

7. *On the PHYSICAL GEOLOGY of TENNESSEE and ADJOINING DISTRICTS in the UNITED STATES of AMERICA.* By EDWARD HULL, M.A., LL.D., F.R.S., F.G.S., late Director of the Geological Survey of Ireland. (Read December 10, 1890.)

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PART I.—§ 1. INTRODUCTION.

A RECENT visit to the Southern States of North America induces me to lay before the Society some observations on the physical aspect of a peculiarly interesting region traversed by the Tennessee River in the State of the same name and the bordering districts. The geological structure of this district has been ably described by Professor James M. Safford, the State Geologist*. The region is now in process of being re-surveyed topographically and geologically under the direction of Major Powell, U.S. Geological Survey, to whom I am much indebted for kind assistance in procuring maps and information†. In the present communication I do not propose to enter at any length into the geological structure of the district here described, but only to single out the most striking features connected with its physical structure, and to endeavour to show how they can be accounted for upon those principles of interpretation which, after many years of discussion and research, are generally adopted amongst geologists. Amongst others we shall have to explain the formation of table-lands, and of the erosion of the gorge by which a great river, the Tennessee, traverses a mountain-plateau in pursuing its way towards the ocean, instead of taking a much more direct course.

* 'Report on the Geology of Tennessee' (1869).

† The sheets, prepared in the Geological Survey Office, are on a scale of $\frac{1}{125,000}$, and are contoured at intervals of 100 feet vertical. A very fine mineralogical map of Tennessee, on a large scale, constructed by Major Kelly, is placed in the Town Hall of Chattanooga.

§ 2. PHYSICAL FEATURES.

1. *The Valley of East Tennessee.*—The physical features of East Tennessee are, when viewed on a large scale, extremely simple, and are a faithful index to the geological structure. Along its eastern margin, where Tennessee joins North Carolina, the State follows the crest of the Unaka Range, which may be regarded as one of the parallel ridges of the Alleghanies, and is nearly continuous with the Blue Ridge of Virginia. This ridge is composed chiefly of granite, gneiss, and crystalline schists, presumably of Archæan age, and forming a prolongation of Professor J. D. Dana's "Archæan Protaxis." It attains an elevation of 6760 feet in Black Mountain in North Carolina*, and ranges in a general south-westerly direction. From its base stretches the great plain known as "the Valley of East Tennessee," which extends south-west into Georgia and Alabama, and in an opposite direction is continued into the Valley of Virginia or Shenandoah. This rich and fertile plain has an average breadth of about forty miles, and along its course winds the Tennessee River, a noble stream of about 450 yards in average width. The plain itself is closely furrowed by parallel valleys and ridges, all trending in north-east and south-west directions, parallel to the strike of the beds. The ridges and furrows are in fact the outcrops of the harder and softer strata. The whole valley is underlain by Cambrian and Silurian formations, often highly inclined or thrown into numerous flexures. This series is surmounted by the Devonian beds, here very thin, and consisting chiefly of black shale, which lie close to the base of the northern margin formed by the Cumberland Table-land, which I now proceed to describe.

2. *Cumberland Plateau; Walden's Ridge.*—The north-western margin of the Valley of East Tennessee is formed by the escarpment of the Cumberland Plateau, which rises abruptly above the plain to a height of 1300 to 1600 feet, or 2000 to 2200 feet above the ocean. The crest of the escarpment, formed of massive grit and conglomerate of Carboniferous age, breaks off into mural precipices, often perfectly vertical. As the Tennessee River hugs the base of this escarpment for many miles, the full height of the cliff is thus obtained at one sweep; and as the slopes as well as the summit of the ridge are covered with primæval forest, except where the naked cliff offers no footing for vegetation, the view of this grand escarpment is as striking as it is beautiful.

