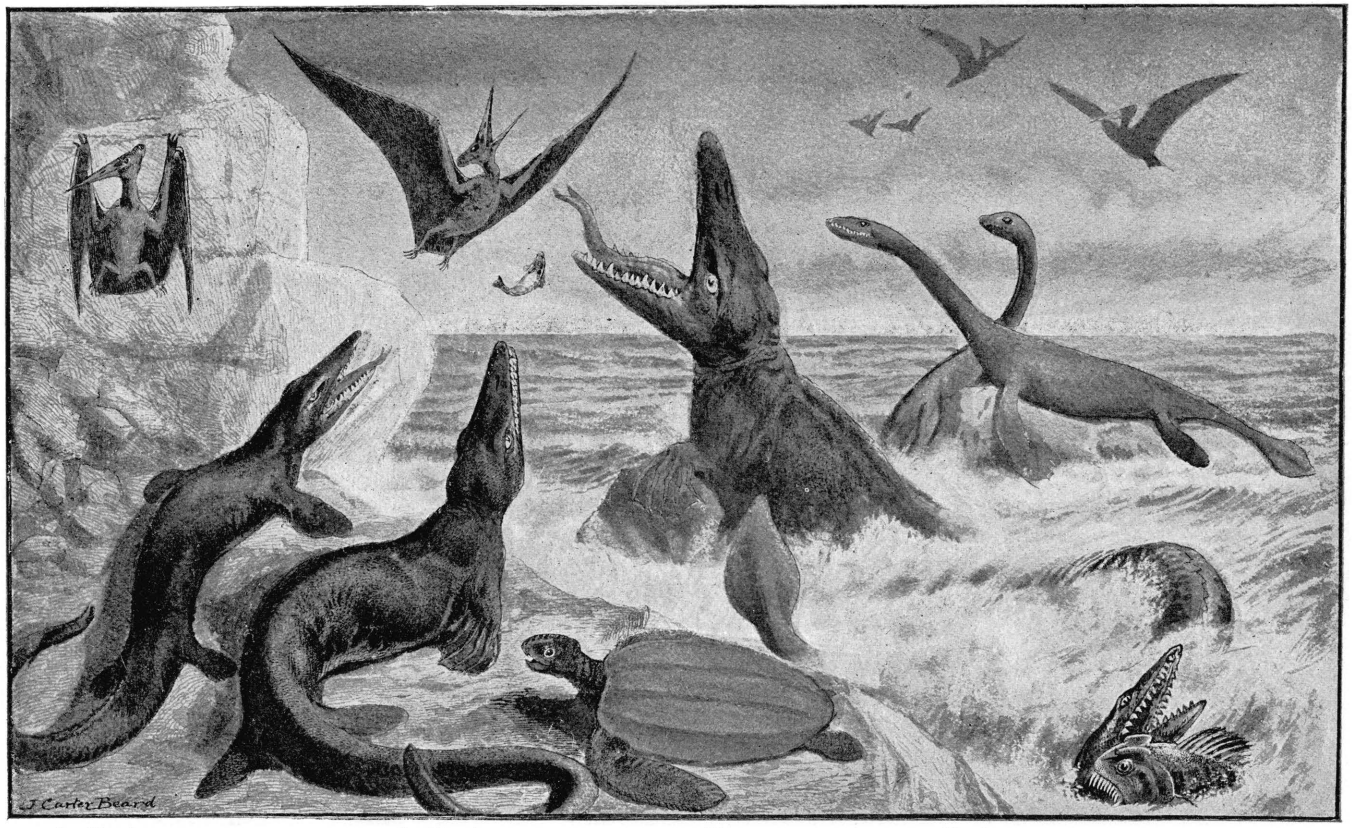
THE
UNIVERSITY
GEOLOGICAL
SURVEY
OF
KANSAS.

VOL. IV.

PALEONTOLOGY.
Part I.



Ornithostoma. Ornithostoma. Mosasaurus. Plesiosaurs.
Tylosaurus. Platecarpus. Protostega. Clidastes.
Xiphactinus (fish).

REPTILES OF THE KANSAS CRETACEOUS OCEAN.

(From Popular Science Monthly, by permission.)

THE UNIVERSITY

GEOLOGICAL SURVEY

OF

KANSAS.

CONDUCTED UNDER AUTHORITY OF THE BOARD OF REGENTS
OF THE UNIVERSITY OF KANSAS.

VOL. IV.

PALEONTOLOGY.

PART I.

UPPER CRETACEOUS.

SAMUEL W. WILLISTON,
Paleontologist.

TOPEKA:
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1898.

MEMBERS OF THE UNIVERSITY GEOLOGICAL SURVEY

FRANCIS H. SNOW,
Chancellor, and *ex officio* Director.

SAMUEL W. WILLISTON,
Department of Historical Geology and Paleontology.

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FOR VOLUME IV.

SAMUEL W. WILLISTON, Paleontologist.
GEORGE I. ADAMS, Assistant Paleontologist.
ERMINIE C. CASE, Assistant Paleontologist.
CLARENCE E. McCLUNG, Assistant Paleontologist.
WILLIAM N. LOGAN, Assistant Paleontologist.

Chancellor F. H. Snow,

Ex officio Director of the University Geological Survey:

DEAR SIR—I have the honor herewith to submit to you for your approval the first part of my report upon the Paleontology of Kansas, to constitute a volume of the University Geological Survey of Kansas. That such a work, completed and now in progress, is possible is chiefly due to your zealous wisdom and foresight, whereby the rich material illustrating this field of Kansas geology has been brought together in the museum of Kansas University. I desire, also, to express to you my hearty thanks for the many facilities and constant encouragement that have been afforded me by yourself and the Board of Regents in the prosecution of the work. Respectfully,

SAMUEL W. WILLISTON.

DEPARTMENT OF HISTORICAL GEOLOGY AND PALEONTOLOGY,
UNIVERSITY OF KANSAS, FEBRUARY 1, 1898.

TO THE MEMORY

OF

PROF. BENJAMIN F. MUDGE,

The first State Geologist of Kansas,

AN EXCELLENT TEACHER, A FAITHFUL FRIEND,

AN HONEST MAN.

CONTENTS.

PREFACE.

THE science of Fossils, or Paleontology, is that upon which the geological history of the earth mainly rests. Without it, geology would be but a fragmentary science, a science of the structure of the earth only. By the aid of fossils, the succession of rocks, their distribution and relations are determined. They are the key which unlocks the most difficult problems of stratification. Upon them the seeker after the economic substances of the earth must mainly depend. Until the paleontologist has deciphered the records, the geologist can only grope blindly. The study of fossils, then, needs no apology from the economist. As a pure science, paleontology is inextricably united with the science of biology, the science of living things; as an applied science, it is equally intimately related to the structure and history of the earth. In the tracing of the rocks' strata, physical characters are often deceptive and unreliable; paleontological characters are decisive and incontrovertible.

Kansas has long been a famous region for the paleontologist. Perhaps no equal area in the United States presents such varied and remarkable fossil records as does Kansas. The fame of her fossils is world-wide. The pages she has added to the geological history of the earth are already classic.

But, while the state has furnished so much of interest and of value to the sciences of geology and paleontology, the published accounts, what there are of them, have been accessible only to the specialist in scattered and abstruse papers.

Constantly is the writer in receipt of inquiries from citizens of our state, especially teachers, seeking information regarding its fossils. Invariably he has been compelled to reply that such information is accessible only to the specialist and investigator. Specimens are often sent for identification, which the senders might easily determine for themselves if only they

knew where to find the information. Nothing whatever has been published by the state that will aid the student in his researches. Many of the fossils of our state have been described in scattered and voluminous reports, that can be found only in those libraries that especially collect such works. For several years past the writer has been gathering the literature concerning Kansas paleontology, either in his own private library or in the library of the University. The value of the literature consulted in the preparation of the present volume is at least $1000. No better reason can be given for the need of such reports as the present. More important still is the fact that a large part of the present volume is composed of information here published for the first time, and which must necessarily be otherwise accessible only to the investigator who has the disposition and time to devote years of study to the work. Very many high schools and other institutions of the state have specimens or collections of fossils, whose value at the present time is very slight, since a very incomplete knowledge or total ignorance of what they are prevents their use as means of education or instruction; and it is one of the chief hopes of the writer that the present work will stimulate many of the young people of our state to an intelligent interest in its geology as based upon the study of its fossils.

The material treated in the present work is believed to be fairly complete. The work is in no sense a preliminary one, but one that is hoped will not need revision for many years to come.

The reader may find accessible in the preceding volumes of this series much of interest and value regarding the physical features of the state. The different formations have been mapped out, so far as the paleontologist has defined them. The formations and localities of the economic products have been, so far as possible, made known. But the general student wishes also to learn something himself of the facts upon which these results are largely based.

The writer has been engaged for the larger part of twelve years in the study of the geology and paleontology of the state.

His first studies began in 1874, since which time he has spent over three years in camp in field exploration within the state. For the past eight years he has been collecting the material to serve for the present work. The splendid collections of fossils made by Prof. F. H. Snow and Judge E. P. West have been so supplemented that now it is possible to give a fairly good review of the very diverse and extensive field of Kansas paleontology. As an example, it may be stated that all the material figured and described, with hardly an exception, in the present work is now the property of the University of Kansas. From this material it has been possible to add very much that is new to what had previously been known concerning the animals described.

The present work deals with the fossils of the western part of state solely for the reason that more preparatory work has been done upon them in the University in recent years. At present, Mr. J. W. Beede, a graduate student of the department of Paleontology of the University, has far advanced toward publication a work upon the Invertebrate Fossils of the eastern part of the state, and his report will form a part of the next volume of this series. The remainder of the fauna of the Upper Cretaceous is also nearly ready for publication, the Plesiosaurs and Pterodactyls by the writer; the Fishes by Mr. Alban Stewart (K. U.'96), a graduate student of the department.

Other work is already in preparation for publication, including the vertebrate and invertebrate faunas of the Lower Cretaceous, the Dakota, and the Tertiary, based upon large and valuable collections now in the University museum.

It is the aim in the present and following volumes to so picture and describe the fossils of the state that they may be understood by the ordinary reader of intelligence. But, at the same time, it is imperatively necessary that the descriptions should be accurate, and accuracy can only be obtained by the use of scientific language. The general reader will find in the introductory parts of the different chapters those portions of more general interest. The student or observer with the actual fossils in his hands will be able to follow by the aid of the figures

the strictly scientific descriptions. For extended description of the Upper Cretaceous horizons, the reader is referred to papers by Mr. W. N. Logan and the writer in the second volume of this Survey reports.

The writer desires here to express his warmest thanks to Prof. E. C. Case (K. U. '93), of the Wisconsin Normal School, for the preparation of his part on the Turtles; to Dr. George I. Adams (K. U. '93) for the chapter on the Upper Cretaceous; to Mr. C. E. McClung (K. U. '96), instructor in Zoology in the University, for the chapter on the Microscopic Organisms of the Cretaceous; and especially to Mr. W. N. Logan (K. U. '96), now fellow of Chicago University, for the extensive work on the Invertebrates. Messrs. Case, Adams and Logan were former students in the department of Paleontology of the University; Mr. McClung, the writer's former assistant in Microscopic Anatomy. They have all given their careful and skilled labor wholly without remuneration from the state, and with but very slight expense.

All the drawings illustrating the vertebrates, save the first five plates, have been made for this work under the writer's immediate and constant supervision. For their accuracy he is alone responsible. Most of those of the Mosasaurs and part of those of the Turtles have been made by Mr. Sydney Prentice (K. U. '96), and thanks are due him for the fidelity, skill and zeal that he has shown in their production. The plates upon the skull, especially, have required an unlimited amount of patience on his part to insure their accuracy. The larger part of the figures illustrating the Turtles were made by Miss Mary Wellman (K. U. '92), and do not need commendation. All of the photographs used in the volume have been made either by the writer or under his immediate direction. The illustrations for the Invertebrates have been largely copied or redrawn from previous authors.

S. W. WILLISTON.

PART I.

THE UPPER CRETACEOUS OF KANSAS:

A HISTORICAL REVIEW.

