Art. XXX.—*On the Silurian age of the Southern Appalachians;* by Frank H. Bradley.

1. *Introduction.*

Emmons, in his American Geology, refers most of the rocks along the western line of North Carolina * to his Taconic system, and says (vol. i, pt. 2, p. 24) that "the locality at the Warm Springs [Madison County, N. C.] is a good exhibition of the development of the Lower Taconic rocks in the Southern States;" but he also states (p. 25) that, in Cherokee County [near Murphy], the system is separated [divided] a few miles, by the interposition of a ridge of primary schists with staurolite.

Safford, in his Geology of Tennessee, 1869 (pp. 177–8), says, of the metamorphic rocks of the eastern border of that State: "A portion of the beds are certainly referable to the Ocoee group: the remainder, although conformable, may be older, and most likely are. * * The question of the greater age of [these] other parts is not so easily settled, and must remain open for the present. I know of no sufficient reason for referring any of these rocks to the Huronian or Laurentian series of Canada." Again (p. 193): After the Ocoee, the Chilhowee sandstones reappear and continue up the [French Broad] river to the State line. * * In North Carolina, a short distance beyond the line, the Ocoee group sets in again, and is the formation to within a mile of the Warm Springs. Then follows a Knox belt. The Springs are located on the Knox dolomyte. * * Beyond the Springs follow Chilhowee sandstones, then Ocoee rocks, and finally gneiss." The Knox group, here referred to, includes the Quebec group and the Calciferous: the Chilhowee sandstone is the typical Potsdam; and the Ocoee is the Lower Potsdam or Acadian group.

Professor Kerr has just issued a new geological map of North Carolina, which shows a strip of "Huronian" along the western line of the State, apparently covering the whole area there assigned by Emmons to the Taconic, even including the Warm Springs region. As the text of his report has not yet appeared,

* Since taking residence in Knoxville, in 1869, the writer has had his attention particularly drawn to the local features of the Lower Silurian rocks of East Tennessee and of the metamorphic strata which occupy the adjoining portions of North Carolina and Georgia. Most of the data given in this paper have been gathered incidentally, in connection with trips for the examination of mining properties; though, the clew to the Blue Ridge puzzle having thus been secured, a final trip was made solely for the purpose of completing its solution. Thus much to explain what some will regard as a trespass upon the preserves of the State geologists of North Carolina and Georgia, though neither of these officers has yet been able to make other than very hasty visits to the region in question. Without an opportunity of examining all the literature of the subject, reference can be made only to the works of Emmons, Safford and Kerr.

we cannot fairly criticize his non-adoption of the conclusions of Safford, although that geologist had followed the strata so connectedly, from their less altered and more fossiliferous regions, and was therefore least of all liable to be in error.* East of this Huronian is marked a belt of "Laurentian," the southern part of which is included in the area in question. The writer would here express an opinion, long held as a suspicion, but latterly confirmed by the results of the recent examinations of the crystalline rocks by Dana, Irving, Brooks and others, that the typical Huronian strata of the lake region, as well as large areas elsewhere so named, are simply metamorphic Silurian. It is pleasant to know, from correspondence, that some eminent geologists have reached the same conclusion.

The writer's conclusion, briefly stated, is that the rocks of that portion of North Carolina south and west of the Little Tennessee, together with the metamorphic area of Georgia, north of a line parallel with and ten miles south of the Chattahoochee (and *probably* that south of this line), and the entire metamorphic area of Alabama, are *Silurian or newer*, with the possible exception of two or three small patches not over ten miles in diameter. To the northeast of the Little Tennessee, there are large areas of rocks of the same age, but of undetermined boundaries, and including some patches which are pretty certainly Archæan. One of these latter forms and surrounds the "Bluff," on the borders of Cocke County, Tenn., and Madison County, N. C., where there are extensive outcrops of protogine and unakyte, with heavy beds of porphyritic hematite. This area—probably of the same age as the iron-bearing rocks of Missouri—adjoins the Warm Springs region before mentioned; and it may be well to say here that in Emmons' figure (l. c.) of the section there exposed, No. 15 is Chilhowee sandstone; 14 and 13 are Ocoee, separated by a fault from 12, which is Knox dolomyte, and whose cavernous structure give vent to the waters warmed by flowing through the deep fissures of the fault to the heated substrata; No. 11 is Knox shale; 10 is Chilhowee sandstone; 9 to 1 are Ocoee, probably resting upon Archæan. If this is "typical Lower Taconic," it is typical Lower Silurian as well. It is perhaps pertinent to note here that Emmons's Upper Taconic (l. c., pp. 62–68) is plainly only the slightly (or not at all) metamorphosed Silurian of the Great Valley.