The escarpment above described forms the south-eastern margin of the Cumberland Table-land, the surface of which is slightly undulating, formed of Carboniferous beds, and which, below Chattanooga, immediately on the west, is traversed by the Tennessee River through a deep and winding gorge about twenty miles in length, where the States of Georgia and Alabama on the south join

* The granitoid rocks of North Carolina are remarkable for the number, beauty, and size of the minerals they have yielded; specimens are exhibited in the museum of the Smithsonian Institution, Washington.

on to that of Tennessee on the north (see Map, fig. 1, facing p. 74). We shall have to discuss the mode of formation of this remarkable gorge later on. The Cumberland Plateau has a breadth of about forty miles north of Chattanooga (lat. $35^{\circ} 15' N.$), and it breaks off along the north-western margin in a precipitous and lofty escarpment, as along the valley of East Tennessee, but much indented by valleys and coves; while the south-eastern escarpment is seldom broken, but sweeps along the banks of the river in a nearly direct or gracefully-curving line, the indentations of the streams being hardly noticeable*.

The Cumberland Table-land is the southerly prolongation of the Appalachian Mountains; and, though deeply indented by the Cumberland River and its branches in the North-west, is nowhere absolutely cut through by these streams; so that it is only in the gorge of the Tennessee, close to Chattanooga, that the complete intersection of the range is effected. To the south of this gorge the table-land continues into Northern Alabama, till the Carboniferous strata sink down and disappear beneath those of Cretaceous and Tertiary age which border the shores of the Gulf of Mexico. Several terraced and nearly isolated hills, portions of a once continuous plateau, occur along the Tennessee near Chattanooga, of which "Lookout Point," rising abruptly from the river-bank to a height of 2126 feet above the sea, or 1450 feet above the stream, is the most conspicuous example (see Map, fig. 1).

The average elevation of the Cumberland Plateau may be taken at 2000 feet above the surface of the ocean, and 1350 feet above the Tennessee River at Chattanooga; but towards Pennsylvania on the north, at Cross Mountain, it rises to about 2800 feet†, where its structure becomes more complicated. Confining our attention, however, to the region of Tennessee and the borders of Kentucky, we observe that this table-land has the character of a well-defined plateau, formed of massive grit and conglomerate, or other strata, of Upper-Carboniferous age, and intersected by deep ravines, which open out to the south and west, and form the channels of streams draining into the Tennessee, the Cumberland, and the Ohio. (See Sections, figs. 2 and 3.)

Over its whole surface and its flanks this table-land is enveloped in almost continuous virgin forest, consisting of trees of great variety and often of noble stature, with an undergrowth of smaller plants. Nearly fifty varieties of forest-trees may here be counted, including, amongst others, cedars, pines, maples, chestnuts, satin-wood, poplars, and oak of several varieties. These forests give cover to many wild animals, including pumas, bears, deer, hogs, and smaller game. Rattlesnakes and other venomous reptiles lie concealed under the fallen logs, and at night the groves and low-lying woods at the foot of the plateau are lighted up by myriads of fire-flies, while the air is resonant with the croaking of the

* According to Professor Safford.

† In Walden's Ridge, east of the Sequachee Valley, there are tracts reaching the 2300 or 2400 feet level.

tree-frogs. From the crest of the escarpment at various points beautiful and extensive prospects may be obtained of this region of wooded plateaux and wide valleys, where the white man has as yet done little to alter the natural landscape, or to diminish the extent of the primæval forest*.

3. *The Sequachee Valley.*—The table-land thus described is intersected longitudinally by a remarkable valley, that of the Sequachee River, for a distance of sixty miles, in a nearly straight line north-eastward from the banks of the Tennessee near Jasper, with an average breadth of four miles. The narrow plateau thus formed between the valley of East Tennessee and the Sequachee is known as "Walden's Ridge" (see Map, fig. 1). The direction of the Sequachee Valley is therefore parallel to that of the eastern boundary-scarp of the table-land itself, where it overlooks the Valley of East Tennessee. On either side it is bounded by steep and densely-wooded slopes, generally crowned by cliffs of grit or conglomerate; and at its upper end the Sequachee River has its origin in copious springs issuing forth at the foot of the sandstone cliffs.

