GEOLOGIC STRUCTURE IN THE INDIAN AND TRINITY SPRINGS LOCALITY, MARTIN COUNTY, INDIANA

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Introduction. The purpose of this paper is to present the details of the topography, stratigraphy and structural geology of a locality in southwestern Indiana which has hitherto received little attention in these respects. Some rather unusual drainage and topographic features first attracted the attention of the writer, and a detailed study of them led to the consideration of the geologic formations of the region. It was found that the unconformity between the massive basal sandstone of the Pennsylvanian system and the Chester formations of the upper Mississippian system possesses some rather unique relief characteristics. It is believed, however, that the valley-like relief features of this notable unconformity as revealed in the locality are a general characteristic of the unconformity over a rather large area, and it is hoped that the study will call attention to the detailed characteristics of this wide-spread unconformity elsewhere. In addition to the relief features of the Pennsylvanian-Mississippian unconformity, it was discovered that the region possesses an anticlinal structure of greater size and distinctness than is common in southwestern Indiana. The features of topography, and geologic structure are depicted on the specially prepared maps which constitute the most important part of this presentation.

Location of the Area. The area which is the subject of this paper consists of 12 square miles in the middle northeastern part of Martin County, Indiana. The area is six to 10 miles north-northeast of Shoals, the county-seat, and about 15 miles southwest of Bedford in Lawrence County which adjoins Martin on the east. The area is in congressional Township 4 north, Range 3 west, and comprises all of sections 8, 9, 16, 17, 20, 21, 29, and 28, and parts of sections 7, 10, 15, 18, 19, 22, 27, and 30, as shown on the accompanying maps. The villages of Indian Springs and Cale are near the northern margin along the Chic. Mil. and St. Paul Railway which crosses the northern part of Martin County. The village of Trinity Springs is near the southern margin of the mapped area and about three miles south of Indian Springs. The area has been designated the Indian and Trinity Springs locality after these two villages which in turn have been named for two highly mineralized springs near which they are located.

An improved road leads south through the region from Indian Springs to Shoals, passing about one-half of a mile west of Trinity Springs. The Williams-Bedford road leads east from Indian Springs through Cale and thence northeast. Another improved road passes through Trinity Springs and connects with the Shoals road and the Williams-Bedford road. Other roads shown on the maps are in poor condition and are subject to little travel.

The region is in the Indian Creek drainage basin a short distance north of the junction of Indian Creek with the East Fork of White River. Sulphur Creek joins Indian Creek just south of the center of the area. These two streams are fed by springs and flow throughout the year. Physiographically the region is located in the driftless area a few miles east of the glacial boundary in southwestern

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Indiana. It is wholly within the Crawford upland which constitutes the most rocky and rugged physiographic division in southern Indiana[1]. Geologically the region is located along the boundary zone of the Mississippian and Pennsylvanian formations. It is with respect to the features pertaining to the boundary that the region is especially interesting topographically and geologically.

Altitude and Topography. The altitudes in the Indian and Trinity Springs locality range from 460 feet above sea level on Indian Creek at the southern margin of the area to 775 feet in the hills about three-fourths of one mile southwest of Indian Springs village. The maximum relief of the region is therefore 315 feet. The rather flat floors of the valleys of Indian and Sulphur creeks are below 500

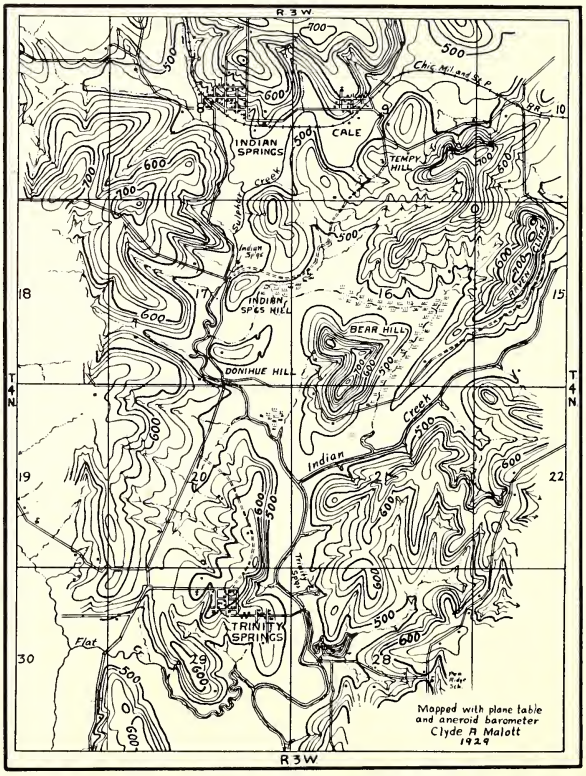

Fig. 1—Topographic map of the Indian and Trinity Springs locality, Martin County, Indiana Contour interval: 25 feet.

feet. The rugged upland ridges and the outstanding isolated and nearly isolated hills reach varying altitudes up to the maximum of 775 feet. The topographic map, Fig. 1, based upon plane-table sketches and barometric determinations of altitude, shows the altitudes and the topography of the region in terms of 25-foot contours.

[1]See *Handbook of Indiana Geology*, 1922, pp. 98-102 and 215-220.

Topographically the region consists of the main and minor valleys of a highly dissected upland plain with a relief of 300 feet or more. Only a small part of the area reaches back away from the influences of the main valleys. Consequently the outstanding topographic features are in close association with the flat-floored main valleys rather than with the intervalley upland plain which would be included in a larger section of the same region.

