

SUPPLEMENTARY OBSERVATIONS ON THE SKULL OF THE FOSSIL PORPOISE *ZARHACHIS FLAGELLATOR* COPE

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During the past ten years a rather large number of vertebrae and other portions of skeletons of cetaceans have been obtained from the Calvert Miocene formation of Maryland. Most of these specimens were obtained by digging into the Calvert Cliffs. During severe storms many tons of sandy clay are dislodged from the face of the cliff by the undercutting action of the incoming tide. Many specimens are destroyed in this manner and at the same time others are exposed. Worn vertebrae and fragments of bones are found at frequent intervals on the beach along the Calvert Cliffs after a storm. With the exception of the zygomatic processes and the condyles, the bones of the skull do not withstand being rolled about by the waves and are soon broken up. When remains of pelagic mammals are found undisturbed in the greenish sandy clay, they are usually well preserved. Complete skeletons of these mammals are rarely found, but broken ends of bones and portions of skulls are often found protruding from the face of the cliff.

Norman H. Boss, to whom we are indebted for most of the specimens described in this and the preceding papers,¹ has been extremely fortunate in locating and collecting specimens of fossil porpoises. One of the skulls which he collected during the past year belongs to the Miocene porpoise, *Zarhachis flagellator*. Although incomplete, this skull supplies most of the structural details which were missing on the other specimen. The locality at which this skull was obtained is less than 2½ miles south of the previous discovery.

The only certainly known remains of *Zarhachis flagellator* from the Atlantic coast province of North America belong to four individuals. One of these is the type specimen, a single anterior caudal vertebra; a fairly complete skeleton which was described in 1924 represents the second specimen; the third is the cranial portion of a skull hereinafter described and figured; and of the fourth the right periotic alone was collected.

¹ Kellogg, R., A fossil porpoise from the Calvert formation of Maryland. Proc. U. S. Nat. Mus., vol. 63, publ. 2482, pp. 1-39, pls. 1-18. March 26, 1924.

The Calvert formation of Maryland has yielded a rather large number of porpoises and in the main these species have their nearest affinities with those in the Tortonian stage of Europe. A few of them appear to have no counterparts in the European stages or at least none have been described and one of these is *Zarhachis*. Without entering into a discussion of the fauna as a whole, it is sufficient to observe in the present connection that *Zarhachis* appears to represent a highly specialized aberrant type whose family allocation is more or less a matter of personal opinion in the light of available data. If it is desirable to associate this porpoise with other genera, it must be done with the understanding that it is merely a matter of convenience. That *Zarhachis* exhibits certain characters in common with *Inia*, *Lipotes*, and *Platanista*, there can be no doubt, but whether they arose from one or three types of toothed whales can not be demonstrated from the specimens now known. According to our present knowledge, *Zarhachis* represents a type which can not be referred to any of the recognized families of toothed whales, unless the limits of these families be redefined. A natural grouping of some of the South American Miocene porpoises is not possible at present because of the lack of adequate data on the construction of their skulls. The ancestry of the *Zarhachis* type of porpoise is completely unknown at present. No fossil porpoises with this type of skull have been described from the Miocene formations of Europe. For this reason there can be little doubt but that it represents a migrant from some other region, probably the south Atlantic, which became associated with more widely distributed types during the latter part of the Miocene period.

The skull of *Zarhachis* is modified in many ways, as will be noted in the descriptive portions of this and the preceding paper. For the purpose of bringing into stronger relief the characters of this porpoise, it is necessary to compare them carefully with living river porpoises. The morphological characters involved in the construction of the skull will form the main subject of this paper.

ZARHACHIS FLAGELLATOR Cope

Specimen.—Cat. No. 10911, division of vertebrate paleontology, United States National Museum. The brain case and the proximal portion of the rostrum are represented; the lachrymals, jugals, periotics, tympanics, and bones of the inner ear are missing. Fragments of three ribs were found near this skull.

Locality.—The occurrence of this specimen is as follows: Near latitude 38° 38' 45" N., and longitude 76° 32' W., on the western shore of Chesapeake Bay, approximately 3½ miles south of Chesapeake Beach, Calvert County, Md. Shown on Patuxent quadrangle or Patuxent folio. No. 152, United States Geological Survey.

