GEOLOGIC STRUCTURE OF THE UNIONVILLE GAS FIELD, MONROE COUNTY, INDIANA

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Location. The Unionville gas field is located in Benton Township, northeastern Monroe County, about eight miles northeast of Bloomington. It embraces an area of eight or nine square miles, between Unionville Station on the Illinois Central railroad and the village of Old Unionville, three miles east.

History of the Field. The structural conditions in the vicinity of Unionville had been considered to be favorable for the accumulation of gas or oil for several years before drilling operations were commenced. Logan wrote of the possibilities of oil or gas production in the area, in 1922.[1] It was not until October of 1929, however, that the first well was drilled, by the Ohio Oil Company and the Petroleum Exploration Company. This well had an initial production of 900,000 cubic feet of gas. To the present time, fourteen wells have been drilled by the same companies, ten of them being good producers with an average of nearly one million cubic feet of gas per well. Three were dry holes, having been located too far west on the structure, while another was drilled as a deep test to the Trenton formation, which proved unproductive. Drilling is continuing and it is probable that several more successful wells will be drilled.

The gas is obtained from the Devonian limestones of Onondaga age, known to drillers as the "Corniferous lime." The gas horizon is reached at an average of 40 to 50 feet below the top of the formation, and between 750 and 900 feet below the surface, depending upon the altitude of the top of the well.

Topography

The southwestern portion of the area is a fairly level, upland plain, capped by Harrodsburg limestone, while farther to the north and east, where the limestone is very thin or entirely absent, the streams have cut down into the softer shales and sandstones, forming sharp, narrow ravines which soon develop into broad, flat valleys. This highly dissected region is characteristic of Borden (Knobstone) topography.

A level, narrow ridge extends across the entire district, from Unionville Station in section 18 northeast for two miles, and then directly to the east through Old Unionville and for some distance into Brown County. This is commonly called the "Unionville Ridge" and has an average elevation of nearly 900 feet. It forms the divide between the tributaries of Bean Blossom Creek on the north and of Salt Creek on the south. The main valleys have been cut down to an elevation of between 650 and

[1] Logan, W. N. Handbook of Indiana Geology, Part V, p. 842, 1922.

"Proc. Ind. Acad. Sci., vol. 42, 1932 (1933)."

700 feet. Several lesser ridges lead to the north and to the south from the main divide.

Many of the ravines contain small waterfalls, formed either by a resistant limestone layer in the lower Harrodsburg limestone, or in the upper Borden, by a harder sandstone ledge which is underlain by more easily eroded sandstones or shales. Springs are a common feature along outcrops of the Harrodsburg-Borden contact.

STRATIGRAPHY

The rocks outcropping in the area are of Mississippian age. The highest formation is the Harrodsburg (Warsaw) limestone, which is present on the higher hills or divides but which, over the greater portion of the area, has been removed by erosion. The sandstones and shales of the Borden Group underlie the Harrodsburg limestone, and are the only other rocks which are found in the Unionville Region.

Harrodsburg limestone. The lower 25 to 30 feet of the Harrodsburg has been called the Ramp Creek member of the lower Harrodsburg, by Stockdale.[2] It is characterized by the great numbers of geodes in the basal portion and by highly crinoidal limestone layers, but contains many shaly and sandy horizons and "bastard rock." Practically all of the limestone outcropping in the Unionville region belongs to this lower member, which shows a considerable lithologic variation in different places. For instance, the limestone horizons, highly crinoidal or crystalline at one outcrop may, in a comparatively short distance, change to a very siliceous or shaly rock, almost devoid of fossils. This is especially true of the basal layers, the more massive and persistent horizons appearing higher up in the formation. In the same manner, the basal siliceous geode layer, which also contains a considerable amount of chert toward the top, varies in thickness from only a few inches to a maximum of twelve feet, and in a few localities may be entirely absent, being replaced either by the fossiliferous limestone or by a sandy layer.

Outcrops of the Harrodsburg limestone are found almost entirely across the area from west to east, along the Unionville ridge and on several of the higher divides to the north and south, being cut off near the center of section 10 by the Mt. Carmel Fault. On many of the hills, although no actual outcrops of limestone can be found, a residuum of chert, geodes and small slabs of limestone is present. (See Fig. 1.) This residuum has been left from the decomposition and erosion of the limestone. The approximate altitude of the base of the Harrodsburg can be determined with a fair degree of accuracy, by noting the thickness or amount of the residue and the amount of decomposition which it has undergone.

