ART. XVI.—*Fox Hills Sandstone and Lance Formation ("Ceratops Beds") in South Dakota, North Dakota and Eastern Wyoming;** by TIMOTHY W. STANTON.

THE Laramie question is a perennial problem for stratigraphers and paleontologists, but with the continued rapid accumulation of facts, as the detailed investigation of the stratigraphy is carried over the entire area involved, it is reasonable to hope that the problem will not be perpetual.

At the present time one of the most important points at issue is the relationship of the Lance formation† ("Ceratops beds") to the Laramie formation and to the conformable Cretaceous sequence beneath the Laramie. Some geologists hold that the Lance formation wherever it has been studied rests unconformably on the Laramie or some older formation and that the unconformity beneath it represents a long, complex epoch of elevation and erosion. In this paper evidence will be presented to show that in the rather widely distributed areas discussed there is a real transition from the marine Cretaceous Fox Hills sandstone into the Lance formation and that sedimentation was practically continuous from the one into the other and probably on through the Fort Union.

The data to be discussed were obtained in three areas mostly during the summer of 1909. One of these, which includes the Cheyenne River and Standing Rock Indian Reservations in northern South Dakota and southern North Dakota just west of the Missouri River, was examined for coal lands by Messrs. A. L. Beekly, Max Pishel and V. H. Barnett under the general supervision of Mr. W. R. Calvert. This investigation afforded an excellent opportunity for the study of the Fox Hills sandstone in its typical area and of its relations with the overlying Lance formation. A second area, which has been described in some detail by Prof. A. G. Leonard, is along the Little Missouri from Marmarth to Yule in the southwest corner of North Dakota, where I spent five days. The third area is the well known Lance Creek region in Converse County, eastern Wyoming, where Hatcher made his great collection of the Triceratops fauna. Nearly a week was spent here in company with Messrs. M. R. Campbell and R. W.

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† The name Lance formation has recently been adopted by the United States Geological Survey for the "Ceratops beds" of eastern Wyoming and adjacent areas. It is an abbreviated form of the term "Lance Creek beds" which J. B. Hatcher applied to these deposits in 1903 (American Geologist, vol. xxxi, p. 369) with the statement that the name is taken "from the principal stream in the region where they are best represented in Converse County, Wyoming."

Stone. The three areas, though separated by intervals of 100 to 150 miles, all belong to the same general region, throughout which it is evident that closely similar conditions prevailed in the closing stages of the Cretaceous.

Standing Rock and Cheyenne River Indian Reservations.

A detailed description of this area will be given by Mr. Calvert and his assistants in a report which is in preparation. For the present purpose it is only necessary to direct attention to a few points. The area lies on the west side of the Missouri River between Cheyenne River on the south and Cannonball River on the north and it is divided into three approximately equal parts by Moreau and Grand Rivers, tributaries to the Missouri from the west.

The rocks are little disturbed and usually appear horizontal in ordinary exposures, but a more general study of their distribution shows that they dip a few feet in the mile toward the north or northwest. The lowest formation exposed is the Pierre shale, the upper part of which is seen in the valleys of all the streams mentioned except the Cannonball. Above the Pierre is the Fox Hills sandstone in many places forming bluffs for long distances along the streams. This is the highest marine Cretaceous formation in the section. It extends up the Missouri as far as old Fort Rice, North Dakota, a few miles above the Cannonball, and underlies the higher ground in a broad belt of country southwest of that point. Overlying the Fox Hills sandstone is the less resistant non-marine Lance formation which in published reports has been called "Ceratops beds," "Laramie," "lower Fort Union" and "somber beds." It frequently forms badlands in the inter-stream areas on the reservations and extends up the Missouri valley to Bismarck and beyond. As the streams have cut through both the Lance formation and the Fox Hills sandstone for long distances, the relations between the two formations are easily studied.

