The Drainage Area of the East Fork of White River.

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"Every river appears to consist of a main trunk, fed from a variety of branches, each running in a valley proportioned to its size, and all of them together forming a system of valleys, communicating with one another, and having such a nice adjustment to their declivities that none of them join the principal valley either at too high or too low a level, a circumstance which would be infinitely improbable if each of these valleys were not the work of the streams flowing through them."*

Streams are among the most important agencies which give form and expression to the surface of the land. The study of streams, therefore, involves to a great extent the consideration of the nature and origin of many topographic forms—hills and mountains, plains and valleys—and the changes they pass through.

Every person is familiar with the manner in which the rainwater that falls is gathered into rills, rivulets and brooks, which unite to form larger rivers. Every one is aware, also, that streams are turbid after heavy rain. Yet comparatively few people have thought of the work and change upon the surface of the land which is done by even the smallest of the rills and all along the course of the river; nor have they thought that the smallest rill down the hill slope or along the roadside is adding to the work of the large streams, or adding to the extent of the drainage area of the stream.

The drainage area of a stream is the land area which is drained by the main stream and all its tributaries—and the tributaries of the tributaries.

The drainage area of the East Fork of White River is composed of the western central and southern part of Indiana, including the greater part of twenty-five of the ninety-two counties of the State, and a total of about 7,000 square miles, or a little less than one-fifth of the total area of Indiana. This area is mapped out in full on the accompanying map, with the exception of a few counties lying to the north of the area shown.

*Illustrations of the Huttonian Theory of the Earth; by John Playfair.

The geological conditions of the country greatly influence the course and action of streams. The heavy curved line across the map represents the southern limit of the ice sheet. Thus this drainage area is partly in the glaciated and partly in the unglaciated portion of the State. It is in the unglaciated region that we have the most picturesque scenery. The entire area, subjected to the processes of weathering and stream erosion for millions of years, was maturely dissected into a complex network of valleys, ridges and isolated hills. Over this surface the ice-sheet passed several times, extending as far as the boundary shown. Its effect was to smooth off the hills, fill up the valleys and to leave the surface covered over with a great mass of loose, foreign material from the northern regions. Since glacial times the streams have to some extent removed the loose material from some of the old valleys and are forming a system of new drainage in the surface of the drift. Geologically speaking, this glacial accumulation is of very recent origin and the streams seem to have made only a small beginning in the work they will be able to perform.

An accurate topographic map of the drainage area would show the contrast in the physical features of the glaciated and unglaciated portions better than any other description or illustration that could be given to a person who had not been over the area to investigate the contrast. In the glaciated area the contour lines would run in large regular curves and far apart, showing the smoothness and regularity of the surface. South of the drift limit the lines would be very close together, with a very winding course and sharp curves, showing a region of deep, narrow valleys, irregular divides and abrupt cliffs.

In attempting to work out the geographic history of an area whose drainage has been arrested by the invasion of an ice-sheet, we find that the story of the life resolves itself into four fundamental parts. First: What are the topographic characteristics of the area during the preglacial history. Second: What changes took place during the glacial history. Third: What has happened since the disappearance of the ice-sheet; its post-glacial history. Fourth: What was the effect produced by the above events on the unglaciated parts of the area.

It is doubtful if the entire glacial area in Indiana was covered by the ice-sheet at any one time. At its extreme limit the ice deposited but little drift; and as a rule there is not a well-defined ridge of drift along the glacial boundary, though some drift is to be seen—as in Chestnut Ridge, in Jackson County, and a similar ridge in southern Morgan County.

DRAINAGE MAP
INDIANA

From the east border of the river, a few miles below Columbus, northeastward to Whitewater valley, in southern Fayette County, there is a well-defined ridging of drift standing twenty to forty feet above the border tracts. Upon crossing Whitewater, the border leads southeastward and is not so well defined as west of the river, though there is usually a ridge about twenty feet high.

From the north line of Jackson County, following the boundary around to the west and south, it is in many places hard to trace as a well-defined line. The ice-sheet must have been very thin, since the topography shows little, if any, modification. In many places, however, heavy beds of gravel and till lie against the hill slopes to the north and east. Many large granite bowlders are also piled up along the hillsides and scattered along the streams. In this area in the counties of Hendricks, Rush, Johnson, Shelby, Henry, Decatur and Randolph, there is a form of moraine known as "bowlder belts," long, narrow, curving strips of country, thickly covered with large bowlders. Low, winding ridges of sand and gravel parallel to the ice movement mark the course of a sub-glacial drainage through Madison, Hancock, Shelby and Bartholomew counties. The longest glacial drainage channel in the State extends from Grant County to White River, in Bartholomew, but it is not now occupied by any one continuous stream. Most of the streams in the glacial area are known as sand and gravel streams and afford great quantities of sand of economic importance and an abundance of gravel suitable for road material and ballast. In several of the counties are overwash aprons in which the sand and gravel are spread out over broad areas.