Borden Group. The total thickness of the Borden, as obtained from the records of the gas wells, averages 665 feet, but only the upper formations are exposed.

The highest and most important Borden formation in the Unionville region is the Edwardsville formation. (See Fig. 2.) This was formerly

[2] Stockdale, P. B. The Borden (Knobstone) Rocks of Southern Indiana. Ind. State Dept. Cons., Publication No. 98, p. 240, 1931.

Fig. 1. Residuum of chert and geodes left from the decomposition of the basal Harrodsburg limestone.

known as the "Riverside sandstone," but was renamed "Edwardsville" by Stockdale.[3] The upper portion is usually a succession of fine-grained sandstone and siltstone beds, with shaly partings. Some of the sandstones form prominently resisting ledges. One of these called by Stockdale the *Mt. Ebel sandstone member*, proved to be of considerable value in determining structural conditions where outcrops of the Harrodsburg were absent. It is of a dark yellow color, often mottled by iron streaks and ranges from one to five feet in thickness. It occurs between five and

Fig. 2. Contact of the Harrodsburg and Borden at the west end of the Illinois Central railroad tunnel. The limestone is underlain by the basal chert and geode layer. The top of the Borden (Edwardsville formation) is at the level of the top of the concrete.

[3] Stockdale, P. B. The Borden (Knobstone) Rocks of Southern Indiana. Ind. State Dept. Cons., Publication No. 98, p. 220, 1931.

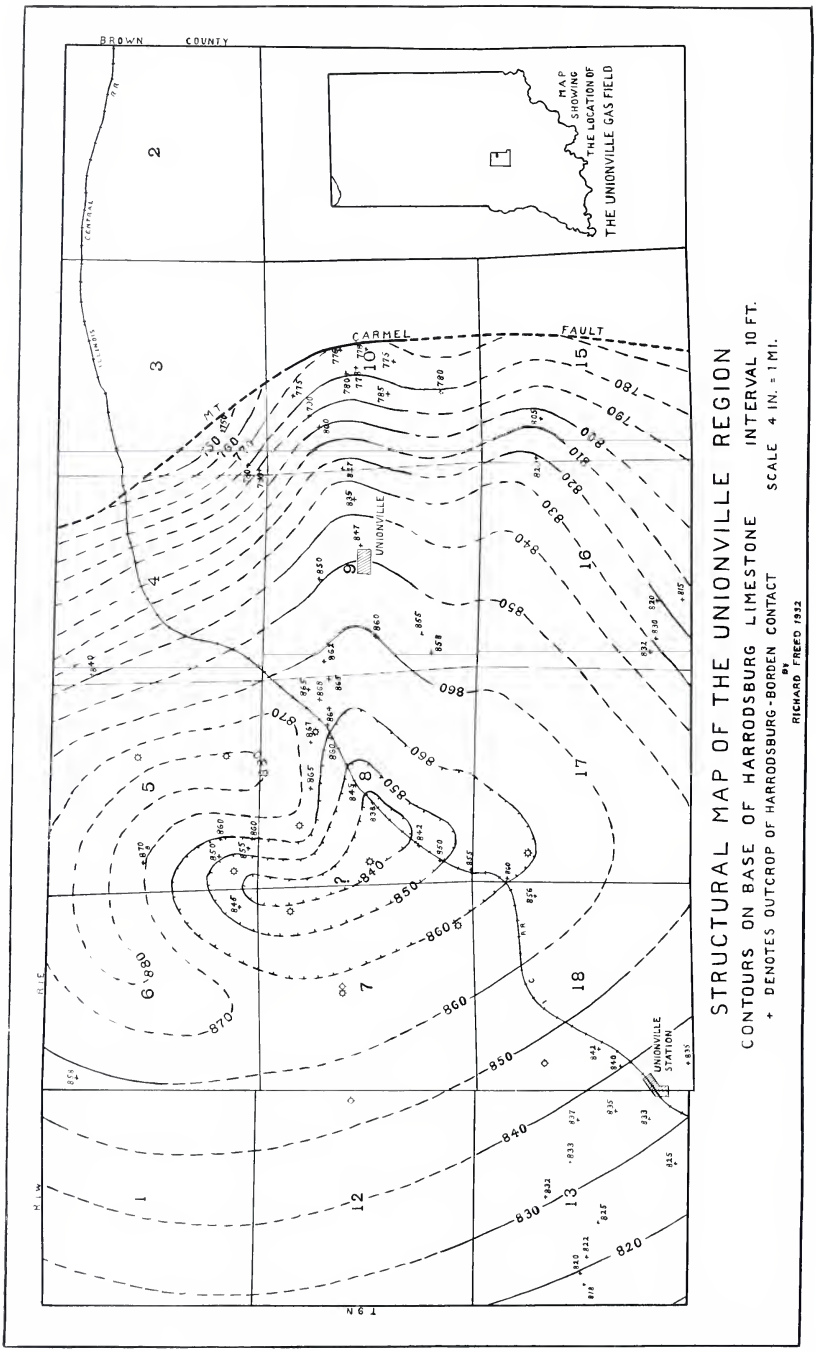
BROWN COUNTY
MAP SHOWING THE LOCATION OF THE UNIONVILLE GAS FIELD
CARMEL
FAULT
UNIONVILLE
UNIONVILLE STATION
STRUCTURAL MAP OF THE UNIONVILLE REGION
CONTOURS ON BASE OF HARRODSBURG LIMESTONE
INTERVAL 10 FT.
+ DENOTES OUTCROP OF HARRODSBURG-BORDEN CONTACT
SCALE 4 IN. = 1 MI.
RICHARD T. FREED 1932