By GEORGE I. ADAMS.

ADDENDA.

By S. W. WILLISTON.

Plates I–IV.

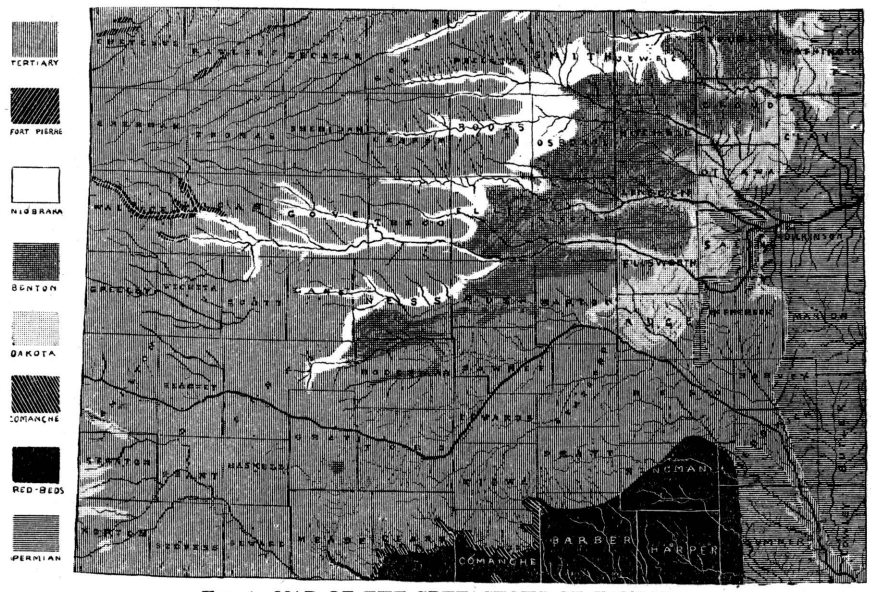

FIG. 1. MAP OF THE CRETACEOUS OF KANSAS.

THE UPPER CRETACEOUS.

By GEORGE I. ADAMS.

In 1853 Congress authorized the exploration of several lines across the western portion of the continent, for the purpose of selecting a route for a transcontinental railway. Each expedition was accompanied by a geologist. The results of their observations were published in the Pacific Railroad Reports. Among those who pushed into the western territory was Professor Hall, the veteran geologist of the New York survey. His official duties requiring his time in New York state, he employed Meek and Hayden to explore a part of the upper Missouri river region. The results of this work, mainly paleontological, were published jointly by Professors Hall and Meek.[1] This work was the beginning of long-continuing labors which they pursued jointly and separately. Their section of the Cretaceous along the Missouri river, known as the Meek and Hayden section,[2] has served as a basis for much subsequent work.

The Cretaceous formation of Kansas lies within the south interior region of the Cretaceous area of North America, as divided by White[3] for the purpose of discussion and correlation. The Missouri river section by Meek and Hayden has been used as a standard for reference in the study of this area, and is substantially still so used. It includes only formations which are referred to the Upper Cretaceous. A later nomenclature and grouping of these divisions, which was proposed by Eldridge,[4] was adopted by White. His table showing the relation of the section is given on next page.

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1. Mem. Amer. Acad. Arts and Sci., 1856.
2. Proceedings Amer. Phil. Soc., 1856.
3. Bulletin No. 82, U. S. G. S., Correlation of the Cretaceous, 1891.
4. American Jour. Sci. xxxviii, 313-321, 1862.

Upper Missouri Section of Meek and Hayden.	ELDRIDGE.
Not recognized	Laramie formation.
No. 5, Fox Hills group No. 4, Fort Pierre group	Montana formation.
No. 3, Niobrara group No. 2, Fort Benton group	Colorado formation.
No. 1, Dakota	Dakota formation.

This table does not include the Lower Cretaceous, of which the Comanche series[5] is now recognized; but, as it is the purpose of this paper to deal only with the Upper Cretaceous, the section of Meek and Hayden is wholly adequate, since the development of our knowledge of it in Kansas is largely the result of attempts to identify the members of the Missouri river section in the territory along the Smoky Hill river. The following sketch gives in chronological order abstracts of the more important papers:[6]

1855 — Doctor Schiel's Report. The series of limestones from Westport, Mo., to the Little Arkansas he considered to belong to the same formation. There he found "a white, fine-grained, non-fossiliferous limestone, and a red, ferruginous sandstone, out of which Pawnee Rock is formed. The latter was also found on Coon creek, and, from specimens brought by Captain Gunnison, he concludes that it extends up the Republican fork of the Kansas river. It supports a loose conglomerate of quartzose rock, which is seen to extend some thirty miles along the Arkansas west of Fort Atkinson. It is probable that these strata belong to the chalk formation, which, going westward, we find distinctly represented. About thirty miles further west we meet with another limestone of the Cretaceous period."

1856 — Engleman's Report.[7] This gives a general description to Fort Riley. He describes a sandstone along the Republican from above Fort Riley for forty-eight miles, that is, to eighty miles from the fort. He is inclined to think that it cannot exceed 200 or 300 feet in thickness. From Professor Hall's

5. *Vide* Prosser, vol. II, Kans. Univ. Geol. Surv. 1897, for historical summary.

6. For bibliography of Kansas Geology, see Hay, Trans. Kans. Acad. Sci. 1893-'94.

7. Geol. Ex. from Ft. Leavenworth to Bryan's Pass, 35th Cong., 1st ses., Sen. Ex. Docs. 2, pp. 489-520, Washington, 1856.

description of the route west of the Missouri in Sternberg's report, he thinks the beds may be Cretaceous. He next describes the Cretaceous formation, which was first observed seventy-four miles from Fort Riley, which is made up of chalky limestones, marls, slates, and shales. This formation extends beyond the borders of the state. He mentions some fossils. A list of fossils by Shumard accompanies the report.

1857—Hayden.[8] This article on the country bordering the Missouri river has a map accompanying it, showing the geology of northeastern Kansas, colored from information furnished by Major Hawn. In a paper immediately following, he gives a section of the rocks of northeastern Kansas above the coal measures, by Major Hawn. These beds were not seen at any one place, but their thickness and order of succession were determined in the region east of the sixth principal meridian by Major Hawn, while carrying on the lineal survey. The beds are correlated by Hayden with the New Jersey section, the Alabama section, and the Triassic and Jurassic of Marcou, from his section of Pyramid Mountain, New Mexico. The article concludes for Kansas that there is at the base of the Cretaceous series a series of beds concerning which evidence is lacking that they are not older than any portion of the Cretaceous. The section is correlated with Cretaceous, No. 1, No. 2(?), and the lower part of No. 3.

1859—Meek and Hayden.[9] In this article it was stated that No. 1 was carried too low in a previous paper (Proc. Acad. Nat. Sci. Phil., 1857). A paper by Hawn (Trans. Acad. Sci. St. Louis, I, 171) is cited in which the formation in Kansas is placed on a parallel with No. 1, but the whole is referred to the Trias. These beds were examined with care, and dicotyledonous leaves were found, proving their identity with No. 1 of the Nebraska section. Doctor Newberry is referred to as authority in the paleobotany. Between No. 1 and the beds containing Permian fossils there is a series of beds which the writer states may be Jurassic or Triassic, or both, but more probably the former,

8. Proceedings Acad. Nat. Sci. Phil. 1857.
9. American Jour. Sci., 1859.

though as yet there is no paleontological evidence. An article in the Proc. Academy of Natural Science, Philadelphia, 1859, was also published in the Transactions of the American Philosophical Society, 1863 (read 1861). The latter is accompanied by a map. These articles contain the following points of interest here: Certain beds between No. 5 of the Coal Measures and the Cretaceous are suspected of being of Jurassic or Triassic age, probably Jurassic. Reference is made to his previous discoveries of the Cretaceous age of the higher beds. Nos. 1, 2 and 3 are considered the equivalents of the Cretaceous of Nebraska, as found by Mr. Engleman. (*Vide* Rep. Sec. War, Dec. 5, 1857, p. 497.)

1866—Mudge. The First Annual Report of the Geology of Kansas, by B. F. Mudge, contains the following concerning the Cretaceous: "No unconformability has been observed from the Coal Measures to the Cretaceous. This formation, which is represented rather largely, has not been definitely studied, since it lies beyond the settlements. Chalk is said to be found in it. So far as known, it appears to have a resemblance to the Cretaceous of England." Under his division Triassic, he describes fossil footprints of birds[10] found in the sandstone northwest of Fort Riley. A few miles distant, in what appeared to be the same horizon, he discovered dicotyledonous leaves. He is inclined to place the deposits in the Lias.

1866—Swallow. In his Preliminary Report of the Geological Survey of Kansas, Swallow refers No. 1 of his section, 295 feet of brown ferruginous sandstone, to the Cretaceous, but states that he saw no proofs of its age. Nos. 2 and 3, which are similar in character, he refers to the Triassic(?).

1867—Hayden.[11] This article refers to the report by Swallow, and states concerning the beds referred to the Triassic with a question, that they may be Permian, or even Jurassic, so far as any evidence yet obtained goes. He is inclined to think that they belong to the Trias.

1869—Hayden.[12] In speaking of the Cretaceous rocks (p. 13),

10. See article on Cretaceous Birds, this volume.
11. Notes on Kansas Geology, Amer Jour. Sci., 1867.
12. Preliminary Rep. U. S. G. S. of the Ters., 1869.

he says that they show five well-marked divisions, Nos. 1, 2, 3, 4, and 5, or Dakota, Benton, Niobrara, Fort Pierre, and Fox Hills. In discussing their characters, he refers briefly to the Cretaceous of Kansas at Hays City and Fort Wallace.

1872—Hayden.[13] Part I, chapter IV, by Hayden, gives a sketch of the geological formation along the Union Pacific railroad to Fort Wallace. The formation west nearly to Salina he refers to the Permo-Carboniferous series. At the 155th mile-post he says he reached the beds of doubtful age, intermediate between the Permian and the well-known Cretaceous No. 1, or those which include the rusty sandstones of the Dakota. He mentions the Dakota as occurring near Salina, at Fort Ellsworth, and as far west as Fort Harker. At Wilson he saw "the chalky limestones of the Niobrara filled with *Inoceramus problematicus*." At the 280th mile-post he reported indications of the Tertiary. At Hays City massive rocks of No. 3 were seen sawed into blocks and used in buildings. At eight miles west of Fort Hays an exposure in a cut showed sixty feet of shale of No. 2, the Benton group, filled with concretions. On the summit of the hill he observed massive layers of yellow chalk. In concluding he says: "We have, therefore, between Salina and Fort Wallace, exposures of Cretaceous beds Nos. 1, 2, and 3. In No. 1 are well-preserved impressions of dicotyledonous leaves; in No. 2, not far from Fort Wallace, remains of gigantic reptiles have been found; while No. 3 contains invertebrates and fragments of the remains of fishes."

