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THE VERTEBRAL COLUMN OF *COELOPHYSIS* COPE

BY
E. C. CASE

UNIVERSITY OF MICHIGAN
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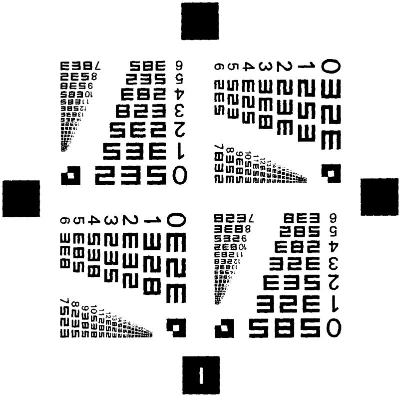

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CONTRIBUTIONS FROM THE MUSEUM OF GEOLOGY

UNIVERSITY OF MICHIGAN

Editor: EUGENE S. MCCARTNEY

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(Continued on inside of back cover)

THE VERTEBRAL COLUMN OF *COELOPHYSIS* COPE

E. C. CASE

In the summer of 1921 the author collected from the upper Triassic beds of Crosby County, Texas, the major portion of the presacral part of the vertebral column of a small dinosaur that appears to belong to the genus *Coelophysis* Cope. The bones were found in their natural position, but were unfortunately preserved in a very loose, crumbly clay that prevented their collection in the most advantageous manner. The bones had been somewhat crushed and rotted before fossilization and parts had become separated and the interspaces filled with a black matrix. This has compelled very long and tedious labor in fitting the fragments and assembling the parts. A preliminary description of the specimen, number 7507 of the Geological Museum of the University of Michigan, was given in Publication No. 321 of the Carnegie Institution of Washington, but the work has now gone so far as to warrant a more detailed description of the specimen.

In 1887 Cope described some fragmentary material from New Mexico and referred it to the genus *Tanystrophaeus;* later in the same year he referred the same material to Marsh's genus *Coelurus* and described three species, *bauri, longicollis* and *willistoni.* In 1889 he established the genus *Coelophysis* for the three species. The three species were established upon very fragmentary material from different parts of the body and are indistinguishable by the descriptions. No figures were published by Cope, but in 1906 Huene published figures made from plaster casts furnished him by the American Museum of Natural History. The specimen here described was identified by comparison

with Huene's figure of the cervical vertebrae of *C. longicollis* and will be referred to as *C. aff. longicollis*.

When the specimen was collected it was supposed that the matrix would retain the vertebrae in their natural position, but unfortunately much of it crumbled away and only a part of the series is in connection; the other vertebrae can, however, be placed with great certainty by their characters, so there is very little doubt of their position in the restoration offered.

The obviously striking thing about the vertebral column is the presence of elevated neural spines. Three vertebrae, reckoned as the eleventh, twelfth and thirteenth of the series, are in connection and have the spines complete (eleventh, thirteenth) or nearly complete (twelfth). Numerous fragments and incomplete spines show that the elevated condition continued throughout the post-cervical series and many of these have been placed in their, probably, correct places. A similar specialization in the dinosaurs has been reported by Huene for *Ctenosaurus* from the upper Triassic of Germany and by Stromer for *Spinosaurus* from the Cenomanian of Egypt.

There are 22 vertebrae in the recovered series; 15 is the largest number of dorsals reported in any Coelosaurian dinosaur. Accepting this number would leave 7 vertebrae in the preserved cervical series, but the author is somewhat in doubt on this point; the character of the vertebrae seems to indicate at least 16 for the dorsal series.

The *first* of the series (cervical 4 or 5) has lost the articular faces of the centrum and the left anterior zygapophysis. A fragmentary and detached posterior face of a centrum is tentatively assigned to this vertebra. It is the longest of the series. The anterior zygapophyses were long and strong with the articular faces nearly horizontal. The posterior zygapophyses show the peculiarity which is best represented in the third of the series. The two zygapophysial processes diverge at a rather large angle, the upper edge continuing as a sharp ridge to the posterior extremity of the zygapophyses; the articular face looks almost directly downward and the space between the zygapophyses has a thin floor, complete to the posterior edge, upon

which are developed two low ridges running nearly parallel to the zygapophyses. The vertebra is injured by decay in the mid-dorsal region, but it seems certain that the base of the neural spine was small.