The thickness of the drift over the State varies greatly, the greatest thickness in the State being about 500 feet. While in this area the drift would be from 50 to 100 feet, there is on the higher points but a thin coating, but the filled valleys make a higher average. It is the glaciated part of the area that is of importance from an agricultural standpoint. The glacial drift is a very productive and permanent soil, and can not be surpassed in the production of the cereals, while the bluffs, knobs and hills of the driftless area are proving to be favorable for the growing of fruits.

The rocks of the State are all sedimentary, and in the area here discussed were laid down upon the bed of a shallow sea receding to the southwest. Thus the strata dip gently to the southwest, at the rate of about 20 to 40 feet to the mile.

In the State there are six different geological periods represented—the

Pleistocene (no rock outcrop), the Coal Measures, the lower Carboniferous or Mississippian, the Devonian, the Silurian, and the Ordivician or lower Silurian. All of these are found in the territory of this drainage area; and of the twenty-five or more formations as subdivisions of the above-named periods there are at least eighteen of these found as surface outcrops in this area. These formations may be listed as follows: *Merom Sandstone.*—A massive coarse-grained sandstone lying unconformably on the coal measures. It furnishes glass-sand and some building stone. *Mansfield Sandstone*, the basal member of the coal measures, is a medium to coarse-grained stone. It is quarried for building purposes and for whetstones and grindstones. *Coal.*—This area is just in the edge of the Indiana coal field. The coal is, therefore, very thin-bedded and is mined only by drifting. *Shales.*—The shales of the coal measures are in many places from 25 to 40 feet in thickness, and are of value in the manufacture of cement, paving brick and sewer tile. Associated with these shales in Martin, Greene, Lawrence and Orange counties are considerable deposits or iron ore; there are also beds of fireclay underlying the coal. *Huron.*—This consists of a series of thin bedded limestones separated from each other by shales and sandstones. *Mitchell Limestone* consists of massive compact layers of dark blue and gray limestone with interbedded impure fossiliferous limestone, shales and chert. *Salem Oolitic Limestone.*—The massive fine-grained stone so well known as a building and ornamental stone. *Harrodsburg Limestone.*—A very fossiliferous limestone, and also contains great numbers of geodes and chert in the lower members. *Knobstone.*—A series of shales and sandstones reaching a thickness of more than 500 feet. This formation has its western outcrop in the eastern half of Monroe and Lawrence and extends to the east as the surface stone for many miles. To the present time but little use has been made of this group, but it is growing to be of economic importance. *New Albany Shale.*—A persistent underlying brown to black shale at the top of the Devonian System. It is rich in bitumen and when kindled will burn. The laminated structure and joints are shown in the illustration. *Hamilton Group.*—The Sellersburg and Silver Creek limestones. The former is a white to gray limestone, rather thin bedded but persistent, stretching from the Falls of the Ohio, north through Clark, Scott, Jefferson, Jennings and Decatur counties. The Silver Creek lies beneath the Sellersburg. It ranges in thickness from 15 to 16 feet in the Silver Creek region to 5 or 6 feet in the vicinity of Lexington, in Scott County, and disappears altogether as a per-

sistent formation in the northern part of the same county. *Niagara Group.*—The member of the group found in this region, is a soft, massive, buff, sub-crystalline to a bluish-green, shaly, limestone, with a characteristic bed of bluish-green shale several feet thick at the base of the formation. *Pleistocene.*—The area deeply covered with glacial drift and having no rock outcrop.

Triassic to Tertiary, Inclusive.—"The only deposits of these ages known (with the possible exception of the Merom Sandstone) are some gravels found on certain high ridges in Martin and Perry counties, and possibly elsewhere. These are outside the drift area, and above any known stream deposits of gravel. Taken in connection with the uniformity of elevation reached by the highest hills, in the Mansfield sandstone area, the Knobstone area and the Silurian area in the southern part of the State, it has been suggested by Mr. Frank Leverett of the United States Geological Survey, that at least southern Indiana was reduced to base level in Tertiary times. In that case the present and pre-glacial topography of Indiana would date from some time in the Tertiary. This Tertiary erosion might also account for the absence of cretaceous deposits, if any such were ever laid down in the State. Until more study shall have been given these gravels and their interpretation, the matter of this paragraph must be considered more as a suggestion than as a demonstrated fact."* (See Report State Geologist 1872, p. 138; 1897, p. 22.)

