

## THE MOUNT CARMEL FAULT.

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Early in the fall of 1916 the attention of the writer was attracted to a reversal of dip in some beds of limestone lying in eastern part of Monroe County. In places this reversal of dip was noticeable in the limestones which overlie the Knobstone shales and sandstones, in other places in the sandstones of the Knobstone and again in beds of limestone occupying certain horizons in the Knobstone. Upon an investigation of the available geological literature I found in the Report of the State Geologist for 1893, pages 390-91, that Siebenthal discusses the Heltonville Limestone Strip as follows: "Commencing at Limestone Hill, eight miles southeast of Bloomington and extending east of southeast through Heltonville to, and probably beyond, Fort Ritner, Lawrence County, is a band of limestone from one-half to one and a half miles in width, bordered sharply, both east and west, by Knobstone, and known in that neighborhood as the Limestone Strip. Isolated patches of similar limestone occur north of this strip and in line with it. The strip is well developed in the vicinity of Heltonville, Lawrence County, where it gives exposures of the Harrodsburg, Bedford Oölitic and Mitchell limestones."

At many points the Knobstone contains intercalated lenticular beds of limestone, and it is possibly conceivable that the conditions which prevailed while these beds were being deposited might have been extended over a narrow territory like the Heltonville strip. However, the fact, first, that Knobstone has not been found overlying this limestone, and second, that it shows the lithological facies of the Harrodsburg, the Bedford Oölitic and the Mitchell limestones, and the faunas of these formations, identifies it with them and shows conclusively that it is a narrow band of these formations, occupying a depression in the Knobstone, and not an included member of the Knobstone.

This depression may have resulted from a double fault or may be an old erosion channel. Some things seem to point to one as the origin and some to the other. The facts at hand incline us to the latter view.

The most palpable objection to this view is the fact that no nonconformity exists between the Knobstone and the Harrodsburg limestone at their contact a few miles west of the strip. Another objection is that the bottom of the channel, at present at least, is not all of uniform elevation throughout its length. The principal objections to the view of a double fault are two—at no point was a direct vertical contact of Knobstone and limestone visible, nor was there to be seen any of the tilting, crushing and shattering which usually accompanies faulting. On the other hand, as the vicinity of the contact line is approached the shaly layers of the limestone become more and more argillaceous and apparently pass over into the Knobstone. To determine the exact conditions under which the limestone strip was laid down would require more extended study than is consistent with the scope of this report. What has been done was to trace upon the accompanying maps the outcrop of the Bedford oölitic and to examine the bed more carefully at places where it is now being quarried, namely at Heltonville and Fort Ritner.”

In the proceedings of the Academy of Science of Indiana for 1897, page 262, J. A. Price discusses the boundary of the limestone strip and says in conclusion: “It is not possible, from data in hand, to say surely whether this strip of limestone owes its existence to an unconformity or a fault.”

In 1903 J. F. Newsom published a description of a “Geologic Section Across Southern Indiana” as a part of the 26th Annual Report of the State Geologist. On pages 274 and 275 Newsom refers to the structure as a fault in the Knobstone area. He gives its extent as being from near Unionville in Monroe County to a point in the northern part of Washington County.

In referring to the discussions of Siebenthal and Price in the 27th Annual Report of the State Geologist, 1903, on page 90, Ashley says: “It is evident that if the limestone strip north of White River is due to a fault its effects should continue to the south rather than turn and follow the outcrop. A glance at the map in the region north of Campbellsburg is alone sufficient proof of the fault character of the disturbance.”

In studying this structure in detail the writer has found that it is much more extensive than Newsom stated; that there is a second fault;

that other disturbances were connected with it and that the actual contact which he has found presents some interesting features.

*Extent of the Fault.*—While I have not yet been able to trace the fault to the borders of the State at either of its extremities I have been able to trace it far beyond its mentioned boundaries and feel confident that the particular disturbance under discussion extended from the Ohio to the Wabash along the western border of the Knobstone outcrop and perhaps beyond. Tracing the fault south of Campbellsburg in Washington County is difficult because the area on each side of the rift is occupied by limestone.

Along the northern end of the displacement glacial deposits conceal the bedrock to such an extent as to render observation difficult. Under these circumstances the best that can be done is to trace the disturbance by the reversal of dip of the limestones, as the finding of the rift will be extremely difficult. By such observations as it was possible to make I have traced the disturbance from a point southeast of Campbellsburg in Washington County to a point northwest of Waveland in Montgomery County.

*Rift.*—The actual contact of the rocks along the fault plane is revealed in only a few places. There are numerous places where the harder, more resistant stratum of limestone stands forth like a wall on one side of the rift, but the opposite side is occupied by mantle rock which was derived by the weathering of the Knobstone and which conceals the actual rift. Excavations made at such places would doubtless reveal the actual contact of the limestone and the Knobstone.