The *second* vertebra (cervical 5 or 6) has the centrum complete, but the zygapophyses are lost except a portion of the right posterior one. From this it is apparent that the articular faces were still nearly horizontal. The anterior face of the centrum is injured, but the beginnings of the articular faces for the capitulum and tuberculum of the rib are clearly indicated. In this vertebra the characteristic unsymmetrical lower line of the centrum, with the posterior face lower than the anterior one, is

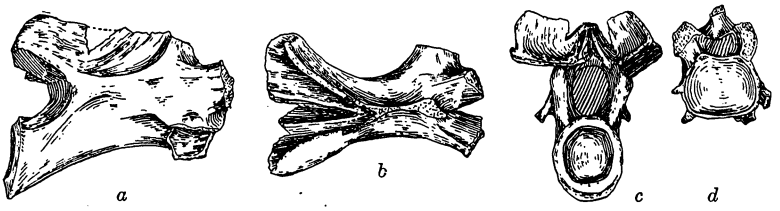


FIG. 1. The third vertebra of the series: *a*, lateral view; *b*, upper view; *c*, posterior view; *d*, anterior view. All figures $\times 1/2$

evident. The vertebra is injured by decay in the mid-dorsal region, but there is indication that the neural spine was still small.

There are present the apices of three spines which cannot be connected with any of the vertebrae; these are tentatively assigned to the anterior cervicals of the series. The upper ends are marked by deep antero-posterior grooves; the three fragments increase (or decrease) in size progressively. The smallest is regarded as probably belonging to the second vertebra.

The *third* vertebra (cervical 6 or 7) has the centrum and the posterior zygapophyses complete; the anterior zygapophyses are lost. The posterior zygapophyses show the peculiar character of the region especially well. The upper edges are elevated and extend nearly to the posterior end. The floor of the intermediate space is complete and the two low ridges are well preserved;

the best idea of the condition can be obtained from Figures 1 *a*, *b*, *c*, *d*. The process for the capitulum of the rib lies near the lower edge of the articular face of the centrum, the process for the tuberculum descends from the middle line of the centrum and the articular face reaches as far forward as the anterior edge of the face of the centrum.

The *fourth*, *fifth* and *sixth* vertebrae (cervicals 7, 8, 9 or 8, 9, 10) are fortunately in connection as it is in this region that the sudden shortening of the centra, which marks the beginning of the dorsal series, takes place.

The *fourth* vertebra is still elongate with the characteristic unsymmetrical form of the centrum. The anterior zygapophyses still run almost horizontally forward, but the articular face is inclined somewhat inward and upward. The posterior zygapophyses are incompletely preserved, but show the continued presence of the condition so clearly revealed in the preceding vertebra. The anterior end of the right anterior zygapophysis of the fifth vertebra is in contact with the posterior zygapophysis of the fourth, and the line of contact shows that the articular faces have become decidedly oblique in position. The process for the capitulum of the rib is now scarcely free from the edge of the centrum, but is still at the lower edge. The process for the tuberculum starts from a point posterior to the mid-line of the centrum and runs forward without descending very much; the articular face is free from the rim of the centrum. The neural spine is lost, but there is evidence of a strong base.

The *fifth* vertebra is noticeably shorter than those which precede it and the lower line of the centrum is more nearly symmetrical. The zygapophyses are in bad condition, but it is evident that they have entirely lost the peculiar characteristics of the preceding vertebrae and the articular faces have assumed the decidedly oblique position of the vertebrae which follow. The face for the capitulum of the rib is now a distinct facet on the edge of the centrum, but is still at the lower edge. The process for the tuberculum is a short but true transverse process; it originates from the middle of the centrum and extends forward and downward as far as the anterior edge of the centrum.

The base of the neural spine is preserved and shows the same characters as appear in the spines which are completely preserved. It is safe to assume that the elevated condition of the neural spines is fully established in this vertebra.

