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CONTRIBUTIONS FROM THE MUSEUM OF PALEONTOLOGY
(*Continuation of Contributions from the Museum of Geology*)
UNIVERSITY OF MICHIGAN

VOL IV, No. 13, pp. 227–274 (11 pls., 29 figs.) FEBRUARY 20, 1935

DESCRIPTION OF A COLLECTION OF ASSOCIATED SKELETONS OF *TRIMERORHACHIS*

BY
E. C. CASE

UNIVERSITY OF MICHIGAN PRESS
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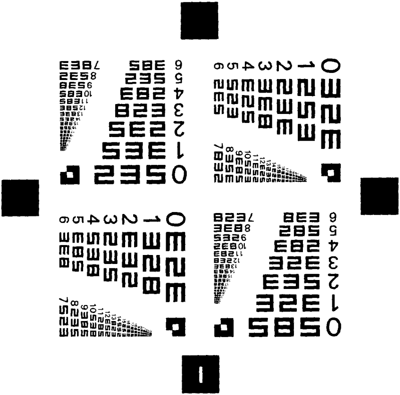

RIT ALPHANUMERIC RESOLUTION TEST OBJECT, RT-1-71

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(Continuation of Contributions from the Museum of Geology)

UNIVERSITY OF MICHIGAN

Editor: EUGENE S. MCCARTNEY

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(Continued on inside of back cover)

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DESCRIPTION OF A COLLECTION OF ASSOCIATED SKELETONS OF *TRIMERORHACHIS*

By E. C. CASE

IN THE summer of 1933 a joint expedition from the Museum of Comparative Zoölogy, Harvard University, and the Museum of Paleontology, University of Michigan, spent some weeks in the Permo-Carboniferous beds of north-central Texas. In the course of the work Mr. W. H. Buettner, of the Museum of Paleontology, discovered a slab containing sixteen skulls of *Trimerorhachis*, with a large amount of associated material from the axial skeletons. The débris from the exposed portion of the slab contained eight other skulls, more or less complete, and much other material of the skeleton. The find was made in the Wichita division of the Permo-Carboniferous a few miles south and east of Dundee in Archer County.

Remains of *Trimerorhachis* are among the most commonly occurring fossils of the beds and have been repeatedly described, but most of the discoveries have been of isolated skulls or fragmentary material gathered from the débris of disintegrated bone beds. The refractory nature of the matrix or the fragmentary condition of the bones recovered has made it difficult to give a coherent account of the osteology of this form. The fortunate discovery of this collection of material before dispersal and its careful preservation by Mr. Buettner and his associate, Mr. T. E. White, of the Museum of Comparative Zoölogy, make it possible to give a satisfactory description of the skeleton. It is interesting to note that in the large amount of literature upon *Trimerorhachis* most of the points in the skeletal anatomy have been described by one author or another, but mixed with so much of unavoidable

error in interpretation that redescription with confirmation and correction seems desirable.

The skeletons were embedded in a soft clay, which in most cases disintegrated in water and left the bones singularly clean and revealed all the minute details of the osteology. In places, however, especially where the skulls were in close contact, the clay was hardened by the deposition of calcareous material, which rendered the cleaning very difficult. The animals had evidently gathered in some small space, possibly the last water of a desiccating pool; the death struggles of the final survivors disturbed the cadavers softened by decay, so that there is little continuity in the skeletons. The close proximity of the bones shows how intimately the animals were crowded together before death. The author in his field experience in the region has come across several places where collections of *Trimerorhachis* had evidently occurred in the same way, but had been weathered out, leaving an immense number of fragments of bones which could not be reassembled. Evidently the incident of collection in a place of final refuge and the tragedy of destruction were not uncommon in the region in late Permo-Carboniferous time.

Very little besides the bones of *Trimerorhachis* was found — a few fish scales, a single small vertebra of a reptile, a single toe bone of a reptile (?), a single small humerus of the reptilian type, a few coprolites, probably of *Trimerorhachis* since they are of the amphibian type; these are all that cannot be referred to *Trimerorhachis*. Infrequent spots of charcoal-like material indicate the presence of plant material, but it is so thoroughly decomposed that nothing of its original character could be determined.

The majority of the skulls were complete when petrified, with the lower jaws and the clavicles and interclavicles in position; with few exceptions the skulls lay with the top uppermost. However, there were many isolated jaws and fragments of skulls and of thoracic shields scattered through the matrix. The whole layer of bone was not over two or three inches thick and terminated abruptly both above and below. Two partly complete vertebral columns and several shorter series of vertebrae were found in continuity, and several limbs with associated foot bones were

preserved, little disturbed. Scattered through the matrix and mingled with the bones were considerable patches of the dermal scutes; these were not continuous, but appeared to have collected as the skin decayed. A number of true osteoderms occurred in the matrix; these were scattered and cannot be assigned to any definite position in the body.

After the fossilization of the specimens the clay had cracked and checked in periods of desiccation. The skulls and other bones are crossed by such cracks and there has been some displacement in the process. The thinness of the bones of the skull and the consequent fracturing and distortion explain the difficulty which has been repeatedly met in interpreting less favorably preserved material. (See Plate I.)

In the following account of the osteology of *Trimerorhachis* it is impossible to give credit for every point that has been correctly observed and described or to correct every error that has been made; those familiar with the literature will be able to recognize changes in, or confirmation of, points previously described. No attempt has been made to assign the individuals of the group to any particular species. They correspond closely to the *T. insignis* of Cope and are either of that species or are closely related.

THE UPPER SURFACE OF THE SKULL

None of the figures published since the earliest description by Cope has tried to show the nature of the sculpture or to trace the course of the sensory grooves. Of all the attempted restorations, that by Abel, *Stämme der Wirbelthiere*, Figure 202, combined from previous efforts, is nearest to the correct interpretation. By comparing his restoration with the figures of this paper it will be seen that the most notable faults of his figure are as follows:

1. The squamosal extends to the posterior end of the skull covering the quadrate but is separated from it by the posterior inner end of the quadratojugal;
2. The outline of the various elements of the skull roof is inaccurate in several instances;
3. The septomaxillary cannot be identified in any of the present skulls.

The slab originally contained sixteen skulls, all more or less complete and all but one lying in the normal position, i.e. with the upper surface upward. Seven of these were removed; four were sent to the Museum of Comparative Zoölogy at Harvard University, and three were used for detailed study. In addition to the skulls in the slab there were three nearly complete, numbers 15944, 16009A, and 16009B,[1] which were collected in the weathered débris and from the broken edges of the slab, and there were more or less complete remains of at least eight other skulls. From the lot six skulls have been selected as most nearly complete and have been carefully examined. When necessary or advantageous, detailed information has been gathered from the fragmentary material. It is noteworthy that a majority of the skulls were still in association with the clavicles and the interclavicle, indicating a strong attachment during life which resisted the processes of decay.

In studying the several skulls selected and especially in mapping the sutures an attempt was made to examine each one independently of the others; each outline was then completed without reference to any previously made. The general scheme was, of course, in the mind of the author, but a very conscious effort was made to follow the sutures without the influence of previous knowledge. The results are shown in the diagrams associated with the photographs of the skulls (see Plates II–VI).

The photographs reveal clearly the pattern of the deeply and sharply incised sculpture. Over most of the skull it is decidedly reticulate, approaching a linear arrangement in restricted areas only, as on the adjacent portions of the frontals and parietals and upon the squamosals. The only figures showing the sculpture, previously published, are the very imperfect ones prepared by Cope for the second volume of the Hayden Survey and published in 1915, under the editorship of Dr. W. D. Matthew. These figures appeared in reduced size in various preliminary papers by Cope. In the same figures, also, is found the only previous

[1] Unless otherwise indicated numbers refer to the collection of the Museum of Paleontology in the University of Michigan. The slab has been numbered 16009, and this number, with letters, refers to skulls upon the slab.

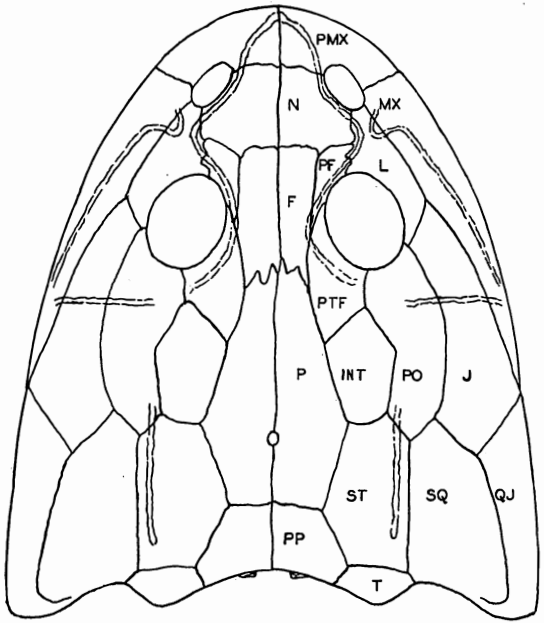

FIG. 1. Upper surface

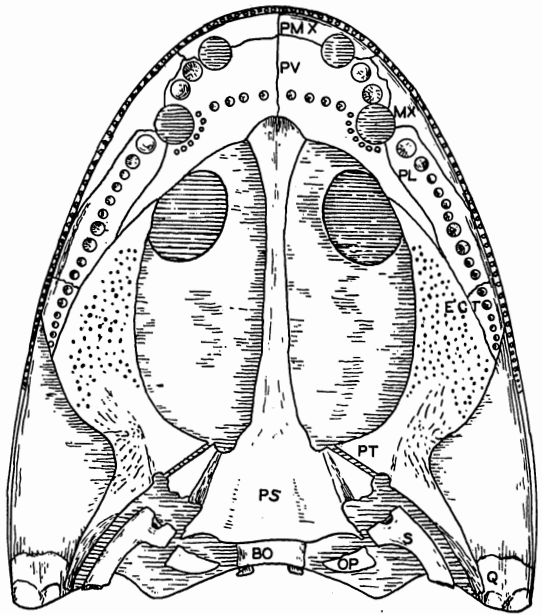

FIG. 2. Lower surface

Reconstruction of upper and lower surfaces of skull, about two thirds of the natural size of an average specimen. Explanation of lettering: BO, basioccipital; ECT, ectopterygoid; F, frontal; INT, intertemporal; J, jugal; L, lachrymal; MX, maxillary; N, nasal; OP, opisthotic; P, parietal; PF, prefrontal; PL, palatine; PMX, premaxillary; PO, postorbital; PP, postparietal; PS, parasphenoid; PT, pterygoid; PTF, postfrontal; PV, prevomer; Q, quadrate, QJ, quadratojugal; S, stapes; SQ, squamosal; ST, supratemporal; T, tabular

suggestion of the course of the sensory grooves; Cope figured and described the small part of the system that could be made out on the specimen in his hands (*Proc. Am. Phil. Soc.*, 1880). This description was reprinted by the author in Publication 146 of the Carnegie Institution of Washington. It at first appeared that there was a general distribution of the sculpture without reference to the separate elements, but closer inspection shows that each bone had a distinct point from which the sculpture developed; this is most obvious in the nasal, intertemporal, and squamosal bones and least obvious in the parietal, postparietal (dermsupra-

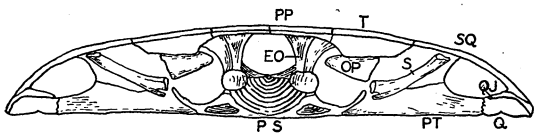

FIG. 3. Reconstruction of posterior face of skull. Same scale as in Figure 1. EO, exoccipital. Other lettering as in Figures 1 and 2

occipital), supratemporal, and tabular bones. A comparison of the various diagrams will show a close approximation in general outline of the bones with numerous minor variations; some part of the variations may be due to the difficulty of tracing the sutures, but in general this could be done with confidence and the diagrams are close to the original pattern. The writer has been impressed with the fact that almost every point in the surface of the skull has been seen and noted by some one of the numerous workers who have examined the previously known material, but because of the imperfection of the material each author has made, with some correct observation, more or less erroneous interpretations. The reconstructions of the skull, Figures 1–3, have been made from evidence drawn from several specimens.