Horizon.—The specimen was discovered and excavated by Norman H. Boss on December 30, 1923. The jagged extremity of the rostrum was found protruding from a layer of greenish sandy clay about 8 feet above the beach at a point less than 50 feet from the end of the cliff north of the Boy Scout camp. Shattuck's zones 6-8 are not clearly differentiated at this point and the specimen came from one of these three zones.

SKULL

Dorsal view.—As mentioned in the preceding paper,² the arrangement of the bones which comprise the dorsal surface of the brain case corresponds in a general way with the skull of the Chinese porpoise, *Lipotes vexillifer*, now living in Tung Ting lake and its tributaries. There are a number of rather obvious differences, as, for instance, the development of a high crest on the extremity of each supraorbital process, the projection of the ascending processes of the premaxillae behind the nasals, the presence of a pair of crescentic orifices for nerves on the posterior walls of the "blow holes," the outward curvature of the vomerine trough to form a portion of the dorso-anterior wall of each nasal passage, and the prolongation of the anterior extremity of the zygomatic process and the postorbital projection of the supraorbital process so that they overlap. In its general features, the skull of *Zarhachis* is characterized chiefly by the exceedingly long and slender rostrum which comprises more than five-sixths of the total length of the skull, the "upended" supraorbital processes of the frontals, and the pair of crescentic orifices on the posterior walls of the nasal passages below the relatively thick nasals, peculiarities that are most noticeable when contrasted with skulls of other known porpoises. Since the rostrum was fully described in the previous paper, there is no necessity for a detailed discussion of this part of the skull.

All of the brain case posterior to the nasal passages and the "upended" supraorbital processes was missing from the first skull (Cat. No. 10485, U.S.N.M.). A small fragment of bone which appeared to be a portion of the vertex was found alongside of this skull and it was so placed in the restoration³ of the brain case. The brain case of the second skull (pl. 1) is in a fair state of preservation and the description that follows has been prepared in the form of a supplement to the preceding paper.

Behind the antorbital notches, the maxillae push back over the frontals and expand into relatively thin horizontal plates. The outer border of each maxilla is deflected obliquely upward and inward to conform with the curvature of the "upended" crestlike portion of the

² Kellogg, R., A fossil porpoise from the Calvert formation of Maryland. Proc. U. S. Nat. Mus., vol. 63, publ. 2482, pp. 1-39, pls. 1-18. March 26, 1921.

³ Kellogg, R., Idem, pl. 1.

supraorbital process. The maxilla sheathes the internal face of this "upended" process and its outer margin follows the crest of the latter. Behind this process, the maxilla expands horizontally and is applied to the platelike lateral extension of the frontal which in turn contributes the roof for the temporal fossa. The temporal fossae are not visible from a dorsal view and the external margin of the maxilla curves backward from the postorbital projection to the transverse crest of the supraoccipital. At the level of the nasals the whole maxilla curves strongly upward to the transverse crest of the supraoccipital. The dorsal margin of the supraoccipital and the posterior borders of the maxillae together comprise the transverse lambdoid crest. Behind the temporal fossae the lateral margins of the supraoccipital are applied to the posterior borders of the parietals and these combined bones form the thin posteriorly directed lambdoid crest which follows the curvature of the inner and lower margins of each temporal fossa.

As in the other skull (Cat. No. 10485, U.S.N.M.) the raised convex portions of the premaxillae are widest in front of the premaxillary foramina and taper rapidly posterior to the latter, disappearing in front of the nasal passages. Both premaxillary foramina are compressed dorso-ventrally and of large size; the greatest diameter of the right foramen is 10.5 mm. The right foramen is situated 42 mm. in front of the level of the antorbital notches and the left 37 mm. From each foramen a broad groove passes forward along the internal border of the raised convex outer portion of the premaxilla. On the other skull a groove also extends backward from each foramen in an oblique direction across the premaxilla and terminates near the level of the posterior margin of the "upended" crestlike portion of the supraorbital process. On the second skull the orifice of the premaxillary foramen looks inward and forward. This change in direction of the foramen leaves the posterior margin elevated above the level of the anterior groove and shuts off the posterior groove at the source. The premaxillae are separated by an interval of 17 mm. above the porous pluglike portion of the presphenoid. The presphenoid does not rise to the level of the premaxillae, as in the first skull. Behind the level of the antorbital notches the dorsal aspect of the ascending process of each premaxilla is convexo-concave, the surface sloping from the external to the internal margin. Between the nasal passages and the antorbital notches the internal border of each premaxilla is deflected obliquely downward. The peculiarities of the premaxillae are essentially the same on both skulls. At the level of the anterior margins of the nasals the premaxillae are quite deep, and at the postero-external angle the dorsal surface is raised at least 20 mm. above the horizontally expanded plate of the maxilla. The posterior end of each premaxilla is obliquely truncated,

