stratford		C. H. Welles	3	32	7-20	do	Domestic		
82	Watertown	Oakville	W. H. Smith	6	14	7	do	do	75	
83	Washington	Washington Depot	E. C. Whitehead	3	18	4-10	do			

a Additional details concerning wells marked with an * are given on p. 151.

b Drilled; 6 inches in diameter.

Records of wells in till in Connecticut—Continued.

No.	Town.	Locality.	Owner.	Diameter.	Depth.	Depth to water level.	Quality.	Use.	Cost.	Remarks.
				Feet.	*Feet.*	*Feet.*				
84	Washington	Washington Depot	R. W. Squires		22	21	Hard	Domestic		
85	Westbrook	Westbrook	A. L. Burdick	3	18	7	do	do		
86	Wilton	Wilton	E. Benedict	3	20	Var.	do	do		
87	do	do	H. Chichester	4	25	7; var.	Soft	do		
88	do	do	S. Comstock	3	20	10	do	do		
89	do	do	J. Gilbert	3	21	4-19	Hard	do		
90	do	do	C. W. Horton	10	17	6-8	Soft	do		
91	do	do	W. T. Jelliffe	3½	20	14	Hard	do		
92	do	do	B. N. McQueen	3	32	10-20	Hard, iron	do		
93	do	do	J. F. Knapp	6	12	3	Soft	Stock	$96	Stoned.
94	Woodbridge		Mrs. F. P. Gilbert	3	40		Hard	Domestic		Rock at bottom.
95	do		F. I. Baldwin	4	30	2	do	Domestic, stock		Water comes from hardpan.
96	Woodbury	Hotchkissville	N. H. Bloss	4	12	6; var.	Soft	Domestic		Main supply at 25 feet.

NOTES.

1. Passes through 3 feet of moist clay loam above 14 feet of hardpan. This is one of six dug wells varying from 16 to 28 feet in depth, and is stoned, jug shape.

4. An excavated spring, the water being transported by a pipe with a 50-foot fall.

5. Passed through hardpan for the entire depth. The water level varies greatly, the well being nearly dry in some seasons. A stream the size of a lead pencil was struck 6 feet from the top and another stream was encountered below a flat rock.

6. In hardpan, with loam above. Water flows into the well from the northwest.

10. Supply said to be practically unlimited and lowered with difficulty. Well is in sandy clay underlain by hardpan.

21. Put down in 1900 through 14 feet of hardpan and obtained a strong flow from quicksand.

27. Passed through 3 feet of soil and 22 feet of "clay hardpan" containing "stones as large as a water pail." No streams of water were encountered, the water oozing from the hardpan in drops.

29. Blasted into rock 5 feet and occasionally becomes dry; 35 feet away is an unfailing well sunk 7 feet in till and containing soft water.

33. Never failing, but varies in amount of water with seasonal changes. Passes through 3 feet of loam and 15 feet of hardpan.

39. Passed through 2 feet of topsoil, 8 feet of clay subsoil or hardpan, and 6 feet of sand and gravel. Water came in from several small veins (probably from sand and gravel). Water level lowers in dry seasons, but ordinarily rises within 8 feet of surface.

43. Flows in wet seasons and occasionally runs dry at the same time as an adjacent stream. The well is located on a sandy knoll, and may be in stratified drift.

55. First 5 feet were soil and clay subsoil; first water struck at 9 feet, yielding 40 barrels a day. Remaining 19 feet through hardpan containing and underlain by coarse gravel at the bottom, from which issued a large stream of water rising within 3 feet of the surface. According to Rev. R. E. Turner, local artesian conditions prevail.

63. Struck water at 13 feet below the surface, where rocks occurred in sand and water came in as a strong flow. Has never been dry.

RECORDS OF WELLS IN STRATIFIED DRIFT.

The available records of wells in stratified drift are summarized in the following table:

Records of wells in stratified drift in Connecticut.[a]

No.	Town.	Locality.	Owner.	Type.	Topographic position.	Diameter.	Depth.	Depth to principal source.	Depth to water level.	Yield per minute.	Quality.	Cost.	Use.	Material yielding water.	Remarks.
						In.	*Feet.*	*Feet.*	*Feet.*	*Galls.*					
1	Andover	Andover	Thos. Sullivan	Drilled	Valley	5	63	50	45		Soft	$300	Domestic	Gravel	Supply constant.
2	Ansonia	Ansonia	Y. M. C. A	Dug		30	6		1	24	do		House, boilers, plunge.		
3	do	do	H. J. Smith	do	Valley	30	84		2		do	250	Domestic		Water rises in well with rise of river.
4	Avon	Avon	J. P. Neville	Driven		2	26		14	Good.	do		do		
5	Beacon Falls		C. H. Hoffman	Dug	Stream bed.	36	10	8	5	[b]500	Hard	25	do	Gravel	Varies with season.
6	Berlin	Berlin	E. J. Clark	do		36	16	11	11	Large.	do		do		
7	do	do	C. W. Hollister	do		36	35	4			do		do		
8	Branford	Branford	Richard Bradley	do	Hill		44	39–44		Good.	do	250	Domestic, stock.	Gravel, quick-sand.	
*9	do	do	J. W. Nichols	do	Slope	36	17	15		Good.	do	100	Domestic, lawn.	Gravel	
10	Brooklyn	Wauregan	Church of the Sacred Heart.	Driven	do	6	48	48	12	Good.	Soft	150	Domestic, boiler.	do	
11	Canaan	South Canaan	Mrs. J. B. Copon.	Dug			17	17	2	Good.	Hard		Domestic	Quicksand.	Water comes in just above rock.
12	do	Falls Village	R. Pendleton	do		30	12		Varies.		Soft	25	do	Gravel	
13	Coventry	South Coventry.	Mrs. M. Colburn.	Drilled	Slope	6	45	35	24	Small.	do	132	do	Clay	Water becomes soily when heavily pumped.
14	Cromwell	Cromwell	E. S. Coe	Dug	Hill		40	30			Medium.		do		
15	do	do	F. K. Hallock	Driven	Slope	6	84		24		Hard		do	Sand	
16	Derby	Derby	Derby and Ansonia Brewing Co.	Drilled	Ridge	6	155	28		50		800	Brewing	Gravel	Well penetrates rock, but water comes from gravel.
17	Eastford	Phoenixville	L. N. Snow	Dug	do	30	30				Hard		Domestic	do	
18	do	do	M. L. Latham	do		48	28		22		Soft	60	do		
19	East Haddam	East Haddam	F. L. Ray	do	Hill	36	22				do		do	Clay	Temperature 50° in summer, 48° in winter.
*20	East Hartford		F. A. King	Driven	Plain	1¼	20	20		8	Medium.		Domestic, stock.	Sand	Temperature 50°.
*21	East Lyme	Crescent Beach	A. P. Carroll	do	Plain near coast.	2	16		2	[c]15		[d]3	Cottages	Gravel	Water enters at contact with rock.
22	Fairfield	Greenfield Hill	S. J. Gorman	Dug	Hill	36	48		0 in winter.	[e]2,500	Medium.		General	do	Pumping lowers.

23	do		G. H. Bradley	do		40	27	18	8		Soft		Domestic		
24	Farmington	Farmington	Wm. Potts	Drilled			78							Clay, gravel.	Well was blocked by clay.
25	Glastonbury	Buckingham	O. E. Bailey	Dug		48	24	24			Soft		Domestic		Dry in dry weather.
26	do	do	E. C. Weir	do	Hill	36	16	8	Varies.	1½	do		do	Gravel	Water obtained by siphon.
27	Griswold	Glasgo	Glasgo Yarn Mills.	Drilled	do	6	93		26	8	do	276		do	
28	Guilford	Guilford	C. Griswold	Driven		2	65			Good.	Hard			do	
29	Haddam	Haddam	G. Parmelee	Dug		40	50	46	46	Good.	Soft	200	Domestic	Sand	
30	do		County Orphans Home.	do			21				do	200	do	Gravel	
31	Hamden	Mount Carmel.	A. E. Woodruff	Drilled		6	50					100	General	do	
32	do	do	Mount Carmel Bolt Co.	Dug	Slope	30	35				Medium.		Boiler, drinking.		Temperature 51°.
33	Killingly	Danielsonville.	Jas. M. Paine	Drilled	do	6	142	118	62	7	Soft	417	Tenements, stores.	Sand	Water from sand at top of rock. Pumping lowers to 50 feet.
34	do	Attawaugan	Attawaugan Co.	Driven	Plain	6	112	80	25		Hard	375	Domestic	Sand, gravel.	
35	Ledyard	Gales Ferry	J. C. Hazler	Drilled		6	33		15	1	Soft				Easily lowered.
36	Mansfield	Mansfield Depot.	A. K. Brown	do	Valley	6	75	65	40	Small.	Soft, iron	300	Domestic	Sand	
37	Meriden	Meriden	C. Rogers & Bros.	do		1½	47				Hard		General, except for boilers.	Gravel	
38	Milford	Woodmont	A. G. Chapin	Driven	Slope	6	35			Good.	Soft	175	Domestic	do	
39	do	Milford	B. B. B. Gregory	Drilled		6	35	29	28		Hard		do	Sand, gravel.	
40	do	do	Mrs. A. M. Coupland.	do	Plain	6	92	25, 60			Medium.		do	Gravel	
41	Montville	Uncasville	J. B. Lathrop	do	Valley	6	70		55	Large.	Soft	210	Domestic	do	Pumping does not lower.
42	do	do	Chas. Ramage	do	do	6	40	39	20	3					
43	do	do	M. E. Fox	do	Slope	6	32	28	24		Hard		Domestic	Sand	9 feet of water ordinarily; 3 feet in dry times.
44	do	do	J. F. Schofield	do	Plain	6	78	51		Good.	Soft	234	Domestic, lawns.	Sand, gravel.	Temperature 48°.
45	New Haven	New Haven	F. B. Shuster Co.	Driven		2	58		20		Hard		Washing	Gravel	See analysis, p. 178.
46	do	do	do	do		2	72		20		do		do	do	
*47	do	do	Dining hall, Yale University.	Driven, 9 wells.	Flat	1, 2	±27	25–27	21		do		Condensing ammonia.	Sand	Temperature 48°.
48	do	do	Hygienic Ice Co.	Driven, 40 wells.	Plain	2	35–70		f 20–25	160	do		Cooling	do	In different parts of city; temperature 52½°.
*49	do	do	Yale University gymnasium.	Driven, 34 wells.	do	1½	27	20		150	do	600	Swimming pool.	do	Temperature 52°.
*50	do	do	Sperry & Barnes.	Driven, 40 wells.	do	2	42			Large.			General	Gravel	Temperature 53°. See analysis, p. 178.

a Additional details concerning wells marked with an asterisk are given on p. 156. b Daily. c 10,000 gallons daily. d Per foot. e Weekly. f Seasonal variation.

Records of wells in stratified drift in Connecticut—Continued.

No.	Town.	Locality.	Owner.	Type.	Topographic position.	Diameter.	Depth.	Depth to principal source.	Depth to water level.	Yield per minute.	Quality.	Cost.	Use.	Material yielding water.	Remarks.
						In.	*Feet.*	*Feet.*	*Feet.*	*Galls.*					
51	New Milford	Boardman	A. G. Barnes	Driven	Valley	2	70		12	Large.			Domestic, stock.	General	From gravel under sand.
52	do	do	do	do	do	2	80		12	Large.			do	do	
53	Newton	Newton	C. L. Mitchell	Dug	Plain	36	22		10–20		Soft, iron		Domestic	do	
54	North Canaan		J. D. Clemens	Driven		$1\frac{1}{4}$	20		10		Hard	*a* $3	do	Sand, gravel.	
55	North Haven	Hamden	Jas. H. Webb	Drilled	Plain	8	143		40		do		Washing, stock.	Gravel	Rock below 40 feet; temperature 48°.
56	Norwalk	Norwalk	R. & G. Corset Co	Dug	Valley	36	20		8		do			do	See analysis, p. 178.
57	do		Roton Point Improvement Co.	do		144	10						Hotel	do	
58	Norwich	Norwichtown	Miss M. A. Cryer.	Drilled	Plain	6	50				Hard, iron.	200	Domestic		Clay above gravel.
59	Old Mystic	Old Mystic	A. A. Haley	do	Valley	6	31		7	20	Soft			Coarse gravel.	
60	Old Saybrook	Saybrook Point.	C. E. Jackson	Dug	Plain	36	17		6	Large.	Hard	25	Domestic	Sandy soil.	
61	do	do	J. T. Beckwith	do	Elevation		25		20		Medium.	50	Domestic, hotel.	Gravel	
62	do	do	W. G. Bulkeley	do		30	20		12				Domestic		
63	Plainfield	Moosup	Floyd Cranska	Drilled	Valley	6	100		10	30	Hard		do	do	Rock at 60 feet.
*64	do	Central Village	F. A. Carey	do	Hill	6	55		25	3	Soft, iron		do	Clay, gravel.	
65	Pomfret	Pomfret	R. J. Sabin	Dug	Slope	72	12	12	Var.		Iron	25	Stock	Gravel	
*66	Ridgefield	Ridgefield	Ridgefield Water Supply Co.	Drilled, 5 wells.	Plain	6	60		50	$\frac{1}{2}$	Soft		Town supply.	do	
67	Seymour	Seymour	Joseph Riegal	Drilled	do	6	110	83	23		do	440	Hotel, tenements.	do	Pumping does not lower.
68	Sprague	Baltic	Baltic Mills Co.	do	Slope	6	101	60	40	Good.	Hard	200	Domestic	do	
69	Stafford	Stafford Springs.	A. Howard	Driven	Island		35	35		Good.				do	
*70	Union		J. M. Leach	do	do	$1\frac{1}{2}$	33			Large.	Medium.	25	Domestic	do	
*71	do	Mashapaug	J. H. Howard	do		2	38		20		Soft, iron		do	do	
72	do	do	do			2	47		20		do		do	do	Temperature 52–60°.
*73	do	do	G. W. Crawford	Dug		36	15		9	Good.	Soft		do		Well 8 feet away with hard water.
74	Washington	New Preston	N. B. Mead	Drilled		6	110		30	Small.	Milky		do	Sand, gravel.	Pumps dry.
75	Waterbury	Hopeville	Mrs. F. B. Wood.	Dug and drilled.			53	43	42		Hard		do	Gravel	

*76	do	Waterbury	C. Tracy	Drilled	Hill	6	200		40	60	Soft	1,200	do	do	Pumping lowers 10 feet.
77	Westbrook	Westbrook	H. R. Parker	Driven	Plain	1¼	20		12	Large.			do	Gravel, sand.	
78	West Hartford	Elmwood	Mrs. E. W. Talcott.	Drilled		6	51		20	1½	Hard		do	Gravel	Pumping lowers 2 feet.
79	Westport	Westport	Westport Water Co.	Dug		180	15			(*b*)	do		Town supply.		
80	Willington	South Willington.	A. Korper	do		48	28	26	21		do	100	Domestic		
*81	Woodbury	Woodbury	M. A. Hurd	do	Valley	36	20		13		Soft		do		Well bottom at river level.
*82	do	do	L. J. Allen	do	do	24	31				Hard		do		

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a Per foot.

b 150,000 gallons daily.