1876—Mudge.[14] Concerning the Cretaceous, he says that the Fort Pierre and Fox Hills groups are wanting, and that the Benton group also appears to be absent. He reports the Cretaceous as resting conformably, or nearly so, upon the Permian, and that he had found no fossils of the Jurassic or Triassic. In his description of the Niobrara, he divides it into two divisions: the Niobrara proper and the Fort Hays. The division between them is considered by him to be the bed of limestone about sixty feet thick where fully exposed. In the upper division, verte-

13. Final Rep. U. S. G. S. of Nebr., etc., with map, 1868 (printed 1872).
14. Bulletin Geol. and Geogr. Surv. of the Ters, ii, No. 3, 1876.

brates are found in abundance, while below they are rare. Of the Niobrara proper he gives a description of the physical features and areal extent, and mentions the fossils which it contains. The thickness is given as seventy-five feet in Trego county and 200 feet in Ellis county. He makes the statement that Hayden mistook exposures near Fort Wallace for Benton. He records the occurrence of seams of calc and heavy spar. He states that he discovered a bed of Baculites near Sheridan (McAllaster) and on referring specimens of them to Meek, received the following reply: "One fact in regard to your specimens, however, is curious to me. All the other forms like this that I have ever seen from any part of the far west come from Nos. 4 and 5. Can it be possible that you have found an outlier of Nos. 4 or 5?" Mudge, however, states that the beds are clearly Niobrara, since characteristic fish and saurians are found not more than fifteen or twenty feet above and not 200 yards distant. This same error was perpetuated by both Cope and Marsh in the descriptions of fossils from this region. The massive beds of stratified limestone or chalk before mentioned, together with all the deposits above the Dakota, he calls the Fort Hays. He refers to Hayden's statement, that the Niobrara limestone filled with *Inoceramus problematicus* is exposed at Wilson, and states that this rests directly on the Dakota, and all that which Hayden supposed might be Benton is above this stratum, and thus concludes that the Benton is not seen in Kansas. He remarks that the lower portion of the Fort Hays may be Benton, although there does not appear to be any line of demarcation. He says that the only persistent stratum is a buff, sandy limestone, never over ten inches thick (the Fence-post layer of Cragin), which is much used for building. He describes a bed of blue shales containing concretions (Victoria shales) above this horizon. The fossils of the formation are mentioned. The total thickness of the Fort Hays is given at 260 feet. The Dakota is made to include all the Cretaceous east of the Niobrara. No Triassic or Jurassic fossils having been discovered after ten years' search, he concludes that the Dakota rests directly upon the Permian, and is conformable with his Fort Hays group

above it. The lithological characters of the limestone are mentioned, as also the occurrence of coal. Thickness, 500 feet.

1877—Mudge.[15] This paper is practically a reprint of the previous one, but gives much additional matter concerning the writer's collecting and the fossils described from the formation. Concerning the Benton he makes the same limits, but states that if he could spend a few days in the field with Hayden they might conclude that the lower portion of the Fort Hays is Benton, and therefore calls it the Fort Hays only provisionally.

1878—Mudge.[16] This repeats largely former reports. It gives a map, vertical section of the rocks of Kansas, and a horizontal section from southeast to northwest corners of the state. The Triassic and Jurassic are not represented. This allows the Dakota to rest directly upon the Carboniferous, and nearly, if not quite, in conformity. The Pierre and Fox Hills of the Cretaceous, as also the Eocene and Miocene, are reported to be wanting. The Pliocene rests upon the Niobrara or middle Cretaceous. He again repeats Meek's inquiry about beds containing *Baculites anceps*, and states that the beds are not Fort Pierre or Fox Hills. He says that in a former report he was doubtful whether the Benton is represented in Kansas. A more careful examination induces him to believe that what he called Fort Hays corresponds nearly in age to the Fort Benton. The upper portion of the Benton is formed by a bed of limestone sixty feet thick; under this is a bed of blue shale sixty feet thick, containing septaria. Below this are 140 feet of shales and layers of limestone. The total thickness is given at 260 feet. The Dakota group includes all the Cretaceous east of the Fort Benton. The principal part of the paper is composed of a discussion of the areal, geological and topographic features, and notes concerning fossils described by others.

1882—St. John.[17] The Cretaceous is laid down directly upon the Carboniferous floor, and, notwithstanding statements to the contrary, there is marked evidence of non-conformity between

15. Ninth An. Rep. U. S. G. S. of the Ters., 1875 (printed 1877).
16. First Bi. Rep. Kans. St. Bd. Agr., 1877-'78.
17. Third Bi. Rep. Kans. St. Bd. Agr., 1881-'82.

them. The Cretaceous is made up of at least three divisions—the Dakota, Benton, and Niobrara; the upper members appear to be absent. He says concerning the Benton that certain limestones, if indeed they are not to be relegated to the Niobrara, afford stratigraphical evidence upon which to base the limits of the western exposure. He estimates the total thickness at 2200 feet. He says concerning the shales at the top of the Niobrara, that they strongly resemble the "Colorado shales," *i. e.*, Fort Pierre and Fox Hills. He says that the salt springs and wells of the Cretaceous are probably supplied from the Carboniferous deposits. To the south of the Arkansas valley, horizons discovered by G. S. Chase are characterized by a molluscan fauna which indicates affinities with the Texas Cretaceous fauna.[18] He believes that the Cretaceous has been eroded progressively more deeply toward the east, so that the Tertiary rests upon successively lower beds toward the east.

1887—St. John.[19] In southwestern Kansas only the Dakota and Niobrara have been identified with certainty. Beds now known to belong to the Comanche series are here described as Dakota. Those described by him as Niobrara are referred since to the Benton.

1888—Hay.[20] From the north boundary of the state to McPherson county the Dakota sandstone rests upon the Permo-Carboniferous, an example of erosive non-conformability. From McPherson county south the Triassic beds intervene. A shorter period of erosion appears to have taken place there. The Dakota is from 300 to 500 feet thick. The passage to the Benton is without break, the beds being absolutely conformable. Total thickness probably does not amount to 400 feet. The Niobrara consists of two conspicuous strata, a succession of soft limestones, beneath which is a thick shale bed containing concretions. This shale, with occasional intercalations of limestones, is 100 to 300 feet in thickness. The limestones do not reach 100 feet. The Fort Pierre and Fox Hills appear to be ab-

18. Probably the first reference to the Lower Cretaceous in Kansas.
19. Notes on the Geology of Southwestern Kansas, Fifth Bi. Rep. Kans. St. Bd. Agr., 1885-'86.
20. Sixth Bi. Rep. Kans. St. Bd. Agr., 1887-'88.

sent. There is an outcrop in Norton county of two well-marked strata above the yellow chalk, the lower a green sand, the upper a green clay with yellow streaks. These beds are of doubtful reference.

1893—Williston.[21] In this article the Niobrara is estimated to be 430 feet in thickness, and the dip to the north or northeast is shown to be greater than was previously suspected, except perhaps by St. John. The division line between the Niobrara and Benton is placed at the top of the stratified beds, following Mudge, but he is doubtful whether the Niobrara should not also include the stratified beds and perhaps also the subjacent dark blue shales. The stratified beds are called the Fort Hays, thus limiting Mudge's term. No distinction into chalk and shales is admitted for the Niobrara. He states his belief that the beds containing the *Baculites anceps*, to which Meek had referred, are Fort Pierre and not Niobrara. A similar statement was given in a paleontological paper in the Kansas University Quarterly for July, 1892, the first time that the Fort Pierre had been recognized in the state. Other paleontological matters are discussed in this paper. In 1892 Williston prepared a map of the geology of Kansas, which was published in Thomas's School Charts. This was the first time that all of the different geological epochs of the state had been given for Kansas. A modified copy of the map was published in a later paper (Kans. Univ. Quart., 1894), with the different divisions of the Cretaceous given nearly as they are at present located.

1896—Cragin.[22] The rocks of the North American Interior Cretaceous are considered as belonging to two great series, the Comanche series and the Platte series, the latter including the Dakota, Benton, Niobrara, Fort Pierre, Fox Hills, and Laramie. The divisions occurring in Kansas are given as follows: The lower portion of the Benton is named the Russell formation, one horizon of which is the Downs (or Fence-post) limestone. The upper portion is called the Victoria clays, which contains the Cannon-

21. Transactions Kans. Acad. Sci., 1891-'92 (pub. 1893).
22. Colorado College Studies, March, 1896.

ball zone.[23] The lower portion of the Niobrara is named the Osborne limestones. This he states formed the upper part of Mudge's Fort Hays. The upper Niobrara is named the Smoky Hill chalk, with a lower or Trego zone, the Norton zone, and the Graham jasper horizon. The Lisbon shales named by him are supposed to be the Fort Pierre. The Arickaree shales are referred to the Fox Hills.

1897.—Logan.[24] In this paper the Upper Cretaceous is divided as follows: The Benton is divided on lithological grounds into the upper and lower groups. The lower group is subdivided into the Bituminous shale, at the base, the Lincoln marble, Flagstone, Inoceramus and Fence-post horizons. The upper group consists of the Ostrea shales and the Blue Hill shales. The Niobrara is divided into the Fort Hays and Pteranodon beds. For the Fort Pierre no divisional term is used. In a foot-note it is stated that the beds called the Arickaree shales, and referred to the Fox Hills, had been previously referred to the Fort Pierre by Hay.

1897.—Williston.[25] In this paper the line of division between the Niobrara and Benton is taken below the Fort Hays beds, following Cragin. Fort Hays is used instead of Osborne limestone. The upper portion of the Niobrara is called the Pteranodon beds (Marsh, Odontornithes, 1880). The suggestion is made that the name Pteranodon, being in all probability a synonym, should be changed to Ornithostoma beds. The Pteranodon beds are divided on paleontological grounds into the lower or Rudistes beds, and the upper or Hesperornis beds. The Fort Pierre at McAllaster is estimated at least 100 feet in thickness. The name Blue Hill is used in part for the Victoria beds. (See summary of sections, opposite page.)

From the foregoing, it will be seen that the Upper Cretaceous of Kansas is now quite well understood. The various geologists who have studied it from time to time have slightly modified

23. The Cannon-Ball crossing of the Missouri River, illustrated in Hayden's Report, 1870, to which Cragin refers, is in the Fort Pierre.

24. Kansas Univ. Geol. Surv. II, 1897.

25. Kansas Univ. Geol. Surv. II, 1897.

SUMMARY OF SECTIONS.

	Hayden, 1872.	Mudge, 1876.	Mudge, 1882.	St. John, 1882.	Hay, 1888.	Williston, 1893.	Cragin, 1896.	Logan, 1897.	Williston, 1897.
Fox Hills. No. 5.		Reported wanting.	Reported wanting.	Reported wanting.	Reported wanting.		Arickaree shales.	Reported wanting.	
Fort Pierre. No. 4.		Reported wanting.	Reported wanting.	Reported wanting.	Norton county beds of doubtful reference.	Recognized.	Lisbon shales.	Recognized.	Recognized.
Niobrara. No. 3.	Repre- sented.	Niobrara: Nio- brara proper.	Niobrara.	Niobrara. ?	Niobrara: Limestone.	Niobrara. Fort Hays limestone.	Niobrara: Smoky Hill chalk: Graham jasper. Norton zone. Trego zone. Osborne.	Niobrara: Pteranodon. Fort Hays.	Niobrara: Pteranodon: Rudistes beds. Hesper- ornis beds. Ft. Hays.
Benton. No. 2.	Repre- sented.	Fort Hays.	Benton.	Benton.	Shale with concre- tions. Benton.	Benton.	Benton: Victoria clay with Cannon-ball zone. Russell formation, containing Downs or Fence-post limestone.	Benton: Upper: Blue Hill shales. Ostrea shales. Lower: Fence-post. Inoceramus. Flag. Lincoln marble. Bituminous.	Benton: Blue Hill shales.
Dakota. No. 1.	Repre- sented.	Dakota.	Dakota.	Dakota.	Dakota.	Dakota.	Dakota.	Dakota: Salifer- ous: Gypsiferous. Salt marsh. Ferru- ginous: Lignite.	

the early divisions, but the tendency has been to recognize the same general groupings. There are, however, some questions of nomenclature which it may be well to mention here.

The divisions of the Dakota by Logan are the only ones so far proposed. As he remarks, there seem to be no well-marked dividing lines. The divisions were made for convenience, and may prove to be valid.

The division of the Benton into Upper and Lower is upon lithological grounds. The names used by Logan for the lower group must stand; but his division of Blue Hills is precisely identical with the Victoria shales previously proposed by Cragin, and must be given up on the ground of priority. Cragin's Russell group does not correspond with the Lower, since it does not include the Ostrea shales.

The division line between the Benton and Niobrara is in accordance with Gilbert's eastern Colorado section. (17th Ann. Rep. U. S. G. S., 1896.)

The Niobrara is divided into the Fort Hays and Pteranodon beds. The name Fort Hays was limited by Williston in 1893. The Pteranodon beds are further divided by Williston into the Hesperornis and Rudistes, on paleontological grounds. Cragin's Trego and Norton zones may correspond to these divisions, based upon lithological grounds, and scarcely recognizably characterized. Nevertheless, it is a question whether or not these terms should take precedence over Williston's.