Premaxillaries. — The premaxillaries have small exposure on the upper surface and articulate with the maxillary rather nearer to the posterior end of the narial opening than is shown in Abel's figure. The teeth are all small; in no specimen have there been found any enlarged teeth or tusks. In four skulls, numbers 15994, 16005, 16009B, and 16009D, there is definite evidence of

an opening in the median line, entirely surrounded by the premaxillaries. In three of the specimens this region is not perfectly preserved on both sides, but the opening is outlined on one of the premaxillaries; in number 16005, however, it is complete in outline and well represented. The opening is about as large as that of the external nares and in the specimens transversely oval. A part of the transverse elongation is due to the flattening of the specimen during fossilization, though it must have been somewhat wider than long and nearly at the anterior extremity of the skull in life. This opening or deep pit receives the anterior ends of the sensory grooves from either side and may have sheltered a receptor gland or organ associated with the sensory system. As nearly as may be counted there were twelve rather widely spaced teeth in the premaxillary of number 15994, and if the spaces represent empty alveoli the number would be nearly twice as large.

Septomaxillaries. — Huene identified a septomaxillary in one of the specimens in the collection of the American Museum of Natural History in New York. It is not possible to demonstrate such an element in any skull in this collection. In number 16005, and possibly in one or two others, there are fragments of smooth thin bone in the proper position, but these may easily be fragmented portions of the thin floor of the nasal cavity.

Nasals. — The nasals are roughly quadrangular bones, as shown in the plates, and form a large portion of the inner borders of the external nares.

The sculpture is notably deep, with the grooves and ridges radiating from a center near to the edge of the narial opening.

Frontals. — The frontals are straight-sided elements, nearly filling the interorbital space. The anterior ends are slightly enlarged by lateral expansion toward the prefrontals. The posterior ends are unsymmetrical in correlation with the anterior ends of the parietals. The sculpture is reticulate on the anterior portion, but becomes distinctly linear on the posterior third.

Prefrontals. — The prefrontals are the least consistent in form of any shown in the diagrams. This may be due in part to the difficulty in tracing the sutures in a region which is the most

disturbed portion of the various skulls, but there is a similarity of form which renders the bone very consistent in its general shape and relations. In all the specimens the bone originates well posterior to the narial opening; the posterior end is a narrow process, which in all specimens laps over the postfrontal on the median side. In no case does the frontal take part in the orbital rim, being excluded from it by the meeting of the prefrontals and the postfrontals.

Lachrymals. — The lachrymals reach from the orbit to the nares. They form the outer anterior portion of the orbital rim and part of the posterior border of the nares. In two or three of the specimens they apparently extend well forward on the outer side, nearly touching the premaxillary, although in no specimen is the maxillary completely excluded from the opening. Posteriorly they meet the postorbital, excluding the jugal from any part in the orbital rim, but in every case the jugal approaches the orbit much closer than is shown in Abel's diagram. The sculpture of the anterior portion is one of close-set pits, becoming roughly linear on the posterior half.

Postfrontals. — The postfrontals have a long anterior process which meets the prefrontal, as described. The posterior part is expanded, meeting the postorbital at about the center of the posterior edge of the orbit. The outline is variable, but there is consistently present a process extending backward to separate the anterior edges of the intertemporal and the parietal.

Postorbitals. — The postorbitals are large elements in the skull, with a definitely convex and regular outer edge for contact with the jugal. It meets the lachrymal anteriorly and with the postfrontal completes the outline of the orbit posteriorly. The orbits are oval, with the longer axis definitely inclined inward anteriorly; this is evident in all the specimens, despite any crushing, distortion, or imperfection of the orbital rim.

Intertemporals. — The intertemporals are small though clearly separate and well-defined bones. They are roughly pentagonal but show considerable varations in outline owing to the different development of the surrounding bones. The sculpture is imperfectly radial.

Parietals. — The parietals are decidedly variable at the anterior end; the sutures with the frontals show greatly prolonged indentations in some specimens and a much more regular course in others. The frontal-parietal suture is farther back than it is drawn in some restorations; the anterior point hardly reaches as far forward as the orbit.

The proportions of length to breadth are notably variable, but in none of the specimens are the bones as short and broad as they are represented in Abel's diagram. The sculpture shows an ossific center a little posterior and lateral to the parietal opening; it is rather closely reticulate and resembles that of the posterior bones of the skull roof. Only in the anterior portion does the sculpture become linear and continuous with that of the frontals.

Jugals. — The jugals have a large anterior-posterior extension and reach their greatest breadth in the region of the junction of the postorbital and the squamosal. They approach close to the orbit, much closer than those figured by Abel, but are excluded from it by the meeting of the lachrymal and the postorbital. The sculpture is roughly linear. Apparently the jugal takes no part in the lateral edge of the skull as the maxillary continues back to the quadratojugal; however, the variations in shape of the bones of the skull are so great that it is very possible that in some individuals this bone might reach the external border near its posterior end.

Quadratojugals. — The quadratojugal forms the greater part of the support for the quadrate. Its extreme posterior end is smooth, and there is a small projection of the end inward which underlies the squamosal. This projection is excavated by an opening, the quadrate foramen (Fig. 4), which is completed by the quadrate; the squamosal has no part in the border, although the descending flange of the squamosal extends back

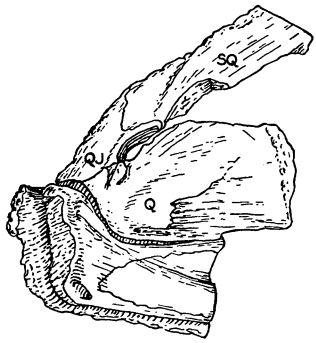

FIG. 4. Quadrate region of left side, number 1115, University of Chicago. Lettering as in Figures 1 and 2

over the quadrate nearly to the foramen. It is possible that with the extremely variable character of the bones the squamosal might touch the border of the opening in some individuals. The outer portion of the posterior end of the quadratojugal approaches very closely the outer border of the cotylus of the lower jaw, but the quadrate underlies the greater part of the posterior end.

Squamosals. — The squamosals maintain a fairly uniform size and outline through the series of skulls. The ossific center is near the posterior inner edge, close to the border of the otic notch; the sculpture radiates very distinctly from this center and becomes linear on the outer and anterior portions of the bone. The posterior border is turned down in a descending process which unites with a rising process of the pterygoid and articulates with the inner edge of the quadrate. This process continues forward and inward on the lower side and terminates its attachment at the suture between the squamosal and the supratemporal, but the lower end extends forward under the supratemporal, leaving a decided notch above, perhaps for the passage of the ophthalmic branch of the Vth nerve. The appearance of the lower surface is somewhat deceptive since the tabular underlaps the supratemporal decidedly, forward and outward, and the squamosal underlaps the supratemporal, forward and inward. The exposure of the posterior portion of the latter bone is notably restricted on the lower surface. This may be seen in number 16002.

Tabulars. — The tabulars show notable variation in their proportional length and breadth, but have the same relations to the adjacent bones in most of the specimens. In two, number 15994 on the right side and number 16009B on the left side, the supratemporal sends an extension backward between the tabular and the squamosal and occupies a very definite position in the posterior rim of the skull. In other specimens the supratemporal approaches very nearly to the rim, and in still others the tabular has a relatively broad contact with the squamosal. On the under surface the tabular (number 16002) has a low rugose line running forward and inward from the inner edge of the otic notch.

Postparietals (*dermsupraoccipitals*). — The postparietals show their greatest irregularity of outline in the sutural connection with

the parietals. The sculpture is regular and merges into that of the adjacent bones. There is no clear indication of the location of the ossific center. The descending flange is well defined near the center of the posterior edge and carries a good sutural face for the upper end of the exoccipital (number 16002).

Maxillaries. — The maxillaries have little exposure on the upper surface of the skull. The suture with the premaxillaries is near the center of the outer border of the narial opening; it forms the posterior half of the outer rim and joins the lachrymal near the posterior outer corner. The suture with the lachrymal is visible on most of the flattened skulls, but in the uncrushed condition the exposure must have been small. The maxillary diminishes in vertical extent posteriorly and terminates in a slender edge beyond the jugal-quadratojugal suture. There are fifty, more or less, teeth and alveoli in the left maxillary of number 15994, and approximately as many in numbers 16005 and 16009B. There is no suggestion of a maxillary tusk in any of the specimens, but the teeth are gradually and uniformly, though only slightly, enlarged toward the anterior end.

Sensory system.[2] — The anterior commissure extends across the nasals very close to the nasal-premaxillary suture and connects with the opening or deep pit bordered by the premaxillaries. (See Fig. 1, page 23, and Plates II–VI.)

The supraorbital groove follows the inner side of the narial opening, bends outward posterior to the opening, crosses the nasal-lachrymal suture, and lies upon the lachrymal for a short distance; it then curves back upon the prefrontal and continues close to the inner border of the orbit. The suture between the prefrontals and postfrontals and the frontal lies in the groove for a short distance. Opposite the posterior inner corner of the orbit the groove disappears for a short distance; this is constant in all the skulls.

The temporal groove appears suddenly upon the postorbital and passes directly outward across the jugal to join the infra-orbital groove. This portion of the sensory system is well defined in all the skulls, beginning sharply and continuing with clearly

[2] The terminology employed is that suggested by Moodie in the *Journal of Morphology*, Vol. 19, p. 511, 1908.

marked edges. Its position relative to the orbit is somewhat variable, e.g. in number 16005 it is much more posterior than in number 15994.

From its origin on the postorbital the posterior portion of the temporal groove extends almost directly backward upon the supratemporal, a little lateral of the median antero-posterior line of that bone. This portion is obvious but is discontinuous, being frequently broken by cross ridges of the sculpture. It terminates upon the supratemporal near its posterior border. The two parts of this groove, the posterior and the transverse, are separated by a considerable space on the postorbital, but in a few skulls the course is suggested by a slight modification of the sculpture.

The infraorbital groove begins as a sharp hook upon the lachrymal (see Fig. 1, p. 231) and passes outward to the maxillary, upon which it continues for a short distance and then disappears; it does not appear upon the quadratojugal or the squamosal in any of the specimens.

The posterior commissure is uncertain. There is a well-defined narrow groove very close to the posterior edges of the postparietals (dermsupraoccipitals) and the tabulars as far as the inner edge of the otic notch. This groove is obvious upon all the specimens, though whether it is a trace of the sensory tract or a peripheral alteration of the sculpture is uncertain.

THE LOWER SURFACE OF THE SKULL

Quadrate. — The quadrate is markedly different in form from that of the Triassic Stegocephalia such as *Buettneria.* The quadrate region was figured by Williston (1915) though not described. The following account is taken in part from number 1115 in the collection of Walker Museum in the University of Chicago, the specimen figured by Williston, and is confirmed by several specimens in the present collection, notably number 16001. It is a thin plate of considerable antero-posterior extent with the condylar region confined to the posterior portion. The thin anterior portion is convex upwardly and is largely covered by the squamosal, quadratojugal, and the quadrate process of the pterygoid, but its posterior third is free.

The quadrate articulates above with the quadratojugal; the elongate suture on the mesial portion of the posterior face is interrupted by the quadrate foramen. The anterior or inner part of this mesial portion is overlapped by the squamosal above and by the extremity of the quadrate process of the pterygoid below (see Figs. 2, 4). The anterior end of the quadrate is not enlarged and is roughened for the attachment of cartilage, as in *Buettneria*. The lower face is smooth. Just below the quadrate foramen is the opening of a small canal which runs forward and inward into the body of the bone but does not perforate it. The condylar face is bipartite, being divided by an oblique groove into a more elongate inner face and a shorter outer face.

The quadratojugal overlaps the outer portion of the articular part of the quadrate and comes in close relation with the outer edge of the angular or the articular of the lower jaw. It overlaps the posterior mesial face of the quadrate and is attached to it firmly by squamous suture. The suture between the quadratojugal and the squamosal runs obliquely backward and inward to a point opposite the middle of the quadrate foramen, curves forward to the anterior end of the foramen, and then runs to the lower edge of the two bones, excluding the squamosal from any part in the edge of the foramen, though it may touch the anterior edge as an individual variation in some specimens. There is a descending flange of the posterior edge of the squamosal which overlaps the mesial part of the quadrate and meets the pterygoid near the middle. The posterior edge of the pterygoid turns upward as a continuation of the vertical part of the quadrate process and overlaps the lower half of the mesial portion of the quadrate, meeting the squamosal (see Fig. 4).

