



Notes on the Geological Structure of Tazewell, Russell, Wise, Smyth and Washington
Counties of Virginia

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Notes on the Geological Structure of Tazewell, Russell, Wise, Smyth and Washington Counties of Virginia. By John J. Stevenson, Professor of Geology in the University of the City of New York.

(Read before the American Philosophical Society, November 21, 1884.)

Introduction.

- I. *Geological Structure: the Faults and Anticlines.*
- II. *The Several Groups.*
- III. *The Area drained by Holston River.*
- IV. *The Area drained by Clinch River.*
- V. *The Salt and Gypsum Deposit of the Holston Valley.*

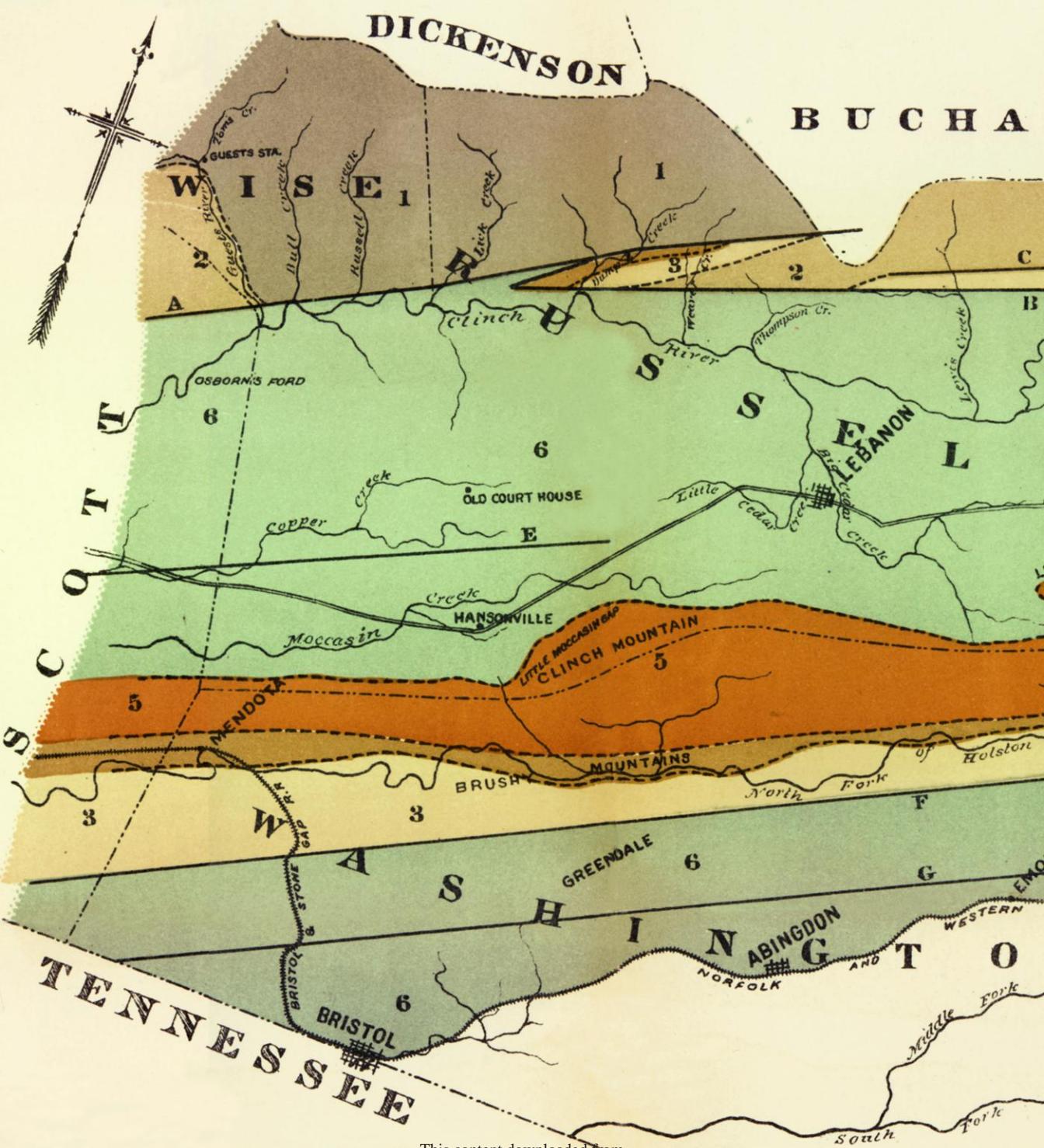
INTRODUCTION.

This memoir is practically a continuation of the writer's memoirs on southwestern Virginia, read before this Society in August, 1880, and in January, 1881. In it the description is carried eastward so as to connect with the reconnaissance work described in the writer's memoir, read in October, 1881. This, however, differs from those in that it contains no references to economic geology except in so far as may be needful to the explanation of structure.

Little has been published respecting the geology of this region, the only memoir of material importance being that by Prof. J. P. Lesley, read before this Society in 1871.* The writer is indebted to this for some useful information, which will be acknowledged fully in its proper place. A note in *Science* by Mr. E. G. Squier, makes one wish that that observer had published more of his work. Brief notices of the Saltville basin and vicinity have been published by Profs. W. M. Fontaine and C. H. Hitchcock, but these give little of detail.

Like the region described in the writer's previous memoirs, this shows no monotony of surface. The Great valley of Virginia, with its floor of Cambro Silurian rocks, occupies a great part of Washington and Smyth counties, and has as its north westerly boundary the irregular Walker mountain. That mountain is a low ridge of limestone in Washington county, but in Smyth county it becomes double, consisting of a Medina ridge, Big Walker, separated by a Clinton valley from the Devonian ridge, Little Walker, which overlooks the valley. Rich valley separates Big Walker mountain from Brushy mountain, a ridge of Devonian and Lower Carboniferous, which is separated by a narrow and somewhat indefinite Poor valley from Clinch mountain, these two ridges bearing the same relation as Big and Little Walker. There is then a succession of "Poor" and "Rich" valleys; the latter, with limestone soils, are either

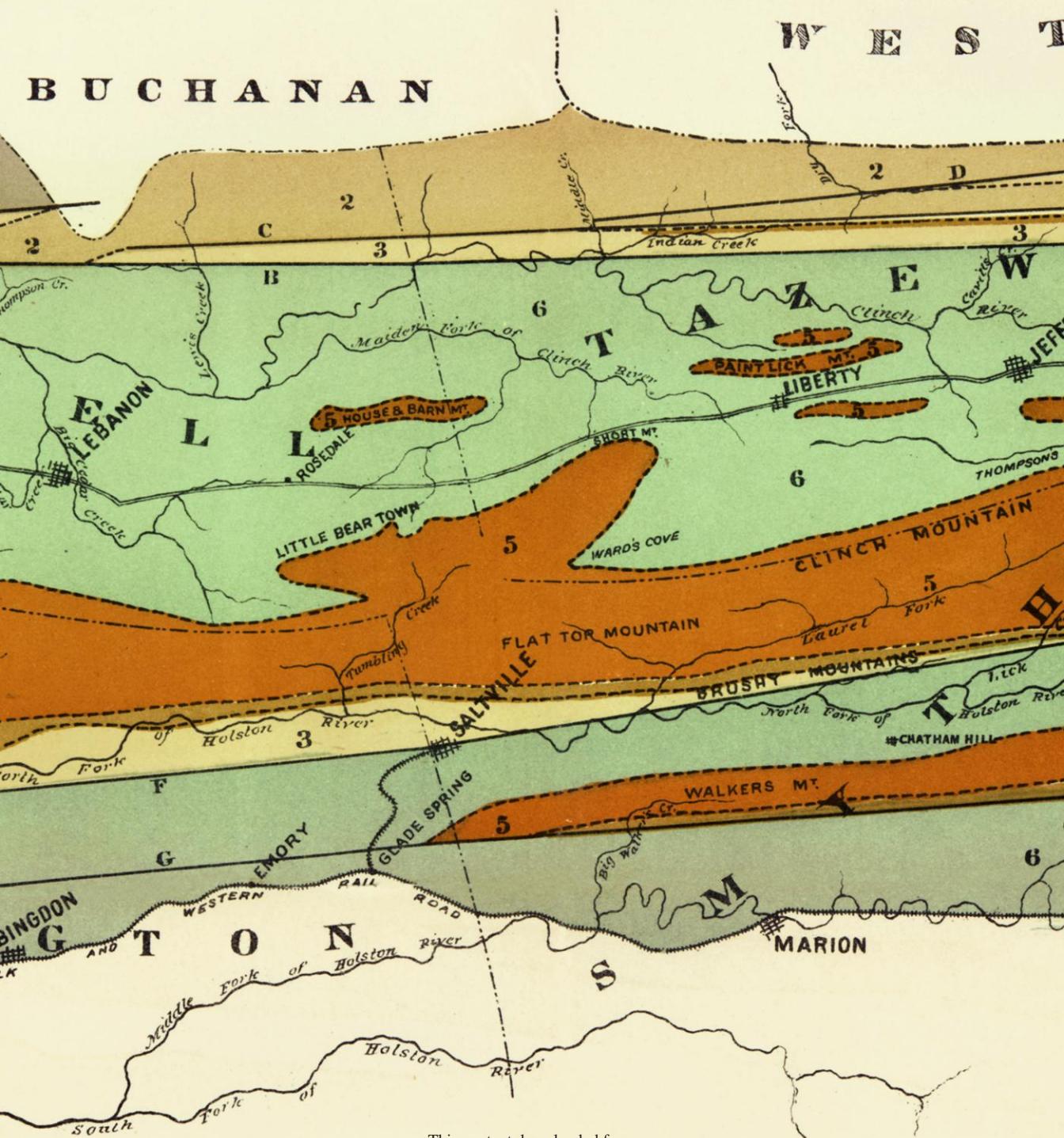
*Lesley. *The Geological Structure of Tazewell, Russell and Wise Counties in Virginia.* Read April 21, 1871.

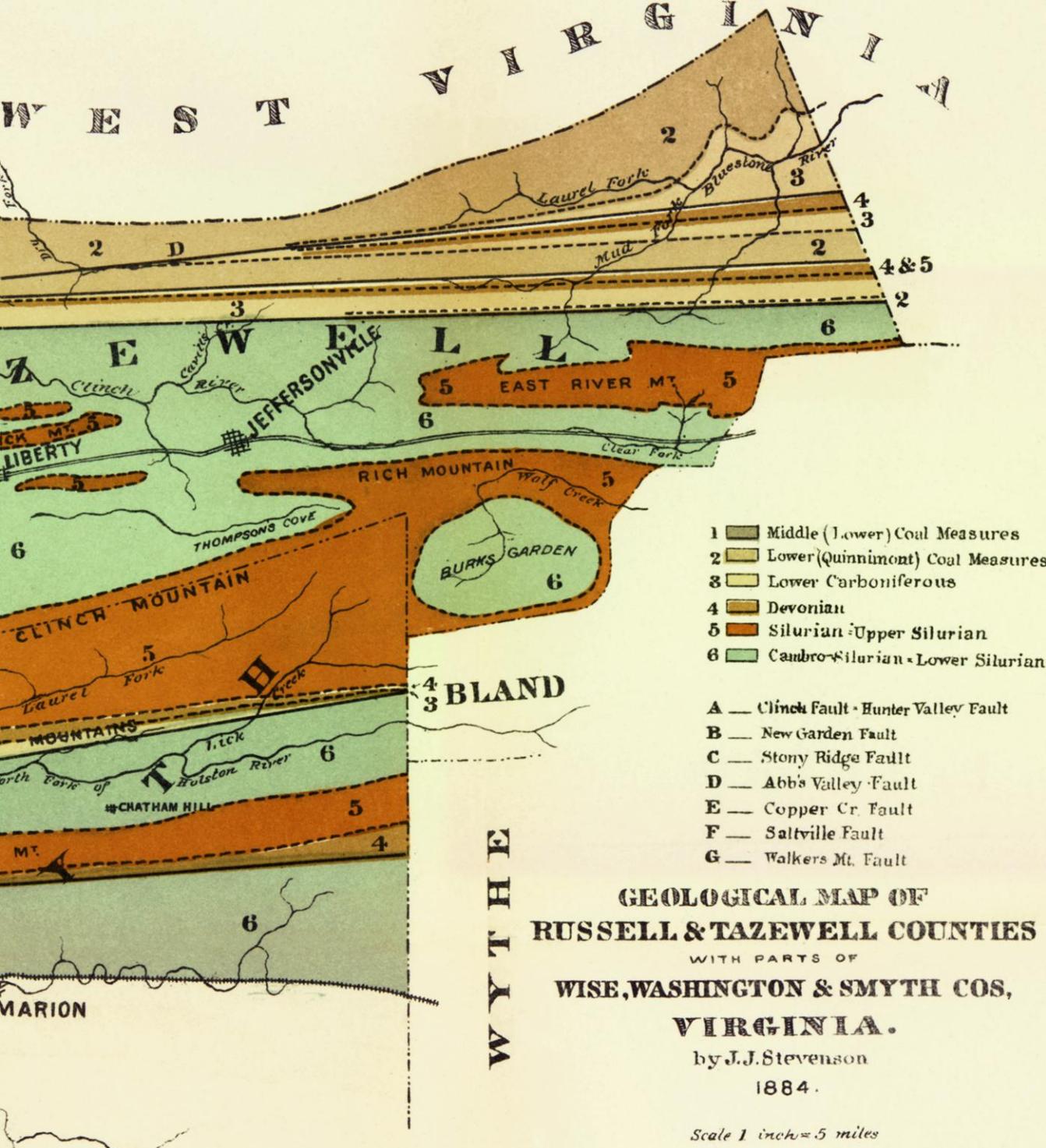


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Lower Carboniferous or Cambro-Silurian, while the former are either Silurian or Devonian. *The Poor valley* is that which follows the southerly foot of Clinch mountain from far beyond the Tennessee line north-eastward into Bland county. *The Rich valley* is that which lies along the northerly foot of Walker mountain, rudely following the Saltville fault to just beyond Saltville.

The region between Clinch mountain and Clinch river shows many broad "bottoms," and much handsomely rolling land. The immediately underlying rocks are Trenton and Knox in most of the region, but toward the eastern end strips of Hudson and Medina are held in narrow synclinals, and form short ridges which are striking features of the scenery.

Two limestone ridges, Copper and Moccasin, are persistent.

The whole area is fairly well watered, though in those parts directly underlaid by limestone springs are apt to be uncertain, as the waters frequently disappear through newly made crevices in roofs of caverns, where they join underground streams, which occasionally break forth with enormous volume. The principal water ways are the Clinch and the two forks of the Holston. The Clinch, rising in eastern Tazewell, drains nearly the whole of that county and Russell with much of Wise. Its important tributaries from the south are the Maiden Spring fork in Tazewell and Copper creek, which, rising in Russell, enters the river in Scott county. The tributaries from the north are numerous, but, with the exception of Guest's river in Wise county, they are very short. Bluestone river and Wolf creek, draining the eastern part of Tazewell, flow to the New river. The North fork of the Holston river rises in Bland county not far east from the Smyth county line and drains the space between Walker and Clinch mountains, with a narrow strip north from Clinch mountain in Scott and Russell counties. The South fork of Holston drains the Great Valley. The Clinch and Holston unite in Tennessee to form the Tennessee river.

Only the southern part of the area under consideration has railroad facilities. The Norfolk and Western Railway follows the valley; its New River branch, passing through Pulaski and Giles counties of Virginia and Mercer county of West Virginia, reaches the extreme north-east corner of Tazewell county at the Pocahontas mines; its Saltville branch extends from Glade Spring to Saltville. A railroad to extend from Bristol to the Big Stone gap in Wise county has been graded from Bristol to Mendota, about sixteen miles, but no work has been done on it for some time. Clinch mountain makes very difficult access from the valley to the region beyond, for, in its whole length of more than 100 miles from the Tennessee line to the eastern edge of Bland county, there is but one water gap, and only one wind gap which affords easy grades for a wagon road. The former, Big Moccasin, has been taken for the Bristol and Stone Gap road, and the other, Little Moccasin, has been occupied by a survey for the Norfolk and Cincinnati Railway Company. This is a difficult pass for railway operations, but Mr. Oramel Barrett, Jr., has succeeded in locating

an available line through it. Some conception of the difficulties to be overcome by a road in passing from the valley to Clinch river may be had, when one remembers that in that interval the line must cross Walker mountain, Rich valley, Brushy mountain, Poor valley, Clinch mountain, and the irregular limestone ridges of Tazewell county. Roads have been projected and survey lines run across the headwaters of streams entering Clinch river from the north, having for object the passage into Kentucky. None of these has advanced beyond the preliminary surveys.