Fig. 3

ten feet below the base of the Harrodsburg limestone and is characterized by the presence of large forms of *Derbya keokuk, Syringothyris textus,* several species of *Productus* and *Eumetria.* Below the Mt. Ebel sandstone is found a succession of siltstones, argillaceous sandstones of gray to drab color. These abound in worm markings, but other fossils are rare.

The total thickness of the Edwardsville rocks in the Unionville area averages around 180 feet.

Structural Conditions

Mt. Carmel Fault. The Mt. Carmel Fault is the feature which has produced the structural conditions as they now exist in the area. (See Fig. 3.) It has been traced from Washington County to southern Morgan County, a distance of about fifty miles. Newsom called it the "Unionville Fault" in 1903, from its exposures one mile east of the village of Old Unionville.[4] In the same year Ashley named it the Mt. Carmel Fault, from Mt. Carmel Church in northwestern Washington County. The latter name is the one which has come into common use.[5]

The fault can be traced for only a short distance in the Unionville region. This is in section 10, one mile east of Old Unionville, both north and south of State Highway 45. About 150 yards west of where the road makes a turn to the north, a small ravine leads to the north. This ravine is in Harrodsburg limestone. At the place where the ravine joins another from the east, the base of the limestone lies at an altitude of 780 feet. Limestone occurs in the north bank of the second ravine for a distance of about thirty feet, being suddenly cut off by a weathered, fractured rift zone. This fault zone is followed by fairly massive ledges of sandstone of the Edwardsville formation, which is present all the way up the ravine to the top of the hill, 200 yards to the east, where the elevation is 890 feet. The width of the rift zone is twenty-five feet, and the trend of the fault at this place is nearly due north and south.

One-half mile north of where the fault crosses State Road 45 in section 10, the fault line makes a turn toward the northwest at an angle of between 30 and 35 degrees. It then enters the valley of Shuffle Creek, and cannot be located again for a distance of two miles. In the northwest quarter of section 4, evidence of displacement can be seen in a small ravine a short distance south of the Shuffle Creek road. Further proof that the fault is nearby is found in the presence of low-lying beds of limestone one-half mile to the northwest, along the road descending into Bean Blossom valley. The fault has been located again several miles north of Bean Blossom Creek, in Marion Township.[6]

South of the State Road in section 10, the fault has been followed for one-fourth mile, where it appears to bend slightly east of south and enters the valley of Brummets Creek. It was not traced farther in the area covered in this paper, but it can be seen in numerous localities farther south in Monroe and Lawrence Counties.

