

ART. IV.—*Rhinocerotidae of the Lower Miocene* by FREDERIC B. LOOMIS.

FORMERLY the Lower Miocene beds of America were considered by vertebrate palæontologists to be practically barren of vertebrate fossils; but three years ago Mr. Peterson opened in them the Agate Spring quarries from which have been taken literally hundreds of skulls and disassociated skeletons, among which two species of rhinoceros of the hitherto rare genus *Diceratherium* are far the most abundant. In the "breaks" of the neighboring hills scattered remains have also been found, and it was the fortune of the Amherst '96 expedition, during the summer of 1907, to find a small pocket of rhinoceros bones some 300 yards north of the above mentioned quarries. These latter remains are remarkable in that they represent seven different rhinocerine species all buried together. Four of the species are new and as they represent some unexpected phases, they are not only described, but a broad study of the whole group in the Lower Miocene is here undertaken. While with the three new species added in this paper, thirteen species of *Diceratherium* are now known, the genus has never been carefully studied, partly because the early species assigned to it were never figured and were with difficulty accessible. For this paper the Yale Museum has allowed the study of the Marsh material and the figuring of his types, which were but briefly characterized. The following paragraphs will therefore consider the genus *Diceratherium*, as to its characteristics, distribution and the systematic relations of its species. The *Aceratheria* of the Lower Miocene will also be described, as the genus has not previously been found in the American strata later than the Oligocene.

The genus *Diceratherium* was established in 1875 by Marsh for the species *D. armatum*,* its distinctive feature being the presence of a pair of horn cores on the nasal bones. While the animal was rather long-limbed and light built, as the skeletal material is mostly disassociated no attempt will here be made to discuss this part of the skeleton. The teeth vary considerably, the

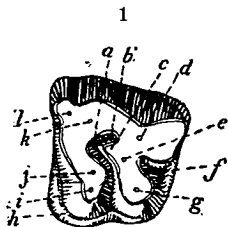


FIG. 1. *Diceratherium niobrarense* P.; second upper molar, one-half nat. size. Key to terminology: a, pre-fossette; b, med. fossette; c, crochet; d, metacone; e, metaconute; f, postfossette; g, hypocone; h, cingulum; i, protocone; j, protoconute; k, paracone; l, narastyle.

* This Journal, vol. ix, p. 242, 1875.

earlier forms from the John Day beds showing but little complication; but with the advance of time the crochet and crista develop, and increase progressively until they meet and isolate the median fossette. The premolars of any jaw grade in their characters unto the molars, but there is a tendency for the premolar to attain any feature earlier than the molar. The upper canine is wanting but that of the lower jaw is moderately developed, having a triangular cross section. The incisors are reduced to $\frac{1}{4}$, the upper one being elongated and oval in section as in *Aceratherium*, while the lower incisor is a mere button-like rudiment. The first lower premolar is usually wanting; so that the generic dental formula is $\frac{1}{1} \frac{0}{1} \frac{4}{3} \frac{3}{3}$.

It is in the John Day beds of Oregon that the first Diceratheres are found, full fledged as to the nasal horn cores; but, were only the dental series of such a form as *D. armatum* considered, the simple cross ridges and well developed cingulum, would proclaim it an Acerathere. On the other side the species *Aceratherium tridactylum* from the Protoceras beds has a pair of low roughened bosses on either nasal bone seeming to indicate incipient horns. This species was considered by Hatcher* as already a Dicerathere, but Osborn places it among the Aceratheres, where the writer would leave it, as the form still has the second upper incisor and the more dolicocephalic type of skull which characterizes the Aceratheres. However, it is, as Osborn indicates, closely related and probably ancestral to the Diceratheres, the White River Aceratheria being the stock from which the genus *Diceratherium* arose. The John Day species (especially *D. armatum*) are very Acerathere-like, in the strong development of the cingulum and the absence or weak development of the crochet and crista. The European species are likewise among the less specialized members of the genus; but they are differentiated by the strongly projecting protoconule fold, which has sometimes been described as an "antecrochet." It seems to the writer simply an enlargement of the protoconule region, and is characteristic of both *D. minutum* (= *crozieri*) and *D. douvillei*, and also of the American species *D. hesperium*; so that these three species make a convenient and related sub-group. The later American forms from the Lower Harrison beds all have crochet well developed, *D. niobrarense* being the simplest of them, and having an aspect very suggestive of the John Day phase. The other species have a crista, which the crochet tends to meet. On the wall of the crochet away from the median fossette are often tiny ridges which give the enamel a characteristic wavy appearance. The latest species known is *D. oregonensis*, in which the crochet and crista are broadly united.