Parasphenoid. — The parasphenoid is preserved in various skulls and as isolated bones; it is especially clear in numbers 16000 and 16003. Number 16000 shows the posterior portion of a skull with parts of the pterygoids in place and with the greater part of the parasphenoid, including the cultriform process, nearly to its anterior end (see Pl. VIII, Fig. 1). Number 16003 is an isolated parasphenoid showing the upper surface but lacking most of the process. These permit a very complete description of the bone.

The lower surface is nearly smooth, with hairline markings. There is no rugosity or suggestion of the presence of teeth. The anterior end is drawn out into a long, slender cultriform process gradually narrowing anteriorly and ending in contact with the prevomers, but with a space where the parasphenoid rises above the prevomers in the midline, as is common in many Stegocephalia. The lower surface of the process is marked with strong though narrow linear grooves.

Where the process joins the body of bone it broadens rather rapidly and the edges pass into the articular surfaces for the pterygoids.

From the origin of the basipterygoid process a deep groove runs outward and backward, marking off the articular portion from the rest of the bone. This groove deepens to the rear and ends in a sharp notch at the posterior edge. In number 16000 it seemed possible to detect a small foramen on each side near the anterior end and just within the groove, but this could not be confirmed in several other specimens. The foramina for the entrance of the internal carotid arteries should occur at these points; the position and the direction of the canals described as visible on the upper surface suggest such foramina; it is probable that they were very minute and they are difficult to detect. The posterior edge shows a deep notch at the termination of the groove and then passes with a gently convex border to the corresponding notch of the opposite side.

The inner, upper, surface of the parasphenoid, number 16003, shows the osseous floor of the brain case. The posterior portion is nearly complete, but the cultriform process is broken off a little anterior to its origin. On the upper side of the preserved portion of the process is a small median projection located in the midline and about one fourth as wide as the process. This projection is attached by its posterior end and extends forward and upward; the anterior end is free (see text Fig. 5 and Pl. VIII, Fig. 2). The upper anterior portion is marked off from the rest of the projection by a shallow crescentic groove convex anteriorly. This groove seems to be natural and not the result of injury. The identity of this process and its continuity with the parasphenoid

has been assured by repeated observation by the author and his colleagues. The only suggestion as to its function that can be advanced is that it gave attachment to a cartilaginous septum which divided the canal above the parasphenoid and between the sphenethmoids. Pfannenstiel (1932) has described and figured

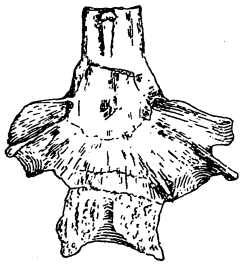

FIG. 5. Upper surface of parasphenoid, number 16003. × 1

the probable cartilaginous structures in *Mastodonsaurus*. He indicates the presence of a cartilaginous septum rising from the parasphenoid and dividing the ethmoidal cavity into lower and upper parts; the upper part shelters the anterior portion of the brain and the origin of the olfactory tract. It is possible that the process marked "epipterygoid" in his Figure 4 (p. 9) is the equivalent of the process described above.

Just at the base of the cultriform process there is a prominence extending across the middle of the bone, but not reaching the edges; its anterior edge is abruptly above the rest of the bone and is underlain by matrix. Posterior to this is a small prominence near the center of ossification of the parasphenoid, very narrow antero-posteriorly and more extended transversely. Between the two prominences is a shallow concavity. These two prominences are apparently on a thin plate of bone lying upon the upper surface of the parasphenoid (see Fig. 5); if it is a distinct plate, as seems certain, it is the last remnant of a basisphenoid, so much reduced that it no longer reaches to the points of contact of the parasphenoid with the pterygoids. Pfannenstiel (1932) in his interpretation of the cartilaginous cranium of *Mastodonsaurus* affirms the presence of a cartilaginous basisphenoid (see his Fig. 4, p. 9). It is possible that this thin plate is the last remnant of an osseous

basisphenoid and that the processes indicate the position of the *sella turcica.*

The sides of the parasphenoid extend outward and backward from the base of the cultriform process and carry the articular faces for the pterygoids. The edge rises slightly on the upper face and, with a second nearly parallel ridge nearer the midline, forms the borders of a shallow but rather wide groove extending nearly to the center of the bone. Just outside the most posterior of the two prominences on the basisphenoid bone the groove ends in a sharp edge facing outward. This edge is roughened for the attachment of some cartilage which lay in the groove.

The inner one of the two ridges mentioned rises a short distance from the edge described above and rapidly becomes a high, thin process which extends to, and overhangs, the posterior edge of the parasphenoid. Immediately within the point of origin of this ridge is a small foramen, leading into a canal which runs forward and inward, probably the internal opening for the internal carotid artery. If the thin basisphenoid were removed the canals of either side might well appear as grooves in the parasphenoid, such as have been repeatedly observed in the Stegocephalia. These canals continue in a direction that would cause them to terminate in the minute foramina on the lower surface, suggested on page 240. The outer ends of the ridges are slightly heavier on their upper surfaces as if for attachment to some ligament. This is different from the course suggested by Pfannenstiel (p. 28 and Fig. 11), for the canals carrying the internal carotids are much more like the course found in *Buettneria* and *Laccocephalus.*

Just medial to the inner ridge the posterior edge of the parasphenoid is notched by a concavity which is in the exact position to shelter the lower portion of a cartilaginous otic capsule. This suggestion is strengthened by the position of the opisthotic and stapes described below.

Still farther toward the center of the bone is a third very slight linear elevation nearly parallel to the ones described. This elevation thickens the posterior edge of the bone, and in this thickening is a deep pit, probably for attachment of the rectus capitis muscle. Dr. D. M. S. Watson informs the author that this is

different from the usual condition in *Trimerorhachis*, where the attachment is in an incision or groove on the lower surface of the parasphenoid rather than in a pit in its posterior edge. On the right side of number 16003 a bit of bone in the matrix seems to carry the ridge farther back, but since it does not occur in the left side and is not present in several other specimens it is probably adventitious.

The posterior edge of the basicranium is very different in numbers 16000 and 16003. In the first, showing the lower surface, the edge extends but little posterior to a line connecting the otic regions, and the posterior edge of the basioccipital is on a line with the parasphenoid. In number 16003, showing the upper surface, there is a strong median projection. This projection is, in all probability, the basioccipital in place or a little displaced backward. Of two isolated basioccipitals in the collection of the Museum of Paleontology, one from southwest of Wareka, Oklahoma, shows the articulation with the parasphenoid extending to the posterior edge; the other shows that at least one third of the bone was free. The position of the basioccipital was probably subject to individual variation or age variation.

Basioccipital. — The basioccipital is well ossified and slightly convex below. The greater part of the lower face is marked with strong linear rugosities for firm articulation with the parasphenoid. The posterior face is deeply excavated. The excavation contracts anteriorly and is carried forward on the upper surfaces as a narrow median groove which bore the forward extension of the notochord. The rest of the upper face is strongly rugose for attachment to the exoccipitals and perhaps, anteriorly, to cartilage. In number 16003 there is a considerable space between the basisphenoid and the basioccipital. This space is smooth and does not indicate the presence of any intervening cartilage, but it is improbable that the union of the exoccipitals forming the floor of the foramen magnum extended as far forward as the posterior edge of the basisphenoid.

Exoccipitals. — The exoccipitals are in position in number 16000 and that of the left side is practically undisturbed. It lies upon the basioccipital and rises to the under side of the

postparietal (dermsupraoccipital). The condylar face is inclined inward and backward and is rugose for cartilaginous attachment to the first vertebra with relatively little movement possible. The condylar portions carrying the faces project posterior to the basioccipital and must have formed the main attachment to the vertebral column. The exoccipital apparently did not come in contact with the parasphenoid in the uncrushed skull.

Two isolated exoccipitals of the left side, number 16011, are complete. Seen from the rear they are L-shaped, with the lower branch of the L extending forward and inward; this lay upon the basioccipital and met the similar process from the bone of the opposite side. The condylar face is at the angle where the two branches meet (see Figs. 6–7). The rising process is roundly

FIG. 6

FIG. 7

FIG. 6. Exoccipital of left side, anterior view, number 16011. × 2

FIG. 7. Same, posterior view. × 2

triangular in section, presenting three faces — a posterior, an anterior, and an outer. The posterior is flattened and set off from the other two faces by rather sharp edges; in the larger of the two specimens the edge between the posterior and the outer face is very sharp; in the smaller it is rounder and less conspicuous. Just below the midheight of the edge between the posterior and the anterior faces there is a small, irregular protuberance which probably marked the separation between the foramen magnum and the cartilaginous supraoccipital.

The anterior face looks almost as much inward as forward; it passes into the outer face over a low rounded surface with no sharp separation between the two. At the base of this face, below the level of the protuberance marking the lower edge of the supraoccipital, are three foramina. These are present in both specimens and in two incomplete exoccipitals that preserve the lower part only. In the two complete exoccipitals the foramina are almost in line horizontally, the most posterior opposite the median line

of the face, the second opposite its anterior edge, and the anterior one well out upon the lower branch of the bone. The foramina are of nearly equal size. In the two incomplete bones the anterior foramen is larger than the others and opens at the bottom of a pit; in one the pit is relatively very large. These must be individual variations and not due to age, since the fragments correspond in size with the complete bones. Because of the small size of the canals it has been impossible to trace them through the bone, but it would appear that the two posterior ones perforate the bone directly to the outer surface.

The outer face is separated from the posterior by a very sharp ridge on the larger of the two bones and by a much less conspicuous one on the smaller. On the larger there is a single foramen opposite the posterior two of the anterior face; on the smaller there are two foramina very close together in the same position. In the two fragments there is but a single foramen. It would appear

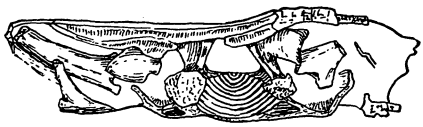

FIG. 8. Posterior view of skull, number 16000. × 1.
Compare reconstruction, Figure 3

that in three specimens the canals from the anterior face united and that in the fourth they remained separate. The whole face is slightly concave, and with the notch on the parasphenoid and the excavated inner face of the opisthotic it outlines the cavity which sheltered the cartilaginous otic capsule.

Opisthotics. — In number 16000 there is a small bone on each side, just outside the exoccipital, which can only be the opisthotic. These bones are in the form of blunt, hollow cones with very thin walls. The apex of the cone points outward. The upper side of the cone touches the postparietal (dermsupraoccipital) and the upper part of the inner edge touches the upper part of the exoccipital. On the left side the lower part of the inner edge touches the extremity of the ridge which lies outside the notch

for the otic capsule. On the right side the opisthotic is somewhat disturbed; it is separated from the ridge on the parasphenoid by the proximal end of the stapes (see Figs. 3, 8).

The opisthotic has the appearance of a bone which is wasting away into cartilage. The edges are very thin and, as it were, frayed out. The contact of the lower edge of the cone with the ridges of the parasphenoid is as in *Eryops*, and either in the cartilage adjacent to this or to the ridge of the parasphenoid must lie the last of the proötic, which was no longer ossified.

Stapes. — In number 16000 the stapes are shown in position. The bone is thin but relatively broad. The main portion passes

FIG. 9. Lower face of stapes of left side, number 16000. × 2

outward and back to the otic notch, where it ends in a hollow, blunt extremity; evidently it was attached by a plug of cartilage to the tympanic membrane. The proximal end is broader (see Fig. 9) and is divided into a larger, thicker posterior (as the bone lies in the specimen) part and a smaller, thinner anterior part; between these but nearer the thinner part is a good-sized stapedial foramen. The thinner, anterior part may have come in contact with the parasphenoid, as suggested by Watson (1916). It resembles the smaller process of the stapes in *Buettneria*, which is in close association with a small process in the parasphenoid.