Several wagon-roads with good grades were constructed many years ago by State aid, and some excellent pikes were constructed by private companies. The engineering of the Tazewell pike and of the Hayter's Gap road as they cross the abrupt Clinch mountain is remarkably good. The grades of the Fincastle pike passing through the county seats of Tazewell, Russell, Scott and Lee on the way to Cumberland gap are very easy. The common roads, as in too many other parts of our country, are far from being good; often a very fair wagon road terminates suddenly in a mere trail with almost impassable grades. The traveler finds horseback the more comfortable as well as the more expeditious mode of conveyance.

The especial industries of the region are grazing and tobacco culture. The limestone soils yield grass equal to that of Kentucky, and beef cattle from the ridge land of Russell and Tazewell are thought to be equal to those from any other region of our country. The timber is superb, walnut, poplar, oak, ash and hickory being still plentiful beyond Clinch river. The mineral resources are important. Brown hematites occur at many localities; fossil ore is present in greater or less quantities on Big Walker, Clinch, Paint Lick, Rich and East River mountains; oxide of manganese was seen on Rich mountain and Copper ridge; barium sulphate is present at times in considerable quantity; the Estillville marbles are of the finest quality and in almost unlimited quantity; salt and gypsum of great excellence are found in the valley of the North Holston; north from the Clinch river is the great coal field, containing in Tazewell and part of Russell the soft coking coals of the Quinnimont group or Lower Coal measures, while in western Russell and in Wise county, north from Stone mountain, are the harder coals, the shipping coals of the Middle Coal measures. For the present, however, none of all these resources, agricultural and mineral, is available, except that of converting grass and grain into beef, the cost of transportation destroying the value of the rest.

The following lists of altitudes have been supplied to me by the gentlemen whose names precede the lists:

*Altitudes on and near the Line of the Norfolk and Cincinnati Railroad.
From Oramel Barrett, Jr., Chief Engineer.*

Elevations above mean tide at Norfolk, Virginia, all taken with the level, except a few by barometer which are specially indicated.

Washington County.

Abingdon station, sub-ballast on N. and W. R. R. . . . 2056.8

Walker Mountain summit, on turnpike from Abingdon to Liberty.....	2145
Low water, N. F. of Holston, mouth of Little Moccasin creek, barometer.....	1430
Same at mouth of Wolf creek, below Saltville.....	1508
Little Moccasin gap, summit on line between Washington and Russell counties.....	2377
Clinch Mountain summit, one mile N. E. of Little Moccasin gap, by triangulation; is about average altitude of the crest for nine miles north-east to near Hayter's gap.....	4244
Clinch Mountain summit (Rich mountain), at head of Stuart run.....	3264
Hayter's gap in Clinch mountain	3025

Russell County.

Divide between Big Moccasin and Little Cedar creeks, close to Abingdon and Lebanon pike.....	2341
Little Cedar creek just below Mr. Brown's milldam, three miles south from Lebanon	2090
Dickersonville, in front yard of dwelling between house and store.....	2043
Summit of Copper ridge near Wise C. H., road at head of Copper and Ocean Cove creeks.....	2288
Fincastle pike, eastern base of Copper ridge, one mile and a half N. E. from Dale Carter place.....	2075
Summit of Copper ridge in public road at head of Jesse or Mill branch.....	2226
Springs at head of Jesse branch.....	2025
Surface of low water in Clinch river at mouth of Dump creek.....	1480.5
Grissell coal bed on Dump creek.....	1720
Eastern base of Sandy ridge at head of Hurricane fork of Dump creek.....	2000
Gap in Sandy ridge at head of Hurricane fork of Dump creek, and Caney fork of Indian creek, the latter flowing into Russell fork of Big Sandy river..	2302
Sandy ridge, approximate average elevation of, for several miles east and west from the above-mentioned gap	2600
High knob on Sandy ridge, back of ex-Sheriff James Kiser's house, at head of Dump and McClure creeks, barometer.....	3100
Bower's gap in Sandy ridge at head of Weaver and Indian creeks.....	2300
Little Cedar creek in front of Lebanon.....	1970

Surface water in mill-dam, Big Cedar creek at Elk Garden.....	2120
In public road in front of residence of Mr. W. A. Stu- art, on Big Cedar creek.....	2170
War gap, in spur of Clinch mountain, drained by branch of Big Cedar creek.	2500
In meadow, front of Rosedale store, looking toward Big Cedar creek.	2330
Front of E. R. Baylor's store, on divide between Big Cedar creek and North fork of Indian creek of Maiden Spring fork.....	2448
Clinch river at mouth of Lick creek	1404.5
Same at mouth of Jim Jack creek, above Lick creek..	1408

Dickenson County.

Surface of low water in Russell fork of Big Sandy river at mouth of Indian creek.....	1415
Same at mouth of Frying Pan creek.....	1266.6
Same at mouth of McClure creek.	1240.5
Same at the mouth of Pound fork.....	1170
Same in the "Breaks" at the base of the highest "tower," two and three-fourths miles from the Ken- tucky line.	1060
Same at Kentucky line by barometer.	850

Wise County.

Summit of Whetstone Mt., 200 feet north from Wise Court House road, between Russell and Whetstone creeks.....	1843
Surface of water in Russell creek, one-fourth mile be- low R. Dickenson's house, directly below mouth of Little Russell creek,	1530
Summit of Bull hill, between Russell and Bull creeks, close to Wise Court-House road.....	1910
Surface of water at junction of Little and Big Bull creeks	1425
Summit between Dry fork of Bull creek and Crab Orchard creek.....	2097

Elevations in Southwest Virginia, by South Atlantic and Ohio Railroad
levels, reduced to tidal elevations, taking Bristol, Tenn., on Norfolk
and Western Railroad, at 1670 feet above tide. John C.
Oliphant, Superintendent and Engineer.*

Washington County.

Bristol	1670
Summit of Walker mountain.....	2077
N. F. Holston river at Mendota	1325

* In the body of this memoir, this road is referred to as the Bristol and Stone
Gap R.R.

Scott County.

Moccasin gap in Clinch mountain.....	1233
Summit at Troublesome creek.....	1565
Clinch river at Spear's ferry.....	1185
Flat Lick summit.....	1540
Slemp's gap, end of Powell mountain.....	1320

Wise County.

Wild Cat summit.....	1905
Mineral city.....	1550
Big Stone gap.....	1555
Divide between Powell and Guest's rivers.....	2160
Guest river, near Lost creek.....	2090

Dickenson County.

Divide between Guest's and Pound rivers, at head of Indian creek.....	2605
Mouth of Indian creek of Pound river.....	1513
Big Sandy river at Kentucky line.....	854

I. THE GENERAL STRUCTURE.

As is already familiar to those who have read Prof. Lesley's memoir of April, 1871, or that of January, 1881, by the writer, the especial interest attaching to Southwest Virginia lies in the great faults or cracked anticlinalis which have so great extent both longitudinally and vertically. So far as known to the writer, the existence of these faults was first indicated by Prof. W. B. Rogers in his earliest report on the geology of Virginia,* three principal faults being shown on the long cross-section. The existence of the Saltville and New Garden faults is asserted in a paper on Thermal Springs by the same author and in a long memoir on the structure of the Appalachian Chain by Profs. W. B. and H. D. Rogers.† Some of these faults are very simple in structure, but others are sufficiently complex. Groups of anticlinalis occur, canoe-shaped and overlapping, thus reproducing the features so characteristic of Silurian and Cambro-Silurian areas of Central Pennsylvania.

The structure may be considered most conveniently by going from the Great Valley northward to the Coal Measures area, taking the more prominent features in order as follows:

The Fault of Walker mountain.

The Saltville fault.

The Clinch Mountain group of folds.

* W. B. Rogers. Report of the Geological Reconnaissance of the State of Virginia. 1836.

† These papers are contained in the volume of Transactions of the Association of American Geologists and Naturalists. 1840-42.

The Copper Ridge fault and the Elk Garden anticlinal.
The House and Barn synclinal.
The Clinch River system of faults.
The Stone Mountain anticlinal.

The Fault of Walker Mountain.

The Great Valley of Virginia extends in Washington and Smyth counties from Walker mountain south-eastwardly to the limit of those counties. It is underlaid by Cambro-Silurian rocks whose calcareous beds have yielded readily to erosion. The dip is undulating, and one well-marked anticlinal is crossed frequently by the turnpike between Seven-mile ford and Bristol.

The fault of Walker mountain is clearly the same with that which is termed the *South Fork of Holston Upthrow* on Prof. Lesley's map of 1871. As, however, it nowhere approaches the South fork of Holston, the writer prefers to retain the name applied to it in his memoir of 1881. It is wrongly placed on the map accompanying that memoir, though its position is given rightly in the text as at about four miles from Bristol. The error arose from a misunderstanding respecting the true place of Walker mountain, so that on that map, this fault occupies very nearly the place of the Saltville fault.

This fault, in much of Washington county, brings the Trenton limestone into contact with the lower part of the Knox group. Where it is crossed between Bristol and Mendota cannot be determined accurately without detailed study, but the course is shown approximately by a rather low ragged ridge of limestone which can be followed without difficulty to the eastern edge of Washington county. The line of fault is crossed by the Saltville branch of the Norfolk and Western Railroad at the water station, somewhat less than two miles from Glade spring. Thence the downthrow rapidly increases, and within two miles the ragged ridge of limestone becomes Walker mountain with Medina and Clinton, the fault line passing just north from Washington springs. The downthrow continues to deepen, Devonian is held on the northerly side of the fault, and the mountain is divided into Big and Little Walker, Medina and Chemung ridges, separated by a valley of Clinton and Hamilton. This structure is well shown on Chilhowie creek, though at the place of the fault, nearly three miles north from the railroad, everything is wholly concealed. It is altogether probable that the lowest beds of the Lower Carboniferous are held on the north side of the fault toward the eastern edge of Smyth county, for in the adjoining county of Wythe Vespertine coal beds occur and they have been worked. Unfortunately one cannot determine with equal ease the changes which take place on the southerly or upthrow side of the fault; the Knox limestones have yielded to erosion and solution and for the most part their surface is deeply buried under débris. There is no room for doubt, however, that

the cherty beds of the Knox, which weather with a fretted surface, are exposed along the southerly side as far eastward as the Saltville railroad.

Northward from the fault of Walker mountain the sequence is regular until, at a distance of about four miles, the

Saltville Fault

is reached. This was designated in the writer's previous memoir as the fault of the *North Fork of Holston*, the name applied to it by Prof. Lesley. That observer having touched this fault only near Saltville, naturally applied to it the name of the river by which it is crossed more than once in that neighborhood. But, as will be shown, that name is misleading, and "Saltville" is much preferable, as the line of the fault passes through the widely known village of that name.

This fault is crossed by the Bristol and Stone Gap Railroad grade within a few rods north from the Rich Valley road and only a little way south from the deep cut on Wolf Run summit. Its place is wrongly indicated on the writer's earlier map, on which it should be very nearly where the Walker Mountain fault has been placed. The course of the fault eastward from the railroad is almost straight to Saltville on the border of Smyth county. It passes through that village not many yards from the salt-shaft: it lies between the Broadford road and the river; is crossed by the latter probably twice within six miles east from Saltville, and is again crossed or touched by it at ten miles from Saltville; it is crossed by Cove creek at a little way north from I. H. Buchanan's house and by Lick creek at only a little way north from the Saltville and Sharon Springs road. Beyond ten miles eastward from Saltville, that road lies south from the fault.

The North fork of Holston rises in Bland county, follows a very serpentine course through Knox and Trenton limestones for fifteen or twenty miles, and touches the Saltville fault at ten miles east from Saltville. Thence until very near the Broadford, six miles from Saltville, the river is south from the fault, but in the next three miles the fault is crossed certainly more than once. At somewhat more than three miles east from Saltville the river crosses to the northerly side of the fault, finally. Within Washington and Scott counties the river bed and the fault are from two to five miles apart, with the clumsy Brushy mountain occupying the interval. In a distance of seventy or eighty miles the North fork of Holston crosses or touches the Saltville fault not more than four times, all of them within a space of eight miles; while during the rest of its flow through Bland, Smyth, Washington and Scott counties it is from one to five miles either north or south from the line of fracture. Its course seems to be dependent on neither the fault nor the character of the rocks for it is serpentine alike through the yielding limestones of the Trenton, the refractory sandstones of the Knox, the hard and soft limestones of the Lower Carboniferous, the soft shales and hard sandstones of the Lower Carboniferous, Devonian and Silurian.

The relation of the Saltville fault to the Burk's Garden anticlinal of the
PROC. AMER. PHILOS. SOC. XXII. 118. P. PRINTED FEBRUARY 19, 1885.

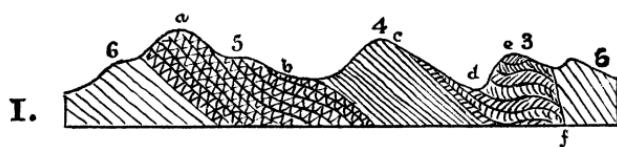


FIG. I.—From Moccasin creek to the Saltville fault beyond Wolf Run summit. *a*, Clinch Mt. *b*, Poor valley. *c*, Brushy Mt. *d*, N. F. of Holston river. *e*, Wolf Run summit. *f*, Saltville fault. *3*, Lower Carboniferous. *4*, Devonian. *5*, Silurian. *6*, Cambro-Silurian.

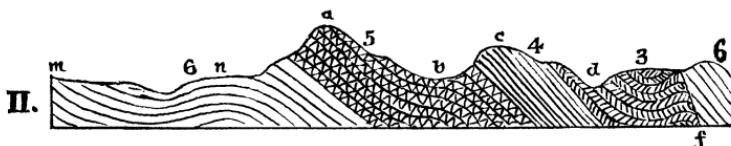


FIG. II.—From Fincastle pike to the Saltville fault through Hayter's gap. *a*, Clinch Mt. *b*, Poor valley. *c*, Brushy Mt. *d*, N. F. of Holston river. *f*, Saltville fault. *m*, southerly slope of Elk Garden antclinal. *n*, Loop anticlinal. Numbers as in Fig. I.

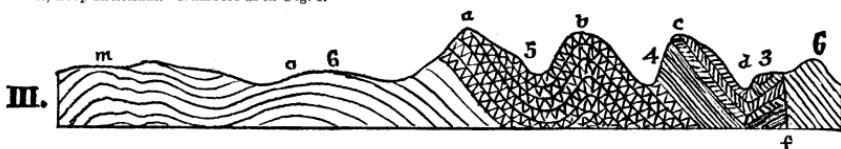


FIG. III.—From Fincastle pike at Liberty to the Saltville fault at nine miles west from Saltville. *a*, Clinch Mt. *b*, Flat Top Mt. *c*, Brushy Mt. *d*, N. F. of Holston river. *f*, Saltville fault. *m*, Elk Garden anticlinal. *o*, Cove anticlinal. Numbers as in Fig. I.

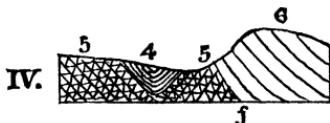


FIG. IV.—Apparent structure of Clinch fault at gap of North fork of Clinch river, through Buckner's ridge. *f*, Fault. Numbers as in Fig. I.