The Fort Pierre was first reported by Williston. Cragin has since proposed the name Lisbon shales for certain outcrops, but has not in any way differentiated them or given any characters by which they may be distinguished from the rest of the Fort Pierre.

The argument for the use of the Arickaree beds rests upon similar grounds. They were first reported by Hay to be Fort Pierre. Such being the case, the names Lisbon shales and Arickaree shales may be with propriety used for the two horizons.

General Section of the Upper Cretaceous of Kansas.

Montana (Eldridge),	Fort Pierre (Hayden)		Arickaree shales (Cragin). Lisbon shales (Cragin).
Colorado (Eldridge),	Niobrara (Hayden),	Pteranodon beds (Marsh)	Hesperornis beds (Williston). Rudistes beds (Williston).
		Fort Hays beds (Mudge, Williston).	
	Benton (Hayden),	Upper group (Logan)	Victoria shales (Cragin). Ostrea shales (Logan).
		Lower group (Logan)	Fence-post (Cragin). Inoceramus (Logan). Flagstone (Logan). Lincoln marble (Logan). Bituminous (Logan).
	Dakota (Hayden),	Saliferous (Logan)	Gypsiferous (Logan). Salt marsh (Logan). Lignitic (Logan).
		Ferruginous (Logan).	

ADDENDA TO PART I.

By S. W. WILLISTON.

THE first vertebrate fossil obtained from the Upper Cretaceous of Kansas was the type specimen of *Elasmosaurus platyurus* Cope, collected by Dr. Theophilus H. Turner, the physician of the garrison at Fort Wallace, and taken east by Dr. J. L. Leconte. It was described by Cope in Leconte's Notes on Geology of the Route of the Union Pacific Railroad, 1868, p. 68.

The next specimen obtained was a part of a cranium of *Tylosaurus proriger* Cope, the type, collected by Colonel Cunningham and Mr. Minor "in the vicinity of Monument station, and sent by them to Prof. Louis Agassiz." The locality is probably Monument station of the overland route, in the vicinity of Monument Rocks, in the valley of the Smoky Hill river. Other specimens were later obtained by Drs. J. H. Janeway and George Sternberg in the vicinity of Forts Hays and Wallace, and by Mr. Webb, of Topeka.

The first to make any systematic collections of fossils from the Cretaceous of Kansas was the late Prof. B. F. Mudge, at that time professor of geology in the Kansas Agricultural College. I was a student at that time under him at this college, and well remember the ardent enthusiasm that he evinced in the discoveries he made. His first expedition, as I remember, was up the Republican and Solomon rivers into the wholly uninhabited region, the home then of the bison and roving bands of marauding Indians. It was made shortly after the close of the college year in 1870. A chance acquaintance whom he met on the expedition, and who had recently come from Philadelphia, urged him to send his specimens to a young and promising naturalist in that city who was especially interested in vertebrate fossils. Although Professor Cope was then less than thirty years of age he had already achieved renown among naturalists, and it was to him that Professor Mudge wrote ask-

ing if he would be kind enough to examine the fossils and tell him what they were.

Mrs. Mudge has kindly placed in my hands a part of the correspondence that followed, and I give herewith a letter from Professor Cope, after he had received the first consignment of fossils.

It will be observed that Professor Cope speaks of a specimen found near the vicinity of Sheridan, now McAllaster. This specimen, with others, was, I believe, taken later in the season, while on a brief trip for the purpose of examining the geology in the vicinity of Wallace. He had no team or outfit, but collected the specimens from the immediate vicinity of the station.

PHILADELPHIA, October 28, 1870.

Prof. B. F. Mudge: ESTEEMED FRIEND—The fossils arrived in safety, thanks to the careful packing, and I have examined and determined most of them. The collection is a valuable one, and is an earnest of what can be done for the geological survey of Kansas under more favorable opportunities for collection.

I found portions of six species of reptilia, all of the order *Pythonomorpha*, and five species of fishes, of the new family of *Saurodontidæ*. Of the reptiles, there were two distorted vertebræ of a large *Elasmosaurus*, the species not determinable; one vertebra of a large *Liodon*, probably *L. proriger* Cope. The limb bones and accompanying vertebræ belong to a *Polycotylus* (Cope), but whether to *P. latipennis* is not yet determined. The three other reptiles are quite determinable, and new to science. I have called them *Liodon mudgei*, after the state geologist of Kansas, *Liodon ictericus* (two individuals sent), and *Clidastes cineriarum*—the last from the gray clay limestone near Sheridan.

The fishes are quite interesting, and have enabled me to define a *new family*, and correct the work of Agassiz and Leidy. They belong to the genus *Saurocephalus* of Harlan, which has been heretofore regarded as a *Sphyrænoid* fish. I find that it has not the least relationship to that order, but forms a new and interesting group near the *Ganoids* and *Characius*. In order to determine it more fully, I am exceedingly desirous of getting more complete remains, especially of the cranium and fins. The following is a list of the species:

Saurocephalus phlebotomus Cope, n. sp.
S. prognathus Cope, sp. nov.
S. napahaticus Cope, sp. nov.
S. thaumas Cope, sp. nov.

This last is the large fish eight feet long without head from 100 miles up the Solomon. Its remains were highly interesting and enabled me to determine many new points in the structure of the group. I found by means of it that the group has a vertebrated tail; also that its anal or caudal fin-ray is that which has always been referred to the *Ptychodon* genus of sharks by Professor Agassiz. The pectoral rays have just been described by Leidy as a new genus of catfish, *Xiphactinus audax!* Then there is a new genus of the same family, *Ichthyo-*

dectes ctenodon Cope, which is based on jaws and thirteen vertebræ from the yellow chalk. I hope that this species also may at some future time be more fully developed.

I hope these researches, so successfully commenced, may cover the whole vertebrate fauna of the strata. I have studied especially the mammals and birds, as well as the reptiles and fishes. If you desire any part or all of my manuscript for the annual report to the legislature, I will send it on; in the meantime it will appear in *Silliman's Journal* and some abstracts here.

I remain, with much regard, etc., EDWD. D. COPE.

Late in the season of 1870, Professor Marsh, with an escort of United States soldiers, spent a short time on the upper part of the Smoky Hill river collecting vertebrate fossils. The material then collected served for the description of a number of interesting types by Marsh. It included the first known specimen of "Odontornithes," a foot bone brought in with other material, but which was not discovered in the material until after other specimens had been obtained later. In June of the following year Marsh again visited the same region, with a larger party and a stronger escort of United States troops, and was rewarded by the discovery of the skeleton which forms the type of *Hesperornis regalis* Marsh, together with other material.

In 1871 Prof. E. D. Cope visited the regions and made many valuable discoveries, besides giving important notes concerning the geology of the formation. "The geology of the regions marked by this formation (the Niobrara epoch) is quite simple. The following description of the section along the line of the Kansas Pacific railroad will probably apply to similar sections north and south of it. The formations referable to the Cretaceous period on this line are the Dakota, Benton and Niobrara groups, or Nos. 1, 2, and 3, etc."

In 1872 Professor Mudge made another expedition into the Cretaceous for fossils. The party accompanying him consisted of Professor Merrill, of Washburn College, Professor Felker, of Michigan Agricultural College, Professor Warder, of the Indiana Geological Survey, and seven students of the Agricultural College. They explored northwestern Kansas, traveling over 900 miles. It was on this exposition that Professor Mudge found the remarkable specimen of *Ichthyornis*, from the North Fork of the Solo-

mon, which furnished to the world the discovery of the then startling fact of birds with genuine teeth. Under the date of September 2 of that year, Professor Marsh wrote to him inquiring about his summer collections in the Cretaceous, with the offer to "determine any reptilian or bird remains without expense," and stating that he would give him "full credit" for their discovery. Under date of September 25 he again wrote to him, acknowledging the receipt of a box of fossils, and stating that the "hollow bones are part of a bird, and the two jaws belong to a small saurian. The latter is peculiar, and I wish I had some of the vertebræ for comparison with other Kansas species." The latter is the *Colonosaurus mudgei* Marsh, which was afterwards found to belong with the bird specimen.

In the autumn of 1872, Marsh, with a small party, made another expedition into the same region. These were the only times that Marsh personally visited these regions, all of his collections being afterward obtained by parties employed by him.

In 1873 Mudge again spent some time in the exploration of the Cretaceous beds in the more northern part of the state — the only region that was at all safe from marauding Indians.

In 1874 Professor Mudge began systematic collections for Yale College, assisted by Mr. Henry Turner, of Clay Center. In July of that year his party was joined by Mr. (now Doctor) Harry A. Brous, of Manhattan, and myself, and explorations were continued into November along the Saline and Smoky Hill rivers.

In 1875 explorations for Yale College were continued by Professor Mudge, assisted by Mr. Brous and myself, from March to October.

In 1876 the party under charge of Professor Mudge consisted of Mr. Brous, Mr. E. W. Guild, who had been collecting the previous year independently, for Yale, Mr. G. P. Cooper, of Topeka, and myself. Work was continued until late in November.

In 1877 the party (under charge of myself) collecting for Yale College consisted of Mr. Guild, Mr. Cooper, and my brother, Mr. F. H. Williston.

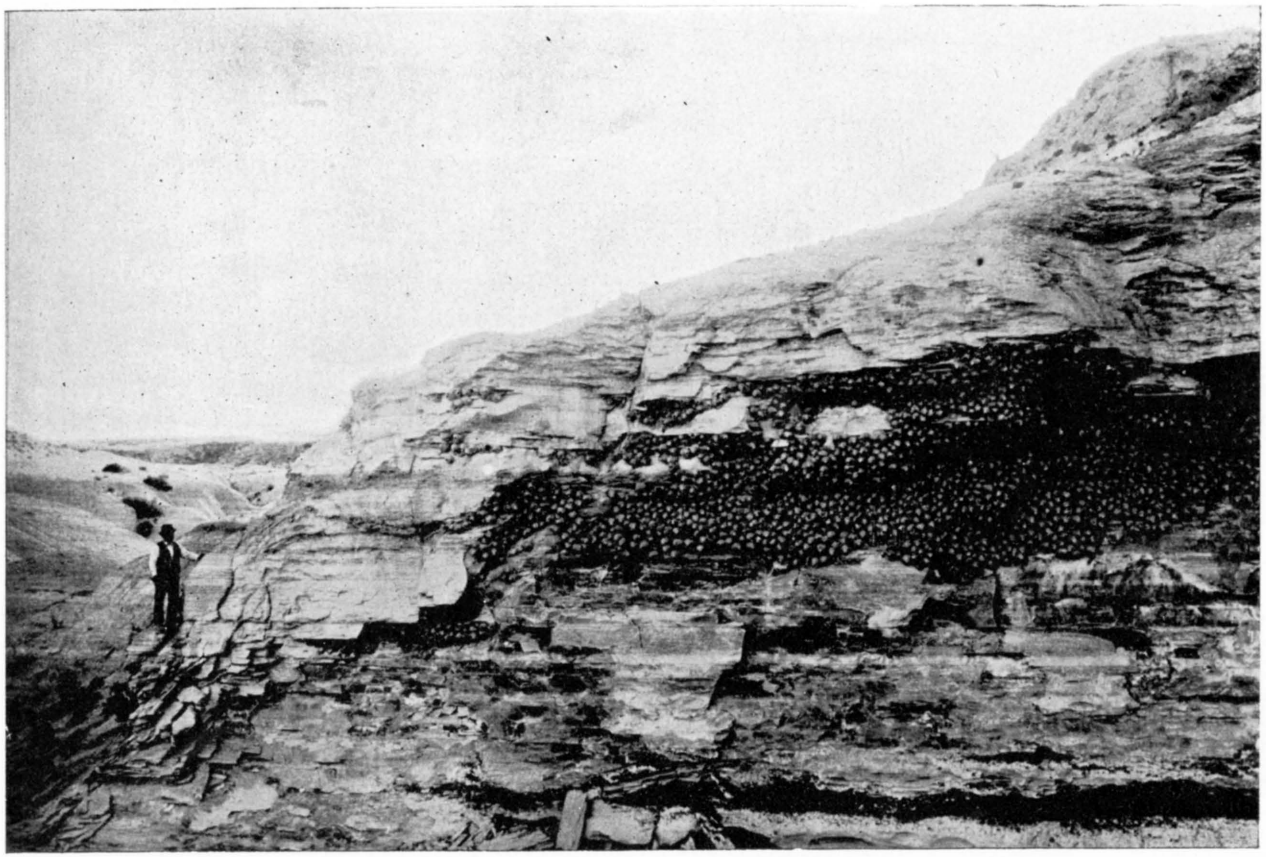
Meanwhile Mr. Charles Sternberg had collected by himself in

these regions, during 1875, for Professor Cope. In 1877 Mr. Sternberg was in charge of a party for Professor Cope, composed of Mr. (now Dr.) Russel Hill, of Philadelphia, Mr. Wilbur Brous and Mr. Knipe, of Manhattan. For several years following Mr. Guild collected for Yale College and Mr. Sternberg made some collections for Harvard University.