* It is but justice to Professor Safford to say here that, during five years of frequent reference to his Report, in connection with field-work upon nearly all parts of the geological series exposed in East Tennessee, the writer, while recognizing many *local* deficiencies and some errors, such as are unavoidable in rapid work, has been constantly gratified and surprised at the thoroughness of the Report in all its *general* features. It has been and continues to be a great loss to Tennessee, as well as to science, that Professor Safford has not been employed to complete the detailed survey of the State.

Before giving further details of observations, it may be well to mention briefly the characters of the unaltered portion of at least the lower part of the series supposed to be represented by the metamorphic strata in question, beginning with the upper layers.

2. *Silurian of East Tennessee.*

Throughout East Tennessee the Cincinnati group is composed chiefly of shales, more or less calcareous, but includes generally two marked beds of limestone—the upper a red, compact, crinoidal marble; the lower, called by Safford the "iron-limestone," a strongly ferruginous rock, and so siliceous as to leave in many cases a tolerably solid skeleton, after its lime has all been removed by percolating waters, though in others, again, it decays entirely to a sandy clay. This lower bed is quarried, near Knoxville, as a flagging-stone, and proves very satisfactory, though its surfaces are quite irregular. Fine specimens of ripple-marks are common on these slabs; and the false-bedding of beach-sands is often well shown upon weathered edges of layers. The lowest beds of this group are generally shales. The total thickness has been estimated by Safford at about 1,850 feet.

The Trenton group is represented by heavy-bedded, red, gray and variegated marbles, of an estimated thickness of 380 feet, certain layers of which are extensively quarried and shipped for both building and monumental purposes.

The Chazy—"Maclurea beds" of Safford—consists of about 500 feet of bluish, impure limestone, generally very shaly, though at some points quite solid. The usual *Maclurea magna* is quite abundant, as are also various undescribed species of Sponges.

This is followed, below, by the Knox group, consisting of three members—a limestone, a shale and a sandstone. The limestone is mainly a very impure dolomyte, though with some purer layers, and includes also two or more thin beds of sandstone, one of which is probably the equivalent of the Saccharoidal sandstone of Missouri. The middle and lower portions are especially siliceous, being commonly crowded with cherty nodules and bands, the layers sometimes showing a thickness of five feet or more of solid chert. These are so numerous that the outcrops of this series are constantly marked by vast quantities of cherty masses, large and small, and more or less disintegrated, according to the varying percentage of included dolomyte. This included mineral is often crystallized, and its removal by weathering leaves numerous rhombohedral cavities, which Safford has noted as peculiar to chert of this horizon. Perhaps, a still more constant mark is the oölitic structure, which