The stapes lies in a different position relative to the opisthotic on the two sides of the skull. On the left side it is just outside the opisthotic. If it were restored to its probable normal position the thicker part of the proximal end would lie in the large opening between the opisthotic, the parasphenoid, and the exoccipital, which is the locus of the fenestra ovale on the cartilaginous otic capsule.

On the right side the proximal end has been forced into the otic cavity and appears to separate the opisthotic from the parasphenoid. This is evidently a displacement by pressure, probably in the decaying skull.

As shown in Figures 3 and 8 the posterior face of the skull is notably different from the figure given by Broom (1913, Fig. 6, p. 572). The restored tabulars and postparietals (dermsupra-occipitals, in dotted line) are far too high. His description and figures of the opisthotic in no wise correspond with the condition in number 16000. He says (p. 574) of the specimen examined by him: "On the right side the bone is considerably displaced, but on the left side only slightly crushed down. In my drawing of the occiput, I have shown it in correct articulation with the exoccipital." In view of the perfection of preservation of number 16000 and the extreme fragility of the opisthotic, one wonders whether Dr. Broom was not misled by some displaced element in a less well preserved specimen.

On page 574 and in Figure 7 Dr. Broom describes and figures a large proötic in close connection with the bone he calls the opisthotic. In the present collection there is no evidence of a bone of such size, nor any seeming possibility of its presence. It is far more likely, as suggested above, that the proötic was reduced to cartilage, or, less probably, was a small element closely associated with the pterygoid; in the upper Triassic Stegocephalia this bone has disappeared or is closely united with the rising process of the pterygoid which forms the only osseous support for the lateral wall of the brain case.

Pterygoids. — The pterygoid has the usual tripartite form with attachments anteriorly to the ectopterygoid, palatine, and prevomer, mesially to the parasphenoid, posteriorly to the squamosal and quadrate. The portion of the pterygoid anterior to its articulation with the parasphenoid is a flat plate, broad posteriorly and narrowing anteriorly. The inner edge is deeply concave, forming the outer border of the large interpterygoid vacuity. The relations with the ectopterygoid, palatine, and prevomer are shown in Figure 2, p. 231.

The portion opposite the juncture with the parasphenoid is the broadest and is marked with roughly linear rugosity which extends some distance upon the quadrate process. Anterior to the rugosities the surface is armed with numerous small, sharp teeth, separated posteriorly by a narrow band of rugosity but

merging anteriorly and covering the bone to, or nearly to, its juncture with the prevomer. In some of the fragmentary material there are a few enlarged teeth on the outer edge, adjacent to the enlarged teeth of the palatine. The articulation with the parasphenoid is carried on a strong inward projection free of teeth and rugosities, which reaches to the base of the cultriform process of the parasphenoid. The articular surface is clearly shown in number 15999 and in three isolated fragments numbered 16032. It is deeply concave on the pterygoid, with a flange running above the process on the parasphenoid. The articular face is marked, especially in one of the fragments of a smaller individual, by

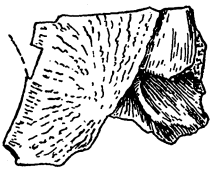

FIG. 10. Lower surface of an imperfect right pterygoid, number 16032, showing articular surface for parasphenoid. × 1½

linear elevations, indicating a somewhat firm attachment. The posterior edge of the pit is formed by a strong vertical partition, which separates it from a second pit on the quadrate arm of the pterygoid just before it becomes vertical in the skull (see Fig. 10). This second pit could have received the lower end of an epipterygoid. Such a bone is to be expected in the skull, but none has been found. The epipterygoid remained cartilaginous in many forms until late in life, and it is possible that in *Trimerorhachis* it was never ossified.

The quadrate process becomes vertical and runs in a gentle curve outward and backward to its attachment to the quadrate. In two specimens, numbers 16000 and 16001, there is an apparent vacuity in the vertical process just posterior to the second pit described above, but since it is absent in number 15999, which shows both sides of the process, and since there is no morphological reason for the presence of such a vacuity, it is probably accidental.

The upper edge of the quadrate process comes in contact with a descending flange from the squamosal and overlaps it posteriorly. This connection extends forward at least as far as the origin of the quadrate process.

Sphenethmoids. — In all the skulls in which the cultriform process of the parasphenoid is preserved it is pressed closely against the under side of the roof of the skull, but in number 16000 it is bent sharply down, then broken about its midlength and bent sharply up again. Evidently some hard substance, such as an included pebble or bone, prevented its being pressed against the skull roof. The condition is shown in Figure 11. Both sides of the triangle formed by the bend of the parasphenoid are filled by a thin, exceptionally smooth bone. This bone disappears by fracturing at the points where the parasphenoid approaches the skull roof. Similar thin and smooth bone, easily distinguishable,

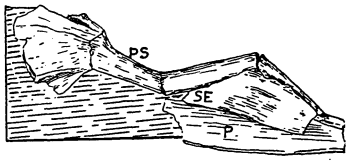

FIG. 11. Lateral view of parasphenoid and sphenethmoid, number 16000. × 1. P, parietal; PS, parasphenoid; SE, sphenethmoid

is present in the interpterygoid vacuities in two or three other specimens. The character and the position of this peculiar bone suggest strongly the presence of walls lateral to the space between the process of the parasphenoid and the roof of the skull. Such a wall is not unexpected. A well-formed sphenethmoid occurs in *Eryops*, and Pfannenstiel (1932, Fig. 7, p. 15) has described and figured a structure in *Mastodonsaurus* which he interprets as the cartilaginous sphenethmoid. The absence of any trace of this bone in other specimens is easily explained by its extremely fragile condition. It was evidently embedded in cartilage and was in process of disappearance. In the Triassic stereospondylous forms the chondrification was completed and all trace disappeared early in the decay of the cadaver.

Palatines. — The palatine and the ectopterygoid are narrow elements carrying a single row of teeth. The palatine overlaps the ectopterygoid opposite the posterior one of the palatine tusks. The suture is close and was difficult to find, but is visible on number 16008 and is confirmed by an isolated palatine of the left side. The palatine articulates with the maxillary, ectopterygoid,

pterygoid, and vomer. There are enlarged tusks at the posterior end and others just posterior to the internal narial opening. The sutures are as shown in Figure 2, p. 231.

Ectopterygoids. — The ectopterygoids are very slender elements that extend backward from the palatines and carry a single row of teeth in continuation with those on the palatine, which diminish in size toward the posterior end.

Prevomers. — The prevomers lie between, and take part in, the borders of the internal nares and the anterior vacuities. Each bone articulates with the palatine and pterygoid posteriorly, with the maxillary and premaxillary laterally and anteriorly, with the prevomer of the opposite side in the median line, and with the parasphenoid posteriorly in the median line. There is a vacuity at the posterior edge of the united vomers on the midline, formed by the rise of the anterior end of the parasphenoid, as is common in the Stegocephalia. The narial opening is bordered by the palatine and the prevomer. On the inner side of the opening the prevomer carries five or six rather long but slender teeth. Just anterior to the opening there are a large tusk and a socket, and from these a series of smaller teeth, numbering five or six, cross the prevomer in a line slightly convex forward, to join a similar series on the opposite side.

The exact position of the sutures between the prevomer and the premaxillary and maxillary is difficult to make out because the lower jaws are present in most of the specimens and obscure this region, but as shown in a somewhat disturbed specimen, number 16004, and in isolated bones, they are very closely as represented in Figure 2.

Maxillaries. — The maxillary appears as a thin edge on the lower surface. There are no enlarged teeth. The posterior end of the tooth row is about in line with the base of the cultriform process of the parasphenoid. The small teeth are crowded together; in number 16005 at least sixty can be counted. The posterior portion of the maxillary is a thin dentigerous bar that gradually diminishes in width and thickness to a point at the posterior end.

Premaxillary. — The palatine surface of the premaxillary is

covered in most of the specimens, but is shown in part in numbers 16004 and 16005, and the dentigerous edge is visible in several. The teeth are all small, of the same size as those in the maxillary, and there are no tusks.

Hyoid apparatus. — In several of the skulls there are long slender bones that lie in close association on the palatal surface. These are too long and heavy to be ribs and must be referred to the hyoid series. Williston (1916) mentions the presence, in the very complete skeleton described by him, of similar elements which can only be unusually large hyoid or epibranchial bones. Amalitzky (1924) described the hyoid apparatus of *Dvinosaurus* as follows:

"*The branchial apparatus.* — Three skulls have, on their palatal side and on the sides of the occiput, a well-preserved branchial apparatus recalling that of the Axolotl. In *Dvinosaurus secundus* we may observe seven little bones lying freely on the palatal side, namely, the median, unpaired, basibranchiale, and three lateral pairs of bones, of which the upper, differing from the rest by its triangular shape, must probably be referred to the keratohyale, while two other pairs (similar in shape, but the anterior and external pair larger, and the posterior internal smaller) belong to the keratobranchialia. Three little bones, joining on both sides the back portion of the occiput, better preserved in *Dvinosaurus primus* than in *D. tertius*, also seem to stand in close relation to the above apparatus. These three paired bones probably correspond to epibranchialia. In *D. primus*, besides the above-mentioned epibranchialia, two pairs of keratohyalia are preserved."

The excellent plates accompanying Amalitzky's earlier paper (1921) show the hyoid elements very similar in form to the comparable parts in *Trimerorhachis*.

Sushkin (1923) confirmed Amalitzky's observation and notes that there are four epibranchials on each specimen. He says that the "state of the hyobranchial apparatus is more primitive than in the recent perennibranchiate Urodela" and in a footnote adds that there is reason to suspect a perennibranchiate condition in *Trimerorhachis*.

The lower surface of the skull is peculiar in the presence of the large prenarial openings which accommodated the large tusks at the anterior end of the lower jaw and in the absence of enlarged tusks on the premaxillary and the maxillary bones. The slightly larger teeth of the median portion of the maxillary series and the similarly enlarged teeth of the palatine and the pterygoid were opposed to the corresponding teeth of the dentary and the coronoids. The great reduction of the basisphenoid is not correlated with a sutural union of the pterygoid with the parasphenoid, as in Triassic stereospondylous forms; the connection is by strong articular surfaces. This is interesting in relation to the extreme reduction of the otic capsule, the proötic, and the epipterygoid, which have become fully as cartilaginous as in the later forms. The advanced stage of chondrification of the skull and the strong development of the thoracic and other dermal elements in contrast with the skeleton of the contemporary *Eryops* are in all probability correlated with the aquatic habits of *Trimerorhachis*, as previously suggested by the author (Case, 1933).

Lower jaw. — The lower jaw has been figured and described in detail by Williston and Broom, and the present material very largely confirms their descriptions. Most of the better-preserved jaws are in close association with skulls permitting examination of only one surface, but there are several isolated jaws which may be examined in full detail. These have suffered somewhat from compression, but the individual bones can easily be made out. The right and left jaws of number 16004 show all characters and have been selected as typical; others, as numbers 16006 and 16031, have been used in confirmation. The form and relations of the various bones are represented in text Figures 12–13 and in Plate VII, Figures 2–3.

Angular. — The angular is a strong bone which occupies the usual relations in the stegocephalian jaw. Its sutural relations have been correctly given by Williston.

Articular. — The articular is much as figured by Williston, but is not so nearly covered on the inner side as shown by him. The suture with the prearticular lies anterior to the large foramen, which Williston says permitted the passage of the chorda tympani.