The Fox Hills sandstone was first named by Meek and Hayden* in 1861, who stated that it "is most distinctly marked at Fox Hills, between Cheyenne and Moreau Rivers, above Fort Pierre." In the words of their description "this formation is generally more arenaceous than the Fort Pierre group, and also differs in presenting a more yellowish or ferruginous tinge. Towards the base it consists of sandy clays, but as we ascend to the higher beds, we find the arenaceous matter increasing, so that at some places the whole passes into a sandstone. It is not separated by any strongly defined line of demarcation from the formation below, the change from the

* Proc. Acad. Nat. Sci. Phila., vol. xiii, pp. 419, 427.

fine clays of the latter to the more sandy material above being usually very gradual. Nor are these two formations distinguished by any abrupt change in the organic remains, since several of the fossils occurring in the upper beds of the Fort Pierre group pass up into the Fox Hills beds, while at some localities we find a complete mingling in the same bed of the forms usually found at these two horizons." The total thickness of the formation was then estimated at 500 feet, but in previous papers dealing with only the typical area the thickness was given as 100 to 150 feet, an estimate which is nearer the truth for this particular area.

The variable character of the formation is indicated by Meek and Hayden's description just quoted and this variability as to details becomes impressive after a number of local sections have been examined. In some exposures nearly the whole formation is a soft, friable, cross-bedded gray or yellowish sandstone, usually with many iron-stained concretions and indurated masses as on Cannonball River, 6 miles above its mouth, where single exposures show 60 feet of sandstone and the base of the formation is not seen. At other places similar sandstones occur at the top and at the bottom and include indurated beds of considerable extent, while the middle portion of the formation is made up of more or less sandy shale in bands a few inches thick of alternating lighter and darker color. This banded shale contains considerable vegetable matter in the form of stems and comminuted fragments and in general lithologic character it closely resembles some parts of the overlying Lance formation. At still other localities within short distances either the upper sandstone or the lower one or sometimes both of them are found to thin or disappear as distinct beds, their places being taken by more shaly material. The whole formation gives ample evidence of irregular sedimentation in the presence of strong, variable currents.

The irregular character of the formation may be shown by describing a few local sections beginning on Grand River near the mouth of Dirt Lodge Creek about 20 miles southwest of McIntosh, South Dakota. On the south side of the river the following section is exposed:

Section on Grand River near the mouth of Dirt Lodge Creek.

	Feet
1. Hard gray sandstone with *Tancredia americana* and Halymenites	15
2. Banded shale with *Fasciolaria scarboroughi*, Thracia, Anchura, Scaphites, etc.	50
3. Hard gray sandstone with *Tancredia americana* and Halymenites	10
4. Soft yellowish massive sandstone	40
5. Dark clay shale referred to the Pierre, exposed	75

All except the basal member of the section belong to the Fox Hills.

The hard sandstones of Nos. 1 and 3 are merely local indurations which in some places are seen to pass horizontally into soft friable sandstone. Other exposures in the neighborhood especially on the north side of Grand River show that the upper sandstone, No. 1, is very near the top of the Fox Hills. About a mile northwest of the mouth of Dirt Lodge Creek and not more than two or three miles from the section just described the upper sandstone is represented by a few feet of sandy shale which pass upward into similar sandy shale about 4 feet thick, which is filled with brackish-water fossils including *Ostrea glabra* M. & H., *O. subtrigonalis* E. & S., *Anomia micronema* Meek, and *Corbicula subelliptica* var. *moreauensis* M. & H. Immediately above this brackish-water bed without any apparent stratigraphic break are shales, soft sandstones and carbonaceous beds, weathering into badlands, and locally containing abundant remains of Triceratops, Trachodon, turtles and other members of the Lance formation fauna.

About 3 miles east of the mouth of Dirt Lodge Creek in section 12, T. 20 N., R. 22 E., the oyster bed at the top of the Fox Hills is again exposed with the basal portion of the Lance formation above it. Vertebrate fossils of the types just mentioned are here abundant about 30 or 40 feet above the oyster bed.

A few miles farther east on Grand River near the mouth of Fire-steel Creek the contact of the oyster bed with the underlying sandstone shows an irregular surface suggesting an unconformity, but facts to be recorded on subsequent pages will show that the oyster bed actually belongs to the Fox Hills sandstone as proved by its fauna.

Another instructive section in T. 15 N., R. 18 E., on Thunder Butte Creek about 30 miles south of Grand River, is as follows:

Section on Thunder Butte Creek.