I was unable to visit the source of this stream, but, from the accounts I had from observers in the district, it must be most remarkable. From the foot of the cliff the waters flow down the steep slopes into a natural caldron, formed in the soft shales and grits overlying the Carboniferous Limestone. The latter here forms a barrier, holding back the waters which have hollowed out a tunnel through the rock, and on issuing forth they descend into the valley in a series of cascades.

The flanks of the Sequachee Valley are composed of Carboniferous grits and shales resting on limestone, from below which the Devonian and Silurian strata emerge with a dip in the direction of the sides of the valley (see figs. 2 and 3). The valley is therefore clearly in the line of an anticlinal axis; and to this it probably owes its origin, though it is possible that there may be a fault here running in a parallel direction, along which river-erosion has acted through a lengthened period. It is a striking example of valleys of this kind. The Little Sequachee, a smaller valley further to the west, is probably due to a similar anticlinal flexure.

4. *Rocks of the Cumberland Table-land.*—The geological structure of the Cumberland Table-land is extremely simple. The strata of which it is formed consist of grits (sometimes pebbly), sandstones, and shale, with beds of coal, all of Carboniferous age, resting on Mountain-Limestone, which crops out in two beds, separated by soft red sandstone, all along the base of the escarpment; the two series constitute in part the "Carboniferous" and "Sub-Carboniferous" groups of American geologists (see figs. 2 and 3).

The Carboniferous series is succeeded, in descending order, by dark Devonian shales, which, owing to their friable nature, have

* This region was the abode of Cherokee Indians, who some years ago were transplanted to the Indian Reserves in the Western States. Shell-mound Station is the site of the terrible slaughter of this tribe by its white and more civilized brethren in 1816, under Major Bond.

doubtless facilitated the work of erosion; and these again by the members of the Upper and Lower Silurian groups, occupying the plains and the central portions of the valleys. The Silurian strata, which are thrown into numerous flexures along the valley of East Tennessee, ultimately give place to others of Cambrian age as we approach the Archæan Protaxis of the Unaka range, forming the south-eastern margin of the plain.

PART II.—DEVELOPMENT OF THE CHIEF PHYSICAL FEATURES.

I. *The Cumberland Plateau.*

The physical features, the origin of which I here propose to discuss, are (1) the Cumberland Plateau, and (2) the Gorge of the Tennessee River where it traverses this plateau below Chattanooga. The discussion of the origin of these two leading physical features necessarily involves some reference to the mode of formation of the adjoining areas, that of the Valley of Eastern Tennessee on the east, and that of the Silurian plain of the Cumberland River, or of Nashville, on the west. An inspection of the longer diagrammatic section, from the Archæan Protaxis of the Unaka Range to the plain of the Cumberland River at Nashville, shows in order of succession from east to west—(1) the Unaka Range; (2) the Valley of East Tennessee; (3) the Cumberland Plateau; (4) the Silurian dome or uprise of Nashville; together with the generalized stratification of this tract. (See Sections, figs. 2 and 3.)

1. *The Stratification.*—In dealing with this subject I have to observe that from the base of the Cambrian beds, where they rest discordantly upon those of the Archæan Protaxis, the whole series of Lower- and Upper-Palæozoic formations succeed each other in *apparently* conformable sequence, except at the junction of the Lower- and Upper-Silurian series, where a probable discordance occurs*. Throughout the prolonged period during which these formations were being deposited, there was continuous subsidence, with occasional pauses, over the region lying to the west of the Archæan Continental area, and successive formations of marine strata were laid down in vast sheets over the bed of the ocean, never probably very deep. In later Carboniferous times the marine deposits gave place to those of lacustrine or estuarine origin, but still without any apparent discordance in the stratification; so that the Upper and Lower Carboniferous beds are apparently conformable to each other, and these again to the Devonian and Upper Silurian†.

* According to Professor J. D. Dana, this discordance is very marked in the New-England States, where the Lower-Silurian beds have been metamorphosed and elevated with the Archæan rocks. In their southern prolongation this is not so evident, but highly probable. See J. D. Dana, "Areas of Continental Progress," Bull. Geol. Soc. America, vol. i. 1889.