The broad, flat floors of the valleys of Sulphur, Indian and Flat creeks are in great topographic contrast to the rocky and rugged upland spurs and upstanding isolated hills or hill tracts which rise in relief. Swampy areas are common in the flat valley floors. A set of low terraces marks all of the main valleys. The flood plain areas below the terraces are subject to the backwater floods from White River. In January 1929 backwater from White River extended up Sulphur Creek as far as the railway at Indian Springs and the ice frozen on the surface marked the trees throughout the lowland area at an estimated altitude of 485 feet. These marks on the trees and the trash line formed at the edge of the backwaters along the valleys served as an extensive bench mark in the making of the topographic map by barometer in the early spring of 1929.

The isolated hills or hill tracts are very striking features of relief. Bear Hill near the center of the mapped area rises abruptly more than 250 feet above the alluviated valley floors about it. It is the most conspicuous hill of the entire region because of its abrupt rocky slopes, great height and the broad, flat and swampy valley area which completely surrounds it. Donihue Hill just west of it is a small counterpart of Bear Hill. Both are hills of circum-denudation and hills of circum-alluviation. Indian Springs Hill, named from the mineral springs which issue at creek level just northwest of the hill, rises about 75 feet above Sulphur Creek. This hill is nearly severed from the upland, only a narrow neck on the northwest saving it from being a hill of circum-alluviation. In the northwest corner of Sec. 17, just north of Indian Springs Hill, is a hill of circum-denudation which rises 100 feet or more above the valleys and saddles which encompass it. Tempy Hill, southeast of Cale, is a compound hill tract with abrupt sandstone slopes and bluffs which has been practically severed from the upland plain by valley dissection. Similarly Raven Cliffs Hill with its southwesterly projecting snout and the compound hill tract upon which the village of Trinity Springs is built are abrupt nearly isolated hills of circum-denudation. They are surrounded by valleys and low and open saddles between the heads of minor valleys on the sides away from their cliffed sides along the main valley. These hills of circum-denudation and their relations to the valleys which encompass them are clearly depicted on the topographic map, Fig. 1.

Physiographical Development. The Indian and Trinity Springs locality is in the rugged Crawford upland of southwestern Indiana. In general the upland ridges in the intervalley areas of northern Martin County range from 700 to 800 feet or slightly more in altitude. Some ridges adjacent to the major streams have been unevenly reduced below the common altitude. A careful analysis of the topographic condition of the region indicates that the upland divides are remnants of an old erosion surface reduced to a relatively low relief in which the interstream areas were rarely more than 100 feet above the very broad valleys of the main streams. The common level of the old valleys if restored would be at present about 700 feet above sea level. The presence of cherty stream gravels on the ridge spurs and divides at or near that level along White River

confirms the suggestive origin of the common level of the remnants of the upland plain. These old stream gravels are thought to have been deposited in the wide valley of white River before the close of the Tertiary period and are correlated with the Lafayette gravel of late Pliocene age. Some remnants of these stream gravels are present along the road on the divide north of Pea Ridge School in the NE ¼ of Sec. 28 and the SW ¼ of Sec. 22 at altitudes of 660 to 675 feet. These gravels are probably lower than the general level of the original surface on which they were deposited. They are not far from a great valley meander cut-off of White River which makes a northward swing southeast of Pea Ridge School. The upland surfaces which reach 700 feet or more are regarded as remnants of the late Tertiary peneplain which has been greatly dissected since its uplift at the close of the Tertiary period or in the initial part of the Pleistocene.

The present valleys are trenches developed below the late Tertiary peneplain. The main valleys have been cut out 200 to 300 feet below the level of the old uplifted peneplain. The ridges and hills have been left in relief above the floors of the valleys, and they also have suffered sculpture and reduction in uneven amounts. As a rule the upland ridges near the main streams have suffered the greatest reduction and sculpture.

It appears that the floors of the main valleys have not always been at the level which they now have. First they were cut deeper than their present level of 475 to 495 feet. Then they were filled probably 50 to 80 feet with silts which greatly broadened them. In recent times the silt material has been partly removed and flood plains established at a lower level, leaving areas of the fine grained calcareous silts which stand out as terraces along the valleys. The terraces along Indian, Flat and Sulphur creeks have a common altitude of about 490 feet. They extend as terraces as far up Sulphur Creek as Cale where the present broad flood plain coincides with the terrace level. The valley-fill material is characteristically a laminated calcareous silt which appears to have accumulated in ponded waters held back in Indian Creek valley by the upbuilt valley train formed in White River valley during the early part of the Wisconsin Glacial stage. The present flood plains developed below the silt terraces are post-Wisconsin or recent.

Bear Hill appears to be a meander core which was cut off before the valley filling period of late Pleistocene time. Indian Creek valley is remarkably crooked upstream from the region. It appears that a great valley meander passed about Bear Hill. By lateral planation the spur which once connected the present Bear Hill with the upland in the south part of Sec. 21 was severed through the narrow neck, and Indian Creek then took the short route through the newly opened passage. The abandoned valley loop about Bear Hill is approximately three miles in length. During Wisconsin glacial times the cut-off part of the valley was filled with silts in common with Indian and Sulphur creeks to an altitude of 490 to 495 feet. Its present low, swampy condition is associated with the partly filled channel scar which connects with both Sulphur and Indian creeks, as indicated on the topographic map, Fig. 1. It is apparent that this channel scar was made by Sulphur Creek which has only recently ceased to occupy the upper two-thirds of the old upbuilt valley. It followed up the cut-off valley meander following a course reverse to that of its pre-Wisconsin predecessor. Why it took this route rather than the shorter lower part of the valley loop is not clear. Its abandonment by Sulphur Creek is related to the developmental history of Donihue Hill.

