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CHARLES D. WALCOTT, DIRECTOR

THE BEREA GRIT OIL SAND IN THE CADIZ QUADRANGLE, OHIO

BY

W. T. GRISWOLD

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CONTENTS.

ILLUSTRATIONS.

LETTER OF TRANSMITTAL.

Department of the Interior,
United States Geological Survey,
Washington, D. C. June 7, 1902.

Sir: I have the honor to transmit herewith the manuscript of a paper on the Berea grit oil sand in the Cadiz quadrangle, Ohio, by W. T. Griswold, with recommendation that it be published as a Bulletin, in the economic series.

I believe that this paper marks a distinct advance in the methods of studying oil fields and of determining and delineating the structure of the oil-bearing formations. While it affords an exceptionally favorable opportunity for subjecting the anticlinal theory of oil and gas accumulation to a rigid test, its primary object is to furnish practical information to the well driller. If the data contained in the paper are properly used in the field, a saving in expense of development will be effected amounting to many times the cost of the work done by the Survey.

Very respectfully,

C. Willard Hayes,
Geologist in Charge of Geology.

Hon. Charles D. Walcott,
Director United States Geological Survey.

THE BEREA GRIT OIL SAND IN THE CADIZ QUADRANGLE, OHIO.

By W. T. Griswold.

INTRODUCTION.

The anticlinal theory of the accumulation of oil and gas is now generally accepted. Through the investigations of Edward Orton, I. C. White, and other geologists working in the great Appalachian oil field, it has been placed on a substantial basis, and has been subjected to the supreme test of prediction. Important practical developments, both in the extension of known fields and in the discovery of new productive territory, have followed its application. In a large part of the Appalachian oil field, however, the geologic structure makes it extremely difficult to determine the localities where oil and gas should accumulate in accordance with the theory. To an extent not generally realized the flexures of the strata are irregular and discontinuous, and the development of one oil pool affords little, if any, assistance in locating others on the same or adjacent anticlines. In a region characterized by such irregular structures, only instrumental work of a high degree of refinement will serve to locate the axes of the flexures and the exact form of their slopes. The first essential in such work is an accurate topographic base map, such as has not been in existence for any part of this field until very recently.

In connection with the topographic mapping of the Cadiz quadrangle, in eastern Ohio, an exceptionally favorable opportunity was afforded for working out the details of structure and subjecting the anticlinal theory to a rigid test. The quadrangle contains several oil pools of considerable productiveness, and there is reason to believe that there are others equally valuable, but as yet undiscovered. The location of prospect wells has hitherto been determined largely by guesswork, and this is an extremely expensive method. The main object of the present report is, therefore, to afford some practical guidance to the driller in locating such prospect wells. As will be pointed out more fully later, correct location with reference to the flexures of the strata is only one of several conditions essential for a productive oil or gas well. The other factors are porosity of the reservoir rock and degree of water saturation, and their importance has not been sufficiently recognized heretofore. While these can be absolutely determined only by the expensive method of drilling, an exact solution can not be reached until they are determined. A careful study of all existing data derived from wells already drilled in the region will throw light upon the structure and will enable some forecast to be made concerning the probable condition of the oil sand in a given locality where no drilling has been done. It is fully realized that all predictions in regard to oil and gas are of uncertain value, but it is believed that those here made are conservative, and that they will at least prevent much useless expenditure.

PETROLEUM.

Character and origin.—There has been much discussion, and different theories have been advanced, concerning the genesis of petroleum. A review of these discussions would occupy much space; it is sufficient to make a simple statement of those conclusions which have been reached from the consideration of established facts and which are accepted by a majority of the leading geologists.

Petroleum is a complex mixture of hydrocarbons, belonging chiefly to the paraffin series, which are designated under the general formula, C_nH_{2n+2}. It varies in color from pale straw yellow through reddish and dark brown to black. The specific gravity or density varies from 0.777 to 0.907, or from 50° to 16° of the Baumé scale. It is probably derived from organic matter, both animal and vegetable, contained in the shales and limestones of the Silurian and later ages.

Oil in Pennsylvania.—With the discovery of oil in western Pennsylvania, on Oil Creek, a new industry opened. The earlier developments were confined to the lower lands along the streams, and for some time the higher or hill land was not considered available as oil territory. In a short time it was found that the elevation of the surface of the ground had little or no relation to the oil supplies beneath. It was noticed, however, that the productive territory followed lines running in a northeasterly and southwesterly direction, with a bearing of about 45° from true nortn. This gave rise to the 45°-line theory, and a great deal of prospecting was done by extending exploration from a developed pool on a bearing of 45° to the northeast or southwest. As development proceeded toward the south the bearing lines of productive territory gradually changed until, instead of a 45° line, a bearing of 22° from true north or south seemed to lead to the most profitable extensions.

With the development of the natural-gas industry, Mr. W. A. Earsman and other operators noticed that the most productive wells were located upon or near the lines of anticlinal arches. This important deduction has been expounded and developed by Prof. I. C. White, of Morgantown, W. Va., who has published his conclusions, and has successfully located both gas and oil wells by means of the so-called anticlinal theory.

Relation of oil pools to geologic structure.—Petroleum, being of less specific gravity than the saline waters found in the porous strata beneath the surface, is undoubtedly affected by the slope of the rocks in which it is contained, and tends to collect along lines of nearly equal elevation which parallel the folds of the strata. With this fact in mind, it becomes very easy to account for the 45° and 22° lines which occupied so prominent a place in the early development of the Pennsylvania field. The Appalachian oil field occupies the western flanks of the Appalachian Mountains, the axes of its minor folds having a general parallelism with the folds of that mountain system. Where oil was first discovered these folds have a nearly northeast-southwest direction, but in extending southwest their divergence from true north and south became less, as does that of the major folds of the mountains themselves.

In looking over maps of the oil and gas producing territory, notably those published by the geological surveys of Pennsylvania and West Virginia, and comparing them with maps showing the geologic structure, the gas and oil producing belts and folds are seen to have the same general direction. But there are some notable exceptions to this general statement, if the published information as to the direction of the structure axes is correct. The mapping of the structural lines, however, has been but meagerly and imperfectly done. The minor anticlinal arches have been represented as extending for long distances in straight parallel lines. More detailed work will probably show that their axes are not straight and parallel, but meander with more or less irregularity. This is indicated by the recent work of Marius R. Campbell in Armstrong and Butler counties, Pennsylvania, where the Bradys Bend anticline, instead of continuing in a northeast-southwest direction, makes a sharp bend due west and passes out of Armstrong into Butler County.[a]

It may be assumed in general, therefore, that the minor anticlines do not have anything like the regularity shown on most of the maps now published. They are probably curved and irregular, even much more so than are the larger folds which occur in the mountainous belt to the east. Hence, it would be unsafe to consider any seeming discrepancy between the lines of oil development and the axes of the anticlinal arches as now published as evidence against a theory until very careful geologic work has been done to actually locate the folds.

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[a] Eng. and Min. Jour., February 15, 1902.

Mode of accumulation of oil and gas.—The slope or dip of the oil-bearing formations can have an influence on the accumulation of oil and gas only through the differences in specific gravity between these two substances and the water and air with which they come in contact. Gravity, acting in the manner to be explained below, is the force that has caused the segregation and collection of oil and gas in economic quantities.

The thick shales which constitute an important part of the sedimentary rocks of the oil and gas territory are probably to be looked upon as the source of the oil and gas. These two hydrocarbons, forming in very small quantities over a large territory, have been forced out of the shale into an adjacent porous stratum whenever such porous formation lies in juxtaposition to the oil-bearing shale. These porous strata are saturated with water, and from the nature of their formation must have been so at the time of their original deposition. The porous strata usually consist of sandstone, but in some cases they are composed of limestones which have been under conditions of crystallization that give the rock an open structure.

Assuming a bubble of gas and a drop of oil to have been forced from the underlying shale into a porous sandstone already saturated with water, the natural course of the two particles, owing to their lesser specific gravity, will be to force their way up through the sand rock until a roof or impervious stratum is reached, and here to remain if the cap or cover to the porous stratum is perfectly level. If, however, the cap rock has a slope, there will be a tendency for the hydrocarbons to creep along, always up the slope of the stratum, until a reverse or counter dip is met, at which point an accumulation will be formed, the gas occupying the highest points, with the oil directly beneath it and resting upon the water.

In assuming the existence of a continuously porous stratum entirely filled by water, we are not entirely supported by fact. The sand rocks are of all degrees of porosity, a single bed frequently varying from a coarse conglomerate, with good-sized pebbles having large spaces between them through which any fluid may flow with but little friction, to the finest grained sandstones, through which the passage of a liquid is slow and difficult. At other points the sand grains may be cemented together by lime, iron oxide, or silica into sandstones that are practically impervious to fluids. These differences in the reservoir strata may at any time cause results entirely at variance with the conditions to be expected from the anticlinal theory.