* Amer. Geologist, vol. xx, p. 313. 1897.

During Oligocene times the country west of the Great Lakes and either side of the Canadian line seems to have been teeming with *Aceratheres*, abundant in numbers and varying in characteristics. At the end of the Oligocene all but a remnant of this rich fauna disappeared, its descendants in Europe still flourishing while but a handful still held on in America, as will be shown later. Why the disappearance is unknown. Directly succeeding these *Aceratheres*, it now appears that the *Diceratheres* flourished, apparently as rich in numbers and in species. While longer limbed and somewhat shorter headed, the dentition forbids any thought that these were open country creatures. There are no nibbling teeth and the backs of the canines are worn as when branches are stripped of leaves by drawing them through the mouth. The grinders are also those of a browser. Spreading westward and northward, these *Diceratheres* crossed the Berings isthmus and reached Germany and France, there to become in a short time extinct. In America they multiplied in Lower Miocene times, and in the Harrison period no less than five* species were ranging over Nebraska and Wyoming. In their turn the *Diceratheres* as mysteriously wane and die out, the last one known being only indicated by a single tooth from the Upper Miocene of Oregon.

Throughout the genus, the size and shape of the nasal horns vary in any species with the age and sex of the individual. Variation is also characteristic in the weight and stockiness of the skull as a whole. In all features there is that tendency to fluctuation which is found in a young and developing group, the different species representing apparently points in evolutionary lines: Some of the species can be gathered into sub-groups on common features which represent common descent, but there are still many gaps to be filled before a perfect case of adaptive radiation will be illustrated. The characters which have proven most satisfactory for establishing species are, after size and contour of the skull has been considered in a general way, the pattern of the premolar and molar teeth.

In the following descriptions the Osborn nomenclature has been used, a key to which is given in fig. 1, p. 51. The figures are all one-half natural size except fig. 10. Further measurements are given in the table at the end of the descriptions of the genus *Diceratherium*.

Diceratherium armatum Marsh.

This Journal, vol. ix, p. 242, 1875.

The type is No. 10,003 in the Yale Museum, a complete skull somewhat crushed dorso-ventrally, from "near John Day River in Eastern Oregon."

* Probably as many more will turn up within a few years, judging from the variation of toe bones and other of the less characteristic features.

Thus, the largest species of the *Diceratheres* is characterized by the simplicity of the dental pattern, the crista and the crochet being absent on the second and third molars, and only the crochet faintly indicated on the first molar. The premolars are without the crochet but have the crista incipient. Around the premolars the cingulum is well developed along the front,

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FIG. 2. *Diceratherium armatum* M. ; premolars and molars of type specimen, one-half nat. size.

back and internal face of the tooth ; but in the first molar it is interrupted opposite the protocone and hypocone.

As noted above, in the simplicity of the dental pattern and in the development of the cingulum, *D. armatum* shows a strong affinity to such *Aceratheres* as *A. tridactylum* and *A. occidentale*.

Diceratherium annectens Marsh.

This Journal, vol. v, p. 4, 1873.

The type is No. 10,001 of the Yale Museum from the "John Day valley, Oregon." The type is composed of the incisor, first and third premolars, and the first and second molars, of



FIG. 3. *Diceratherium annectens* M. ; third premolar, first and second molar of type specimen, one-half nat. size.

the upper right jaw, apparently all belonging to one individual. Of these the second molar is marked "type," but the others are included in the description.