Donihue Hill, like Bear Hill, is a hill of circum-alluviation, but it is not a meander core. Donihue Hill appears to be a remnant of a spur which separated

the valley of Sulphur Creek and the valley of the stream which now connects broadly with Sulphur Creek west of Donihue Hill. Apparently Sulphur Creek valley made an eastward turn just south of the center of Sec. 17 and passed between Indian Springs and Donihue hills before entering Indian Creek valley west of Bear Hill. By lateral planation, aided, perhaps, by valley filling, Sulphur Creek severed the ridge between it and the smaller stream south of it. It now goes directly south through the opening along the present route. Donihue Hill is therefore the severed end of a spur and is associated with a case of planation stream diversion or piracy. It is not clear whether this diversion of Sulphur Creek took place before the valley filling period or later. It is quite certain, however, that only recently has Sulphur Creek abandoned the route north of Donihue and Bear hills.

Stratigraphy. The Indian and Trinity Springs locality lies in the zone of the overlap of the Mansfield sandstone of lower Pennsylvanian age and the Chester formations of upper Mississippian age. The Mississippian strata occupy the valleys and the lower part of the valley slopes, while the basal Pennsylvanian Mans-

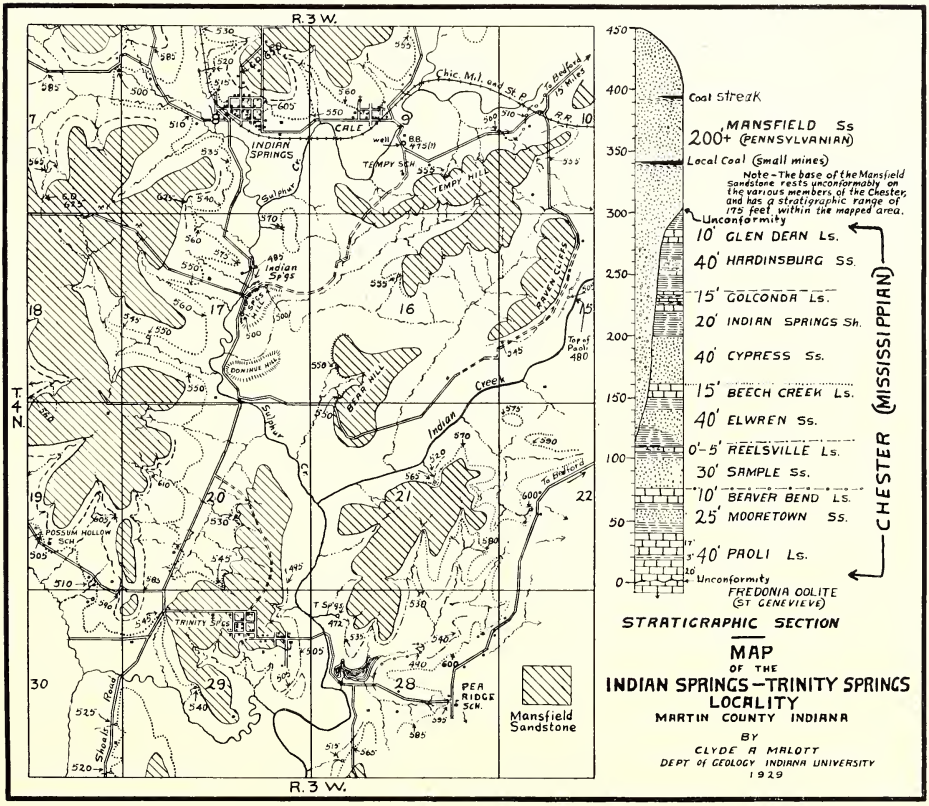

Fig. 2—Map of the Indian and Trinity Springs locality showing the areas of the occurrence of the Mansfield sandstone and the lines of the outcrops of the Chester limestones where they are known to occur. Altitudes are indicated on outcrops of the Chester limestones.

field sandstone occupies the ridges and upper part of the valley slopes, except in the southeastern part of the area along the Williams road northeastward from Pea Ridge School where the Pennsylvanian is absent. The outcrop areas of the Mississippian and Pennsylvanian formations are shown in Fig. 2.

The upper Mississippian or Chester strata of southern Indiana consist of many formations which constitute a series alternately composed of limestone and sandstone chiefly. In all, ten limestone units and nine sandstone or clastic units are now recognized in the outcrop area stretching northward from the Ohio River in Perry and Crawford counties to Putnam County. The limestone units exhibit diagnostic characteristics and are rather readily identifiable. The clastic units, mainly composed of fine-grained massive sandstones rather loosely cemented, are not readily determinable by themselves. They occupy and fill (with or without shale) intervals between the diagnostic limestones. The entire series of units or formations in southern Indiana and their probable correlates in southern Illinois are as follows:

	Indiana	*Illinois*
19.	Negli Creek ls.	Kinkaid ls.
18.	Mt. Pleasant ss.	Degonia ss.
17.	Unnamed Sh. and ls. interval	Clore ls.
16.	Bristow ss.	Palestine ss.
16.	Siberia ls.	Menard ls.
14.	Wickcliff ss.	Waltersburg ss.
13.	Unnamed Sh. and ls. interval	Vienna ls.
12.	Tar Springs ss.	Tar Springs ss.
11.	Glen Dean ls.	Glen Dean ls.
10.	Hardinsburg ss.	Hardinsburg ss.
9.	Golconda ls.	Golconda ls.
8.	Cypress ss.	Cypress ss.
7.	Beech Creek ls.	Paint Creek fm.
6.	Elwren ss.	
5.	Reelsville ls.	
4.	Sample ss.	Bethel ss.
3.	Beaver Bend ls.	Renault ls.
2.	Mooretown ss.	
1.	Paoli ls.	