NOTES.

9. Dug in a springy spot, water being struck almost immediately, with a heavy flow at the bottom. Level varies somewhat with seasonal changes, but even in dry seasons is high.

20. Log shows coarse sand containing much water, beneath which is fine sand underlain by 6 inches of gravel, and clay at the bottom.

21. First 12 feet through gravel, which overlies 50 feet of quicksand that plugged the pipe and prevented inflow. The water horizon is in gravel below the quicksand.

47. Used for condensing ammonia in refrigerator. At 26 or 27 feet below surface is quicksand and below this clay.

49. Located near together and used to supply water for baths and swimming pool.

50. Driven in at sea level; water rises 10 inches in advance of the tide. The pipes, 40 in number, pass through 7 feet of tide water, 25 feet of soft blue mud, 6 feet of hard blue clay, 3 feet of material resembling hardpan, and 2 feet of mixed coarse and fine gravel, which yields the water. A pipe has been sunk 300 feet from the surface, passing through quicksand all the way below the gravel to bed rock.

64. Sunk through 5 feet of black and yellow loam and 16 feet of dark-colored hardpan with cobblestones, reaching rock here at 25 feet below the surface. One-half mile farther north is a second well, 15 feet deep, which passes through soft loam and quicksand and yields an abundance of soft water. Immediately to the east are wells, 10 to 12 feet deep, in gravelly soil. Toward the south the wells are in clay and hardpan.

66. One of a gang of five driven wells (two 6-inch and three 3-inch) supplying the town of Ridgefield. Another 6-inch well is 75 feet deep but of small yield, probably because it passes nearly through the water-bearing gravel.

70. Driven wells on gravel island in small lake. Temperature of water said to be 48° to 52° from February 15 to July, and from July to February will rise to 58° to 62°.

71. Said to have been drilled through hardpan, the water coming in several small veins.

73. Passes through thin layers of loam and gravel and at 12 feet into "closely packed broken rock."

76. Drilled 19 feet into rock, but the supply of water comes at the contact of the rock and the surface material.

81, 82. Said to have passed through sand, gravel, and clay, deriving their water from clay. A complete record of a well in the same vicinity gives 15 feet solid clay; 15 feet hardpan containing pebbles one-half inch to 3 inches in diameter; 41 feet gravelly dark soil; 29 feet bowlder material; 10 feet decomposed dry rock.

CHAPTER VII.

WATER SUPPLY OF TYPICAL AREAS.

WARREN—A HIGHLAND TOWN.

Warren is a typical highland town, with a population of 432, devoted to agriculture and allied interests. It has an average elevation of about 1,000 feet and an annual rainfall of about 50 inches. Mica schist (Berkshire) forms the bed rock in the western and southeastern parts of the town; gray banded gneiss (Becket) occurs at Cornwall Center; and granite occupies the northeast corner of the town on both sides of the west branch of the Shepaug. Glacial till forms a mantle over most of the rock surface and constitutes the principal water-bearing formation.

There are very few places in the town where abundant water is not found at a depth of less than 40 feet, and springs are numerous at low and high levels. In general, the farmers can choose between digging a shallow well and bringing water from a spring, as the cost of digging a 30-foot well is estimated to be the same as installing a pipe line 80 rods long. Mineral springs are not found in the town, and only one windmill is reported. The springs furnish soft water, the wells hard.

The following detailed information regarding the water supply of Warren has been furnished by Myron A. Munson. The numbers refer to locations on the accompanying map (fig. 27).

1. Spring sunk 4 feet, near the house; go for the water.

2. Water for house and barn brought from spring 50 or 60 rods east; soft, and excellent; running since 1852. Also well 14½ feet deep, water 7 feet; poor, apparently surface water mainly.

3. Water obtained from spring.

4. Well 16¾ feet deep; water 5 feet; good.

5. Well 21 feet deep; water 8½ feet; excellent, "soft for a well, makes good suds."

8. Well 15½ feet deep; water 7 feet; rather hard; use rain water also.

9. Well 19 feet deep; water very hard. There are two excellent springs at a distance of 20 and 30 rods.

10. Conditions not favorable for wells.

13. Three wells on the place. The one now in use is less than 20 feet deep. Water was formerly soft; coal ashes were deposited in some near-by depression, since which the quality of the water has deteriorated. The well is unfailing, and the supply so copious that it is difficult to exhaust the well sufficiently to prepare it for cleaning. "It would supply water for a hundred cattle." There are two springs on the place with water having a temperature of 48°.

14. Well about 12 feet deep; water is soft.

17. Water conducted from a spring.

18. Water brought from a spring on a lower level by means of a ram.

19. Water brought to house from spring, which is about 25 feet above the doorstep and 15 rods distant; 2 feet deep; fails in dry season. A second spring, supplying water to barn, boils up through sand and never fails; water is conducted to south barn. A third spring, of constant flow, supplies milk house and horse trough. A fourth spring, unfailing, is used only as pasture supply. Across the swampy meadow to the west is another good spring.

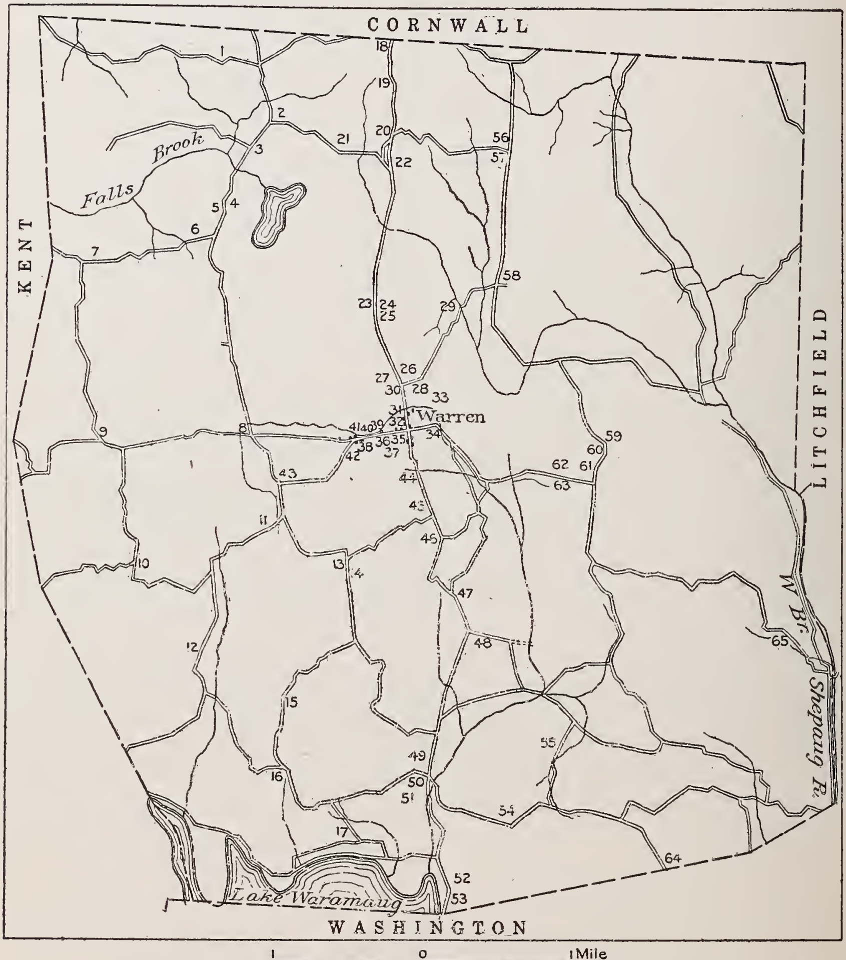

FIGURE 27.—Map of Warren, showing location of wells.

20. Rock ledge exposed; water formerly conducted from a spring. Conditions at the house are unfavorable for wells.

21. Well 18 feet deep; water 5½ feet; not very hard; two springs across the road supply milk houses.

22. Well 12 feet deep; water very hard. Spring at milk house across the road is declared to be "soft and sweet."

23. Well 19½ feet deep; water hard; rain water also used. Spring at milk house consists of three streams, which gush up from sand.

24. Obtains water from a spring in the field.

25. Supply similar to No. 24.

26. Has a "laundry spring" within 3 or 4 rods of the house; a better one 5 or 6 rods away; soft, and seldom failing.

27. Well 12 feet deep; water hard; rain water also used.

28. A good spring of soft water 5 or 6 rods distant from the house, "flowing as fast as can dip;" another colder spring is 4 rods farther away.

29. Well 38 feet deep; water 22½ feet; hard, and unfailing. At 50 rods down the hill to the northeast is an ice pond into which five springs flow. An unsuccessful attempt was made to bring an unfailing spring from a distance of a quarter of a mile. A windmill was installed at the well a few years ago but was later discarded.

30. Well 18 feet deep; water 9½ feet.

31. Well 16 feet deep; water 6¾ feet. Soft water is brought from a spring 30 rods distant.

32. Brings water in pails from an excellent spring of soft water at a distance of 8 or 10 rods.

33. This family obtains water from a good spring 30 rods distant.

35. Water rather hard.

36. Well 17¾ feet deep; water very hard, also contaminated. A new well about 12 feet deep at a distance of 15 rods obtained good water.

37. Well good; unfailing in driest times.

39. Well 13½ feet deep; water hard, yet suitable for washing.

41. Well 16½ feet deep; water said to be good.

42. Well 23¼ feet deep; water a little hard. Used for all purposes, though a little way east and west of the house are two soft springs. Is the "best in town." Never known to fail when drought was most severe.

43. Well 17 feet deep; water 7¼ feet; a little hard; rain water (cistern) also used. Excellent spring 70 rods to the northeast in corner of the orchard; another 150 rods to the southeast. Horse barn supplied from a well 10 feet deep, containing 6¼ feet of water. "The springs about here are soft."

44. Water carried from a spring near at hand, but at a lower level.

45. Well 15½ feet deep; water 6 feet; good. A spring in a swamp near at hand has been used.

46. Well 7 or 8 rods west of house, 15½ feet deep; contains 7½ feet of poor water. Water has been carried from the swamp named above (No. 45) into the cellar of this house, but the method worked poorly, and frequent repairing was necessary.

47. Water conducted from a spring at a considerable distance.

49. Water from spring at a distance of 40 rods.

50. Well 5 feet deep; water hard; unfailing.

51. Water brought from a spring sunk to produce a well of 12 feet depth; soft, good, and unfailing; has been used for fifty years.

52, 53. Two of six houses supplied from a spring on the hills to the east.

54. Unfavorable location for wells. Well measures 36½ feet, the "deepest in the town;" water 13 feet, but is "likely to become scant in the summer."

56. Well 20½ feet deep; water has an iron taste. A well 13¼ feet deep across the road in a corner of the barnyard is said to contain good water.

57. Well a few yards west of the house 16⅓ feet deep; water very hard. A number of good springs on lower ground.

58. Well 13½ feet deep spoiled by drainage from cesspool. There are six good springs, sweet and soft, on the place at no great distance, four of the six never failing. The house is supplied by two springs united, a quarter of a mile distant. A ram is employed.

59. Well 17 feet deep; water 12¼ feet; "soft as a spring;" sometimes fails.

61. Well 12 feet deep; water 6 feet; unfailing; soft, good for washing. Said on the spot to be the "best in town."

62. Well 10 feet deep; water 5⅔ feet, hard. Water is brought from a spring to this house and to the one across the road.

65. Spring of cold water issuing from a beautiful grotto; water is of uniform temperature throughout the year.

NORTH HAVEN—A LOWLAND TOWN.

The conditions surrounding the occurrence and recovery of ground water in the central lowland are illustrated in the town of North Haven, a portion of which is shown on the accompanying map (fig. 28). The area has an elevation of less than 100 feet and is underlain by sandstone, on top of which rest clays, sands, gravels, and till of glacial origin. Sand with large water capacity is the predominating surface formation. In the following descriptions the numbers refer to locations on the map:

1. Well 30 feet deep; contains about 4 feet of water. In sand and gravel the entire distance.

2. Well 30 feet deep; has 6 feet of water. In sand and gravel.

3. Well 30 feet deep, in sand and gravel; has 4 feet of water, "not very good."

4. A drilled well, 115 feet deep, all of the distance in sand and gravel.

5. Well 20 feet deep; has 4 feet of water. In sand and gravel.

6. One well 30 feet deep, with 5 feet of water; one 20 feet deep, with 6 feet of water; both in sand and gravel. There is also an excellent spring at this place, having a fall of 11 feet, which is sufficient to force water to all parts of the house. The ground water in the spring and in the shallow well appears to come from the northwest; that in the other well comes from the northeast.

7. Passes through sand, reaching rock at a depth of 20 feet. The water comes from just above the rock. The well is practically inexhaustible, three families using it all the time.

8. A large supply of good water from a well sunk 17 feet into sand. Has 7 feet of water.

9. Drilled in sandstone to a depth of 153 feet. Most of the water was reached at the 50-foot level.

10. One well is 16 feet deep in red sandstone and near at hand is another well or spring 9 feet deep in which the water is seen to bubble up through the sand at the bottom. One hundred barrels of water have been pumped from this spring at one time without exhausting the supply. Both wells are very close to Quinnipiac River.