This small species is readily distinguished by the fact that on the molars the protoconule and the hypocone are so closely

placed that on a partly worn tooth they actually join and the intervening valley between the protoloph and the metaloph is interrupted. The crochet is only incipient; and the crista, while wide, is not prominent. The cingulum is well developed in front and behind, but internally is wanting except for a trace between the protocone and hypocone.

Diceratherium nanum Marsh.

This Journal, vol. ix, p. 243, 1875.

The type is No. 10,004 in the Yale Museum from the John Day River in eastern Oregon. The specimen is the front of a skull including the upper and lower incisors, the lower canines and the first three upper and lower premolars; all however worn to the roots, so that the dental pattern is obliterated, and the only available character is size. In this it agrees closely with *D. annectens*.

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FIG. 4. *Diceratherium nanum* M.; incisor and first three upper premolars of the type, one-half nat. size.

Diceratherium hesperium Leidy.

Proc. Acad. Nat. Sci., Phila., p. 176, 1865.

The type in this case is a lower molar from the John Day of Oregon. Later to this, Leidy assigned some further fragmentary material, in which was a third upper molar, which is so far the only distinctive specimen. The lower molar used as type is intermediate between *D. armatum* and *D. annectens*, and while it will never be certain that the assigned specimens are the same species, there seems to be a distinct species of this size, which they may well typify. The features of the third upper molar* are that the protoconule and the metacone are much swollen, and there is a small tubercle in the valley between the protocone and the hypocone.

Diceratherium pacificum Leidy.

Proc. Acad. Nat. Sci., Phila., p. 248, 1871.

This type is again fragmentary material from the John Day of Oregon. Here the first molar tooth described is a second upper molar from the right side, which indicates a well marked

* See Rep. U. S. Geol. Surv. Terri., vol. i, pl. ii, fig. 8.

species, characterized by the presence of two moderate crochets, and two strong cristæ. The cingulum is well developed both in front and along the internal face of the tooth.

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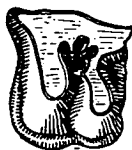


FIG. 5. *Diceratherium hesperium*; after Leidy, one-half nat. size.

FIG. 6. *Diceratherium pacificum* L.; the second upper molar, after Leidy, one-half nat. size.

The writer will be surprised if the second tooth assigned to this species by Leidy* does not prove to belong to some as yet undescribed species. The entire lack of crista and crochet would debar it from belonging to this species.

Diceratherium niobrarense Peterson.

Science, vol. xxiv, p. 281, 1906.

Type is No. 1,271 in the Carnegie Museum, a nearly perfect skull from the Lower Harrison beds of Agate Spring Quarry, Sioux Co., Nebraska.

The species is characterized by moderate size, the skull being relatively narrow and high, with a comparatively small brain case. The occipital crest is high, and joined by a strong sagittal crest formed by the union of the ridges from over the orbits. The nasal bones project considerably beyond the horn cores: the orbit is large; and the wide zygomatic arches are heavy. Of the teeth the premolars have preserved the cingulum intact along the inner face, and are without either crochet or crista. The molars are in like manner primitive, having the internal cingulum only slightly interrupted opposite the hypocone, while the crista is wanting and the crochet quite moderate in development. As noted by Peterson, the species resembles *D. armatum* of the John Day and is probably a direct derivative of that form, having advanced in the moderate development of the crochet and in the skull becoming narrower and higher. In size it is about $\frac{4}{5}$ as large as *D. armatum*. See fig. 1 on page 51, and for further figures see Peterson.†

* See Rep. U. S. Geol. Surv. Terri., vol. 1, pl. ii, fig. 7.

† Ann. Carnegie Museum, vol. iv, p. 46, 1906.

Type is No. 1,583 in the Amherst College Museum, being the first and second upper molars, found in the Lower Harrison beds, 300 yards north of Agate Spring Quarry, Sioux Co., Nebraska. Named for Mr. O. A. Peterson, who has made the Lower Harrison fauna, especially the *Diceratheres*, famous.