In southern Indiana it is only in Perry County along the Ohio River that all 19 of the recognized formations are present. The Mansfield sandstone forming the base of the Pennsylvanian in Indiana and resting unconformably on the Chester and lower formations, progessively descends lower and lower stratigraphically northward from the Ohio River. In the Indian Springs locality of Martin County the Glen Dean limestone is the highest Chester unit. Farther north, in middle western Putnam County, the Mansfield sandstone descends below the Chester and rests upon sub-Chester formations from there northward.

The thicknesses of the formations and the general characteristics of the clastic intervals are indicated for the Chester series in the Indian and Trinity springs locality in the stratigraphic section shown in Fig. 2. Only the top of the Paoli limestone shows at the very eastern margin of the region near the center of Sec. 15 in the bed of Indian Creek. Nearby is a poor exposure of the Mooretown

mostly composed of shale. The Beaver Bend limestone is exposed at or near drainage level in the W. ½ of Sec. 15, in the W. ½ of Sec. 10, along the branch just north of the center of Sec. 28, and along the foot of the bluff on the northwest side of Indian Springs hill in Sec. 17. It appears to be 5 to 15 feet thick, its greatest thickness being at Indian Springs Hill. Where exposed in the roadside near the railway in the W. ½ of Sec. 10 it is very impure, containing pebbles of clay and much sand. Usually it is a relatively pure, white, oolitic limestone.

The Sample sandstone is rather massive where exposed in the region. Excellent exposures of it occur in the railroad cut west of the center of Sec. 10; in the bluff at the bridge across Sulphur Creek just southeast of Cale; in Indian Springs and Donihue hills; and at and near drainage level at the Trinity Springs in the NW ¼ of Sec. 28. It is difficult to find the top of the sample sandstone in much of the mapped area, because of the poor development of the Reelsville limestone unit in the region. The Reelsville is only a few feet thick and appears to be normally developed in only a few outcrops in the southeastern part of the area. It is about five feet thick in the SE ¼ of Sec. 21, and in the NW ¼ of Sec. 28 where it is exposed as a weather-stained oolitic limestone. Its horizon is identified elsewhere by thin fossiliferous plates of limestone one-half of an inch or more in thickness imbedded in shale, or by a very fossiliferous brown sandstone horizon a few inches to a few feet thick. Both of these phases are exhibited west of Indian Creek along the abandoned railway cuts in the NE ¼ Sec. 29, near the village of Trinity Springs.

The Elwren clastic interval of sandstone and shale is not readily distinguished in many exposures which are certainly below the Beech Creek limestone. It appears to make up a part of the massive sandstone below the Beech Creek limestone in the N ¼ of Sec. 9, just northeast of Cale. Ledges of it show below the spring east of the railway one-fourth of one mile northeast of Indian Springs village. It is quite probable that the upper part of the sandstone in Indian Springs and Donihue hills is Elwren sandstone, though the horizon of the Reelsville limestone is not discernible. The soft olive shale exposed in the road below the pebbly Mansfield sandstone in the southeast edge of Bear Hill is Elwren. Shows of sandstone and shale occur below the Beech Creek springs in the SW ¼ of Sec. 28, in SE ¼ of Sec. 28, in NE ¼ of Sec. 21, and in the NW ¼ of Sec. 16.

The Beech Creek limestone is the most wide-spread readily identifiable limestone unit in the area and perhaps also throughout the Chester outcrop area in southern Indiana. Springs very commonly issue from its base, heading in a sharp valley which ends abruptly in an overhanging wall of the Cypress sandstone. Twenty such springs are located along the outcrop line shown in Fig. 2. The limestone may be identified by the presence of large delicately marked crinoid stems which show on its weathered surfaces. The limestone is a hard, gray, semi-crystalline limestone which exhibits in weathered surfaces ragged cubical blocks a few inches across. Except where the limestone is overlaid by the Mansfield sandstone the fine-grained massive and evenly laminated Cypress sandstone rests directly over it. The Beech Creek appears to be rather uniformly 15 feet thick throughout the area.

The Cypress sandstone is about 40 feet thick and typically is a massive, evenly laminated sandstone which holds its thickness and characteristics with little variation throughout the outcrop area of the Chester in southern Indiana. It rests upon the Beech Creek limestone usually without a trace of shale. Twenty feet of shale commonly intervene between it and the Golconda limestone formation

above. This shale is a foil rock for the massive resistant sandstone and benches are commonly formed on the Cypress sandstone. This shale is always present and it has been called the Indian Springs shale after the outcrop one-fourth of one mile northwest of the village of Indian Springs above the outcropping bench of massive Cypress sandstone and below the outcropping slabs of Golconda limestone. The 40 feet of Cypress sandstone and the 20 feet of blue-gray shale constitute the clastic interval between the Beech Creek limestone and the Golconda limestone.

The Golconda limestone formation is usually poorly developed in the eastern section of its outcrop. In the Indian and Trinity Springs locality it does not occur east of Indian and Sulphur Creek, because its horizon is occupied by the Mansfield sandstone. Exposures are few on the western side of the area. The formation is about 15 feet thick and is composed of several layers of limestone separated by argillaceous shale a few inches to several feet thick. Its known exposures with their altitudes are indicated in Fig. 2.