Although these sedimentary beds must have been completely saturated with water when first deposited, they are not always so at present. Some porous beds are freely saturated through their whole extent; others are saturated only in the lower portions of the folds, while the portions which occupy anticlines are almost entirely free from water. This condition of complete or partial saturation of the porous rocks becomes of the greatest importance in the application of the anticlinal theory to the accumulation of oil. The natural gas, by reason of its less specific gravity than water, oil, or air, will continue to rise in a porous rock until stopped by an impervious cover. The oil, on the other hand, can continue upward only so long as it has the water upon which to climb, and must, therefore, stop at the water line, although this may be but part way up a decided slope. The accompanying sketch, representing an imaginary section through folded strata of petroleum-bearing shale and a porous sandstone capped with an impervious limestone, shows the theoretical method of accumulation of the hydrocarbons.

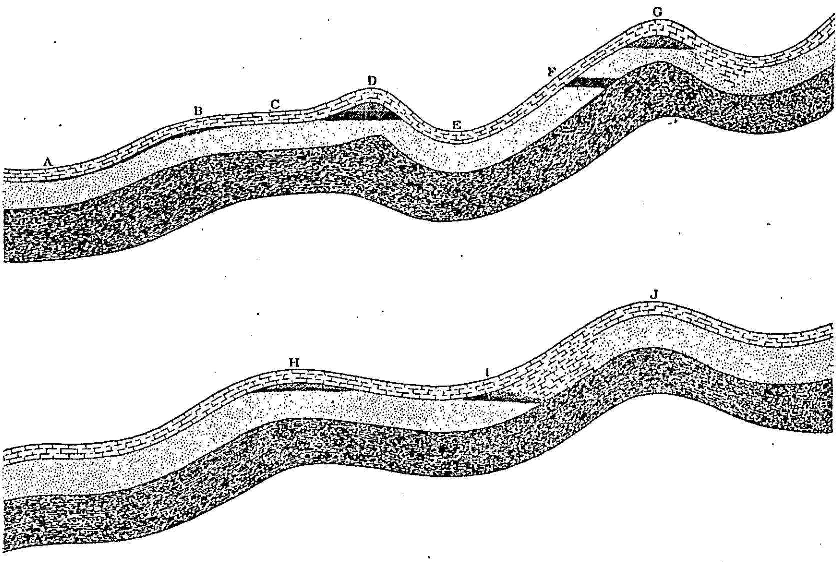


FIG. 1.—Ideal section showing method of accumulation of oil and gas.

The oil and gas, entering the sand rock all along its base, work their way to the roof A, and gradually creep along to the right to the bend or crest of the terrace at B, where the strata become so nearly level that the horizontal tendency of the oil particles is not sufficient to overcome the friction through the sand, while the gas, having more buoyancy, and therefore more force of lateral motion, moves on, leaving the accumulation of oil, unaccompanied by much gas, at the break represented at B. The hydrocarbons entering between C and E gradually work upward until a dome, or anticline, is reached at D, which completely captures both gas and oil. From E to G the tendency is to work toward G, but the higher portion of the sand rock is not completely saturated with water, and the oil can move only to the upper surface of the water, while the gas passes on to the highest attainable point, leaving what may be a considerable distance between the accumulations of gas and oil.

In the second sketch the same forces have acted, forming an accumulation at H. At I the sand rock has become impervious, and an obstruction is formed that nullifies all calculations from the geologic structure, for it is evident that the oil and gas accumulations will take place at the bottom of the barrier opposed to its movement, though it be near the bottom of a decided slope.

The factors in the problem.—It is evident, therefore, that three important unknown factors affect the accumulation of oil, in addition to the fundamental conditions of a petroleum-yielding shale in juxtaposition to a porous stratum suitably capped with an impervious layer.

First and most important is the internal condition of the sand, which must be such as to allow the passage of the fluid between its particles. Second is the amount of water in the porous stratum, a knowledge of which is necessary for determining at what point with reference to the structure the accumulation of oil may be expected. Third is the geologic structure, or the slopes of the porous stratum. If the strata have a gradual and regular slope over a considerable area, the probabilities are that there have been no accumulations of oil of economic value, but that the supply which has entered the porous stratum is evenly distributed along its upper surface.

The first two factors, relating to the porosity of the rock and the degree of saturation, can be determined only by the expensive method of the drill. The third, however, in certain localities may be to a great extent elucidated by careful geologic work. It is evident that if the cap of the oil-bearing formation formed the present land surface, so that its slopes with its high and low points could be seen, the most probable locations for the collection of oil and gas could be readily selected. This condition is represented in the accompanying map of the Cadiz quadrangle. The surface drainage and the culture, with the Government land-survey lines, are represented as a base, upon which are shown, by means of 10-foot contours in red, the position, slopes, and grades of the top of the cap of the Berea grit oil sand. The present land surface with its hills and valleys is entirely disregarded, and the surface represented by the contours is that which the region would have if all the rocks above the Berea grit were completely removed.

THE CADIZ QUADRANGLE OIL FIELDS.

Location and topography.—The Cadiz quadrangle, Ohio, is bounded by parallels 40° 15′ and 40° 30′, and by meridians 80° 45′ and 81° 00′. It includes parts of Jefferson, Harrison, and Carroll counties, Cadiz being the principal town. Near the western side of the quadrangle is a north-south ridge which divides the waters flowing directly into the Ohio River from those flowing west and south and finally entering the Ohio at Marietta. The streams have cut their channels into the easily eroded formations to a depth of nearly 300 feet, leaving a confused mass of hills and valleys, with very little or no level land. The hill slopes are seldom too steep for farming, and the country is in a high state of cultivation. The many beds of limestone disintegrate readily, forming arable land of excellent quality.

Areal geology and stratigraphy.—The geologic section exposed by the stream erosion includes about 150 feet of the Upper Productive Coal Measures (Monongahela) and 300 to 400 feet of the Lower Barren Measures (Conemaugh). The Pittsburg coal (No. 8), the bottom of which is the dividing line between these two formations, outcrops near the bottom of the deepest valleys in the southeast corner of the quadrangle. Here is obtained a section above the Pittsburg coal nearly 300 feet in thickness. Toward the northwest the Pittsburg coal rises until, at a point a few miles south of the northern border of the quadrangle, it is found only upon the summits of the highest ridges. Here is obtained a section below the Pittsburg bed fully 300 feet in thickness. In this vertical distance of 600 or 700 feet are found a number of strata that can be easily recognized whenever seen in outcrop, and may be used as guide horizons in determining the geologic structure.

The upper surface of the workable coal in the Pittsburg bed is taken as the datum plane from which the vertical distance, above or below, is calculated to other horizons, in all cases the top of the stratum mentioned being taken.

The Pittsburg bed has a thickness of about 4½ feet of workable coal, and above this is a thin bed of fire clay, followed by 1½ feet of impure coal, or coal blossom.

In ascending order from the Pittsburg bed the following easily recognizable strata are found: (1) a hard, dark-blue limestone, lying but a few feet above the Pittsburg coal, and called "Upper 8 limestone;" (2) a thin bed of coal, rarely over 6 inches, occurring in the shale and known as the "Pittsburg rider vein;" (3) a coal bed with a thickness of from 8 to 16 inches, known as "Meigs Creek coal;" (4) an 8-inch bed of cream-white limestone, intersected by thin seams of crystallized calcite, here referred to as "Meigs Creek white limestone."

Below the Pittsburg coal are found (1) a bed of limestone very similar to that above, here called "Lower Pittsburg lime;" (2) a bed of coal less than 1 foot in thickness, and called "No. 7 b;" (3) the Ames limestone, from 2 to 4 feet in thickness, of a greenish color, and carrying a great number of crinoidal stems; (4) the Ames coal, often found directly beneath the Ames limestone; (5) a bed of coal from 1 to 3 feet in thickness, called "No. 7 a."

In selecting the measurements for determining the vertical distance between these different strata, only those were used which were obtained where the formations were known to be lying nearly level, or where the horizontal distance between the two outcrops was small. In cases where two outcrops of the same bed could be obtained and the outcrop of another stratum was found approximately halfway horizontally between the two, an average of the elevations of the two outcrops of the one bed above the other was used in order to eliminate the error from dip of the strata.

The most useful beds for plotting the geologic structure have been the Meigs Creek coal, the Pittsburg coal, and the Ames limestone. The other strata have not always been found in their expected positions, and the number of good comparisons between them and the Pittsburg coal have been fewer, so that their true position is not considered so well established.

The following tables give the determined vertical distance between the top of the workable coal of the Pittsburg bed and the top of the various coals and limestones mentioned above:

Vertical distance from Pittsburg coal to top of Meigs Creek white lime.

	Feet.
Church at Bloomfield	132
One and a half miles south of Smithfield	119
On Smithfield and Cadiz road near Piney Fork	113
On Cadiz and York road near Hurford Creek	111

Vertical distance from Pittsburg coal to top of Meigs Creek coal.

At the town of Bloomfield	99
On hill between two McIntyre creeks, north of Smithfield	92
One and a half miles southwest of Smithfield	94
On Smithfield and Cadiz road near Piney Fork	97
On Cadiz and York road near Hurford Creek	94
On farm road near north line of township 10, range 4	93

Vertical distance from Pittsburg coal to top of Pittsburg rider vein.

On Cadiz and York road near Hurford Creek	26
On Cadiz and Unionvale pike near Cadiz	24
On road near north line of township 10, range 4	21
On ridge east of Amsterdam	26

Vertical distance from Pittsburg coal to Upper No. 8 limestone.