	Feet
1. Friable gray and yellow sandstone with many large indurated masses locally containing an oyster bed with an abundant brackish-water fauna mingled with many specimens of marine Fox Hills species (see list on p. 180). Some evidence of channeling and erosion at base of oyster bed	20
2. Banded shale and shaly sandstone	50
3. Dark, somewhat sandy, shale referred to the Pierre with *Avicula linguiformis* E. & S., *Mactra warrenana* M. & H., etc. Exposed	30

In this section the sandstone forms relatively a small part of the Fox Hills and the absence of a prominent lower bed makes the base of the formation uncertain. The fossils from the underlying shale so far as it is exposed belong to the Fox Hills fauna. The oyster bed in the upper member of the section at one point is a conspicuous indurated very fossiliferous bed fully fifteen feet thick, but it thins abruptly within a few yards to two feet or less, the variation being due to the irregularity of its base. In other exposures less than ¼ mile distant its position is only marked by scattering brackish-water shells. The Lance formation is seen in neighboring higher exposures.

The exposures a few miles farther south in T. 14 N., R. 19 E., on the south side of Moreau River show a section similar to that last described, but they give a better contact with the overlying Lance formation.

Section on south side of Moreau River.

	Feet
1. Soft sandstone, sandy shale, and carbonaceous shale in alternating beds a few feet thick, forming the base of the Lance formation. Fossil plants at the top and associated with Unio in the lower 4 feet (Lot 5423. See list below),	40
2. Soft friable cross-bedded gray sandstone irregularly stratified with bands of darker sandy shale. Large concretions or indurated masses near the base contain Fox Hills species of Scaphites associated with Corbicula (No. 5969. See list on p. 180). The Corbicula occurs in abundance to the top of the bed	30 to 40
3. Banded shale with a few marine Fox Hills fossils	60
4. Dark, somewhat sandy, shale referred to the Pierre but containing a Fox Hills fauna. Exposed	50

The fossil plants collected in the lower 4 feet of the Lance formation at this place have been examined by Dr. F. H. Knowlton, who refers them to the Fort Union and identifies the following species:

5423.
Thuya interrupta Newb.
Sequoia Nordenskiöldi Heer
Populus cuneata Newb.
Viburnum marginatum Lesq.
Sequoia acuminata?? Lesq.
Leguminosites? n. sp.
Cyperacites sp.
Monocotyledon—new

This list is given for the purpose of showing that the Fort Union flora ranges to the base of the Lance formation. All the other plant collections from this formation were likewise referred to the Fort Union.

The minimum thickness of sandstone in the Fox Hills of this region was seen in a section at Rattlesnake Butte near the northwest corner of T. 11 N., R. 19 E., about 15 miles south of Moreau River.

Section at Rattlesnake Butte, South Dakota.

	Feet
1. Hard gray sandstone with *Glyptostrobus Ungeri* Heer, *Taxodium occidentale* Newb., *Viburnum marginatum* Lesq., *Cornus Newberryi* Hollick, and other plants referred to the "lower Fort Union"	25
2. Clay shale	10
3. Carbonaceous shale	4
4. Clay shale with some carbonaceous bands	8
5. Carbonaceous shale	7
6. Soft, friable yellowish sandstone with large concretions or indurated masses in the upper part, forming top of Fox Hills	12
7. Banded shale with a few marine Fox Hills shells	90

This is the base of the local exposure, but in the neighborhood dark shale referred to Pierre is seen not many feet lower. The upper 5 members evidently belong to the Lance formation. No. 6 did not yield any fossils at this point, but on Mud Butte, about 5 miles south, the same horizon yielded the mixture of brackish-water and marine Fox Hills species listed as No. 5870 on p. 179.

It is evident from these sections that the Fox Hills sandstone is variable throughout its thickness. The lower part is no more constant than the upper. Its base is therefore indefinite, and it is by no means certain that the top of the dark shale necessarily taken as the top of the Pierre in the different sections represents exactly the same geologic horizon. The fauna of at least the upper 100 feet of Pierre shale is essentially a Fox Hills fauna, indicating shallow marine waters and differs very little from that of the overlying sandstone, while it lacks all the species which in other areas are especially characteristic of the Pierre.

The most common and characteristic species of this fauna in the Fox Hills sandstone and the upper part of the Pierre shale are as follows:

Avicula linguiformis E. & S.
Avicula nebrascana E. & S.
Cucullæa shumardi M. & H.
Limopsis striatopunctata E. & S.
Leda (Yoldia) evansi M. & H.
Nucula cancellata M. & H.
Nucula planimarginata M. & H.