† I use the expression "apparently conformable," because, though there may be discordances of stratification, they are so small as not to have been recognized.

2. *Epoch of Greatest Terrestrial Movements.*—The prolonged period of subsidence and deposition above described at length gave place to an epoch of elevation and contraction of the crust, acting with greatest effect and intensity along the line of the Alleghanies, and parallel with the Atlantic sea-board, where the Palæozoic strata are folded, flexured, and even reversed, along parallel axes, as so admirably illustrated by the late Professor H. P. Rogers *. The foldings of the strata, it is well known, generally subside in a westerly direction towards the Valley of the Ohio, and ultimately pass into widely extended dome-shaped centres of elevation with intervening areas of depression. Amongst the former are the "Cincinnati uplift" and the anticline of the Nashville Silurians; amongst the latter is the region of the Cumberland Plateau, which lies along the centre of a broad syncline.

3. *Direction of Greatest Vertical Movement and Erosion.*—From what has been said, it clearly follows that the greatest amount of vertical movement, consequent on powerful lateral thrust, was along the Archæan Protaxis of the Alleghanies. All along this line the Palæozoic strata were elevated thousands of feet above the ocean, and subjected in consequence to great denudation; this process was doubtless facilitated by the flexures and fissures accompanying the movement. Away from this axis of disturbance, the strata (as has been already observed) were but slightly moved, with the result that they remained under water and undenuded, or but slightly emergent, long after those on the border of the Archæan Protaxis were being subjected to extensive erosion.

Under these conditions denudation proceeded more rapidly along the tract bordering the Protaxis, and especially along the arches or anticlinal flexures. The synclines, or trough-shaped areas, were protected from erosion to a greater or less degree. In the region with which we are specially concerned, the line of the Unaka Range and Blue Mountains, which was perhaps never altogether submerged, was upraised gradually into high land. The Cambrian and Silurian strata were subjected to erosion; and streams carrying the materials flowed down the flanks of the emergent land into the sea or estuary to the westward. This process was going on all through the Mesozoic period. As time went on, these western tracts, wherever in the line of anticlines, were themselves elevated and eroded, and ultimately the synclines themselves; but the necessary result of this unequal process of erosion would be to leave the synclinal tracts relatively higher than the anticlines. At a later epoch the Cumberland Plateau began to be formed by the cutting back of the strata in the direction of their dip; the massive Carboniferous grits, resting on softer strata largely formed of shales, presenting the necessary conditions for the development of a crested ridge.

4. *Formation of the Cumberland Plateau.*—We are now in a position to understand the primary conditions under which this plateau was developed. First there are the required stratigraphical

* 'Geology of Pennsylvania.'

Fig. 1.—Map of a part of the State of Tennessee, showing the Gorge of the Tennessee River near Chattanooga.

MAP AND SECTIONS
TO ILLUSTRATE
DR. E. HULL'S PAPER ON THE PHYSICAL GEOLOGY
OF
THE TENNESSEE AND PARTS OF ADJOINING DISTRICTS
IN THE
UNITED STATES OF AMERICA.