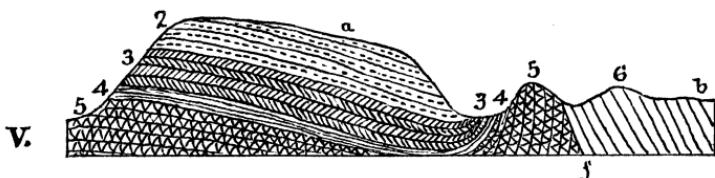


FIG. V.—Cross-section along Stony creek, through Powell mountain and Buckner's ridge. *a*, Powell-Stone Mt. *b*, Buckner's ridge. *f*, Clinch fault. *2*, Lower Coal Measures, Quinimont. Other numbers as in Fig. I.



FIG. VI.—Clinch fault on Osborn Ford road. *f*, Fault. Numbers as before.



FIG. VII.—Structure on Robinson fork of Lewis creek, after Squiers. *xy*, line of New Garden fault. *a*, Lower Coal measures (Quinimont). *E*, Lower Carboniferous. *b*, Knox beds.

Clinch Mountain group of folds is of no little interest as having some bearing on the relative age of the folds and faults. The anticlinal originates probably at but a little way from Little Moccasin creek, and as it increases steadily eastward, it thrusts the outcrops of the successive groups further and further toward the south-south-east. On Wolf run, along the railroad grade, the whole of the Lower Carboniferous column is exposed, the red shales being well shown in the long cut at the summit. These rocks describe a synclinal and anticlinal which are distinct on Wolf run. On this railroad line, then, the Knox beds are in contact with the very top of the Lower Carboniferous. Eastward the red shales are cut off more and more in the fault, so that at Saltville only a small part remains exposed, and the fault passes very near the crest of the anticlinal seen on Wolf run. At ten miles east from Saltville, the greater part of the limestones have been swallowed up, while on I. H. Buchanan's property, sixteen miles from Saltville, there remain merely the clayey limestones and the shales at the base of the series; and at the line of Bland county all has disappeared save the coal-bearing shales.

So this fault, in crossing the strike of the rocks, carries down in succession the several divisions of the Lower Carboniferous. Its course can be followed by the eye without difficulty, for the ragged hills of Knox sandstones and limestones, near whose northerly foot it passes, go directly to Garden mountain, the southerly slope of the Burk's Garden anticlinal. It is wholly probable that, beyond the eastern border of Smyth county, the Lower Carboniferous disappears, so as to bring the Chemung and Knox into contact; while still further east the Lower Carboniferous may re-appear as the anticlinal loses strength.

What erosive effects have been due to the influence of the fault cannot hardly be ascertained. Unquestionably there is what is termed a valley in the vicinity of the fault for much of the distance within Washington and Smyth counties—but it is in the vicinity only; such a valley can be found in the vicinity of almost any other line which one may choose to draw within the limestone region. Rich valley, now on one side, now on the other side of the fault in Washington county, is merely a succession of cross-valleys separated by irregular divides; but in Smyth county it is altogether south from the fault, except near Saltville, and is separated from it by the rugged ridge of Knox beds.

The Clinch Mountain Series of Folds.

This series enters the State from Tennessee at ten or twelve miles west from the line of Washington county, and extends thence in an E.N.E. direction through Scott, Washington, Smyth and Bland counties into Giles. Clinch mountain is the bold ridge at the north with a Medina cliff for its crest, with Clinton for its southerly slope and with Hudson and Trenton forming the northerly slope; a Poor valley of Clinton and Hamilton separates it from Brushy mountain, a clumsy mass near the State line, but owing to encroachments by the Saltville fault becoming simpler

and better marked until it is a single ridge with a cliff of Chemung sandstone for its crest.

In a section extending from Moccasin creek to the Saltville fault at Wolf Run summit this series shows monoclinal structure from Moccasin creek until within about two miles of the summit, where one crosses the petty folds already mentioned. At not far from twelve miles further east, near Little Moccasin creek, a new feature is introduced and the Poor valley is divided by a gentle anticlinal, the structure being as represented in Fig. 1. This anticlinal may be the same with that which is designated the Burk's Garden anticlinal, or it may be a petty fold dying out on the Tazewell pike in the synclinal north from that anticlinal. The development of the anticlinal and the accompanying synclinal on the northerly side pushes the Clinch outcrop of Medina northward so as to form the irregular Brumley mountain, which at ten or twelve miles further eastward is cut off by the growing Loop anticlinal. The Clinton shales held up by the new anticlinal, widen Poor valley into Brumley and Hayter coves extending from Little Moccasin creek eastward almost to Tumbling creek, somewhat more than fifteen miles in a direct line.

A projection somewhat like Brumley mountain, but better defined, is shown further east beyond the Cedar Creek loop or cove, the first of the coves or anticlinal valleys with Medina rim. Brumley mountain forms the south-westerly boundary, Little Bear town the easterly and northerly, while the notched border of Clinch mountain forms the southerly and south-easterly border. The cove is not wholly enclosed, as the Medina has been removed from the north and north-west for probably five miles. The structure along a section beginning at the Fincastle pike and passing through Hayter's gap in Clinch mountain to the Saltville fault is shown in Fig. 2. The Loop anticlinal is crossed by the road to Hayter's gap just north from the Rich Mountain road. It is complex and apparently attains its maximum further west, where it cuts off the Medina of Brumley mountain. It diminishes quickly eastward so that the Medina outcrops of both Clinch and Little Bear town unite at the head of the cove or loop. The Burk's Garden anticlinal in Poor valley attains to no material elevation along this line, and is simply a broad roll, which serves to carry the outcrop lines of Devonian and Lower Carboniferous southward, as is well shown at Saltville, where nearly the whole of the Lower Carboniferous red shales have disappeared in the fault, which there passes very near the crest of the Wolf Run anticlinal.

The next section, that passing from Liberty on the Fincastle pike to the Saltville fault about nine miles west from Saltville, is shown approximately in Fig. 3. The Thompson-Ward cove, also on the northerly side of Clinch mountain, is crossed by the Tazewell pike along the line of this section. It is not far from twenty miles long and is enclosed on all sides by Medina, save on the north-west, where there is a gap of nearly six miles. The westerly end is known as Ward's cove, enclosed by Short mountain on the north-west and on the south by Clinch mountain, which is continuous

along the southerly side of the whole cove. The east end, known as Thompson's cove, has Clinch mountain as its southerly boundary and Rich mountain as the northerly. This is a typical cove ; the Medina outcrops approach very gradually at each end so as to give a distinctly lozenge-shape to the outline. The Medina has been removed by erosion for a distance of fully six miles, the distance between Short mountain and Morris knob, the latter being the end of Rich mountain ; while Plum creek has made a water gap through Rich mountain almost due south from Jeffersonville, the county seat of Tazewell county. There evidently the whole of the Medina has been removed for a distance of nearly three miles—but the ridge is persistent on both sides nearly to the gap. The Cove anticlinal is not the same with the Loop anticlinal ; as the latter diminishes, the former, lying somewhat further north, increases.

The synclinal between the Cove and the Burk's Garden anticlinal is very close and complex along the Tazewell pike ; the dips are abrupt, and three subordinate folds were seen in the Clinton, between Clinch and Flat Top mountains. The pike crosses Clinch mountain at but a little way west from the maximum of the Cove anticlinal, crosses the northerly division of the Poor valley, and ascends the Burk's Garden fold which, within six miles, has brought up Medina through the Clinton to form a bold ridge, known as Flat Top or Poor Valley mountain. The Saltville fault is reached beyond Brushy mountain, but the exposures do not suffice for determining how much of the Lower Carboniferous has been cut off.

From this line eastward, the structure of the belt between the Elk Garden anticlinal at the north and the Saltville fault at the south becomes simpler. As the Cove anticlinal diminishes, the synclinals on each side gradually approach until they unite in the valley of Wolf creek, between Rich mountain and Garden mountain. The Medina outcrop of Clinch mountain passes round the easterly end of the Thompson-Ward cove, and forms the crest of Rich mountain eastward from Plum creek, while the Clinton of the northerly Poor valley is continuous with that of the Wolf Creek valley. That the Cove anticlinal wholly disappears before the road leading from Jeffersonville to Burk's Garden is reached is not altogether certain. In descending the southerly slope of Rich mountain along that road, one leaves the Medina at the summit, and quickly comes upon exposures of the Clinton, the dip being almost east of south ; but the dip is reversed soon, and the synclinal is close. Exposures in the Wolf Creek valley are not detailed, but the presence of a very gentle anticlinal explains the greatly diminished dip shown on the slope of Garden mountain. The rapid increase of the Burk's Garden axis is shown by the clumsy mass known as Bear town, from which the Medina walls of the Garden pass out. These walls unite at the east end of the Garden to form Round mountain, and thence the fold diminishes. Prof. W. B. Rogers, in one of his memoirs, speaks of this as the "great Garden anticlinal." Burk's Garden has an extreme length of about six miles, and an extreme width of not far from four miles. The surrounding wall is broken only at the

gap of Wolf creek at the north, by which the road from Jeffersonville enters. The immediately underlying rocks of the enclosure are Trenton, while Hudson and Medina are shown in the Garden mountain.

The Copper Creek Fault and the Elk Garden Anticlinal.

The Copper Creek fault of the writer's previous memoir was observed in Russell county on the Abingdon and Wise Court-House pike, at a little way from the summit between Tarr's fork of Moccasin creek and a petty branch of Copper creek. The fault is clear because of repetition of the section, and its place is indicated by abrupt steepening of the dip. The line was not followed eastward from that locality, but the fault certainly disappears before Little Cedar creek has been reached, ten miles further east, for there it is represented by two close anticlinals, or by an anticlinal with channeled crest. In the Elk Garden, three miles east from Lebanon, this anticlinal is crossed by the Fincastle pike, near Mrs. Smith's house, where it brings up the ferriferous beds at the top of the Knox group; it is distinct as a triple-crested fold passing just south from Liberty in Tazewell county. It passes near Jeffersonville in the same county, and is crossed by the pike at the school-house, about four miles east from Jeffersonville. The course of this axis varies somewhat under the influence of the Loop and Cove anticlinals, so that beyond Jeffersonville it is little more than north of east. This fold is interesting only in that it illustrates the disappearance of a fault in an anticlinal. The Trenton and Knox alone cross it, all newer beds having been removed by erosion.

The House and Barn Synclinal.

This trough lies directly northward from the Elk Garden anticlinal, and appears to be practically co-extensive with it. Some indefinite flexures of Trenton and Knox beds were seen in Scott county, very near the line which this synclinal, if continuous, would follow; but the first real trace is found in Russell county, between the Wise Court-House road and Old Russell court-house, on the way to Osborn's ford. It is thoroughly distinct at six miles further eastward, where the Mill creek and Abingdon roads unite at Little Cedar creek, about two miles west from Lebanon, where it holds the upper or clayey limestones of the Trenton. It passes immediately north from Lebanon, and is distinct on Little Cedar creek, near the road leading to Nash's ford. At both localities it is shallow and double, but its rapid deepening eastward is shown on the road leading from Black's ford to Rosedale; while immediately east from that road it holds a narrow ridge, House and Barn mountain, which carries a slender crest of Medina. This mountain, lying at about a mile and a half north from the Fincastle pike, is cut off by the Maiden Fork of Clinch river; but, within two miles beyond that stream, the Medina ridge again begins, now under the name of Paint Lick mountain, and continues for nearly twelve miles, when it is cut off by Plum creek, a tributary to Clinch river. Paint Lick is no doubt a double synclinal even at its western extremity, but this was not

determined by actual examination. Be that as it may, the mountain is quickly divided into two very narrow synclinals, separated by a narrow, compressed anticlinal, along which a valley has been eroded to the Trenton. The ridge in the southerly synclinal retains the name Paint Lick, while the short irregular ridge in the other trough is known as Deskins mountain, and continues for but three or four miles.

Erosion has been performed so faithfully beyond Plum creek that, for a distance of fully eight miles, all rocks newer than Trenton have been removed from the synclinal; but, at say four miles east from Jeffersonville, the Medina ridge is reached again in East River mountain, which clearly represents Paint Lick. It, however, is distinctly double, two synclinals separated by a narrow anticlinal, which evidently widens eastward, so that the synclinal mountains are wholly separate and bear distinct names. Deskins mountain appears to be represented by Dial mountain, an irregular little mountain with Medina crest. No examinations were made east from the Dial or north from East River mountain, so that the coloring of that portion of the map is not exact.

Within Tazewell and eastern Russell, the rocks rise regularly or nearly so from the synclinal to the New Garden fault, the rate of dip increasing toward the fault; but westward, as the synclinal becomes less pronounced, the rocks become distorted at a distance of two or three miles from the line of fracture. A synclinal occurs on the high limestone ridge, known as Copper ridge, within Scott county, but it disappears before reaching Mill creek in Russell county, for there no traces of it were found. Even where this indefinite synclinal exists, the rocks are badly twisted at varying distances from the line of displacement. Thus, on the road to Osborn's ford, the distortion begins at some distance above Barlow Nickels' house, or more than two miles south from the fault; on the road, one mile east from Lick creek of Clinch river, sharp folding was seen at a mile or more south, and it evidently continues almost to the fault; further east, the greatest complications are in the shales near the river, while disturbance appears to be wholly wanting near the line of fault; still further east on Lewis creek, near the mouth of Indian creek, and on Cavitts creek, the disturbance is insignificant, and the dip is regular for the whole distance.

The Clinch River System of Faults.

The general name here employed is that applied by Prof. Lesley to two members of the system, and it includes the Hunter Valley fault of the writer's previous memoir. No name less open to objection can be proposed; but this should not be taken as implying anything more than that in a general way the faults and the river are nowhere separated by an interval of more than a few miles.

Clinch river rises in eastern Tazewell, and flows thence through Russell and Scott into Tennessee; the distance within Virginia is, in direct line, not far from ninety miles, but by the river channel is probably one hundred and thirty or one hundred and forty miles. At about twenty miles

from its source, the stream first reaches the line of fault, near which it lies for about six miles, crossing it more than once in that interval. This is between the mouth of Indian creek and the western line of Tazewell county. At, say, twenty-five miles further west, measured directly, the river again reaches the fault, and, within the next seven or eight miles, crosses and recrosses the line more than once, if the map may be trusted. Above the former space, the interval between river and fault gradually increases to not far from six miles with the mountains of the House and Barn synclinal in it. Between the two contact spaces, the river channel-way is bow-shaped, the interval increasing rapidly to six miles on Lewis creek, and thence diminishing slowly until it disappears below Lick creek. Below the second contact-space, the interval steadily increases, and at length the river flows very near the line of the Copper Creek fault.

The Clinch Fault.

The course of the Clinch fault in Scott county is shown approximately by Buckner's ridge, composed of Knox beds, except near the line of Russell county, where it is made up of Quinnimont beds. The fault enters Russell county very near the mouth of Guest's river; is crossed at the mouth of Russell creek (Squier); is cut by Clinch river both above and below the mouth of Whetstone creek; and by Lick creek at but a little way from the river. At this last locality, the course changed somewhat to the northward, so that the fault is crossed by Caney fork of Dump creek very near Abram Kiser's house, and by Dump creek very near the mouth of Hurricane fork. Beyond this stream it was not followed. It should be found passing through the loop of Buchanan county at not more than four miles north from the southernmost projection of Big Butt mountain, on whose southerly slope Robinson fork of Lewis creek has its sources.

Thus far the structure has been comparatively simple and the direction of the fault-line almost straight—at least, its deviations can hardly be shown on a map of ordinary scale. Where first observed by the writer, on the north fork of Clinch river, in southern Scott county, the relations are apparently as shown in Fig. 4; but, within a very little way, where the road crosses Buckner's ridge, there is no upturning at the fault, the Lower Helderberg, Oriskany and Hamilton continuing to the very line of fault without change of dip. But still further eastward, the Pattonsburg and Wallen Valley faults having died out, and the Stone Mountain anticlinal having become fully developed, the reversal of dip is shown again, so that the Hamilton, Lower Carboniferous and Quinnimont are crossed in succession as one goes north-westward from the line of fault. On Stony creek, also in Scott county, the same condition is shown even more clearly, for there the Knox beds have been removed by erosion for some distance, so as to expose the Silurian beds, as represented in Fig. 5. Thus far the ridge marking the course of the fault is Knox, but on the road leading from Osborn's ford to Guest station, the "hanging rock" is Quinnimont.