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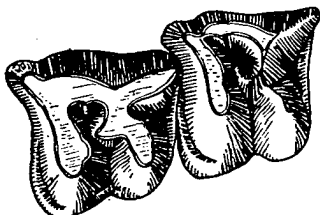


FIG. 7. *Diceratherium petersoni*; first and second molars (type specimen), one-half nat. size.

The species is the largest of those from the Lower Harrison and closely approximates *D. armatum* in size. The anterior cingulum is reduced and the internal one absent except for a trace between the protocone and the hypocone on the first molar. The crochet is strongly developed but not united to the distinct, though small, crista. In specialization this species is intermediate between *D. niobrarense* and *D. schiffi*.

While no skull was found, numerous scattered teeth were collected.

Diceratherium schiffi sp. nov.

Type is No. 1,042 in the Amherst College Museum, being an incomplete skull, including the right upper premolar and molar dentition together with the entire brain case, from the Lower Harrison beds, 300 yards north of Agate Spring Quarry, Sioux Co., Nebraska. The species is named to honor Mr. M. L. Schiff, one of the supporters of the expedition on which the type was found.

The species is the smallest and most specialized of the genus so far found. The low flat skull has an unusually wide brain case. The occipital crest is low and the ridges from over the orbits fail to unite in a sagittal crest, but remaining wide apart in both young and old individuals, cause the flat dorsal surface between the orbits to extend back to the rear of the skull. The orbit is large, and the zygomatic arch moderate both in weight and width. On the premolars the internal cingulum is

incomplete. The crochet and crista are united, thus isolating the median fossette, and on the outer face of the crochet wall are tiny ridges which gave a crenulated appearance to the enamel wall when worn. On the molars the anterior cingulum is weak, the internal one wanting, and that on the posterior border is raised. While the crochet is large, it does not unite

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FIG. 8. *Diceratherium schiffi*; left upper premolar and molar series of the type; one-half nat. size.

with the moderate crista. The species has affinities with *D. cooki*; but is smaller and of lighter build; has a wide flat skull in contrast to the high and narrower one of *D. cooki*. It has also the crista better developed.

In the experience of the Amherst part this was the commonest species, there being in the collection three incomplete skulls and several jaws.

Diceratherium cooki Peterson.

Science, vol. xxiv, p. 281, 1906.

The type of the species is a skull in the Carnegie Museum, from the Lower Harrison beds of the Agate Spring Quarry, Sioux Co., Nebraska.

The heavily built skull is relatively short and high, with a high occipital crest and a moderate sagittal crest formed by the confluence of the two ridges from over the orbits. The orbit is small, and narrow zygomatic arch of moderate weight. The nasal bones do not project in front of the horn cores, but end abruptly, giving the skull a very characteristic appearance. On the premolars, the cingulum is greatly reduced; while the strong crochet unites with the feeble crista, thus isolating the median fossette. In like manner on the molars, the cingulum is reduced to traces on the front, inner side, and rear of the teeth. The crochet is very large and the crista weak, but the two do not unite.

As noted above, this species resembles in dentition *D. schiffi*, but has a shorter and higher skull, with a sagittal ridge, where the latter has a broad flat area. The crochet is larger and the crista weaker than in *D. schiffi*.

Diceratherium aberrans sp. nov.

Type No. 1,321 in the Amherst College Museum, a single tooth, being either the first or second upper right-hand molar, from the Lower Harrison beds near Agate Spring Quarry, Sioux Co., Nebraska. While a single tooth is undesirable for a type, this is so aberrant and specialized that the writer feels bound to call attention to it.



FIG. 9. *Diceratherium cooki* P. ; a second upper molar, one-half nat. size.
FIG. 10. *Diceratherium aberrans* ; type specimen, nat. size.