and their posterior margins form a continuous curve with the posterior border of the protuberance behind the nasal passages. There is a relatively large dorso-ventrally compressed foramen in the maxilla at the posterior extremity of the premaxilla which opens into a short, deep groove.

In the preceding paper it was stated that "skulls of *Lipotes* and *Inia* may appear more specialized than that of *Zarhachis*⁴ because of the elevation of the vertex and the shifting of the nasals to a vertical position." This opinion was based upon a small fragment of bone which appeared to represent a portion of the vertex. Further on⁵ it was said that "this fragment is very important, for it shows that the vertex of the skull was not strongly elevated, or at least no prominent protuberance, like in *Inia* or *Lipotes*, was present." On reexamination it has been found that this fragment differs in a number of respects from the vertex of the second skull. The protuberance behind the nasal passages may have changed with age and varied according to sex. Nevertheless certain peculiarities of this fragment are not readily interpreted on the basis of conditions in the second skull, and there are some features which suggest the interpretation given in the preceding paper. This second skull, however, shows that other portions of the attempted restoration are incorrect and also that the protuberance behind the nasal passages is broader than in *Inia* and *Lipotes*.

The nasal bones do not overhang the nasal passages; their antero-posterior diameter is about equivalent to one-half of their breadth. The nasals are applied to the anterior surfaces of the frontals, as in *Lipotes* and *Inia*, but they are proportionately larger bones and actually increase the size of the protuberance behind the nasal passages. From a dorsal view the nasals are almost subtriangular in outline, but the posterior margin is more or less emarginate and the anterior concave. Inferiorly they are overspread by the extremities of the ectethmoids. In the case of *Inia* and *Lipotes* the nasals consist of thin plates of bone applied to the anterior surface of the protuberance behind the nasal passages, and their dorsal margins do not extend upward to the level of the dorsal surfaces of the frontals.

A narrow interparietal may be present between the crest of the supraoccipital and the protuberance behind the nasal passages. A narrow groove follows the posterior border of this protuberance and may possibly represent a suture between the combined frontals and the narrow strip of bone which, because of its position, may very well represent the interparietal. An interparietal seems to be present in the skull of *Inia geoffrensis* (Cat. No. 239667, U.S.N.M.). Both condyles are visible when the skull is viewed from above.

⁴ Kellogg, R., Proc. U. S. Nat. Mus., vol. 63, 1924, p. 7.

⁵ Kellogg, R., Idem, p. 13.

The exposure of the frontals on the vertex of the skull appears to be restricted to the protuberance behind the nasal passages. Posteriorly the frontals abut against a narrow strip of bone which has been referred to as the "interparietal" and anteriorly they are sheathed by the nasals. The protuberance separates the posterior extremities of the maxillae on the vertex of the skull. Laterally the frontals are overspread by the ascending processes of the premaxillae and by the horizontally expanded plates of the maxillae. At a lower level, a thin plate of the frontal projects laterally, forming the roof of the temporal fossa and in front of this each frontal sends out a large supraorbital process which contributes a complete osseous roof for the orbit.

The construction of the crescentic foramina below the nasal bones in the skull of *Zarhachis* (pl. 2) proved very puzzling on first examination. In order to obtain more explicit data on the relations of the bones involved, it seemed advisable to make a comparative examination of the skulls of as many genera of living toothed whales as were available for study. In the course of this review skulls were found in various stages of growth, and these have cleared up whatever uncertainties may have existed in regard to the construction of this portion of the brain case. The interpretations herewith given for the bones inclosing the nasal passages have been confirmed by direct comparison with disarticulated skulls of living dolphins.