Exposures are wanting for some distance below this Quinnimont wall on Little Stony creek, but the place of the rock in its group seems to indicate that here the Knox and the Quinnimont are in contact, as in Fig. 6. No Quinnimont occurs east from the mouth of Russell creek, and thence to the Caney fork of Dump creek, the Middle Coal measures (Lower Coal measures of Pennsylvania) are in contact with the Knox group.

The New Garden Fault.

But at or very near Bee branch of Caney fork of Dump creek, a cross-fault is given off, which extends in a south-west direction for about three miles. At that distance, it unites with the New Garden fault, which first shows itself at not far from three miles below the mouth of Dump creek, and follows very nearly the line which would have been followed by the Clinch fault had not its course been changed at Lick creek. The cross-fault gives a wedge-shape to the Knox area, the point being at Bee branch of Caney fork, and brings that group into contact with Hamilton and very probably with Clinton (?) shales. The New Garden fault is crossed by Dump creek, at barely a mile from the river, and there the Lower Carboniferous limestone is brought into contact with shales, much contorted and belonging probably to the Knox group.

No examinations were made along the immediate line of fault between Dump and Lewis creeks, though the southerly side was followed somewhat closely for several miles. A very great change takes place in this interval. On Dump creek, Middle Coal measures on the north side and Devonian or Silurian on the south side of the Clinch fault are in contact; but the downthrow between the faults increases so that before reaching Big Butt mountain, the Middle Coal measures on the north side of Clinch fault are in contact with Lower Coal measures (Quinnimont) on the southerly side; while, according to Mr. Squiers, an anticlinal has developed along the northerly side of the New Garden fault so as to bring the Lower Carboniferous limestone into contact with the Knox. The writer's examinations were not made in sufficient detail along Lewis creek to decide respecting the exact relation of the limestone and coal, but the strip of Lower Carboniferous must be very narrow. Mr. Squiers' diagram as given in *Science*, No. 68, is reproduced in Fig. 7.

The New Garden fault continues evidently in the direct line, being crossed by Clinch river in the bend opposite mouth of Indian creek; passing south from the Baptist Valley road and thence for four miles to Low's fork of Indian, where the road turns into the valley; crossed by Cavitt's creek near the forks in Wright's valley, and, according to Prof. Lesley, by the Jeffersonville and Abb's Valley road near Capt. Frank Peery's house, six miles from Jeffersonville. As shown from mouth of Indian to Cavitt's creek, this fault brings the top of the Lower Carboniferous into contact with the Knox. The dip of the Lower Carboniferous shales is usually abrupt and no upturning was observed near the line of faulting. The downthrow evidently increases eastward, for on Cavitt's creek the very

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top of the Lower Carboniferous is shown and Prof. Lesley states that a coal bed is shown near Capt. Peery's house on the Abb's Valley road.

The Stony Ridge Fault.

A new member of this series, the Stony Ridge fault, has its origin somewhere between Lewis creek and the line of Tazewell county ; but, as the interval between Lewis and Middle creeks, about ten miles, was not examined, the place of its origin was not ascertained. In all probability, however, the anticlinal on Lewis creek marks the beginning of this fracture. The downthrow on the northerly side brings into contact with the Devonian and Silurian the Lower Coal measures (Quinnimont), which form the Big Stony ridge separating Abb's valley and Crockett's cove from Wright's valley. If one descend Low's fork of Indian from the New Garden fault, he crosses the Lower Carboniferous shales and limestones and reaches the Devonian before coming to the Lower Coal measures on Laurel fork of Indian. On Dry fork of Sandy, the whole of the Lower Carboniferous, the Devonian and possibly the upper beds of the Silurian are passed before one comes to the Lower Coal measures (Quinnimont) beyond this fault, which is crossed by the stream at barely one mile above the mouth of Dick's creek ; while on the road leading to Crockett's cove, the other side of Stony ridge is reached, the Lower Carboniferous is shown at three miles from the mouth of Dick's creek and the road soon descends into Crockett's cove, which is separated from Abb's valley by a narrow divide. The Stony Ridge fault is crossed by Cavitt's creek, where Silurian is present, and it must be found at the West Virginia line, since the Big Stony ridge is said to be continuous to that line.

The Abb's Valley Fault.

Near the old Scott mines on Middle creek, an anticlinal occurs, which Prof. Lesley has suggested may mark the origin of a new fault which he has named the Abb's Valley fault. There is every reason to suppose this true. The fault develops eastward slowly until near the Dry fork of Sandy, where the upthrow becomes very marked, bringing the Lower Carboniferous and Devonian to the surface in Crockett's cove. The fault passes at but a little way north from the forks of the road in that cove. The downthrow on the northerly side diminishes eastward, for along Laurel fork and other tributaries to Bluestone river, a thickness of from 500 to 900 feet of Lower Carboniferous shales was seen between the river and the Lower Coal measures (Quinnimont). The length of the exposed column of Lower Carboniferous increases eastward in West Virginia to the New River.

The Stone Mountain Anticlinal.

The structure of this fold makes it necessary to study it from the east westward.

The Stone Mountain anticlinal was observed first on Russell creek in Wise county ; the place of its axis is concealed on Bull creek as well as

on the tributary to Guest's river crossed by the Wheeler Ford road ; but it is crossed by the Osborn's ford and Guest's Station road at little more than a mile from Guest's river ; further westward it passes between High Knob and Little Stone gap. The anticlinal can be traced thence to the Tennessee line, the axis lying close to Stone or Cumberland mountain.

The fold is utterly insignificant on Russell and Bull creeks, but becomes well-marked on Guest's river. It is crossed by the Middle Coal measures on the former streams, but the Lower Coal measures are brought up in the gorge of Guest's river. Thence westward, the increase in strength is rapid and the Lower Coal measures are raised quickly to form the Powell-Stone mountain lying between Buckner's ridge and the valley of Butcher's or South fork of Powell river. The dip on the southerly side is gentle throughout, but soon becomes abrupt on the northerly side—at Guest's river it is from 5 to 7 degrees, but at Little Stone gap the rocks are almost vertical and so remain to beyond Pennington's gap in Lee county.

Three well-defined faults, described in the writer's previous memoir as the Pattonsville, Wallens Valley and Poor Valley, develop on the southerly side of this fold and cut off abruptly the clumsy Powell-Stone mountain. The Carboniferous rocks have a curved outcrop at the westerly end of that mountain, while in Powell mountain beyond North fork of Clinch river, in Wallens ridge and in the broad valley of Powell river, the Devonian, Silurian and Cambro-Silurian are exhibited. From Big Stone gap in Wise county the area affected by the fold embraces only the precipitous Stone mountain and a very narrow space directly adjoining it on the south-east. The fold from Little Stone gap to the State line is so abrupt as to resemble a fault ; its trend is at an acute angle with the lines of faulting.

Vertical Extent of the Faults.

The following table shows approximately the vertical extent of the several faults—the extremes only being given.

Clinch	8500 to 1000
New Garden	7500 to 6600
Stony ridge	2300 to ??
Abb's valley	1700 to ??
Saltville	10000 to 7000
Walker mountain	7500 to 8000

II. THE GEOLOGICAL GROUPS.

Benches and terraces, beautifully preserved, were seen at many places, but the time allotted to this reconnaissance left few opportunities for making measurements of altitudes. Clinch river is bordered for the most part by high hills, so that in order to secure available grades, wagon roads usually follow the gorges of tributary streams. For this reason, the existence of terraces is concealed from the traveler until the river is reached. But where, as in a few cases, the road descends directly from

the bordering ridge, avoiding the stream, the presence of terraces is distinct. The higher benches, which apparently have no relation to the river terraces, are equally distinct. Only one measurement of a higher bench was made.

A few measurements of river terraces were made on Clinch, which are approximately correct.* In descending Copper ridge, in Scott county, to Osborn's ford, a bench was seen, 640 feet above low water, at Morton L. Harris' house, somewhat more than a mile from the river. It carries a detrital deposit, containing small waterworn pebbles of quartz and other materials, none of them larger than a hen's egg. No other terrace or gravel deposit was seen along the road on this side of the river until the "bottom," fifteen feet above low water, was reached, as the road follows an irregular ravine; but a terrace was seen on the northerly side of the river at eighty feet above the "bottom," on which is a thick deposit of clay, sand and gravel, with many large boulders of Coal Measure conglomerate. This terrace is conspicuous on the opposite side of the river at a little way above the ford, where there is an intermediate terrace, whose altitude was not ascertained. In descending Copper ridge to Nash's ford, almost due north from Lebanon in Russell county, river terraces were observed at 155, 40 and 15 feet above low water at the ford, and the highest one extends a long way southward from the river. Each bench bears a thick deposit of detrital matter with great quantities of boulders. What the condition is on the north side of the river was not determined, as the road follows a deep ravine for several miles.

The only satisfactory measurement obtained along the North fork of Holston was near Laurel fork, seven miles east from Saltville. The deposit is from 85 to 90 feet above low water and contains boulders of large size in sand and clay. The river road follows for nearly a mile. Well-marked terraces were observed along this river at many places, but no good measurements were obtained.

Sufficient evidence has been secured by measurement and observation to prove that the streams in this region are as handsomely terraced as are those of Western Pennsylvania and the adjoining parts of Maryland and West Virginia, both east and west from the Allegheny mountains; and the writer's observations in the Flat Top region of Tazewell county and the adjacent part of West Virginia satisfy him that the geologist who enters this region with time to make detailed observations, will find the higher system of parallel benches as beautifully preserved as they are in the areas of Maryland, West Virginia and Pennsylvania, described by the writer.† It is very interesting to note that these higher benches are well preserved only in softer rocks, the shales and sandstones of the Devonian and Car-

*The writer's barometer became deranged early in the examination and was useless; so that the trustworthy measurements are few.

† Stevenson, Surface Geology of Southwest Pennsylvania and Adjacent Portions of West Virginia and Maryland. Read before Amer. Phil. Soc., Aug. 15, 1879.

boniferous, as though the agency to which they owe their origin had not been long at work.

The only deposit of Quarternary age, aside from the terrace deposits, is that near Saltville, in Smyth county, where a conglomerate overlies the great mass of gypsum. This material has been exposed by a railroad cut west from Saltville, where it is said to have yielded remains of *Mastodon*. It is a conglomerate of red and blue clay, sandstone and large, mostly waterworn blocks of Knox chert and calcareous sandstone, the cement being mostly selenite. A small part only of the original mass remains, by far the greater part having been removed by erosion. No deposit of similar character was seen at any other of the gypsum bearing localities.

The deposits of gypsum and common salt occurring at Saltville and other localities on the North fork of Holston river, belong in all probability to the Tertiary. Their character and relations will be considered in another part of this memoir.

The Coal Measures.

It is unfortunate for the nomenclature of the Carboniferous that the rocks of that age were first studied and classified in Pennsylvania. Had the study and classification been made in Virginia, the nomenclature would have been different and would have been better applicable to the several areas in which Carboniferous rocks occur. The Coal measures begin with the Seral or Pottsville Conglomerate of Pennsylvania; which in that State is for the most part of little economical importance, but in Virginia and much of West Virginia is equally important with the overlaying beds, the Lower Coal measures of the accepted nomenclature. The proper terms fitted for the whole of the Appalachian area are:

Upper Coal Measures, equivalent to the Upper Coal measures of Pennsylvania, Ohio and West Virginia, beginning with the Pittsburgh coal bed and continuing to the top of the series;

The Middle Coal measures, equivalent to the Lower Coal measures of the States already mentioned; and

The Lower Coal measures, equivalent to the Seral or Pottsville conglomerate of Pennsylvania, the Millstone grit of Ohio and the Quinnimont group of Virginia and West Virginia. It attains great thickness in the Virginias, where it contains the coking coals of the New river and its tributaries.

The Coal measures do not cross to the south of the Clinch system of faults though they are entangled among them. The Middle and Lower groups only are reached in the area examined.

The Middle Coal measures occur within Wise and Russell counties as far east as the line of Buchanan county. They are cut off by the Clinch fault which passes into Buchanan county between Dump and Lewis creeks, so that in that county the Middle and Lower Coal measures should be found faulted against each other north from the latter creek. The more

important coal beds described in the writer's sections* made on the headwaters of Powell river in Wise county are persistent and have been recognized as far east as Dump creek. The associated rocks show the same characteristics as on the headwaters of Powell river. Limestone appears to be absent and one of the sandstones is coarsely conglomerate.

The Lower Coal measures form the mass of Powell-Stone mountain under the Stone Mountain anticlinal in Scott county, but they quickly pass under the Middle Coal measures, owing to the rapid disappearance of that axis eastward. No exposure appears on the northerly side of the Clinch fault beyond Russell creek eastward. But the beds reappear on the southerly or upthrow side of that fault beyond Weaver creek in Russell county; as well as on the downthrow side of the Stony Ridge and Abb's Valley faults in Tazewell county. The important mines at Pocahontas on Laurel fork of Bluestone river in eastern Tazewell are in a bed belonging to this group. Scott's mines on Middle creek, Christian's mines on Laurel fork of Indian and Sayers' old mine on Dry fork of Sandy, all in Stony ridge, are in beds belonging to the Lower Coal measures. No rocks belonging to the higher group occur in Tazewell county or in Russell county east from Lewis creek. The full thickness of this group is not exposed within the area examined and the higher beds must be sought for in Buchanan county of Virginia and McDowell county of West Virginia. The passage to the Lower Carboniferous is gradual.

The Lower Carboniferous.

Lower Carboniferous rocks occur in irregular strips along the fault lines. The most important is that on the northerly or downthrow side of the Saltville fault, which tapers in width from nearly five miles on the Tennessee line to almost nothing at the easterly boundary of Smyth county. The whole section is shown best in this strip. A narrow strip extends for a little way on both sides of Dump creek along the New Garden fault and another, also on the downthrow side of the same fault, begins near Lewis creek and continues eastward certainly beyond Cavitt's creek. A third strip is shown on the upthrow side of the Abb's Valley fault in Crockett's cove and Abb's valley, while a fourth develops on the downthrow side of the same fault along the waters of Bluestone river.

The section of the Lower Carboniferous as shown in Washington county was given in the previous memoir. There Prof. Safford's classification was accepted as follows :

Mountain limestone.....	1. Red shales, sandstones and thin limestones ; 2. Limestones and calca- reous shales.
Silicious group.....	1. Cherty limestone ; 2. Protean group.

*Stevenson. Notes on the Geology of Wise, Lee and Scott counties, Virginia.
Read before Amer. Phil. Soc., Aug. 20, 1880.

The Protean group of Safford is practically equivalent to the Vespertine of Southern Pennsylvania and the latter name will be employed as more convenient. The group is represented by shales, sandstone and thin *coal beds*, with occasional impure limestones.

The best general section of the Lower Carboniferous is that obtained along the railroad grade from Wolf Run summit to the North fork of Holston near Mendota. This section has been given in the writer's "Reconnaissance;" but on that line the Vespertine is wholly concealed and at best is reduced to utter insignificance. The beds previously referred by the writer to the Vespertine prove to belong to the Chemung. The thickness of the Vespertine increases eastward, so that at Laurel fork, about seven miles east from Saltville, it is not far from five hundred feet. This group is divided almost midway by a white or grayish-white sandstone which, for a long distance, forms a low but well marked ridge along the southerly face of Brushy mountain. Some beds of very impure limestone occur in the upper shales and the passage to the more calcareous division through silicious limestones and hard calcareous shales is very gradual. *Coal beds* occur in this group at many localities between Little Moccasin creek and the eastern edge of Smyth county, but they have no economical importance.

The Vespertine is apparently of insignificant thickness among the Clinch faults. Its place is shown on Dump creek near the New Garden fault; on Indian creek between that and the Stony Ridge fault; in Crockett's cove near the Abb's Valley fault and on several other streams; but at all of these localities the group is practically wanting or has become more calcareous, so as to be merged into the middle division—a condition which, according to Prof. Safford, prevails in Northeastern Tennessee. But the whole of the Lower Carboniferous column is greatly diminished among the Clinch faults within the area examined, just as was observed in comparing the region about the headwaters of Powell river with that along the North fork of the Holston.