On Cadiz and Unionvale pike near Cadiz	12
On ridge east of Amsterdam	19

Vertical distance from Pittsburg coal to Lower No. 8 limestone.

On Cadiz and Unionvale pike near Cadiz	7
On ridge east of Amsterdam, west summit	11
On ridge east of Amsterdam, east summit	9

Vertical distance from Pittsburg coal to coal No. 7 b.

	Feet.
On Cadiz and Unionvale pike near Cadiz	134
On Cadiz and Hopedale road near Greenough	127

Vertical distance from Pittsburg coal to top of Ames limestone.

From ridge south of Opossum Hollow into Opossum Hollow	218
From ridge north of Opossum Hollow to Skelley road	213
On road from Bloomfield to Bloomfield station	221
On ridge south of Amsterdam	220
On road from East Springfield to Shane post-office, via Town Fork	217
Near Carmen station	205
Near Richmond	230

METHOD OF CONSTRUCTING THE CONTOUR MAP OF THE OIL SAND.

From the permanent bench marks established, spirit-level lines were run over nearly every road and up a great many hollows, establishing the true elevation of about five hundred outcrops of recognizable geologic horizons. By then adding to or subtracting from each elevation thus determined an amount equal to the vertical distance between the particular bed located and the Pittsburg coal, the elevation of the Pittsburg coal at these points was obtained. These points were then plotted and there was thus prepared a map having marked upon it the elevation of the key horizon, the Pittsburg coal, at 500 points. By connecting the points of equal elevation a contour map showing the folds of this key horizon was made, the accuracy of this map depending upon the number of elevations obtained and their even distribution over the quadrangle.

The vertical distance from the Pittsburg coal to the Berea grit at each test well was obtained by comparing the elevation of the mouth of the well with the elevation of the Pittsburg coal at that point and adding this difference of elevation to, or subtracting it from, the distance from the mouth of the well to the Berea grit as given by the well record. This distance from the Pittsburg coal to the Berea grit was found to vary, but with a quite remarkable regularity. The true position of each test well was then plotted and the vertical distance between the Pittsburg coal and the Berea grit marked upon the map. The positions of the different test wells were connected by straight lines and these lines were divided so that each subdivision represented the horizontal distance in which the vertical distance from the Pittsburg coal to the Berea grit decreased 5 feet. The points of equidistance from coal to sand were then connected and a drawing was built up called the convergence sheet. This shows by a series of lines the points of equal distance between the Pittsburg coal and the Berea grit.

The convergence sheet was then placed over the plot showing elevations of the key horizon, and it showed at once the amount that should be subtracted from the elevation of the Pittsburg coal to determine the elevation of the Berea sand at any point. The elevation of the Berea sand at every point where it was determined was then marked on the map and the points of equal elevation were again connected, resulting in a contour map of the oil-bearing sand (Pl. I).[a] The map was drawn in 10-foot contours, as this seems the most desirable interval for the use of the oil operator, though it is hardly to be expected that the drill will always find this degree of accuracy in the work.

In making such a map in the manner above outlined it is evident that there are several sources of error which can not be entirely provided against. Thus, a bend or change of dip may occur at a point at which there is no outcrop of any one of the guide horizons. The difference of elevation having been determined at two points, the slope of the oil sand between them is represented as uniform, while, in fact, it may be horizontal for a part of the distance and have a steep dip for the remainder. The records of test wells, although carefully taken at the time of the drilling, can sometimes be procured only from the memory of the driller, and the only check upon their correctness is from the resulting appearance of the divergence sheet. Again, a sudden change in the rate of divergence between the key horizon and the oil sand may occur where no test well has been drilled, in which case the divergence sheet will show an erroneous uniformity. All of these conditions probably do happen, making the map more generalized than the contour interval would indicate.

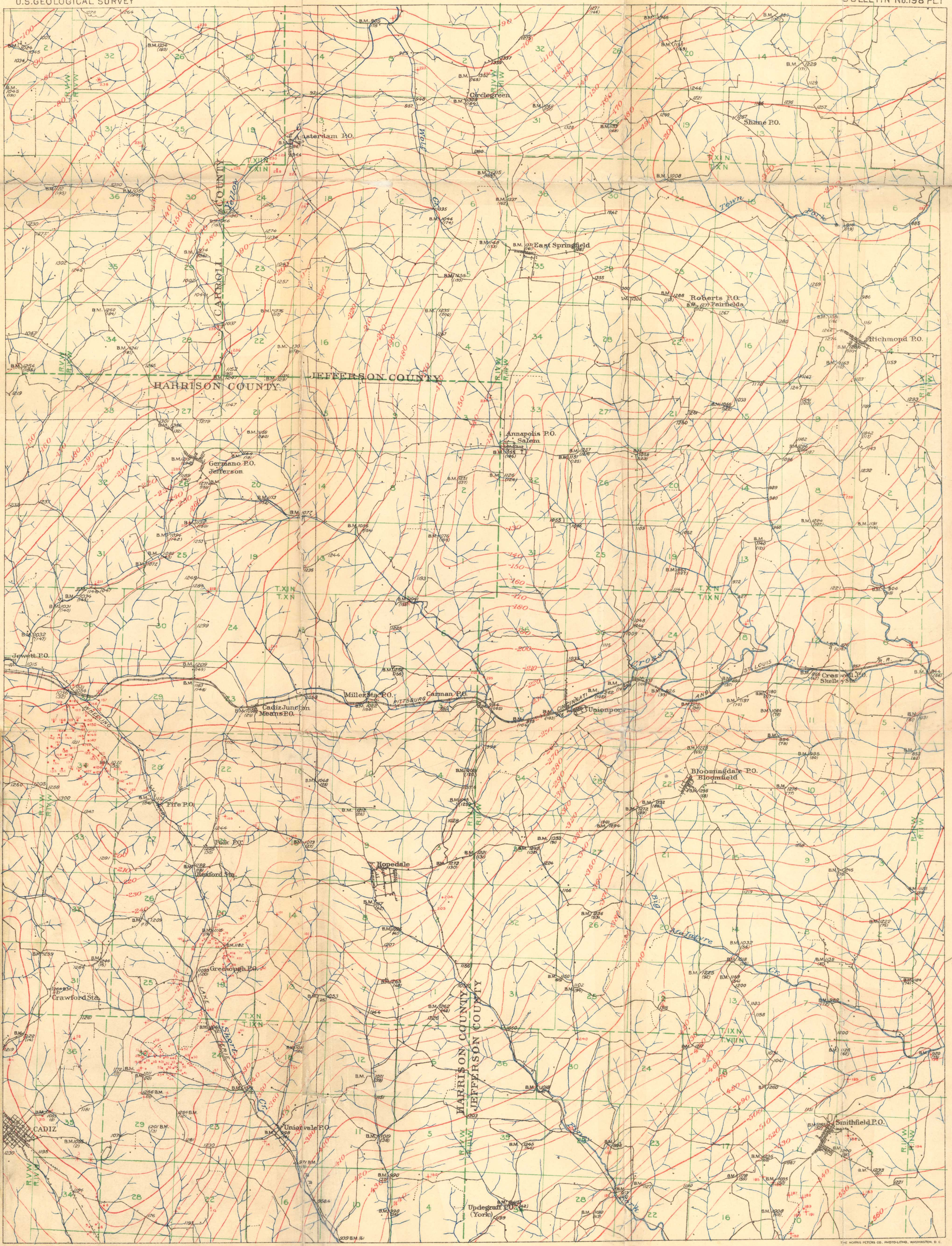
The true elevation of the top of the sand, although very desirable to know, is not absolutely necessary to the usefulness of the map. If there is an error of 20 to 30 feet in the elevation of the sand—the probable maximum error—there will be the same or nearly the same error in the elevation of adjacent portions of the bed, and the relative dip or slope between the two places will be approximately as represented upon the map. Since this is the really important feature of the map, the errors in absolute elevation, due to the causes above enumerated, are less serious than they might at first sight appear.

RELATION OF PRODUCTIVE TERRITORY TO STRUCTURE IN THE CADIZ QUADRANGLE.

Description of the structure.—The accompanying contour map of the Berea oil sand shows a system of parallel folds, forming elongated domes and canoe-shaped basins, with an indication of cross folding about at right angles to the principal system. The most prominent feature is the main anticlinal arch, which extends from near the southwest corner of the quadrangle in a northeasterly direction, passing just east of the town of Salem, where it attains its greatest height.

[a] As the key horizon map and the convergence sheet represent merely steps in the process of making the map of the oil sand, it is not deemed necessary to publish them.