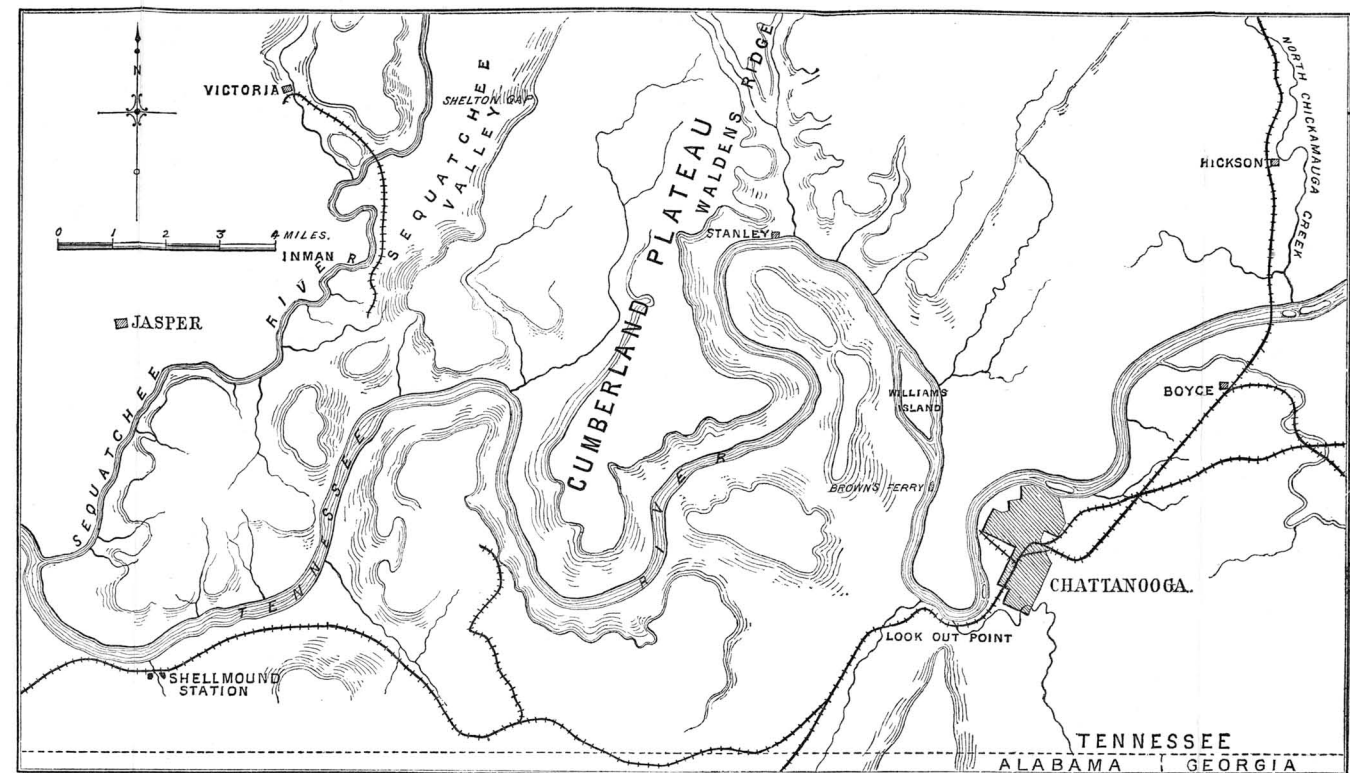
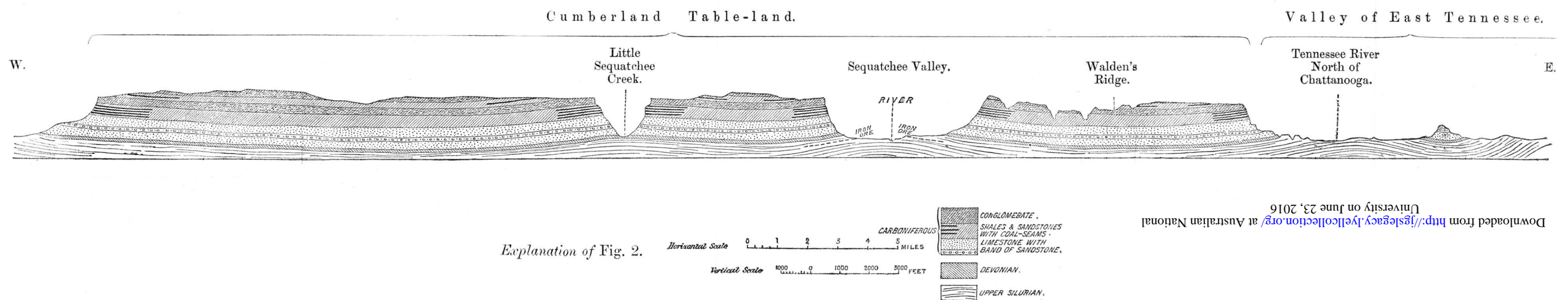
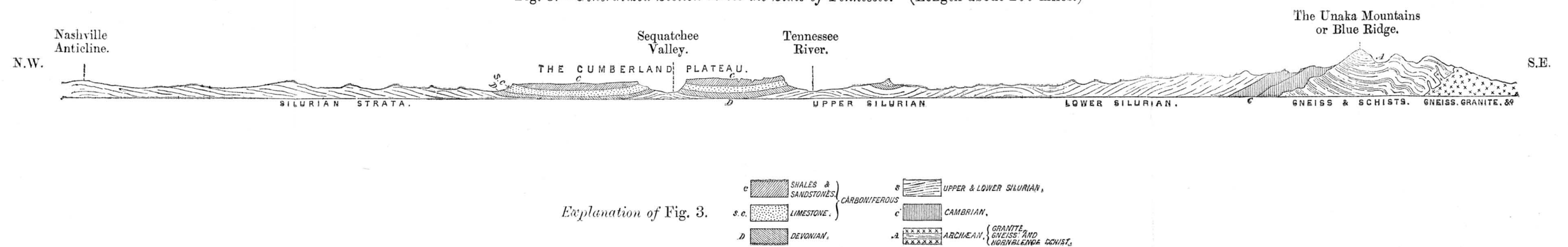


