Art. XVII.—*The Ceratops Beds of Converse County, Wyoming;* by J. B. Hatcher.

In the December number of this Journal for 1889, Prof. O. C. Marsh gave the name Ceratops beds to certain strata in the upper Cretaceous of Wyoming, Montana, and Colorado, containing the remains of horned Dinosaurs (*Ceratopsidæ*) and many other reptilian and mammalian forms.

Of these beds, those in the northeastern portion of Converse county, Wyoming, are best known and have been most thoroughly explored. Fully ninety per cent. of all the vertebrate fossils described by Prof. Marsh from the Ceratops beds were found in this region. This fact is sufficient to warrant a more detailed description of the stratigraphical and geographical position of the beds, and of their geological and lithological characters, than has yet appeared. Not only has this region proved especially rich in vertebrate fossils, but the Ceratops beds seem to have attained a greater development here than has been noticed elsewhere. Since the present border of the beds is nearly that of the eastern shore of the fresh-waters in which they were deposited, and erosion has exposed many continuous sections in them down through the underlying Fox Hills sandstones and into the Ft. Pierre shales, this region offers exceptional advantages for determining the position of the Ceratops beds and for establishing their age upon stratigraphical as well as paleontological evidence.

Geographical Position of the Ceratops Beds.

The Ceratops beds of Wyoming have thus far been explored only in a very limited region in the northeastern part of Converse county. Going north from Lusk, a small station on the Freemont, Elkhorn, and Missouri Valley railroad, they first appear about twenty-five miles from that place, occupying the summit and northern slope of a yellow sandstone ridge extending in a westerly direction from Buck creek to Lance creek and crossing the latter stream near the mouth of Little Lightning creek, a small tributary from the west. A short distance west of Lance creek, the Ceratops beds pass under other beds composed of very similar material, and presumably of Cretaceous age. From Buck creek, the eastern border of the Ceratops beds has been traced in an almost continuous exposure, extending northeasterly to the Cheyenne river, and crossing this stream a short distance below the mouth of Lance creek. From this point, it takes a more

northerly direction, and skirting the western slope of the Black Hills, it has been traced to the north line of Converse county and on into Weston county. As stated above, the eastern shore of the fresh-waters in which the Ceratops beds were deposited was nearly that of the present border of these beds. The eastern limit of the fresh-waters was confined to the western slope of the Black Hills and that chain of minor uplifts connecting them with the Laramie range to the southwest. The Black Hills were at one time connected with the Laramie range through the Rawhide range and a less elevated series of uplifts extending in a northeasterly direction from the latter to the southern limit of the Black Hills. Remnants of this connecting range are still to be seen in the bluff just back of Lusk, known as Silver Cliff; on Duck creek two and one-half miles a little west of north of Lusk; near the head of Old Woman creek, about six miles north of the last mentioned place; in the ridge on the east side of Sage creek, two miles below Hat Creek post-office and eight miles northeast of the locality just mentioned; in another bluff ten miles below this and on the same side of the creek, but farther to the east; and doubtless in many other places as yet unobserved. The Ceratops beds were originally confined to the western slope of the Black Hills and of the less elevated series connecting the latter with the Rawhide range. This is conclusively shown by the absence of the Ceratops beds not only on the eastern slope of this range where they could have been removed by erosion, but in the region to the eastward where all the beds are approximately horizontal, and where, if they ever existed, remnants of them, at least, should yet be seen. The surface of the region to the east of the Black Hills and their southwestern extension, as just described, is composed for the most part of Miocene deposits, with many sections showing the underlying beds. In all such exposures in this region, hundreds of which have been examined, the Miocene is underlaid by marine Cretaceous or older formations. In no instance have the Ceratops beds been observed east of the Black Hills or their less elevated continuation to the southwest.

The Ceratops beds proper, that is, those beds containing remains of the *Ceratopsidæ*, are known to have a surface exposure in that portion of Converse county embraced within their eastern and southern border, as defined above, and a line extending from that point on the latter where it passes under the overlying beds a short distance west of Lance creek, nearly due north to Weston county; i. e. the country drained by lower Lance, Lightning, Cow, Doegie, and Buck creeks, and that portion of the Cheyenne river and its tributaries between the mouth of Lance creek and the north line of

Converse county. The creeks mentioned in this paper will be found on any good map of Wyoming.