198-203



Topographic base from surveys of the U.S.Geological Survey, Chas.D.Walcott, Director, in cooperation with the State of Ohio, G.K.Nash, Governor

Pg 20

CONTOUR MAP OF THE BEREA GRIT OIL SAND

By W.T.Griswold

Scale 1 0 1 2 miles

Thence it swings to a more easterly direction and rapidly falls away before reaching Richmond. The corresponding syncline parallels this fold on the western side, but is interrupted by two cross anticlines, one near the line of the Pittsburg, Cincinnati, Chicago and St. Louis Railroad, the other very nearly agreeing with the location of the ridge road from East Springfield north toward Bergholtz. It thus forms a canoe-shaped basin whose lowest point is but a short distance east of the town of Jefferson, and part of another basin which extends almost due east and west, its center line being very near the location of the middle ridge. To the east of the main anticline the sand descends in terraces or steps to the eastern limit of the quadrangle, the crests of the terraces extending in lines parallel to the main anticlinal folds. Over this slope the intersection of the cross folds has the effect of obliterating the terrace for some distance and throwing its steep slope farther toward the east after passing the secondary fold.

No long and steep slopes exist in the quadrangle. The slope is steepest on the face of the terraces, where it seldom amounts to 100 feet to the mile. This lack of decided slope for a considerable distance is unfavorable to the probable accumulation of a large pool of oil, since no large area of oil-producing territory has been drained into a single continuous reservoir.

Smithfield pool.—The southern half of the quadrangle has been very generally prospected for oil. In the southeast corner, near the town of Smithfield, two producing wells (Nos. 189 and 190) have been found on the farm of Mr. Charles Galbraith. These two producers have been nearly encircled by test wells in hopes of extending this pool, but with unfavorable results. The two producing wells seem to be upon a nearly level terrace and in what appears to be a most unlikely place for the accumulation of oil, from the indication of the contour map. To the southeast of the producing wells only one coal outcrop was leveled to. Well No. 193 found the sand 20 feet lower than would be expected from this outcrop. It is possible, therefore, that the sand descends faster in the southeast corner than is represented on the map. From this it would seem that the most favorable direction for prospecting is to the southeast of the producing wells.

Bloomfield anticline.—Passing north from Smithfield over the McIntyre creeks the sand is found to rise rapidly, until it culminates in a nose jutting out at right angles to the direction of general folding, with its highest point in sec. 10, and extending southeasterly to east of the colored settlement near McIntyre Creek. This would seem to indicate a favorable point for oil accumulation, and it is probable that if good sand be found on the sides of this secondary anticline it will be saturated with oil, the most probable location being in a northeasterly line through sec. 2, T. 9 N., R. 3, and secs. 32 and 33, T. 6 N., R. 2, with a favorable chance for small wells on the west side of the fold in secs. 2 and 8, T. 9, R. 3. Four test wells have been drilled that may be considered as having a bearing upon this possible oil territory. Well No. 195, on the farm of William Cope, is rumored, though no positive information was obtained, to have found very poor or no sand. Well No. 217, on the farm of J. Dodds, found very poor sand, with but little water and slight show of oil. Well No. 218, on Joshua Moore's farm, found the Berea grit to consist from top to bottom of lime formation, incapable of holding any large amount of fluid. Well No. 196, at Southerland's mill, found very good sand, with indications of oil. After shooting this well a number of barrels of oil were bailed out. Wells Nos. 195 and 217 from their locations could not have been expected to be large producers, but had they made a show of salt water would have very much improved the chance of good producing territory on the anticline. Well No. 196 seems to have made a better show than was to be expected, and is apt to suggest the idea that the impervious sand extends for a considerable distance down the side of the anticline. Well No. 218 proves nothing except that poor sand exists at the point where the well was drilled. With the evidence of these wells taken into consideration, this area must be regarded as having favorable structure, but with strong probabilities of finding poor sand.

Salem area.—On the eastern side of the main anticline, north of the secondary fold above mentioned, no noticeable features are shown, and a selection of the most favorable territory would be very hard to make, though a test well in the south part of sec. 20 or 26 would have a fair show of success, and if a failure, would furnish valuable data as to the probability of an oil pool in that locality.

Piney Fork test wells.—To the west of Smithfield, on and near the Piney Fork of Short Creek, four test wells have been drilled. Well No. 182, on the farm of Alexander S. Thompson, gave a fair show of oil. This well is shown by the map to be at the crest of a small terrace. The other wells, Nos. 181, 183, and 240, were simply dry holes.

Bricker pool.—From this locality westward no favorable territory is shown until reaching the producing area on the main anticline northeast of the town of Cadiz. Here the Bricker pool was opened up in sec. 30 by well No. 49, which started at 150 barrels. The sand at this pool is very favorable, and it has furnished a number of wells that started at over 100 barrels per day. This pool is not giving evidence of long life. The productive territory has been definitely limited by four gas wells on the west, three dry holes on the north, also three dry holes on the south, with a strong salt-water well, No. 57, on the east.

Southern extension of main anticline.—Beyond the three dry holes on the Rife farm, the southern extension of the eastern slope of the anticline has been tested only by well No. 13, on the Porter farm. This well found 3 feet of good sand, with good show of oil and large amounts of salt water. The map represents this well as located too far down the slope of the anticline. Its results, however, give evidence for the probability of producing territory in the northeast quarter of sec. 28 and the southeast quarter of sec. 29.

The area west of the anticline may all be considered as favorable territory for small wells. Although not shown on the map, it is known that a strong syncline parallels the line of the anticline just off the western edge of the quadrangle, and encounters the cross anticline at the Jewett oil field, which field covers a considerable area with small-producing wells.

Snyder pool.—On the eastern side of the main anticline, 2 miles northeast of the Bricker pool, what is known as the Snyder field has been developed during the last year. The sand here is not so favorable as at the Bricker pool, but a number of 30- and 40-barrel wells have been found.

Northern extension of the main anticline.—North and northeast of the Snyder pool six wells have been sunk in the attempt to find other pools by an extension of the alignment of the Bricker and Snyder pools, with uniformly unfavorable results. With the information shown by the contour map, these results would not have been unexpected. It is here that the influence of the cross anticline has come in, and the terrace face has been moved over to the east of the town of Hopedale, where it again takes up its northeasterly direction, and is in fact the extension of the Bricker and Snyder pool terrace. Two test wells have been drilled at the southeast end of this terrace. The first well, No. 203, found sand, with a show of oil, and led to the drilling of the second well, No. 204, with the intention of striking the sand fully 10 feet higher than in the first well. This they failed to do, finding the sand only 2 feet higher in the second well than in the first. This slightly increased elevation showed very favorably in the oil indications, and the well was put to pumping, resulting in from 1½ to 2 barrels a day.

Wells Nos. 205 and 206 were small producers, but not from the Berea grit sand, since they were sunk only to the Cow Run sand. Other wells near Nos. 205 and 206 were drilled to the Berea grit, and were unproductive. Their location and records have not been procured. The result of well No. 202, in sec. 28, was not learned. Well No. 201, in sec. 23, is reported as a gas well.

From the structure and indications of test wells already drilled, a very favorable line for finding oil seems to exist in a northeasterly direction from the southeast quarter of sec. 3, toward the town of Unionport.

Amsterdam pool.—The accumulation from the canoe-shaped basin on the western side of the main anticline has been discovered in part at Amsterdam.

The sand at the Amsterdam wells is of such a poor quality that it probably would have been reported as all lime had it not been oil-producing. The wells are small, but will probably improve when spots of better sand are found. The limits of this field have been determined across the dip of the sand by a salt-water well, No. 205, and a gas well in sec. 19, not located on the map. The lateral extensions along the strike are as yet not defined by test wells. The indications are that the extensions will be to the southwest in a diagonal line through sec. 30, and to the east in an almost due east line through the south half of sec. 7.

USE OF THE STRUCTURE MAP.

To obtain the most valuable result from the use of the map of the oil sand, it is necessary to know the true elevation of the mouth of a contemplated well. For this purpose the elevations of the surface at a great many intersections of roads and other spots have been printed on the map. The letters "B M" have been prefixed to two hundred of these elevations, and beneath each has been placed one of the numbers of the consecutive series appearing in the first column of the bench-mark descriptions on pages 34 to 42. These bench marks have been so distributed that it is hoped any point may be reached by not over 1 mile of leveling.

After obtaining the true elevation of the mouth of the proposed well, add to it the elevation of the oil sand, as shown by the contour map, at the point where the well is to be drilled, disregarding the minus sign. The sum will be equal to the depth of well required to reach the top of the sand, and by increasing this amount by 40 to 60 feet the total depth of well will be found. By subtracting 350 feet from the computed distance from mouth to top of Berea sand, a very close estimate can be made of the casing required to extend through the Big Indian sand.

WELLS AND BENCH MARKS IN CADIZ QUADRANGLE, OHIO.

List of wells in the Cadiz quadrangle.