11. Drilled well 45 feet deep; in rock for almost the entire distance. Gives an abundant supply of good water.

12. Drilled in red sandstone to a depth of 126 feet, most of the water being reached at a depth of about 45 feet; yields a good supply of water. A spring also occurs in the back yard.

13. Well 25 feet deep; walled with stone. After every freshet the sand pours in at the crevices so that it needs cleaning frequently. The water is excellent and abundant.

14. Well 15 feet deep; contains 5 feet of water. It does not fail, and the water is soft and good.

15. Well 16 feet deep; holds 8 feet of water. The water is very good, but fails in dry seasons. Spring 300 yards to the northeast gives an abundance of water for house use and is high enough to send water into all the rooms of the second story by gravity. There is also a spring at the barn.

16. Constant spring of good water.

17. Said to be about 20 feet deep.

18. Well 17 feet deep. The first few feet are in sand and the remainder in red sandstone, with a sharp easterly dip. The water occurs in the rock and varies but little with the seasons.

19. Well 22 feet deep; has about 4 feet of soft water.

20. Well 30 feet deep, the last 18 feet in red sandstone. The water found in the rock is soft and plentiful.

21. Well 30 feet deep, in sand and gravel. About 5 feet of soft water stands constantly in the well.

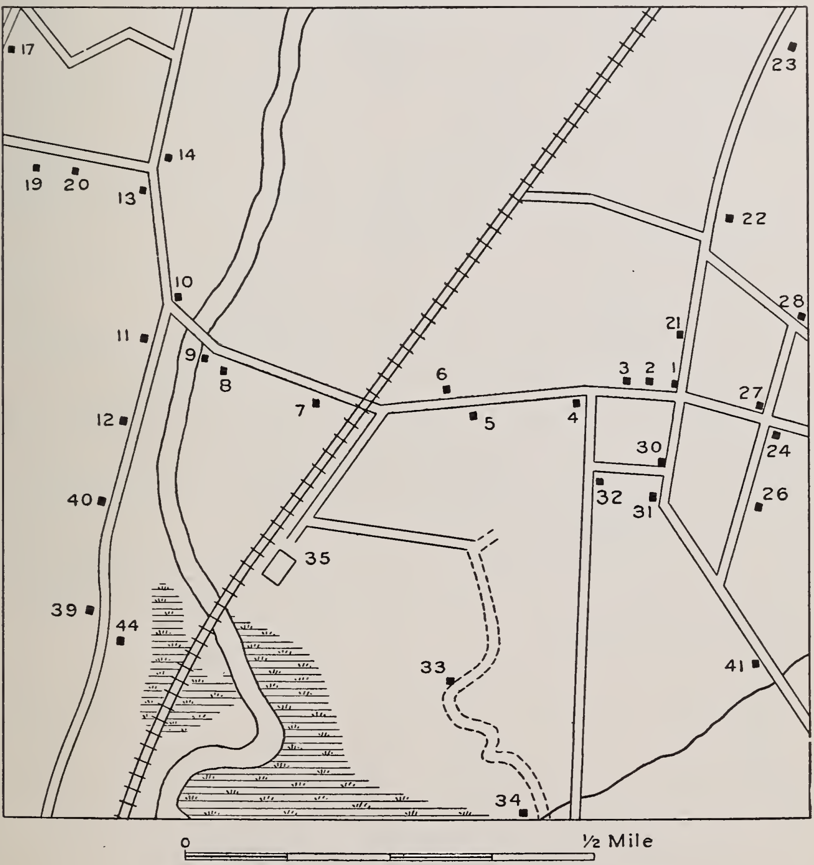

Figure 28.—Map of North Haven, showing location of wells.

22. Well sunk 35 feet in sand. Water is plentiful and not very hard.

23. Two wells; one at barn 25 feet deep with 3 feet of water; one at house 30 feet deep with 5 feet of water. Neither well runs dry.

24. Well 30 feet deep; has 5 feet of water. The first 25 feet are said to be in hardpan and the remainder in sand. Abundant water was found in the sand.

25. Well 30 feet deep. The first 25 feet are in the hardpan, then comes 2 inches of sand in which the water is found, and then about 4 feet more of hardpan. The water is plentiful, varies from 3 to 11 feet in depth, and is soft enough to be used continually for a laundry.

26. Drilled well 128 feet deep. It is reported that the first 84 feet are in sand and hard gravel and the last 44 feet in hardpan.

27. Drilled well 140 feet deep; derives water at depth of 100 feet, near contact of rock and till. Water is hard, rises within 25 feet of the surface, and does not vary in amount with seasons.

28. Well dug in hardpan to a depth of 44 feet. In the spring it sometimes contains as much as 15 feet of water. "This water will rust a tin in one night."

29. A very old well, dug and walled with brick; 45 feet deep; amount of water varies from 5 to 15 feet.

30. Dug well, 29 feet deep; contains 4 feet of water.

31. Dug to a depth of 45 feet in course gravel. Became dry during one season.

32. Dug to a depth of 12 feet in sand and gravel. It was dry once, but only for a short time. Ordinarily about 2 feet of water stands in the well.

33. Family gets water from a spring which issues at the top of a layer of clay.

34. Well 15 feet deep; has 2 feet of water. Walled with brick, but abandoned on account of surface contamination.

35. Drilled well, 195 feet deep; yields 8 or 10 gallons a minute. The first few feet are in sand, then comes about 50 feet of clay underlain by red sandstone. There are several recently drilled wells in this neighborhood, and their use has been followed by a great decrease in the number of cases of malaria.

36. Water for drinking purposes is brought from a spring which emerges at the contact of sand and clay.

37. Dug through sand and strikes a clay stratum at 13 feet.

38. Dug to a depth of 15 feet 6 inches, where it strikes sandstone; contains 7 feet of water and does not fail.

39. Dug in rock to a depth of 15 feet; contains about 7 feet of water.

40. Well on the hill is dug to a depth of "about 50 feet," the last 40 feet being in sandstone. At this same locality a shallow rock spring with insufficient water was converted into a satisfactory supply by drilling 10 feet into the rock.

41. Dug well 7 feet deep, the last 4 feet in red sandstone. The ground water is seen to come from the northwest.

42. Well at barn dug to a depth of 13 feet 6 inches, in sand and gravel; yields hard water. Well at house, in the cellar, is about 15 feet deep; passes through gravel to hardpan, where an abundant supply of soft water is procured.

43. Conditions same as at No. 42.

44. Drilled well in sandstone with a depth of "over 100 feet."

VICINITY OF BRANFORD POINT—A COAST REGION.

The region about Branford Point is fairly typical of the coast resorts along the Connecticut shore. It includes rocky knolls, stretches of sand flats and beaches, and expanses of marsh land. The bed rock of this area is gneiss, much broken by joints and planes of parting. The soil cover is till and beach sands. The insufficiency of supply and the danger of contamination by salt water have made it advisable to conduct water by pipe line from Branford River and to make this the chief supply. Two small springs are reported from this area.

The following descriptions accompanying the map (fig. 29) give detailed information regarding conditions which are typical of the water at Connecticut resorts.

1. Well 25 feet deep; contains about 5 feet of water, which is soft enough to make good suds.

2. Well has constant supply, medium in softness. It is 23 feet deep and contains 5 feet of water.

3. Well 24 feet deep; contains about 4 feet of water of medium softness.

4. Same depth and character as No. 3.

5. Well 27 feet deep; contains 3 feet of water.

6. One of the wells at this place is situated 5 feet from the edge of a salt marsh, but has never been known to become brackish. It is a driven well to a depth of 14 feet and contains 4 feet of water. The other well is sunk through glacial till, is 22 feet deep, and derives water from the contact of rock and till.

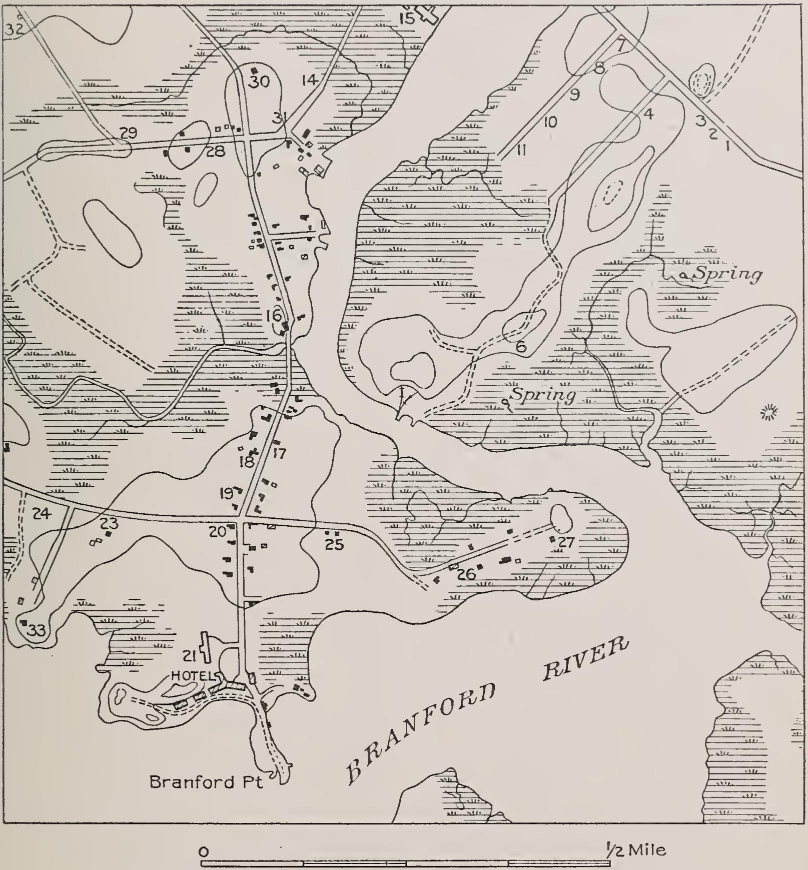

FIGURE 29.—Map of vicinity of Branford Point, showing location of wells.

7. A permanent well with water of medium softness; 32 feet deep; contains 4 feet of water.

8. Water said to be harder than in the other wells of the vicinity. The depth of the well is 33 feet and the water stands at 29 feet.

9. Well of hard water, 33 feet deep.

10. Dug to a depth of 25 feet; contains 4 feet of hard water.

11. Well 25 feet deep; has 4 feet of hard water; has never been known to fail.

12. Well 25 feet deep; has 4 feet of water.

13. Although situated very near the salt marsh and the tidal river, this well contains good water. It is 26 feet deep and has 3 feet of water. It has never failed.

14. This place is supplied by a well driven 5 feet below the cellar floor. Fresh water enters "like a spring" at the edge of the marsh.

15. This factory is located mostly on "made land" recovered from a salt meadow. Wells were brackish and were accordingly abandoned.

16. Well 12 feet deep; contains 1 foot 6 inches of water. Water became brackish and has been discarded in favor of city water.

17. Well 23 feet deep; contains a constant supply of about 3 feet of hard water.

18. Well 25 feet deep; contains 2 feet of hard water.

19. Well 25 feet deep; has 3 feet of soft water; yield regular.

20. Well 22 feet deep; has 3 feet of hard water.

21. Well at barn 15 feet deep; contains about 4 feet of water. City water used at house.

22. Well sunk in rock much broken by joints which permit access of salt water.

23. Well 25 feet deep; contains 2 feet 6 inches of water which is little affected by dry weather. Water is claimed to be soft and palatable.

24. Rain water is used because wells give brackish water.

25. Two driven wells in house, each 24 feet deep. One of these wells has yielded a good supply of soft water for twenty years.

26. On a narrow neck of land between two salt marshes and not over 20 feet from one of them; 16 feet deep; contains 3 feet of hard water.

27. Well 17 feet deep; contains 3 feet of water, which is wholesome but a little hard.

28. Well 23 feet deep; contains a constant supply of hard water.

29. Water is medium in softness. Well 25 feet deep, with 3 feet of water, and does not fail.

30. Well 22 feet deep; contains 2 feet of water of an unsatisfactory quality.

31. Well 24 feet deep; contains 3 feet of water of medium softness.

32. Well 25 feet deep; contains 4 feet of soft, wholesome water.

33. Well 16 feet deep, with 5 feet of water of good quality.

CHAPTER VIII.

CHARACTER OF GROUND WATER OF CONNECTICUT.

INTRODUCTION.

Pure water, as a compound of hydrogen and oxygen, is not known in nature. Descending rains take from the atmosphere considerable of its impurities and carry them to the ground; carbonic acid, sulphates and nitrates, especially near cities where coal is used for fuel, sodium chloride in the vicinity of the sea, and atmospheric dust contribute to the rainfall. Of the common gases rain water contains about 25 cubic centimeters per cubic meter, consisting of nitrogen about 64 per cent, oxygen 34 per cent, and carbonic acid 2 per cent. With the exception of chlorine, however, all the impurities of the air may be disregarded in the study of ground water.

After water enters the soil, it gathers materials from rocks and from decomposing organic matter. Sodium and potassium are taken from rocks containing feldspars. Calcium and magnesium are extracted from limestones and in less degree from rocks of other types. The minerals taken up by water in its subterranean course are chiefly silica, iron, aluminum, calcium, magnesium, sodium, potassium, chlorine, organic acids of uncertain composition, and the carbonate, bicarbonate, sulphate, and nitrate radicles. Barium, strontium, lithium, and other elements occur less commonly in appreciable quantity. Free carbonic acid gas is an ordinary ingredient of natural water, and oxygen, hydrogen, nitrogen, hydrogen sulphide, and hydrogen phosphide in solution are occasionally encountered.

As the value of water for any given purpose is determined by its composition, chemical study of surface and ground waters becomes a matter of great practical importance. The composition of ground water in Connecticut is of prime interest, because only the larger cities within the State receive their water supply from brooks or lakes. Of the 168 towns in the State 140 depend entirely on wells and local springs for their water supplies, and it is estimated that 40 per cent of the population obtain water for domestic purposes from more than 90,000 wells and springs.

COMPOSITION.

DETERMINING CHARACTERS.

The composition of the ground waters within the State is determined by the character of rock from which they are drawn. Shallow wells and springs in glacial drift contain substances leached from the upper soil and include nominal amounts of chlorine, sulphates, carbonates, nitrates, silica, calcium, magnesium, potassium, and sodium, with iron and aluminum in small amount, and a relative absence of organic matter. The deeper wells in the drift contain the same substances, but larger amounts of iron and less nitrates. Waters from glacial till and from rock are characterized by their relatively high content of calcium, magnesium, and sulphates. This is particularly true of water from sandstone and closely packed till or hardpan.