Very few exposures of the Hardinsburg clastic interval are present in the Indian and Trinity Springs locality, chiefly because of the covering of talus from the Mansfield sandstone which caps the ridges. Very little sandstone appears to be present. It is characteristic of the interval to be composed largely of shale north of Orange and southern Martin counties. The Glen Dean limestone is known to outcrop in only two places within the mapped area. A few feet of rather hard Glen Dean limestone outcrop one-fourth of one mile north of Indian Springs Village in the N ½ of Sec. 8, and another exposure of it occurs in the ravine near the western margin of the area in SW of the SE ¼ of Sec. 7.

The Mansfield sandstone of Pottsville age is the basal formation of the Pennsylvanian system in Indiana. It rests upon various members of the Chester formation from the Elwren sandstone and shale to the Glen Dean limestone in the region, its base having a stratigraphic range of about 175 feet. Its base is therefore notably uneven. Usually a thin band of limonitic sandstone forms the base. The formation in Bear Hill is 230 feet thick and the lower 100 feet of it is a pebbly, and gritty sandstone which exhibits much cross-bedding. Little normal bedding is exhibited in the pebbly sandstone. The pebbles and grits are composed of milky vein quartz. The pebbles are well rounded and smoothed and range in size from peas to quail eggs, though few of them exceed one-half of an inch in diameter. Near the turn of the road on the southwest side of Bear Hill the base of the formation contains white kaolin. Here it rests on the Elwren shale in which are residual boulders of the base of the Beech Creek. Elsewhere, as in southwestern Lawrence County beds of clay and kaolin are in places several feet in thickness. In practically all cases the kaolin occurs where the contact is on the argillaceous shale just below one of the Chester limestones. The kaolin outcrop along the road near the southwest part of Bear Hill is the only known occurrence of kaolin in the region.

The pebbly sandstone forming the lower part of the formation composes a goodly part of the formation in the hill upon which the village of Trinity Springs is located. Also pebbles show conspicuously in the lower part of the formation composing Tempy Hill, Raven Cliffs, and the hill mass northeast of the Trinity Spring chiefly located in Sec. 21. No pebbles appear to be present in any of the sandstone occupying the upland west of the Indian Springs-Shoals road. Here the base of the formation is much higher than in the areas where the pebbly sandstone occurs. It appears that the pebbly sandstone occurs only where the base

of the formation is notably low. Above the massive pebbly sandstone the formation is commonly well bedded. A local coal is mined at a number of places west of the Indian Springs-Shoals road. The coal is about 65 feet above the base of the formation in the locality. Still 55 or 60 feet higher is another coal a foot or more in thickness underlaid by an underclay. Neither of these coals appear to be in Bear Hill or the other hills east of the Indian Springs-Shoals Road. Sandstone shows nearly to the top of the hills southwest of Indian Springs village, indicating a maximum thickness of about 150 feet in the western side of the area. Including the pebbly sandstone which forms the lower and older part of the formation deposited in the pre-Pennsylvanian depression extending northeast-southwest through the region, the Mansfield sandstone appears to be at least 250 feet thick in the region.

Geologic Structure and the Indian Springs Anticline. The geologic structure in southwestern Indiana is relatively simple. The region is well down the gently dipping western flank of the Cincinnati geanticline adjacent to the broad structural basin which centers in southern Illinois. The normal dip of the strata is about 35 feet west or slightly south of west to the mile. The structure is usually quite simple, though it does possess small irregularities of dip and changes in direction of dip. Terraces and slight flexures are common. Small faults are likely present, though the evidence of their existence is usually more suggestive than it is conclusive. Reversals of dip for more than a few hundred yards are rare, and anticlinal structures with a closure of more than 15 or 20 feet are also rare. Small anticlinal structures do exist in the surface rocks, though it is difficult to substantiate them. Rarely are they more than one-half or three-fourths of a mile across. More commonly the structural flexures are shallow dip-inclining basins bordered by positive terraces or "noses" on which closures are rarely well substantiated.

In the Indian and Trinity Springs locality, the altitudes on the Beech Creek and other Chester limestones indicate the presence of two dip-inclining synclines with an anticline between them. Carefully checked barometrically determined altitudes on exposures of the Beech Creek and other limestones of the Chester series compose the structure data of the region. In all, 43 separate altitudes are on the Beech Creek and 25 or 30 on the other outcropping limestones. These are shown on both Figs. 2 and 3. In Fig. 2 the data are all the actually determined altitudes, while in Fig. 3 the altitudes on the Beaver Bend, Reelsville and Golconda limestones have been either raised or reduced to the horizon of the Beech Creek. The structure contours shown in Fig. 3 are interpretative of the altitude data recorded on the map. The data substantiate the presence of a well defined anticline at the Indian Springs about one mile south of the village named after these highly mineralized sulphuretted springs. A discussion of the data of the Indian Springs anticline follows.