Number on map.	Farm.	Tp.	R.	Sec.	Owner.	Number.	Elevation of mouth.	Distance from mouth to cap of sand.	Elevation of cap of sand.	Thickness of sand.	Elevation of Pittsburg coal.	Distance from Pittsburg coal to cap of sand.	Remarks.
							Feet.	*Feet.*	*Feet.*[a]	*Feet.*	*Feet.*	*Feet.*	
1	R. R. Cochran	10	5	6	Cadiz Oil and Gas Co		1,151	1,414	−263	50	1,180	1,443	Dry hole; first well near Cadiz.
2							1,075						Produced a few barrels natural; after shooting no oil.
3	C. M. Hogg	9	4	35				1,431					
4	....do	9	4	35			1,063						
5	G. Fryer	9	4	34	Cadiz Oil and Gas Co		1,034	1,345	−311	50	1,185	1,496	Gas well.
6	....do	9	4	28	....do		1,022	1,317	−295	59	1,185	1,480	Do.
7		9	4	34	....do								
8		9	4	34	....do		1,144						
9	Jos. Thompson	9	4	34	....do	1							
10	....do	9	4	34	....do	2							
11													
12	Jno. Clifford	9	4	22			1,107						
13	S. B. Porter	9	4	22	Wilson & Pratt	1	1,213	1,572	−359	31	1,145	1,504	Small show. Good sand; some oil, with large quantity of salt water.
14	Geo. Kerr	9	4	17			1,036						
15	J. & J. W. Rife	9	4	29	Ohio Oil Co	1	1,133	1,423	−290		1,192	1,482	Dry hole.
16	....do	9	4	29	....do	3	1,186	1,477	−291	53	1,194	1,485	Do.
17	....do	9	4	29	....do	2	1,220	1,498	−278		1,203	1,481	Dry hole. Poor sand; lime extended 35 feet.
18	Samuel Thompson	9	4	30	....do	2	1,156	1,440	−284				Gas well.
19	....do	9	4	30	....do	1	1,177	1,460	−283		1,201	1,484	Do.
20	....do	9	4	30	....do	4	1,130	1,410	−280				Do.
21	....do	9	4	30	....do	3	1,196	1,479	−283	26	1,205	1,488	

[a] Minus sign indicates distance below sea level.

List of wells in the Cadiz quadrangle—Continued.

Number on map.	Farm.	Tp.	R.	Sec.	Owner.	Number.	Elevation of mouth.	Distance from mouth to cap of sand.	Elevation of cap of sand.	Thickness of sand.	Elevation of Pittsburg coal.	Distance from Pittsburg coal to cap of sand.	Remarks.
							Feet.	*Feet.*	*Feet.*[a]	*Feet.*	*Feet.*	*Feet.*	
22	Samuel Robb	9	4	30	Hogg & Glover	5	1,179	1,463	−284				
23	do	9	4	30	do	7	1,124	1,408	−284		1,203	1,487	
24	do	9	4	30	do	2	1,159	1,452	−292				
25	do	9	4	30	do	1	1,072	1,368	−296				140 barrels.
26	do	9	4	30	do	3	1,114	1,402	−288				
27	do	9	4	30	do	4	1,135	1,417	−282	33			Strong gas.
28	do	9	4	30	do	6	1,193						
29	John Bricker	9	4	30	National Oil Co	6	1,135		−285				Records of National Oil Co. do not give top of sand cap; 17 feet was subtracted from record of top of pay sand for elevation of cap rock.
30	do	9	4	30	do	4	1,120		−303				
31	do	9	4	30	do	8	1,114		−280				
32	do	9	4	30	do	9	1,105		−288				
33	do	9	4	30	do	3	1,097		−289				
34	do	9	4	30	do		1,037		−308				
35	do	9	4	30	do	12	1,135						
36	do	9	4	30	do	10	1,032		−303				
37	do	9	4	30	do	16	1,156		−290				
38	do	9	4	30	do	14	1,178		−307				
39	do	9	4	30	do	13	1,151						
40	do	9	4	30	do	15	1,205		−294		1,187	1,481	
41	do	9	4	30	do	20	1,216						
42	do	9	4	30	do	17	1,214						
43	do	9	4	30	do	19	1,198		−301				
44	do	9	4	30	do	18	1,187						

45	Samuel Robb	9	4	30	do	3							
46	do	9	4	30	do	5							
47	do	9	4	30	do	1							
48	do	9	4	30	do	4							
49	John Bricker	9	4	30	do	1	1,037		—291				180 barrels.
50	do	9	4	30	do	11	1,086		—301				
51	Samuel Robb	9	4	30	do	2							
52	John Bricker	9	4	24	do	2	1,069		—294				
53	Jno. Baker	10	4	25			1,096						Dry.
54	Robt. Junk	10	4	25			1,099						Do.
55	Ingram Clark	10	4	25	Ohio Oil Co	1	1,195	1,480	—285				Do.
56	Samuel Robb	9	4	30	National Oil Co	6	1,085		—297				
57	Robt. Busby	9	4	24	do	1	1,023	1,326	—303		1,180	1,483	Salt water.
58	Emmit Thompson	9	4	36			1,150	1,418	—268		1,208	1,476	Dry.
59	J. S. Black	9	4	18			1,011	1,368	—357		1,138	1,495	
60	F. Barricklow	9	4	24									
61	D. Robb	10	4	19	Ohio Oil Co	1	1,029	1,335	—306		1,194	1,500	
62	John B. Thompson	10	4	19			1,062						
63	W. Beadle	10	4	19	National Oil Co	3	1,185	1,493	—308				
64		10	4	19			1,092						
65	P. H. Stephens	10	4	19	Davis & Johnson	2	1,190						
66	do	10	4	19	National Oil Co	1	1,092						
67	do	10	4	19	do								
68	do	10	4	19	do	2	1,123						
69	do	10	4	19	do	4							
70	do	10	4	19	do	3							
71	do	10	4	19	Davis & Johnson	3	1,205						
72	do	10	4	19	do	1	1,225						
73	Jacob Snyder	10	4	20	do	1	1,178	1,470	—292				
74	do	10	4	20	do	4	1,215	1,483	—268				
75	do	10	4	20	do	9	1,162	1,425	—263				
76	do	10	4	20	do	5	1,196	1,455	—259				
77	do	10	4	20	do	2	1,208	1,470	—262		1,211	1,473	
78	do	10	4	20	do	8	1,224	1,480	—257				

[a] Minus sign indicates distance below sea level.

List of wells in the Cadiz quadrangle—Continued.

Number on map.	Farm.	Tp.	R.	Sec.	Owner.	Number.	Elevation of mouth.	Distance from mouth to cap of sand.	Elevation of cap of sand.	Thickness of sand.	Elevation of Pittsburg coal.	Distance from Pittsburg coal to cap of sand.	Remarks.
							Feet.	*Feet.*	*Feet.*[a]	*Feet.*	*Feet.*	*Feet.*	
79	Jno. O. Copeland	10	4	20	Davis & Johnson	1	1,202	1,475	−273				
80	Jacob Snyder	10	4	20	.....do	3	1,163	1,455	−292				
81	Wm. Croskey	10	4	14	.....do								
82	.....do	10	4	13	.....do								
83	F. B. Cole	10	4	20	Amsler & Rowley	3	1,184	1,449	−265		1,211	1,476	
84	Jacob Snyder	10	4	20	Davis & Johnson	7		1,470					
85	F. B. Cole	10	4	20	Amsler & Rowley	2	1,206	1,464	−258		1,213	1,471	
86	.....do	10	4	20	.....do	1	1,230	1,487	−257		1,213	1,470	20 barrels.
87	Jacob Snyder	10	4	20	Davis & Johnson	6	1,212	1,470	−258		1,213	1,471	
88	F. B. Cole	10	4	20	Amsler & Rowley	5	1,218						
89	.....do	10	4	20	.....do								
90	E. Norman	10	4	20	Hogg & Hedges	3							
91	.....do	10	4	20	.....do	1	1,224	1,487	−263		1,213	1,476	Do.
92	.....do	10	4	20	.....do	2	1,125	1,382	−257		1,213	1,470	30 barrels.
93	.....do	10	4	20	.....do		1,078						
94	F. B. Cole	10	4	20	.....do	1	1,075						
95	.....do	10	4	20	.....do	2							
96	.....do	10	4	20	.....do	3	1,126						
97	O. Snyder	10	4	20									
98	S. Laughidge	10	4	20									
99	Jno. M. Copeland	10	4	20	Ohio Oil Co.	1	1,217	1,476	−259				
100	S. B. McGavran	10	4	26	Wallace & Co.								
101							1,157						
102													
103							1,214	1,456	−242		1,233	1,475	
104							1,159						
105							1,123		−251				

106							1,086						
107							1,075						
108	J. Brindle	10	4	28	F. N. Donalson	2		1,352					Gas well.
109	....do	10	4	28	....do	1		1,410					
110	Mintur	10	4	28	....do	1	1,198	1,410	−212				
111		10	4	28									
112	Maggie Finicum	10	4	34	F. N. Donaldson	1	1,234	1,444	−210				
113	....do	10	4	34	....do	2	1,198	1,414	−216				
114	Mintur	10	4	28	....do	2		1,443					
115		10	4	34									
116	Maggie Finicum	10	4	34	F. N. Donaldson	3		1,296					
117	Joseph McCullough	10	4	34	Ohio Oil Co	1	1,081	1,295	−214				
118		10	4	34									
119	Joseph McCullough	10	4	34									
120	....do	10	4	34	Ohio Oil Co	3	1,165	1,400	−235	3			
121	....do	10	4	34	....do	2	1,180	1,394	−214				
122		10	4	34									
123		10	4	34									
124		10	4	34									
125		10	4	34									
126		10	4	34									
127		10	4	34									
128		10	4	34									
129		10	4	34									
130		10	4	34									
131	Joseph Thompson	10	4	34	Ohio Oil Co	5	1,275	1,500	−225		1,232	1,457	
132	....do	10	4	34	....do	6	1,285	1,510	−225				
133		10	4	34									
134	H. L. Thompson	10	4	34	Ohio Oil Co	6	1,193	1,409	−216				
135	....do		4	34	....do	5	1,158	1,365	−207				
136	....do	10	4	34	....do	4							
137	....do	10	4	34	....do	11							
138	....do	10	4	34	....do	3	1,124	1,334	−210				
139	....do	10	4	34	....do	12							

[a] Minus sign indicates distance below sea level.