The highest point in the State is in the southern part of Randolph County, which at the highest level is about 1,285 feet above sea level. It is on this height of land that both the East and West forks of White River have their source. The C., C., C. & St. L. R. R. (Peoria Div.) passes along this divide between the head waters of these streams. The West Fork increases in volume and velocity more rapidly than the East Fork, which reaches its destination by a very winding course. Its length is greatly increased and its slope decreased by its numerous meanders, but it is still a moderately swift stream. After reaching the unglaciated area the direction of the stream is greatly influenced by the joint planes in the geological formations. The main streams of these forks grow farther apart until they reach Shelby and Marion counties, where they approach each other,

Note.—For description, composition, structure, extent, uses, etc., of the various formations named above, see Thompson, 17th Ann. Rep., pp. 30-40; Hopkins, 20th Ann. Rep., 1895, pp. 188-323; Kindle, 29th Ann. Rep., pp. 329-368; Hopkins and Siebenthal 21st Ann. Rep., 1896, pp. 291-427; Blatchley 22d Ann. Rep., 1897, pp. 1-23; Ashley 23d Ann. Rep., 1898; Siebenthal 25th Ann. Rept., 1900, pp. 330-39 ; 30th Ann. Rep., 1905; E. R. Cumings, in Pro. Ind. Academy of Science, 1905, pp. 85-100.

then again turn from one another until, in the western part of Lawrence and Martin counties, they come nearer and at the southwestern corner of Daviess County are united in one stream at an elevation of about 425 feet. Both forks are fed by numerous tributaries, which produce an intricate drainage system. In many places the heads of these tributaries approach each other very closely and have in some cases resorted to piracy. It is obvious from the varying character of the valleys and the terraces which border them, that both forks suffered many disturbances during the glacial period. As has been stated, we know that valleys have been excavated by the streams flowing through them, and it is also true that the terraces beautifying their sides are in most cases due to the same agencies—that is, terraces owe their origin to the processes of corrosion, or of deposition, or to both. Many of the terraces are due principally to the re-excavation of preglacial valleys. In much of the unglaciated area there are marks of several well-defined drainage levels. The region ranges in elevation from 150 to 300 feet; the streams cut down rapidly from the upland, then run off with a slight gradient through deep valleys with rather flat and comparatively wide bottoms and very steep sides, with stepped and sloping terraces with gracefully bending curves which add much to the attractiveness of the valleys. The upper terraces are formed by the streams cutting down through the formations of the original table-lands. The lower terraces are composed of mixed materials of the higher levels. The best examples of these terraces are in the Salt Creek and Clear Creek valleys, and in the principal valley of the main East Fork and its adjacent side valleys. Some of these terraces are shown in the illustrations.

This entire drainage area affords much for interesting study and exploration, but, as stated above, it is in the unglaciated portion that is found the most picturesque scenery. The diversified physical features produced by the processes of erosion and the weathering of the various geological formations give a region of rugged and beautiful scenery. Some of the characteristic and marked scenic points are described below.

"Weed Patch Hill," in Brown County, is a high ridge in the Knobstone, forming the divide between two of the main branches of Salt Creek. At its highest point it is a little more than 1,000 feet in elevation. One of the illustrations gives a view looking northwest from this elevation and gives an idea of the Knob topography. "Guinea Hills" is a ridge rising to a considerable elevation, extending in a northeast and southwest direction through the southwest part of Scott and the northwest part of Clark coun-

ties. These hills form the divide between the tributaries of the Muscatatuck, one of the chief branches of the East Fork, and the headwaters of Silver Creek, which flows south into the Ohio. It is interesting here to note that water falling on the high bluffs of the Ohio near Hanover, and to the north within one mile of the river, does not there flow into the Ohio, but finds its way into the Muscatatuck and the East Fork, and after covering a distance of more than 300 miles flows into the Ohio at the southwestern corner of Indiana. The "Haystacks" are conical shaped hills which, seen from a distance, have the appearance of haystacks; these are plentiful in the central part of Lawrence County. "Rock Houses" are large openings between and under large rock masses due to undercutting and the breaking off and tilting of the rocks. "Honeycombs" are rock surfaces in which the softer parts have been weathered out, giving a porous, honeycombed appearance. These are found in the region of the Oolitic Limestone and the Mansfield Sandstone. One of the most interesting spots to visit is the "Pinnacle," near the town of Shoals, the county seat of Martin County. Here a high ridge of Mansfield Sandstone, one hundred ninety-six feet above the level of the stream, terminates abruptly within a few yards of White River. Large masses of rock that have broken off, lie around the foot of the ridge in every position. From this point one obtains a good view of the character of the topography of this region. To the northwest of this ridge the formations have been cut through by disintegrating forces, and there has been left standing at some distance from the head of the ravine a tall mass of sandstone, which has received the name of "Jug Rock," from the fancied resemblance to an old-fashioned jug. On the upper side it is forty-five feet high and on the down-hill side, seventy feet high; it is capped with a flat projected layer of harder sandstone. At the south of the deep-wooded ravine is the "Glen," an under-cut sandstone cliff with an intermittent cascade. Across a valley to the north is "House Rock," a large sandstone cave, the entrance to which is about thirty-five feet high, and the main room, with an opening in the top, is very much higher. It is formed principally by the tilting of large rock masses. The sandstone in front of the cave is weathered into an elaborate fretwork. Other points of interest as one goes down along the river are the "Acoustic Rock," "Buzzard's Roost," "Hanging Rock," "Kitchen-middings," "Shell-bank," and the "Hindostan Falls."

