GEOLOGIC STRUCTURE OF A SMALL AREA WEST OF MILL SPRINGS, KENTUCKY

By Thomas S. Knapp

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the Department of Geology of the University of Michigan.

April 30, 1932

INTRODUCTION

This paper describes the geological structure of the rocks in a small area in Wayne, Pulaski, and Russell counties a few miles west of Mill Springs, Wayne county, Kentucky. The area, which is shown in the north-central part of the Monticello, Kentucky, topographic sheet of the United States Geological Survey, is rectangular in shape. Its length in a north-south direction is about 6 miles and its width about 3½ miles. See map 1.

The study of the structural geology of the area was suggested to the writer by Professor G. M. Ehlers of the Department of Geology of the University of Michigan, to whom the writer is greatly indebted for aid in planning the field work and in preparing the manuscript of this paper.

The writer is also indebted to Mr. Joseph Conrad Twinem, of the University of Maine, and Mr. Robert Hefferan, a senior in the University of Michigan, for assistance in the field.

PHYSIOGRAPHY OF AREA

The area is located in the Highland Rim section of the Interior Low Plateaus physiographic province.

The major topographic features of the area are the result of erosion and deposition by the Cumberland River during past and present geological times. Three distinct topographic levels have resulted from the work of this river. The lowest of these is represented by a river flat, the "river bottom" of the local residents. The average elevation of this flat is about 640 feet above sea level. In summer the Cumberland River is usually about 50

feet lower than the river flat; in the winter season it often covers the flat. A higher topographic level, the Highland Rim Plateau, is present at an elevation of 900 to 950 feet. This level was produced by planation of the river during late Tertiary or early Pleistocene time. The surface of this plateau is modified by sink holes, which are very numerous in the southeastern part of the area, and by stream erosion, which has been especially active north of the river. The highest topographic level is the Cumberland Plateau, the average elevation of which is about 1300 feet in adjacent areas.

A small outlier of this plateau, the summit of which has been lowered to an elevation of 1100 feet by erosion, is located close to the eastern boundary of the area about 1¾ miles northeast of Rankin. See map 1.

STRATIGRAPHY OF AREA

The area is located on the southeast limb of a saddle connecting the Jessamine and Nashville Domes of the Cincinnati Geanticline. Owing to the position of the area on the southeast side of the saddle, the regional dip is to the southeast. Except where local reversals of dip occur, successively younger beds are encountered as one proceeds southeastward across the area.

Rocks of Mississippian age compose most of the stratigraphic section, but older beds of Ordovician and Silurian age outcrop at Shinbone Cliff and at many places in the tributary streams on the north side of the Cumberland River.

Description of Formations

Richmond Formation:- The Richmond formation, which is included in the Ordovician system by most geologists and in the Silurian system by others, is the oldest formation exposed in the area. It outcrops at Shinbone Cliff, in Little Cub Creek, and in Forbush Creek. The lower half of the formation consists of a thin and even-bedded ripple-marked and sun-cracked greenish-grey limestone; the upper part consists of uneven and thicker bedded buff-grey limestone which has a nodular appearance on weathered surfaces. According to Donald C. MacLachlan[1], 46 feet of Richmond are exposed at Shinbone Cliff.

Brassfield Formation:- The Brassfield formation of lower Silurian age rests disconformably upon the Richmond. The Brassfield formation is a massive buff to reddish-grey magnesian-limestone, containing fluted cystid columnals. At Shinbone Cliff it is approximately 10 feet thick. Good exposures of the formation are present along Forbush Creek and some of its tributaries.

Crab Orchard Formation:- The Crab Orchard formation of middle Silurian age rests disconformably on the Brassfield. It consists of interbedded greenish shale and greenish-grey to buff limestone. Dr. Foerste[2] noted the occurrence of 17 feet of Crab

---

[1] MacLachlan, D. C.: "Geologic Structure of a Small Area in Wayne, Pulaski, and Russell Counties, Kentucky," Papers Mich. Acad. of Science, Arts and Letters, vol. 8, p. 300, 1927.