Lucina occidentalis (Morton)
Tancredi americana M. & H.
Protocardia subquadrata E. & S.
Callista deweyi M. & H.
Tellina scitula M. & H.
Mactra warrenana M. & H.
Cuspidaria ventricosa (M. & H.)
Lunatia occidentalis M. & H.
Lunatia concinna H. & M.
Lunatia subcrassa M. & H.
Anchura (*Drepanochilus*) *americana* (E. & S.)
Pyropsis bairdi M. & H.
Fusciolaria (*Piestochilus*) *culbertsoni* M. & H.
Fasciolaria buccinoides M. & H.
Pyrifusus newberryi M. & H.
Fusus (*Serrifusus*) *dakotensis* M. & H.
Cylichna volvaria M. & H.
Haminea minor M. & H.
Cinulia concinna M. & H.
Sphenodiscus lenticularis (Owen)
Scaphites conradi (Morton)
Scaphites conradi var. *intermedius* Meek
Scaphites abyssinus (Morton)
Scaphites nicolleti (Morton)
Scaphites cheyennensis (Owen)

At some localities as on Grand River near Dirt Lodge Creek the sandstones are filled with *Tancredia americana* M. & H., with very few other species.

At the top of the Fox Hills sandstone with its purely marine fauna there is a rather thin but widely distributed brackish-water bed, already several times referred to, which contains Ostrea, Anomia, Corbicula, Melania, etc., in great abundance. The zone in which this fauna occurs varies in thickness from 3 or 4 feet up to 40 feet and is lithologically very similar to the underlying marine beds, but its base is irregular at many places and shows channeling and other evidence of erosion. It was therefore regarded by the field geologists as the basal member of the overlying Lance formation resting unconformably on the Fox Hills. In the study of this brackish-water bed evidence was found at several localities, distributed over a considerable area, that there is a distinct transition without a break of any importance between the marine Fox Hills sandstone and the brackish-water deposit. The paleontologic evidence consists of distinctive Fox Hills species belonging to such marine genera as Scaphites, Lunatia, and Tancredia, found directly associated in the same bed with the brackish-water forms and occurring with them in such a way that they must have lived together or near

each other and been imbedded at the same time. Such a mixture of faunas was found at five localities, as shown in the following lists. The marine Fox Hills species are marked with an *.

5870. Mud Butte, SW 1/4 Sec. 25, T. 11 N., R. 18 E., about 20 miles south of Moreau River.

Ostrea subtrigonalis E. & S.
Ostrea glabra M. & H.
Anomia micronema Meek
Modiola meeki (E. & S.) ?
Corbicula occidentalis M. & H.
Corbicula cytheriformis M. & H.
Corbicula subelliptica var. *moreauensis* M. & H.
Panopœa? sp.
* *Teredo* sp.
Neritina bruneri White
Neritina (*Velatella*) *baptista* White
Melania insculpta Meek var.
Melania wyomingensis Meek
Viviparus sp.
Melampus sp.
* *Scaphites conradi* (Morton)

The stratigraphic relations at this locality have been described in connection with the Rattlesnake Butte section on p. 177.

5871. Sec. 2, T. 11 N., R. 19 E., about 4 miles south of Moreau River.

Ostrea subtrigonalis E. & S.
Anomia micronema Meek
Corbicula subelliptica var. *moreauensis* M. & H.
* *Lunatia concinna* H. & M.

Mr. Barnett reports that the fossils were obtained from a small exposure of friable sandstone in which the fossiliferous band is two feet thick.

5938. SE 1/4 SW 1/4 Sec. 18, T. 17 N., R. 26 E.

Ostrea glabra M. & H.
Anomia sp.
Corbicula occidentalis M. & H.
* *Tancredia?* n. sp.
Melania insculpta Meek
* *Scaphites conradi* (Morton)

Mr. Barnett states that the fossiliferous bed is an indurated sandstone about 40 feet thick at the top of the Fox Hills.

5969. Sec. 27, T. 14 N., R. 19 E. South side of Moreau River, above Thunder Butte P. O.

Corbicula nebrascensis M. & H.
Melania insculpta Meek
* *Scaphites conradi* var. *intermedius* Meek
* *Scaphites cheyennensis* (Owen)

The section in which this collection was obtained is described on p. 176.