is often very perfect throughout large masses. This structure also frequently occurs in the lower layers of the limestone, where the upper graduates into the middle member, or Knox shale. This upper member carries a greater variety of ores than any other bed in all this region; but, as yet, it appears doubtful whether any of them are in sufficient quantity and of such purity as to be of much practical value. Pyrite, galenite and sphalerite are of frequent occurrence in small quantities; and, at a few points, there are indications of considerable bodies of lead and zinc ores, the weathered portions of the latter showing much calamine and smithsonite. Barite is also quite abundant, though often impure. Fluorite also occurs in small quantities. These mainly occur at the filling of cavern-like chambers irregularly following the "joints" of the strata; but little is yet known of their extent, and nothing as to any law of their distribution. They also occur in grains disseminated through the mass of the rock. The most abundant ore along the outcrop of this series is limonite, which occurs in immense beds, both compact and ochreous. It is plainly a surface accumulation, resulting from the decomposition of pyrite and siderite in the limestone, and varying greatly in degree of purity, according to local conditions. Some beds are so filled with larger or smaller masses of chert as to be worthless; while others are almost entirely free from such impurities. Most of this ore contains more or less manganese ore, partly in the form of wad, partly as psilomelane. The very general dissemination of iron through the limestone, as sulphide, as oxyd, or as carbonate, is evidenced by the color of the heavy beds of reddish-brown clay accompanying every outcrop, which have been formed from the impurities of the rock, as the lime and magnesia salts have been dissolved away.*

* These immense beds of debris, along the outcrops of all but the very hardest and most siliceous rocks, are the constant characteristic of all this southern region, and, with the entire absence of drifted material above the level of the old river-terraces, afford the best of evidence that no glaciers have ever existed in the region. The immense amounts of river gravel, however, which bestrew the slopes of the valleys, up to from 170 to 200 feet and more above the present stream-levels, would indicate vast accumulations of snow upon the higher parts of the mountains; and it is not improbable that traces of glacial action may yet be found about their summits. These deposits indicate that, about Knoxville, the Holston was 170 feet above its present level, and filled a valley at least four miles wide, while its discharge was by the valley of the Coosa River, directly to the Gulf of Mexico, instead of by the present valley of the Tennessee. The Clinch must then have formed the main source of the Tennessee, and possibly this may also have found a southwestern outlet after passing Chattanooga.

The deep disintegration of the rocks will also account for the *entire absence of lakes* in this region, since any body of water, if ever formed here, would find little difficulty in cutting down its outlet so as to drain its bed. The most southern body of water in the Appalachians is said to be at Mountain Lake, Giles County, West Virginia, which is not far from the region, on the Greenbrier River, where Stevens recently reported finding glacial markings. (This Journal, III, vi, 371).

The middle member of the Knox series is the Knox shale, which in the neighborhood of Knoxville is a nearly pure clay shale; but it is said to become more calcareous to the northeast, forming at some points a pretty solid limestone, not readily distinguished from the Knox dolomyte proper. The Knox sandstone is ferruginous and quite commonly very argillaceous and glauconitic. The Knox group, as a whole, represents the Quebec group and the Calciferous sandrock; and the plane of division is not readily determined. The thin bands of limestone at the top of the shale contain numerous trilobites, mostly of species as yet undescribed, which appear to be closely related to those occurring at the base of the Quebec group in Canada. The maximum thicknesses are stated by Safford as: Dolomyte, 4,000 feet; shale, 1,500 to 2,000 feet; sandstone, 800 to 1,000 feet. At some points, the two lower members are very thin or even wanting.

Next comes the Chilhowee sandstone, generally a heavy-bedded rock, occasionally white, generally ferruginous, often pyritous. This, at most of its outcrops, is metamorphosed into an extremely compact quartzyte, though commonly interlaminated with some few thin beds of sandy shale. *Scolithus* borings occur abundantly in this rock at some points; but, instead of this being the universal rule, as stated by Safford, it is the exception at outcrops thus far examined by the writer. Thickness, 2,000 feet or more. As already stated, this is considered to be the typical Potsdam sandstone.

Lowest of all the recognized Silurian, we have the Ocoee group, of the Acadian epoch, or Lower Potsdam. The beds are all more or less metamorphosed, and consist mainly of slates and conglomerates. As these are of very uniform character, and outcrop in the region of greatest disturbance and most numerous faults, it would be extremely difficult, if not impossible, to determine their actual thickness. Safford says that this *may* be 10,000 feet.