In a skull of a young *Berardius bairdi* (Cat. No. 14218, division of mammals, U.S.N.M.) from Bering Island the presphenoid rests in the trough of the vomer and the thin lateral walls of the vomer embrace the lower half of this bone. Dorsally, there is a second platelike bone coextensive with the nasal passage which fits into a groove on the upper margin of the lateral wall of the vomer and sheathes the upper half of the presphenoid. One of these platelike bones is present in each nasal passage. These bones fulfill the requirements of the ectethmoids. Posteriorly, each ectethmoid meets the corresponding frontal edge to edge on the outer border of the frontal fontanelle. In older individuals the dorsal margins of the anteriorly directed ectethmoids meet on the mid line and fuse with a perpendicular plate of bone which extends forward from the base of the nasals to a point in front of the nasal passages, thus completely inclosing the presphenoid. The thin longitudinal perpendicular plate either represents the mesethmoid or a dorsal prolongation of the combined ectethmoids. With age, these lateral ectethmoids sheath the internal borders of the frontals and extend upward on the posterior walls of the nasal passages until they meet the anterior margins of the nasal bones from below. Minute foramina are sometimes present in these bones in some of the genera of living porpoises.

In most mammals the ethmoid plate ossifies into a median mesethmoid bone bounded below on either side by an ectethmoid. These ectethmoids develop as the cribriform plate. On each side of the perpendicular mesethmoid in skulls of the Miocene porpoises *Diochotichus*, *Ceterhinops*, and *Squalodon* there is a relatively large aperture through which the nasal branch of the ophthalmic division of the fifth cranial nerve passes. In skulls of living porpoises, like *Delphinus* and *Pseudorca*, there is a continuous sheet of bone extending upward to the base of the nasals and from which arises the mesial longitudinal perpendicular strip of bone that constitutes the most dorsal portion of the wall between the nasal passages. In each nasal passage in the skull of *Lipotes* a fissure appears to separate the longitudinal perpendicular plate or mesethmoid superiorly from the laterally placed ectethmoid. Inferiorly, the fissure extends obliquely downward across the posterior wall of each nasal passage. These fissures may represent one of the later stages in the closure of foramina similar to those in the *Zarhachis* skull. The thin longitudinal bony partition may represent either a dorsal continuation of the combined ectethmoids or the mesethmoid. Most writers in recent years have held that the pluglike porous bone, which rests in the trough of the vomer and terminates the mesorostral gutter, consists of the presphenoid below and the mesethmoid above, the bones being so intimately fused with each other that their limits can not be defined with any degree of accuracy. Such an interpretation of the mesorostral plug would place the mesethmoid below the cribriform plate in most porpoises and in others a portion would actually lie behind it. The flat plate-like bone which sheathes the anterior surface of the internal borders of the frontals, conceals the frontal fontanelle, and extends upward to meet the anterior margins of the nasals from below, unquestionably represents the combined ectethmoids in the living porpoises or the cribriform plate of other mammals. The telescoping of the rostral and facial portions of the skull was accompanied by a forward thrust of the presphenoid and a backward thrust of the trough of the vomer, and as a result of one or the other, or possibly both, of the above movements, the lower portions of the ectethmoids were separated on the mid line and overspread the presphenoid laterally. Other bones may be included in these lateral plates and, in the case of *Ziphius cavirostris* Kernan⁶ refers to them as including the sphenoidal turbinals.

A skull of a young *Grampus griseus* (Cat. No. 15, 773, division of mammals, U.S.N.M.) from Cape Cod, Mass., shows how the *Zarhachis* type of orifice may have developed. On this young

⁶ Kernan, John D., The skull of *Ziphius cavirostris*. Bull. Amer. Mus. Nat. Hist., vol. 38, art. 11, p. 390, August 1, 1918.

