NOTES ON THE RELATION OF THE MT. CARMEL AND HELTONVILLE FAULTS TO THE DENNISON ANTICLINE.

Ralph E. Esarey, Indiana University.

The area under discussion is located in townships four and five north, ranges one and two east, Lawrence and Jackson counties, Indiana. The small town of Leesville occupies the geographical center of the region. Most of it lies in eastern Lawrence County, with but a narrow strip of Jackson County included.

Geography.—The country is rough and hilly, being in many areas entirely unsuited to agriculture. Farming and lumbering on a small scale are the main occupations. The hillsides are generally too steep for cultivation or even pasture lands as they are soon depleted of soil if cleared. The tops of the hills are more adapted to growing crops, especially if capped with limestone. The flat, narrow valleys of the Knobstone shales furnish the best lands for cultivation, however.

Physiography.—The greater part of the territory lies in the Norman Upland, a physiographic division of Indiana extending northward from the Ohio River to the glaciated area which is contained within the areal outcrop of the Knobstone formation. The topography in general is that of the Norman physiographic division except where modified by special structural conditions connected with faulting and its concomitants. This type of topography as described by Dr. Malott is as follows:

"Everywhere it is maturely dissected by stream action. The long sharp ridges are the reverse of the deep stream trenches. The dissection has reached that degree where the amount of material left in the divides and ridges is about equivalent to the amount that has been carried away by erosion in the carving out of the valleys between the ridges. Everywhere steep slopes exist with rarely a bluff. The valleys have the same general shape and the same depth where they are of equal size; the shapes are monotonously alike. The valleys descend sharply and deeply to near their local base level and then become flat-bottomed areas flanked by steep ascents, but never by bluffs. The valleys are always V-shaped where they have not reached their local base levels. No waterfalls of any consequence exist. The Norman Upland is known for its symmetry of drainage lines. The perfection of development is largely due to the mature stage of the erosion cycle in an area of considerable relief and the symmetry results from stream development in rocks of uniform structure and lithology."[1].

However, there is an outstanding departure from this type of topography entirely within the limits of the outcrop of the Knobstone

[1] Indiana Handbook of Geology, Part II, pp. 93-94. Physiography of Indiana.

"Proc. Ind. Acad. Sci., vol. 34, 1924 (1925)."

rocks. On the west or downthrow side of the Mt. Carmel fault is a limestone strip varying in width from a mile to two miles and extending north from this region into Monroe County and south as far as White River. It is a portion of the Harrodsburg limestone, the main body of which now outcrops farther to the west, and which at one time covered this entire region. It has been protected from erosion by its low elevation subsequent to the time of faulting. Upon this strip the topography and drainage are similar to that of a limestone plain, in direct contrast to the Norman Upland type. Drainage is largely of the subterranean type, as only a few shallow stream channels have been cut upon the resistant limestone. The surface is gently rolling, with much less relief. Sinkholes compose the most conspicuous surface features, although they are not extensively developed. The major streams have left the resistant limestone area and have intrenched themselves in the softer shales upon either side.

Drainage.—The East Fork of White River, which flows in a westwardly direction immediately to the south, receives directly or indirectly the drainage of the whole area. Guthrie, Leatherwood and Little Salt creeks, all tributaries of White River, constitute the primary drainage channels.

The region is generally well drained, there being little if any swampy or marsh lands present. The streams are rapid and flow over bed rock throughout most of their courses. A number of small waterfalls are developed where the more resistant Harrodsburg limestone overlies the soft shales and sandstones of the Knobstone, the falls occurring at the contact of these two formations.

Stratigraphy.—The Osagian and Meramecian divisions of the Mississippian include all of the rocks of this area appearing at the surface. The Borden, locally called Knobstone, is the lowest division present and occupies the eastern half of the territory. It consists of sandy shales, sandstones and thin limestones, with an average thickness of 500 feet, and, according to well records, totals more than 600 feet in places. The Borden has been divided into the New Providence, the Kenwood, the Rosewood and the Holtsclaw series.

The Warsaw or Harrodsburg limestone overlies conformably the Borden formation and comprises the highest member of the Osage. It is in the main a thin-bedded, highly fossiliferous limestone, of a coarse crystalline structure with a characteristic geode layer at its base. It varies from 60 to 90 feet in thickness and outcrops in the central and western portions of the territory under discussion.

The Salem limestone, the lowest member of the Meramecian, is present in only the extreme western and southwestern edge of the area.

A number of wells drilled in this vicinity show the existing stratigraphy beneath the outcropping rocks. The section in a general way is as follows:

Rockford limestone—basal member of the Osage, correlating with the Kinderhookian; thickness four feet.

New Albany shale—Devonian in age; a brownish black oil shale; 124 feet in thickness at this point.

Below these two formations is revealed a long series of thin limestones, shales and sandstones making up the remainder of the Devonian, all of the Silurian which happens to be present and part of the Ordovician.

The so-called Trenton limestone of Ordovician age, a horizon sometimes productive of oil and gas, was reached at approximately 1,700 feet below the surface in one well. No deeper wells have been drilled in this vicinity.

Structural Conditions.—The abnormal structural conditions of the outcropping and sub-surface rocks of this region are due primarily to faulting and its accompanying features. The Mt. Carmel fault which lies one-half mile east of Leesville and extends in a general north-south direction, is the largest contributing factor. The Heltonville fault, which is a mile west of the Mt. Carmel fault and roughly parallel to it, is not of such magnitude, but is responsible to some degree for the structural conditions.