Fig. 2.—Section across the Cumberland Plateau to the East Tennessee Valley.



Explanation of Fig. 2.

Fig. 3.—Generalized Section across the State of Tennessee. (Length about 200 miles.)



Explanation of Fig. 3.

conditions, namely hard grits or sandstones resting on soft strata, and these occupying the line of a low synclinal axis, ranging in a N.E. and S.W. direction. The strata in this position being the latest which were upraised, were preserved almost intact; while those continuous with them, and forming the flanks of the parallel anticline, were denuded away. The simple conditions here stated are somewhat modified by the two secondary anticlines along the Sequachee Valleys; but these do not affect the general position, and are themselves examples of lesser valleys eroded along anticlinal axes.

It should also be observed that the Tennessee River, continued into the Clinch River, keeps close to the base of the escarpment of the Cumberland Plateau (Walden's Ridge); and we may suppose that, as this escarpment was cut back in the direction of the dip, the river itself gradually moved westward, or in the same direction*. Thus the Cumberland Plateau was developed by the erosion of the Valley of East Tennessee on the one hand, and by a somewhat similar series of physical operations along the Valley of the Cumberland River on the other or western side.

11. *The Gorge of the Tennessee through the Cumberland Plateau.*

The course of this stream, the fourth in size in the United States, is most remarkable, and requires to be explained on geological principles. Descending (under the name of the Little Tennessee) from the Blue Ridge (or Archæan Protaxis), it crosses the Unaka ridge in a north-westerly direction to Kingston; here it joins the Clinch River, coming down the Shenandoah Valley in a south-westerly direction; and this course it retains, flowing along the foot of the Cumberland Plateau to Chattanooga, when it changes its course, and traverses the plateau by the gorge already described. Ultimately the Tennessee, instead of continuing its course in a southerly direction into the Gulf of Mexico, makes a great sweep to the northward and joins the Ohio at a distance of about forty miles above the junction of that river with the Mississippi, thus adding to its course a length of about 800 miles!

The east and west saddle or water-parting, from which the streams drain into the Tennessee on the one side and into the Gulf of Mexico on the other, descends to a level of about 920 feet above the waters of the Gulf a few miles south of Chattanooga. The level of the saddle is only 270–280 feet above the river at Chattanooga; so that (to put the case in popular language) we may say that the Tennessee, rather than take a direct course towards the Gulf by crossing a saddle which is only 270–280 feet above its bed, has preferred a channel through a table-land rising 1400–1500 feet above its bed—a course

* If we regard the direction, the Tennessee River is the real continuation of the Clinch downwards, and the Little Tennessee is a lateral tributary. The Tennessee at a former period probably ran in a channel further east and at a higher level.

which shows that the original relative levels of the saddle and the plateau have been absolutely reversed.