List of wells in the Cadiz quadrangle—Continued.

Number on map.	Farm.	Tp.	R.	Sec.	Owner.	Number.	Elevation of mouth.	Distance from mouth to cap of sand.	Elevation of cap of sand.	Thickness of sand.	Elevation of Pittsburg coal.	Distance from Pittsburg coal to cap of sand.	Remarks.
							Feet.	*Feet.*	*Feet.*[a]	*Feet.*	*Feet.*	*Feet.*	
140	H. S. Thompson	10	4	34	Ohio Oil Co.	1	1,201	1,408	−207				
141													
142													
143													
144													
145													
146	H. L. Thompson	10	4	34	Ohio Oil Co.	10	1,218	1,432	−214				
147	John McCullough	10	4	34	do	1		1,417					
148	do	10	4	34	do	4	1,237	1,448	−211		1,240	1,452	
149	T. M. Lee	10	4	35	do	2	1,212	1,426	−214				
150	do	10	4	35	do	1		1,390					
151	A. M. Busby	10	4	35	do	2	1,162	1,364	−202				
152	do	10	4	35	do	6							
153	do	10	4	35	do	4	1,051						
154	R. D. Lee	10	4	35	do								
155	do	10	4	35	do	3	1,034	1,239	−205				
156	do	10	4	35	do	4	1,033	1,236	−203				
157	do	10	4	35	do	5	1,038						
158													
159	A. M. Busby	10	4	35	Ohio Oil Co.	1	1,096						
160	do	10	4	35	do	3	1,030	1,227	−197	39			
161	Maggie Busby	10	4	35				1,232					
162	S. E. Thompson	10	4	35	E. Thompson Co.	7				36			
163	do	10	4	35	do	6	1,199	1,409	−210	34			
164	do	10	4	35	do	5	1,148	1,354	−206	40			
165	do	10	4	35	do	4	1,125	1,336	−211	40			
166	do	10	4	35	do	1	1,082	1,288	−206	41			

167													
168													
169													
170	A. M. Busby	9	4	35	Jewett Oil Co.	1	1,036	1,240	−204				Gas.
171	do	9	4	35	do	2	1,072	1,269	−197				Do.
172													
173													
174													
175													
176													
177													
178													
179													
180	W. Harvey Johnson	9	4	3			1,148	1,588	−440		1,099	1,539	Dry.
181	K. Southerland	8	3	28			979				1,068		
182	A. S. Thompson	8	3	29			991	1,446	−455	55	1,091	1,546	Some oil.
183	W. Vermillion	8	3	29			988						
184													
185	L. Runyon	8	3	17			1,039	1,582	−543		1,026	1,569	Full record.
186	J. and J. Galbreth	8	3	11			1,033						
187	do	8	3	10	Ohio Oil Co.	2	1,234	1,764	−530		1,025		
188	do	8	3	10			1,091	1,628	−537		1,024		
189	C. Galbreth	8	3	10	C. Galbreth	1	1,069	1,610	−541		1,023	1,564	
190	do	8	3	10	do	3	1,094	1,634	−540		1,023	1,563	
191	do	8	3	10	do	2	1,114	1,655	−541		1,023	1,564	
192	W. S. Purviance	8	3	10			1,002	1,551	−549		1,021	1,570	
193	Eliza Lewis	8	3	4			1,073	1,654	−581	47			
194							1,053						
195							985						
196	J. W. Southerland	7	2	36			918	1,432	−514		1,062	1,576	
197	M. Semeral	9	3	17			1,067	1,380	−313		1,197	1,510	
198													
199													
200	W. S. Blackburn	9	3	23			918	1,221	−303	43	1,203	1,506	

[a] Minus sign indicates distance below sea level.

List of wells in Cadiz quadrangle—Continued.

Number on map.	Farm.	Tp.	R.	Sec.	Owner.	Number.	Elevation of mouth.	Distance from mouth to cap of sand.	Elevation of cap of sand.	Thickness of sand.	Elevation of Pittsburg coal.	Distance from Pittsburg coal to cap of sand.	Remarks.
							Feet.	*Feet.*	*Feet.*[a]	*Feet.*	*Feet.*	*Feet.*	
201	T. M. Reed	9	3	23			939	1,199	−260		1,221	1,481	Gas.
202	E. Hervey	9	3	28			1,038	1,344	−306		1,197	1,503	Full record.
203	M. McFadden	9	4	2			1,110	1,390	−280		1,210	1,490	Good sand.
204	C. Hedges	9	4	2			1,152	1,430	−278		1,212	1,490	1½ barrels.
205							998						
206							987						
207	C. Morrigan	10	4	12			1,025	1,182	−157		1,308	1,465	
208	L. B. Rolston	10	4	18			1,071				1,273		
209	Lowmiller	11	4	26			1,152	1,368	−219		1,238	1,457	
210	Jno. Condo	11	4	25			1,118						
211	Geo. Crabb	11	4	31			1,041						
212	L. B. Rolston	10	4	8			1,190				1,238		
213													
214	H. Starr	9	3	18			911	1,191	−280		1,228	1,508	
215		9	4	35			1,108	1,400	−292		1,201	1,493	
216													
217	J. Dodds		3	21	Amsler & Rowley		1,121	1,526	−405		1,122	1,527	Poor sand.
218	J. & L. Palmer		3	3			1,070	1,472	−402		1,150	1,552	Do.
219	Geo. Folhr				Ohio Oil Co.			1,170					
220													
221	W. Andrews	10	3	6			880	1,085	−205		1,250	1,455	
222							1,228						Coal test well.
223							933						
224	A. J. Anderson						898	995	− 97	40			Gas.
225	John Knox	11	4	18			961	1,167	−206		1,277	1,483	Salt water.
226	Wm. Seaton	11	4	24			945						
227	A. Long	12	4	13	W. C. Kennedy & Co.	2	933	1,109	−172				

228	Wm. Seaton	11	4	24	.....do	2	1,070					
229	A. Long	12	4	19	.....do	1	993	1,163	−170			
230	.....do	12	4	19	H. N. R. O. I. Co	1	953	1,114	−161			
231	.....do	12	4	19	.....do	2						
232	.....do	12	4	19	.....do	3	1,040	1,196	−156			
233	M. & J. Hess	11	4	24	.....do	1	1,016	1,164	−149		1,316	1,465
234	Robt. H. Miser	11	4	3	Wallace & Co.		1,087	1,268	−181		1,333	1,514
235	Soloman Burrier	11	4	28	Carrol & Jeffee Oil Co.		1,032	1,209	−177		1,289	1,466
236	Adam Burrier	11	4	22	.....do		1,052	1,257	−205			
237	T. A. Stenger	12	4	31			1,135					
238	R. Gibson	12	4	32			1,177	1,277	−100			

[a] Minus sign indicates distance below sea level.

List of bench marks in the Cadiz quadrangle.

[Numbers and elevations of permanent bench marks in heavy-faced type.]