In 1878 Professors Mudge, Snow and Dyche (then a student) spent some time in Gove county collecting for the University. It was on this expedition that Professor Snow obtained the specimen of *Tylosaurus* showing the skin.

For a number of years prior to 1895 Mr. H. T. Martin collected for Yale College. In 1890 Prof. George Baur collected several weeks for Professor Zittel, of Munich. In 1889 and 1890 Judge E. P. West obtained many valuable specimens for the University of Kansas. In 1891 a party under my charge, composed of Mr. (now Professor) E. C. Case, Mr. (now Professor) E. Slosson and Mr. Charles Sternberg spent about two months on the Smoky Hill river searching for specimens for the University of Kansas. Mr. Charles Sternberg, in the latter part of that year and in the following, made considerable collections for Professor Zittel. In 1895 Messrs. H. T. Martin and T. R. Overton spent the season in making collections for the University of Kansas. During the past two years collections have been made by Mr. Martin and Doctor Mathews for the American Museum, of New York city. Some additional specimens of value have been obtained by purchase for the University of Kansas from Mr. Sternberg, Mr. Martin, and others.

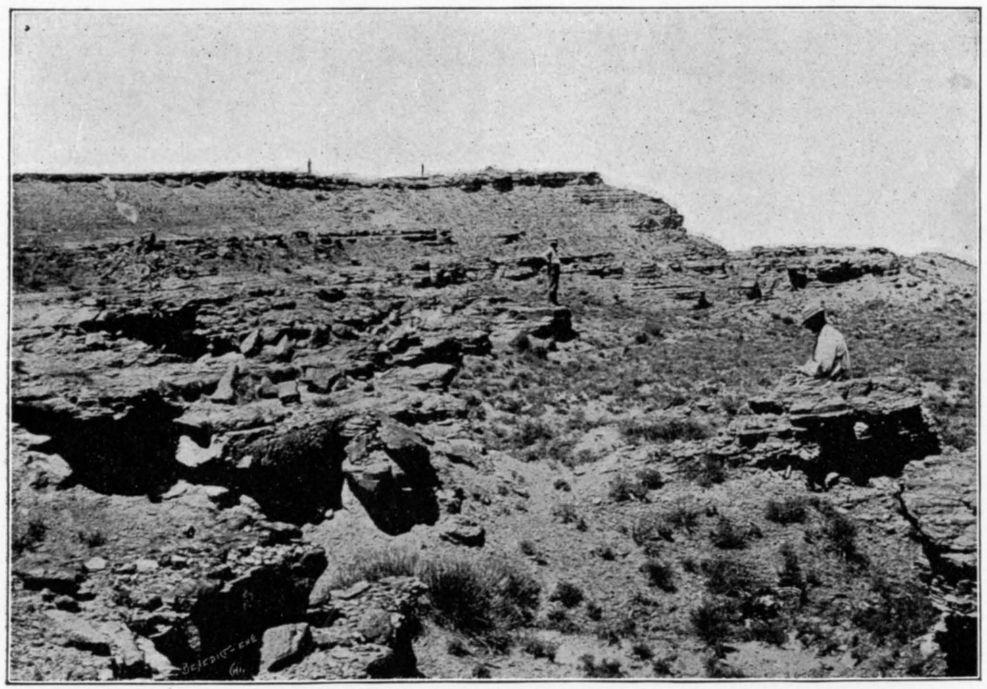
This in brief represents the explorational work in the Niobrara Cretaceous deposits to the present time. The few months of collecting done by Marsh and Cope was under ample protection of soldiers. While yet the danger was fully as great or greater, the various other parties spent over thirty months in the same regions with no protection other than what their own rifles and revolvers afforded. Immigrants were massacred almost within rifle shot of the parties at different times, but fortunately no encounter was had by the explorers, though at times the danger was escaped almost marvelously.



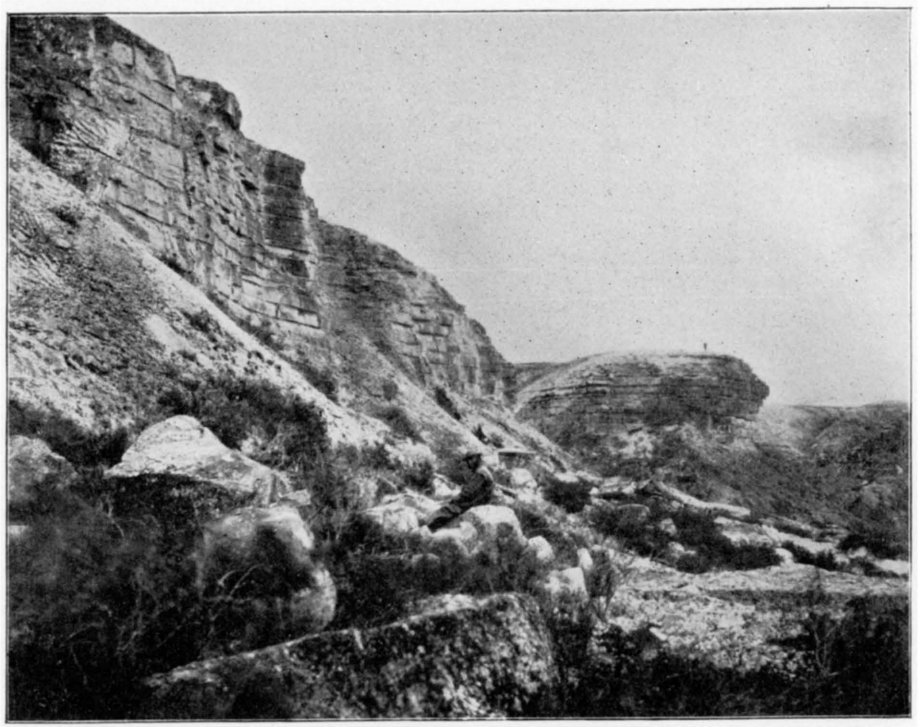
AV—4

VIEW OF CHALK BLUFF IN RUSH COUNTY. With nests of swallows, *Petrochelidon lunifrons*.

CASTLE ROCK, NIOBRARA CHALK. Trego County.



NIOBRARA CHALK. Plum Creek, Gove County.



FORT HAYS BEDS, NIOBRARA CRETACEOUS.
Gove County, Smoky Hill River.

PART II.

BIRDS.

By S. W. WILLISTON.

Plates V–VIII.

BIRDS.

By S. W. WILLISTON.

Remains of birds always have been and always will be the rarest of vertebrate fossils. From the habits of the great majority of species, together with the lightness and buoyancy of their bodies in the water, it is very evident that, even where they are abundant, they will not often fall into such positions that they will be fossilized. Although, with our present evidence, they first made their appearance in geological history as far back as the Jurassic formation, scarcely two score of valid species have thus far been discovered from the Mesozoic, and all of those, with one or two exceptions, are from the Upper Cretaceous formations.

The famous *Archeopteryx*, from the Jurassic of Solenhofen, the earliest bird known, has long been renowned for its strange mingling of reptilian and avian characters. With the wings imperfectly developed, there were long reptilian fingers with claws, adapted for seizing and grasping. The jaws were provided with well-developed teeth, and the tail was elongated as in reptiles, each individual vertebra provided with a pair of long feathers.

The famous footprints of the Connecticut Triassic sandstone were, for a long time, supposed to have been made by birds. More recent discoveries of the remarkable reptiles known as Dinosaurs have shown that it was not only possible, but very probable, that all of them were made by these animals and none by birds.

From the Lower Cretaceous no bird remains are yet known. From the Upper Cretaceous, aside from the footprints noticed below, the only remains yet known in America are from the Green Sand of New Jersey, the Niobrara Cretaceous of Kansas,

and the Fox Hills Cretaceous of Wyoming. *Laopteryx*, the supposed bird from the Jurassic of Wyoming, was founded upon very incomplete remains, and is, in all probability, not a bird, but a small Dinosaurian reptile.

Twenty species of birds have been described from the American Cretaceous, the larger number of which are from the Kansas Cretaceous. Not a few of these are based upon very slight material, and it is not at all improbable that future fortunate discoveries will unite some of these and at the same time add new forms to the number already known.

Bird remains, in Kansas, are, as elsewhere, among the rarest of the vertebrate fossils. One is likely to search weeks, and even months, without finding a single bone, even fragmentary. Among the thousands of specimens of vertebrates that have been collected in Kansas, not more than 175 of birds, of all kinds, have hitherto been discovered.

BIRDS OF THE NIOBRARA CRETACEOUS.

The first specimens of birds known from Kansas were obtained by the expedition of Professor Marsh in 1870. In the following year a much more complete specimen of a *Hesperornis* was obtained by another expedition in charge of Professor Marsh, and, in 1872, still other specimens.

By far the most important specimen of these early years, if not the most important of all those succeeding, as well as the one from which the discovery of the dentition was made, was one discovered by the late Professor Mudge, and sent by him to Professor Marsh. It was found by him near Sugar Bowl Mound, in northwestern Kansas, in 1872, and was first described by Marsh in October of that year under the name *Ichthyornis dispar*.

An incident related to me by Professor Mudge in connection with this specimen is of interest. He had been sending his vertebrate fossils previously to Professor Cope for determination. Learning through Professor Dana that Professor Marsh, who as a boy had been an acquaintance of Professor Mudge, was interested in these fossils, he changed the address upon the

box containing the bird specimen after he had made it ready to send to Professor Cope, and sent it instead to Professor Marsh. Had Professor Cope received the box, he would have been the first to make known to the world the discovery of "Birds with Teeth." (See Addenda to Part I.)

During the succeeding years, the large collections of birds from this state were made for Professor Marsh by Mudge, Brous, Cooper, Guild, F. H. Williston, and the writer. Other bird remains have been obtained by Sternberg and Martin. In the University of Kansas museum there are portions of some twelve or more birds, including one specimen of a *Hesperornis*, much the most complete and perfect of any hitherto discovered. They apparently do not represent any new species or new forms, though not all agreeing with those described by Marsh.

In the present paper it is not worth while entering into any detailed description of these forms, inasmuch as the very complete and richly illustrated monograph of Professor Marsh[26] must remain indispensable to all those who wish to obtain more complete information.

The following list includes all the known species of birds from the Kansas Cretaceous, based upon fossil remains:

RATITÆ—Odontolcæ.

Hesperornis.

Marsh, Amer. Journ. Sci., III, 56, Jan., 1872.

H. regalis Marsh, Amer. Journ. Sci., III, 56, 1872.

This species is the best known and the most common of all the species from the Kansas Cretaceous. Practically the complete skeleton is known. See pl. VI.

H. crassipes Marsh, Amer. Journ. Sci,, XI, 509, June, 1876 (*Lestornis*).

This species was discovered by Mr. G. P. Cooper, and collected by the present writer from the yellow chalk of Plum creek, in Gove county, Kansas. It is peculiarly characterized by the presence of a rugosity on the posterior outer side of the tarso-metatarsal, above its mid-

26. Odontornithes; a Monograph of the Extinct Toothed Birds of North America. By Othniel Charles Marsh. New Haven and Washington, 1880.

dle, as though for a spur. The specimen, which comprises a considerable portion of the skeleton, was first described as the type of the genus *Lestornis*. Marsh, later, thought that the roughening might be a sexual character.