The limestones and upper shales are often richly fossiliferous. The collector cannot fail to get good returns on Wolf run and the North fork of Holston in Washington county; along a road following the same river for several miles below Saltville; and on Low's fork of Indian creek in Tazewell county.

The Devonian.

This age is represented by Chemung and Hamilton; the Catskill and Corniferous appear to be wholly wanting.

The Chemung is represented by sandstone varying in color from light gray to brown, the color becoming darker in the upper beds. It forms the crest of Brushy mountain and is fairly well exposed in many of the ravines cut through that mountain. A section was obtained on the rail-

road grade near Mendota in Washington county, which, condensed, is as follows:

Chemung.

1. Shales and sandstones, shales gray to reddish blue, sandstones gray and flaggy.....	33'
2. Sandstone, above brownish-blue, hard, irregular fracture, flaggy with nodules of clay; below irregularly flaggy, clayey, micaceous, with large fucoids.....	31'
3. Conglomerate	0' 4"
4. Sandstone, brownish, fossiliferous, with <i>Spirifera</i> , <i>Rhynchonella</i> , <i>Chonetes</i> , <i>Goniophora</i> , <i>Edmondia</i> , etc.....	11' 8"
5. Conglomerate, ferruginous, pebbles as large as chestnuts	0' 10"
6. Sandstone with some fossils.....	5'
7. Conglomerate	0' 6"
8. Sandstones, not wholly exposed, with <i>Spirophyton</i> and <i>Productella</i> in the lower portion.....	268'
	350'

The upper part becomes harder and thicker further eastward. Whether or not the conglomerates are persistent was not determined, but no fragments of them were seen at any locality beyond Little Moccasin creek; nor were any traces seen on Little Walker mountain along the road leading from Lyons gap to Chilhowie Springs.

The Chemung appears to be wholly absent along Stone mountain in Lee and Wise counties and no trace of it was found along Buckner's ridge in Scott county between the Hamilton black shale and the Lower Carboniferous limestones. But the group is present further east among the Clinch faults, for it was recognized on Indian creek at the mouth of Laurel fork, on Dry fork of Sandy and in Crockett's cove.

The Hamilton consists almost wholly of shales, is ill-exposed everywhere and no satisfactory line of separation could be found between it and the Clinton below. It was measured near Mendota, where the total thickness appears to be not far from 900 feet. The relations of these shales to the group in more northern localities could not be determined as the few fossils observed were so imperfect as not to be identifiable. The greater part of the shales, however, appears to represent the Marcellus epoch and the black shales alone remain under the Stone mountain anticlinal in Lee and Wise counties.

The Hamilton is shown on the northerly side of Little Walker and Brushy mountains; without doubt it is present on Eagle Nest and Dump creeks in Russell county as well as on Dry fork of Sandy and on Cavitt's creek in Tazewell county, but no separation from Clinton was attempted on any of those streams.

The Silurian or Upper Silurian.

Clinton and Medina alone represent this age within the area examined. In Scott, Lee and Wise counties the Oriskany and Lower Helderberg are exposed repeatedly by faults there developed on the easterly side of the Stone Mountain anticlinal. Those groups were recognized even under the Clinch fault on Stony creek in Scott county; but they evidently thin out somewhere between the Clinch fault and Clinch mountain and their disappearance eastward is equally well-marked. There is no reason to suspect a fault between Clinch mountain and Brushy mountain; on the contrary, the succession of Clinton, Hamilton and Chemung is shown on the bluff northerly side of Brushy mountain at nearly two miles east from Laurel Fork gap; many petty gaps show conformability throughout and that the Clinton passes gradually into the Hamilton. The same conditions are shown in passing from Big to Little Walker mountain. Beyond doubt, the Clinton is reached on Dump creek, Dry fork of Sandy and Cavitt's creek, but no Oriskany was observed on any of those streams, nor was anything seen which could be referred to the Lower Helderberg, except possibly a limestone found on Dry fork of Sandy at half a mile above the Stony Ridge fault. The disappearance of these groups in a south-eastward direction is in great contrast with the great thickening of the Lower Carboniferous and Devonian in the same direction.

The *Clinton* forms a bench on the southerly slope of Big Walker and Clinch mountain sand is the surface rock in much of the Poor valley following the foot of each mountain. Narrow strips occur along the crests of Paint Lick, East River, Dial, Deskins and possibly of House and Barn mountain. The group consists of variegated shales with the whitish sandstones which everywhere lie near the fossil ore and are characteristic of the group through its extent. The fossil or "dyestone" ore is present on all the mountain mentioned. Limestone appears to be wholly absent. The thickness of the group was not ascertained, but it cannot be less than 1000 feet.

The *Medina* forms the crest of Big Walker mountain; of Clinch mountain, and its outliers, Rich, Garden, Short, Little Bear Town and Brumley; of House and Barn mountain; and it makes a double outcrop near the summit of Paint Lick and East River mountains.

The upper or white Medina, in irregular layers and from 200 to 300 feet thick, forms jagged cliffs. It contains a few thin layers of conglomerate, but, for the most part, the rock is very far from being coarse and some of the upper layers weather with polished surface. No fossils were seen aside from the characteristic *Arthropycus harlanii*.

The lower Medina, a mass of red to reddish-brown sandstone and shale, forms a terrace on the sides of the Medina ridges. It does not differ from the beds recognized as lower Medina in the central tier of counties in Pennsylvania, where it is sometimes called the terrace formation. The thickness is not far from 400 feet; but at all exposures the group is so badly

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contorted that the true thickness can be ascertained only after detailed examination. This part of the Medina is very closely allied to the Cambro-Silurian. It contains *Ambonychia radiata* and *Rhynchonella capax* in Southern Pennsylvania; it contains the same forms, with others equally characteristic of the Hudson, in Southwest Virginia. These fossils can be collected in Lyons gap on the northerly side of Big Walker mountain in Smyth county and in Hayter's gap on the north side of Clinch mountain in Russell county. In each case the exposure is conspicuous, being at the roadside and well known to the people living in the neighborhood.

The Cambro-Silurian or Lower Silurian.

This is represented by Hudson, Trenton and Knox or Calciferous, the Utica being absent or so changed that it cannot be separated from the Hudson or Trenton. Rocks of the Trenton and Knox are the surface beds in the Great valley as well as in the broad area between Clinch mountain and the Clinch series of faults. Hudson beds occur at the northerly foot of Big Walker and Clinch mountains and outcrop around the synclinal mountains with Medina crest, which are seen in Tazewell county northward from Clinch mountain.

The Hudson consists of red to yellow sandy shales and the passage to lower Medina is wholly imperceptible. The yellow shales below become calcareous and the passage to the Trenton is equally gradual. The upper beds of the latter group are very argillaceous, but the limestones become much purer lower down in the column, until the marbles are reached near the bottom of the group. These are thoroughly characteristic. Toward the bottom of the marbles some massive limestones occur containing much black chert; these mark the passage to the silicious Knox group in which are several beds of white chert and many thick beds of very hard and slightly calcareous sandstones. This is merely the Calciferous of New York, vastly increased in thickness.

No detailed section of any portion of the Cambro-Silurian was attempted, but enough was observed to show that the writer's estimate of 3250 feet for the thickness of the Knox group is materially below the truth.

III. THE AREA DRAINED BY THE HOLSTON RIVER.

In going from Bristol northward toward Mendota, one rides on Trenton and Knox beds until the Saltville fault is reached at a little way beyond the Rich Valley road. The Walker Mountain fault is crossed at about four miles north from Bristol, not far from the Reedy Creek road. The red, more or less calcareous shales, forming the top of the Lower Carboniferous and dipping sharply toward the south-south-east, are exposed in the railroad cut at Wolf Run summit just beyond the Saltville fault. A well-marked anticlinal is shown on Wolf run at a few rods above the school-house; the place of the synclinal was not determined, as exposures are somewhat indefinite below Whetstone run, but long before the river has been reached

the dip is again south-eastward and so continues apparently to the crest of Clinch mountain.

Lower Carboniferous limestones, of which the section was given in a previous memoir, are well shown along the run and the railroad grade beyond the river crossings, but the lower or Vespertine portion is wholly concealed. A detailed section of the Devonian beds, as shown along the railroad, is as follows, the top being at the northerly side of the little valley opening from the east.

Chemung.

1. Shales, alternating beds of gray and reddish-blue ; sandy ; the gray beds hold thin flaggy sandstone ; the bluish beds are more clayey and some of them are almost fissile.	20'
2. Sandstone, flaggy, gray, hard.....	13'
3. Sandstone, brownish blue, fine grained, hard and grit like ; fracture irregular ; in layers one foot or more thick ; some layers contain flattened nodules of clay.	15'
4. Sandstone, irregularly flaggy; clayey; some parts micaceous ; fucoids one inch in diameter and more than two feet long.	16'
5. Conglomerate, pebbles from size of pea to an inch and a half, mostly white quartz, some of dark quartzite and occasionally some of blue limestone and chert.....	0' 4"
6. Sandstone, color and structure like No. 3.	3'
7. Sandstone, flaggy.....	4' 8"
8. Sandstone, in color and structure like No. 3 ; near the top is a ferruginous layer, 2 to 4 inches thick, with <i>Spirifera disjuncta</i> , <i>Rhynchonella</i> , <i>Chonetes</i> and <i>Edmondia</i> . Specimens can be obtained only with difficulty as they are indistinct on fresh surface, while the weathered surface is very soft ; fine specimens of a large <i>Goniophora</i> occur in the other parts of the rock.....	4'
9. Conglomerate, ferruginous, coarse, many pebbles larger than chestnuts, and mostly white quartz.	0' 10"
10. Sandstone, flaggy ; contains in middle a fossiliferous layer crowded with <i>Chonetes</i>	5'
11. Conglomerate, pebbles smaller than in the others.	0' 6"
12. Sandstone, laminated to flaggy, light gray to bluish and reddish-gray ; thin layers of laminated shale separate the sandstones ; no fossils aside from bits of carbonized wood, indistinct <i>Calamite</i> -like stems, some trails and indeterminate fucoids	95'

13. Concealed.....	108'
14. Sandstone, flaggy but irregular; many layers crowded with <i>Spirophyton</i> ; <i>Productella</i> present but not plentiful.....	15'
15. Concealed.....	55'
 Total of Chemung.....	 350'

Hamilton.

16. Shales, arenaceous; dark gray; laminated to fissile; no fossils observed except one obscure <i>Chonetes</i>	136'
17. Concealed.....	33'
18. Shales yellow to ashen, clayey to sandy.....	88'
19. Concealed in river "bottom".....	200'
20. Shales like No. 18, laminated to fissile	300'
21. Shales, alternating black and gray, probably.....	150'

Total of Hamilton.....	907'
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This brings one to the Clinton rocks which form the bench of Clinch mountain, there being no Oriskany or Lower Helderberg. The Poor valley road from Mendota to Little Moccasin creek lies in Hamilton or Clinton for most of the way and reaches the North Fork of Holston at the big bend about four miles below the creek. Following the curve of the stream, the road soon touches the white sandstone of the Clinton and fragments of fossil ore occur in considerable numbers. But at somewhat more than a mile below Little Moccasin creek, the road and river pass from the Silurian into the Devonian, so that at the mouth of that creek they are in the Chemung, with a cliff of Chemung rocks on the south side of the river and the Lower Carboniferous just beyond.

On Little Moccasin, the Hamilton is shown at the roadside for some distance above Mr. Kutz' house. The Chemung sandstones form the crest of Brushy mountain, which, from this line north-eastward, is an imposing ridge. The lower black shales of the Hamilton are no longer shown, but they are said to have been exposed in a mill-race not more than one-fourth of a mile above Mr. Kutz' house. Everything is concealed thence until beyond the road leading into Brumley cove, where an exposure begins as follows :

Clinton.

1. Sandstone and shales, the latter predominating; dip 27°.....	10'
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Medina, upper.

2. Sandstone with thin shale and <i>Arthropycus</i> ; much of it snowy white; dip 22°.....	95'
3. Concealed.....	75'
4. Massive sandstone, dip 20°.....	45'

Medina, lower.

5. Red shales and sandstones, dip 20° to 15°..... 400'

Bits of fossil ore occur along the exposure of No. 1, but the ore was not seen in place. The white Medina, with a total thickness here of about 215 feet, forms a handsome cliff on both sides of Little Moccasin gap, the dip at the northerly crest of Clinch mountain being not far from 20 degrees; thence the outcrop extends northwardly to form Brumley mountain east from the gap. The red beds of the lower Medina are moderately well exposed; the higher beds are sandy and tend to be hard. The exposures of red and yellow shales belonging to the Hudson continue until Lilly's house is reached, at nearly three miles from the river, where the Trenton limestone is shown. The exposures between the house and the summit of the gap, somewhat more than half a mile, show little aside from reddish, impure, very argillaceous limestones, in which the dip gradually diminishes until, at the summit, it becomes barely 10 degrees toward south of south-east. Compact limestone begins just beyond the summit and continues until the "bottom" of Big Moccasin creek. It is dark blue, weathers grayish, is in thick layers separated by thin beds of shale, and contains few fossils, only some bryozoans having been seen. Shaly limestones appear in the "bottom," but the massive beds at the base of the Trenton are soon reached and they remain in sight to Hansonville. Very little chert was seen thus far.

Moccasin ridge is beyond Hansonville. White chert is abundant from the first summit of the ridge to Tarr's fork of Moccasin and the massive limestones seen along that stream contain great balls and lenticular masses of black chert. These beds are exposed on the north branch of that fork, where they dip south of south-east at from 15 to 22 degrees. The lower beds shown at the summit between Tarr's fork and a branch of Copper creek have cherty reticulations on the layers so that the vertical surfaces of the beds acquire a fretted appearance. Here one comes to the shales of the Knox group and the road passes into the area drained by the Clinch river.

Returning to Clinch mountain. Medina forms the crest of Brumley mountain, which attains its most northerly extension almost due south from Lebanon and thence has an almost eastward trend into the "loop" of Cedar creek. There at Hayter's gap, the mountain is crossed by the road leading from Lebanon to Saltville, along which the white Medina is seen at the summit and the Clinton shales are reached at, say, half a mile from the Poor Valley road. These shales form the mountain bench which fades into Poor valley and they are shown occasionally along the road until it leaves the valley to pass through Brushy mountain at nearly six miles from Saltville. The axis of the Burk's Garden anticlinal is not shown here, nor is it exposed on Tumbling creek, three or four miles further east, though there both slopes can be recognized.

Tumbling creek is formed by the union of several streams in the north-

erly extension of Clinch. No attempt was made to follow it to its head. The erosion above the first forks is very deep and there is some reason to suppose that Hudson beds have been reached; but as this is merely conjecture the space is colored on the map as Silurian.

The Devonian and Lower Carboniferous are exposed in numerous gaps through Brushy mountain where the Vespertine's notable increase in thickness is very well shown. The upper bluff of the Chemung is more than 200 feet thick and forms a bold cliff.

The "short" road to Saltville reaches the North fork of Holston at somewhat more than five miles below that village and thence follows all the windings of the stream. It exposes the lower limestones of the Lower Carboniferous and excellent collections of fossils can be made at several places. Twice it passes wholly below the limestones and enters the Vespertine, reaching the black shales which contain streaks of impure coal. As the road approaches Saltville it leaves the river and goes through a little ravine, in which the massive limestones of the Lower Carboniferous are exposed. The synclinal observed on Wolf run is crossed before Saltville has been reached, but the anticlinal is concealed, as much of the Saltville basin has been eroded from it, the axis passing very near the railroad station. Calcareous shales of the Lower Carboniferous make up the hills on the northerly side of the Saltville basin and are very fossiliferous. These hills are rounded and are so nearly of the same height that they may be remnants of a terrace. The hills on the opposite side of the valley are rugged, heavily wooded and show a cliff of Knox limestone.

The peculiar features of this Saltville basin, with its salt and gypsum will be discussed in another part of this memoir.

Only Cambro-Silurian rocks are shown between Saltville and Glade Spring and the dip appears to be regularly south of south-east. The Walker mountain fault is crossed at but a little way from the water-station, nearly two miles from Glade Spring. The turnpike from Glade Spring to Bristol is, for a great part of the way, very near the line between Knox and Trenton, and for miles at a time the surface material is very red, the characteristic color of this horizon and of another nearly midway in the Knox group.