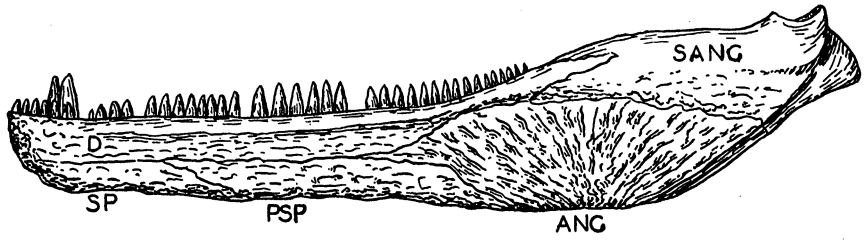

FIG. 12. Outer surface of lower left jaw, after Williston. × 1

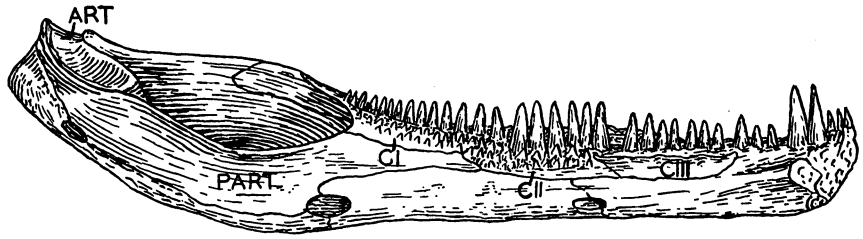

FIG. 13. Inner surface of lower left jaw. × 1

Explanation of lettering: ANG, angular; ART, articular; CI, CII, CIII, coronoids; D, dentary; PART, prearticular; PSP, postsplenial; SANG, surangular; SP, splenial

Others suggest that it transmitted the mandibular branch of the Vth cranial nerve. Goodrich (1930, p. 462) says that the two nerves come together and lie alongside of the cartilaginous mandible in early stages. The canal penetrates the articular forward and inward and enters the posterior end of the cavity for the Meckelian cartilage. The course of the suture is correctly shown by Broom, but he indicates a sharp, angulated elevation of the posterior end of the prearticular rising above the inner edge of the jaw which does not occur in any of the specimens in this collection; the angulated anterior end of the cotylus is formed by the articular, and the prearticular does not rise to its summit. The cotylus is obscurely divided into an outer, smaller and an inner, larger face, the latter extending decidedly more anteriorly. The anterior edge of the cotylus is much elevated, especially on the inner side; the posterior end of the bone is sharply divided by the groove for the sensory tract. The inner portion is more slender and more prominent than the outer, and forms a true postarticular process.

Prearticular. — The prearticular covers the anterior half of the inner face of the articular, forms the inner edge of the upper Meckelian opening, and joins the coronoids I and II and the postsplenial by a narrow wedge extending between them. It articulates with the angular below, but is separated from it and from the postsplenial, in part, by the posterior of the two lower Meckelian openings.

Surangular. — The surangular is separated from the articular for some distance by a long splint of the dentary which extends back between them. Posterior to the end of the splint the suture is so close that it cannot be followed in most of the specimens, though it can be in some. The bone extends down on the outer side of the postarticular process almost to the lower edge and then turns upward, crossing the deep sensory groove obliquely to the cotylar surface. The outer edge of the cotylus is formed by the surangular, which comes in close contact with the edge of the quadratojugal, giving that bone the appearance of having a part in the articulation.

Dentary. — The dentary articulates with the surangular by a

long interdigitating suture; anteriorly it forms the upper half of the outer surface of the jaw. Williston figures thirty-eight teeth in a single row on the dentary, and the same number, or a few more, occur in numbers 16004 and 16009B. The teeth of the median portion of the dentary are notably enlarged and were evidently used in opposition to the enlarged teeth of the palatine. There are large tusks at the anterior end within the marginal row of small teeth.

Splenial. — The splenial forms the lower half of the anterior portion of the outer side of the jaw. On the inner side of the jaw it articulates with the dentary and coronoid III. The anterior Meckelian opening is small in all the specimens, and in most is obscured by the crushing of the bones.

Postsplenial. — The postsplenial underlies the dentary and the anterior portion of the angular on the outer side of the jaw; on the inner side it underlies coronoid II and the anterior end of the prearticular. It forms the anterior border of the posterior one of the lower Meckelian openings.

Coronoids. — There are three coronoids as determined by Williston; they are here called coronoids I, II, and III. These are all clear in an isolated left ramus, number 16006, and the teeth are beautifully shown in several fragments on which they have been naturally weathered out. As indicated in Figure 13, coronoid I sends a process backward on the inner side of the dentary and the surangular, forming a portion of the outer and most of the anterior edges of the upper Meckelian opening. It joins the prearticular on the inner side of the opening, completing the anterior border. The teeth upon the coronoids do not occur as figured by Williston; on coronoids I and II there is an outer row of larger teeth adjacent to the larger teeth of the dentary. These two rows of larger teeth probably received between them the larger teeth of the palatine. On the inner side the teeth are smaller and more numerous. Coronoid III was either toothless or sparsely supplied with small teeth; probably the condition was variable (see Plate VII, Figs. 2–3).

Sensory groove system. — The sensory groove lies almost entirely upon the lower side of the jaw and is clearly marked through-

out its course. It appears on the anterior part of the dentary and continues across the splenial, postsplenial, and surangular; it occurs upon the posterior end as an exceptionally deep groove on the surangular on the outer side of the postarticular process.

Structure of the teeth. — The teeth, as in most of the Stegocephalia, are conical and capped with a smooth, hard enamel or vitreodentine, which disappears toward the lower part of the tooth, exposing the folds of dentine which occur as vertical ribs or markings on the surface. On Plate VIII, Figures 3–5, are photographs of polished surfaces of the teeth, taken at various levels. Figure 3 is from near the apex. It shows very clearly the large pulp cavity and the folds of dentine arranged in a radial pattern. The alternation in size is due to the presence of folds of different ages; the new folds appear at the bottom and rise as the tooth grows. Figure 4 is from a section near the middle of a tooth. The nearly equal size of the folds suggests that no new ones are forming. The number of folds is nearly the same in the two sections, eighteen near the tip and twenty near the middle. Since the sections are from different teeth it is probable that the number of folds was not rigidly fixed and also that there were not more than two sets of them developed in *Trimerorhachis*. In Figure 5 there are twenty folds, one set much longer than the other. In some of these a light line in the center shows the extension of the vasodentine inward. These lines have been retouched in three of the folds, but can be seen in the untouched portions.

Figures 6 and 7 of Plate VIII are photographs of vertical sections of teeth. In both, the vertical folds can be seen rising from the base of the tooth with extensions of the pulp cavity at the base of each fold and the line of infolded vasodentine disappearing (Fig. 6) toward the apex. The sections are very similar to those of *Eryops* published by Stickler (1899) and Case (1911). In Stickler's sections there is a slight suggestion of irregularity in the line of dentine ("trabeculae-dentine" of Stickler) in the center of each fold of tubulidentine, but this is not apparent in the polished surfaces in *Trimerorhachis*. In neither of the genera is there any approach to a labyrinthine structure.

The sections of the teeth in *Eryops* show more numerous folds; one from near the base of a small tooth from a jaw figured by Stickler has thirty-four or thirty-five folds, but gives evidence of only two sets. It is possible that, as Stickler suggests, the larger teeth would have more numerous folds, as the increase of size resulted from the upgrowth of new folds from the bottom. As shown by the author (1932) in the typical labyrinthine teeth of the Triassic *Buettneria*, there are at least four sets of folds which are more numerous, reaching as many as sixty in one large tusk.

Thoracic girdle. — It is noticeable that several of the specimens in the collection have the clavicles and the interclavicle preserved in their normal relations to one another and approximately, or actually, in their proper position with reference to the skull. The thoracic shield lay well forward, the anterior end reaching to the middle of the broad posterior portion of the parasphenoid. This preservation of the shield in its proper position and relations indicates the presence of strong cartilaginous attachments. Aside from those in position there are many isolated bones of the thoracic girdle scattered through the slab.

Clavicles. — Seven nearly perfect clavicles have been cleaned and several others showing one side or the other are preserved on the slab. The outer surface has the characteristic sculpture of this bone in the Stegocephalia. It is reticulate near the posterior outer angle, changing to elongate ridges and grooves radiating toward the anterior end and the inner edge (see Plate VII, Fig. 1). Only two of the clavicles retain the slender scapular process. This rises rather abruptly from the posterior outer corner and extends upward at almost a right angle to the rest of the bone. There is no ridge on the outer edge leading into the process, such as occurs in *Buettneria*. The process is curved slightly to the rear, is very thin laterally, and terminates in a sharp point, with no roughening or other indication of cartilaginous attachment (see Fig. 14). Upon all the clavicles there is a very slight indication of the presence of a sensory tract, such as has been described in *Buettneria* (Case, 1932), in the form of several irregular depressions arranged in a line and breaking the pattern of the sculpture. They would hardly have been noticed if their

presence had not been suggested by the well-developed grooves in the Triassic form.

Interclavicles. — There are several interclavicles present, either isolated in the slab or in association with the skulls. The sculptured area of the outer surface is distinctly pentagonal, with the center of ossification about one third of the length of the bone from the posterior end. The sculpture is reticulate at the center and becomes linear and radial toward the periphery. Outside the sculptured area there is a relatively broad margin for articu-

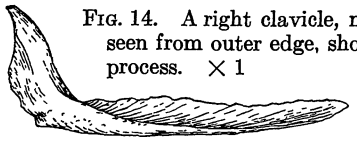

FIG. 14. A right clavicle, number 15995, seen from outer edge, showing scapular process. × 1

lation with the overlapping clavicles. The marginal portion rapidly becomes paper-thin and no specimen shows it perfectly preserved, but it is very nearly complete in one specimen on the slab (see Plate IX, Fig. 3). There is no prolongation of the anterior end; both the sculptured and the articulate portions terminate in almost straight transverse edges. A specimen of an interclavicle in the collection from a neighboring locality, number 15446, shows two short prolongations of the posterior end, as if there had been extensions of the bone into the surrounding cartilage (see Plate IX, Fig. 2; and also Plate IX, Fig. 1). This is also indicated upon one of the specimens in the collection. The upper surface is smooth, with no marks of attachment or any irregularities except a few lines radiating from the ossific center to the posterior edge.

Scapula. — Williston has figured and described the scapula (1916, Fig. 5). He remarks that no trace of the coracoid has ever been found, and that it was in all probability cartilaginous; this conclusion is borne out by the present material, since no trace of any such bone has been noted. The scapula has a well-developed cotylar surface strengthened by a prominent ridge on the inner side. The exact attachment of the scapula and the clavicle is not shown in any specimen; the scapular process of the clavicle ends, as described above, in a fine point, and there

is no facet or point of attachment for it on the anterior edge of the scapula; the scapular process must have ended in the thick cartilage bordering the scapula. The ridge on the inner face of the scapula extends to the upper end and forms a broad roughened surface; evidently there was a considerable mass of episcapular cartilage. The foramen is oval in outline and is much larger than that figured by Williston (see Figs. 15 and 16).

Vertebral column. — Most of the material of the vertebral column in the slab and in isolated blocks is badly disturbed and

FIG. 15

FIG. 16

FIG. 15. Outer side of a scapula of the right side, number 16040. × 1

FIG. 16. Inner side of same specimen. × 1

there is little continuity, but there are two specimens in which the column can be traced for some distance; there are also several short series of vertebrae in association. One vertebral column is apparently continuous with a skull on the slab, immediately behind and partly covered by the skull numbered 16009B (see Plate X, Fig. 1). In this column there are twenty-one vertebrae in continuous series from the most anterior; after a short break there are eleven more, and then two series of five and four respectively, separated by longer intervals. The last group lies close to an ilium and a femur, with which they seem to have belonged. No great difference can be detected in the vertebrae of the whole series. The neural spines and arches are exposed from the right side; the intercentra and the pleurocentra are largely hidden by the matrix, which could not be farther removed without endangering the preservation. The posterior vertebrae have somewhat longer arches and spines, and the spines are more sharply inclined to the rear; this is in accord with a short series of vertebrae found isolated in which the spines are sharply bent back and the anterior zygapophyses much elongated. Another short series which from their small size might be reckoned as caudal show no difference from the anterior ones of the long

series. Unfortunately no specimen retains the caudal region, and the length of the tail cannot be given. Williston in his description of a nearly complete specimen gives thirty-two presacral vertebrae, and Abel gives thirty-one; these figures are fairly concordant with the number in the two long series described above; undoubtedly there was some variation in the number.

The second series of vertebrae is continuous with the skull numbered 16009D. It consists of eight intercentra exposed from the ventral surface, then after a very short interval five neurocentra

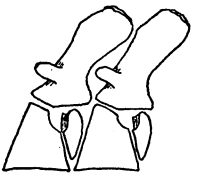

FIG. 17

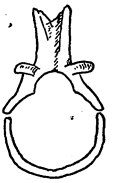

FIG. 18

FIG. 17. Two anterior dorsal vertebrae, seen from the left side; reconstructed. × 1½

FIG. 18. An anterior dorsal vertebra, seen from in front; reconstructed. × 1½

exposed from the right side; posterior to this the course of the column is indicated by ribs lying in normal opposition as far back as the pelvis and the two posterior limbs (see Plate XI, Fig. 1).