Folding, with probably slight fracturing has occurred a few miles west of the major fault as a result of the downthrow on that side. Some crumpling and brecciation are visible along the immediate plane of the fault.

The Mt. Carmel Fault.—The Mt. Carmel Fault[2] appears to be a normal or gravity fault with the downthrow side to the west. It runs north by northwest; to be exact, ten degrees west of north. Here the fault lies for the most part within the areal outcrop of the Borden series, thus making it difficult to trace for any great distance. Outcrops and exposures, by which the fault line can be exactly located, are few and wide apart. Between these the line is covered with mantle rock and its approximate location only is determinable.

The throw or vertical displacement of the strata at Leesville is about 200 feet, if the Harrodsburg limestone may be assumed to have had a normal dip prior to the disturbance. At no place has the writer found the heave or horizontal displacement to be of any magnitude. The fault is practically sealed at Heltonville. Near Leesville a displacement of less than ten feet has occurred. South of Ft. Ritner, across White River, the Salem limestone abutts directly against the Borden shales.

The hade or inclination of the fault plane from the vertical, cannot be determined from the exposures found. It may be either a normal or a reverse fault, but since it is from the inclination of the fault plane that the name is derived, this fault cannot be classified as yet.

One-half mile east of Leesville in section 23 along Guthrie Creek is a brecciated zone which includes the actual fault plane. The zone of shear is 50 to 60 feet wide, showing the effects of faulting upon incompetent sandy shales. Some of the broken material has been re-cemented by the filling of the cracks and crevices with calcite. In turn these re-cemented rocks have been fractured, manifesting two distinct periods of uplift. Inter-penetration of the shales with the abutting

[2] Petroleum and Natural Gas in Indiana, by W. N. Logan, pp. 58-62.

limestones has occurred east of Heltonville along Leatherwood Creek at the fault line. The brecciated zone is here only five to ten feet in width.

A retorsal, or dragging of the strata on the downthrow side, is present along much of the fracture. Where the fault line cuts through the Borden series a zone of shattering and crumpling usually exists instead, due to the character of this formation.

Heltonville Fault.—About one mile west of the Mt. Carmel fault, in the southeast edge of the town of Heltonville, evidences of another fracture are found. It has been named the Heltonville fault by Dr. Logan.[3] Here the limestone on the west has been faulted against the Knobstone. Slight brecciation and dove-tailed inter-penetration has occurred, the limestone being thrust into the softer shale. This fault is traceable for only a short distance both north and south. It appears to parallel the Mt. Carmel fault. Dr. Logan suggests that this fracture changes into a fold; and there are indications of this a few miles south of Heltonville. The minimum amount of displacement is about 100 feet.

The area between these faults may be a single block of limestone and shale, titled to the east, producing a graben or rift valley. Again a scissors fault may be responsible for the structural irregularities here.

The Dennison Anticline.—The Mt. Carmel fault has caused a downward displacement of the rock strata of about 200 feet, thus reversing the normal dip of the rocks on the west side of the fault. Therefore, in order to allow the rocks to dip to the east toward the fault line, folding or fracturing, or both, must have occurred somewhere west of the actual break. As a matter of fact folding accompanied by slight fracturing has actually resulted approximately two miles west of the fault. The fold, where the dip changes from the east to the southwest, or back to normal, roughly parallels the Mt. Carmel fault throughout its entirety.

The course of the fault line changes its direction somewhat radically in section 23, just east of Leesville. This abrupt turn from a southeast direction to almost directly south, amounting to 20 degrees or more, causes a similar deflection in the fold two miles to the west. As a result the rocks dip away from the turn in the fold in all directions except due northwest, where they are prevented from so doing by the continuation of the fold. The crest of the anticline is in section 29, near the Dennison schoolhouse, from which it has derived its name. The structure covers approximately 36 square miles in areal extent and is semi-elliptic in shape, the long axis extending in a general north-south direction. To the northwest the fold continues parallel to the fault, preventing complete closure of the contour lines in that direction.

From the Dennison school the dip of the rocks to the east toward the fracture amounts to over 100 feet per mile, this being the steepest part of the anticline. The dip to the south is about 60 feet per mile, while that to the west is even more gradual, averaging 45 feet. The structure gradually flattens out to the south and west as the rocks

[3] *Loc. cit.*, pp. 59-60.

return to their normal inclination. The total amount of reversal of dip is near 200 feet, and would be, of course, the same as the throw of the Mt. Carmel fault, if there are no fractures accompanying the folding.

Exploitation.—The Dennison Anticline is of sufficient size and extent to serve as a collecting structure for oil and gas. This fact was ascertained a number of years ago and as a consequence six wells have been drilled upon the structure.

The horizons productive of oil and gas in this vicinity are the Devonian and the Trenton limestones, the last named being a sandy dolomite in the Ordovician, productive of petroleum throughout much of the state. The former sand, sometimes called the Corniferous, is reached at about 650 feet from the surface and the Trenton at about 1,700 feet.

The anticline has been rather thoroughly tested for oil and gas as deeply as the Devonian sands. W. H. Weitknecht and Company has drilled four wells on the Dennison structure, located in sections 3, 4, 28 and 33 respectively. Some gas was obtained in each of them along with a showing of oil. The wells were not continued to the Trenton sand, being subsequently abandoned and plugged.

Mr. Claude Malott drilled two wells to the Corniferous sands on the Beavens and Zollman farms in sections 5 and 36 respectively. A small amount of gas accompanied by a showing of oil was found, but neither in commercial quantities.