The *sixth* vertebra is decidedly shorter than those preceding it and the lower line of the centrum is symmetrical. The zygapophyses are turned sharply upward and the articular surfaces face almost directly inward and outward. The face for the capitulum of the rib is perhaps a little higher on the edge of the centrum than in the fifth and is supported by a strong ridge running back from it upon the side of the centrum. The transverse process now runs forward carrying the anterior zygapophysis upon its upper surface; below the zygapophysis it turns sharply outward, its articular face is still as far forward as the anterior edge of the centrum. The transverse process is still very short and the base is heavy, but the beginnings of the deep pits on all sides of its base, so characteristic of the vertebrae of the mid-dorsal region, are already apparent.

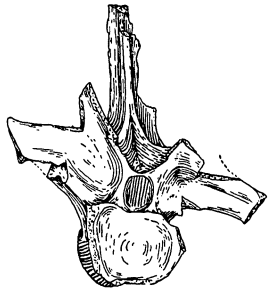


FIG. 2. Anterior view of the seventh vertebra of the series. × 1/2

The *seventh* vertebra (Fig. 2; possibly cervical 10) has the facet for the capitulum of the rib somewhat off the edge of the centrum and supported by a strong posterior ridge. The transverse process is still a continuum of the anterior zygapophysis, but is now longer, the distal end is anterior to the edge of the centrum in the specimen, but has probably been forced into this position by distortion; it could not have extended beyond the anterior edge of the centrum in the natural condition. A strong supporting ridge is present running from the base of the transverse process obliquely downward and backward to the posterior edge of the centrum. This vertebra has a nearly complete spine; its base is longer, antero-posteriorly, than thick, and is formed by four converging ridges originating from the inner (posterior) edges of the anterior zygapophyses and from the outer surfaces

of the posterior zygapophyses. These ridges continue up on the spine giving it a cruciform cross-section in its lower portion. Above the middle of the spine the anterior ridges die out and are replaced by a median ridge and the posterior ridges converge to form a single one, giving the upper part a somewhat oval cross-section. The apex is not preserved.

The *eighth* vertebra has the facet for the capitulum above the middle of the edge of the centrum. The transverse process is well developed and stands directly out from the middle of the neural arch. Its origin from four supporting ridges is well shown. Below, two ridges converge, one from the upper part of the anterior edge of the centrum and the other from the posterior edge. Above, the two ridges originate from the zygapophyses in the same manner as in the seventh vertebra. At the points where these ridges converge there are deep pits at the base of the transverse process. The spine of this vertebra is complete for about 4 centimeters above the base, the upper part is represented by a detached piece. The base is formed by ridges which converge from the zygapophyses as in the preceding vertebra. The two anterior ridges soon die out upon the surface of the spine, but between them there is a ridge on the anterior face of the spine which dies out below, between the zygapophyses, but above becomes the anterior edge of the spine. The posterior ridges are continued upward on the sides of the spine, gradually converging; between them a ridge is developed on the posterior edge of the spine which dies out below, but becomes the posterior edge of the spine above, so that a cross-section of the spine above the middle point is distinctly cruciform.

The *ninth* vertebra lacks the extremities of the transverse processes and the neural spine. The capitular face is near the upper level of the anterior rim of the centrum and is apparently beginning to form a distinct projecting process. The anterior zygapophysis is beginning to separate from the transverse process; a ridge on its outer surface is continued from the upper (anterior) edge of the transverse process. A similar ridge from the outer edge of the posterior zygapophysis forms the posterior (upper) edge of the transverse process. The lower face of the

process is formed, as before, by two ridges which converge upward from the anterior and posterior edges of the centrum. The pits between the converging ridges have now become very deep.