No. on map.	Elevation.	Description.
	Feet.	
1	**1,280.10**	Aluminum tablet sunk in west end in first landing of stone step at north entrance to Cadiz court-house.
2	1,056.00	B. M. cut in top of guard wall of stone arch bridge on Cadiz and Unionvale pike, 1 mile east of Cadiz.
3	1,201.00	B. M. painted on floor of coal wharf near brick house on Craig farm.
4	998.05	B. M. painted on top of bridge No. 192 B of Wheeling and Lake Erie R. R.
5	**971.40**	Copper tablet sunk in northwest bridge seat of bridge No. 193 A of Wheeling and Lake Erie R. R., one-half mile south of Unionvale.
6	938.60	B. M. painted on northwest wall of wagon bridge near Jobe Station on Wheeling and Lake Erie R. R.
7	925.60	B. M. cut in top stone of northeast abutment of Wheeling and Lake Erie R. R. bridge at Hurford Station.
8	1,083.40	B. M. painted on south rail of bridge on Cadiz and Bricker road, 1 mile east of Cadiz.
9	1,171.70	Floor of small bridge at intersection of roads near the residence of Samuel Thompson.
10	1,211.70	B. M. painted on bottom rail of fence at forks of roads near Bricker oil field.
11	1,256.30	B. M. painted on fence post at summit by large oak tree on road from Bricker oil field to Craig schoolhouse.
12	1,264.18	B. M. painted on fence rail on west side of road at summit near red house.
13	1,228.65	Top of highest rail of Cadiz Branch R. R. at street crossing at north end of Cadiz.
14	1,222.40	Top of south rail of Cadiz Branch R. R. at Looftsboroughs' crossing.
15	1,263.60	Top of west rail of Cadiz Branch R. R. opposite Crawford station.
16	1,243.70	Top of rail at road crossing over Cadiz Branch, eight-tenths of a mile south of Limestone Station.
17	1,209.10	B. M. top of railroad spike driven in top of post on east side of Cadiz Branch at road crossing one and eight-tenths miles south of Falk Station. Elevation of west rail at road crossing, 1,211.90.
18	1,198.90	Road crossing over Cadiz Branch at tunnel where Wheeling and Lake Erie R. R. passes under.
19	1,116.00	Road crossing over Wheeling and Lake Erie R. R. one-half mile north of Greenough Station.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
20	1,093.30	Top of rail opposite Greenough Station on Wheeling and Lake Erie R. R.
21	1,063.10	Road crossing over Wheeling and Lake Erie R. R. one-half mile south of Greenough.
22	1,013.50	B. M. painted on base of Wheeling and Lake Erie R. R. trestle bridge "192 A."
23	1,181.70	B. M. on stone at southwest corner of culvert at crossroads in Snyder oil field.
24	1,018.40	B. M. painted on northwest post of bridge over stream flowing south near white house on hill.
25	1,053.00	B. M. on top of south rail of bridge over stream near crossroads.
26	1,212.00	B. M. painted on west end of culvert at forks of roads from Hopedale to Millers Station and Cadiz Junction. Marked 1222. Elevation doubtful. Made by Wetzel from Parman, 1209.3.
27	1,079.25	Floor of bridge over headwaters of Cross Creek on road from Hopedale to Falks.
28	1,048.00	Floor of bridge over headwaters of Cross Creek on road from Hopedale to Cadiz Junction.
29	**1,099.27**	Copper tablet sunk in top stone of north side wall of turntable at Cadiz Junction.
30	1,225.58	Top of rail on Cadiz Branch R. R. at road crossing at Falk Station.
31	1,009.55	B. M. painted on floor of bridge No. 184, Wheeling and Lake Erie R. R.
32	1,036.01	B. M. cut on northwest wall of overhead bridge of Wheeling and Lake Erie R. R. under Pittsburg, Cincinnati, Chicago and St. Louis R. R.
33	1,053.93	B. M. of Pennsylvania R. R. on bridge No. 73. Elevation by Pennsylvania R. R., 1052.79.
34	1,111.93	B. M. painted on top of bolt on southeast corner of overhead bridge of Wheeling and Lake Erie R. R.
35	1,072.00	Floor of bridge by oil well in Jewett field.
36	958.20	Floor of bridge over Hurford Creek, one and a half miles north of Hurford Station.
37	990.2	B. M. painted on rock at forks of road.
38	1,019.1	B. M. painted on iron bridge over Hurford Creek at crossroads near schoolhouse.
39	1,071.2	Elevation of ground at junction of roads on Hurford Creek by house.
40	1,064.80	Center of grass plot at junction of roads by church.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
41	1,096.5	Floor of bridge with stream flowing east one mile south of Hopedale.
42	1,117.4	Floor at the southwest corner of bridge at the south end of Hopedale.
43	1,262.00	Ground at intersection of roads in sec. 1, T. 1 N., R. 4.
44	1,018.70	Coping of east abutment of wood truss bridge over Piney Fork Creek.
45	1,156.90	B. M. painted on stone at southwest corner of crossroads York.
46	1,245.22	Ground at forks of roads, three-quarters of a mile north of York.
47	1,189.60	B. M. on stake at foot of guideboard, Smithfield, Mount Pleasant, and Portland.
48	973.00	Southwest corner of abutment of bridge over Piney Fork Creek at Southerland's mill.
49	1,008.50	B. M. painted on southeast abutment of iron bridge one mile south of Smithfield.
50	1,035.3	B. M. painted on southeast wing wall of iron bridge seven-tenths of a mile south of Smithfield.
51	**1,240.08**	Aluminum tablet sunk into the northwest water table of brick schoolhouse at Smithfield, marked 1240, Steubenville.
52	1,255.00	Ground in center of road at entrance to cemetery at north end of Smithfield.
53	1,260.30	Ground at junction of roads near schoolhouse No. 9. Guideboard; 5 miles to Bloomfield.
54	1,169.2	B. M. on rock east side of road by white house 3 miles north of Smithfield on Smithfield-Bloomfield road.
55	1,018.40	B. M. painted on northwest wing wall of bridge over Big McIntyre Creek on Smithfield-Bloomfield road.
56	1,092.30	Ground opposite watering trough at brown house on hill north of Big McIntyre Creek.
57	991.60	Northeast abutment of bridge over Piney Forks Creek on Smithfield-Cadiz road.
58	1,127.00	Ground on summit of hill in front of white house.
59	1,177.60	Ground at foot of guidepost at forks of roads 1½ miles west of Smithfield.
60	1,231.00	Foot of guidepost at forks of road three-fourths of a mile west of Smithfield.
61	1,233.30	B. M. on west end of culvert 1 mile east of Smithfield on ridge road.
62	1,120.30	Ground in center of road in front of house in pines on road north from Smithfield.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
63	829.14	R. R. B. M. on northeast coping stone of arch bridge No. 53 over Cross Creek, 300 feet east of Reeds Station.
64	837.12	R. R. B. M. on northeast coping stone arch bridge over Cross Creek 900 feet west of Reeds Station.
65	845.50	R. R. B. M. on northeast coping stone of bridge No. 55.
66	**844.29**	Copper tablet sunk in northeast coping stone of bridge No. 56 of Pittsburg, Cincinnati, Chicago and St. Louis R. R. over Cross Creek. Marked 844 Steubenville.
67	865.79	B. M. cut on top stone of northwest wing wall of iron wagon bridge at Skelley Station.
68	**1,298.26**	Aluminum tablet sunk in northwest water table of schoolhouse at Bloomfield. Marked 1298 Steubenville.
69	1,222.92	Ground at intersection of roads one-half mile northeast of Bloomfield.
70	1,196.07	Ground at intersection of roads 1½ miles northeast of Bloomfield.
71	1,180.00	Ground at intersection of road to Skelley and ridge road south of railroad.
72	969.00	B. M. painted on northwest corner of wing wall of bridge abutment over Big McIntyre Creek at Tunnel Mill schoolhouse.
73	920.50	B. M. painted on northwest corner of abutment of bridge over McIntyre Creek at Southerlands Mill.
74	1,184.50	Ground at crossroads 1 mile from Southerlands Mill toward Bloomfield.
75	1,222.00	B. M. painted on root of oak tree in triangular grass plot at intersection of roads.
76	1,245.00	B. M. painted on west end of box culvert at cross roads to New Alexander and Bloomfield.
77	1,276.00	Ground at foot of guidepost at forks of road 1½ miles east of Bloomfield—Bloomfield-Loftus road.
78	1,087.40	Floor of bridge on road from Skelley to Opossum Hollow.
79	993.80	B. M. painted on stone by gate to low white house in Opossum Hollow.
80	995.33	B. M. painted on rock by gate to yellow house in Opossum Hollow.
81	1,030.80	Ground at cross roads three-fourths mile southwest of Reeds Station.
82	853.00	Ground at bend in road east of stream crossing in Opossum Hollow.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
83	1,174.00	Junction of roads south of Opossum Hollow.
84	1,246.70	Ground at summit in short turn of road southwest of Loftus crossing.
85	1,226.60	Ground at intersection of roads south of Loftus crossing.
86	1,124.57	B. M. on step to white church near schoolhouse near Slab Run.
87	1,136.87	Ground at foot of post opposite lane in negro settlement.
88	1,251.90	Ground at road turning south from mud pike one-half mile west of Bloomfield.
89	1,271.70	B. M. on stepping in front of house at intersection of mud pike and road to Unionport.
90	1,294.60	Ground in center of road in front of white house.
91	1,352.94	Ground under Hopedale triangulation signal.
92	1,224.60	B. M. on white limerock 300 feet south of Memorial Church.
93	1,235.60	B. M. on root of tree at intersection of roads 2 miles southwest of Bloomfield.
94	1,108.90	B. M. marked on stone at end of sluice at intersection of roads.
95	1,150.30	B. M. cut on log at mail box at intersection of roads.
96	888.73	B. M. cut on southwest coping stone of bridge No. 58 of Pittsburg, Cincinnati, Chicago and St. Louis R. R. over Cross Creek nine-tenths mile west of Skelley Station.
97	900.41	R. R. B. M. northeast coping stone bridge No. 59, at west end of tunnel No. 7, 1 mile west of Skelley.
98	912.54	B. M. on northwest wing wall of wagon bridge at Bloomfield Station.
99	926.54	R. R. B. M. on northeast coping of stone bridge No. 61, at east of tunnel No. 8.
100	937.10	R. R. B. M. on northeast coping of bridge No. 62, six-tenths mile west of Bloomfield.
101	953.95	R. R. B. M. on northeast coping stone of bridge No. 64, 1 mile west of Bloomfield.
102	961.99	R. R. B. M. on northeast coping stone of bridge No. 65, 1 mile west of Bloomfield.
103	**976.31**	Aluminum tablet sunk in northeast coping stone of bridge over Cross Creek, 1,200 feet west of Unionport Station. Marked 976 Steubenville.
104	978.86	R. R. B. M. on northeast coping stone of bridge No. 67, west of Unionport.
105	983.83	R. R. B. M. on northeast coping stone of bridge No. 68, 1½ miles west of Unionport.
106	876.23	Floor of bridge over stream near Willow Grove schoolhouse, one-half mile north of Skelley Station.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
107	1,223.78	B. M. painted on rock 60 feet north of brick house west side Skelley-Richmond road.
108	1,206.37	B. M. painted on rock at entrance to cemetery, Skelley-Richmond road, 3½ miles north of Skelley.
109	1,241.60	Ground on summit at entrance to house 1 mile south of Richmond.
110	1,163.49	B. M. painted on southwest abutment of bridge, Skelly-Richmond road, one-half mile south of Richmond.
111	**1,185.83**	Aluminum tablet sunk in stone step of brick schoolhouse at the south end of Richmond, marked 1286 Steubenville.
112	1,276.70	Ground at intersection of roads at Fairfield.
113	1,287.93	B. M. marked on east end of culvert at road north one-half mile west of Fairfield.
114	1,302.49	B. M. painted on nail in bridge at road south from pike 3½ miles west of Richmond.
115	904.00	Elevation of bridge at Reeds Mills. New bridge since B. M. made; elevation thought to be about the same.
116	1,190.90	Ground in center of road opposite yellow house on road between Reeds Mills and Richmond.
117	1,041.58	Floor of bridge over stream.
118	872.33	B. M. painted on floor of bridge over small stream near old mill on Town Fork.
119	914.15	Floor of bridge over Town Fork on road from Richmond to Shane post-office.
120	1,137.34	Floor of bridge on Richmond and Steubenville pike 1½ miles east of Richmond.
121	1,140.26	Intersection of roads on ridge between Richmond and Bloomfield station.
122	1,086.00	Floor of bridge on small stream on Richmond-Salem road 2 miles from Richmond.
123	1,058.00	Floor of bridge on Richmond-Salem road 3 miles from Richmond.
124	1,057.00	Floor of bridge on Richmond-Salem road 1 mile east of Salem.
125	1,160.70	Ground at intersection of roads 1 mile east of Salem.
126	1,126.43	Ground at intersection of roads one-half mile south of Salem.
127	962.70	Floor of bridge over large stream on Unionport and Richmond road.
128	997.00	Floor of small wooden bridge on Carman Hopedale road.
129	1,045.70	B. M. on stump in front of barn on Carmen Hopedale road.
130	1,272.70	Ground at intersection of mud pike and road to Carman.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
131	1,221.27	Ground at foot of post holding sign for sale of coal at intersection of mud pike and county line road.
132	1,292.00	Ground at foot of fence post at northeast corner of intersection of mud pike and ridge road to Unionport.
133	1,251.00	B. M. painted on culvert at private road to west from ridge road from mud pike to Unionport.
134	1,314.30	Middle of road at summit on ridge road to Unionport.
135	1,206.40	Middle of roads at forks on hill south of Unionport.
136	1,178.50	B. M. on stump at forks of section-line road and Bloomfield and Unionport road.
137	1,013.90	Floor of bridge on Bloomfield and Unionport road.
138	1,218.80	Ground in road in front of white house on hill south of Unionport.
139	....	
140	1,289.10	B. M. cut in southeast curbstone at corner of streets in center of town of Jefferson.
141	1,169.37	B. M. painted on southeast corner stone of bridge one-half mile south of Jefferson toward Jewett.
142	1,094.20	Floor of small bridge by old sawmill 1⅓ miles south of Jefferson toward Jewett.
143	1,079.54	B. M. painted on northeast corner of stone bridge 2 miles south of Jefferson toward Jewett.
144	1,046.53	B. M. painted on rock covering spring at crossroads near schoolhouse 2½ miles south of Jefferson toward Jewett.
145	1,034.27	B. M. painted on northwest corner of stone bridge $2\frac{8}{10}$ miles south of Jefferson toward Jewett.
146	1,031.34	Floor of bridge near flour mill at intersection of roads 3 miles south of Jefferson toward Jewett.
147	1,032.49	B. M. painted on rock at intersection of roads 1 mile from Jewett toward Jefferson.
148	1,183.48	Ground at intersection of roads over tunnel on Pittsburg, Cincinnati, Chicago and St. Louis R. R. west of Cadiz Junction.
149	1,208.60	Top of section stone in crossroads by brick church.
150	1,139.45	Floor of small bridge on Jefferson-Cadiz Junction road 1 mile south of Jefferson.
151	1,271.49	B. M. painted on stone at forks of roads from Jefferson to Cadiz Junction and Millers station.
152	1,112.80	B. M. painted on top of watering trough opposite house 1½ miles east of Jefferson on Jefferson and Millers station road.
153	1,076.68	B. M. painted on northwest corner of bridge at road north 2 miles east of Jefferson.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
154	1,055.58	B. M. painted on bridge.
155	1,041.55	B. M. on top of stepping-stone in front of brown house near crossroads.
156	1,252.00	B. M. painted on stone at southwest corner of schoolhouse at road intersection 1 mile north of Millers station.
157	....	
158	1,022.27	R. R. B. M. on northeast corner of bridge No. 71, Pittsburg, Cincinnati, Chicago and St. Louis R. R., 600 feet west of Millers station.
159	....	
160	1,086.54	B. M. painted on bridge in woods on road from Richmond to Shane post-office at foot of first hill from Richmond.
161	**1,331.08**	Aluminum tablet sunk in southeast corner foundation stone of public school building at East Springfield, marked 1331, Steubenville.
162	1,337.00	Ground on summit at road to right from Ridge road, 1 mile north of East Springfield.
163	1,215.21	Floor of small bridge on Ridge road 1½ miles north of East Springfield.
164	1,309.00	Ground in middle of road opposite church, one-third of a mile south of Circle Green post-office.
165	1,302.00	Ground in middle of road opposite Circle Green post-office.
166	1,277.00	Ground on summit of road by schoolhouse on North Ridge road.
167	1,062.38	Floor of bridge over stream on road from Circle Green post-office to Middle Ridge.
168	1,152.82	Floor of bridge over small stream near schoolhouse on Middle Ridge road.
169	1,154.77	Ground at intersection of roads on ridge north of Hildebrand Creek.
170	1,008.00	Floor of iron bridge over town fork of Yellow Creek.
171	1,228.87	Ground at crossroads near church, 1½ miles northeast of stone post-office.
172	879.56	Floor of bridge over Hildebrand Creek.
173	1,148.00	Floor of bridge over Wolf Creek eight-tenths of a mile northwest of East Springfield.
174	1,046.17	B. M. painted on bridge $1\frac{7}{10}$ miles northwest of East Springfield.
175	**905.45**	Copper tablet sunk into southwest wing wall of iron bridge over Yellow Creek, 2 miles north of Amsterdam.
176	933.90	Floor of iron bridge on Main street in the town of Amsterdam.