In Washington, Lawrence, Orange and Monroe counties the subterranean drainage has an important place. The ground water working along

the point planes and on the more soluble parts of the limestones has produced a great variety of sink-holes, caves and "lost rivers." The sink-holes are basin shaped depressions many feet deep, and often hundreds of feet in diameter, with an opening at the bottom which leads into some underground channel; in some cases the openings have become filled and the water is held in the basin. In many places a stream runs into these holes, then by underground passages for a great distance, and again comes to the surface in the form of springs. Valleys, sometimes two to four miles in length, are drained through underground channels. This gives rise to a confusing system of hills and valleys, though a well-defined drainage may be worked out which in itself is usually made up of sink-holes. There are many pure water springs in this region and also many springs of mineral waters. The best known of these are the French Lick and West Baden Springs, Trinity and Indian Springs. Lost River, a main branch of the East Fork, through Orange and Martin counties, has many "lost" tributaries in Orange County. The numerous caves and the mineral springs are described in the State Geologist's Reports for the years 1896 and 1901-02.

The greater or less degree of uniformity in the volume of the river in the course of a year is one of its chief physical features and depends very much on the manner in which the water supply is obtained. The streams of this area depend for their increase wholly upon the rains, which, occurring frequently and at no fixed periods, and discharging only comparatively small amounts of water at a time, except in periods of the heavy rainfall of several days' duration, preserve a moderate degree of uniformity in the volume of the streams. This uniformity is aided by the fact that under normal conditions only about one-third of the rainfall finds its way directly over the surface to the streams, the remaining two-thirds sinking into the ground and finding its way to springs, reservoirs, or gradually oozing through at a lower level until the soil becomes drained of its surplus moisture, a process which continues for weeks and helps to keep up the volume of the stream. But, on the other hand, man has done a great deal to destroy the uniformity of the volume. By the removal of the forests, the cultivation of the soil, and the use of ditches for drainage, a greater part of the water is at once thrown into the stream and greater fluctuations occur. Owing to the streams being hemmed in by lofty, abrupt cliffs, which resist the free passage of the swollen streams, and the velocity being checked by winding courses, greater floods occur from the same amount of rainfall than formerly.

View upper half of the Pinnacle, Shoals, Ind. Distance from top to water level 196 feet.

Hanging Rock, an undercut sandstone cliff, southwest Lacy, Martin County.

Showing laminated structure and joints in the New Albany Black Shale. Scott County.

Rectangular Blocking in the Huron Limestone. Greene County.

Jug Rock, a column of sandstone capped with a harder layer of sandstone. (See description.)

House Rock, a cave formed by the tilting of large blocks of sandstone, north of Shoals, Martin County.

View in Salt Creek Valley, showing high terraces in background, southeast Stobo, Monroe County.

Recent terraces in Salt Creek Valley southeast of Stobo, Monroe County.

Salt Creek Valley near Harrodsburg, Monroe County.

White River Valley, looking north from the Pinnacle, Shoals, Ind.

Gullies in the clay and shale of the Knobstone, eastern Monroe County.

Recent gullies in clay and shale, eastern Monroe County.

Showing east side of City Waterworks Reservoir, Bloomington. The water is supplied by springs from the underground drainage of sink-hole region in Mitchell limestone.

Boating along Public Highways during Spring Flood, 1906, in River Valley near Shoals.

Undercut Sandstone Cliff with overhanging Icicles, southern Martin County.

The Glen, an undercut sandstone cliff with an intermittent cascade, Shoals, Martin County.

View looking northeast from Weedpatch Hill, showing Knobstone topography.

Many gravelly and rock bottom streams are used as public roads. This view in southern Martin County.

Silurian exposure on the Muscatatuck directly south of Vernon.

View on Clear Creek along Monon Railroad between Bloomington and Harrodsburg.