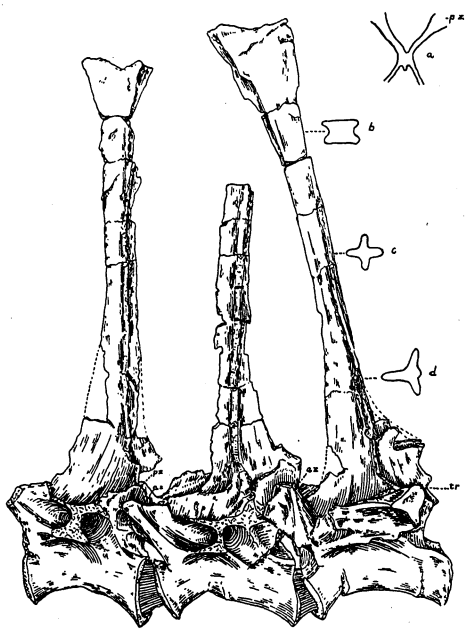


FIG. 3. Lateral view of the left side of the eleventh, twelfth and thirteenth vertebrae of the series: *a*, cross-section at the base; *b*, *c*, *d*, cross-sections at the points indicated. × 1/2

The *tenth* vertebra differs little from the ninth except that the face for the capitulum of the rib is borne upon a short but distinct stalk.

The *eleventh*, *twelfth* and *thirteenth* vertebrae (Fig. 3) are in connection.

The *eleventh* is the first of the series to have a complete spine. The centra have now begun to elongate again. The capitular face is indicated by a small but distinct surface on the upper angle of the anterior edge of the centrum; this is the last

vertebra to show such a face; posterior to this the ribs were all single-headed as is shown by several well-preserved rib heads. The transverse process is now long and well formed. All the supporting ridges are slender and sharp and the pits are very deep. The two lower supporting ridges have fused into a single one at their inner ends, giving the process a triangular section. The relation of the anterior zygapophyses to the transverse processes and the neural spine has changed decidedly; the ridge on the outer surface of the zygapophysis no longer runs to the anterior upper edge of the transverse process, but downward and backward until it joins the anterior lower supporting ridge. The ridge originating on the inner (posterior) edge of the zygapophysis no longer runs to the base of the spine, but to the anterior upper edge of the transverse process. The ridges from the posterior zygapophysis remain as before. The base of the spine is now formed in a different way and has a different cross-section. The anterior edge is formed by the thin ridge originating between the anterior zygapophyses and continuing up on the spine gradually broadening into a narrow face. The two ridges from the posterior zygapophyses form the outer posterior angles of the base of the spine, which has a distinctly Y-shaped cross-section, but gradually die out leaving a face notably wider than the anterior face. Both the anterior and the posterior faces become concave near the apex. The apex is widened antero-posteriorly, but is not thickened.

The *twelfth* vertebra has lost the upper half of the spine, the *thirteenth* has the apex somewhat larger than that of the eleventh; otherwise they show little change from the eleventh.

From the *fourteenth* to the *eighteenth* vertebra, inclusive, there is little change in form from the eleventh. There are sufficient fragments and incomplete spines with the apices attached to show that the elevated condition of the neural spines continued at least as far back as the eighteenth. The spine of the fifteenth is very probably in connection with the vertebra and is complete except for the extreme apex.

The *nineteenth* vertebra has the centrum somewhat heavier; this is the beginning of the notable increase in weight of the

posterior vertebrae. The zygapophyses here begin to change from the very oblique position, with the articular faces nearly vertical, to a more horizontal position; this change is progressive in the succeeding vertebrae and is complete in the twenty-second, the last presacral vertebra. Beginning with the nineteenth vertebra the supporting ridges of the transverse process change their relations in correlation with the changing position of the zygapophyses. The upper (posterior) edge of the anterior zygapophysis loses its connection with the transverse process and is again attached to the base of the neural spine; the ridge on the outer surface of the zygapophysis regains its connection with the transverse process. The transverse process becomes shorter and heavier and the pits at its base become more shallow.