[4] Newsom, J. F. Geologic Section Across Southern Indiana. 26th Indiana Report, p. 274, 1903.

[5] Ashley, G. H. Geology of the Lower Carboniferous Area of Southern Indiana. 27th Indiana Report, p. 91, 1903.

[6] Freed, R. and Rogers, R. A Fault Along Bryants Creek, Northern Monroe County. Proc. Ind. Acad. Sci., Vol. 41, 1931 (1932).

The amount of the throw has not been accurately determined in this region, but it probably averages around 150 feet. The ridge immediately east of the fault in section 10 has an altitude of nearly 900 feet and is composed entirely of Borden rocks. The base of the Harrodsburg at the fault lies at 980 feet, giving a throw of at least 120 feet. Assuming a normal rise of 30 feet per mile from Unionville Station to the fault line in section 10, the base of the limestone, before faulting, would have been at 925 feet, 145 feet above its present location. In the southwest quarter of section 3, the throw is at least 30 feet more than it is in section 10.

The elongated anticline on the west or downthrow side of the fault was named the Dennison Anticline by Esarey in 1924.[7] It is present throughout the extent of the fault, from northwest Washington County to southern Morgan County. The crest of the anticline is undulating, with numerous domes and depressions. The dome in the Unionville region is probably the largest one of the entire anticline.

Structure of the Dome. The dome of the Unionville region is unusual in that a syncline is present nearly where highest portion would be expected to be found. This synclinal area will be described later.

In the western and southwestern parts of the area, in sections 12 and 13, the dip is normal, 30 to 35 feet per mile toward the west-southwest, the lowest contour being the 810 foot level. In the center of section 7 and the northwest quarter of section 18, the 860 foot elevation is reached. The rocks lie practically level for more than one-half mile before dipping into the synclinical areas in section 8 and the southern part of section 5. In the northern portion of section 17 and in the eastern part of section 8, elevations of 860 to 865 feet are found. The highest portion of the structure appears to be in a narrow strip which extends from the northeastern quarter of section 8 through the center of section 5 and into the east half of section 6. The limestone in this area is practically all gone, but elevations of the Mt. Ebel sandstone in several places show that the structure reaches at least 880 feet.

The reversal, or dip toward the fault, begins in the western parts of sections 4, 9 and 16. The dip is at first very little, but as the fault is approached it becomes greater, as much as fifty feet in less than one-half mile. The total amount of reversal from the northeast quarter of section 8 to the fault in section 10 is approximately 100 feet, while in section 3 it is at least 30 feet more. It may be still more, farther south, in section 15.

Determination of the actual amount of reversal to the north and south is difficult because of the almost complete absence of the Harrodsburg limestone. In Marion Township, north of the area mapped, some of the residuum from the decomposition of the limestone can be found. Along a north-south road between sections 32 and 33, a considerable amount of chert and geodes, together with some limestone, makes it quite certain that the Harrodsburg-Borden contact lies between 850 and 860 feet. This is about one mile north of the 880 contour in the northern part of section 5, and it shows that there is an appreciable dip toward

[7] Esarey, R. E. Notes on the Relation of the Mt. Carmel and Heltonville Faults to the Dennison Anticline. Proc. Ind. Acad. Sci., Vol. 34, p. 138, 1924 (1925).

the north. It is probable that this dip continues toward the north and northwest and may reach to well below 850 feet in the vicinity of Bean Blossom Creek, two miles north.

On the south, the 850 and probably the 840 foot contours are closed, but it is doubtful whether the closure is much greater in this locality. There is some evidence that the structure again rises south of section 17, perhaps to form a second, smaller anticline, but the actual conditions will not be known until further work has been done.

The Syncline. The sag or syncline in section 8 is most admirably displayed in the cuts along the Illinois Central railroad, for a distance of three-fourths of a mile southwest of the railroad tunnel. The strong dips of the rocks can easily be seen, and the Harrodsburg-Borden contact is present in most of the cuts, making an accurate study of the syncline quite simple. (See Fig. 4.)