The small tooth is considerably longer than wide, which is unusual among the *Diceratheres*. Its cingulum appears as remnants along the front and inner faces. The striking feature, however, is the development of the crista until it almost equals in length the proto-loph, having on its anterior side a strong crochet-like process. In like manner the crochet is developed to enormous size, and extends to the crista though it does not unite with it. The great development of these two usually moderate processes spreads the proto-loph and meta-loph wide apart, causing the considerable lengthening of the tooth.

Diceratherium minutum Cuvier = *D. Croizeti* Pomel.

See Osborn, Bull. Amer. Museum Nat. Hist., vol. xiii, p. 237, 1900.

This form from France and Germany is one of the simpler types of the genus, and occurs in the Upper Oligocene apparently equivalent to the John Day. On both molars and pre-molars the internal cingulum is greatly reduced, and the crochet is but little developed, while on only unworn teeth can any crista be detected. The region of the protoconule is much swollen, making a fold which is very characteristic of the European forms and has been termed an "antecrochet," though the writer cannot feel that it is the true one.

Diceratherium douvillei Osborn.

Bull. Amer. Museum Nat. Hist., vol. xiii, p. 239, 1900.

A second European species from the Lower Miocene (Burdigalian) of France. It is differentiated by Osborn by its size,

the well-developed crochet, no crista, and a large "antecrochet," this being as above the swollen protoconule fold. This and the foregoing species are closely related to each other and represent the European invasion of these American Dicera-

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FIG. 11. *Diceratherium minutum*; second molar, after Cuvier, one-half nat. size.

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FIG. 12. *Diceratherium douvillei*; second molar, after Osborn.

theres. The two species with their swollen protoconule folds show also relationship to the little known *D. hesperium*.

Diceratherium oregonense Marsh.

This Journal, vol. v, p. 5, 1873.

The type is a broken molar tooth from the Loup Fork of Oregon. This very much worn tooth shows the continuation of the features of *D. schiffi* and *D. cooki*, the crochet having united with the crista and thus isolated the median fossette. The internal cingulum is well developed. This is the latest known Diceratheres, and in all probability the genus became extinct during early Loup Fork times.

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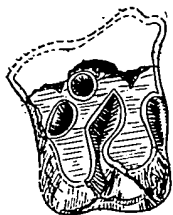


FIG. 13. *Diceratherium oregonense*; type specimen, being probably molar 2, one-half nat. size.

Beside the rich fauna of Diceratheres, two Aceratheres have been found within the past year in these Lower Harrison beds; a matter of considerable interest, as it has heretofore seemed that except for the species of Aceratherium which migrated to Asia and Europe, the genus had died out in America. It now appears, however, that a few forms maintained themselves in this country at least as late as the Lower Miocene. The two species show but slight modification from their Oligocene progenitors, as will be seen from the following descriptions and figures.

Aceratherium stigeri sp. nov.

Type is No. 1,040 in the Amherst College Museum, a skull lacking only a part of the occipital crest and the premaxillae,

from the Lower Harrison beds, 300 yards north of Agate Spring Quarry, Sioux Co., Nebraska. The specific name is given to honor Mr. W. D. Stiger, an earnest promoter of the expedition on which the type was found.



FIG. 14. *Aceratherium stigeri*; the premolar and molar series of the type specimen, one-half nat. size.

The small skull is elongated, light in build, and rather narrow. The orbit is large and the zygomatic arch light. The premolar teeth are crowded, there being neither an anterior or posterior cingulum, though one is developed along the inner face around the protocone, running out on the hypocone. Crista and crochet are wanting on these teeth of a rather old individual, except that on the fourth premolar there is a faint trace of a crista, and on the third premolar a small antecrochet is developed. On the molars the cingulum is reduced as in the premolars; and both crochet and crista are wanting. The protoconule, however, is swollen, making a considerable fold as in European *Diceratheres*. *A. stigeri* is closely related to *A. egrerius*, but is smaller and has the cingulum on the premolars and the crochet on the molars less developed.

Measurements.