Grampus skull, the dorsal margins of the lateral platelike bones or ectethmoids do not meet above the presphenoid as in an older individual and above the level of the latter there is a fissure which extends inward from the internal margin of each ectethmoid to the rudimentary foramen for the nerve. In addition to this fissure, there is a shallow groove leading upward from the foramen and passing obliquely across the upper extremity of the ectethmoid. The ectethmoid has enveloped the foramen. In other mammals, the nasal branch of the ophthalmic division of the fifth cranial nerve passes outward on each side of the mesethmoid between the latter and the ectethmoid.

A critical examination of the *Zarhachis* skull (pl. 2) shows that the ectethmoid in the region of the crescentic foramen is more noticeably modified than is the case in the skull of the young *Grampus*. As in the latter, a fissure extends inward from the internal margin of the ectethmoid to the foramen, but the whole bone is more or less involuted. Each ectethmoid in the region of these crescentic orifices is twisted almost at right angles to the main body of the bone. The curvature of the ectethmoid around the foramen is so unusual in appearance that one might view the semiovoidal rostral border or the margin which is visible on plate 2 as being actually the outer margin of the ectethmoid, and the that border which surrounds the foramen at the bottom or at the caudal end of the deep crescentic aperture is the internal margin. If this is the true explanation, then the flattened condition of the ectethmoid in living porpoises is a later development and is indicative of one of the methods by which the closure of the foramen has been effected, with the accompanying loss of the sense of smell. It should also be noted that the thin perpendicular plate extending from the nasals to a point in front of the nasal passages has been destroyed.

The dorsal border of the anterior wall of each nasal passage is very thin and projects dorsally for 15 mm. or more above the porous plug-like portion of the presphenoid. Although a number of genera of toothed whales were studied, no skulls were found in which the construction of the nasal passages corresponded to the *Zarhachis* type of architecture. In *Phocaena* (Cat. No. 3659), *Tursiops* (Cat. No. 22299), and *Lipotes* (Cat. No. 218293), the dorsal margin of the anterior wall of each nasal passage is formed by a portion of the internal border of the maxilla. In all the toothed whales examined, the maxilla contributes part of the anterior wall of the nasal passage and, with the exception of *Inia* and *Stenodelphis*, it always constitutes the upper border of the anterior wall. In *Inia* and *Stenodelphis*, however, the premaxillae are thickened dorso-ventrally and closely approximated at the base of the mesorostral gutter; they constitute the upper border of the nasal passages. In *Zarhachis*, however, at

least half of the upper border of the anterior wall of each nasal passage is contributed by the vomer whose upper margin rolls over or is folded outward so that it meets the maxilla slightly external to the mid line of the nasal passage. The peculiar curvature of the lateral walls of the trough of the vomer around the upper borders of the nasal passages does not appear to be duplicated in any of the living toothed whales. The maxilla contributes the outer wall and about one-half of the dorsal border of the anterior wall. Inferiorly, the palatine extends upward in each nasal passage for a distance equivalent to about three-fourths of the depth of the anterior wall and is inserted between the maxilla and vomer in the shape of a subtriangular wedge. The dorsal margin of the surface of the palatine which takes part in the formation of the nasal passage is emarginate.

In front of the nasal passages, the trough of the vomer assumes the shape characteristic of most dolphins. At the level of the anterior margin of the nasal passages, the greatest depth of the trough of the vomer is 98 mm., but at a point 180 mm. in front of these passages, it does not measure more than 25 mm. in depth. For a distance of 75 mm. in front of the nasal passages, the dorsal margins of the lateral walls of the vomer slope forward and downward at a very steep angle. This may be associated with the mesial depression of the internal borders of the premaxillae behind and in front of the premaxillary foramina. Anterior to this depression, the reduction of the lateral walls of the vomer is rather gradual. From a ventral view, the vomer is seen to be split along the mid line of the axial ridge, but this may be abnormal. The axial ridge is wedged in between the opposing faces of the maxillae and in correlation with this compression and with the slope of the internal surface of the maxilla, the floor of the mesorostral gutter is rather narrow posteriorly and it becomes so narrow about 140 mm. in front of the nasal passages that it would appear V-shaped in cross section. The lateral border of the trough of the vomer rolls over and is overspread by the thin margin of the horizontal plate of the premaxilla, which overhangs the mesorostral gutter.