Walker mountain increases in height very rapidly eastward from Glade Spring and it is soon double, one ridge being capped with white Medina and the other with Chemung. The red Medina is fairly well shown, near Lyons gap, where some of the layers contain many Hudson forms. The yellow shales of the Hudson are not well shown but the limestones of the Trenton are well exposed on the Rich Valley road and thence until near Saltville, where the Knox beds are reached.

In going eastward from Saltville along the Tazewell pike, one finds immediately beyond the first fork of the road an exposure of Lower Carboniferous dipping south-eastwardly, showing that the anticlinal has not been cut away wholly. Beyond the North fork of Holston Lower Carboniferous limestones are shown dipping south-eastwardly, at from 10 to

50 degrees, the rate increasing as Brushy mountain is approached. The pike follows the river to the Broadford, six miles from Saltville. The river cuts into the Vespertine shales at somewhat more than four miles from Saltville and there exposes in the upper division a *coal bed* about 3 inches thick. The hard gray sandstone underlies these shales. A *coal bed* was once opened above this sandstone on the run passing by Dr. Watson's residence about five miles from Saltville; its thickness is not known with any degree of certainty, but is believed to be somewhat more than one foot. That a *coal bed* exists in the lower shales is thought to be probable, as fragments of *coal* have been obtained in the run behind the sandstone ridge. For the greater part of the distance between Dr. Watson's residence and the Broadford, the road lies in Vespertine shales, and at one place a side-cutting exposes two streaks of *coal*.

Beyond the Broadford the road passes into the limestones and does not return to the shales until very near Laurel fork. There the Vespertine beds with sandstone nearly midway are shown with dip of 20 degrees in direction of the stream and having a thickness of not far from 500 feet. The sandstone is between 15 and 20 feet thick, the estimate being made from a somewhat imperfect exposure. The shales rest on a conglomerate sandstone separated by a few feet from reddish brown or bluish brown sandstones of the Chemung, occurring in flags 2 to 8 inches thick, fine grained, with a somewhat conchoidal fracture and exposed along the stream above the mill-dam with a dip of nearly 25 degrees. The sandstone with conglomerate layers, contains much *Spirophyton*, but no fossils were observed in the fragments of the main body of sandstone. This rock is the cliff which forms the crest of Brushy mountain from near Mendota to beyond the line of Bland county.

Débris from this cliff effectually conceals everything on the northerly side of Brushy mountain except at one place, say two miles above the gap, where, however, the wall is precipitous, so that detailed examinations cannot be made. At the same time the sequence of Clinton, Hamilton and Chemung can be made out very clearly. Clinton shales are exposed at the crossing of Laurel fork in Poor valley two miles from the gap, and there one begins to ascend the Poor Valley or Flat Top mountain which marks the course of the Burk's Garden anticlinal and divides the Poor valley. The lowest beds of the Clinton cross the anticlinal here and fragments of fossil ore are abundant at many places on the southerly side of the mountain; the lowest shales are very black. The Flat Top mountain ends at a few miles east from the pike in a clumsy mass known as Bear town. The axis of the fold passes very near to the crest of Flat Top, for at a few rods beyond the summit, the rocks are dipping north-westwardly at 15 degrees. The rate increases lower down the mountain side, where a subordinate fold is shown with dip of 60 degrees on its northerly side.

Clinton shales are well exhibited on the southerly side of Clinch mountain, where two minor folds were seen, one of them overturned. The dip is from 30 to 50 degrees south-eastward. Fragments of fossil ore are

abundant alongside of the road and the ore is shown in place along the reversed fold. It is shown again higher up the mountain, where it carries not a little brown hematite. White Medina is reached at the crest of the mountain.

Returning now to the mouth of Laurel fork. The Saltville fault is reached just beyond the Taylor property at ten miles eastward from Saltville. Thence eastward the road and river are south from the line of fault. The fault is at some distance north from the road at Mr. I. H. Buchanan's property, where Lower Carboniferous is represented only by the lower shaly limestones and the Vespertine shales below. On the first stream entering Cove creek below Mr. Buchanan's house, the Knox sandstones extend fully one-third of a mile northward from the road. Coal occurs in the Vespertine shales on Mr. Buchanan's farm where it was opened many years ago. The thickness of the bed is said to be 2 feet at one opening, 18 inches at another; its place is no longer exposed, but the bed lies very near to the gray sandstone. The coal burns nicely, but according to Mr. Buchanan it is very sulphurous.

Gypsum occurs in vast quantity on the I. H. Buchanan farm, sixteen miles from Saltville, as well as on that immediately adjoining. It has been obtained on the Taylor farm, ten miles, and on the Pierson farm five miles from Saltville; all of them along this road. These deposits will be referred to in another part of this memoir.

The road lies in the Knox group, east from Mr. Buchanan, and white cherty rock forms at many places the striking feature of the surface. The shales of the group are shown on Black hill and the limestones were followed almost to the county line. The road and river come together again near the mouth of Lick creek.

No obscurity respecting relations of the beds occurs until after leaving this main road and turning up Lick creek on the road leading to Burk's Garden. Except for very short distances this part of the area drained by Lick creek is a wilderness. The course of the stream is very tortuous and one has much difficulty in determining his place. The ridges all become very high and, viewed from Black hill on the main road, appear to be trending toward the southerly boundary of Burk's Garden. Brushy mountain, the Vespertine ridge and the ridge of Knox sandstones, all lying north from the Sharon Springs road, are bold and, as seen through the trees on Lick creek, abrupt. Exposures are very rare until within three miles of the summit of Garden mountain, where Clinton shales are shown. The structure is not wholly simple, for some imperfect exposures indicate the presence of more than one anticlinal in the shales. Lick creek rises on the side of Bear town, the clumsy knob in which the Medina ridges, bounding the Garden, unite.

IV. THE AREA DRAINED BY CLINCH RIVER.

The turnpike, from Abingdon to Wise Court-House, crosses the ridge between Tarr's fork of Big Moccasin creek and a branch of Copper creek at a little way above Mr. G. W. Morton's house. The rate of dip increases rapidly in Knox limestones until at that house it becomes sixty degrees. There the Copper Creek fault is crossed and the shales are shown on the long grade. The dip gradually diminishes and the marbles, first reached near the Sulphur Spring Church, remain in sight to the old Court-House, beyond which the underlying white chert and its ferruginous earth are exposed. As usual, the lower members of the marble group contain great nodules of black chert. Some of the marbles near Williams' store are of decided beauty.

Fossils are very rare, but a somewhat earthy bed on Copper ridge, not far from Dickensonville, on the road to Osborn's ford, contains *Orthis pectinella*, *O. lynx*, *Strophomena alternata* and some bryozoans.

The dips are almost regularly south of south-east on both Moccasin and Copper ridge until within about seven miles of Osborn's ford on the latter ridge, where a north-westward dip is distinct. There is difficulty in determining the structure along the crest of Copper ridge, because the rocks are deeply buried by the coating of decomposed material usually containing brown hematite, and always of a deep red color. At little more than a mile and a half from Osborn's ford the dip becomes very irregular, and the cherty limestones and calcareous sandstones are thrown into many and close folds, a condition which is continuous thence to considerably beyond the ford on the road to Guest's station; but all exposures cease in the broad "bottom" at about half a mile from the ford, so that the relation of the Knox limestone to the Lower Coal measures (Quinnimont) cannot be ascertained directly.

The "Hanging Rock" on Little Stony creek, at about a mile from Clinch river, is a massive sandstone belonging to the Lower Coal measures; it dips north of north-west at between sixty and seventy degrees, and the thickness as exposed is not far from seventy feet. The rock contains some conglomerate layers, and it is said to be underlaid by coal. This wall is clearly at some distance north from the Clinch fault, as for not less than fifty rods below it the hillsides show great blocks of sandstone, and a somewhat indefinite exposure seems to show the sandstone in place.

The "blossom" of a coal bed was seen at the sharp bend of the road, one-fifth mile beyond the wall. The bed appears to be one foot thick; it has shales below and a soft massive sandstone at a very few feet above. So far as exposed, the rocks have northerly dip until the open space beyond Buckner's ridge is reached, where exposures show the dip to be south of south-east. Thence to the summit of this Powell-Stone mountain no exposures were seen aside from fragmentary exhibitions of shale and sandstone. The broad, very gently undulating summit of the mountain is formed by a massive Quinnimont sandstone, fully ninety feet thick, and

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varying greatly in color and structure. It is almost white on the unweathered surface, but many parts contain so much iron as to weather yellow to a considerable depth. Much of it is very soft and readily breaks down into loose sand. Many layers are conglomerate with pebbles seldom much larger than a good-sized pea, and the sand covering the mountain summit contains great numbers of these white pebbles. This great sandstone, which in all probability is the "Bee Rock," or topmost bed of the Lower Coal measures, is almost horizontal until within little more than a mile of Guest's river. From the summit to that river no exposures were found; but just above the ford at 585 feet, by barometer, below the last exposure, this rock is shown in the river bank dipping north of north-west at between six and eight degrees. So the great Stone Mountain anticlinal has diminished wonderfully from Little Stone gap, where the dip is almost vertical on this side of the axis.

Guest's station is on Little Tom's creek on the road to Gladesville or Wise Court-House. Between it and Guest's river, the exposures are poor and indefinite. A thick sandstone is shown at several places near the station. The dips grow gentler beyond the station and become insignificant towards Roberts knob, a conspicuous hill half a mile or so northward. This hill is capped by a thick sandstone with conglomerate layers, while in the hollows about its base, nearly 700 feet below the top, is a *coal bed*, which, exposed in the beds of runs, has supplied blacksmiths for half a century. The bed is said to be not far from six feet thick, and its place seems to be near that of the *Kelly* or of the *Imboden* bed of the Powell River sections.

On the pike leading to Wheeler's ford, variegated shales are shown at barely half a mile from the station dipping west of north at not quite seven degrees; with them is a *coal bed*, of which the "blossom" is shown at a little way beyond. The road is but little off the strike for some distance, and soon rises to a massive sandstone, under which the "blossom" of a thin *coal bed* is shown at the first summit. Exposures, however, quickly become indistinct as the road descends to a broad basin eroded by several small branches of Guest's river. Here one should cross the axis of the Stone Mountain anticlinal, but, though not far from 650 feet below the "Bee Rock," on the crest of Powell-Stone mountain, yet that rock is not reached, which shows a flattening of the arch at the rate of certainly more than 150 feet per mile.

The Dry fork of Bull creek is reached beyond the next summit, and exposures become as unsatisfactory as can well be imagined. A *coal blossom* was seen near the summit, but thence only fragmentary exhibitions of cross-bedded or irregularly flaggy sandstones occur, which afford no definite measurements of dip. A southerly dip was observed at several places, but it could not be measured. At about a mile up the Dry fork, a sandstone is shown, thirty to forty feet thick, somewhat cross-bedded, and containing small pockets of pebbles. The dip is distinctly northward on Bull creek, where reached by the road, the dip being influenced by the

Clinch fault little more than half a mile away. This dip becomes gentler further up Bull creek, so much gentler that the following measurements obtained in crossing from Bull creek to Russell creek are probably not far out of the way :

Middle Coal Measures.

1. Sandstone	25'
2. Shales	10' to 15'
3. <i>Coal bed</i>	blossom
4. Sandstone and shale.....	120'
5. <i>Coal bed</i>	blossom
6. Sandstone and shale.....	100'
7. <i>Coal bed</i>	blossom
8. Sandstone and shale to Bull creek	180'

The intervals between these coals are very suggestive of their relation to beds on Powell river, but one is not justified in making identifications on so slender a basis.

Russell creek is reached by the road at little more than a mile from Clinch river. The dip at Mr. Dickenson's house is distinctly south of south-east. Mr. Dickenson digged *coal* on a little branch of Russell creek at about one-third of a mile north from the road. The exposure is very indifferent, though it extends for more than fifty feet. Manifestly, the dip is considerable, and the coal is very much twisted. Prof. Lesley, in his notes on this region, regards this coal as the same with that mined north from Guest's station.

Coal beds were seen between Russell and Whetstone creeks at 25, 85, 157 and 205 feet above the former stream, and a compact sandstone with nests of very coarse conglomerate makes the summit. The dip varies from 42 to 45 degrees on the Russell side of the ridge, but beyond the summit it diminishes rapidly, and is reversed at an inconsiderable distance. Prof. Lesley gives a diagram of this hill in his memoir. Exposures cease soon after the summit has been passed, and no more occur until beyond the river, the abrupt wall of Knox beds shows that the Clinch River fault has been crossed. The road reaches Clinch river at Kincaid's hole, whence it follows the stream to Wheeler's ford at the mouth of Lick creek. The river crosses the fault about midway between the two points. The ridge marking the course of the fault is cut away for some distance on both sides, but it quickly regains its height, and is very bold where cut by Lick creek at a little way from the river. The immediate line of faulting was not seen, but the rocks are turned up sharply on both sides, the Knox beds dipping south-eastwardly at forty degrees, and a sandstone above the fault dipping even more sharply in the opposite direction. The limestones, however, are more contorted than the Coal Measures beds, for they are thrown into a succession of folds, one of which passes very near to Mr. Field's house, a mile north-east from Lick creek, where the dip is N. 40° E. at 20 degrees.

The road leading to Dump creek past the Harrold's Valley Baptist Church lies south from the Clinch fault. The area of Knox limestone begins to narrow at a little way beyond the church, and a new line of hills, composed of Devonian and Lower Carboniferous, comes in between the road and the Clinch river. These are due to the cross-fault, which unites with the Clinch fault near the Gravel Lick road at Caney fork of Dump creek. This cross-fault is crossed by the Harrold's Valley road just where it emerges from the limestone ridge upon the valley of Dump creek. There one passes at once to the Hamilton shales lying south-east from the Knox limestone and in contact with it. The width of the limestone area here is less than half a mile, and it decreases rapidly, for no limestone crosses Caney fork, and on the east side of that stream the Clinton (?) shales are in contact with the Middle Coal measures along the Clinch fault.

A coal bed has been exposed on the Gravel Lick road at the mouth of Bee branch of Caney fork by Mr. A. Kiser. So far as shown, it contains about four feet of good coal, but it dips at 55 degrees toward S. 25° E. The line of faulting passes very near this place on Caney fork, and near the mouth of Hurricane fork further east. Important developments of the coal beds have been made on Hurricane fork, where beds, answering to the *Lower Splint*, the *Imboden*, and an intermediate bed of the Powell river sections, have been opened. The thickness is reported to be greater than at localities on the headwaters of Powell river in Wise county.

The Devonian rocks are well shown along both Dump creek and Caney fork, each of which flows for a considerable distance at the northerly foot of the Brushy ridge, lying between Caney fork and the river. The Chemung rocks are well shown on the road following Caney fork, where they are more fossiliferous than at localities examined in the Holston area. Immediately below the mouth of Caney fork, Dump creek enters a short gorge through this ridge. The St. Louis limestone is reached above the store, the Vespertine apparently being absent. The exposure of the limestone and its associated shales extends for little more than 300 feet. The New Garden fault is crossed in the ravine below the store. Thence to the river the road lies in contorted shales with occasional limestones, belonging most probably to the Knox group.