HARD AND SOFT WATERS.

As water takes up chemical compounds during its percolation through the ground, it often becomes what is commonly known as "hard" water, the term indicating its ability to form insoluble calcium and magnesium soaps when used for washing purposes. The greater proportion of the mineral constituents dissolved in shallow ground waters is obtained near the surface in what is known as the belt of weathering. This is the unsaturated zone between the ground surface and the level of the water table. The mineral constituents of this belt are relatively insoluble in their natural state, but they are continually undergoing oxidation, hydration, and carbonation, which result in the formation of compounds soluble in water. In the upper portion of the soil there is a large amount of organic matter which is oxidized through natural decay to carbonic and other acids. These acids, dissolved in water, attack the rocks and increase the mineralization of the underground supply. Calcium and magnesium in equilibrium with the bicarbonate radicle in water constitute temporary hardness, so-called because the minerals may be removed by boiling the water. If, however, the sulphate rather than the bicarbonate radicle is present the water is said to be permanently hard because boiling will not remove the dissolved minerals. The amount of calcium and magnesium present determine the relative hardness of water, and the proportions of the bicarbonate and sulphate radicles determine its character. The oxidation of iron sulphide is probably a source of sulphuric acid, which may decompose rocks with which it comes into contact. Among the most common constituents of crystalline rocks are silicates of iron, aluminum, calcium, and magnesium. These silicates in themselves are practically insoluble in water at ordinary temperatures, but in the presence of waters containing carbon dioxide they are subjected to chemical changes and are carried away in solution.

There are many other methods by which water obtains mineral matter in solution, but those cited above are sufficient to illustrate the processes. It has been estimated by Reade[a] that for the entire earth there is removed annually in solution 96 tons of material per square mile, consisting of calcium carbonate, 50 tons; calcium sulphate, 20 tons; sodium chloride, 8 tons; silica, 7 tons; alkaline carbonates and sulphates, 6 tons; magnesium carbonate, 4 tons; oxide of iron, 1 ton.

MATERIAL TAKEN INTO SOLUTION.

Although there are many factors determining the character and the amount of the materials taken into solution by underground water, only two need be considered in this discussion. They are the character of the material traversed by the water, and the distance which the water has traveled underground. The waters of the glacial drift exhibit great variability of composition and are almost equally divided between hard and soft waters. In general the waters from the finely divided clay till are hard and those from the sand and gravel deposits are soft, owing to the character of the material. The sand and gravel deposits are composed largely of coarse grains of quartzose materials, which are dissolved with great difficulty by water, but the till is made up in part of masses of finely divided heterogeneous material which not only offer a more varied assortment to be acted on by waters but also give greater opportunity for solution owing to their fineness of grain. The deep-well waters of the sandstone are much harder than those of the crystalline rocks. In the latter the crevices afford the only passage for the water, and consequently the solvent action of the water is largely confined to the immediate walls of the crevices. In sandstone, however, the water traverses the entire rock, passing not only through the seams but also through the small pores between the grains, and thus has a vastly greater surface for action. Many of the sandstones of Connecticut are arkoses containing as great variety of mineral constituents as the original crystalline rocks.

In regard to the distance that the water travels, it is manifest that the longer and the slower the passage the greater opportunity there will be for solution. Increase of heat and pressure increases the solvent power of water; the waters which have penetrated deeply and have been subjected to great heat and pressure often have a larger proportion of dissolved minerals than those at shallow depths.

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[a] Reade, T. Mellard, Chemical denudation in relation to geological time.

Analyses of waters from 13 wells in crystalline rock give an average of 132 parts per million of total solids. Analyses of 18 well waters derived from Triassic sandstone areas average 655 parts per million of solid matter. Exclusive of three well waters that contain over 1,000 parts of solid matter, the average for 15 well waters from sandstone is 377 parts per million. Five well waters from glacial drift average 263 parts of mineral matter. The analyses of 25 spring waters give an average of 73.5 parts of total solids. It is impossible to state from the available data whether springs from one source contain more mineral matter than those from a different source. The information at hand gives no indication of any definite increase of mineral matter with increase in depth of the well, and though there might be such increase in very deep wells, it seems that within the ordinary limits of well depth in Connecticut—between 100 and 500 feet—the relation of mineral content to depth has no practical bearing.

NORMAL DISTRIBUTION OF CHLORINE.

Chlorine, which is a constituent of common salt, is present in all natural waters and comes from salt deposits within the earth or from salt-laden spray from the ocean. In Connecticut there are no deposits of salt or other chlorine compounds from which waters might derive appreciable amounts of chlorine, but this substance is present in them in considerable quantity and the proportion of it in ground water decreases regularly with increase of distance from the coast. The obvious inference is that the natural waters obtain their chlorine from the minute particles of sea water that are blown inland by the winds. The amount of chlorine in normal waters of Connecticut has been determined for different parts of the State,[a] and a map prepared under the direction of Prof. H. E. Smith, of the Yale Medical School, indicates the normal distribution of chlorine by means of isochlors or lines defining the areas within which the waters in their natural state contain certain definite amounts of chlorine. (See Pl. V.) The value of knowledge regarding the normal distribution of chlorine is that it affords a ready basis for testing the purity of both surface and subterranean waters. Salt is present in all animal dejecta and eventually finds its way to the water courses, both above and below ground; consequently if a water contains more chlorine than the normal amount for the area in which it occurs, the presence of sewage or other contaminating matter may be suspected. Excess chlorine in wells immediately adjacent to salt water is not necessarily an indication of sewage contamination, but usually of the admixture of sea water.

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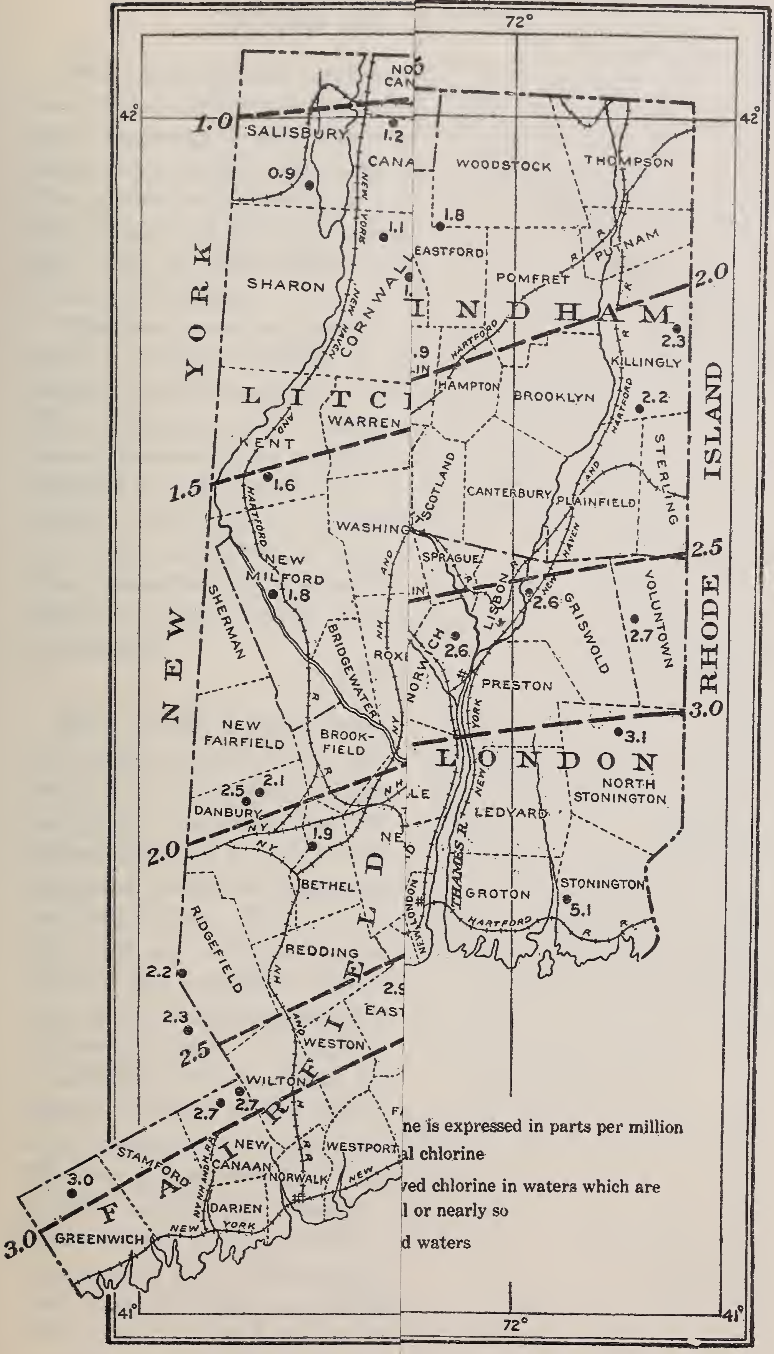
[a] Rept. Connecticut State Board of Health for 1902, pp. 227-242.



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MAP OF CONNECTICUT, SHOWING DISTRIBUTION OF CHLORINE.

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USES OF WATER.

WATER FOR DOMESTIC PURPOSES.

The uses to which underground water is ordinarily put in Connecticut are relatively few in number. Owing to the ease with which large amounts of soft water are obtained, city supplies are usually taken from ponded reservoirs fed by surface drainage and by springs. For private residences and manufactories outside of cities, however, wells constitute the chief source of water supply for general purposes, and even in cities some manufacturing concerns find it expedient to use well water.

The three main purposes for which well and spring waters are used are for domestic supply, as in cooking, drinking, and washing, for boilers, and for coolers. A reasonably soft water is desirable for all these purposes and is particularly necessary in the case of boiler water, because hard waters form a scale in boilers, causing a heavy expense for additional fuel, cleaning of flues, extra firings, and boiler repairs. Soft water is preferable for general domestic use, though it is not so palatable as hard water. In breweries, distilleries, and other manufacturing establishments where a supply of cool water effects a great saving in artificial refrigeration, well waters are economical.

WATER FOR BOILERS.

Most of the large manufacturing establishments in Connecticut are on the banks of the more important streams, where abundant water for boilers may ordinarily be obtained from the heavy sand and gravel deposits that fill the major valleys. Such supplies are reasonably soft and cold and are satisfactory for cooling and boiler purposes, although frequently unsafe for drinking owing to surface contamination. Wells penetrating a considerable distance into the rock are preferable as sources of drinking water. Water from wells in the crystalline areas is usually soft enough for boiler use, but that in the sandstone areas is likely to be hard and is frequently disastrous to boilers. A study of Connecticut waters with regard to their availability for steaming purposes has been made by George H. Seyms, chemist of the Hartford Steam Boiler Inspection and Insurance Company, who has kindly allowed free use of his valuable data. Mr. Seyms has classified Connecticut waters in regard to their use in boilers, taking into account the average proportion of the different constituents in the normal waters of the State and assuming that one-half of the total solids is incrusting matter. Water containing less than 250 parts per million of solid matter is pronounced good. Water containing between 250 and 500 parts of solid matter is fair for boiler use, but if the amount exceeds 500 parts the water is unfit for general boiler purposes. In making this estimate the fact has been taken into account that in most parts of the State supplies of soft surface waters may be obtained at reasonable rates. Increased hardness means increased cost of maintenance and where hard waters are used for boilers, as in the Western States, it is only because supplies of soft water are not available. The water supplies of Connecticut are recommended by Mr. Seyms for boiler purposes in the following order: (1) River waters (where uncontaminated by factory wastes); (2) ponded reservoirs; (3) small streams (as compared with rivers); (4) springs and shallow wells 30 to 50 feet deep; (5) deep wells. Wells in sandstone are less suitable as a source of water for boiler use than those in crystalline rocks.

CONTAMINATION.

INTRODUCTION.

That the ground water of Connecticut is liable to contamination and needs careful and frequent examination is well shown by the analyses of tainted waters made by the state board of health and by the typhoid epidemics which have occurred within the State. In 1893 the health officers of 119 towns reported on the condition of water supply,[a] and pronounced the water of only 82 towns unqualifiedly good. In 1898 analyses were made of water from 247 wells on the premises of public schools in the State; only half of them were free from suspicion of dangerous contamination and many were highly polluted.[b] In 1899 only three out of 14 suspected wells examined were declared safe.[c] In 1902 the water supplies of 101 hotels and restaurants and summer resorts were inspected, and only 20 out of 33 samples taken from springs, wells, and cisterns were considered safe.[d]

Sixty cases of typhoid, probably caused by water from a well 25 feet from a house, occurred in 1882 at Portland.[e] The drainage from a vault entering the quicksand caused typhoid at Guilford during the same year.[f] Water from a well in Middletown gave typhoid to an entire family in 1884.[g] The analyses of water from three wells at Madison in 1885 revealed the source of pollution which caused 14 cases of fever.[h] Contaminated water at Money Island caused 21 cases of typhoid in 1891.[i] The epidemic at Stafford in 1894 was traced to a polluted well.[j] The great epidemic at Stamford in 1895, in which 386 people were afflicted, was caused by milk delivered in cans which had been washed in well water infected by drainage from vaults.[k]

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[a] Ann. Rept. Connecticut State Board of Health, 1893, p. 110.

[b] Idem, 1898, pp. 279, 280.

[c] Idem, 1899, p. 21.

[d] Idem, 1902, pp. 223-226.

[e] Idem, 1882, p. 140.

[f] Idem, 1882, p. 144.

[g] Idem, 1884, pp. 79-81.

[h] Idem, 1885, pp. 342-344.

[i] Idem, 1891, pp. 205-213.

[j] Idem, 1894, pp. 232-238.

[k] Idem, 1895, p. 161.

Typhoid at Easton in 1895 was traced to a well adjoining a pig pen.[a] Thirty cases of typhoid in Glastonbury in 1895 were caused by a contaminated well at Hopewell.[b] An investigation of the typhoid at Ridgefield in 1901 showed that the entire ground water of an area covering several blocks had been contaminated by sewage.[c] The typhoid epidemic, 84 cases in all, at Bristol in 1903 was due to infected water from a farm well and spring.[d] Several less conspicuous occurrences of typhoid are likewise directly traceable to contaminated ground water.