Posterior view.—The back of the brain case (pl. 3) has been crushed in a dorso-ventral direction and the extent of this crushing is best illustrated on the posterior face of the skull. The lower half of the supraoccipital was too thin to support the great weight of the sediments which overlay the skull, and the bone fractured in many directions. A portion of the supraoccipital was thrust downward into the foramen magnum and it also buckled inward above the condyles. The displacement or amount of crushing at the center of the foramen magnum may equal 20 or 25 mm. Another consequence of this crushing is shown by the buckling of the parietals and frontals in the temporal fossae.

The posterior face of the *Zarhachis* skull resembles *Lipotes* more closely than *Inia*. The supraoccipital is wider than high, bounded on the sides and at the top by a flaring lambdoid crest. In *Lipotes*, the supraoccipital is traversed by a distinct median ridge, extending from the lambdoid crest almost to the foramen magnum. A low median crest is present on the upper half of the supraoccipital in *Zarhachis*.

The unusual depth of the thin lambdoid crest is the characteristic peculiarity of the back of the skull. On the inner and lower sides of the temporal fossa the crest curves ventrally and laterally, following the contour of the posterior border of the fossa. At the level of the lower border of the temporal fossa, the crest on the right side is fully 32 mm. deep. The thin lambdoid crest overhangs the exoccipital on each side. The exoccipitals project downward and backward, and are of a different shape than those of *Lipotes* and *Inia*, the most noticeable modification in the latter genera being associated with the development of a paroccipital process. In these living river dolphins, the exoccipital is distinctly constricted above the paroccipital process. This process projects outward and backward. In *Zarhachis*, the exoccipitals are larger, although they are not produced outward far enough to conceal the zygomatic processes from behind. The more detailed features of the exoccipitals are shown on the photograph reproduced on Plate 3. Laterally and anteriorly, the exoccipital is in contact with the squamosal, superiorly it is coalesced with the supraoccipital, while below and internally it fuses with the basioccipital. The deep jugular incisure may mark the junction of the exoccipital with the falcate process of the basioccipital.

The foramen magnum originally was probably slightly wider than high. The condyles are semielliptical in outline. They are strongly convex from side to side and are borne on distinct necks. The internal borders of the condyles are sharp edged and concave; the external borders are rounded off.

Lateral view.—Aside from the relatively large size of the "upended" extremity of the supraorbital process and the massive zygomatic process, the skull (pl. 4) is characterized by a short temporal fossa and a protuberance on the vertex. The protuberance behind the nasal passages is the highest point on the dorsal profile. The transverse crest of the supraoccipital is the next highest point and from this crest the maxilla slopes forward to the base of the rostrum.

Above the orbit the extremity of the supraorbital process bends abruptly upward and forms a broad crest. Portions of the outer margin of the maxilla are visible on the upper margin of this crest from a side view and it also sheathes the entire internal surface. The greatest vertical depth of the right supraorbital process is 64 mm. and the greatest anteroposterior diameter is 96 mm. The external face of the extremity of the supraorbital process is more or

less flattened and slopes obliquely upward and inward. There is no distinct preorbital apophysis, but the postorbital projection is rather long and attenuate. The orbit is relatively longer than in *Lipotes*. The lachrymal and jugal are missing.

As on the first skull, the zygomatic process of the squamosal is greatly thickened dorso-ventrally in contrast to the long attenuate process of *Inia* and *Lipotes*. As viewed from the side, the slope of the posterior half of the dorsal profile of the zygomatic process is very steep; the inferior profile is biconcave. The anterior extremity is bluntly pointed; the postglenoid process is relatively thin and curves forward. The greatest length of the right zygomatic process along the glenoid face is 98 mm. and the greatest depth near the middle is 57.5 mm.

Attention has already been called to the distortion which has resulted from crushing. In addition to the previously mentioned details, it may be noted that the lateral platelike extension of the frontal and the superimposed maxilla have been depressed below their original level. A thin layer of matrix lies between the upper surface of the anterior half of the zygomatic process and the bones mentioned above.