While the Chilhowee and Ocoee groups, within the Tennessee line, may especially be considered semi-metamorphic, the sandstones of the former having been well cemented without concealing or even confusing the granular structure, the shales of the latter having been squeezed into smooth slates, but showing no crystallization, and the pebbles of its conglomerates well combined with the finer paste by a sort of aqueous fusion while yet plainly showing their pebbly character; yet lesser degrees of metamorphism are plainly to be traced in many of the higher layers, far out into the Great Valley. Good examples of this are abundant in the "iron-limestone" about Knoxville, where the lines of original stratification are often much contorted, while the mass is most thoroughly compacted.

3. *From Athens to Murphy.*

As was long ago stated by Rogers, the dips, throughout large portions of the Appalachians, are mainly to the southeast, the upward displacement along the numerous lines of faults being generally on their southeastern sides. As a consequence, it is at many places difficult to recognize the successive outcrops of the different beds, until one has become somewhat familiar with their local features and forms of metamorphism. In tracing the section, however, from the railroad at Athens, Tenn., across to Murphy, N. C., and thence to Clarkesville, Ga., there appears to be less than usual of this faulting; and the equivalencies of the beds are determined with comparative ease. At Athens, the shaly, calcareous beds, with some of the heavier and more compact ones of the iron-limestone, of the Cincinnati group, form the hills, with moderate northwesterly dips. About two miles southeast, these are suddenly cut off by a fault, the Knox dolomyte abutting against them, though still showing northwesterly dips. Two miles farther on, at the crossing of Middle Creek, we pass an anticlinal, along whose back the erosion has cut slightly into the Knox shale. Knox dolomyte follows, with southeast dips, until, about two miles farther, at Jesse Dodson's, another anticlinal of the shale appears, after which regular southeast dips bring in the complete series for about four miles, the light-colored Trenton marbles appearing about nine miles out, and ten miles bringing us into a gap of a line of high red knobs formed of the iron-limestone beds. These include many thin streaks of hematite, partly in the compact "specular" form, partly oölitic, partly in a powdery or scaly condition, which has been locally mistaken for cinnabar. The hard ore can sometimes be traced, within short distances, from the "specular" condition into the unaltered oölitic "dyestone," inclosing corals and other fossils in perfect preservation, or again into a ferruginous sandstone. The ores of this belt have not yet been found in sufficiently thick beds to pay for mining, though many carloads of good ore have been gathered from the accumulations along the weathered outcrops. These iron-limestone beds recur, in several successive waves, for about four miles, one of the synclinals bending low enough to show a considerable mass of the overlying "red marble." Finally, thirteen miles out, the layers rise in sharp northwest dips, as we approach the foot of the southwestern section of the Chilhowee Mountain range. The Knox group forms the base and northwestern face of the mountain; and the heavy beds of the Chilhowee sandstone form its crest, in bold cliffs overlooking the valley to the southeast, 1,100 feet below. White Cliff Springs, of chalybeate and sulphur water, are a favorite summer resort, near the summit, and sixteen miles from Athens. Such springs are frequent

along the outcrop of this sandstone, resulting from the decomposition of the pyrite therein contained.

Looking northeastward, toward the other section of this mountain, to be hereinafter described, we see no intervening ridges and no apparent outcrop of the sandstone, but only a confused cluster of low, rounded, shale hills.