"It is now universally recognized that the degree of prevalence of typhoid fever in a given community is a reliable measure of the extent to which sewage is an ingredient in its drinking water. The prevalence of typhoid in cities is a true index of the quality of the water supplies."[e]

The annual death rate from typhoid in Connecticut has been steadily decreasing, and this satisfactory record is due largely to the increased attention paid to the character of water supplies.

CONTAMINATION BY SEWAGE.

Sewage is the most widespread source of contamination of water in springs and wells. Drainage from vaults, cesspools, broken sewers, slops thrown on the ground, pig pens, and other sources of filth passes readily into the ground water and is the common vehicle for substances dangerous to health.

LOCATION OF WELLS.

The location of a well is the most important consideration in obtaining pure water. The well should be placed at a considerable distance from any known source of contamination, on ground of relatively high elevation, and should be surrounded by an open, clear space, preferably grass covered. The direction of the flow of ground water for the area should be determined, if possible. Many wells in Connecticut are located in utter disregard of the simplest principles governing the movement of underground water. Instances might be cited where cesspools and other waste reservoirs are within 25 feet of wells used for domestic supply. For some wells the worst possible locations seem to have been selected. The writer has noted between 40 and 50 wells located on slopes below cesspools, in such manner that the contaminated waters, either in drift or in rock, are carried with certainty into the wells. It is not the depth but the location of a well which usually determines its purity, and a 20-foot well located with care may be much safer than a 100-foot well sunk without

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[a] Ann. Rept. Connecticut State Board of Health, 1895, p. 90.

[b] Idem, 1895, p. 99.

[c] Idem, 1901, pp. 301-305.

[d] Idem, 1903, p. 88.

[e] Idem, 1899, p. 21.

regard to surrounding conditions. A good illustration of this is the well on the New Haven Green, a shallow well in the heart of the largest city of Connecticut. The quality of the water is good, because the surface about it is protected on the south and east by pavements and because its water is received from the Green, a grass plot 16 acres in extent, kept clean by the city authorities.

There is a general impression that soil will filter the impurities from water within a few feet of its source and that contamination of wells is due chiefly to material falling in at the top. No more dangerous error could be propagated. The purifying power of a soil is limited and it may easily be overburdened. In fact, the value of any soil filtration is uncertain, and it is impossible to state that water will be purified by passing through any amount of soil. The uncertainty is greatly increased by the existence of more or less open channels, which offer rapid passage to underground water with little filtration.

DEPTH AND CONSTRUCTION OF WELLS.

Shallow wells are much more likely to become contaminated than deep wells, and as probably 80 per cent of all wells within the State are less than 25 feet in depth, the importance of care in their maintenance is evident. There is in Connecticut, particularly in the rural districts, a strong prejudice in favor of the shallow, open well and a belief that clear, sparkling, palatable water is sure to be pure. The danger in these beliefs is very real, for certain parts of sewage tend to give water a sparkle which is highly appreciated by those unacquainted with its character. Drilled or bored wells have many advantages over shallow dug wells. There is less chance for foreign substances to drop into the well, and it is possible to shut off all surface and seepage water. The "old oaken bucket" has sentimental advantages, but iron pipes and creaking windmills are much better symbols of the purity of drinking water.

CONTAMINATION IN DIFFERENT ROCK TYPES.

Contamination of water in shallow drift wells has been the cause of many typhoid epidemics in Connecticut, as at Bristol, Easton, Glastonbury, Guilford, Madison, Middletown, Portland, Ridgefield, Stamford, and Stafford. The water supply at Camp Coffin was found to be contaminated in 1896 by water that collected in a pool used for washing clothes and reached the well by sinking through a considerable depth of sand and gravel. In 1903 the Chamber of Commerce of New Haven made an investigation of the local water supply, which led to the recommendation that all wells within the city should be abandoned as sources of water for domestic uses. The wells examined are mostly in till or stratified drift, range in depth from 20 to 220 feet, and are located in all sections of the city. Six samples were taken from wells 20 to 30 feet deep, eight from wells 30 to 50 feet deep, five from wells 50 to 100 feet deep, and nine from wells over 100 feet deep. The committee reported that, with the exception of a few samples from the outskirts of the city, all showed evidence of a past contamination in a more or less marked degree. In Hartford, Waterbury, and other cities analyses of water derived from sand and gravel deposits commonly indicate considerable sewage contamination, although the water is obtained at points 30 to 50 feet below the surface. In fact, it is doubtful if any well is safe in a thickly settled community.

Spring water may likewise become contaminated by sewage-laden ground water, as illustrated at Forestville and South Norwalk during the typhoid epidemics of 1900.[a]

Though drilled wells are much less subject to sewage and drainage contamination than shallow-dug wells of large diameter, equal care should be taken in their location. A number of deep wells have been drilled in the low central portion of Hartford, and many of them show heavy contamination in waters supposed to be derived more than 200 feet below the surface. This is a portion of the city which received for years a large amount of drainage, so that whatever water enters the rock through the soil carries with it considerable contaminating material. Some of this water finds a ready passage through more or less open joints and enters the wells. The contamination of many such wells results from imperfect casing and the consequent entrance of water from the surface. There is little doubt that in certain wells imperfect joints allow shallow waters to enter the well at the contact of the rock and the drift. Such poor construction may be due to carelessness, or to intention, owing to the desire of the driller to obtain a sufficient supply of water. The entrance of any water at the junction of the casing and the rock may be detected if a mirror is used to reflect light into the well.

That contaminated water may circulate through considerable distances of sandstone is shown by the experience of Hartford, already described. At the Wallingford Sanitarium a well was contaminated by gasoline which flowed through the bedding planes of rock for a distance of 225 feet at a depth of 8 feet below the surface. Many similar cases might be cited.

Even wells sunk in granite and other crystalline rock are not free from contamination by circulating water. The typhoid epidemic at Sachem Head was caused by drinking water from a well blasted in rock to a depth of 16 feet. It was shown that the contaminated water passed through joints for a distance of 6 feet. At Millstone

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[a] Ann. Rept. Connecticut State Board of Health, 1900, pp. 274-285, 286-289.

Point brackish water was seen to be supplied from a rock seam at a distance of 150 feet. Part of the ground water of Fishers Island is known to come through crystalline rock from the Connecticut mainland, 3 to 4 miles distant.

CONTAMINATION BY SEA WATER.

The Connecticut wells which have been contaminated by sea water are within 200 or 300 feet of open salt water, on old salt marshes, along tidal streams, or on islands. They are practically all in rock where the surface water has presumably been entirely cased off. The surface water, however, is usually fresher than that derived from the rock itself. In a well drilled for the Norwalk Iron Works Company, Norwalk, at an elevation 10 feet above sea level, fresh water was found in sand and gravel deposits at a depth of 60 feet, but salt water only was obtained at lower levels in the rock. The well was accordingly plugged at a depth of 60 feet and the rock water excluded. At many points along the coast pipes have been driven in deposits of sand and gravel near the shore and abundant supplies of fresh water have been obtained. These wells may, however, receive increments of salt water when the water table is brought below sea level, either by pumping or by dry seasons. In deep-driven wells near the shore which derive their supplies from the bottom of closed tubes, the head of fresh water is almost without exception sufficient to prevent the inflow of brine. In New Haven a series of wells have been driven through 6 feet of salt water into the sand deposits below and have obtained good supplies of fresh water.

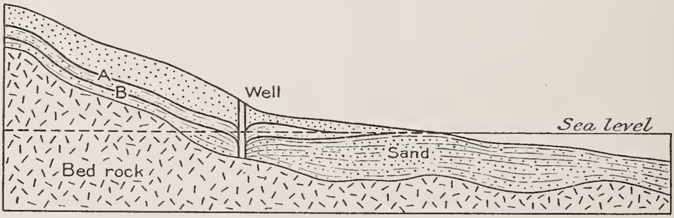

FIGURE 30.—Diagram illustrating the manner in which a well near the sea may be contaminated by salt water during the dry season. A, normal water table; B, depressed water table.

In wells deriving water from rock in which the supply necessarily comes through fractures it is possible that the fractures may have such position as to give more ready access to sea water than to fresh underground waters. The possibility of contamination by this process increases rapidly with nearness to the sea, especially if the rock outcrops beyond the shore line. Figure 30 represents the direction of circulation of water contributing to such well, the ground water above the rock being entirely cased off.

RELATIVE VALUE OF WATER SUPPLIES.

Experience has shown that water in Connecticut is to be recommended for domestic use in the following order: (1) Surface supplies, preferably from lakes that are constantly under supervision and subjected to frequent inspections and examinations; (2) deep wells so located that the surface area contributing to them is known to be free from contamination; (3) springs, especially deep-seated ones, like those along fault lines known to derive their water from regions not subject to contamination; (4) shallow wells and intermittent springs; (5) lakes and streams whose character has not been carefully determined.

ANALYSES.

In the following tables of analytical results the data are given in ionic form, in parts per million, having been recomputed, if not originally expressed in that manner. The column headings are in general self-explanatory. "Total solids" indicates the total dissolved matter found by evaporating a measured quantity of water and weighing the dried residue. "Organic and volatile matter" represents the difference in weight between the dried solids and the solids after being ignited at low red heat; the figure serves as a rough measure of the organic matter, though it also represents loss of water of crystallization, volatilization of some inorganic constituents, and other factors. The term "total hardness" is given to a figure found by adding standard soap solution to a measured amount of water till the mixture forms a good lather when shaken vigorously; the equivalent of the quantity of soap consumed is usually expressed as calcium carbonate ($CaCO_3$). The "permanent hardness" is found by adding soap solution to water that has been boiled and filtered; it represents the hardness due to calcium and magnesium in equilibrium with acids other than carbonic acid. The "temporary hardness" is estimated either by subtracting the permanent from the total hardness or by titrating the water with normal acid.

Analyses of well waters from crystalline rocks.

[Parts per million.]

No.[a]	Analyst.	Hardness as $CaCO_3$.		Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Organic and volatile matter.	Soluble residue.
		Total.	Alkalinity.													
10	Unknown	95											234	570		
18	H. Southern Eng. Co.	97	60		Trace.	31				71	18		22	193	9.1	
26	Unknown	36											9.4	126	10	
40	E. E. Smith	36	28		Trace.							4.0	4.0	69	9	
57	Unknown	26			Trace.							.4	22	132	14	
58	S. P. Wheeler				1.9			58			17		7.0	[b] 84		
59	G. H. Seyms							High.					High.	12,013		11,925
102	H. E. Smith			18	.9	15	1.8	10		59	13	3.1	4.0	95	6.4	
133	S. P. Wheeler	63											25	212	12	
177	H. T. Vulté	11	11									Trace.	9.3	106	6.0	
(c)	H. E. Smith		48									.3	9.7	202	8.0	
(d)	do		62									.2	4.3	102	12	
185	G. H. Seyms							High.					High.	1,052		868
[e] 185	do							High.					High.	4,746		4,668
192	Unknown											5.3	6.0	124	24	
198	G. H. Seyms										High.		High.	308		232
208	Levi Wilcox				Trace.	21							13	138	80	
[f] 208	do					19							26	203	75	
204	Unknown	60										.7	1.2	122	17	
209	State chemist	140											34	347	39	
210	G. H. Seyms													268		192
211	Levi Wilcox	101										11	28	297	116	
227	G. H. Seyms										High.		High.	4,056		3,852
[g] 227	do										High.		High.	208		176
233	H. E. Smith	35										.9	2.8	48		
237	do	30										.2	2.6	68	10	

[a] The numbers refer to the well records on pp. 78-89.

[b] Trace of lithium.

[c] Well of C. I. Hempstead, Glenbrook, Stamford; drilled 140 feet; 80 feet in rock.

[d] Well of Stamford Water Co., Stamford; 247 feet deep.

[e] Seven months later than first analysis.

[f] Same well at depth of 122 feet.

[g] Same well after one year's constant use.

Analyses of well waters from sandstone.

[Parts per million.]

No.[a]	Analyst.	Hardness as $CaCO_3$.		Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Organic and volatile matter.	Soluble residue.
		Total.	Alkalinity.													
8	Unknown	......	......	20	15	[b] 326	[b] 106	118	([b])	([b])	1,201	......	213	2,524	410	......
([c])	H. E. Smith	48	......	......	......	......	......	......	......	......	......	2.6	5.0	100	8.5	......
15	G. H. Seyms	......	......	......	......	......	......	......	......	......	......	......	......	112	......	84
26	do	......	......	......	......	High.	High.	......	......	......	High.	......	......	316	......	224
([d])	do	......	......	......	......	......	......	......	......	......	......	......	......	288	......	164
([e])	do	......	......	......	......	......	......	......	......	......	High.	......	......	536	......	332
([f])	do	......	......	......	......	......	......	......	......	......	High.	......	......	2,312	......	1,256
([g])	do	......	......	......	......	......	......	......	......	High.	......	......	......	816	......	368
69	H. E. Smith	240	96	......	......	......	......	......	......	......	430	.4	13	628	......	......
74	Unknown	......	......	18	.7	146	31	90	......	......	469	9.2	22	941	......	......
([h])	G. H. Seyms	......	......	......	......	......	......	......	......	......	......	......	......	156	......	108
85	H. E. Smith	......	......	19	2.0	330	9.9	24	......	......	802	.2	3.7	1,296	57	......
([i])	G. H. Seyms	......	......	......	......	High.	......	......	......	......	High.	......	......	376	......	284
112	Unknown	274	......	......	Trace.	82	41	......	......	150	164	......	......	722	......	......
([j])	G. H. Seyms	......	......	......	......	High.	High.	......	......	......	High.	......	......	2,580	......	1,848
117	H. E. Smith	52	......	......	......	10	......	......	......	......	......	12	......	110	9.0	......
152	do	28	......	......	......	......	......	......	......	......	......	.4	2.0	69	5.0	......
165	Unknown	......	......	14	......	44	11	5.5	......	116	54	......	8.5	258	62	......
189	do	110	......	......	......	......	......	......	......	......	......	......	10	241	......	......

[a] The numbers refer to the well records on pp. 116-123.

[b] Carbonates of calcium and magnesium, 54 parts; trace of lithium (Li) and the phosphate radicle (PO_4).