In brief, therefore, we infer that when the river began to erode its channel in the region of the Cumberland Plateau, this tract was relatively lower than that to the south of its present course. By the process of denudation these relations have been reversed; but the river, having once begun to wear down its channel, continued to deepen it as the land rose; so that, having once selected its course, it never afterwards left it.

If it be permitted to compare small things with great, we may say that the process of valley-erosion as applicable to the Tennessee is somewhat analogous to that which took place in the South-east of England during later Tertiary times, in consequence of which streams, such as the Medway and the Ouse, pass into the sea by channels traversing the escarpments of the Chalk and Lower Greensand. The high grounds forming the sources of these streams in the centre of the Wealden area represent the ridge of the Unaka and Blue Mountains; the plain of the Weald Clay represents the Valley of East Tennessee, and the escarpments of the Greensand and Chalk the Cumberland Plateau. How these channels were formed, together with the adjoining escarpments, has been ably explained by Messrs. Foster and Topley in their joint paper on the "Denudation of the Weald" *, and further illustrated by Sir Andrew Ramsay †. The principles of interpretation which have been adopted in the one case are applicable in the other, though on a larger scale, and need not be repeated ‡.

The effects of denudation here described were doubtless accelerated during the "Pluvial" or "Champlain" Period, corresponding to the later stages of the Glacial Period. This region was, it is true, far to the south of the limits of the great ice-sheet of North America, as shown by Mr. T. C. Chamberlain §; but the evidences of extraordinarily copious rainfall and of the former erosive and transporting action of the rivers over the regions lying along the margin of the great ice-sheet are abundantly evident, and are fully recognized by American geologists. Along the eastern side of the Alleghanies the representative of this epoch is the "Columbia Formation" described by Mr. W. J. McGee ||; and to a similar stage is probably referable the remarkable deposit of red loam by which the surface of the country in the valleys of the Tennessee and Sequachee is overspread to a depth of many feet or even yards. The effects of extensive aqueous erosion, and the consequent deposition of sediment in the valleys beyond the reach of existing streams, are everywhere manifest in this part of America.

* Quart. Journ. Geol. Soc. vol. xxi.

† 'Phys. Geol. & Geogr. of Great Britain.'

‡ It is right to observe that Professor Safford and Mr. J. P. Leslie account for the preservation of the Cumberland Plateau by faulting, which has relatively lowered the Carboniferous strata; but the well-defined escarpment with which the strata crop out along the Valley of East Tennessee near Chattanooga seems to me to show that such a cause is insufficient.

§ 'Seventh Annual Report U.S. Geol. Survey,' p. 155.

|| *Ibid.*, "Taxonomy of the 'Columbia Formation,'" p. 611, &c.

DISCUSSION.

Mr. TOPLEY thought the parallel drawn by the Author with the Wealden area was in part justified, but there were differences connected with minor points. The structure had been worked out in detail for the Wealden area, but a similar state of things existed in other parts of England. The watershed between the East Tennessee valley and the Gulf of Mexico must have been greatly lowered.

Prof. HUGHES asked if the gravels of the high terraces were composed of Silurian or Carboniferous detritus, as he wished to know whether the Carboniferous beds of the plateau had been continued over the East Tennessee valley at the time of the formation of the gorge. The northerly direction of the river after leaving the plateau suggested change of level.

Mr. WILLS compared the area described with the gorge of the Avon at Bristol.

Dr. HYLAND had not been led to any definite conclusion during his short stay in the region.

The PRESIDENT found difficulties here, as elsewhere, in realizing the form of the ground when the rivers began to flow, and in discovering whether there were subterranean movements which affected the denudation. He felt that the explanation of the topography might not be so simple as Prof. Hull made out, and would like to have more details as to the structure of the ground.

The AUTHOR, in reply, concurred with the remarks of the President as to the complex character of the subject. He thought the fault drawn by Prof. Safford on the east side of the plateau had little to do with the formation of the escarpment. He had no evidence to adduce in answer to Prof. Hughes's question. There was no more reason why the river should have flowed south on the west than on the east of the plateau.