FIG. 4. Anterior view of the twenty-first vertebra of the series. × 1/2

The *twentieth*, *twenty-first* and *twenty-second* vertebrae show a continuous progress in the characters noted above. In the twentieth the transverse processes are still long, but stand out nearly at right angles to the body of the vertebra; in the twenty-first the processes are notably shorter; in the twenty-second the processes have apparently disappeared, but this may be due, in part, to the condition of the specimen. Two detached spines have been tentatively assigned to the twenty-first and twenty-second vertebrae. That associated with the twenty-first (Fig. 4) is represented by the upper half only; the spine is thicker and evidently much shorter than those of the mid-dorsal series and the apex is much heavier. The spine associated with the twenty-second is nearly complete and can almost certainly be attached to this vertebra. The base is thin but elongate antero-posteriorly; the apex is larger than the preceding one and decidedly heavier.

Intercentrum. — A single intercentrum was found with the specimen; it is very thin and relatively broad antero-posteriorly; it apparently comes from the cervical region.

Ribs. — There is in the material a considerable quantity of fragments of ribs. Some fragments have been fitted together to form nearly complete ribs. There are two very incomplete ribs of extraordinarily large size; they are so disproportionate that the author long attempted to fit them to the vertebrae as distorted neural spines. From the scarcity of fossils in the beds and from the isolated position of the specimen there seems little doubt that these ribs belong with the other material, but aside from their bicipital condition, which indicates their position in the anterior part of the series, the author is at a loss to place them. There are four rib heads (Fig. 5) which show the bicipital condition. Two of these were found closely united and as they

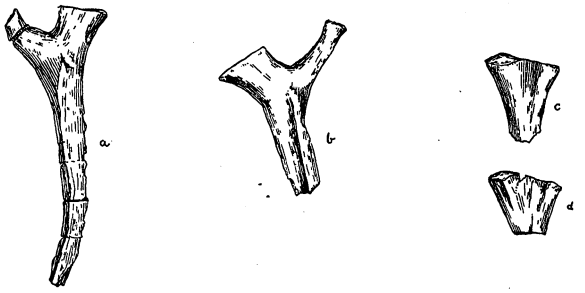


FIG. 5. Ribs: *a* and *b*, double-headed ribs of the cervical series; *c* and *d*, single-headed ribs of the dorsal series. × 1/2

are of the same size and from opposite sides it is probable that they are a pair. Their form is best shown by Figure 5 *a*. There are eight rib heads which are not divided into capitulum and tuberculum; one was found attached to the fourteenth vertebra in the natural position and has been left so in the prepared specimen. In all these rib heads there is a distinct division into capitular and tubercular portions, but the portions are united by thin but continuous bone.

The reconstruction shown in Figure 6 has been drawn as the vertebral column would appear in the semi-upright position. The frequent fracturing of the vertebrae and recementation by

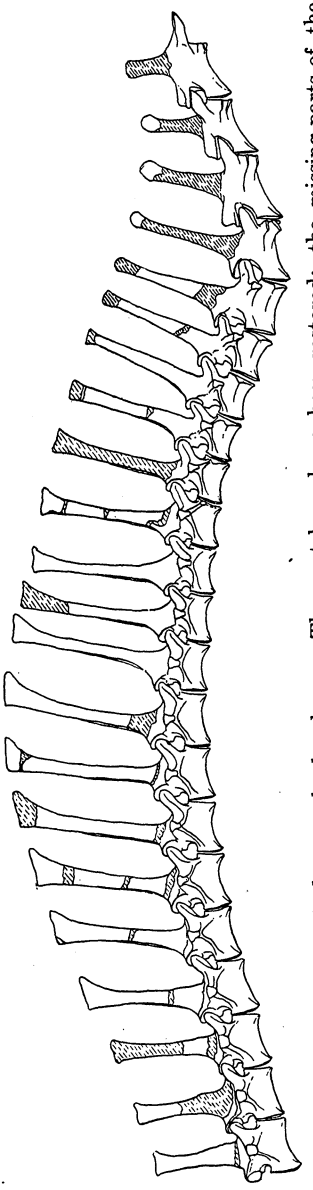


FIG. 6. Reconstruction of the vertebral column. The vertebrae have been restored; the missing parts of the spines are lined and the parts placed in probably correct position are detached. ×1/2

the matrix, the frequent loss of parts by decay or impossibility of fitting together all of the very large number of fragments, and the distortion of some of the bones, have rendered it impossible to indicate all the restored parts of the vertebrae, but the author believes that nothing in the drawing is unwarranted by actual evidence from one side or the other. The spines of the eleventh, twelfth and thirteenth vertebrae are actual fits and the parts are continuous; in most of the other vertebrae the spines have been placed where closely approximate fits or the character of the spine indicated that they belong. Only in the case of the apices of the second, third and fourth vertebrae has a doubtful assumption been made.