[c] Well of Mount Carmel Bolt Co., Mount Carmel, Hamden; dug 35 feet deep and 30 inches diameter.

[d] Well of Billings & Spencer Co., Hartford; drilled 250 feet

[e] Well of G. W. Brown, Linden Building, Hartford; drilled 235 feet.

[f] Well of Hartford Woven Wire Mattress Co., Hartford; 250 feet deep; water at 200 feet; flow, 15 gallons a minute.

[g] Drilled well of Long Bros., Hartford.

[h] Well of Goetz Bakery, Manchester; drilled 200 feet deep in soft brownstone.

[i] Well of Charles Parker, Meriden; 1,000 feet deep.

[j] Well of Tuttle Brick Co., Newfield, Middletown; drilled 264 feet.

Analyses of well waters from stratified drift.

[Parts per million.]

No.[a]	Analyst.	Hardness as $CaCO_3$.		Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Organic and volatile matter.	Soluble residue.
		Total.	Alkalinity.													
45	Unknown	....	....	....	....	74	11	....	....	....	26	28	44	404	48	....
50	T. B. Osborn	....	....	12	....	31	30	85	....	170	83	....	105	528	98	....
(b)	G. H. Seyms	....	....	....	....	High.	....	....	....	....	....	....	....	368	....	212
56	H. E. Smith	134	....	....	....	....	....	....	....	....	....	....	26	298	30	....
(c)	Unknown	....	....	....	Trace.	36	Trace.	9	....	72	30	....	13	....	....	....

[a] The numbers refer to the well records on pp. 152–155.

[b] Well of National Folding Box and Paper Co., New Haven; 2-inch test well 100 feet in gravel.

[c] Well of Waterbury Brass Co., Waterbury; 35 feet deep.

Analyses of well waters from till.

[Parts per million.]

Well.	Analyst.	Hardness as $CaCO_3$.		Silica (SiO_2).	Iron (Fe).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Organic and volatile matter.	Soluble residue.
		Total.	Alkalinity.													
(a)	H. E. Smith	21	....	....	....	....	....	....	....	....	....	1.8	2.6	79	15	....
(b)	Unknown	54	....	....	....	....	....	....	....	....	....	2.2	5.9	107	15	....

[a] Well of R. K. Jones, Turnerville, Hebron; dug 16 feet deep.

[b] Well of W. E. Bond, New Canaan; dug.

Analyses of spring waters.

[Parts per million.]

No.[a]	Analyst.	Hardness as $CaCO_3$.		Silica (SiO_2).	Oxides of iron and aluminum ($Fe_2O_3+Al_2O_3$).	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Nitrate radicle (NO_3).	Chlorine (Cl).	Total solids.	Organic and volatile matter.
		Total.	Alkalinity.											
1	Unknown	43									8.8	6.0	94	23
4	R. H. Chittenden			18	0.3	4.0	1.1	4.0	15	8.0		1.5	45	
8	H. E. Smith			14	.2	2.4	1.1	3.1	14	1.8	.2	1.2	34	2.7
9	C. A. Seitz			25	14	12	9.0	116	323	5.6		2.6	346	2.2
19	H. E. Smith	22	18								2.6	2.5	50	7.5
23	S. P. Wheeler			6.0	1.2	2.1	1.4	14	12	1.3		18	50	
([b])	H. E. Smith	73	59								2.2	2.0	101	14
32	Unknown			9.5	1.0	10	6.0		58	1.6		1.3	61	
34	R. B. Riggs			7.2	Trace.	4.4	.4	6.7	17	3.5		5.4		
([c])	H. E. Smith	16	13								.1	2.5	37	11
([d])	do	23									3.7	3.2	60	11
([e])	do	58	47								1.1	3.7	72	12
([f])	do	36	30								.4	3.1	63	7.5
([g])	do		8.0								.0	1.0	22	8.0
55	do	23									.7	3.3	93	
([h])	do	44	40								3.0	3.1	62	10
62	Unknown											4.0	72	22
63	G. F. Barker			23	11	6.0	2.2	5.0	17	29		3.6	107	24
65	Unknown	20									9.7	2.0	52	16
([i])	H. E. Smith	42	38								1.5	4.3	72	18
69	R. H. Chittenden	7.0		10	.2	3.0	1.0	3.5	13	2.4		2.6	38	8.0
66	E. S. Sperry			6.3	.4	2.2	1.0	7.3	10	9.1		3.1	42	8.0
[j]74	Unknown			34	13	5.1	.3	12	6	14		3.2	122	29
83	H. E. Smith			11	.8	8.3	2.6	8.7	26	11	8.0	7.3	71	
90	S. P. Wheeler	28											56	20

[a] The numbers refer to the spring records on pp. 191–194.
[b] On Whitman place, at Farmington.
[c] Spring of J. V. Palmer, Millville, Naugatuck.
[d] Cherry Hill Spring of H. B. Gorham, Highwood, New Haven; from sandstone.
[e] Spring of Mrs. D. Auger, Fair Haven, New Haven.
[f] Spring of Stillman Water Co., near East Rock, New Haven.
[g] Spring of G. H. Bush, Norfolk.
[h] Quinnipiac Spring of L. R. Hemingway, North Haven.
[i] Spring of Z. Chaffee, Pomfret.
[j] Phosphates present.

CHAPTER IX.

WELL CONSTRUCTION IN CONNECTICUT.

DUG WELLS.

The common type of well in Connecticut is naturally the most primitive type—an excavation in the ground to a depth below the level of ground water, the interior being lined with brick or stones. These wells are usually dug in clay, sand, and glacial drift, but a few, where the surface material is shallow, are blasted into the underlying rock. Some wells are dug into rock and water is obtained from crevices, but in general the rock excavation serves merely as a reservoir for water draining from the drift. Such wells are usually 2 to 4 feet in diameter inside the stone casing and from 10 to 50 feet in depth.

Very few dug wells are properly constructed in Connecticut and many are extremely old, it being not unusual to find wells sunk more than a hundred years ago. The ordinary stone casing is very inefficient as a protection against the entrance of surface water, the openings between the stones being in many wells large enough to permit the passage of rats and other small animals. Brickwork is used as a lining in some of these wells, but probably the safest method of protecting such a well against contamination is by tiling.

Too much care can not be taken in the location and protection of open, shallow wells. A well of the open type containing clear, sparkling water has been considered one of the most valuable possessions of home. Such wells are, however, peculiarly liable to dangerous contamination. Many of them are located on low ground, because water may be procured there at less expense, and some are walled up with poorly cemented stone and either open or covered only with loose boards. The tops of many of these wells are but a few inches above the level of the ground and may readily serve as resting places for impurities carried by wind or on the feet of animals and men.[a] The advantages of the small drilled or bored well, as compared with a dug well, are the decreased probability of the entrance of impurities at the time the well is put down, less opportunity for rats, frogs, and other animals to enter the well, and the ease of shutting out surface and seepage waters. It can not be too plainly stated that open wells are dangerous to health.

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[a] See a discussion of this subject by Crider, A. F., and Johnson, L. C., Water-Supply Paper U. S. Geol. Survey No. 159, 1906, pp. 74–75.

As dug wells usually reach but a few feet below the level of ground water, any fluctuations of the water table materially affect the yield of the wells. In dry seasons the water table may sink below the bottom of the well, with a consequent total loss of supply. This loss of supply, owing to drought, is more noticeable in wells located on hills than in those along stream channels.

Dug wells are of value in rural communities, but in cities and thickly populated areas they are extremely unsafe because of the general contamination of the soil and the impracticability of keeping out surface water.

The average cost of a well of this type, as ordinarily constructed in Connecticut, is about one-fourth to one-half that of the average drilled well, but when it is carefully constructed and cased so as to admit water only at the bottom, the cost is not far from that of a well constructed on more sanitary principles.

DRIVEN WELLS.

For wells in sand and gravel a method of well construction is recommended which, although commonly used throughout the United States, is little appreciated in Connecticut. This is the driven well, consisting essentially of a pipe, usually 1 to 2 inches in diameter, driven into the ground by means of a heavy weight. These pipes are perforated near the base either by boring round holes or by cutting straight slits with beveled inside edges. In some wells the perforated pipe is fitted with a jointed conical tip; in others a hollow open tube is fitted with a perforated section of some noncorrosive material and a sharp steel shoe, so that it can be driven directly into the ground. The contents of the tube are then washed out by water. As the water can enter the well only through the perforations, the position of the base of the pipe determines definitely the depth at which the water enters a well of this type, thus differing radically from a dug well, in which more or less water enters from top to bottom. Such wells are usually put down in a connected series known as "gangs," all connected with a central pipe or main through which the water is pumped. In very favorable localities large supplies may be obtained in this way at relatively small expense. There are several such gangs in New Haven; one of 34 wells at the Yale gymnasium which supplies the swimming pool with 150 gallons a minute was driven at a cost of $600. Another gang of wells furnishes the Yale dining hall with water for cooling, and 40 such wells, each with a diameter of 2 inches, are used by the Hygienic Ice Company.

Wells of this type can be driven only into unconsolidated material, where the water horizon is in sand or gravel. Many places in Connecticut are favorably situated for obtaining water from driven wells, particularly those towns along the main river valleys and near the coast where the sand deposits are heavy. The average cost of such wells is 70 cents a foot and the yield and character of the water obtainable at any place may be readily and cheaply ascertained by means of a single test well costing not more than $20 or $25.

The quality of the water obtained from driven wells is largely determined by their location in reference to possibility of sewage contamination. Although derived from greater depths the water from driven wells of moderate depth is not necessarily better than that from dug wells situated in the same contaminated district, for the flow of ground water through sand and gravel is more rapid than through till, in which the dug wells are commonly constructed. In thickly settled communities the water of driven wells often shows contamination. There are many localities where unpolluted waters may be obtained by driven wells and this method of construction is advised for the Connecticut Valley lowlands, where larger yields and softer quality may generally be obtained from drift than from the underlying sandstone.

DRILLED WELLS.

Of the various methods of obtaining supplies of underground water, drilled wells should probably rank first in importance. Although the most expensive, they are most free from contamination and yield the most constant supplies.

As the process of drilling wells is not generally familiar, it seems advisable to present a brief statement of the methods employed in Connecticut. The two main methods of well drilling are known as churn drilling and rotary or core drilling, the former being far the more common. A churn-drilling rig includes a movable boiler and engine mounted on a frame which is ordinarily drawn by horses or by traction. Attached to the front of this rig is a collapsible derrick which acts as a support for the rope and tools used in the drilling operation. The drilling tools consist of a heavy steel bit, with other devices, such as jars and sinkers, which serve to prevent wedging of the bit, to add weight to the blow, etc. The bit is supported by the rope, and by means of a walking beam or other device is lifted and allowed to drop suddenly 20 to 30 inches, giving a succession of blows at the rate of 25 to 40 a minute. The sharp edge of the heavy bit breaks and crumbles the rock where it strikes, and by continually twisting the supporting rope the bit is made to strike a new spot each time. The result is a round and even hole with a diameter slightly greater than the width of the bit. The diameter of the drill hole is usually 6 inches, although 8-inch wells are not uncommon.

Owing to the presence of glacial drift, a layer of sand or gravel or till is usually traversed before the drill strikes rock. The unconsolidated material carries more or less "surface water," which it is desirable to exclude. To accomplish this purpose, the careful driller inserts a casing, consisting of heavy iron pipe with water-tight joints. The iron casing should extend from the surface to bed rock, and it is particularly important that a tight joint be made where the casing meets the rock. This junction should always be examined by means of reflected light from a mirror to detect the presence of any surface water. Water is kept in the hole during drilling operations, and after every few feet of progress the tools are removed and the well cleaned out by means of a "sand bucket," a hollow tube with a valve at the bottom.

As the chief water horizon in drift is at the contact of rock and the overlying material, it is important to know the character of the rock mass encountered. This is not always easy to determine, for it is not an uncommon occurrence to strike large bowlders that lie many feet above the bed rock and may be readily mistaken for solid ledge. The driller may assure himself in this regard by drilling into the supposed ledge. If it is a bowlder he will pass entirely through it in the course of a few feet. Moreover, the nature of the rock will ordinarily indicate whether it is part of the underlying strata or a fragment carried from a distance.

The rate of drilling, or number of feet a day, varies widely with the character of the rock, and the price charged for drilling is ordinarily regulated by the driller's knowledge of the bed rock in the locality. In crystalline rocks—to which the drillers generally apply the term "granite"—the rate varies between 2 and 25 feet a day. The price for drilling in crystalline rocks varies between $2.50 and $8 a foot, the average being $4.25 a foot. In such wells the same rate is charged for the surface material as for the rock, but the driller furnishes the casing without additional expense. In sandstone drilling is much easier and the average price charged is about $2 a foot for a 6-inch well. For an 8-inch well the price is 50 to 75 cents a foot additional. The average drilled well costs more than a dug well and much more than a driven well, but it possesses advantages not shared by the other types.

Core drilling or "diamond drilling" has been employed with considerable success by one contractor in the western part of Connecticut. In this process the drilling tool consists of a rapidly rotating pipe, the end of which is edged with diamond fragments, chilled steel, or other sharp cutting material which wears away the rock below the cutting edges and leaves a cylindrical core within the pipe. This core is broken off and removed by various devices, leaving a hole of the desired diameter.

Drilled wells are far safer in sanitary respects than either of the other types considered. The process of construction is such that with proper care the surface water may be entirely cased off and a supply obtained from a sufficient depth to insure safety. It should not be forgotten, however, that fissured rock may have openings large enough to allow the passage of water without adequate filtration; this is much more likely to occur where the rock outcrops in the vicinity of the well than where a mantle of glacial drift overlies the ledge. In one place near New Haven where the soil was only 2 feet deep, gasoline leaking from a buried tank at a distance of 150 feet entered the rock and was carried into a drilled well at a depth of at least 18 feet. The gasoline may have entered the well through a crevice or by percolation through the rock itself. Although the contamination of deep-drilled wells is possible, it is an unusual occurrence and is generally due to imperfect casing.

A dishonest driller may sink a deep hole into dry rock and arrange the casing in such a manner that the water from the soil and the upper surface of the rock enters and fills the hole, giving the appearance of a yield from a great depth. The water is large in amount and may show a satisfactory analysis. Sooner or later, however, the ground water establishes channels of ready circulation and any contamination from surface water may enter and penetrate to the bottom of the well.