Descending the southeastern face of the mountain, we find its foot composed of the Ocoee slates, semi-metamorphosed, dipping northwest. In the middle of the valley is a knob of the Ocoee conglomerate, apparently occupying the axis of the anticlinal, since southeast dips at once recur, the slates forming the ridge bounding the valley on the southeast. The second and third ridges show small synclinal patches of the Chilhowee sandstone on their crests, with slight intervening anticlinals, while the fourth is a sharp anticlinal in the slates, which brings us to the Coca Creek waters, where the outcrop of these slates, with some small quartz veins, has yielded small amounts of placer gold. At one point here, I saw a small outcrop of the Chilhowee, dipping southeastward, and apparently cut off by a fault. Indeed, slight faults are frequent in the slates which here form the mass of the Smoky Mountains along the State line. These disturbances, however, though preventing any accurate determination of the true thickness of the beds, in no way interfere with the continuity of the mass and the constancy of the general southeasterly dips. These dips continue for about five miles beyond the State line, the beds showing more and more thorough metamorphism, the slates becoming micaceous and talcoid schists, and the inclosed beds of conglomerate becoming gneisses, more or less pebbly or even porphyritic. Here, on the eastern slope of Long Ridge, just beyond Hennegar's, northwest dips set in again, and continue about nine miles, to Davidson's, in similar beds: at this latter point, an anticlinal of softer hydromica schists and gneisses, partly staurolitic, with thin quartz veins and much iron sand, appears for half a mile, and represents the copper-bearing beds of Ducktown, the ores of which are said to be exposed in the bed of the Hiwassee, perhaps three miles west of this point. The beds appear to lie conformably beneath the true Ocoee, on both sides of the anticlinal; and there seems to be no reason for referring them to a distinct group, as was done by Emmons; and here Kerr has not followed him. The series shows a much wider outcrop at Ducktown, a dozen miles southwest, where, as is well known, rich copper mines have been developed.* The ore-deposits here are irregular masses of "stock-work," though filling crevices which run

* Still more extensive deposits would doubtless have been located, had more convenient access made mining more profitable. In the present condition of affairs, the Ducktown works, though economically managed, return hardly a living profit, and await the coming of a promised railroad for lower freights and cheaper fuel.

nearly parallel with the inclosing strata, in consequence of schistose structure especially favoring splits in that direction. At many points, they *look* like *regularly interstratified beds.* Conditions have here favored most thorough metamorphism, probably by reason of a more open and porous condition of the material, allowing more abundant percolation of the heated mineral waters. The wall-rock, at some points, is of the toughest possible quartzyte; at others, a micaceous gneiss; again, a tremolyte or hornblendyte. Both the walling and "horses" of the same material are often permeated with copper, iron and zinc sulphids. The true gangue is quartz, at some points very abundant, at others scarce.

Passing on from this belt, the southeast dips bring in again the schists and gneissoid conglomerates of the Ocoee, and the gneisses and gneissoid quartzytes of the Chilhowee and the Knox sandstones. Above this latter bed, which is here, of course, undistinguishable from the Chilhowee, the Knox shale is represented by fine-grained blue mica slates speckled with mica crystals; and, within a quarter of a mile of Murphy, we find the Knox dolomyte, in white, speckled, gray, dove-colored and nearly black marbles. These materials being so much more easily eroded and dissolved than most of the quartzose rocks, have caused the formation of a long line of valleys, and are themselves generally covered. Before treating of them in detail, or passing on to more easterly outcrops, let us review the strata along another line of approach.

4. *From Knoxville to Murphy.*

At Knoxville, just north of the railroad track, a line of fault, essentially the equivalent of, and probably continuous with, that noticed just southeast of Athens, separates the upper shales of the Cincinnati group from the Knox dolomyte, both having southeast dips. The dolomyte, with its characteristic cherts and sandstones, forms the ridge upon which the main part of the city of Knoxville stands, and extends across to the south bank of the Holston, where it is regularly overlaid by the shaly limestones of the Chazy, the fine quarry-marbles of the Trenton, and the shales and iron-limestones of the Cincinnati, which latter form a line of high red knobs, with thin streaks of compact and oölitic hematite. About three miles out, a low rounded hill, between flat shale valleys, shows a synclinal of the upper "red marble." The iron-limestone, in successive waves, then occupies the surface nearly to Rockford—say for six miles—and then yields place to the Knox dolomyte, which continues to beyond Maryville. This town, sixteen miles from Knoxville, stands near the crown of a low arch, which appears to be the equivalent of the sharp anticlinal in the valley southeast of White Cliff, though here somewhat farther out from the main