The measurements given below are taken along the chord of the lower face of the centrum. Some of the vertebrae have been distorted in the process of fossilization; these are rather obviously indicated by the lack of harmony in the figures. The general sequence in the change of length is easily seen.

Vertebrae	Cm.		Vertebrae	Cm.	
1st.....	incomplete		12th.....	3.6	
2nd.....	4.8		13th.....	3.75	
3rd.....	5.4		14th.....	4.35	distorted
4th.....	5.0		15th.....	3.85	
5th.....	3.4		16th.....	3.85	
6th.....	3.1		17th.....	4.10	distorted
7th.....	2.96		18th.....	4.40	distorted
8th.....	2.9		19th.....	4.00	
9th.....	3.4	estimated	20th.....	4.20	distorted
10th.....	3.1		21st.....	4.00	
11th.....	3.4		22nd.....	4.20	distorted

The Museum of Geology of the University of Michigan contains other remains of Triassic dinosaurs from the same locality and horizon as the specimen described above. Most of them can be referred to the same genus.

The posterior portion of a skull, No. 7473, University of Michigan, was described by the author in Publication 321 of the Carnegie Institution of Washington; as then suggested, it is very probable that this is the skull of the genus *Coelophysis*.

An ilium, No. 8870, University of Michigan, is very nearly the same size as that of *C. longicollis* Cope, as restored and figured by Huene, but is somewhat different in form. The general shape is best realized from Figures 7 *a* and 7 *b*. The distal end of the posterior process is very heavy, being 2.45 centimeters thick; the anterior process is relatively short. The interior crest is high, showing a strong attachment of the sacral ribs. The face for the ischium is heavy and nearly semicircular in outline. The face for the pubis is injured by decay. The depth of the acetabulum is 2.34 centimeters.

A large femur, No. 3396, University of Michigan, was described by the author in Publication 321 of the Carnegie Institution and referred to some unrecognized genus of dinosaur; its large size, 42.16 centimeters in length, precludes its reference to *Coelophysis*, but it may well be associated with some of the large teeth mentioned below.

There are four lots of caudal vertebrae in the collection, all from the mid- or posterior caudal regions. Two of these lots are of a form too large to be referred to *Coelophysis*, but the

other two lots may well belong to that genus. The first of these lots, No. 7277, University of Michigan, consists of three incomplete vertebrae of very elongate form and much reduced neural arches and zygopophyses. The second lot, No. 9805, University of Michigan, is a single very slender, elongate caudal

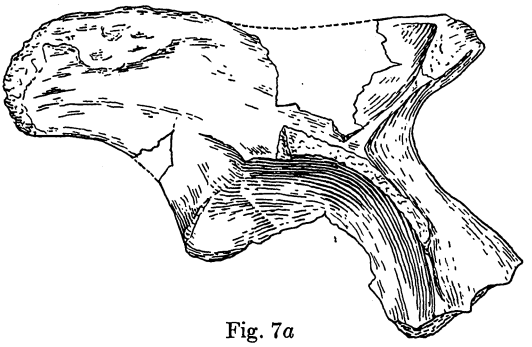


Fig. 7*a*

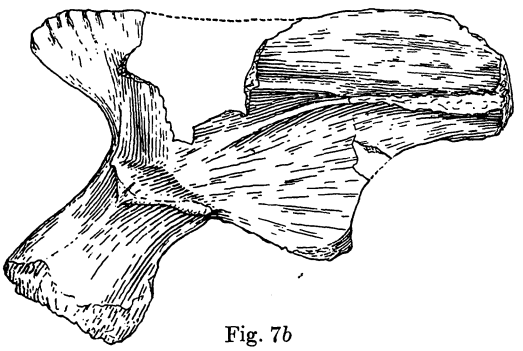


Fig. 7*b*

FIG. 7. Ilium, No. 8870, U. of M.: *a*, outer view; *b*, inner view. × 1/2

from near the posterior end of the series (Fig. 8). The zygapophyses are lost, but the neural canal is still open and of relatively good diameter. Length, 2.35 centimeters; height of the face of the centrum, 3.9 millimeters; breadth of the same face, 5.3 millimeters.