To give a minimum possibility of contamination the following points should be observed: The well, of whatever kind it may be, should be located as far away from and as high above sources of contamination, like cesspools, open sewers, and barnyards, as circumstances permit; the well site should be selected where the glacial drift above the rock is deep, rather than on a thinly covered rock or on bare ledges; the well should be properly cased—a point to which too little attention is paid in constructing either dug or drilled wells. The driller usually furnishes casing from the surface to the rock, but where circumstances indicate that more casing is needed for safety the owner should not hestitate to assume the slight extra expense required to insure absolutely safe construction.

CHAPTER X.

SPRING WATERS.

INTRODUCTION.

If the surface of Connecticut were level and the soil of uniform composition and texture, the ground water would tend to assume a plane surface at a small distance below the cover of soil. Such a water table would rise and fall with each increase and decrease in precipitation, but there would be no well-marked channels to conduct ground water to the surface. Connecticut, however, is a region of topographic inequality and variability of soils and bed rock and the imprisoned waters find many avenues of escape.

The normal outlet for ground water is near the level of lakes, swamps, and rivers, where it emerges in large amounts although rarely in definite channels. Below the earth's surface there are innumerable openings from which water is poured unnoticed into streams, lakes, or marshes along the shore line where salt water mingles imperceptibly with fresh. If the floor of Connecticut River were exposed suddenly to view by removing the water, we should see tiny rills issuing from cracks and seams and porous places in the rock and drift forming the river bed.

To speak broadly, any definite outlet for ground water is a spring, regardless of its size or of the geologic conditions which surround it.

TYPES OF SPRINGS.

There are springs which emerge from the ground with a force to turn mill wheels and with a volume to float a river steamer. There are springs which come from great depths and furnish vast quantities of hot water. The springs of Connecticut are of another kind—small and widely distributed, containing cold water of exceptional purity, and those suitable for domestic purposes and local supplies are to be numbered by the thousand.

The three types of springs commonly found in the State may be classed as seepage springs, stratum springs, and fault or joint springs.

SEEPAGE.

Many hillsides and lowlands bordering streams and ponds are saturated with moisture and the ground is soft and springy under the foot. This is especially noticeable during the early part of the year, when ground water is particularly abundant. These marshy places are "seeps" and are caused by ground water returning to the surface from the rocks beneath. Such diffused seepage, rather than drainage along definite channels, is the normal method for the escape of water from the ground, and, in fact, it is only where this return seepage is concentrated by some local geologic conditions that a stream issues from the ground as a spring.

When seepage is restricted to a limited area it may form a seepage spring, in which the water slowly escapes from sands or gravels over a space of a hundred square feet, more or less. In its natural state a seepage spring is marked by the presence of water-loving plants and in many places also by the presence of an oily-looking scum or film on the water, which is often mistaken for petroleum but which in reality is the result of decomposing vegetation. The particular factors which have served to concentrate the water at this place are not always easy to determine, but ordinarily a slight difference in texture of the sands or the presence of a thin mantle of drift over rock is sufficient to bring the water to the surface. As a rule the water can be still further concentrated by digging a hole or sinking a barrel into the ground in the zone of most vigorous seepage, thus furnishing a small local reservoir which receives the ground drainage from a larger area.

There is, of course, no sharp line between general diffused seepage, seepage springs, and springs proper, although the term "spring" ordinarily implies a distinct stream of water issuing with some force from an opening a few inches or, at most, a few feet in diameter. No distinct channel need be exposed at the surface, but there must be at hand a definite horizon or zone along which the circulation of ground water is sufficiently rapid to form a constant stream of appreciable size.

STRATUM SPRINGS.

The horizon most suitable for the transmission of large amounts of water is the plane between strata of different degrees of permeability. In such positions the water occupies a definite zone in some porous stratum and is confined by strata through which it passes with difficulty. A stratum spring may originate between two sedimentary beds, between drift and underlying rock, between clay and sand, or even between sands of slightly different structure. Where the edges of water-bearing strata are exposed at the surface, as in stream valleys or in artificial sections, the water is allowed to escape and soon tends to excavate channels along which further progress is rapid.

Where an impervious bed overlain by porous strata is exposed for long distances, a line of springs may be formed at the contact between the strata. Lookout and Raccoon mountains, in Tennessee, are bordered by a fringe of springs which reach the surface at the contact of the capping sandstone with a prominent bed of shale. In the

Snake River canyon, Idaho, a line of springs of great volume emerges from sedimentary beds underlying lava. The edge of the North Haven plain in Connecticut is marked by numerous springs. This sand plain is underlain by clay which forms a basement bed for the ground water, and where the beds are truncated by Quinnipiac River springs emerge from the bedding plane between the clay and the overlying sands. Similar conditions are reported from the Po Valley of Italy, where the water penetrates the sand and remains underground for several miles, finally emerging as a long line of springs where the water table is forced to the surface by more pervious beds. Probably 75 per cent of the springs in this State owe their existence to the concentration of water between beds of sand, clay, till, and rock.

FAULT AND JOINT SPRINGS.

Ground water occupies all open spaces within the earth's surface and moves along joints and faults and seams as well as between beds of stratified series. The rock walls forming the two sides of a fault are usually sufficiently separated to allow the passage of water and the fissure is usually of sufficient depth to permit a profound circulation. Ground water from a large area may be contributary to a single fault zone and may exert pressure sufficient to drive the water along the crack with considerable power. Most of the famous hot springs of the world are located on fault lines. Many small springs in Connecticut are located along faults;[a] their temperature, however, indicates that the water in them does not come from very great depth.

TEMPERATURE.

The temperature of the ground below a depth of 50 or 60 feet is not affected by daily or seasonal changes at the surface, and the temperature of water which comes from those depths is therefore subject to only slight variation, remaining at about 47°, which is the average annual temperature of the State. No hot springs are reported from Connecticut, and temperatures under 45° are rare. Of the springs recorded on pages 191–194 only five have temperatures less than 45°, and none over 55°. The well-known Arethusa Spring at Seymour has a temperature of 47°, which coincides with the average annual temperature of the State. In a nonvolcanic region like Connecticut the temperature affords some indication of the depth from which water comes, and the absence of high temperature implies that even in fault springs the occurrence of water is relatively a surface phenomenon.

It is frequently reported that the water from springs is colder than normal in summer and warmer in winter. These statements, however, are not borne out by the facts.

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[a] See map by W. H. Hobbs, in Water-Supply Paper U. S. Geol. Survey No. 67, 1902, p. 80.

INTERMITTENT SPRINGS.

If Connecticut received a uniform and evenly distributed rainfall and were forest covered, the springs of the State would be practically permanent in position and constant in yield. The rainfall, however, is not uniformly distributed, the region is partly woodland and partly farms, and the strata consist of many varieties of rocks and soil. The result is that some springs are constant, some vary in yield, and some cease entirely during parts of the year. The flow of a spring is much more constant than the rainfall, because water in rocks is absorbed and stored much more rapidly than it escapes, and the rainfall from a large area returns to the surface through a few channels. The soil is a reservoir filled within a few hours and then allowed to drain off for several weeks. In Connecticut the supply of water in the soil is usually renewed by rain before the reservoir is emptied, and the springs are kept flowing at varying rates of speed.

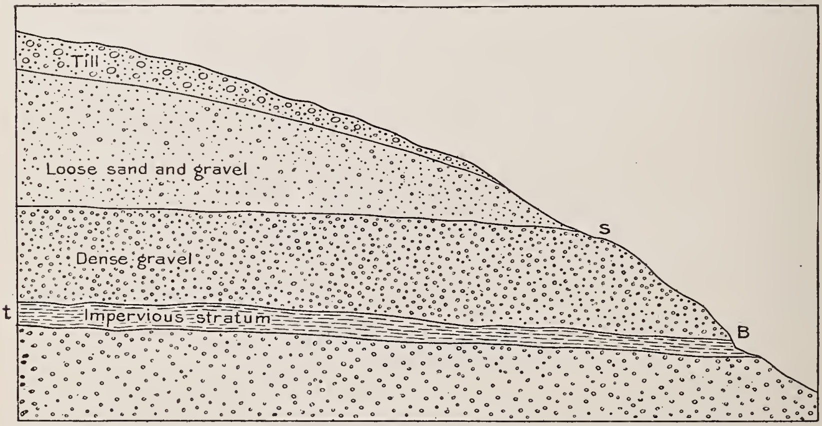

FIGURE 31.—Diagram illustrating conditions for intermittent spring. For explanation, see text.

The fact that ground water returns to the surface gradually is the chief factor which insures permanency of flow and carries springs and rivers through periods of drought. In certain parts of the country the principal supply for rivers is furnished by ground water, and during parts of the year the only water which enters Connecticut brooks is supplied by springs and seeps.

A spring which normally gives a continuous flow may become intermittent during dry seasons. The hill shown in figure 31 consists of sand and till, which allows water to be absorbed in large amounts and to sink to the impervious stratum along which ground water flows to the surface as a spring at B. When the water stands at "S," temporary springs may form, which cease to flow when the water's level drops to "t." In unusually dry seasons the water table may sink below the second outlet, thus producing an intermittent spring from one that has been constant for several years.

MINERAL SPRINGS.

All springs contain mineral matter in larger or smaller amounts, but its presence may not affect the color or odor or taste of the water. In a popular sense, mineral springs are those which are notable for the large amount of their mineral content, for some conspicuous characteristic of the water, such as color, odor, or taste, or for the presence of unusual mineral ingredients considered to be of therapeutic value. Dissolved rock material is sometimes deposited about the mouths of springs in quantities amounting to several tons a year. Even the ordinary cold-water spring carries to the surface appreciable amounts of rock. It has been estimated that the combined activity of 900 ordinary springs in the eastern part of the United States results in piling up each year rock enough to form a block 10 feet square and 2 miles long.

Several springs in Connecticut are reported to have medicinal value. Many springs, however, pass as medicinal merely because they have a forbidding odor or taste, and prove on examination to have little in their favor. It hardly needs to be stated that disagreeable characteristics are no evidence of the therapeutic value of water. There are no springs in Connecticut with an unusual abundance of rare mineral constituents, and few that are conspicuous because of their color and odor.

VOLUME OF SPRINGS.

Springs vary in size from minute trickling rills to streams that give rise to small brooks. The amount of water in a spring depends directly on the available supply from which it is drawn, and this in turn is directly related to the amount of rainfall and to the size of the area which is contributary to the spring. The attitude and structure of the rock are also important considerations. The rock may be stratified, may have open bedding planes of wide extent, or may be dense and massive. Its texture may be coarse or fine. It may be easily soluble or resistant to chemicals. Furthermore, the distribution of farm and forest land and the relative position of hills, plains, and valleys have much to do with collecting water and guiding it along the channels leading to a spring.

USES AND PRODUCTION OF SPRING WATERS.

The chief use of spring water in Connecticut is for domestic purposes. Thousands of houses are supplied by springs, either in their natural state or covered and connected with pipes, and some small villages derive a large proportion of their common supply from such sources. Springs are so abundant and so widely distributed that most farm houses have spring water either directly at hand or easily obtainable by a short pipe line.

The dairying industry requires large amounts of cold water flowing regularly through the cooling rooms, and Connecticut is highly favored in this regard.

Fifteen springs report sales of table water for 1908 and there are known to be many others which have more or less local use. About nine-tenths of the production is sold for table purposes. One spring is the site of a resort with accommodations for about 80 people. During 1908 the output of water increased about one-third and the value decreased one-seventh as compared with the record for 1907. The sale of water from 15 springs for 1908 was 424,826 gallons, at an average price of 9 cents a gallon.

The springs from which water was sold during 1908 are enumerated in the following list:

Althea Springs, near Waterbury, New Haven County.
Arethusa Spring, Seymour, New Haven County.
Aspinock Mineral Springs, Putnam Heights, Windham County.
Buttress Dike Spring, Woodbridge, New Haven County.
Cherry Hill Spring, Hamden, New Haven County.
Crystal Spring, near Little River, Middlesex County.
Elco Spring, Bristol, Hartford County.
Glenbrook Spring, Glenbrook, Fairfield County.
Granite Rock Spring, Higganum, Middlesex County.
Highland Spring, near Mount Higbee, Middlesex County.
Hillside Spring, Meriden, New Haven County.
Live Oak Spring, Meriden, New Haven County.
Mohican Spring, Fairfield, Fairfield County.
Oxford Mineral Spring, Oxford, New Haven County.
Park Spring, Norwich, New London County.
Pequabuck Mountain Spring, Bristol, Hartford County.
Quinnipiac Springs, Montowese, New Haven County.
Red Rock Spring, Meriden, New Haven County.
Rock Ledge Spring, New Haven, New Haven County.
Stafford Mineral Spring, Stafford Springs, Tolland County.
Varuna Spring, Stamford, Fairfield County.

RECORDS OF SPRINGS.