mountains. The northeastern section of the Chilhowee Mountain, indeed, is still nine miles beyond us. In approaching it, we pass over all the upper beds of the Lower Silurian, together with the shales and oölitic hematites of the Upper Silurian (Clinton, or Safford's "Dyestone group"), and the Black shale and soft gray calcareous shales of the Lower Subcarboniferous, and suddenly reach a fault of perhaps 10,000 feet, where the last-named beds abut against the Ocoee slates and conglomerates. The slates, at some points in this neighborhood, are quite chloritic, and so nearly black as to have been frequently mistaken for *anthracite*. Above the Ocoee, the mass of the mountain consists of the heavy beds of the Chilhowee sandstone, with high southeast dips. Montvale Springs, a favorite summer-resort, nine miles from Maryville, are near the foot of the mountain, and derive their chalybeate waters from the decaying pyrite of this formation. Several other strong chalybeate springs occur at various points along the mountain, but have not been similarly improved. Passing the summit, we find the southeastern foot-slopes faced with imperfect slates, representing the Knox shale, and the hollows beyond occupied by the Knox dolomyte, much disturbed and altered. The rough form of the country does not favor a full understanding of the disturbances without a thorough study of details; but it is at least evident that the dolomyte finally abuts against the Ocoee group, across a fault of several thousand feet, near the foot of the State line range, here called the Smoky Mountains. The Ocoee continues, with southeastern dips, for several miles up the Little Tennessee; but, at Rocky Point ferry, three miles beyond the line, let us cross the river, pass over a high spur to Cheowa River, and ascend the valley of that stream. The slates and conglomerates here pass rapidly into schists and gneisses. About fifteen miles from the ferry, we encounter the Chilhowee, in the form of a heavy-bedded, fine-grained gneiss, occupying, for a mile or so, the axis of a synclinal. It is reported that, on Snow Bird Creek, a western fork of Cheowa, a bed of limestone, which must be the Knox dolomyte, occupies a considerable area on the line, joining this outcrop with the synclinal noticed at Long Ridge on the other route. Northwestern dips of the Ocoee now continue on to the head of the river, consisting of hydromica schists and gneisses with staurolites and garnets, chlorite schists with garnets and quartz veins, and some bands of gneiss and quartzyte. As we approach the summit gap, toward Valleytown, we find an irregular anticlinal, equivalent to that at Davidson's on the other route, followed by very confused dips, as though the mountain bed suffered a tremendous squeezing in this region. These disturbed foldings continue even down to the valley-level, where sharp anticlinal folds occur in the micaceous gneiss, just before it dips beneath the Knox marble. It

is not improbable that careful examination might detect small patches of the marble caught and held in some of the folds high up on the mountain-side. The point at which we have now struck this formation is about seventeen miles northeast of Murphy, along the direct line of outcrop.

If, instead of crossing at Rocky Point and ascending Cheowa, we follow up the Little Tennessee, we find heavy-bedded, gray, Chilhowee quartzytes exposed as, near Hazelnut Creek, we approach and pass the synclinal just noticed as running from Long Ridge across Cheowa. Hereabouts are also laminated micaceous sandstones and chloritic slates, with veins of milky quartz. These and similar beds continue to above the mouth of the Tuckaseege, whose dip is at first pretty regularly northwest, but soon becomes irregular, turning to southwest and even to south, as if some transverse axes of fold were developed, not far to the northeastward. As we approach and pass the mouth of Nantahala River, the same beds come down again, after we pass the axis of an anticlinal about a mile below Ashe's Mill: the dips, at first nearly east, soon become S. 20° E. Along the axis of the anticlinal, which is the equivalent of that running from Ducktown past Davidson's, there are said to be copper ores in schist along Stekoa Creek. Five or six miles above the Nantahala, near Wm. Dehart's, we are supposed to reach the range of the Valley River marble, though its outcrop has not yet been reported quite so far northeast.

(To be continued.)

Knoxville, Tenn., Jan. 25th, 1875.