Description of the Deposits.

The Ceratops beds are made up of alternating sandstones, shales, and lignites, with occasional local deposits of limestones and marls. The different strata of the series are not always continuous, a stratum of sandstone giving place to one of shales and *vice versa*. This is especially true of the upper two-thirds of the beds. The lack of continuity in the different strata has rendered it well nigh impossible to establish any definite horizons in the upper members of the series. All the deposits of the Ceratops beds of this region bear evidence of having been laid down in fresh-waters. Among the invertebrate fossils found in them, only fresh-water forms are known. There is no evidence that marine or brackish-waters have ever had access to this region since the recession of the former at the close of the Fox Hills period.

The sandstones largely predominate in the lower members of the beds. They are always fine-grained, massive to well-stratified, and nearly white to yellowish brown in color. They are occasionally compact and hard, but for the most part quite soft and friable. They are composed of sharp, angular grains of quartz with some clay and mica, the whole being loosely cemented together with carbonate of lime. Almost everywhere in the sandstones are numerous concretions of varying size and shape. Some are almost perfect spheres and vary from the size of a marble to 18 or 20 feet in diameter. Others are from a few inches to several feet in transverse diameter and sometimes several hundred feet in length, a cross section forming a nearly perfect circle. Others still are very irregular in form. These concretions usually show no concentric structure, and while they sometimes enclose foreign objects, as a *Triceratops* skull or a single bone as a nucleus, they are for the most part simply centers of solidification and not true concretions. This is frequently shown by the cross-bedding in them, so often seen in the sandstones themselves.

The shales are almost entirely wanting in the lower 400 feet of the Ceratops beds, but they are well represented in the succeeding series. They are quite soft and loosely compacted, composed mostly of clay with more or less sand in places. The prevailing color is dark brown, but they are sometimes red or bluish. They are well stratified and finely laminated, and contain occasional limestone concretions enclosing numerous invertebrates.

The lignites occur in thin seams, never more than a few inches thick, of only limited extent, and with many impurities. At no place in the Ceratops beds of this region have workable coal beds been found. These do occur, however, in the Ceratops beds of Montana. The best exposure of them observed there is in Fergus county, on Dog creek, about 15 miles from its mouth, just above where it enters the Bad Lands of the Missouri. Workable coal seams occur in Wyoming, in the beds west of Lance creek, which overlie the Ceratops beds, and will be referred to later.

Intercalated with the sandstones, shales, and lignites, are quite local deposits of limestones, clays, and marls. The latter are composed almost entirely of fresh-water shells, fragments of bone, teeth, etc.

Along their southern and eastern border, the Ceratops beds dip to the northwest, at an angle of about 16° between Buck creek and Lance creek. One half mile east of Lance creek, the dip is 29° to the northwest. This angle of inclination rapidly diminishes toward the interior, and is scarcely noticeable in the vicinity of Lightning, Cow, and Doegie creeks. The fold is quite abrupt as is further shown by cracks which were made in the strata at the time of disturbance at right angles to their dip and parallel with their strike. These fissures have been filled by infiltration with materials now harder than those forming their walls, and now appear in many places as projecting veins, from a fraction of an inch to a foot or more in width, and from a few yards to several hundred in length.

Stratigraphical Position of the Ceratops Beds.

The Underlying Beds.—Along their southeastern border, especially between Lance and Buck creeks, are many fine exposures of the Ceratops beds and the underlying Fox Hills. Perhaps the best exposure is that made by a small tributary emptying into Buck creek, about four miles east of Lance creek and one-half mile northwest of the Buck creek pens used by the cattle men for round-up purposes. This watercourse has here cut its way in a southeasterly direction, at right angles to the strike, down through the lower half of the Ceratops beds, through the underlying Fox Hills sandstones, and into the Ft. Pierre shales. At this place, the bed of Buck creek and the rounded hills of that region at the head of this stream, embraced between the border of the Ceratops beds and Fox Hills sandstones on the north and the bluffs of Miocene clays and conglomerates on the south, are composed of Ft. Pierre shales. All the strata of this entire section dip to

the northwest at an angle of 16°. The exposure is a continuous one, and commencing from below, the section is as follows:

At the base are the Ft. Pierre shales of unknown thickness, several hundred feet of which are exposed. They consist of argillaceous, finely laminated, dark shales, quite soft and easily eroded. They contain many limestone concretions and numerous invertebrates; among others are *Baculites ovatus*, *B. compressus*, *Scaphites nodosus*, *Placenticeras placenta*, *Nautilus Dekayi*, etc.