The form and the make-up of the vertebrae are best realized from a consideration of Figures 17 and 18 and from the following description. The neurocentrum is composed of right and left halves originally loosely attached by cartilage, but becoming more firmly united with age; in the collection several vertebrae show the anterior and the posterior faces of the spines on which a deep groove marks the line of union; in many cases the two halves are separate and the inner faces carry the rugosity of cartilaginous attachment. The complete spine shows a fairly broad distal end, which was evidently covered by cartilage. In all, the spine slopes backward. There is a well-developed anterior zygapophysis but the articular surface is roughened, not smooth. In none of the vertebrae is there a posterior zygapophysis or more than a suggestion of attachment to the succeeding neural arch. In some there is a slight thickening or a point of rugosity. The posterior vertebra evidently clasped the one in front between the zygapophyses and was held to it by cartilage.

The lower edge of the neural arch is expanded and thickened, with a wide surface inclined slightly outward and roughened for cartilage. In none of the vertebrae is there a distinct transverse process; the thickened base, far too wide for the attachment of the intercentrum alone, must have served as the support of the rib head. The space between the two sides of the neural arch is relatively large, and since there is no separation of a neural canal from the notochordal canal the partition must have been entirely cartilaginous. In a few vertebrae in which the two sides of the arch are in normal relation there is a groove with rough surface at the line of union of the neural arches; this may be due to the presence of the cartilage of attachment or may indicate the cartilage surrounding the nerve cord. If the latter possibility is correct the nerve cord was of small diameter.

Many isolated pleurocentra have been recovered and some are preserved in the slab in approximately their correct relations to the other elements of the vertebrae, but the parts of the vertebrae were so loosely attached around the large notochordal canal that, with the decay of the chord and the connecting cartilage, the vertebrae were easily crushed and the parts disarranged. The pleurocentra are small, lenticular bodies slightly curved to fit around the notochordal space; the upper end is slightly larger and blunter than the lower; the anterior edge of the upper end is reflected to form a distinct facet; the lower end is drawn out into a sharp point (see Figs. 19–20). The position and the relations of the pleurocentrum are shown in only one place in the various series, but this confirms the conditions suggested by related forms.

The intercentra are very thin and nearly semicircular, indicating a very large notochordal space; they are relatively wide, antero-posteriorly, in the median line, but are drawn out to a sharp point at the extremities; there is a small indentation or roughening on the posterior edge near to the extremity, which corresponds to the distinct facet occurring in other rhachitomous forms. The lower face is smooth, without sculpture or markings in most of the many isolated specimens that have been recovered, though in a few there are small rough protuberances, one on either side of the median line. In a single intercentrum, noticeably

heavier than any other recovered, these protuberances are drawn out into sharp points; it is probable that this is the intercentrum of the anterior cervical vertebra.

The intercentra are so thin and fragile that they are almost invariably broken across in the median line into right and left halves. In the series of vertebrae associated on the slab with the skull numbered 16009D there are eight intercentra exposed from the ventral surface in continuous series, all of which are broken across in the median line; this, in connection with the

FIG. 19 FIG. 20

FIG 19. Lateral view of a pleurocentrum. × 3
FIG. 20. Anterior view of same specimen. × 3

heavier intercentrum described above, casts some doubt upon the bipartite condition of the anterior cervicals which has been reported and commented upon in earlier papers.

The vertebral column was evidently very weak, and there must have been a large amount of cartilage not only between the vertebrae but between the elements of each individual vertebra. There was little if any differentiation of the vertebrae in the various regions (cervical, dorsal, and lumbar) beyond the elongation of the neurocentra and the anterior zygapophyses (see Fig. 21). In no previous description has there been any note of differentiated anterior cervicals, and there is nothing in this collection beyond the single heavier intercentrum mentioned above. Gadow, in a posthumous work edited by Gaskell and Green, *The Evolution of the Vertebral Column* (p. 101, Fig. 29), has given his interpretation of the first two cervical vertebrae in *Trimerorhachis*. He considers the parts homologous with those of the vertebrae following. He says: "*Trimerorhachis* seems to possess both separate ID1 [interdorsal 1] and ID2 [interdorsal 2]. The lateral occipital and the basioccipital parts of the condyle articulate with neural elements, and with a paired intercentrum (BV1) [basiventral 1]."

As stated above, the paired condition of the first few intercentra is not certain.

There is no distinct sacral vertebra, and Williston has noted that in all the numerous ilia inspected by him there is no suggestion of attachment to a sacral rib other than a slight roughening of the upper end, as if for the presence of a loose cartilage. Unfortunately no specimen has been recovered which shows the length of the tail or the composition of the caudal vertebrae; there is good reason to suspect that the interventrals (hypocentra

FIG. 21. Four vertebrae showing elongation of neurocentra. × 2

pleurale) occurred in some stage of ossification or cartilage and that chevron bones were present.

Ribs. — Ribs occur in large numbers in the matrix and in some places in association with the vertebrae to which they belong. In general, they are as figured by Williston, but are much more curved than as represented in his figure. The anterior ones are elongate and are widened distally, even the most anterior ones, and are decidedly curved, partly inclosing the thoracic region, but since this region was relatively broad there is a considerable space between the distal ends of the ribs on the ventral surface. The head of these ribs is broadened but ended in a cartilage and is without distinction of tuberculum or capitulum. Williston figured eight ribs of this character. Posterior to these the ribs are oval or rounded in section and are not expanded at the distal end. The head is sharply folded in the long axis of the rib, giving an appearance of a bicipital condition. All the ribs are curved, though less so in the posterior part of the series.

Limbs and feet. — Ample and repeated descriptions have been given of the upper and lower bones of the limbs, but no specimen has previously been recovered which showed, even approximately,

the characters of the feet. In the slab and in isolated specimens there are several limbs with the bones in association and with the feet more or less perfectly preserved. In none are the bones of the feet in undisturbed and perfect condition. In no case is there any suggestion of carpal or tarsal elements; these regions must have been entirely cartilaginous. As mentioned below, there are numerous small bony scutes and nodules, but these could not be confused with carpal or tarsal elements.

Anterior limb. — In number 16002 the humerus, radius, and

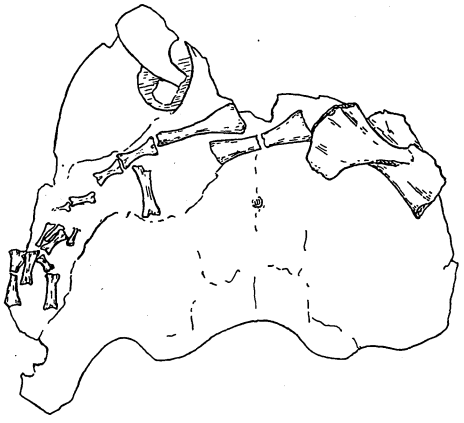

FIG. 22. An anterior limb and foot lying across top of skull, number 16002. × ⅔

ulna and numerous foot bones of the right side lie across the top of a skull. The limb bones have been left undisturbed and are as shown in Figure 22. The ulna has been displaced distally and is in contact with one of the metacarpals; this metacarpal is in contact with three phalanges, the last obviously a terminal phalange but with the distal end lost. The other bones of the foot have been disturbed in position, and some of them even reversed so that the proximal elements are farthest from the radius and the ulna. There are three metacarpals in the lot and three, perhaps four, first phalanges, and four, perhaps five, second phalanges, with two terminal phalanges. None of the foot bones have articular termination; all end in a depression which was

filled with cartilage in life. The terminal phalanges are drawn out to a very slender shaft distally which ends in a small nodular expansion. The same shape occurs in all the isolated terminal phalanges in the matrix. Evidently the toes ended without claws or with very feebly developed ones.

In number 16007, which consists of four blocks of hard matrix, all fitting into a single mass and filled with commingled bones, there are four metapodials in seemingly normal position and re-

FIG. 23. Front limb and foot, number 16007. × 1

lationship; these are so close to a humerus, a radius, and an ulna that they would be associated with them were it not for the presence of an ilium and ischium almost as close; however, the probabilities are that the propodial bones are those of a front foot. As shown in Figure 23, there are four metacarpals (?) lying in nearly normal position, with those of the first and the second digits somewhat separated from those of the third and the fourth. The metacarpal reckoned as the first is shorter than the second; it is followed by a first phalange that is so much more slender distally than proximally that it could have been followed by but a single other phalange, the terminal one. The second and the third metacarpals are at least a fourth longer than the first; the second is followed, after a short space, by a single phalange which could not, from its form and size, be a penultimate one. The third

metacarpal is of the same size as the second; the fourth metacarpal is smaller than the second and the third. It seems certain that one of the lateral digits, here considered the first, had but two phalanges and that the next had three. All the metacarpals

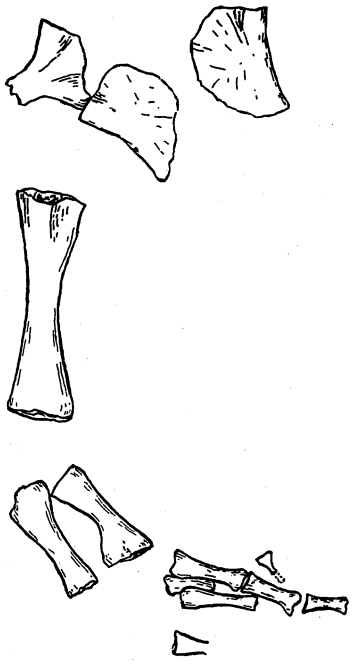

FIG. 24. Right side

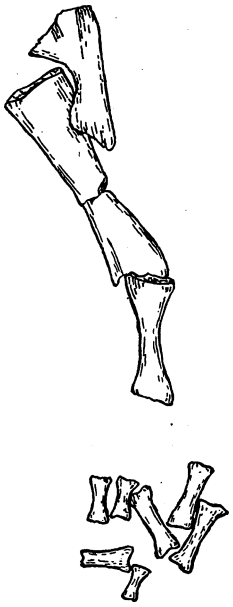

FIG. 25. Left side

FIGS. 24–25. Posterior limbs and feet, with bones of the feet, number 16009D. × 1

and phalanges are flat-oval in section. Because of the fact that most of the Stegocephalia of the time had but four toes on the front foot and because no manus has been found with more than four metacarpals it is probable that *Trimerorhachis* had only four.

Posterior limb. — In cleaning the slab certain foot bones, number 16033, were found in close association but remote from any limb bones. These were removed and fastened to cards in exactly the relations found. One lot had five digits. The first

in the series is a complete digit with metatarsal (?) and three phalanges in position; the next is a single metatarsal (?); next, two phalanges, probably the first and the second, and then two metatarsals (?). The number of digits, five, indicates a hind foot.

FIG. 26

FIG. 27

Reconstructions of front limb (Fig. 26) and posterior limb (Fig. 27). × 1

Associated with the skull, number 16009D, and the attached vertebral column are the two hind limbs in close association with the pelvis. The right limb, Figure 24 and Plate X, Figure 2, extends backward, with the head of the femur close to the acetabulum and with the tibia and the fibula in position. The foot is in place but, unfortunately, is somewhat disturbed. At least four metatarsals are recognizable and in position; they have been turned on edge by pressure and it is impossible to say which is

preaxial and which postaxial. Between the median two lies a short bone, which may be a fifth metatarsal or a first phalange. One digit is sufficiently complete to show two phalanges in continuum with the metatarsal and the evident presence of a third, terminal, phalange. The other digits are too incomplete to furnish any evidence.

The left limb, Figure 25 and Plate XI, Fig. 1, extends forward; the femur and the tibia are in position but the ulna has disappeared. Four, possibly five, metatarsal and three, possibly four, first phalanges are present though in disturbed position.

In Figures 26 and 27 the fore and hind limbs are reconstructed.