5975. North side of Thunder Butte Creek near south line Sec. 12, T. 15 N., R. 18 E.

Ostrea glabra M. & H.
Anomia micronema Meek
Corbicula occidentalis M. & H.
Corbicula cytheriformis M. & H.
Corbicula subelliptica var. *moreauensis* M. & H.
* *Tancredia americana* M. & H.
* *Tancredia?* n. sp.
* *Lunatia subcrassa* M. & H.?
Melampus sp.
Melania wyomingensis Meek
Melania insculpta Meek
* *Scaphites conradi* (Morton)

The section at this locality is described on p. 175.

The brackish-water species elsewhere are found in the Laramie and in the non-marine formations of the Montana group, but the marine forms, especially the ammonoids, which give the best evidence as to age, belong to the Fox Hills fauna. It is clear from these occurrences that there was no erosion interval of any geological importance between the marine Fox Hills and the overlying brackish-water bed, and that the latter belongs to the Fox Hills epoch of sedimentation.

Above the brackish-water horizon is the fresh-water Lance formation consisting of soft sandstones, shales, thin coals and carbonaceous shales, retaining the same general character through 500 or 600 feet of strata. The flora from these beds, ranging from the bottom to the top, is referred by Dr. Knowlton to the Fort Union. Vertebrate fossils are common, especially in the lower 100 feet and ranging down to the base. These include the dinosaurs Triceratops and Trachodon with several other genera that are characteristic of the Lance formation fauna elsewhere.

The history of the epoch immediately following the Fox Hills sedimentation in this region has received two very different interpretations. One is the view here presented, that without any unrepresented interval of importance there was gradual transition from marine conditions through brackish-waters to the land and fresh-water conditions that generally prevailed during the deposition of the Lance formation. The other

adopts the current interpretation of the evidence from fossil plants which refers the Lance formation to the Fort Union formation, assigned to the Eocene, and requires a period between the close of the Fox Hills and the beginning of the Lance formation long enough to represent the Laramie, Arapahoe, and Denver formations of the Denver Basin, together with the long intervals of erosion which preceded the Arapahoe and the Denver, and another interval supposed to be between the Denver and the Fort Union. It has been asserted that the erosion preceding Arapahoe deposition cut down through 14,000 feet of stratified rocks in the Denver area. It is worthy of note that there are no Fort Union rocks or floras known in the Denver Basin and no plant-bearing formations older than the Lance formation in the area now under discussion.

Early in their field work last summer the geologists had determined that the Lance formation immediately overlies the Fox Hills, and had received reports that the plants from near their base belong to the Fort Union flora. Special search was therefore made for physical evidence of the unconformity and hiatus which the facts seemed to demand. The only horizon at which a somewhat generally distributed break was suggested is at the irregular base of the brackish-water bed, and this irregular surface was therefore tentatively taken as the base of the Lance formation on the supposition that it indicated a hiatus in the sedimentary record equivalent to the Laramie and post-Laramie formations of the Denver Basin. That there was no such break in the record at this horizon is definitely proved by the occurrence of ammonoids and other fossils characteristic of the marine Fox Hills in the brackish-water bed as already described. The brackish-water fossils in themselves give evidence of their Cretaceous age. In the first place, almost all of them belong to species that in other areas occur in unquestioned Cretaceous formations. Secondly, brackish waters with such a fauna as the one in question must have had connection with the sea and no connection with Tertiary seas is probable. Marine waters retreated from the region of the Rocky Mountains and Great Plains at or just before the close of the Cretaceous, and there is no evidence that the sea has approached the region since that time. The nearest marine deposits of Eocene or later age are in the lower Mississippi valley and in the Gulf coastal plain of Texas. This fact gives special importance to the occurrence of an oyster bed 500 feet above the base of the Lance formation on the Little Missouri River, North Dakota, which will be described on a subsequent page.

It may be suggested that there is a stratigraphic break between the brackish-water and fresh-water horizons, but no

evidence of such a break has been found there. It is true that at various levels throughout the Lance formation there is evidence of current action and irregular deposition shown in cross-bedding, varying thickness and uneven surfaces of sandstones, and similar phenomena. Such features are characteristic of continental deposits, and have little weight as evidence of important unconformities unless supported by other lines of evidence. In this case all the irregularities observed seem to be of purely local character.

Valley of the Little Missouri from Marmarth to Yule, North Dakota.