Overlying the Ft. Pierre deposits is an alternating series of sandstones and shales with an estimated thickness of 500 feet. In the lower portion of this series, the shales predominate, but toward the middle the sandstones are in excess, and in the upper 50 feet they entirely replace the shales. The sandstones are of a yellowish brown color, very fine grained, firm, and well stratified below, but softer, and quite massive at the top, where they contain numerous large concretions and a rich marine invertebrate fauna. Representatives of this fauna have been sent to Mr. T. W. Stanton of the U. S. National Museum, and were pronounced by him to be characteristic of the uppermost Fox Hills in direct conformity with their stratigraphical position.

The Ceratops Beds.—Next come the Ceratops beds with an estimated thickness of 3,000 feet, resting directly upon the Fox Hills series. Immediately above the Fox Hills is a very thin, but quite persistent, layer of hard sandstone, well stratified, and quite cleavable along the lines of stratification. This stratum of sandstone is about six inches thick, and is regarded as the dividing line between the marine and fresh-water beds. It is overlaid by about 150 feet of yellowish brown, well-stratified sandstones apparently non-fossiliferous. These are in turn overlaid by about 250 feet of almost white, fine-grained, massive sandstones with numerous concretions, but no fossils were found in them. Next comes the fossiliferous portion of the Ceratops beds, consisting, as before stated, of alternating sandstones, shales, and lignites.

All the beds of the entire section are conformable, and bear evidence of a continuous deposition, from the Ft. Pierre shales up through the Fox Hills sandstones and the overlying fresh-water Ceratops beds. The Ft. Pierre shales are not suddenly replaced by the Fox Hills sandstones, but the transition is a gradual one, and it is impossible to say just where the one ends and the other commences. The same is true of the beds overlying the Fox Hills. The thin seam of hard sandstone, just referred to as separating the fossil-bearing Fox Hills sandstones below from the very similar non-fossiliferous sandstones

above, is here regarded as the dividing line between the Fox Hills and Ceratops beds. But this decision, it must be admitted, is quite arbitrary, and the evidence in its favor is negative rather than positive. The only reason for placing the overlying 400 feet of non-fossiliferous sandstones in the fresh-water series is the absence of fossils in them, which may perhaps be accounted for by the destruction of the marine forms brought about by the change from salt to fresh-waters. The overlying non-fossiliferous beds may have been deposited in the fresh-waters before fresh-water forms had distributed themselves over this region. The sandstones of the entire series are very similar, and since there is entire conformity throughout, it is absolutely impossible to determine just where the marine beds end and the fresh-water beds commence. The Ceratops beds of this region are a natural sequence of the Fox Hills. The materials composing both were evidently derived from a common source. The only safe criteria for distinguishing one from the other are their fossils.

The Overlying Beds.—Along their eastern border, the Ceratops beds are occasionally unconformably overlaid by Miocene clays and conglomerate. But these deposits, if they ever extended over any considerable portion of the region now occupied by the Ceratops beds, have been almost entirely removed by erosion. To the west of Lance creek, the Ceratops beds pass under a very similar series of sandstones, shales, and lignites, of about the same thickness, and conformable with them. In this series, the sandstones are more massive than the underlying sandstones; the shales contain more sand; and the lignites are more frequent, of a better quality, and attain a greater thickness, as shown at the Shawnee coal-mine on Shawnee creek, where a single bed of coal is 10 feet thick, and of a quality sufficiently good to enable it to be profitably mined for commercial purposes. Thus far no vertebrate or invertebrate fossils have been found in these beds, but they contain a rich fossil flora, representatives of which have been sent to Prof. F. H. Knowlton of the National Museum, with a request for his opinion as to the age of the beds, based upon the evidence afforded by the fossils. Upon no other evidence than a general similarity to known Laramie deposits in other regions, they are here regarded as Upper Laramie.