Ischium. — Williston figures an incomplete bone (1915, Fig. 6 E) which he regarded provisionally as a coracoid, but suggested that it might be an ischium. In the vertebral column attached to the skull numbered 16009D there are two elements in the proper position and relations to be the ischia. There are in the lot two isolated bones of the same form (see Figs. 28–29 and Plate X, Fig. 2) and several others occur upon isolated blocks. These bones are semicircular in outline. The outer anterior corner, as determined from the pair in place, is thickened with the usual roughened surface for cartilaginous attachment; this thickened portion is in approximation to a similar face on the ilium, and with the cartilaginous pubis formed the acetabulum. The outer edge is complete, nearly straight and very thin; evidently there was no cartilage attached to this portion of the bone. The anterior edge and the anterior half of the inner edge are thickened and were continued in cartilage; the posterior portion of the inner edge which meets the anterior portion at a slight angle is thin and was in close contact with the same portion of the bone of the other side, but the two bones were separated anteriorly by a V-shaped notch, filled with cartilage in life.

Ilium. — The many complete ilia present nothing different from those previously described and figured. There is ample confirmation of the lack of any attachment, other than by cartilage, to the sacral region.

Dermal armor. — Williston (1916) described a skeleton of *Trimerorhachis* which was covered by a "bony armor" of scutes

on both the dorsal and the ventral surfaces. The scutes were described as "oat-shaped" and very abundant. In the slab and in isolated blocks there is an enormous number of these scutes; they occurred in thick layers, much of which had to be removed in cleaning the specimens. In no place were the scutes in normal relations for any distance, but enough can be made out to show that they were elongate and were arranged in an imbricate pattern. A specimen found by Mr. T. E. White near the loca-

FIG. 28. Right ischium, seen from below, number 16054. × 1

FIG. 29. Same specimen, articular face for cartilaginous pubis. × 1

tion of the slab, No. 1080 of the Museum of Comparative Zoölogy, shows the scutes in normal position for a short distance posterior to the interclavicle. The author is indebted to the Director of the Museum of Comparative Zoölogy for permission to publish a photograph of this specimen as Figure 1 of Plate IX. The scutes have a smooth, or slightly punctate border with a sculpture of transverse ridges posteriorly. Where worn, or when a thin section is viewed by transmitted light, the ridges are seen to be an inherent part of the structure of the scute. Microscopic examination of sections shows that the scutes are not bony but cartilaginous. There is a total lack of all histological characteristics of bone but a close-set mass of irregular granules exactly similar in appearance to a section of calcified cartilage.

Scattered through the matrix were a few irregularly shaped true osteoderms. These vary in size from that of a pinhead to a length of several millimeters. Microscopic examination of the thin sections reveals the histological structure of bone. There is no indication where these osteoderms were located in the skin of the body. They are relatively sparse, but they must belong to the *Trimerorhachis* because so little of anything that can otherwise be referred was found in the slab.

Restoration. — In the restoration (Plate XI, Fig. 2) an attempt has been made to indicate the form of *Trimerorhachis*. The proportions are taken from the skeleton outlined by Williston and from measurements from the numerous specimens in the collec-

TABLE I

MEASUREMENTS OF VARIOUS SKULLS

Specimen number	Length of arc of lower jaw	Length of midline of skull	Length of orbit	Width of orbit	Width of interorbital space	Distance from center of orbit to anterior end	Distance from pineal opening to posterior edge	Breadth of posterior end	Breadth across orbits	Remarks
15994	121.3	91	19	16	17	41	24	91	62.5	Nose a little crushed
16009A	123.6	104	19	14	17	44	21	92	58	Orbital region a little crushed
16004	115.5	87	19	13	16	35	24	93	64	Measurements less certain; skull much crushed
16005	133	116	21	14.6	16.5	47.5	29	97.5	72	Breadth less certain; other measurements good
16009B	142	111	22	18	14	38	30	130	91	Distorted laterally
16009C	106	79.5	15	12.5	14	27	22	78	59.5	Lower jaw estimated; other measurements good
16009D	...	89	18.5	14.5	16.5	40	38.5	98	61	All measurements good
Average	106	99.5	19.1	14.7	15.8	38.8	24.7	94	75.5	
Average of all except 16004 and 16009B	96.7	99.8	18.5	14.3	16	39.9	24	87	74.9	Perhaps distorted

tion. The skull is more flattened than that in the Permian Stegocephalia of more terrestrial habit, and in this regard approaches the condition of the aquatic forms of Triassic age. An attempt has been made to suggest very faintly the sculpture and the course of the sensory grooves on the skull; these may have been completely hidden in the living form. The eyeballs are modeled as very prominent, partly because of the necessity of such a protrusion for any degree of lateral vision and partly because observations upon living salamanders show the eyeballs capable of great protrusion and retraction.

The breadth of the body is determined by the length of the ribs and the width of the thoracic girdle. It seems appropriate for an animal of the probable habits of *Trimerorhachis*. The number of toes upon the front foot has been placed at four, in accordance with the usual number in aquatic amphibia of the time; the number was increased to five for the more terrestrial forms. There is no definite evidence upon this point. The number of phalanges has been placed as given in the figures, in part by comparison with living forms and in part by evidence of the disturbed feet, which do not show phalanges for more than the number given.

The length of the tail is entirely hypothetical. No specimen has been found which shows the caudal region in its entirety; with the relatively good-sized limbs and feet it is probable that a large part of the function of progression was taken by them, rendering a long and heavy tail less necessary.

The author desires to acknowledge with thanks the skill and the patience of Mr. Carleton W. Angell, sculptor in the Museum of Zoölogy of the University of Michigan, who modeled the restoration.

Accompanying material. — Comparatively little material not referable to the skeleton of *Trimerorhachis* was found in the slab and accompanying débris, as follows:

A single coprolite with characteristic linear markings and of appropriate size, probably referable to *Trimerorhachis*.

Two scales with the ornamentation found in the fish, *Pyritocephalus*.

A small imperfect coprolite with numerous ganoid scales, probably of a Paleoniscid fish.

A small reptilian humerus, unidentified.

A small sacral vertebra of some Pelycosaurian reptile.

A few small phalanges of reptilian type. Unidentified.

Certain small fragments with four or five long slender teeth. These may belong to *Trimerorhachis*, but nothing like them was found in place in any skull.

This meager list of extraneous material shows that the skeletons are all of a group of similar forms which were isolated in some limited area. Any of the skeletal material might have been swallowed by some individual of the group and regurgitated in the death struggles.

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PLATES I–XI

PLATE I

Photograph of slab containing nine skulls and bones of the axial skeleton

PLATE II

FIG. 1. Photograph of skull, number 16005

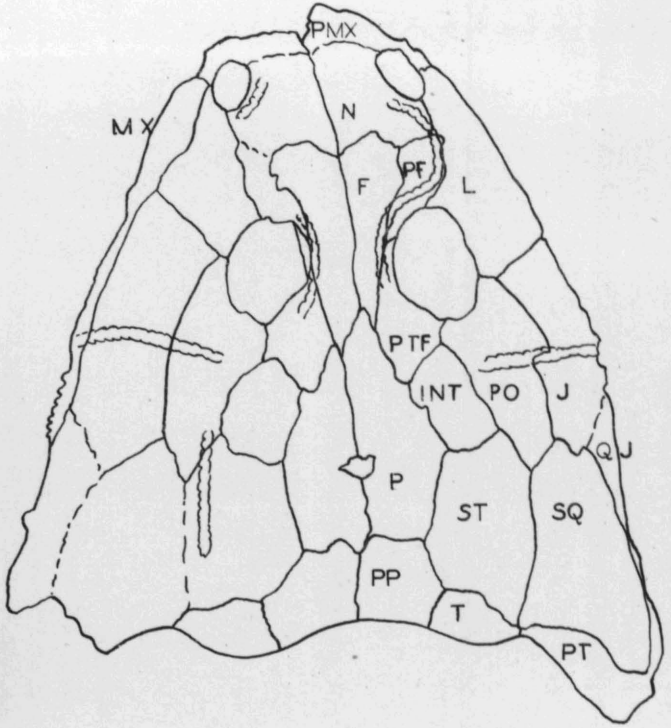

FIG. 2. Outline diagram of same specimen

Explanation of lettering: F, frontal; INT, intertemporal; J, jugal; L, lachrymal; MX, maxillary; N, nasal; P, parietal; PF, prefrontal; PMX, premaxillary; PO, postorbital; PP, postparietal; PT, pterygoid; PTF, postfrontal; QJ, quadratojugal; SQ, squamosal; ST, supratemporal; T, tabular