In the southwest corner of North Dakota, near the town of Marmarth on the Chicago, Milwaukee & Puget Sound Railway, the valley of the Little Missouri cuts down through the Lance formation and the Fox Hills into the Pierre, and shows a section comparable with those in the Indian reservations which we have been discussing. The area has been described by Prof. A. G. Leonard,* and my observations added little to the facts he has recorded.

The Pierre shale is exposed on Little Beaver Creek, about 5 miles southwest of Marmarth, and yields a typical Pierre fauna with less admixture of Fox Hills species than is found in the top of the Pierre in the reservations.

Immediately above the Pierre shale is banded shale with a thickness of about 40 feet overlain by 40 feet of soft massive sandstone, yellow with iron-stained bands and concretions below, grading up into gray sandstone above. This sandstone yielded a few marine fossils, including *Leda* (*Yoldia*) *evansi*, *Tellina scitula*, *Entalis? paupercula* and *Halymenites major*, which confirm Leonard's reference of the sandstone to the Fox Hills. In several bluff exposures along the creek the top of the gray sandstone shows an uneven eroded surface which Professor Leonard has photographed and described† as an unconformity in the following words: "It is well shown at two points on Little Beaver Creek in section 7, T. 132 N., R. 106 W. Here the massive sandstone forming the top of the Fox Hills is seen to have undergone erosion before the deposition of the brown and black highly carbonaceous and argillaceous sandstone, which shows cross-limitation in places. Some of the depressions of the former land surface have been eroded to a depth of 6 feet below the adjoining elevations." Immediately above this eroded surface is the Lance formation, which Professor Leonard has described as "somber beds" and "lower Fort Union," with an estimated thickness of about 600 feet extending northward down the river 15 or 20 miles to the

* 5th Bienn. Rept. N. Dak. Geol. Surv., 1908, pp. 29–114.
† Op. cit., pl. v, p. 72.

neighborhood of Yule P. O. There is a very slight northward dip. Beds of carbonaceous shale and impure lignites are distributed throughout the formation beginning with the basal stratum, and in the upper half, according to Leonard, there are 5 or 6 workable coal beds. Dinosaur remains, including Triceratops and Trachodon, are not uncommon in the lower part, especially in the badlands near the mouth of Bacon Creek, a mile northeast of Marmarth. The formation is in every particular similar to the equivalent Lance formation in the Cheyenne River and Standing Rock reservations.

Irregular deposition and erosion with deep channeling are strikingly exhibited at several localities and on different horizons. One example of erosion which is worthy of description in a separate article is clearly shown in a cut bank by the side of the railroad yard at Marmarth, probably less than 100 feet above the base of the Lance formation. A bed of carbonaceous shale with an average thickness of 20 feet is exposed to its full length of 250 feet. Both the top and the bottom surfaces are irregular as if eroded, and the underlying sandstone and the argillaceous bands in the bed are filled with vertical roots of plants. One end of the bed fingers out into cross-bedded sand while the other end is abruptly truncated and abuts against a friable, cross-bedded yellowish gray sandstone similar to and continuous with the sand that overlies the carbonaceous bed. Here is evidence of erosion at the base of the carbonaceous bed apparently as great as that at the base of the whole formation, and of still greater erosion at the top of the same bed.

It will be noticed that in this area there is no brackish-water bed at the top of the Fox Hills. Instead the change is abrupt from marine to land or fresh-water deposits, but there is evidence that marine or at least brackish-water conditions continued in a neighboring area for some time after non-marine deposition began. Professor Leonard reported the finding of an oyster bed in the upper part of the "somber beds" about five miles southwest of Yule in sect. 16, T. 135 N., R. 105 W., which is only about 15 miles north of Marmarth. The locality was visited last summer and the oysters were found associated with a coal (apparently bed F of Leonard's section*) about 175 feet above the river level and according to Leonard's estimates approximately 500 feet above the base of the Lance formation and certainly above all the dinosaurs that have been found in the region. The abundant oysters referable to *Ostrea subtrigonalis* and *Ostrea glabra* lie a few feet above the coal in a carbonaceous shale. In some places the shells form a nearly solid band 6 inches thick, and they are distributed in thin bands and scattered individuals through 7 feet of shale. Such

* 5th Bienn. Rept. N. Dak. Geol. Surv., 1908, p. 78.

an oyster bed must have been formed in tidal waters connected with the sea, and its presence here argues strongly for the assumption that the underlying portion of the Lance formation was formed near sea level so that a slight downward movement permitted local temporary admission of brackish water into the low lying swamps and marshes in which coal was forming. It is, therefore, most probable that the abrupt change from marine to fresh-water and land conditions seen near Marmarth is purely local, and that the eroded surface at the top of the Fox Hills does not represent a time interval of any geologic importance.