The data which clearly indicate an anticlinal structure at the Indian Springs in the NE ¼ of Sec. 17, are chiefly the altitudes of the exposures of the Beech Creek limestone. The line of the outcrop of the Beech Creek is depicted in Fig. 2. Exposures are plentiful west of the axis of the anticline, but are scanty east of the axis. The highest exposure is in the upland spur west of the road about one-eighth of one mile north of the Indian Springs in the NE ¼ of Sec. 17. Here the top of the limestone is at an altitude of 575 feet and 95 feet above the flood plain of Sulphur Creek. Northward it descends into what appears to be a rather shallow

dip-inclining syncline the axis of which extends nearly west from the village of Indian Springs. In one mile northward from the 575 foot datum the Beech Creek limestone descends 60 feet or to an altitude of 515 feet at the spring in the northwest edge of the village of Indian Springs. East of the crest of the anticline the data are rather meagre. Exposures of the top of the Beech Creek at the two springs on the west side of Bear Hill are 550 feet. At the spring a short distance north of the center of Sec. 16 and at the Tempy Spring in the SE ¼ of Sec. 9, the top of the limestone appears to be at an altitude of 555 feet. The actual figure at the Tempy Spring is 550 feet, but the Mansfield sandstone there rests on the Beech Creek

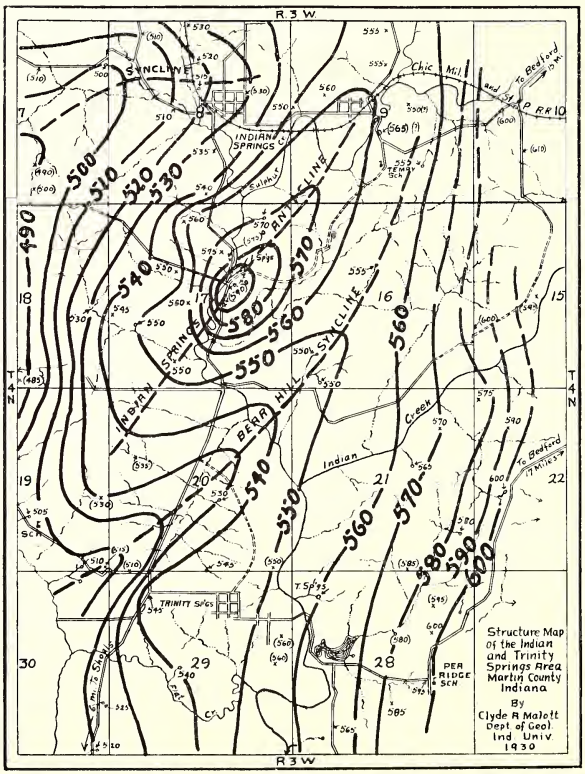

Fig. 3. Structure map of the Indian and Trinity Springs locality. Structure contours are drawn on the Beech Creek limestone.

limestone obviously below the top, and five feet has been added to approximate the former top of the formation. The Beech Creek is well exposed at a spring a little over a mile south of the Indian Springs near the center of Sec. 20 at an altitude of 530 feet, and at another spring in the southeast corner of Sec. 19 it has an altitude of 510 feet. The exposures from the Tempy Spring south-southwest, through Bear Hill to the southeast corner of Sec. 19, are low, and in their relations to the higher altitudes indicated along the axis of the Indian Springs anticline are very

likely along the trough of a syncline. This syncline is designated the Bear Hill syncline on Fig. 3. The Beech Creek data therefore, indicate a structural high near the mineral springs in Sec. 17. The northward dip in one mile is 60 feet, the southward dip in a little over one mile is 45 feet; and eastward and northeastward outcrops of the Beech Creek are 20 to 25 feet lower.

Data on the Beaver Bend limestone in connection with the Beech Creek data indicate that the Indian Springs anticline is about 15 feet higher than the Beech Creek data alone show. Around the north and west sides of Indian Springs Hill in Sec. 17 the Beaver Bend limestone is well exposed at an altitude of 500 feet. No exposures are present on the eastern side of this same hill. North of the mineral springs at the foot of the hill which has the 575 foot datum on the Beech Creek limestone, the top of the Beaver Bend is exposed in the road at an altitude of 485 feet. These figures indicate that the apex of the structure is at the northwest edge of the Indian Springs Hill, at the foot of which the highly mineralized waters of the Indian Springs rise in five separate places practically at creek level. The springs appear to be on the very crest of the anticline. The Beaver Bend limestone is 90 feet below the Beech Creek in the spur just northwest of the mineral springs. The altitude of the Beech Creek at the springs should be 590 feet, as indicated on Fig. 3.

Attention is called to the Beaver Bend limestone northeast of the mineral springs. This limestone passes beneath the alluvial flat of Sulphur Creek at an altitude slightly below 500 feet along the road at the east line of Sec. 9. A large pile of Beaver Bend limestone has been heaped up along the road at the well about 100 yards southeast of the bridge across Sulphur Creek, near Cale and near the center of Sec. 9. This limestone is reported to have been encountered 15 or 20 feet below the surface or at an altitude of 470 or 475 feet. The Beaver Bend limestone here is, then, 25 or 30 feet lower than at the mineral springs a mile southwest. The structural high, then, shows on the Beaver Bend limestone as well as on the Beech Creek.