The following table and notes include the available statistics in regard to Connecticut springs:

Records of springs in Connecticut.[a]

No.	Town.	Locality.	Owner or authority.	Location.	Yield per minute.	Temperature.	Variation in flow.	Quality.	Source reported.	Use.	Remarks.
					Gallons.	°F.					
1	Ansonia		T. W. Sanford	Steep hillside	25		Less in summer	Soft, iron	Crystalline rock.	General, sale.	Rockland Spring; occasionally becomes milky after heavy rains. See analysis, p. 179.
2	Avon	Collinsville	Mrs. F. Konold	Hillside				Soft	Rock	Supply for water company.	
3	Bethel		Gilbert Bros.				Less in dry weather.	do	Gravelly loam.	Domestic	Seeps out gradually; supplies 12 families.
4	Bristol		Mrs. E. G. Fitzpatrick.		(b)	42	Constant	do	Gravel	Sale	Pequabuck Mountain Spring. See analysis, p. 179.
5	Canterbury	Parkerville	Susie E. Witter	Hillside	2		Less in dry weather.	do		Domestic	
6	do	South Canterbury.	Henry Baldwin	Slope	Large.				Gravel		Spring was dry several years and reappeared in a new location.
7	Canton	Canton Center.	C. R. Hamlin								Locality abounds in gushing springs.
*8	do		W. E. Simonds's estate.	Base of hill	75	49½	Constant	Soft	Crystalline rock.	Sale	Massacre Spring. Dug out, staved, and covered. See analysis, p. 179.
9	Chatham	Middle Haddam.	H. S. Hurd	Slope				Soft, chalybeate.	do		Hunts Iron Mountain Spring; dug and staved to a depth of 12 feet. See analysis, p. 179.
10	do	Cobalt	C. B. McLean	Base of hill	(c)	50	Constant	Medium soft.	do	Domestic	
11	Chester		B. Harwood	Hillside	2	42		Hard		do	Carries brown sediment.
12	do		First Baptist Church.	Near base of hill.	(d)		Less in dry weather and ceased once.	Soft	Crystalline rock.	do	Flat taste similar to rain water.
13	do		Moses Joy	Hillside	Large.	55	Constant	do			
14	Columbia		S. B. West	do				do		Stock	Water seeps out.
15	Cornwall	Cornwall Bridge.	C. W. Everett		(e)					Domestic, hotels.	55,000 gallons shipped weekly to New York.
16	Danbury		J. E. Walsh	Base of hill			Less in summer		Crystalline rock.	Domestic	Seeps out and collected in reservoir.
17	do		Danbury Spring Water Co.	Hillside	(f)		Constant			do	Seeps out; supplies 40 families.
18	do		Chas. Hull estate	Base of hill				Soft		do	Supplies 20 families, each 80 gallons per day.

[a] Additional details concerning springs marked with an * are given on p. 195.
[b] 4-inch pipe.
[c] 1-inch stream.
[d] ¼-inch pipe.
[e] 4-inch stream.
[f] 5,000 gallons per day.

Records of springs in Connecticut—Continued.

No.	Town.	Locality.	Owner or authority.	Location.	Yield per minute.	Temperature.	Variation in flow.	Quality.	Source reported.	Use.	Remarks.
					Gallons.	°*F.*					
19	Derby		John T. Cullen	Slope	3	46–52	Less in very dry summer.	Soft, charged.	Crystalline rock.	Sale	Spring is housed in; water retailed. See analysis, p. 179.
20	Ellington		Wm. H. Prescott	Hillside				Soft		Stock	
21	do		Francis M. Charter	Valley	10			Medium soft.		Domestic	
22	Fairfield	Westport	Marion B. Williams.		10		Constant		Crystalline rock.	Drinking	Gives yellowish deposits.
23	do		Mohican Spring Co.	Hillside	15		do		Rock, gravel, dry.	Sale	Mohican Springs; series of springs along a hillside. See analysis, p. 179.
24	Goshen	Milton	Elbert S. Richards.	Base of hill	Large.	46	Less in dry season.	Soft	Sand	Domestic, stock.	Water is warmer in summer.
25	do	West Goshen	S. A. Bartholomew	Hillside	Large.		Never failing	do		do	
26	do	do	H. G. Wright	Valley	(*a*)	55		Soft, iron		Domestic	
27	Hartford		Francis Goodwin	Hillside		53	Constant	Hard	Gravel	Drinking	
28	Kent	South Kent	Don C. Peet	do	Large.	48		Soft	Rock		
29	Lebanon		C. W. Martin	do				Soft, iron	do	Drinking	
30	Libson	Jewett City	E. F. Burleson	Hilltop	(*b*)		Less in dry weather.	Soft	Clay	do	
31	Meriden		Chas. Parker Co.	Valley	14	51		Soft, iron	Sandstone	Sale	Live Oak Spring; dug, walled, and covered.
32	Middletown	Highland	W. E. Wilcox	Slope	8	50	Nearly constant.	Soft	do	do	Highland Spring; dug and tiled. See analysis, p. 179.
33	Milford		Morton Grinnell	Valley		45	Constant	Hard	Gravelly sand.	Domestic	Supply for Milford Water Co.
34	Montville	Uncasville	Chas. S. Johnson	Base of bluff		50	do	Soft	Sand	Sale	Shantok Spring; constant temperature throughout year. See analysis, p. 179.
35	do	do	Eliza D. Geer	Base of hill				do	do		
36	do		Solomon Lucas	Hillside	17		Constant	do		Drinking	
37	New Britain		W. N. Dunham	Base of hill	8	48					Dug to depth of 4 feet.
38	do		American Hosiery Co.	Valley	750			Hard	Gravel	Bleaching, general factory use.	Dug out 30 feet deep and 15 feet diameter.
39	New Canaan		W. C. Clarke	Hillside	3			Slightly hard.	Sand	General	Water is collected in a cement reservoir.
40	New Hartford	Nepaug	Austin Beckwith	do	(*c*)			Soft, with iron and sulphur.	do		Carries a red sediment resembling iron rust.

41	New Haven	Highwood	Marcus Wooding	Slope	Large.		Constant		Sandstone	Sale	Cherry Hill Spring; dug to a depth of 3 feet.
42	do		W. S. Swayne	Base of hill			do		Rock	do	Clear water.
43	do		City	River bank	4				Sand	Drinking	Cold Spring.
44	New Milford	Gaylordsville	H. H. Pomeroy	Near top of hill	(d)		Slight		do	Stock	
45	do	do	E. H. Austin	Valley	(d)	45–56	do	Hard		Domestic	
46	do	Northville	Starr Kinney	Hillside	30	42	Constant	Soft		Domestic, cooling.	
47	do		Leroy Randall	do	Large.		do			Drinking	
48	do		Bridgeport Wood Finishing Co.	do	(d)		Little variation.	Soft	Schist	do	Indian Rock Spring.
49	Newtown	Sandy Hook	Leroy Mitchell	do	15			Soft, iron	Rock	Domestic	
50	North Canaan	Canaan	J. S. Adams					Hard	Limestone		Numerous springs in vicinity, from limestone.
51	do	East Canaan	W. T. Owens								Numerous springs of excessively hard water in this locality.
52	do	do	R. C. Geer	Hillside			Constant	Medium hard.	Gravel	Domestic, stock.	
53	do		W. H. Camp	do	(e)			Hard	Limestone	General	
54	North Franklin.		L. A. Robinson	do	(f)		Constant	Soft		Domestic	
55	North Haven	Montowese	B. F. Judd	Elevated ground.	5		Less in dry weather.	do	Trap rock	Table, medicinal.	Hermitage Spring. See analysis, p. 179.
56	North Stonington.		Thos. B. Hewitt	Valley		50	Constant	do			
57	Norwalk	West Norwalk.	Mrs. M. C. Hite	Hillside	7		do	do	Crystalline rock.	Domestic	Collected in a small reservoir pond.
58	Norwich		Carpenter & Williams.	do			do	do	Sand	Drinking	Puritan Spring; housed in.
59	Old Lyme	Lyme	Louis P. Dessar	do	2½		do	Soft, iron	Granite	Domestic	Deposits an iron sediment.
60	do	do	Chas. T. Ely	Slope	3	52	do	Soft	Sand	Drinking	From sand beneath hardpan.
61	do	South Lyme	Hatchells Improvement Co.	Hillside			do			Domestic	Supplies 5 families.
62	Old Mystic	Mystic	Edwin Lamphere	Flat			do	Chalybeate		Medicinal	Surrounded by a heavy iron deposit.
63	Oxford		S. P. Sanford					Iron, sulphur.	Rock	do	Deposits of iron from water. See analysis, p. 179.
64	Pomfret	Abington	Willis Covell	Hillside	Large.		Constant	Soft	Soil	Drinking	
65	do		A. B. Lapsley	do	1		do	do	Clay	Domestic	See analysis, p. 179.
66	Ridgefield		Chas. Holly	Hill	(g)	48	do	do	Crystalline rock.	Sale	Mamanasco Spring. See analysis, p. 179.
67	do		B. A. Bryon	Hillside	5	40		do	do	do	
68	Seymour		T. F. Gilyard	do	1		Constant	do	Schist	Domestic	
*69	do		R. T. French	Base of hill	5	47		do	Sand	Sale	Arethusa Spring. See analysis, p. 179.
70	Sharon	Ellsworth	S. E. Everett	Hillside	1			do	Crystalline rock.	Drinking	
71	Sherman	Brookfield	C. I. Leach	do		50	Constant	do		Domestic	
72	Simsbury		N. W. Dodge	Valley	1	44			Soil	do	Seeps out.

[a] 1½-inch pipe.
[b] 1,000 gallons per day.
[c] ½-inch pipe.
[d] 1-inch pipe.
[e] 4-inch pipe.
[f] ¾-inch pipe.
[g] 2-inch pipe.

Records of springs in Connecticut—Continued.

No.	Town.	Locality.	Ower or authority.	Location.	Yield per minute.	Temperature.	Variation in flow.	Quality.	Source reported.	Use.	Remarks.
					Gallons.	° *F.*					
73	Southbury		W. Lockwood and N. W. Mitchell.	Base of hill	(*a*)		Less in dry weather.	Soft	Gravel	Drinking	
74	Stafford Springs.		Stafford Springs Mineral Water Co.	do		52	Constant	Soft, iron	do	Hotel, sale.	Used for medicinal purposes.
75	Stonington	Mystic	B. F. Williams	Hillside			do	Soft	Rock	Domestic	
76	Stratford	Oronoque	D. S. Guthrie	do			Less in dry weather.	do	Sand	do	
77	Suffield		E. C. Holdridge	do	1½	45	Constant	do	Gravel	do	
78	Tolland	South Willington.	Mrs. E. J. Holman.	do	1	50	do	do	Crystalline rock.	do	
79	Torrington		W. T. Church	do	(*a*)		Nearly constant.	do	Schist	Sale	Mica Spring.
80	do		Coe Brass Co	Base of hill	(*a*)	50			Rock	Drinking	
81	Vernon	Rockville	Edgar Keeney	Base of bluff	Small.		Little variation	Soft	Crystalline rock.	Domestic	Supplies 3 families.
82	Warren	New Preston	Geo. C. Hopkins	Hillside	(*b*)		Less in dry weather.	do	Hardpan	do	
83	Westport	Southport	John H. Jennings	Base of hill	Good.	50	Constant	do		Sale	Port Royal Spring. See analysis, p. 179.
84	Wilton		Edward Olmstead.	Hillside			Varies		Crystalline rock.	Domestic	
85	Winchester	Winsted	R. E. Holmes	Base of hill	(*c*)	50	Increases with heavy rain.	Soft	do	Stock	
86	Windham	North Windham.	E. H. Hall	Hillside	10		Constant	do	Sand, gravel.	Domestic	
87	Windsor		W. H. Harvey		2			do	Sand	do	
88	do		E. E. Case	Valley	3			do	do		
89	do		Windsor Water Co.	Hill slopes			Decreases 33 per cent in dry weather.	do	do	City supply.	
*90	Windsor Locks		Windsor Locks Water Co.	do				do	do	do	Reservoir fed by seepage springs from sand. See analysis, p. 179.

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[a] 2-inch pipe.

[b] 1¼-inch pipe.

[c] ½-inch pipe.

NOTES.

8. Located at the northern edge of Whortleberry Hill, a ridge of gneiss overlain by sandy till. It is situated in a large seepage area from which flows probably twice as much as issues from the spring. Although rock outcrops are near at hand, it is probable that the water comes from the till and is part of an underflow draining the ridge to the south. Water rises 6 inches above entering point.

69. Inclosed by four sections of 3½-foot tiling sunk into the ground. Water comes from the fine white sand probably resting on a ledge of gneissoid granite. The yield to the bottling works is 5 gallons a minute, and the overflow is probably 10 gallons a minute, giving a total yield of about 15 gallons. The spring is located on a rather flat terrace at an elevation above the river of about 120 feet.

On the hillside, 200 yards away from the Arethusa Spring and at an elevation about 25 or 30 feet higher, another spring issues from light-colored gneissoid granite, with the structure planes dipping about 4° SE. into the hillside. Both these springs maintain nearly the same flow throughout the year.

90. The water supply is obtained from three ponded areas located in a shallow valley and fed by springs. The topography is flat and the soil is porous. The run-off is accordingly small and the soil absorption large. The ground water is near the surface and emerges on a nearly level area at the contact of till and the thin overlying deposit of sand.

The following notes cover a few springs that are not listed in the table:

Granite Rock Spring, Higganum: This spring issues between two large granite bowlders on the upper slope of a high hill, but no rock outcrops are visible. The water is piped to a bottling works. The spring yields between 20,000 and 25,000 gallons a day, with a fairly constant flow, at a temperature of 49° F. when the air temperature is 77°. The output of the bottling works during 1905 was about 50,000 gallons. A second spring, recently excavated, is said to issue from a crevice one-eighth inch wide in the ledge.

Ausantowea Spring, Woodmont: Has been excavated to a depth of 20 feet through hardpan, sand, and gravel, the water horizon being in gravel. Flows 100 gallons an hour and varies little in yield with seasons. The temperature is 57° when the air temperature is 88°. The water is bottled and sold.

Buttress Dike Spring, Woodbridge: This "spring" is in reality a flowing well in which water rises 18 inches above the ground. It is on the side of a steep hill composed of chlorite schist and overlain by a thin layer of sandy till containing numerous heavy bowlders. The water appears to come from a vertical cleavage joint in the rock.

Springs of T. T. Wilcox, two-fifths of a mile southeast of Highland station: Three springs, two of which are reported by Mr. Wilcox to furnish 51 barrels a day, with no seasonal variation, at a temperature of 48° to 50° F. The only contributing area at a higher level than the spring is a hill with an elevation of less than 40 feet and covered with a thin layer of till. The water apparently reaches the surface by working along the bedding planes between sandstone and red shale. This requires a movement up a slope of about 15°.

Spring of Charles Parker, 1 mile southeast of Meriden: This spring is located on the west side of a hill composed of sandstone dipping southeast and capped with a thin covering of glacial drift. The water comes from joints in sandstone, as illustrated on page 136. The temperature of the water is 51° F. when the air temperature is 56°.

Chalybeate Spring, Litchfield: This interesting spring, which was famous in the early days of Connecticut, was described as follows by James Pierce:[a] "It issues from an extensive bed of sulphuret of iron, situated on the eastern side of Mount Prospect, 4 miles west of the village of Litchfield. The spring is copious and perennial, exhibiting in its course much oxide of iron and a white deposit."

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[a] Am. Jour. Sci., vol. 3, 1821, p. 235.

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