Total length of the skull	about 345 ^{mm}
Width between the orbits	117 ^{mm}
Length of the premolar-molar series	168 ^{mm}
Length of second molar tooth	29 ^{mm}
Width of second molar tooth	37 ^{mm}

Aceratherium egrerius Cook.

Science, N. S., vol. xxvii, p. 256.

Type a skull and lower jaws in the private collection of Mr. Harold Cook, from the Lower Harrison beds, at Agate, Sioux Co., Nebraska.

This larger species has an elongate skull, of moderately light build, the facial portion being unusually elongated; so that the

CHART OF THE SPECIES OF DICERATHERIUM

Name	Age	Length of skull	Breadth* of skull	Height† of skull	Length & breadth of molar‡	Premolar characters	Molar characters	Remarks
<i>D. armatum</i> . . .	John Day	557 ^{mm}	230 ^{mm}		50 × 58 ^{mm}	Internal cingulum complete No crochet No crista	Internal cingulum incomplete Crochet incipient No crista	
<i>D. annexens</i> . . .	John Day				28 × 36	Internal cingulum a mere trace Crochet incipient No crista	Internal cingulum a mere trace Crochet incipient Crista weak	Protoconule and hypocone very close
<i>D. hesperium</i> . . .	John Day						Internal cingulum complete Crochet? No crista	Protoconule and metacone swollen
<i>D. pacificum</i> . . .	John Day				33 × 40		Internal cingulum complete 2 crochets 2 cristae	
<i>D. niobrarense</i> . . .	L. Harrison	458	168	150 ^{mm}	40 × 45	Internal cingulum complete No crochet No crista	Internal cingulum nearly complete Crochet moderate No crista	
<i>D. petersoni</i> . . .	L. Harrison				45 × 48		Internal cingulum a mere trace Crochet strong Crista weak	

CHART OF THE SPECIES OF DICERATHERIUM—CONTINUED

Name	Age	Length of skull	Breadth* of skull	Height† of skull	Length & breadth of molar 2	Premolar characters	Molar characters	Remarks
<i>D. schiffi</i>	L. Harrison		182 ^{mm}	125 ^{mm}	30 × 38 ^{mm}	Internal cingulum incomplete Crochet united to crista Minor ridges on crochet	Internal cingulum lacking Crochet large Crista moderate	Skull flat where sagittal ridge usually occurs
<i>D. cooki</i>	L. Harrison	348 ^{mm}	143	144	31 × 34	Internal cingulum lacking Crochet united to crista	Internal cingulum lacking Crochet very large Crista weak	Skull high with sagittal ridge
<i>D. aberrans</i>	L. Harrison				24 × 20		Internal cingulum a trace Crochet enormous Crista as long as the protoloph	
<i>D. minutum</i>	Upper Oligocene				32 × 36	Internal cingulum a mere trace Crochet incipient Crista wanting	Internal cingulum a mere trace Crochet incipient Crista wanting	Protoconule much swollen
<i>D. douvillei</i>	L. Miocene				33 × 39	Internal cingulum complete Crochet double Crista wanting	Internal cingulum incomplete Crochet strong No crista	
<i>D. oregonense</i> ..	Loup Fork				40 × 55?		Internal cingulum complete? Crochet united No crista	

* Breadth is measured between the orbits.

† Height is measured from under the foramen magnum to the top of the crista.

teeth are not so crowded as in the preceding species. On the premolars the cingulum extends around the front, inner, and rear faces. These premolars are very simple, showing no trace of a crista or crochet. The cingulum on the molars is interrupted on the inner face opposite both the protocone and



FIG. 15. *Aceratherium egrerius* C.; the premolar and molar series, one-half nat. size.

hypocone. A crochet is moderately developed, especially on the second and third molars.

This and the preceding species show much resemblance to *A. occidentale* of the Oligocene.

Measurements.

Total length of the premolar-molar series.....	204 ^{mm}
Length of second molar	33 ^{mm}
Width of second molar.....	46 ^{mm}

Amherst College, Amherst, Mass.