The Knox limestones dipping south-eastward at thirty to eighty degrees are reached at the mouth of Mill creek on the southerly side of Clinch river. The dip is very irregular and the steeper dips of the undulations are on the south-easterly side. The top of the massive limestone is reached beyond the first mill, and the shales are shown just above. These hard limestones form a line of abrupt ragged hills, which are characteristic features of the Knox topography. Exposures along this creek are not sufficient to show the structure distinctly above Jesse's mill; but the dip appears to be continuous south-eastward. The Trenton marbles are reached near the summit between this and Little Cedar creek, where some of them are remarkably handsome. The clayey limestones marking the top of the Trenton succeed, and the south-easterly dip continues to where the road

crosses Little Cedar creek. There the dip is reversed, and the same beds are shown in Lebanon. This is the House and Barn synclinal, which, however, is double as a second synclinal is crossed by the Fincastle pike at a little way east from Lebanon. The northerly synclinal is crossed again by Little Cedar creek near the second house north from the pike on the road leading to Nash's ford. Thence on that road the rocks rise regularly to the top of Copper ridge. The white chert underlying the marbles rises with the road to the top of the ridge, and its fragments in the deep red detritus cover the surface. This rock bears very close resemblance to the upper layers of the Medina, both in mode of weathering and in fracture; so that one unacquainted with the true condition might readily suppose Medina present along this line. The top of the ridge is a synclinal, or, if not, the rocks have no perceptible dip, for the fragments of chert are abundant along the road for half a mile. They characterize the crest of Copper ridge in Scott county. Brown hematite is abundant. It was mined forty years ago by Dougherty, who had a small forge on Cedar creek above Mr. John Stinson's house. Shales are exposed all the way from the summit of the ridge to Stinson's, where limestones are reached again.

The shales of the Knox group are shown on the north side of Clinch river, at Nash's ford, where, though crumpled as badly as the laminæ of gneiss or mica schist, they show no signs of metamorphism. The road from Nash's ford to the head of Robinson fork of Lewis creek crosses Thompson creek and follows Breeze fork of that stream to its head. This road barely touches the line of the New Garden fault, reaching it only west from the fork of the road half a mile from Lockhart's store on Robinson fork. The line of the fault was not determined here within about one-fourth of a mile, as there seems to be some Lower Carboniferous limestone which was not separated from the Knox limestone. The New Garden fault lies north from the road for two miles east from Lockhart's store on Thompson's creek, but near the head of the fork next east from Breeze fork of that stream, the road approaches very nearly to the conglomerate ridge, fragments of the sandstone being abundant in the road thence for some distance. The fault line certainly passes very near the heads of the several branches of Thompson's creek. No coal occurs on any of these streams.

The fault is crossed by the northerly branches of Robinson's fork of Lewis creek at a little way from Lockhart's store. The limestones prevail up the side of Big Butt or Big Axe mountain, fully half way up from the store. The soft limestones have yielded to the action of the many streams forming the two forks of Lewis creek, so that here is a fine agricultural space, known as the New Garden. The structure is somewhat complicated, as appears from Mr. Squier's note already quoted; but the writer's examination was not made in detail, his desire being merely to supplement by a new reconnaissance the reconnaissance work already done by others. Robinson's fork follows a rudely eastward course, and the

lower *coal bed* of the Quinnimont or Lower Coal measures has been digged in ravines coming from the north.

Limestone prevails along Lewis creek to its mouth, and the great calcareous sandstones with thin cherty beds so closely resembling the white Medina are well shown at the Clinch river, which is reached at Black's ford. The Trenton limestones are exposed near the top of the abrupt bluff on the opposite side of the river, and the marbles are shown immediately beyond. Soon one comes to the House and Barn synclinal, which is deeper and broader than on Little Cedar creek near Lebanon, and holds at a little way east from this road the narrow House and Barn mountain with its crest of white Medina. This mountain is little more than a mile and a half north from the Fincastle pike. The easterly side of the synclinal is very abrupt and the Trenton marbles are brought up before the pike is reached at Rosedale, where one is in the red clays filled with fragments of white chert.

The pike crosses the Elk Garden anticlinal at a few rods east from the large brick house belonging to Mrs. Smith. The exposures are somewhat indefinite in much of Elk Garden, as the beautiful region eroded by Cedar creek is termed, and there may be more than one crest to the anticlinal as there are both east and west from this place. The disintegrated clayey material, carrying chert and occasionally brown hematite, prevails along the pike until very near the fork of the road leading to Saltville, so that details of structure cannot well be obtained. But on the Saltville road, near Mr. W. A. Stuart's house, the south-easterly dip is pronounced though comparatively gentle, being only fifteen degrees. It becomes undulating just beyond the next fork in the road, and for some distance the rocks are badly twisted. The Loop anticlinal, very well defined, is crossed within a little way north from the road leading to Saltville by way of Rich mountain.

The marbles of the Trenton are shown on the main road at the foot of the grade leading to Hayter's gap, and Trenton fossils abound just beyond the S-bend in the road. Thence exposures are very good along the grade all the way to the summit of Clinch mountain at Hayter's gap. The dip is south-eastward, and varies from twenty to forty-five degrees; but there are many petty crumplings of the red Medina, even the thicker and harder beds being folded closely upon themselves. The yellow more or less fissile shales of the Hudson cannot be less than seven hundred feet thick, while the red mud beds of the Medina cannot be far from four hundred feet. A fossiliferous layer occurs in the lower part of the red beds, but the fossils are not so good in weathered fragments as those found in Lyon's gap of Big Walker mountain.

Red Medina and Hudson shales form the irregular terrace along the north side of the doubly-pointed mountain known at the west end as Little Bear town and at the east end as Short mountain. This terrace passes round the end of Short mountain into Ward's cove, where it is continuous with the bench along Clinch mountain; this is conspicuous in Thomp-

son's cove, and is continuous along Rich mountain to the gorge of Plum creek.

In descending from the crest of Clinch mountain into the Thompson-Ward cove by the Tazewell pike, one comes quickly to the red, yellow and grayish shales of the Hudson. The admirably engineered road doubles on itself again and again as it descends the abrupt slope until it reaches the Trenton limestones only a little way from the toll-gate. The south-easterly dip is very sharp near the summit, but diminishes so that just beyond the gate it is little more than ten degrees. A much more marked decrease occurs beyond the fork of the road near Schnapp's shop, three and a half miles from Liberty. Thence for nearly a mile and a half the dip is barely perceptible, but at that distance the north-westerly dip is very distinct, and it is especially marked where the road crosses the Dry fork. The Elk Garden anticlinal is reached near Liberty, and shows three petty folds on its crest; one near Mrs. Thompson's house; a second near Mr. Barnes' house, and a third very near Liberty.

The synclinal just south from Mrs. Thompson's house holds Short mountain at the west and, at the east, so much of Rich mountain as lies west from the gorge of Plum creek; this portion, as seen from the Fincastle pike, appearing to have a synclinal structure.

The House and Barn synclinal is quickly indicated on the road leading from Liberty to the mouth of Indian creek. The dip becomes abrupt on Paint Lick mountain, but good exposures are few. White Medina is reached just below the summit, and at the summit is the southerly axis of the double House and Barn synclinal. This trough is deep but very narrow, the width between the Medina outcrops being less than one-third of a mile. Clinton is present; fossil ore is shown near the road and many years ago it was mined in a small way at some distance west from this road. The south-easterly dip on the northerly side of this trough is almost vertical.

The road descends to the valley separating Paint Lick from another synclinal known as Deskins mountain, which is shorter and narrower than Paint Lick. The erosion in the valley has just sufficed to expose the Trenton along the petty anticlinal, which is reached and crossed where the road first touches the little stream. The northerly or Deskins trough of the House and Barn synclinal is very narrow here, for its axis is crossed before the gap through Deskins mountain is fairly entered, and there the first exposure shows the limestones dipping toward the south-south-east. The Trenton beds as exposed in the banks of this stream dip at from twelve to twenty degrees toward south-south east, except at one spot where a very abrupt and close anticlinal is shown. The massive limestones of the Trenton are reached at the first fork of the road, and thence almost to the next fork the road lies largely in the marbles. After turning toward Clinch river it passes into the Knox and quickly reaches the lower shaly beds. Lumps of brown hematite occur here. The dip becomes steeper toward Clinch, being thirty degrees where the road first reaches the river;

thence to the mouth of Indian creek it is irregular, sometimes reaching fifty degrees.

Clinch river cuts the New Garden fault in the bend opposite the mouth of Indian creek. The Knox limestone is on the southerly side of the fault with the Lower Carboniferous shales in contact with it. On Middle creek, these shales are reported to extend to very near the coal mines. The Stony Ridge fault develops quickly, for the Devonian and the Lower Carboniferous are well shown on forks of Indian creek between the New Garden and Stony Ridge faults. The road leading from the mouth of Indian to Baptist valley lies in the shales to Low's fork of Indian, about four miles from mouth of Indian. On Low's fork one comes quickly to the Lower Carboniferous limestones, many of which are full of well-preserved fossils. The bottom of the group is reached at the main creek and the Chemung sandstones with *Productella* and *Spirophyton* are exposed just beyond on Laurel fork. The old Christian coal mines on Laurel fork are nearly two miles from the Baptist Valley road, and are in the Lower Coal measures or Quinnimont group. The main fork of Indian creek, rising near J. B. Young's house in the "Sinking Waters" region, flows for most of its length through the Lower Carboniferous beds, though occasionally passing over to the Chemung. Very fine specimens of *Pentremites*, *Terebratula* and *Athyris* have been obtained here.

The road following Indian creek to its head crosses the summit to Dry fork of Sandy river, reaching that stream at about two miles below the Gap store on the Baptist Valley road, the distance being measured along the stream. The course of this stream is very irregular, and often follows the strike of the beds for a considerable distance. The Devonian rocks are exposed at a little way below where the stream was reached, but no details were obtained respecting them or respecting a limestone which was seen at nearly a mile further down the stream.

The Stony Ridge fault is reached at three and a half miles from the Gap store or one mile above the mouth of Dick's creek. There a thick bed of sandstone belonging to the Lower Coal measures is shown at the roadside dipping at a very high angle, while at a few rods further down, but on the opposite bank, D. G. Sayers once opened a coal pit. These rocks continue to the mouth of Dick's creek, beyond which no observations were made along this stream; but the writer was informed at the mouth of that creek that no limestone occurs on the Dry fork between that place and the State line. The limestone certainly makes its appearance within a very little way east from the Dry fork.

The road to Crockett's cove leaves the Dry fork at Dick's creek and turns from the creek northward within about a mile. The Lower Carboniferous beds are reached at about three miles from the mouth of Dick's creek. The limestones form a high ridge, only three hundred feet lower than the Stony ridge, made up of Quinnimont sandstones. The whole strip of Coal measures, fronting on the Stony Ridge fault, is not more than a mile wide. The strip of limestone and Devonian gives the cove, a pleas-

ant little valley, which is evidently continuous geologically with Abb's valley, but is separated from it by a high divide. Stony ridge separates it and Abb's valley from Wright's valley. The limestone strip is very narrow as the dip is abrupt. The Abb's Valley fault passes but a little way north from the fork of the road in the cove so that *coal beds* are accessible within a short distance on that side.

Crossing Stony ridge from Crockett's cove one comes to Cavitt's creek. There exposures are not very clear and the line of the Stony Ridge fault was not seen. The New Garden fault is crossed very near the forks of Cavitt's creek in Wright's valley. It barely fails to show some Coal Measures rocks on its northerly side. From the line of this fault to Jeffersonville on the Fincastle pike, the only rocks exposed belong to the Knox and Trenton groups. All exposures cease soon after Cavitt's creek has been passed, so that the conditions in the House and Barn synclinal along this road are wholly concealed. The southerly side of the synclinal is shown at Jeffersonville with the shaly beds of the Trenton almost vertical. The dips grow gentler as the beds ascend the Elk Garden anticlinal, which the pike crosses at about four miles east from Jeffersonville at a school-house beyond the woolen mill. Thence the dips are comparatively gentle on both sides of the axis.

East River mountain, lying north from the pike and extending eastward to New river, is held in the House and Barn synclinal, and evidently answers to Paint Lick mountain further west in the same trough. Northward from it are two others, very short ridges, both evidently Medina-capped. These were not examined. East River mountain is clearly double, made up of two synclinals, the structure being visible from the Fincastle pike, but better from the summit of Rich mountain. The dip is very abrupt in each of them and the Medina stands in almost vertical walls. The thickness of Clinton cannot fail to be insignificant.

The Plum Creek gap through Rich mountain passes, in all probability, very near the end of the synclinal holding Medina, for at but a short distance further east the mountain is only the northerly side of the synclinal between the Elk Garden and Burk's Garden anticlinals. The red Medina is well shown on the northerly side of Rich mountain along the road leading to Burk's Garden and the white Medina is reached at the summit, where it is dipping south-eastwardly at 40 degrees. The Clinton shales are reached at once and fragments of the fossil ore are shown in the road.

The dip is reversed at a little way down the slope and for a short distance is very abrupt; but it diminishes so that at the mouth of Wolf Creek gap through Garden mountain the dip on the northerly side of the Burk's Garden anticlinal is barely 20 degrees. White Medina forms a fine cliff on the sides of the gap, while the harder rocks of the Clinton are shown at the mouth. Clinton beds underlie Wolf Creek valley between Garden and Rich mountains.

The dip increases abruptly within Burk's Garden, the Trenton shales showing 40 degrees north-west. Few exposures were observed in this "gar-

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den ;" the surface is gently undulating and is covered with a deep soil. This is a beautiful cove, precisely similar in type to the anticlinal coves occurring so frequently in the regions of Pennsylvania, bordering on the Great Valley. The wall of Medina, with its terrace of Hudson and red Medina, is unbroken save by the narrow gap through which Wolf creek passes.

V. THE SALT AND GYPSUM DEPOSITS OF THE HOLSTON VALLEY.*

The salt and gypsum deposits found in the vicinity of Saltville, and at several other localities eastward along North Fork of the Holston and its tributary, Cove creek, possess great economical importance and scientific interest.

A basin of remarkable beauty at Saltville extends on both sides of the Saltville fault, having been eroded in hard silicious beds of the Knox on one side and in the Lower Carboniferous shales on the other ; the length is not far from one mile. The narrow westerly portion, drained by a stream rising in the Knox hills and flowing to the North fork of Holston, is separated by a well marked divide from the principal basin, which, within the memory of some of the older settlers, was occupied by a lake ; now, however, it is drained by a little stream which flows to the river. The salt works are in the larger or eastern portion.

The character of the rock on the divide is well shown in the railroad cut about one-fifth of a mile from the railroad station and almost directly behind Mr. Robinson's house, where it is a conglomerate of red to blue clay, sandstone and large fragments of the chert or cherty sandstone of the Knox group. These are cemented by more or less crystalline gypsum. Remains of *Mastodon* were obtained in this cut, which were deposited in Emory and Henry College, on the Norfolk and Western Railroad, eight or nine miles from Saltville. This conglomerate, which is nearly 100 feet thick in a shaft sunk by Mr. Robinson just north from the railroad, has been eroded from the larger basin as well as from that portion lying west from the divide ; no trace of it occurs elsewhere in the neighborhood.

Gypsum is mined in large quantities by Mr. Robinson immediately west from the divide. It is reached at but a few feet from the surface, clearly has a covering of blue clay, and exhibits many seams of red clay, which are sometimes so extensive as to injure the market value of the gypsum. The rock in the large excavation appears to be without dip and most of the material is saccharoidal, comparatively little crystalline gypsum having been seen by the writer. The presence of gypsum on the divide, under

* I am under very material obligations to Mr. W. Musselwhite and Hon. C. T. Smith, of Saltville, for assistance in gathering information respecting the salt and gypsum deposits. Mr. Musselwhite, who had charge of the boring operations in the vicinity of Saltville, generously placed all of his results at my disposal.

the conglomerate, has been fully proved by Mr. Robinson, who took out large quantities from a shaft 125 feet deep. A large mass encased in clay was exhausted on this property. Seams of indurated black clay are not uncommon here and occasional fragments of sandstone have been seen, but no fragments of limestone are reported. Borings made on Mr. Robinson's property were pushed to the depth of 600 feet without reaching bedded rock. Salty material was obtained at 400 feet, but as the boring was dry, brine was wanting and no attention was paid to the salt. After passing through the conglomerate and the underlying blue clay, the drill pierced only gypsum and red clay.