Lance Creek Area, Converse County, Wyoming.

This well-known area has been described by Hatcher* and by Stanton and Knowlton,† and has recently been further discussed by Knowlton‡ and Stanton.§ In the examination of last summer special attention was given to the Fox Hills sandstone and its relation with the basal portion of the Lance formation. Our principal contribution to the knowledge of the stratigraphy of the area was the discovery that the marine Fox Hills deposits extend about 400 feet higher than had previously been determined, and that non-marine coal-forming conditions were temporarily inaugurated here before the close of Fox Hills time.

The first section examined is on the south side of Cheyenne River at the mouth of Lance Creek, and extending up the creek a mile and a half or two miles. Beginning at the top of a prominent white sandstone the section is as follows:

	Feet
1. White cross-bedded sandstone with irregular brown indurated bands, masses, and concretions	50
2. Soft sandy shale with bands of lignitic shale. Fragments of dinosaur bone were found on the surface here	50
3. Sandy shale full of *Corbicula cytheriformis?* and *Corbicula subelliptica* var. *moreauensis*	1/2–1
4. More or less carbonaceous shale	15
5. Soft massive gray sandstone with many brown concretions	25
6. Gray sandstone and sandy shale with bands of sandstone containing Fox Hills fossils, about	150
7. Cross-bedded, ripple marked, reddish brown sandstone with irregular base	8 to 10
8. Massive soft buff sandstone with many large concretions and indurated masses and an abundant Fox Hills fauna	100
9. Pierre shale with only the top exposed	

* This Journal (3), vol. xlv, pp. 135–144, 1893. Am. Naturalist, vol. xxx, pp. 112–120, 1896. † Bull. Geol. Soc. Am., vol. viii, pp. 128–137, 1897.
‡ Proc. Washington Acad. Sci., vol. xi, pp. 179–238, 1909.
§ Ibid., pp. 239–293.

The following is the list of fossils collected in No. 8 of this section:

Avicula fibrosa M. & H.
Leda (*Yoldia*) sp.
Sphæriola? cordata M. & H.
Veniella humilis M. & H.
Protocardia subquadrata E. & S.
Linearia? formosa M. & H.
Tellina scitula M. & H.
Cuspidaria moreauensis (M. & H.)
Entalis paupercula M. & H.?
Lunatia occidentalis M. & H.
Anchura sp.
Fasciolaria (*Piestochilus*) *culbertsoni* M. & H.
Haminea sp.
Sphenodiscus lenticularis (Owen)
Scaphites conradi (Morton)
Scaphites conradi var. *intermedius* Meek.
Scaphites abyssinus (Morton).

No. 6 yielded the following:

Nucula planimarginata M. & H.
Avicula fibrosa M. & H.
Cardium speciosum M. & H.
Mactra warrenana M. & H.

When studying the section it was believed that the upper four members belong to the Lance formation, but afterward when comparison was made with sections at the south end of the field it seemed more probable that all the beds examined here belong to the Fox Hills. The higher unquestioned Lance formation was not studied at this place.

Two sections, which have been described by Stanton and Knowlton, were studied at the south end of the area, about 30 miles southwest of the mouth of Lance Creek. One of these lies about 2 miles east of Lance Creek, nearly opposite the mouth of Little Lightning Creek, and shows excellent exposures of Pierre, Fox Hills, and the lower part of the Lance formation, all dipping northward 14° to 19°. No attempt was made to obtain a detailed section of the Lance formation, but a measurement across the strike as far as the strata have steep dips shows a thickness of about 1700 feet above the upper white sandstone, which was later determined to be the top of the Fox Hills. To this should be added perhaps 400 or 500 feet for the thickness of the nearly horizontal upper strata of the Lance formation. The lowest point at which dinosaur bones were seen is about 300 feet above the top of the Fox Hills.

The lower part of the section is as follows:

Section on divide between Lightning and Buck Creeks.