[2] Foerste, Aug. F.: "The Cincinnati Anticline in Southern Kentucky," The American Geologist, vol. 30, 362, 1902, and "The Silurian, Devonian and Irvine Formations of East-Central Kentucky," Kentucky Geol. Surv., bull. 7, pp. 114-115, 1906.

Orchard at Shinbone Cliff. A small exposure of the formation also is present in the bank of Cub Creek about 200 feet upstream from the Wayne-Russell county line.

During pre-Mississippian time, the Richmond, Brassfield, and Crab Orchard were subjected to erosion. The Brassfield and Crab Orchard were entirely removed from some parts of the area so that the Mississippian beds were deposited unconformably on the Richmond.

Chattanooga Formation:- The Chattanooga shale is the oldest Mississippian deposit in the area. It is a well-jointed, black, fissile, bituminous shale containing linguloid brachiopods and conodonts. See plate 1, figs. 1 and 2. A brown sandstone, 1 to 2 inches in thickness, is commonly present at the base of the formation. At a few places this sandstone has a thickness of 3 feet. At some localities nodules of marcasite are present in the upper beds of the formation. A small number of cherts occur near the base of the formation along Little Cub Creek. The formation ranges in thickness from 33 to 38 feet.

New Providence Formation:- The New Providence formation, which rests disconformably on the Chattanooga shale, consists of three distinct parts. The lower part consists of a greenish-grey to bluish-grey shale which weathers to a greenish-grey clay. See plate 2, fig. 2. The basal beds contain phosphate nodules, which at some places are very numerous. The middle part of the formation is a hard siliceous, encrinal limestone, containing irregularly shaped masses of chert arranged parallel to the bedding. See plate 2, fig. 1. This limestone, known locally as the "Beaver Creek

sand", is an oil and gas producing stratum in the Monticello-Steubenville pool a few miles southeast of the area. The upper part of the New Providence is lithologically similar to the lower, differing from the latter in being more calcareous. The thickness of the lower New Providence ranges from 23 to 50 feet, the middle from 3 to 7 feet, and the upper from 35 to 50 feet.

Overlying the New Providence in the order named are the Fort Payne, Warsaw, St. Louis, Ste. Genevieve, and Gasper formations of Mississippian age. The Pennsylvanian is represented by the Lee sandstone, which caps the tops of several outliers of the Cumberland Plateau a short distance southeast of the area. River gravels, thought to belong to the Irvine formation of late Pliocene or early Pleistocene age, are present in patches on the Highland Rim Plateau. The alluvium of the river flat may in part be of later Pleistocene as well as post-Pleistocene age.

FIELD METHODS USED IN DETERMINING STRUCTURE OF AREA

The top of the Chattanooga shale was selected as a key horizon for mapping the structure of the area. This selection was made because the shale was very little eroded prior to the deposition of the overlying New Providence shale and is lithologically distinct from overlying and underlying strata.

The elevations of the top of the Chattanooga shale and the locations of these elevations were determined by the use of a telescopic alidade and plane-table.

The approximate elevation of the top of the Chattanooga shale was obtained at many places by first determining the eleva-

tion of the base of this shale or the base of the Beaver Creek limestone. When the elevation of the base of the Chattanooga shale was used, the thickness of the shale, which ranges from 33 to 38 feet, was added to it. When the elevation of the base of the Beaver Creek limestone was used, the interval between this limestone and the top of the Chattanooga shale was subtracted from the elevation of the base of the Beaver Creek limestone in order to obtain the elevation of the top of the Chattanooga shale. Owing to a considerable variation in the thickness of the interval between the Beaver Creek limestone and the Chattanooga shale, it was necessary to make frequent measurements of this interval.