In a few localities the rift is exposed and the plane of the fault is bordered on the one side with limestone and on the other by shale. One outcrop of the rift zone was found in the bed of the north fork of Leatherwood Creek near Heltonville. At this point the Knobstone occurs on one side of the fault plane and the Harrodsburg limestone on the other. The line of rift is distinct, being marked by a thin bed of breccia. The brecciated zone is composed mainly of fragments of limestone in which small fragments of shale are intermingled. These fragments have been cemented together with calcite and the whole zone more or less marbled. In a cross-section of the brecciated rock the veins of calcite stand out clearly, as they are whiter than the fragments of limestone and shale which they bind together. Small quantities of

other minerals are present in some parts of the brecciated zone, but there is an absence of the more insoluble minerals, such as silica or the silicates. This fact leads to the conclusion that meteoric rather than thermal waters have played the leading role in the concentration of these minerals.

*Periods of Movement.*—The question of whether the displacement took place all at one time or was intermittent is an interesting one. All of my attempts to find an evidence of intermittent movement by an examination of surface features have been unsuccessful. If there were intermittent movements of any considerable extent we would probably find them revealed in hanging valleys on the upthrow side and the rapid broadening of valleys on the downthrow side of the fault. In case there were two stages of movement, and the movement in the last stage an exceedingly slow one, the vertical cutting of the main stream might be as rapid as the uplift, but still the rejuvenation of the tributaries should result in a narrowing of the valleys. In the rift zone there is evidence of two stages of movement though the amount of displacement in the second stage is slight. The time interval between the two movements was of considerable length, since the fragments of the brecciated zone were firmly cemented before the second movement took place. Fragments of shale which were included in the limestone fragments during the first movement were faulted by the second movement. These shale inclusions would not have undergone faulting had they not been held rigidly in place by the cementing material.

*Amount of Throw.*—The amount of throw of the fault varies probably from 200 to 300 feet. Opportunities for measuring the amount of throw are not numerous. It can best be computed by estimating the total amount of eastward dip of the formations along the line of contact between the Harrodsburg and the Knobstone. At a point south of Mt. Carmel the difference in elevation of the contact above sea level is 50 feet in a distance of one-fourth mile. Since the width of the down-thrown block is at least one mile and a half in this locality the throw of the fault is at least 300 feet. The amount of dip of the down-thrown beds in other localities is less than at this point, so much less that the indicated throw is not more than 200 feet.

*Age of the Fault.*—The time at which the dislocation occurred can not be fixed definitely. It is probable that it occurred at the close of the

Paleozoic Era when the Appalachian revolution which resulted in the elevation of the eastern part of North America took place. Contemporaneous with or subsequent to that great epeirogenic movement, faulting and minor folding took place in Indiana, Illinois and Iowa, and other States lying as far west as these from the region of maximum disturbance. These faults like the one under discussion have a north-west trend.

*The Heltonville Fault.*—About one mile west of the Mt. Carmel fault there is a second fault. This I have named the Heltonville fault because the rift is exposed a short distance east of Heltonville in the bed of the north fork of Leatherwood Creek, at a point just east of the wagon crossing under the Southern Indiana railroad. This fault lies approximately parallel with the Mt. Carmel fault. The limestone has been faulted down against the Knobstone. Slickenslides have been produced in the limestone and it has been much fractured. In places the limestone has been thrust backward and fragments of the Knobstone shales have been thrust into the limestone. In places these formations are dovetailed, fingers of limestone projecting into the Knobstone and vice versa as first one and then the other yielded to the pressure. The fragments of limestone containing inclusions of shale have been united by calcite veins.

Though the fault character of the disturbance at this point is incontestable it is not equally clear at other points. The disturbance extends both north and south of this point, but it probably passes into a fold in both directions. In Monroe County near Unionville there is an anticline which occupies about the same position in relation to the Mt. Carmel fault as the Heltonville fault does. Similar folds have been noted at intervening points and also to the south of Heltonville.

*Effect Upon Topography.*—The general effect upon topographic conditions within the area of disturbance has been to produce a narrow limestone belt extending parallel with the main Knobstone outcrop and bordered on each side by outcrops of Knobstone. In the southern portion of the faulted area the western belt of Knobstone is absent, but its nearness to the surface along the line of the eastward reversal of dip is revealed in the channels of many streams which have carved their valleys at right angles to the line of reversal. Probably the most marked effect is on the drainage. Both surface and underground

drainage lines are affected. In the faulted area the ground waters which have found their way through the limestone have a tendency to follow the eastward sloping surface of the Knobstone to the rift, and near this point often come to the surface in a stream valley which lies near the rift and generally parallel with it. This tendency of the underground streams is modified by local dips of the strata north or south.

The surface streams, especially those along the line of the fault plane, have been influenced by the displacement. They have worked off the harder limestones on to the Knobstone in many places. These follow the line of rift until a local north or south dip has caused them to change the direction of their course. Small tributaries of the larger cross-cutting streams have developed, as has been noted again and again, along the line of rift.