List of bench marks in the Cadiz quadrangle—Continued.

No. on map.	Elevation.	Description.
	Feet.	
177	**1,275.96**	Aluminum tablet sunk into top foundation stone on north side of schoolhouse 3 miles south of Amsterdam on Amsterdam-Jefferson Ridge road.
178	1,307.00	Ground at foot of guideboard at forks of road 3½ miles south of Amsterdam.
179	1,291.47	Ground in road where private road west leaves 4 miles south of Amsterdam.
180	1,159.56	B. M. painted on small bridge 5 miles south of Amsterdam.
181	1,144.07	B. M. painted on northeast wing wall of bridge at foot of hill east of Jefferson.
182	1,365.60	B. M. on top of marking stone under Jefferson triangulation signal.
183	1,241.57	Ground at road to west from Jefferson-Kilgore road 1½ miles north of Jefferson.
184	1,260.00	Ground at summit opposite large oak tree on Jefferson-Kilgore road 3 miles north of Jefferson.
185	1,254.00	Ground at summit near private road to east.
186	963.97	Floor of iron bridge 1 mile south of Amsterdam on Kilgore-Amsterdam road.
187	965.83	Floor of wooden bridge south of blacksmith shop.
188	984.00	Floor of iron bridge on Amsterdam and Jefferson Valley road 1½ miles south of Amsterdam.
189	1,002.00	B. M. painted on bridge over small stream 2 miles south of Amsterdam.
190	1,246.72	Ground at summit near intersection of roads on section lines.
191	1,046.49	B. M. painted on stone arch bridge 1½ miles north of Kilgore.
192	1,024.31	Top rail of iron bridge near schoolhouse at intersection of roads north of Kilgore.
193	1,334.07	Ground at foot of post with flag at cemetery on top of hill.
194	1,051.39	B. M. painted on stone at private road to right.
195	1,122.54	Floor of bridge three-fourths of a mile east of Kilgore—Kilgore-Amsterdam road.
196	1,065.23	Floor of bridge on county line road short distance south of Salem.
197	1,251.10	Ground in road at short turn to left on Salem to Millers Station road, 1 mile from Salem.
198	1,075.96	Floor of bridge on Salem-Miller road.
199	1,255.50	Ground at intersection of roads.
200	1,235.47	B. M. painted on pump bed at schoolhouse.

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