STRUCTURAL GEOLOGY OF THE AREA

The most prominent structural feature is an elongated dome located in the central part of the area. See map 1. It has a narrow crest which extends N. 25° W. for a distance of about a mile and a half. The elevation of the highest point along the crest is about 685 feet. The closure of the dome is 25 to 30 feet. The dome is slightly asymetrical, the dip on the east side being about 90 feet per mile and on the west side about 80 feet per mile. The crest of the dome plunges to the southeast at a rate of about 80 feet per mile for the first quarter of a mile, decreasing gradually to 25 feet per mile near the southern boundary of the area. The southeast end of the dome is modified by a structural nose which curves to the southwest and disappears in the syncline on the west side of the dome. At its northwest end the dome dips northward at a rate of 50 feet per mile for a

quarter of a mile and then flattens out abruptly into a structural saddle connecting the dome with the homocline occupying the northern quarter of the area. The elevation of the lowest point along the crest of this saddle is about 643 feet above sea level.

In 1927 MacLachlan[3] published a map on which he showed the dome as having a lower and flatter crest than the findings of the present writer would indicate; he also showed the elongation of the dome as extending in a north-south direction instead of in a northwest-southeast direction as determined by the writer. The difference in the form and orientation of the dome as illustrated on MacLachlan's and the writer's maps is due to different methods of determining elevations of the top of the Chattanooga shale. MacLachlan obtained these elevations by reference to elevations given on the Monticello topographic sheet. Careful observations by the writer have shown that numerous elevations on this sheet are incorrect, many of the contours apparently having been plotted without an adequate number of readings. The fact that the present writer based his mapping on a larger number of more accurately determined elevations of the top of the Chattanooga shale is ample reason for believing that the morphology of the dome as shown on map 1 is correct.

In the northeastern part of the area the homocline is modified by a structural terrace, the southern margin of which is at an elevation of 700 feet. Below this margin of the terrace the inclination of the top of the Chattanooga shale is 105 feet to

---

[3] Op. cit., fig. 24.

the mile. This rather steeply inclined surface forms the northeast limb of a pitching syncline, which lies to the east of the dome. North of the margin of the terrace the surface of the structure rises gradually at a rate of about 25 feet to the mile to the northern boundary of the area where the elevation is a little more than 730 feet, the highest structural elevation in the area.

In the north-central and northwestern parts of the area the amount of inclination of the homocline is fairly uniform.

The syncline located south of the terrace previously mentioned and northeast of the dome pitches S. 45° E. A similar pitch for this syncline is shown on the map published by MacLachlan.

A quaquaversal syncline having a slight east-west elongation is present northwest of the dome. The elevation of the bottom of the syncline is between 630 and 635 feet. The only closed contour within the syncline represents an elevation of 640 feet.

The writer's representation of this structure differs from that of MacLachlan. MacLachlan's map shows the syncline as opening to the south, the 640 foot contour not being closed but curving southward around the dome and partly around a faulted anticline located to the southwest. A saddle to the south of the syncline is indicated on his map by a constriction of the 640 foot contour line opposite the southeastern extension of the fault. The absence of outcrops which might give information relative to the elevation of the top of the Chattanooga shale precludes the possibility of determining the exact nature of the structure from direct observation. A factor which has a bearing on the position and height of

the saddle south of the syncline is the orientation of the faulted anticline. The plane of the fault follows the crest of the anticline at Shinbone Cliff. It is therefore possible to obtain the direction of the trend of the anticline from the strike of the fault. MacLachlan[4] states that the strike of the fault is N. 22° W. If this is true, the anticline would pitch into a broad syncline located west of the dome and hence the saddle southeast of the anticline very likely would be low. The supposed lowness of the saddle therefore led MacLachlan to believe that the 640 foot contour was not closed. The writer plotted the fault and found its strike to be N. 55° W. The trend of the anticline, which coincides with this strike, towards the northwest end of the dome and the nearness of the dome very strongly indicate that the top of the saddle is higher than 640 feet. The height of the saddle leads the writer to close the 640 foot contour north of the saddle, thus accentuating the quaquaversal nature of the syncline to the north.