H. gracilis Marsh, Amer. Journ. Sci., XI, 510, 1876.

This species, of smaller size than the preceding, is known from the nearly complete skeleton, according to Marsh, but has never been adequately described.

Baptornis.

Marsh, Amer. Journ. Sci., XIV, 86, July, 1877.

B. advenus Marsh, Amer. Journ. Sci., l. c., 1877.

The type specimen, upon which this species and genus were based, was collected by a member of the writer's party in the yellow chalk. The generic difference is chiefly based upon the small size of the outer metatarsal.

CARINATÆ—Odontotormæ.

Ichthyornis.

Marsh, Amer. Journ. Sci., IV, 344, Oct., 1872.

I. dispar Marsh, l. c., 1872.

The type specimen of this species was discovered, as already explained, by Mudge in 1872. It is, perhaps, the most complete specimen of this group that has ever been found, and the first of any known birds that showed the presence of teeth in the jaws. The teeth were first described as belonging to a reptile, by Marsh, in the Amer. Journ. Sci. for November, 1872, under the name *Colonosaurus mudgei*. The species is at present known from nearly the complete skeleton.

I. agilis Marsh, Amer. Journ. Sci., V, 230, 1873 (*Graculavus*).

This species was based on very imperfect material discovered by Marsh in 1872, and has never yet been adequately described or figured, so that its determination, save by comparison with the type, will be more or less doubtful.

I. anceps Marsh, Amer. Journ. Sci., III, 364, May, 1872 (*Graculavus*).

The type specimen, from the North Fork of the Smoky Hill river, has never been figured.

I. tener Marsh, Odontornithes, p. 198, 1880, pl. xxx, f. 8.

Discovered by Mr. E. W. Guild, on the Smoky Hill river, in 1879.

I. validus Marsh, Odontornithes, p. 198, ff. 11, 14.

Discovered by myself on the Solomon river, in 1877.

I. victor Marsh, Amer. Journ. Sci., XI, 511, June, 1876.

The type specimen was discovered by Dr. H. A. Brous on the Smoky Hill river. Forty other specimens are referred by the author to the same species.

Apatornis.

Marsh, Amer. Journ. Sci., v, 162, Feb. 1872.

A. celer Marsh, Amer. Journ. Sci., v, 74, Jan. 1872 (*Ichthyornis*).

The type specimen was discovered by Marsh in 1872. A more perfect specimen was found later by my brother, Mr. F. H. Williston, in 1877.

The systematic position of the toothed birds from Kansas is by no means yet settled. All ornithologists are, however, agreed that they do not form a separate group, and the name Odontornithes is in consequence generally abandoned. The value of the teeth is subordinate; they do not in themselves justify a separate subclass.

Hesperornis regalis, the best-known species of the genus, was a bird measuring about six feet from point of bill to the tip of the feet when outstretched, or standing about three feet high. It was an aquatic bird, covered with soft feathers, wholly wingless, the rudimentary wing bones doubtless being inclosed under the skin, and not at all effective in locomotion. The legs were strong and moderately long; the neck long and flexible. The bill was long, and was provided with small but effective conical teeth set in the jaw firmly. Those of the upper jaws were few in number and set in the back part, while those of the mandibles

formed a complete series. The jaws were united in front by cartilage only, permitting considerable mobility, which was doubtless very serviceable in swallowing their prey, which must have consisted of fishes caught by diving. The bones of the body were solid throughout, not hollow, as in almost all living birds. The sternum had no keel, as in the flying birds and those descended from flying birds, but was as in the ostrich. The vertebræ and skeleton, aside from the teeth, were not unlike those of modern birds, and, were the skull yet unknown, would be unhesitatingly referred to the subclass to which the ostrich, cassowary and rhea belong. A specimen now in the University museum, collected by Mr. H. T. Martin recently, is remarkable in showing the scuta of the tarso-metatarsal region, together with the feathers. A photographic reproduction of this part of the specimen is shown in pl. VIII. I have sketched in the tarso-metatarsal bone, to show its position. Indications of feathers are also seen on the back portion of the head, and everywhere they appear to be more plumulaceous than the ordinary type of feathers.

In pl. VI is shown the restoration of *Hesperornis regalis*, after Marsh, together with figures of the jaws and of the teeth (pl. VII). It may be added that the birds were of a low degree of intelligence, as proven by the small size of the brain.

Ichthyornis was as different from *Hesperornis* as a dove is from an ostrich. While in *Hesperornis* the wings were rudimentary and the breast-bone without a keel, in *Ichthyornis* the wings were large and powerful and the keel well developed. All the members of this group were small, none perhaps much larger than a dove. The bones were hollow, as in most recent birds. The jaws had teeth, like those of *Hesperornis*, and the birds doubtless fed upon fishes or other small animals. The most peculiar character was, however, the structure of the vertebræ. In all recent birds, as also in *Hesperornis*, the vertebræ have a peculiar articulation, which permitted ample flexure in all directions. The articulation is what is called reciprocal motion, or the saddle-shaped articulation, found, for instance, to a moderate extent in the vertebræ of the human neck. In this

articulation the end of the centrum has the surface concave in one direction and convex in the other, corresponding to similar but reversed concavity and convexity in the adjacent surface of the contiguous vertebræ. In *Ichthyornis* this peculiarity was almost wholly wanting, the two ends of the centrum being nearly alike and gently concave in the middle. This concavity is not nearly so deep as in fish vertebræ, but is nevertheless of that type, which suggested the generic name from *ichthyos*, fish, and *ornis*, bird. In other respects *Ichthyornis* did not differ notably from the common flying birds of the present time. Among recent birds the tern seems to approach *Ichthyornis* most closely, due, doubtless, to similar modes of life. In pl. VII will be seen the vertebræ and jaws of *Ichthyornis*, after Marsh.

Because *Hesperornis* was a swimming bird and *Ichthyornis* a bird of powerful flight, skimming over the waters after the manner of the petrel, they have been more subject to fossilization than the strictly land-inhabiting birds were. Certainly there were many other species and genera of birds in existence at the time when these lived, since the great difference between the two forms could not have been attained without the development of many other forms. Of these, however, we have very few or no remains. Whether all birds contemporary with them were toothed or not it is impossible to say, but the probability is that they were.

In pl. V a restoration of *Hesperornis* as in life is shown, as drawn by Mr. Prentice, under my direction. Of course the coloration is largely conjectural; it is that indicated by living birds of similar habits.

BIRD TRACKS FROM THE DAKOTA CRETACEOUS.

The Dakota Cretaceous in Kansas has yielded many impressions of leaves, but no vertebrate remains of any kind have so far been discovered either in Kansas or elsewhere, save impressions or casts. A record of footprints from this formation was first made by Prof. B. F. Mudge, in 1866, and a later one by Prof. F. H. Snow. I give below the descriptions by both of these writers, in completion of the knowledge of this group of vertebrates from Kansas.

The following is by Professor Mudge:[27]

"In returning recently from an examination of the salt deposits of the Republican valley, we obtained a slab of sandstone, *in situ*, containing four impressions, and, at least, two varieties of fossil footmarks (Ornithicnites). Although the number is small, and the prints not in the best state of preservation, yet the specimens are valuable as showing a new point in the distribution of such fossils.

"The locality at which the tracks were found is on the southwesterly bank of the Republican river, about fifty miles from the mouth. The sandstone here rises from below the bed of the river in a bluff over 125 feet. The stratification is not very regular; in many cases showing an unconformable deposit, such as is frequently seen where sand is deposited in shoal water by varying currents. . . . The slab containing the tracks was found near the highest point of the bluff, on a projection within a hundred yards of the river. It is much weathered, which injures the distinctness of the footmarks.

"SPECIES 1. *Track number C.* Divarication of the lateral toes, 65°; of the inner and middle toes, 35°; of the middle and outer toes, 35°; length of the inner toe, 3.75 inches; of the middle toe, 5.1; of the outer toe, 3.75; of the foot, 5.5; distance between the tips of the lateral toes, 4.1; projection of the middle toe beyond the others, 2.1.

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27. Discovery of Fossil Footmarks in the Liassic (?) Formation in Kansas, Amer. Journ. Sci. XLI, 174, 1866.

"SPECIES 2. *Track number A.* Divarication of the lateral toes, 65°; of the inner and middle toes, 35°; of the middle and outer toes, 35°; length of the inner toe, 2.6 inches; of the middle toe, 3.5; of the outer toe, 3.1; of the foot, 3.75; distance between the tips of the lateral toes, 3.2; between the inner and middle toes, 3.1; between the middle and outer toes, 2.2; projection of the middle toe beyond the others, 1.2 inches.

"Track number B appears to be the left foot of the bird which made number A, as the angle and length of the toes are the same; but the position of the inner toe standing so far back of the others throws some doubt upon it. Number D may be the track of still another species, or it may belong to species 1; it is so indistinct that we cannot decide upon this point." The letters refer to the four different impressions upon the slab.

Later Mudge was led to believe that these prints were the result of Indian work.

In the Transactions of the Kansas Academy for 1888, p. 3, Prof. F. H. Snow described more fully and figured a footprint from the Dakota as follows:[28]

"During the past two years Mr. E. P. West has been assisting the writer in the collection of geological specimens for the University cabinets. In the month of August, 1885, he was so fortunate as to discover, near Thompson's creek, in Ellsworth county, Kansas, a single well-marked impression, which I believe to be a genuine bird track. The piece of rock containing the impression was picked out from a pile of material which had been removed from a well excavation forty-four feet in depth. This well was sunk in the Dakota sandstone, and the geological horizon of the bird track is about 200 feet below the upper level of the Dakota rocks. The horizon of the bird track appears to be identical with that of a fine series of dicotyledonous leaves obtained on Thompson's creek, at a distance of about a mile and a half from the well.

"The impression appears to have been made by the right foot of some bird with elevated hind toe just reaching the ground at its extremity, as in the modern snipes and other wading

28. On the Discovery of a Fossil Bird Track in the Dakota Sandstone.

FIG. 2.
BIRD TRACK FROM DAKOTA SANDSTONE.

birds, or in the family of sea-gulls and terns. That the track is probably that of the right foot, rather than the left, is indicated by the wider separation of the outer toe from the middle toe, resulting from the greater versatility of the outer toe as compared with the inner toe, a character illustrated in many families of existing birds, and carried to an extreme in the cuckoos and the woodpeckers, in which the outer anterior toe is entirely reversed in its direction and becomes a backward-pointing member." (See opposite page.)

"It will be seen, from the accompanying cut, that our bird track exhibits the imprint of all four of the toes. The outer anterior toe is represented for fully two-thirds of its length. The middle and inner anterior toes are entirely impressed, even to the claws at their extremities — the claw being very distinctly marked upon the middle toe. The ball of the foot has left a very deep impression, and the posterior toe has made an unmistakable imprint upon the sand similar to those made at the present time by birds whose hind toes just reach the ground. That this impression is avian in character, rather than reptilian, is evident from the imprint of the hind toe, for no dinosaur or other reptile, either recent or extinct, is known to have a backwardly directed toe. . . . The small size of our Dakota track is a confirmatory indication of its avian character. It measures only two inches from anterior middle claw to claw of posterior toe, being a little larger than the foot of Prof. O. C. Marsh's *Ichthyornis victor* as restored by him in his famous monograph of the Odontornithes."

The slab on which were the prints described by Mudge was left at the Agricultural College. In the general neglect of Mudge's collection, after his connection with the institution ceased, the specimen has been lost. The specimen described by Snow is now preserved in the University of Kansas museum. The description and figure given by Snow describe the specimen sufficiently well. I agree with him in his conclusions. The print is in all probability that of a bird.