The probability of faulting being responsible for the structural conditions in the Indian Springs locality merits discussion. When the structure was first discovered by the writer 11 or 12 years ago, it was assumed that both the Indian and the Trinity springs were associated with faulting. The recent detailed work, however, has failed to verify this assumption. No evidence of actual faulting was obtained, though diligent search was made for features which would indicate the presence of faults in the region. The flat, deeply alluviated valleys mask the rock features in much of the region where it is probable that faults would extend if the structure is a result of faulting. The possible lines of faulting were investigated where it is likely, if they are present, that they would cross the sandstones which make benches adjoining the flat valley floors. No dips, rock fractures or topographic offsets could be found which would in any way suggest faulting. On the other hand, the features suggest lack of faulting. A feature which on casual observation may suggest faulting is the absence of the Beaver Bend limestone at valley level on the east side of Indian Springs Hill and its total absence above drainage level in Donihue Hill and the bluff at Sulphur Creek Bridge just south of Donihue Hill. Its position is likely below drainage level in these places with the possible exception of the east side of Indian Creek Hill, and the interpretative structure contours of Fig. 3 are so drawn. As for the east side of Indian Springs Hill there are several ways to account for its unexpected absence there. The dip from the west side would only need to be about 10 or 15 feet to carry it below

drainage level. The Chester sandstones beneath the Beech Creek limestone where massive, as they are in the locality, often exhibit an unconformable relationship at their bases. Their bases may extend below the level of the horizon of the Beaver Bend limestone. Again it is quite characteristic of both the Beaver Bend and Reelsville limestones to have sandstone facies in which there is little evidence of their presence at their proper stratigraphic positions. Hence this suggestion of a fault is only one of many probabilities and perhaps the least likely of them all. Another locality in which the relations suggest a fault is at the intersection of the Trinity Springs road with the Shoals road. In the ditch on the north side the Beech Creek limestone is overlaid by the Mansfield sandstone. Just across the road west the Cypress sandstone occurs at a higher level. If a fault occurs here with the down throw on the west side, it is not exhibited in the Beech Creek limestone and the Cypress sandstone around the bluff southwest of the cross-road.

The Trinity springs in the NW of the NW ¼ of Sec. 28 issue from three places about which a cement platform has been constructed. A bluff of the Sample sandstone rises 15 or 20 feet above the cement platform on the north. A ravine usually dry enters from the east. Nothing in the sandstone rock which swings nearly half around the springs suggests faulting. The springs issue at or near the expected horizon of the Beaver Bend limestone, though no traces of it are present. It is at drainage level about one-half of a mile southeast of the springs, just east of the artificial lake, as indicated in Fig. 2. The fossiliferous sandstone, interpreted as the horizon of the Reelsville limestone, is higher than expected a short distance southeast of the spring. It appears to be slightly higher than it was found about one-half mile northeast of the springs, and 30 feet higher than it is on the west side of the valley. This was at first regarded as evidence of faulting, but a careful search along the sharp sandstone bench which extends west of the spring on the north side failed to show evidences of a down-throw. It is very probable that the 535-foot datum on the fossil zone is high because of deposition conditions at the time the Chester strata were laid down. The lack of limestone over the massive Sample sandstone is suggestive of a high surface over which the limestone was not deposited, though some organic structures have been preserved in a thin sandstone which latterly passes into the Reelsville limestone at lower levels not far away. The absence of the Beaver Bend limestone above drainage north of the artificial lake and at the foot of the sandstone bluff near the 535 datum make the presence of a fault very improbable and adds much in support of the explanation offered for the horizon of the Reelsville being higher than expected just south of the mineral springs.

The Indian Springs issue from at least five individual openings. Three of them are practically in the bed of Sulphur Creek just north of the bridge on the west side of Indian Springs Hill. The other two are northeast about 50 and 75 yards and line up directly with the three just north of the bridge. They are located in the low flood plain about 20 yards from the steep bluff of Indian Springs Hill and issue as boiling springs directly out of shallow depressions. The line of five springs extends northeast-southwest. Their alignment suggests the possibility that they occur along a fault. They occur between two outcrops of the Beaver Bend limestone which are about 200 yards apart and which show about 15 feet difference in elevation. It is my opinion that they do not rise along a fault.

The depths from which the highly mineralized waters of both Indian and Trinity springs come are unknown. The up-rising highly mineralized waters very likely are associated with the underlying middle Mississippian limestones, some-

what similar to the springs in the low valleys at French Lick and West Baden where the topographic and geologic conditions are nearly identical. The water may come from the underlying St. Genevieve and St. Louis limestones or it may come from still greater depths. After a study of the relations it is the opinion of the writer that there is little significance to be attached to the occurrence of the mineral springs on the Indian Springs anticline. The occurrence of the mineral springs on the top of the anticline is merely incidental, and is more likely associated with the low valley where the thick karst-making Paoli-St. Genevieve-St. Louis limestone unit passes beneath the relatively impervious shales associated with the Chester formations above.

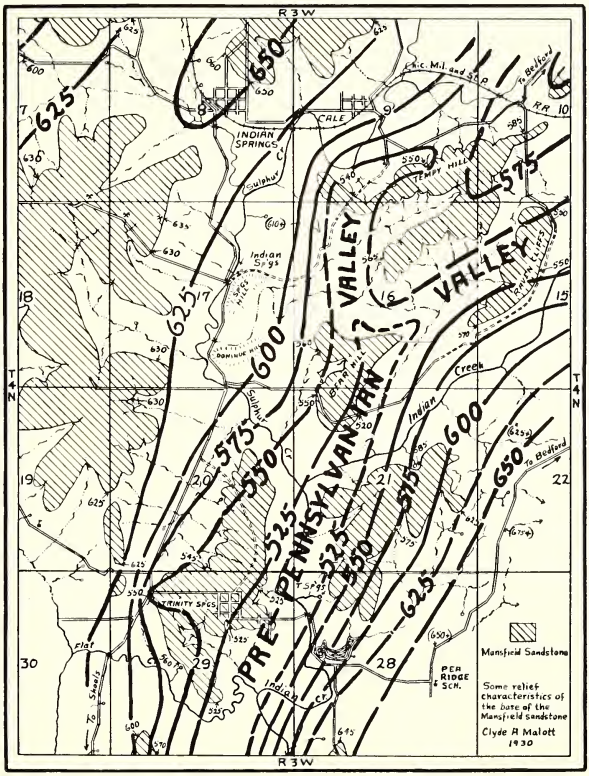

Fig. 4—Map of the Indian and Trinity Springs locality showing altitudes on the base of the Mansfield sandstone with interpretative contours which indicate the position of a pre-Pennsylvanian valley.