	Feet
1. Gray sandstone	10
2. Shale	25
3. Sandstone and shale	20
4. Shale and coal	15
5. Shale with brackish-water fauna	20
Top of Fox Hills.	
6. Massive white sandstone with brown concretions	40
7. Shaly sandstone	5
8. Coal and carbonaceous shale	15
9. Massive white sandstone	60
10. Shale	8
11. Sandstone	10
12. Shale	5
13. Massive white sandstone	100
14. Brownish gray sandstone in alternations of massive and more thinly bedded	130
15. Gray sandstone	30
16. Brown sandstone	20
17. Yellowish sandstone with Fox Hills fauna	30
18. Pierre shale	

The last section examined and perhaps the best exposed and most instructive of all is on Johnson Brothers' ranch, near Buck Creek, about 8 miles east of the section just described. Beginning with the lowest strata of the Lance formation the section follows:

Section on Buck Creek.

	Feet
1. Sandy shale with thin beds of coal	25
Top of Fox Hills.	
2. Massive white sandstone with *Halymenites major*	60
3. Yellowish massive sandstone with brown concretions	20
4. More thinly bedded brown sandstone with *Halymenites*	25
5. Massive white sandstone	75
6. Soft somewhat sandy shales with thin sandstone bands containing marine Fox Hills shells	30
7. Brown shaly sandstone	5
8. Massive white sandstone	60
9. Thin-bedded brown and gray sandstone	130
10. Yellowish massive sandstone with concretions containing Fox Hills fauna	100
11. Pierre shale	

The list of fossils from No. 6 is as follows:

Avicula nebrascana E. & S.
Avicula fibrosa M. & H.
Leda? sp.
Nucula planimarginata M. & H.
Tellina scitula M. & H.
Lamna? sp.

The occurrence of these fossils in No. 6 and of *Halymenites* at higher horizons shows that the strata to the top of the white sandstones are mainly marine and belong to the Fox Hills. In previous descriptions, only No. 10 was referred to the Fox Hills and the age of the overlying 400 feet of sandstones was left doubtful.

In the Lance Creek area the evidence for a gradual transition from the marine Fox Hills into the Lance formation is found in the occurrence of a brackish-water bed at the top of the marine strata, in the presence of coal beds and other evidence of alternating land and marine conditions before the close of the Fox Hills, and in the absence of any indication of an important unconformity anywhere in the section.

As compared with sections in the other areas here discussed the most striking feature of the Converse County sections is the much greater thickness of the Fox Hills sandstone and of the Lance formation. The average thickness of the Fox Hills sandstone in the South Dakota sections described is little more than 100 feet and it is still less at Marmarth, North Dakota, while in Converse County it is 400 to 500 feet, making the ratio about 1 to 4. The Lance formation shows about the same ratio of increase and the marine Cretaceous formations beneath the Fox Hills are also known to be much thicker in Converse County. Farther south in Colorado these marine formations, including the Fox Hills, show a still greater increase in thickness. It is therefore reasonable to attribute the variation in the thickness of the Fox Hills to variation in the rate of sedimentation due to varying distances from the source of supply and perhaps to variation in the height of the neighboring lands. That the varying thickness is not due to erosion from the top is proved in the case of some of the thinnest sections by the presence of the brackish-water beds at the top showing the final stage in marine sedimentation.

The three areas discussed in this paper taken together tell a story of gradually changing conditions near the end of the Cretaceous when the uplift of the Rocky Mountain region was draining the interior sea. The uplift was not uniform nor continuous and the emergence above sea level could not have been simultaneous for all localities throughout the region. As

the sea became shallow the effect of tidal currents and wave action was shown in irregular deposition, cross-bedding and local erosion, and when an area was elevated above tide the deposits formed were subjected to all the varying conditions of flood plains, deltas and marshes. It would depend on the configuration of the coast, the topography and drainage of the adjacent land and the rate of elevation whether at any particular locality the last marine bed would be covered by a brackish-water deposit or followed immediately by land conditions. With such a history it is not surprising that the Fox Hills sandstone varies considerably in thickness and shows somewhat varying relations with the overlying formation.

The bearing which the facts here presented have on the Laramie problem is self-evident. If it is true that there is a transition with practically continuous sedimentation from the Fox Hills sandstone into the Lance formation in the region discussed, then the Lance formation includes or forms part of the Laramie.