PLATE III

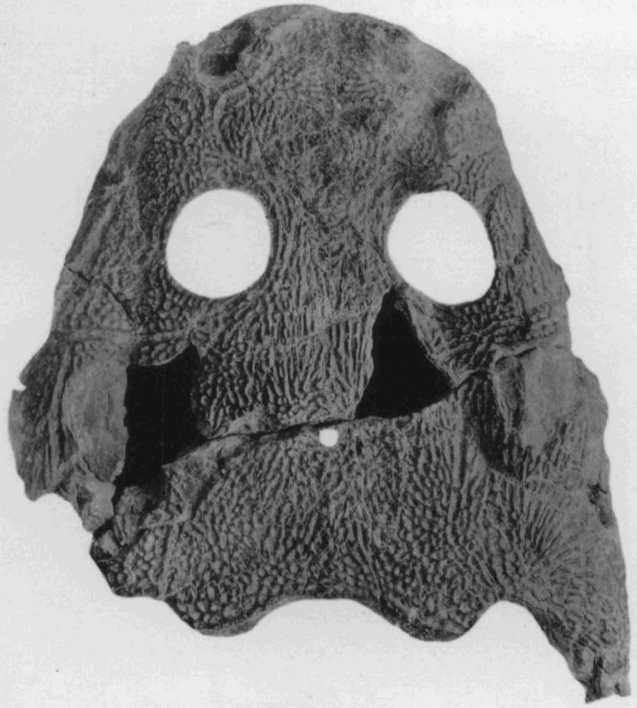

FIG. 1. Photograph of skull, number 5994

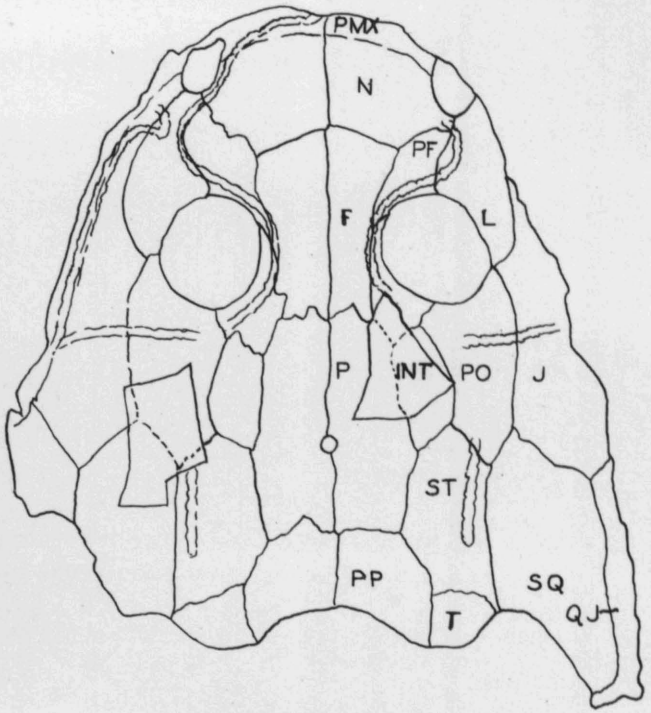

FIG. 2. Outline diagram of same specimen
Lettering as in Plate II, Figure 2

PLATE IV

FIG. 1. Photograph of skull, number 16009B

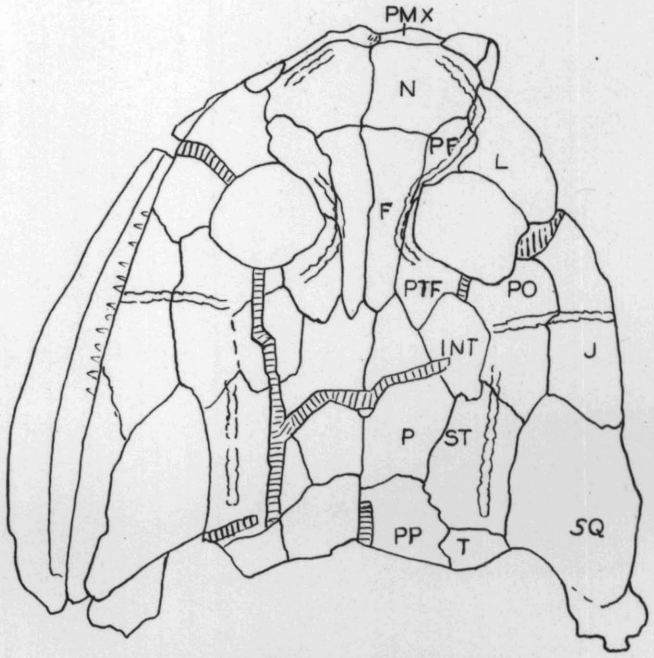

FIG. 2. Outline diagram of same specimen
Lettering as in Plate II, Figure 2

PLATE V

FIG. 1. Photograph of skull, number 16009C

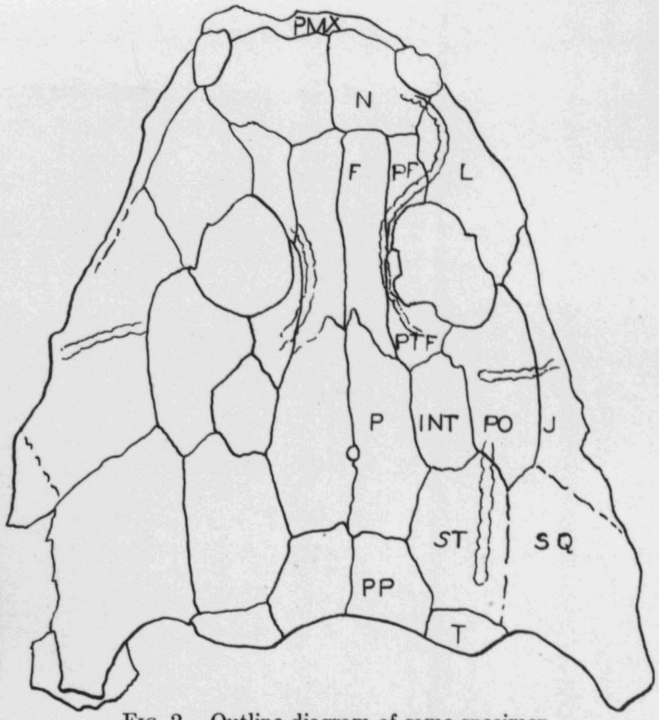

FIG. 2. Outline diagram of same specimen
Lettering as in Plate II, Figure 2

FIG. 1. Photograph of skull, number 16009A

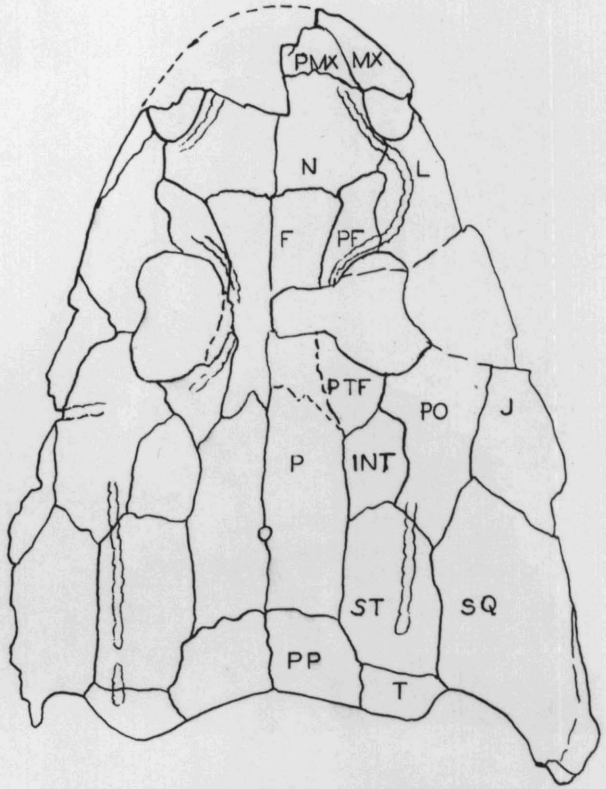

FIG. 2. Outline diagram of same specimen
Lettering as in Plate II, Figure 2

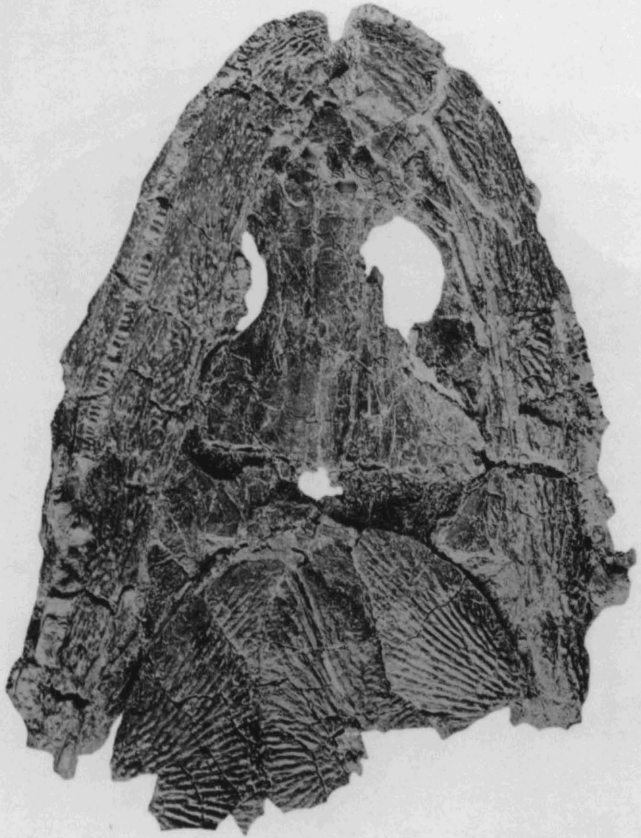

FIG. 1. Photograph of under side of skull, number 16005, with clavicles and interclavicles in place

FIG. 2

FIG. 3

FIG. 2. Inner side of left lower jaw, number 16006

FIG. 3. Inner side of right lower jaw, number 16031. The Meckelian opening partly closed by a hyoid bone

PLATE VIII

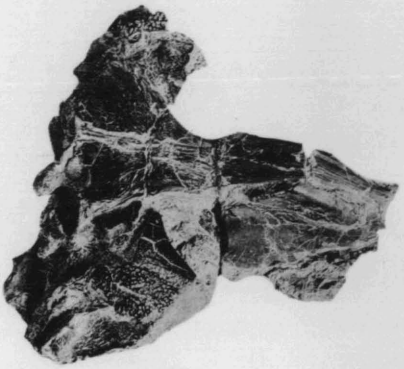

FIG. 1

FIG. 2

FIG. 1. Lower surface of parasphenoid, number 16000, viewed obliquely to show sphenethmoid

FIG. 2. Upper surface of parasphenoid, number 16003

FIG. 3

FIG. 4

FIG. 5

FIGS. 3–5. Polished sections of average-sized teeth. × about 8. The sections are from near the tip (3), the middle (4), and the base (5)

FIG. 6

FIG. 7

FIGS. 6–7. Longitudinal sections of average-sized teeth. × about 8

PLATE IX

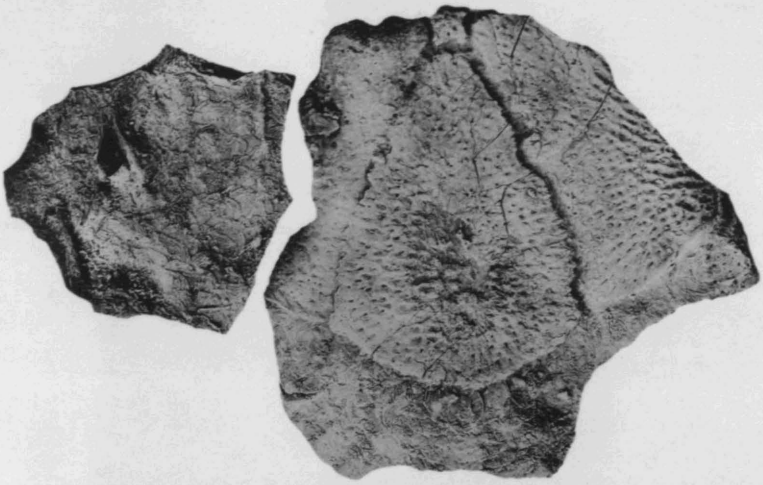

FIG. 1. Photograph of clavicles and interclavicles and an accompanying fragment of number 1080 M. C. Z. showing scutes in position

FIG. 2. Interclavicle, number 15446

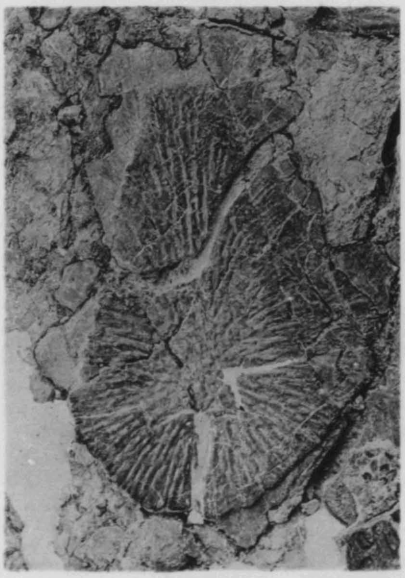

FIG. 3. Interclavicle on slab

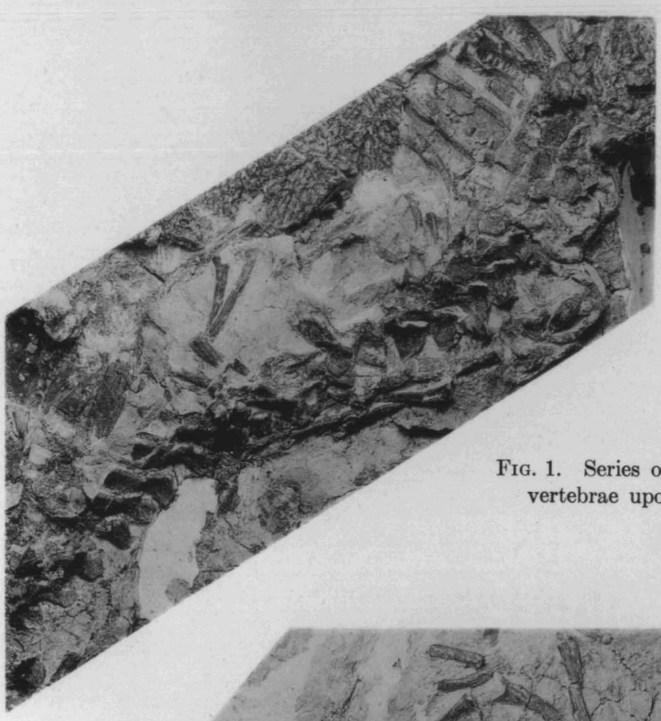

FIG. 1. Series of anterior vertebrae upon slab

FIG. 2. Pelvic region and right posterior limb and foot upon slab

PLATE XI

FIG. 1. Anterior portion of vertebral column shown on Plate X, Figure 2, with left posterior limb and foot upon slab

FIG. 2. Restoration of *Trimerorhachis*

(*Continued from inside of front cover*)

of Michigan, by G. M. Ehlers and T. E. White. Pages 93–100, with 5 plates. Price, $.20.

5. *Gypidula petoskeyensis*, Sp. Nov., a New Brachiopod from the Traverse Group of Michigan, by R. W. Imlay. Pages 101–103, with 1 plate. Price, $.15.
6. A Specimen of a Long-nosed Dolphin from the Bone Valley Gravels of Polk County, Florida, by E. C. Case. Pages 105–113, with 2 plates. Price, $.20.
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