The fault at Shinbone Cliff is a normal fault with a displacement of 15½ feet measured on the base of the Brassfield. The dip of the fault plane, which is easily recognized by a thin band of gouge, is 89° to the northeast, the strike of the fault being N. 55° W.

A considerable drag of the Richmond, Brassfield and Chattanooga strata is present on the northeast or down-thrown side of the fault. The 22 degree dip of the Brassfield strata near the

---

[4] Op. cit., p. 306.

fault decreases very rapidly towards the northeast and at a distance of about 150 feet from the fault is only 5 or 6 degrees.

On the southwest or up-thrown side of the fault the beds are nearly horizontal for the first 5 feet beyond the fault and at a distance of 15 feet beyond the fault the beds dip 6° S. 75° W.

A few hundred yards southwest of the fault the dip of the strata changes to a northeast direction. This is well shown on the face of Shinbone Cliff and in Little Cub Creek. The Chattanooga shale does not have as great a dip as the underlying Brassfield and Richmond and rests on the thin, even-bedded limestone of the lower part of the Richmond a few hundred yards southwest of the fault.

The reversal in dip noted above and the determination of certain elevations of the top of the Chattanooga shale indicate the presence of a nose at the western margin of the area to the southwest of the faulted anticline.

A broad syncline, which flattens out to the south, is present to the south of the saddle connecting the faulted anticline with the dome.

It is quite likely that the folding of the Chattanooga shale in the entire area took place during the interval between the cessation of deposition of this shale and the beginning of deposition of the New Providence sediments. This is indicated by the thinning of the lower part of the New Providence over the higher structural elevations of the top of the Chattanooga shale. The rather striking uniformity in thickness of the Chattanooga formation over the entire area indicates that there was very little erosion during the interval prior to the deposition of the New Providence.

POSSIBILITIES FOR OIL AND GAS IN AREA

Three wells have been drilled near the north end of the dome. Two of these produced gas, the third being abandoned at shallow depth. One of the gas wells located a short distance north of the Forbush Creek supplied the farmhouse of Mr. W. L. Scott with gas fuel for three or four years before it became flooded with water. The second gas well, located about a quarter of a mile southwest of the first well, was drilled to a depth of 1100 feet but was permitted to become flooded as the result of improper casing.

As far as can be learned four gas "sands" were encountered in these wells. According to the driller of the second gas well the gas "sands" consist of porous zones within limestones. These "sands" probably occur in the Lexington or so-called Trenton group.

It is very likely that producing gas and oil wells may be drilled on the dome and possibly on the structural terrace.

Unfortunately an insufficient number of wells have been drilled to indicate the structure of the producing sands. However, intelligent drilling based on the structure of the Chattanooga shale will eventually make it possible to determine the nature of the subsurface structure.

Flint, Michigan

PLATE I

Fig. 1. Typical exposure of Chattanooga shale, about 100 feet north of house of Mr. W.L. Scott located ¼ mile north of mouth of Forbush Creek.

Fig. 2. Outcrop of Chattanooga shale in Forbush Creek showing fissility and jointing.