The Character of the Mississippian-Pennsylvanian Unconformity.

Many writers on Indiana geology have commented on the general character of the great unconformity at the base of the Pennsylvanian system within the state. In the 200 miles from Perry County on the south to Benton County on the north the base of the Mansfield sandstone descends fully 1,200 feet stratigraphically. Many details of the irregularities of the base of the Pennsylvanian have

been given by Ashley in his detailed *Coal Deposits of Indiana*, 23rd Ann. Rept., Ind. Dept. of Geol. and Nat. Res., 1898. Especially illuminating are the diagrams and comments of Logan on pages 683-688 of the *Handbook of Indiana Geology*, dealing incidentally with the nature of the irregularities of the base of the Mansfield sandstone close by the Indian and Trinity Springs locality. It is my purpose here to give some of the details of the relations of the base of the Mansfield sandstone in the region under discussion and to call attention to their significance.

The Mansfield sandstone as a formation in the region has already been described and attention has been called to the unevenness of its base. In Fig. 4 the altitudes of the base of the sandstone are given at such places as were readily determinable. The highest altitude determined for the base is 660 feet, just north of the village of Indian Springs, and the lowest is 520 feet, along the road in the southeast part of Bear Hill. The total known difference of the relief of the base of the formation in the region is, therefore, 140 feet. West of the Indian Springs-Shoals road the base of the sandstone rests on the Hardinsburg sandstone interval or on the Glen Dean limestone at altitudes of 625 to 635 feet. Along the ridge road in sections 28 and 22 in the southeast part of the area, no Mansfield sandstone is present, though the altitudes reach and exceed 650 feet. The highest formation there is the Cypress sandstone. The altitudes are systematically low in a strip one-half to one mile wide extending south-southwest from Tempy Hill and Raven Cliffs, through Bear Hill, the village of Trinity Springs, and beyond. In this strip the altitudes determined range from 520 feet to 565. The Mansfield sandstone rests on the Beech Creek limestone and the Elwren sandstone and shale, approaching the stratigraphic position of the Reelsville limestone at the lowest places. The stratigraphic range of the uneven base of the Mansfield sandstone within the area is about 175 feet.

The altitudes of the base of the Mansfield sandstone indicate quite clearly that the pre-Pennsylvanian topography had a relief of at least 140 feet within the area. The nature of the relief is also revealed by the altitudes. A trough-like valley, filled with the lower and older part of the Mansfield unit, passes through the region in a south-southwest direction. The general character of this pre-Pennsylvanian valley is indicated by the contours drawn on the given altitudes as a basis in Fig. 4. The altitudes of the base of the Mansfield were not obtained in a sufficient number of places to give the details of the buried pre-Pennsylvanian valley, but it is believed that the valley-like trough depicted in Fig. 4 is a river-formed valley whose further development was stopped by the invasion of the region by the Mansfield deposition processes. This same valley has been traced northeast to near the overhead bridge across the railway about two miles west of Williams in Lawrence County. Here the old valley is filled with the characteristic pebbly Mansfield sandstone resting on the Beaver Bend limestone at an altitude of about 600 feet or possibly slightly lower. Nearby the top of the Cypress sandstone is exposed at an altitude of about 700 feet. South of the region the old valley passes near McBrides Bluff on White River at the mouth of Indian Creek, where the massive pebbly Mansfield sandstone rests on the Cypress sandstone 20 feet above the Beech Creek limestone at an altitude of 515 feet. It is thought that it continues south and slightly west to Shoals where the Mansfield sandstone is below the bed of the White River at an altitude less than 450 feet.

Observations made elsewhere along the Mississippian-Pennsylvanian contact indicate that the conditions depicted in the Indian and Trinity Springs locality are characteristic of the base of the Mansfield sandstone. The irregularities of

the contact take on the nature and character of pre-Pennsylvanian valleys. These valleys are filled with the cross-bedded pebbly sandstone which appears to be characteristically present in the pre-Pennsylvanian valleys and wanting or thin on pre-Pennsylvanian upland areas between the valleys. It is my opinion that the Mansfield sandstone occupies pre-Pennsylvanian valley-like troughs where it is composed of massive cross-bedded pebbly sandstone 75 or 100 feet thick, this being the characteristic deposit made in the pre-Pennsylvanian valleys. Where such thicknesses of the massive pebbly sandstone occur I would suspect the deposit very likely be in a low trough-like valley. It is not my opinion that the pebbly phase of the Mansfield sandstone is confined to the valleys, though my observations indicate its absence in areas that are obviously pre-Pennsylvanian inter-valley areas.

These observations open up an interesting perspective of the conditions of the deposition of the Mansfield sandstone. This perspective invites attention to the source of the materials and to the method of transportation and deposition in the valley-trough areas which is characteristically exclusive of the deposition in the deposition of similar materials on the pre-Pennsylvanian inter-valley uplands. More fact-finding studies must be made before these particular characteristics of the limited area under discussion may be asserted to prevail over a wide area. Such studies must furnish the informational data necessary for a proper consideration of the sources of materials, means of transportation to the region of deposit, and the conditions which governed the deposition of vein-quartz facies of the widely distributed basal Pennsylvanian formation in Indiana, Kentucky, Illinois, and other states.