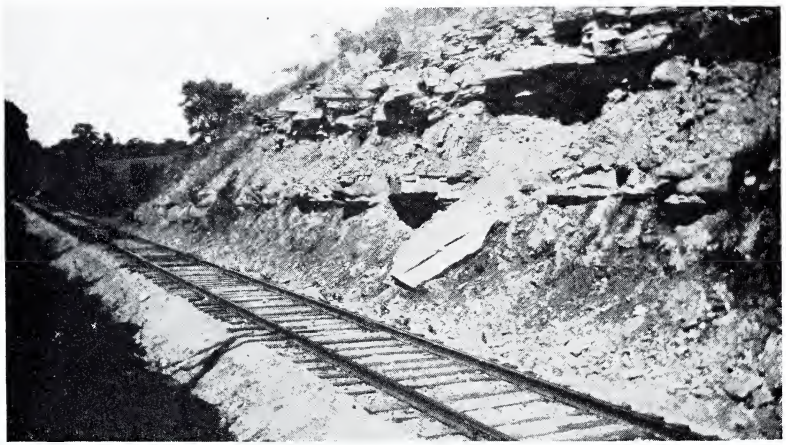

Fig. 4. Rocks of the lower Harrodsburg dipping toward the bottom of the syncline in section 8, seventeen hundred feet southwest of the Illinois Central tunnel.

At the southwest corner of section 8, where the reversal from the normal dip begins, the elevation of the base of the Harrodsburg is nearly 870 feet. To the northeast, through several cuts, the rocks dip quite strongly until at a point 1,500 feet southwest of the tunnel the bottom of the sag is reached. A ravine and railroad fill have destroyed the evidence at this place, but the elevation is probably between 830 and 835 feet. From here to the tunnel the structure again rises, reaching 860 feet at the west end of the tunnel and several feet higher one-fourth of a mile to the east.

There is a rapid rise toward the south from the bottom of the syncline. In several ravines heading south of the road in the south half of section 8 Borden rocks are present, the Mt. Ebel sandstone being found at 860 feet. Adding ten feet to obtain the approximate altitude of the contact gives 870 feet, which is nearly 40 feet higher than the base of the sag one-fourth mile north.

To the north and northeast there is a similar rise to an even higher level, reaching 870 or 880 feet within a distance of one-half mile.

Northwest of the syncline the land becomes so low that determinations of structural conditions based on the Harrodsburg or upper Borden are impossible because of their almost complete absence.

A similar sag or syncline occurs in the southwest quarter of section 5, three-fourths of a mile north and slightly west of the first one. Here again the rocks appear to rise on all sides, although toward the south the fact cannot be established with certainty.

The base of the Harrodsburg limestone is found to have an altitude of about 845 feet in an abandoned quarry in the center of the southwest quarter of section 5. A short distance west the elevation is slightly less than 840 feet. Still farther west it again reaches 845 feet, and in another quarter of a mile the limestone disappears but the Mt. Ebel sandstone is found at 860 feet, making approximately 870 feet for the contact. Similar conditions exist both to the north and to the east, with Borden rocks lying at elevations of between 870 and 880 feet.

There is a possibility that both of the low areas above described may be connected and they have been thus drawn on the map. In one direction from each syncline there is a lack of evidence to prove that they are separate basins. The first might continue toward the northwest, while the second could have an outlet to the south, thus forming a single elongated syncline. If this is the case, it must then be rather crescent-shaped, because almost directly between the two visible low areas, Borden sandstones are found at an elevation of at least 870 feet.

Conclusions Regarding Structural Conditions. As has been stated before, the structural conditions present in the Unionville region are very unusual. The presence of a syncline or of two separate ones in the center of a fairly regular elongated dome or anticline difficult to explain.

It might be expected that minor block faulting could have accounted for the low areas. Their nature, however, and the conditions immediately surrounding them on all sides makes it almost impossible to ascribe them to such a cause. Careful study, moreover, has failed to reveal any evidence of block faulting.

It seems possible that the sags may have been produced in connection with the change of direction of the fault in section 10. But the manner in which the forces acted to produce a collapse so near to the top of the structure cannot be explained by the writer.

It is to be expected that the syncline carries down into the gas-bearing horizon, but positive proof cannot be obtained until further drilling has been done. Assuming that it is present in the Devonian limestones, it is doubtful whether its size is sufficient to produce any noticeable effect upon the amount of gas present. At least one of the wells, in section 5, is located near the lowest portion of the syncline, and good production was obtained from it.