Teeth. — There are twenty-two teeth of dinosaurs in the collection. These are of very different size ranging from a

length of 7 centimeters, from the apex to the beginning of the root, and a maximum antero-posterior diameter of the base of 2.86 centimeters, to a length of 1.1 centimeters and a maximum diameter of the base of 0.37 centimeter. All these teeth have

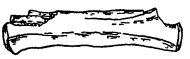


FIG. 8. A caudal vertebra, No. 9805, U. of M. ×1

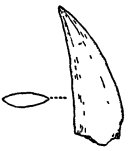
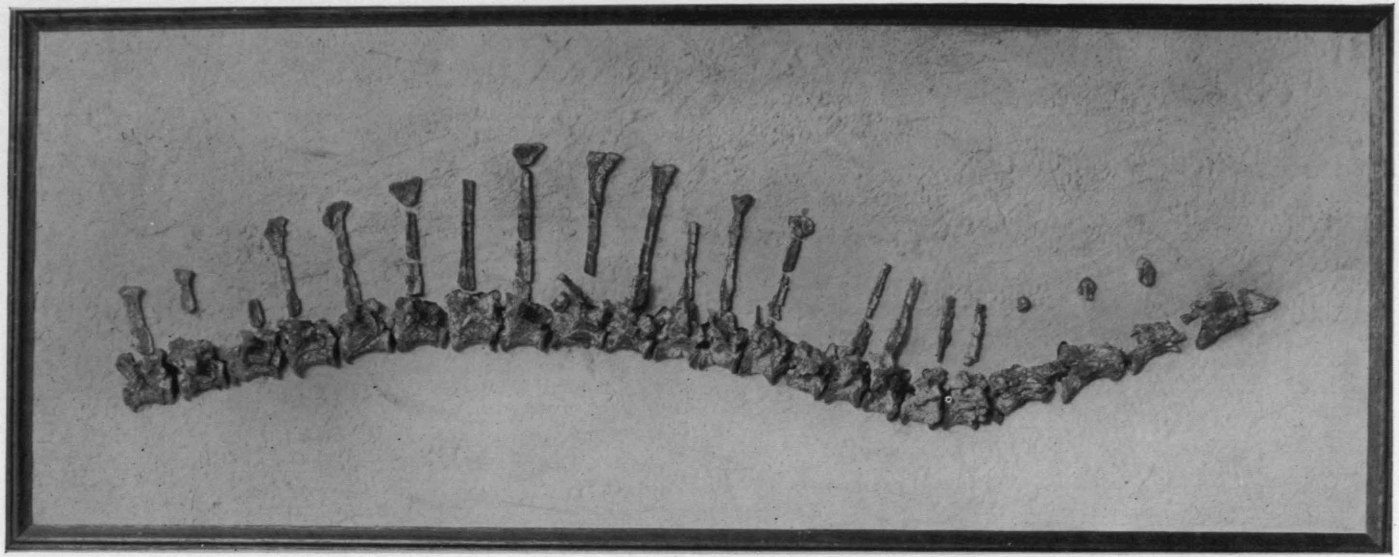


FIG. 9. A tooth referred to the genus *Coelophysis*. No. 2680, U. of M. ×1

the same form, a nearly symmetrical, slender oval cross-section, a slight recurvature, and serrate cutting edges (Fig. 9). There is no possibility of confusing these teeth with the abundant teeth of phytosaurs found in the same beds.

PLATE I



Photograph of the vertebral column of *Coelophysis cf. longicollis* Cope

(*Continued from inside of front cover*)