Age of the Ceratops Beds.

In a series of articles commencing in the April number of this Journal for 1889, Prof. Marsh has referred the Ceratops beds to the Laramie, mainly upon evidence afforded by their vertebrate fossils. Owing to the fact that very few vertebrates

had previously been described from the typical Laramie, as first defined by Mr. Clarence King, and the consequent lack of vertebrate forms known to have come from the Laramie for comparison with those found in the Ceratops beds, it must be admitted that the vertebrate fauna of the latter is, in itself, at present not sufficient proof to establish the Laramie age of the Ceratops beds.

Fortunately the Ceratops beds contain an extensive invertebrate fauna, in which Dr. C. E. Beecher has identified the following: *Unio Couesii*, White, *Sphærium formosum*, M. & H., *Linnæa compactilis*, Meek, *Campeloma multilineata*, M. & H., *Tulotoma Thompsonii*, White, and others known from the typical Laramie, some of which are characteristic of it. The invertebrate fossils may, therefore, be considered as additional evidence of the Laramie age of the beds.

But the most conclusive evidence that the Ceratops beds belong to the Laramie period is that afforded by their actual position in regard to the Fox Hills. As stated above, they conformably overlie the Fox Hills, which is the normal position of the Laramie. This conformability must be regarded as an actual and not an apparent one, since it is shown in an almost continuous exposure for many miles along the southeastern border of the beds, where they are upturned at an angle of from 16° to 29°, and where an unconformability, if any existed, would be plainly visible.

The evidences in favor of referring the Ceratops beds to the Laramie are:

(1) They conformably overlie the Fox Hills sandstones and contain both a reptilian and a mammalian fauna, with decided Mesozoic affinities. Among the reptiles, the Dinosaurs are, in degree of development and point of numbers both as to individuals, and genera and species represented, probably unsurpassed in any previous smilar division of the Mesozoic; while as regards degree of specialization, they are superior to all previous forms. This age was preëminently an age of reptiles.

(2) They contain an invertebrate fauna comprising many forms identical with those already described from the typical Laramie, some of which are unknown except in the Laramie.

(3) They immediately and conformably overlie the Fox Hills, and show evidence of a continuous deposition through both series.

Probable Conditions attending the Deposition of the Ceratops Beds.

The change from marine to fresh-waters which took place at the close of the Fox Hills and the beginning of the Laramie was brought about by the great continental elevation going on

in previous Cretaceous periods, and sufficient to cause a recession of the salt waters at the close of the Fox Hills. During the Laramie, this region was occupied by fresh-waters or in places by dry land.

This period of elevation which brought about the close of the marine Cretaceous is thought to have been followed by a period of subsidence during the Laramie. For, since the beds of the Laramie were evidently deposited in shallow waters, as is abundantly shown by the great number of lignite seams which they contain, and still further in the Ceratops beds, at least, by the absence of continuity of strata, frequent cross-bedding, etc., it is impossible to account for so great a thickness of beds, all bearing evidence of having been deposited in shallow waters, except on the theory of a subsidence going on over the region during the period in which they were laid down. This subsidence must have been so gradual that the upbuilding by sedimentation at the bottom of the waters kept pace with the subsidence; any increase in the rate of the latter increasing the depth of the waters, and a decrease in the rate of subsidence causing a decrease in depth. The latter would bring about a condition requisite for the deposition and preservation of vegetable matter which would be transformed later into lignites.

The Ceratops beds are thought to afford evidence in themselves of having been deposited not in a great open lake, but in a vast swamp, with occasional stretches of open waters, the whole presenting an appearance similar to that which now exists in the interior of the Everglades of Florida. This condition would account for the frequent changes from one material to another in the same horizon, before referred to. In some places in the beds, these changes are quite frequent, strata of sandstones and shales replacing one another in great confusion. It would also explain the cross-bedding so often seen in the sandstones of this region, in localities remote from the present border of the beds, and hence far removed from the shore of the ancient lake or swamp. This cross-bedding could hardly occur in off-shore deposits of a great fresh-water lake of any considerable depth.