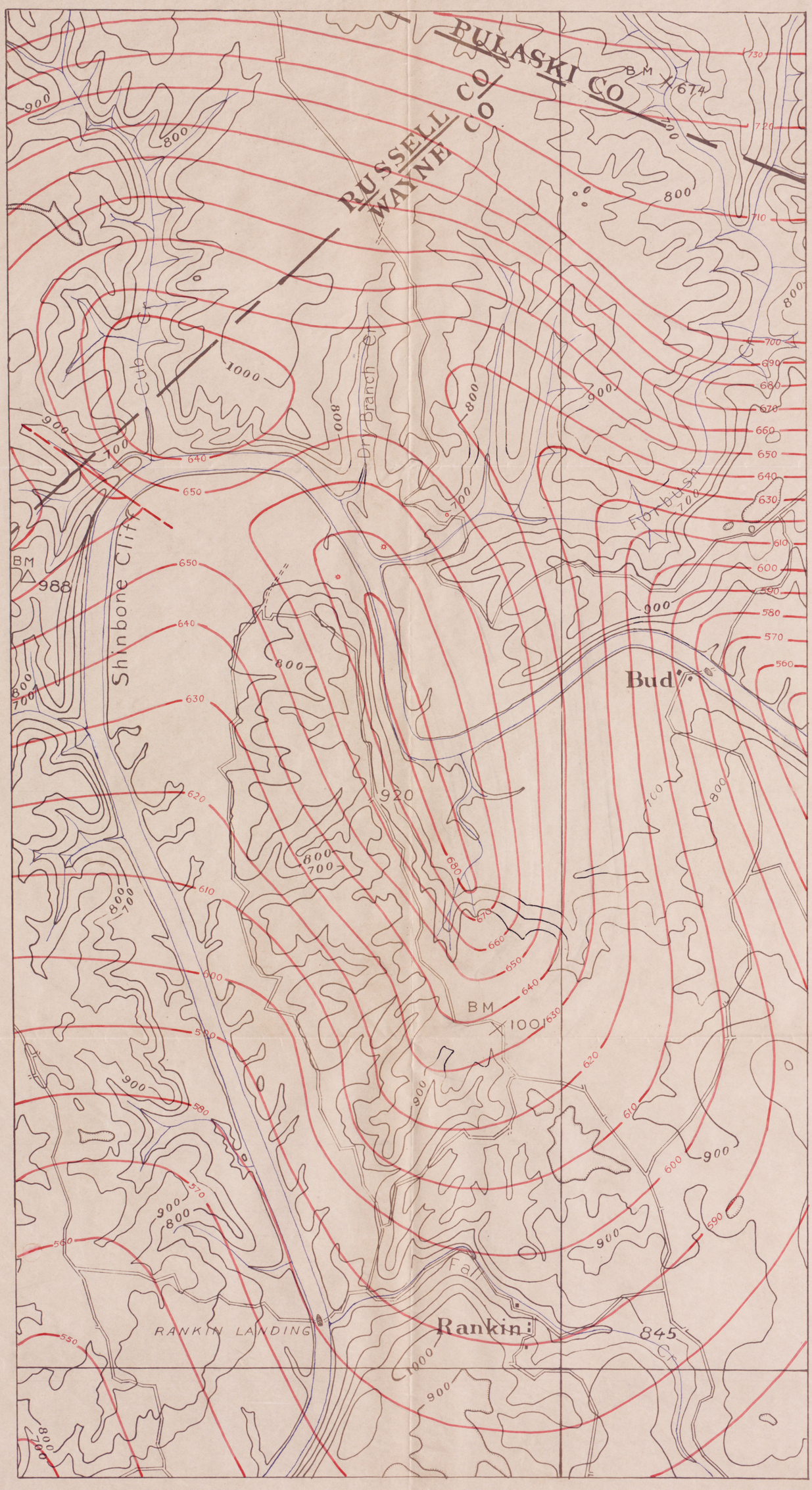
PLATE II

Fig. 1. Typical ledge of weathered Beaver Creek limestone in Cub Creek., The white irregular-shaped masses consist of chert.

Fig. 2. Weathered shale of the lower part of the New Providence, shown in hillside about ¼ mile east of mouth of Forbush Creek.

Map I. Structural and topographic contour map of the area described in this paper. The structural contours indicate the position above sea level of the upper surface of the Chattanooga shale.

MAP I.


RULASKI CO
RUSSELL
WAYNE
Co.
Co.
BM 1674
Dry Branch Cr
Cub
Shinbone Cliff
BM
988
Hot Bush
Bud
920
BM
1001
Rankin
RANKIN LANDING
845
Cr
-800- TOPOGRAPHIC CONTOURS
CONTOUR INTERVAL 100 FEET
-600- STRUCTURAL CONTOURS
CONTOUR INTERVAL 10 FEET
SCALE IN MILES
0 ¼ ½ 1
GAS WELLS
ABANDONED WELL
NORMAL FAULT