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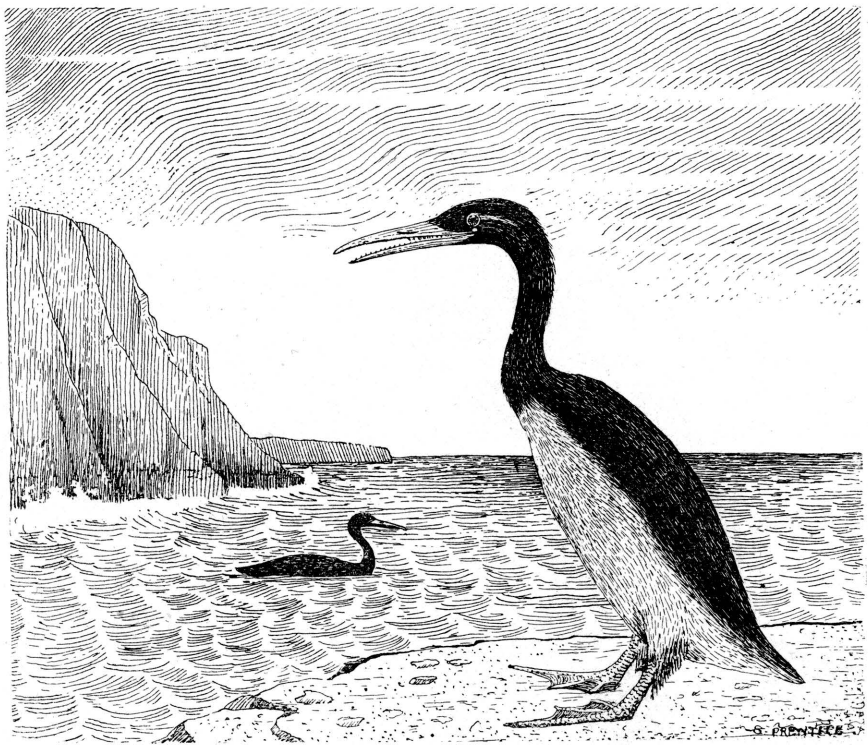
EXPLANATION OF PLATES.

PLATE V.—Life restoration of *Hesperornis regalis* Marsh. Drawn by Sydney Prentice.

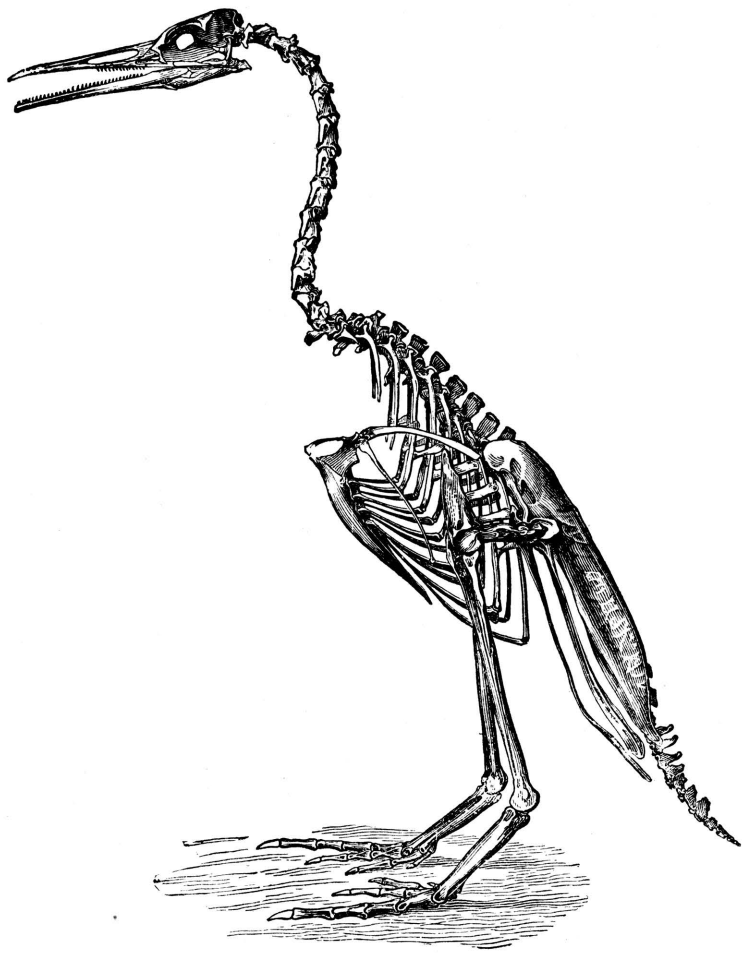
PLATE VI.—Skeleton of *Hesperornis regalis* Marsh. After Marsh.

PLATE VII.—Figs. 1, 2, jaws of *Ichthyornis dispar* Marsh, twice natural size; 3, 4, cervical vertebra of same, twice natural size; 5, 6, mandible of *Hesperornis regalis* Marsh, half natural size; 7, 8, vertebra of same, natural size; 9, tooth of same, much enlarged. All after Marsh.

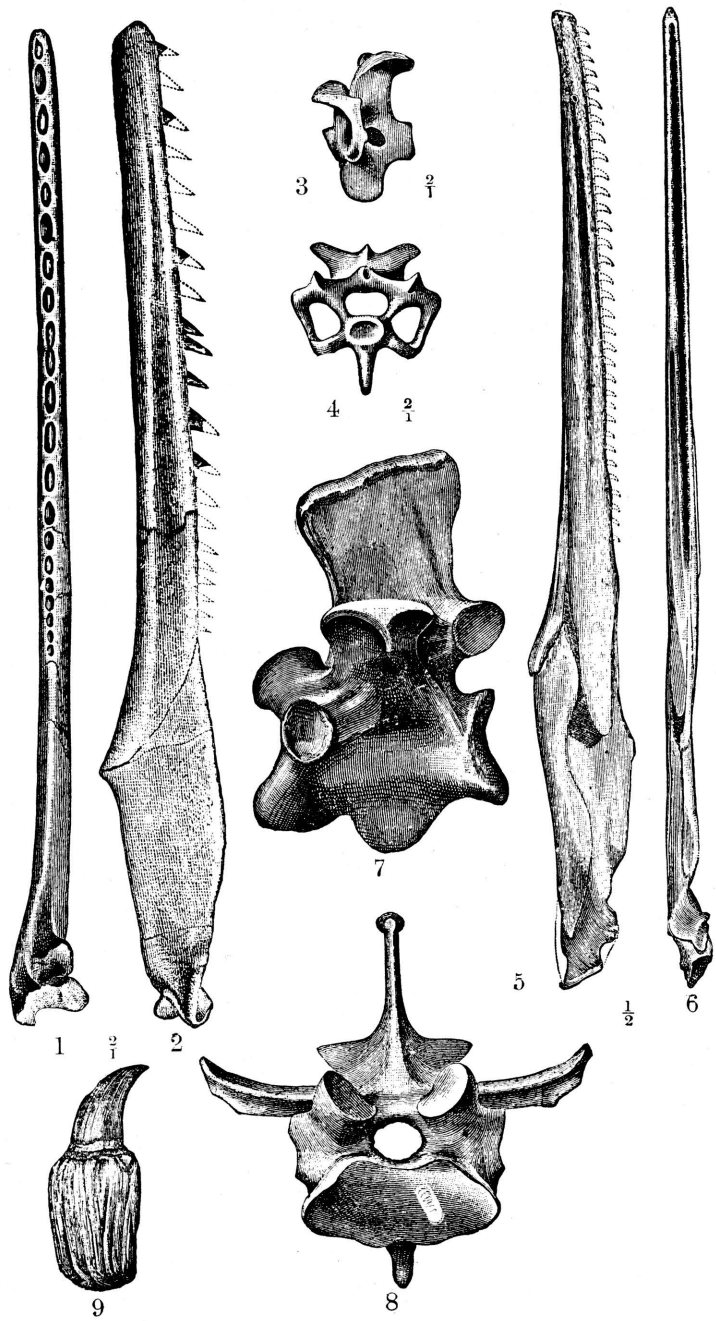
PLATE VIII.—Photograph of scutes and feather impressions of the tarsal region of *Hesperornis* species, from a specimen in the University of Kansas museum. Enlarged.



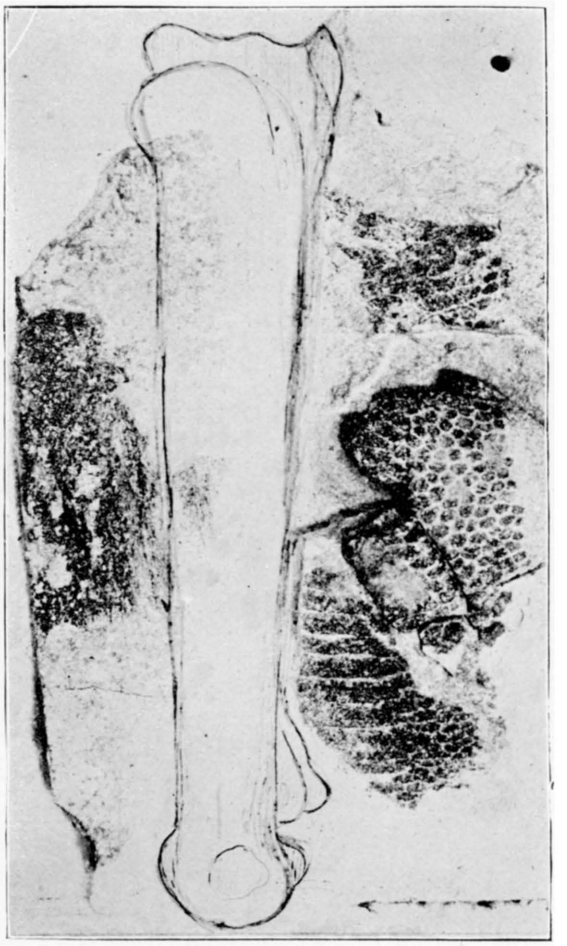
RESTORATION OF *HESPERORNIS REGALIS* MARSH.
About one-fourteenth life size.



SKELETON OF *HESPERORNIS REGALIS*.
About one-eighth life size.



HESPERORNIS, ICHTHYORNIS.



TARSAL SCUTES AND FEATHERS OF *HESPERORNIS*.
Enlarged one-fourth.

PART III.

DINOSAURS.

By S. W. WILLISTON.

Plate IX.

DINOSAURS.

By S. W. WILLISTON.

The group of Dinosaurs comprises the largest land animals that have ever existed, in some cases reaching such enormous proportions as to be almost incredible. In size and structure they are exceedingly diverse, and of course they varied also greatly in their habits. The smallest were perhaps not much larger than a cat, while the largest reached a length of over sixty feet and a height of fifteen or sixteen Unlike the reptiles of the present day, none were crawling animals; they walked erect, either on two feet, after the manner of a kangaroo, which they resembled not a little in form, or upon all four feet, as a quadruped. In all cases, however, the front legs were smaller than the hind ones, and, in the bipedal kinds were as small in proportion to the hind ones as those of a kangaroo are. It is not known what kind of a skin they possessed, but in all probability it was bare, without scales or bony plates, save in a few forms where the body was covered in a large part, perhaps wholly, by bony plates and spines. While the Dinosaurs were in many respects the most specialized of the reptiles, of a higher order of structure than any now living, they were, for the most part, animals of a low order of intelligence. In fact, in some of the very largest forms the brain was very slightly developed, an animal of twenty tons weight or more having a brain no larger than one's double fist. Some of the smaller species were exceedingly delicate in structure, having bones more hollow and light than is the case with any birds known. On the other hand, many of the larger forms were massive and heavy, with thick, solid, heavy bones. Such may have been amphibious in habit, living in marshes, lakes, and rivers, and feeding upon the succulent aquatic vegetation. They were, however, in all cases strictly land animals, never having the limbs in the least

adapted for swimming. In some there are extraordinary developments of horns, plates and spines upon the body and head. A skull of one immense kind, now represented in the University museum, had a pair of horns over three feet in length on the top of the head, and another a foot long over the nose. This skull is seven feet in length, about five feet in width, and as many in height. The thigh bone of the largest species of Dinosaurs, from Wyoming, was over six feet in length, and weighed, as petrified, over 1100 pounds. The bipedal forms were usually of lighter structure, and must have been quicker and more fleet in their movements, probably progressing by long strides and leaps, and it is not at all improbable that some of the smallest, hollow-boned kinds were arboreal in their habits, living among the branches of trees, or perhaps about cliffs and promontories. Many of the bipedal forms, both large and small, were carnivorous in habit, having long, sharp and cutting teeth, which must have been exceedingly formidable weapons. The very largest were herbivorous, as were also many of the smaller ones.