Crossing the divide from the Robinson works, one comes to the Salt-works, whose interesting history would be out of place here. Many years ago a shaft was sunk in search of salt. It passed through 20 feet of blue clay and then 195 feet of red clay and gypsum, reaching at 215 feet abundance of rock salt associated with red clay and gypsum. The supply of brine proved insufficient and after a number of years a well was bored at a distance of a few yards. A large body of water was struck in this at 120 feet from the surface, which immediately rose to within 40 feet of the well-curb. By advice of Mr. Musselwhite, the shaft was connected with the new well by means of a tunnel passing through the saltrock, so that now all pumping is done at the shaft and the supply of brine is apparently inexhaustible. The curb of the well is approximately 45 or 50 feet above the Holston crossing, one-fourth mile beyond the end of the railroad track, so that the almost constant level of water in the wells is practically the same with that of the Holston bed. This great body of water in flowing through the rocksalt becomes almost saturated, 90 per cent; 20 gallons yield one bushel and there appears to be a minimum of bitter waters. The salt when taken from the pans is permitted to drain over them for an hour or two; it is afterwards thrown into bins where the dripping continues for several weeks. The salt is then dry and no longer affected by atmospheric conditions; no rewashing is necessary. Of course, the brine is saturated with gypsum, which is precipitated upon the pans, forming a crust usually spoken of as "rock salt." This deposit, containing not a little salt, accumulates rapidly and adheres so closely to the pans that the labor of removing it adds much to the cost of producing the salt.

The saltrock is at little more than 200 feet from the surface at the well. Mr. W. A. Stuart, President of the Holston Salt and Plaster Co., states that the salt continues to a depth of nearly 600 feet.

The Pierson Plaster Works are on the Holston at nearly five miles east from Saltville. These are idle, but they were worked vigorously for more than five years and the excavations were carried to the depth of 60 feet. The deposit is in the broad river "bottom," and everything points to conditions similar to those seen at Saltville. The soil is underlaid by blue clay which, wherever examined, rests on gypsum, its thickness being approximately 12 feet. No deep borings have been made here to determine the vertical extent of the deposit. Gypsum was once quarried directly under

a bluff on the opposite side of the river on the Miller farm, but the pits were full of water when the locality was visited, so that no information could be obtained respecting the relation of the gypsum to the bedded rocks. On the Pierson place, the gypsum rests on the shales and lower limestones of the Lower Carboniferous.

Explorations for gypsum and salt were made on the Taylor farm at ten miles above Saltville. Here again is a broad river "bottom," very similar to that at the Pierson place, five miles lower down the river. A deep shaft or boring was made here; gypsum was reached under the blue clay at a few feet from the surface and some salt was found first at about 300 feet from the surface. The original "bottom" evidently continued on the north side of a low hill, for there at some distance above the road gypsum has been obtained. The Saltville fault passes through this property and the gypsum appears to be on both sides of it, so that it rests on the calcareous sandstones of the Knox and on the calcareous shales of the Lower Carboniferous.

Buchanan's Plaster Cove on Cove creek and its tributaries is nearly six miles further east. It lies north from the road leading to Sharon Springs and occupies a broad "bottom" on Cove creek, whence it is continuous over a low divide to the "bottom" of a tributary stream on the adjoining farm. The earliest pits were sunk on Cove creek "bottom," near Mr. I. H. Buchanan's former residence. Many shallow excavations were made in order to obtain plaster for agricultural use and a shaft nearly 600 feet deep was put down by Mr. Buchanan to ascertain how much gypsum he owns. This shaft passed through only gypsum and red clay and stopped in that material. The red clay appears to be in comparatively small quantity. As at the other localities the soil rests on blue clay and gypsum has been found everywhere on the "bottom." A little drain comes down the hillside, its channel-way eroded in Vespertine shales which are exposed on both sides; gypsum occurs at its head and no doubt is continuous with the main mass below.

The "bottom" ends at the foot of the Vespertine ridge, nearly a mile from the Sharon Springs road; but a low divide separates it from a tributary which enters Cove creek at about one-third of a mile below Mr. Buchanan's present residence. The rise on this divide is gradual and a narrow strip of gypsum has been traced over it in a succession of pits. Some exceedingly impure limestone is shown at a little distance from the gypsum, but the latter evidently rests on the Vespertine shales. The stream rising on the other side of the summit flows over the shales into the next farm where it has a broad "bottom." Mr. Buchanan has digged gypsum at the very head of this stream and the work continues down the stream. The quarrying has been conducted in a very wasteful manner on the next farm, where a great number of shallow broad pits sufficiently show the enormous amount of gypsum present. Blue clay, often very tough, everywhere overlies the gypsum and at several pits seems to enclose it. The deposit ends on this stream at somewhat more than a third of a mile from

Cove creek, and all of it is north from the Saltville fault, so that it rests wholly on the Vespertine shales. Mr. Buchanan states that gypsum has been digged in very considerable quantity at the road, where this stream enters Cove creek. That gypsum rests on Knox beds. How extensive it is has not been ascertained.

No investigations have been made here with a view to the manufacture of salt and no notes were taken respecting the depth at which salt was first found. Mr. Buchanan's shaft is now full of water and no examinations can be made. There is, however, no room for doubting the occurrence of salt there in the deeper portions. Mr. Buchanan says that the waste material, clay and impure gypsum, was thrown into heaps, to which cattle and sheep resorted, licking them with great avidity. The gypsum is mostly saccharoidal, but there is a good deal of crystalline also. As the latter clogs the mill in grinding it is much disliked and is thrown aside as worthless. Much lies in the waste-piles on Mr. Buchanan's farm which would be excellent for collections.

Mr. Musselwhite states that no gypsum has been found east from this cove on the road to Sharon Springs, and that no gypsum has ever been obtained in the Rich valley which follows the northerly foot of Big Walker mountain.

Resume.

Such are the details obtained either by personal observation or by careful inquiry of those who are familiar with matters no longer open to examination. The facts with reference to the occurrence of these gypsiferous deposits may be summed up as follows :

First. The gypsum deposits are not beds of Carboniferous or Cambro-Silurian limestones changed into gypsum.

Second. These deposits occupy deep basins, which have been eroded in Lower Carboniferous shale or limestone, or in the hard, slightly calcareous sandstones of the Knox group. In at least two localities, branches protrude from the main body into drains or ravines, so that the horizontal plan resembles somewhat the splash made by throwing soft mud against a wall.

Third. The character of the deposit is wholly independent of the rocks on which it rests.

Fourth. The gypsum occurs in irregular masses, encased in red marly clay, which penetrates the gypsum to a variable distance ; there is less of this clay in the eastern basins than at Saltville.

Fifth. At a variable depth, salt occurs with the gypsum, and this salt contains very little of iodides or bromides.

Sixth. Blue clay overlies the gypsum at all localities yet examined.

Seventh. No fossils of any sort have been found thus far in the gypsum, its encasing red clay, or in the overlying blue clay ; but, just west from Saltville, a conglomerate, cemented by gypsum, occurs, in which remains of *Mastodon*, have been found ; this overlies the blue clay, and encloses many fragments of both blue and red clay.

Eighth. These gypsiferous deposits occur in the vicinity of the Saltville fault.

Age of these Deposits.

The basins occupied by the gypsum deposits are very deep, extending more than 600 feet below the present surface at Saltville; more than 400 feet at ten miles east from Saltville; and more than 600 feet below the surface in Buchanan's cove—those being the depths to which exploration has been carried at the several localities. These basins must have been eroded at a time when the continental elevation was greater than now or when the drainage was in a very different direction. It may be suggested that they are great "sinkholes," similar in kind to those which occur so commonly in limestone districts. But there is no probable outlet for waters eroding caverns at more than 600 feet below the present drainage lines; more, the limestones are too far under Pearson, Taylor and Buchanan for their removal to have much effect. The gypsum at those localities rests on Vespertine, between which and the nearest limestones the whole Devonian, Silurian and the upper part of the Cambro-Silurian intervene.

Nothing has been obtained going to show when these basins were eroded. The extent of erosion prior to their formation was very great, for the Coal measures, Lower Carboniferous, Devonian, Silurian and much of the Cambro-Silurian had been removed from the upthrow side of the fault—a very gradual process, as gradual possibly as that by which the fault itself was produced. But nothing can be predicated on this. Geologically speaking, the time required for the removal of 10,000 or 12,000 feet of rock is comparatively short, as abundantly appears from the enormous erosion done in the Colorado area since the later Tertiary and on the Canadian plains of New Mexico since the later Pliocene, where a greater amount of rock has been removed during a period probably no longer than that during which the great faults of Virginia were forming.

One might at first suppose that the blue clay may eventually afford some clue by yielding fossils. It immediately underlies the Quaternary conglomerate of the Saltville basin and everywhere rests on the gypsum. But certainly it was not formed at once after the gypsum ceased to be deposited. The conditions observed on the Buchanan and Taylor properties show that a very considerable thickness of gypsum had been removed by erosion before the blue clay was deposited; possibly more than 100 feet, the strings or branches of gypsum protruding into the little ravines being remnants which had escaped erosion. In every instance, the blue clay rests on eroded bosses of gypsum and does not invade the deposit to a depth of more than a few feet, the investing material being the red clay, which clearly has a different origin. It is sufficiently evident then that a gap exists between the close of the gypsum-making and the beginning of the clay deposit that positively prevents any linking of them together.

But the amount of the erosion and the general relation of the gypsum to the blue clay, with the relation of the latter to the Quaternary conglomerate, suggest that the gypsum is not older than the Tertiary; until some fossils have been discovered, however, the question of age must be re-

garded as undetermined. Fossils may be present and may have been overlooked by the workmen; examinations by geologists have been of the most casual sort, so that the statements respecting absence of fossils are necessarily of no positive value. Capellini's studies in the Tuscan deposits, as well as elsewhere in Italy, bear this statement out; for after the gypsum and its associated marls had been pronounced non-fossiliferous by many geologists, an extensive fauna was discovered, which he has described and illustrated in his numerous memoirs.

Origin of these Deposits.

So long as these deposits could be regarded as of Lower Carboniferous or Cambro-Silurian age, there seemed to be little difficulty in accounting for them as beds of limestone changed by the action of acid springs or as beds of gypsum actually deposited as such from the ocean waters. Improbable as the former explanation might appear in this region where sulphurous springs issue in many places from limestone without having any gypsum in the vicinity, yet it is altogether possible, for Capellini* tells of instances near Cervaro in Naples, where, by the action of hot sulphur springs, nummulitic limestone has been converted from crystalline into fibrous gypsum, containing sandy veins and semi-opal derived from silica of the nummulites. Occasional masses of unchanged limestone were seen there, doubtless owing their preservation to some difference in composition.

The other method of accounting for the beds is even more readily to be received. Newberry has shown for a part at least of the Salina† gypsumiferous deposits that the gypsum was most probably deposited as such in lagoons, and the writer has described beds of saccharoidal‡ gypsum deposited as such in the Carboniferous and Triassic of Colorado.

But this deposit belongs not to any regularly bedded series, so that some other explanation must be sought. Any suggestion of deposit from seawater must be set aside at once for the deposit is fully 1700 feet above tide and there is practically no bitterwater in the brine at Saltville. We have to explain the occurrence of gypsum, rocksalt, red marly clay; the gypsum occurring in great amygdules at 1700 feet above tide, in the vicinity of a great fault, and with many sulphur springs still active in the region.

The general mode of occurrence is very like that of the Permian deposits near Recoaro in Venice, as described by Taramelli.§

The gypsum is in amygdules of great size, accompanied by pale sandy marl, looking like volcanic ash, but distinctly calcareous. Capellini|| in his

* Capellini. *Ariano e dintorni. Cenni Geologici sulle Valle dell' Ufita, etc.* Mem. dell' Accad. di Bologna, 1869, pp. 15 et seq.

† Newberry. *Report of the Geological Survey of Ohio*, Vol. II, p. 194.

‡ Stevenson. *U. S. Explorations west of the 100th Merid.*, Vol. III, pp. 364, 379, 380.

§ Taramelli. *Geologia delle Province Venete*, 1882, pp. 60 et seq.

|| Capellini. *La Formazione Gessosa di Castellina Marittima*. Mem. Accad. Sci. di Bologna, 1874, pp. 16 et seq.

interesting memoir on the gypsum deposits of Castellina Marittima tells of conditions very similar. The amygdules of gypsum are of large size, and are associated with marly gray to yellow clays. He ascribes the formation of this gypsum to the action of sulphur springs on calcium carbonate held in solution ; so that the carbonate was changed into sulphate and deposited as such in the littoral lakes of the Middle Miocene. Dr. Newberry, on the authority of Dr. J. M. Locke, has informed the writer that something very like this is going on in Lake Utah, where the calcareous wash from the Wasatch mountains at the east meets the pyritous wash from the Oquah range at the west, so that calcium sulphate is depositing in the lake.

The origin of the Holston gypsum is to be accounted for in some similar way. Several deep basins were occupied by lakes ; that of the Saltville basin received not a little calcareous matter from the Lower Carboniferous beds forming its northerly shore, and some doubtless was received from the wash of the Knox beds on the southerly shore ; in the basins further east the calcareous matter derived from the wash should be far inferior to the argillaceous matter. But the composition of the gypsum shows *less* of the red clay at Buchanan's than at Saltville. The principal source of the calcareous matter must be looked for not in the wash from the shores, but in springs. That calcareous springs can produce deposits as extensive as those of this region is sufficiently shown by the extensive deposits around many of the springs at the far West. The calcium carbonate in solution would be converted into calcium sulphate by the sulphurous springs also issuing from the fault, and the gypsum would be deposited as such.

The red marly clays were derived from the wash, and are more abundant at Saltville, where the soft red shales at the top of the Lower Carboniferous are fully exposed on the northerly side of the basin. Undoubtedly not a little of the gypsum is derived from this wash, but, comparatively speaking, the quantity must have been insignificant. Had the basins been very large, such as that of the ancient Lake Lahontan, so well described by Mr. I. C. Russell,* the detrital material would have been dropped at the shore, and the calcareous matter would have been deposited by itself in the middle of the lake ; but the Holston basins are very small ; the region is one which always had a great rainfall, so that the wash of sand and clay would be very considerable. The amount of foreign matter and its distribution in the gypsum are conclusive. The sodium chloride must have come from springs and it may have been derived from the great sandstones under the valleys. Whatever was the source, the supply appears to have been cut off at about the same time throughout the whole region, for the top of the "saltrock" is reached at 215 feet at Saltville and at 300 feet in the Taylor shaft or at approximately the same absolute level.

Cafici, in his observations of the Sicilian gypsiferous deposits, and Capellini, in his studies of the Tuscan deposits, find evidence of alternating periods of activity and quiet in the springs ; for the fossiliferous shales

* Russell. Sketch of the Geol. Hist. of Lake Lahontan. Third Annual Report U. S. Geol. Surv., 1881, 1882.

and marls occur between the gypsums. The opportunities for examination in the Holston region are so limited that one cannot determine whether or not any such variations in activity of the springs occurred there.

NOTE.—The map accompanying this memoir is based on the old State map as used by Mr. Boyd in his Resources of Southwest Virginia, but the scale has been changed and a number of alterations have been made. It is still very inaccurate, but no better map is in existence. I have to acknowledge the courtesy of Maj. Powell, Director of the U. S. Geological Survey, and of Mr. Gannett, Chief Topographer of the Survey, in supplying photographic copies of the unfinished maps of the region. These have afforded real aid in working out the geology at localities where the other map had led me into serious error.

Some Notes Respecting Metamorphism. By John J. Stevenson, Professor of Geology in the University of the City of New York.

(Read before the American Philosophical Society, December 7, 1884.)

I have gathered together in this paper a number of notes made from time to time respecting the effect of certain agencies, which are regarded usually as especially active in inducing metamorphism of rocks.

Effect of proximity of Metamorphosed Rocks.

The following section was obtained on Four-mile creek, a stream entering South Park, Colorado, from the west; the rocks are Siluro-Cambrian:

1. Limestone, much altered.
2. Conglomerate and quartzite, imperfectly exposed.
3. Concealed, with occasional outcroppings of quartzite.
4. Quartzite.
5. Limestone, arenaceous, somewhat changed.
6. Sandstone, unchanged, light gray.
7. Sandstone, unchanged, shaly partings, dark gray.
8. Sandstone, slightly changed with layers of unchanged shale.
9. Sandstone, somewhat changed, very micaceous, dark.
10. Quartzite, mostly white, lines of cleavage distinct.
11. Granite and gneiss.

The total thickness of section is not far from 350 feet. A structureless quartzite rests on the Archæan, but above that the degree of change di-

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