The conditions that prevailed over this region during the period in which the Ceratops beds were deposited were probably those of a great swamp with numerous small open bodies of water connected by a network of water courses constantly changing their channels. The intervening spaces were but slightly elevated above water level or at times submerged. The entire region where the waters were not too deep was covered by an abundant vegetation, and inhabited by the huge Dinosaurs (*Triceratops*, *Torosaurus*, *Claosaurus*, etc.), as well

as by the smaller crocodiles and turtles, and the diminutive mammals, all of whose remains are now found imbedded in the deposits. That these animals at one time inhabited the very region where they now lie entombed is conclusively shown by the occasional finding of entire skeletons with every bone in place, at localities far distant from the border of the beds, and in a state of preservation which could not possibly exist had they lived and died on a distant shore, and their carcasses been transported by the waters to their present resting places after death. Moreover, skeletons are sometimes found in an upright position or inclined to one side or the other, showing that the individual met death by miring in the immediate spot where the remains now rest. A noteworthy example of this was that of the skeleton of a Dinosaur discovered in August, 1891, by Mr. A. L. Sullins, and recently described by Prof. Marsh as *Claosaurus annectens.** This skeleton when found was in a partially erect position, the limbs extended, and every bone in its natural position except where exposed and worn away by recent weathering. The ribs were still distended, retaining the exact form and capacity of the thoracic and abdominal cavities. The whole showed that the animal in its wanderings had mired in the quicksands, and in its struggles for liberation had been engulfed by them.

In the sandstones of the Ceratops beds hardly a fossil bone of any considerable size is to be found that does not bear evidence of having been dropped in shallow waters. In many instances, it is still possible to determine the direction of the currents which succeeded in burying the bones, and thus prevented their decay. For instance, on one side of a bone the matrix will be made up entirely of sand, while on the opposite side the stems and leaves of plants have been dropped, and, now partially lignitized, form a considerable portion of the matrix. This arrangement of the materials of the matrix in which the bone is imbedded shows the direction of the current to have been from that side containing only sand, and toward the side containing the plants. So shallow were the waters, the bone itself became an obstacle sufficient to produce an eddy on its lower side, in which the leaves and other vegetable materials accumulated, and sank to the bottom.

Conclusions.

If the Ceratops beds of Converse county, Wyoming, are the equivalents of the typical Laramie of southwestern Wyoming, the remarkable vertebrate fauna of the former will prove of great importance in determining the age of other beds now

* This Journal, vol. xliii, p. 453, May, 1892; and vol. xliv, p. 171, Aug., 1892.

in doubt, containing like or similar faunas. Notably among the latter are the Denver and Arapahoe beds in the vicinity of Denver, Colorado, and their probable equivalents in other portions of the same state, recently described by Mr. Whitman Cross, as "The Post Laramie Deposits of Colorado."* Mr. Cross refers these beds to a period later than the Laramie on account of unconformities existing, in some places, at least, between them and the underlying recognized Laramie and older Cretaceous formations, and in opposition to the evidence afforded by the vertebrate fossils thus far obtained in them. Whether it is better to ignore the evidence afforded by the vertebrate fossils, or to treat these unconformities as local, remains to be decided by future investigations. It is quite possible that Dinosaurs continued into the early Eocene, but they were represented there, if at all, only by degenerate types, and less specialized forms. It would certainly be remarkable, not to say impossible, that a group of Dinosaurs showing so great a development and marked specialization as are to be seen in *Triceratops* and *Claosaurus* should continue uninterruptedly from near the base of the Laramie up into the Tertiary. Nevertheless at least two species of *Triceratops* have been described from the Denver beds referred by Mr. Cross to the Post-Laramie. Regions affording such contradictory evidences should be thoroughly examined, and, where possible, their actual stratigraphical relations should be determined. Results thus attained might be sufficient to harmonize observations now in apparent opposition.

Yale Museum, New Haven, Conn., December 5, 1892.