The Dinosaurs ranged in time from the Triassic to the close of the Cretaceous, some of the most remarkable and extraordinary types occurring in the Laramie Cretaceous. In geographical distribution they seem to have occurred over the entire earth, with the possible exception of Australia, where none have yet been found.

Being land animals, their remains must of course occur with great rarity in marine formations, and, inasmuch as nearly all of the Kansas Cretaceous deposits are marine, they can never be expected to be found here in numbers. In fact, but one single specimen has ever been found in the state, so far as I am aware, though the animals must have lived here about the shores of the Cretaceous seas in great abundance.

In their classification there is not a unanimity of opinion among paleontologists. Many hold the opinion that they constitute a distinct subclass of reptiles, equivalent in the importance of their characters to all the other reptiles combined. Be this as it may, they are by general consent classed in three

distinct groups: the Sauropoda, Theropoda and Predentata of Marsh. Other names may be eventually chosen in the place of these.

The Theropoda comprise bipedal carnivorous forms of more slender constructions and hollow bones, and were among the earliest of the known Dinosaurs. The Sauropoda were the most massive, with the fore legs only a little smaller than the hind ones, and were quadrupedal in habit. They were all herbivorous and probably amphibious. Their limb bones were solid. The Predentata were herbivorous in habit, and either bipedal with hollow bones or more or less quadrupedal and the bones solid. They included three subdivisions: The Stegosauria, with solid bones and small fore limbs, but not walking erect, the body covered with large bony plates and spines; the Ceratopsia, with solid limb bones and extensive horns on the head, their habit quadrupedal; and the Ornithopoda, animals resembling in form the Theropoda, but herbivorous, with solid or hollow bones, and without dermal armor.

The last of these subdivisions includes the only known form from Kansas. The single Dinosaur specimen known from Kansas was discovered by Professor Marsh in 1872, in the Niobrara chalk[29] of the Smoky Hill river, and named *Hadrosaurus agilis* by him.[30] Allied kinds were discovered later in the Laramie Cretaceous by Mr. J. B. Hatcher, and described by Marsh under the generic name of *Claosaurus*, which he proposed for the Kansas species in 1890.[31]

The characters he gave for the genus are as follows: "Premaxillaries edentulous; teeth in several rows, but a single row only in use; cervical vertabræ opishthocœlian; limb bones solid; fore limbs small; sternal bone parial; post pubis incomplete; sacral vertebræ, nine; femur longer than tibia; feet ungulate; three functional digits in manus and pes."[32]

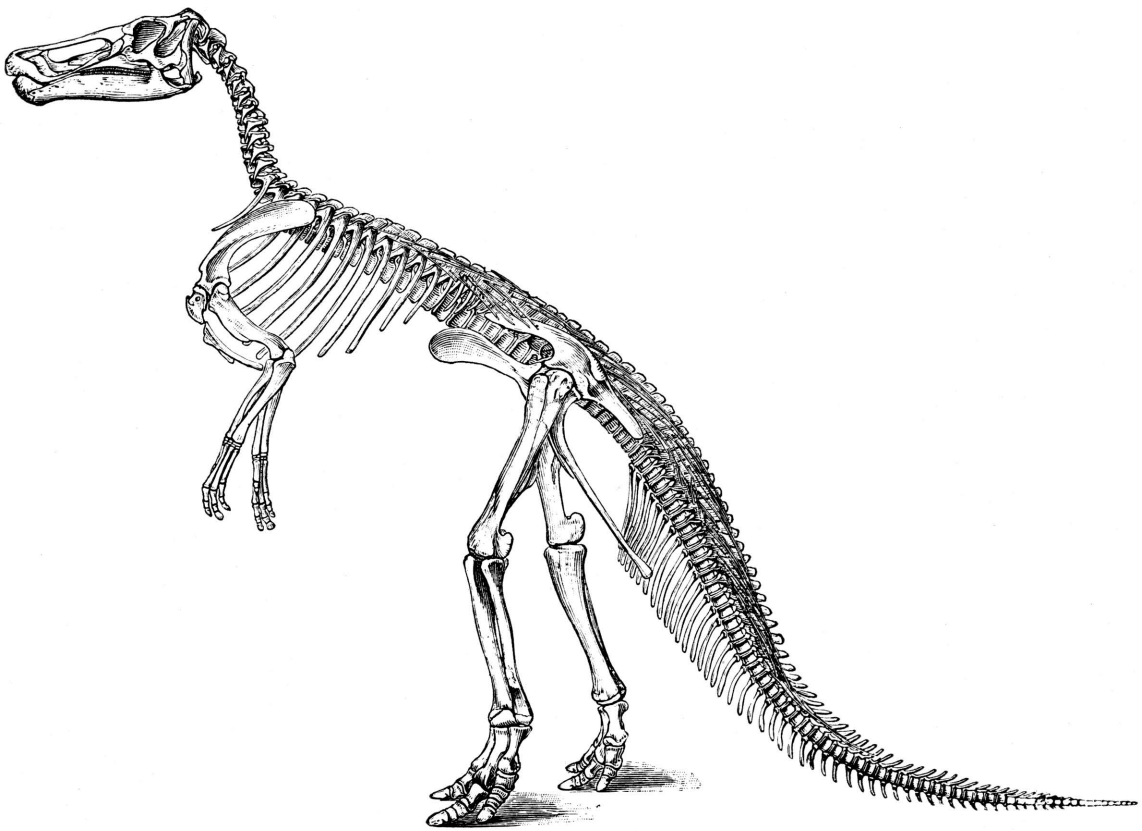
29. It is not impossible that the horizon was Fort Pierre, since the distinction between Pierre and Niobrara was not known to Marsh.

30. American Journ. Sci., April, 1872.

31. American Journ. Sci.

32. Sixteenth Ann. Rep. U. S. G. S., 244.

In pl. IX is given a reproduction of *Claosaurus annectans* Marsh, a Wyoming species, but so closely allied to *C. agilis* that it will show sufficiently well the form and structure of the Kansas species. It is after Marsh.



CLAOSAURUS ANNECTANS MARSH.

PART IV.

CROCODILES.

By S. W. WILLISTON.

CROCODILES.

By S. W. WILLISTON.

The Crocodiles, inclusive of the Gavials and Alligators, are the highest type of reptilian life now existent upon the earth. It is almost impossible to state the number of species now living, since authors are not agreed as to what the valid species are, but they are found in nearly all the tropical and subtropical regions of the earth. They include three distinct types or groups: the Crocodiles, Alligators, Gavials or Gharials. The last group is confined at the present time exclusively to the rivers of the interior of India, in the hottest regions. They are distinctly more aquatic in their nature than are the other forms, and are especially characterized by the great elongation and slenderness of their snout, armed with many sharp teeth.

The Crocodiles are much more extensive in their range, occurring in India, Africa, Australia, and the tropical parts of America. The head is broad and flat, the jaws are shorter and rounded in front, and the powerful teeth are irregular in size. The Alligators are much more nearly like the Crocodiles than the Gavials. Their head is broad and flat, as in the Crocodiles. They may be distinguished by the large tooth of the lower jaw, sometimes called the "canine." It is received into a pit or socket on the upper jaw, and is not visible when the mouth is closed, while in the Crocodiles it passes in a groove on the outside and is visible when the mouth is closed. The teeth of the Alligator are received on the inner side of the upper ones instead of between them, as in the Crocodile. The Alligators, with one exception, which occurs in China, are confined to the southern part of North America and the northern part of South America.

Both the Crocodiles and Alligators are more amphibious in habit than are the Gavials, and their teeth are better adapted

for the seizure of mammals than the slippery fishes that the Gavials seek.

The earliest fossil Crocodiles are found in rocks of Triassic age in both Europe and North America. These early types, however, are of a much more generalized kind than are the modern ones. These Triassic forms are more like the Gavial in shape, but the vertebræ are not concavo-convex as in the modern, but biconcave, and this peculiarity of the vertebræ continues into the Cretaceous and nearly through it, when the modern type of vertebræ takes their place.

The order is divided into three different suborders, based upon the structure of the head, especially the palatine bones and the nasal openings and the structure of the vertebræ. The first, Parasuchia, includes the earliest types, such as *Belodon*, and had amphicœlian vertebræ. The second, the Mesosuchia, have also biconcave vertebræ, and included the Jurassic and most of the Cretaceous forms. The third, the Eusuchia, with procœlian vertebræ, is the modern type.

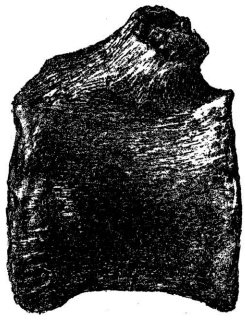
But two crocodilians have been described from Kansas, both Mesosuchian, with a long, gavial-like head. Both are known only from very scanty materials, so that it is difficult to say much about them. The older one was described—but not named—by me from the Lower Cretaceous of Clark county as follows:[33]

"A single vertebra, wanting the neural arch, but otherwise well preserved, I refer somewhat doubtfully to *Hyposaurus* or a closely allied form. It has the articular surfaces nearly flat, with the rims sharp; the body is gently concave on the sides and below, from in front back, and with striæ near each rim for about half an inch. The surface elsewhere is smooth and even, without venous foramina. A transverse section through the middle would give the greater part of an elliptical figure, with the lower side somewhat flattened. Only the base of the pedicels is present, and there is no indication of a sutural union. Springing from them, or possibly from the body itself produced above to meet the arch, there is, on each side, a stout transverse

33. Kansas Univ. Quart., III, p. 3, pl. I, ff. 4, 5.

FIG. 3.

FIG. 4.



process, the base only of which is present, but which appears to be short. In shape and appearance the centrum agrees well with one of *Hyposaurus rogersii*, from New Jersey, except in its more cylindrical shape. Its measurements are as follows:

Length of centrum	40mm.
Transverse diameter of articulating face	50 "
Vertical diameter of same face	38 "

"The upper end of a femur (f. 3) found in the same region, and from near the Red Beds, appears to belong to the same kind of an animal as does the vertebra described above. The shape is not unlike that of a human femur, with the trochanters evidently small and placed much below the level of the head. The neck is stout, the head gently convex, with an angular border. The shaft below the trochanters is somewhat flattened from be-

fore back, but becomes more transverse below. The shaft is hollow, with firm walls, not more than one third of an inch in thickness. The portion preserved measures 210mm.''

From the Upper Cretaceous of Kansas there has been but a single species of Crocodile described, and I am not aware that there has ever been any other bones of these animals discovered than the single vertebra which served as the type of this species. Its horizon is the Benton, and the description by Cope is as follows:

Hyposaurus vebbii Cope.

Proceedings of the Amer. Phil. Soc., 1872, p. 310.

''An anterior cervical vertebra presents the following characteristics. It is that one in which the parapophysis occupies a position opposite the lower third of the vertical diameter. Its centrum is stout in form; the articular faces but little concave; the posterior a little more so than the anterior. The anterior is almost regularly hexagonal; the posterior subround, a little deeper than wide. The inferior surface possesses a strong, obtuse, median carina, which disappears in front of the posterior margin. Anteriorly, it terminates in a short, obtuse hypapophysis. The suture of the neural arch is very coarse. Surface of the bone smooth.

Measurements.

Length of the centrum	37mm.
Diameter of the centrum anteriorly:	
Vertical	32 "
Horizontal	31 "
Diameter of the centrum posteriorly:	
Vertical	32 "
Horizontal	31 "
Length of the surface of the parapophysis	15 "

''As compared with the *H. rogersii*, of the New Jersey Cretaceous, this vertebra is shorter and stouter, and the extremities less concave; the suture for the neural spine is much coarser.

''This Crocodile was discovered in a bluish stratum, encountered in digging a well in Brookville, Kan.''