The temporal fossa is relatively short and produced backward beyond the level of the main body of the supraoccipital. Within the fossa the parietals and frontals have buckled as mentioned before, producing some irregularities. As in *Inia* and *Lipotes*, the parietal is more or less crescentic in shape; it curves around the squamosal on the external wall of the braincase and contributes the posterior border of the temporal fossa and the external plate of the bipartite lambdoid crest, extending downward behind the squamosal until it meets the exoccipital on the lower margin of the temporal fossa. Anteriorly and superiorly, the parietal is suturally united with the frontal and inferiorly it abuts against the alisphenoid. The lateral extremity of the exoccipital is relatively thin and is directed backward. The condyles are large, knoblike in contour, and project beyond the level of the exoccipital. Most of the lower border as well as the anterior end of the external reduplication of the pterygoid is missing, exposing the axial ridge of the vomer. The falcate process of the basioccipital does not project below the postglenoid process.

Ventral view.—The description of the rostrum in the preceding paper fully covered this part of the skull and it seems unnecessary to repeat some of the peculiarities in the present paper, especially as no additional structural details are shown. It will also be noted that the palatal surface of this skull (pl. 5) is not as well preserved as on the first skull. Some additional details are revealed which necessitate a modification of the interpretation given for the relations of the pterygoids on the first skull.

It was stated in the preceding paper that the outer plate of the pterygoid represented the external pterygoid and the internal plate was referred to as the internal pterygoid. This interpretation does not appear to be correct, since both plates are continuous on the right side of the second skull and overspread the inferior face of the basal portion of the alisphenoid; these combined plates and the thin isthmus which unites them form the walls of the longitudinal sinus external to the basisphenoid. In view of the above, it is apparent that the outer plate represents the external reduplication of the pterygoid. The loss of the anterior end of the thin platelike external reduplication of the pterygoid on the right side exposes the pyramidal cavity on the corresponding side of the axial ridge of the vomer for its entire length. On the left side, this thin platelike external reduplication of the pterygoid extends forward 128 mm. in advance of the posterior wall of the nasal passage and contributes the external wall of the pyramidal cavity on the left side of the vomer. Posteriorly, the external reduplication of the left pterygoid extends backward beyond the nasal passages and is bounded by the maxilla anteriorly, by the frontal and alisphenoid superiorly, and by the squamosal posteriorly. The mandibular branch of the trigeminal nerve passes outward through the foramen ovale in the suture between the squamosal and the external reduplication of the pterygoid and follows the trowellike gutter on the external face of the latter. This foramen is situated in approximately the same position as in *Platanista*. There is a remarkable resemblance between the size and relations of these pterygoids and the corresponding bones in *Platanista*. The internal plates of the pterygoids are not as well preserved on this specimen as on the first skull. On the latter the thin internal plate of the pterygoid curves around the lower border of the lateral and anterior walls of the corresponding nasal passage and meets the vomer mesially; it then turns almost at right angles to the latter and is closely appressed to the external surface of the trough of the vomer. On skulls of *Inia*, *Lipotes*, and *Platanista* thin plates of the maxillae have overspread the external surface of the trough of the vomer and conceal all but the axial ridge of the latter. On the *Zarhachis* skull the external surface of the trough of the vomer is not overspread by the maxillae below the level of the palatines. Further comparison with the first skull is scarcely necessary, as it is now apparent that the thin anteriorly directed internal plate of the pterygoid did not by itself form the internal and superior walls of the pyramidal cavity or at least a cavity was not formed which was bounded solely by the internal plate of the pterygoid and its external reduplication as in *Platanista*.

The palatines are not visible from a ventral view when the pterygoids are complete. The sutures defining the limits of the right

palatine are clearly outlined. It is a relatively narrow bone mortised into the maxilla above and bounded externally by the upper margin of the external reduplication of the pterygoid. As now understood, each pyramidal cavity is inclosed on the rear by the internal plate of the pterygoid, on the outside by the external reduplication of the pterygoid, on the inside by a thin internal plate of the pterygoid posteriorly and by the vomer anteriorly, and above by the palatine posteriorly and the maxilla anteriorly. The thin internal plate of the pterygoid does not project as far forward as in *Platanista*, but otherwise the relations between the palatines and pterygoids are essentially the same in both genera. The external reduplication of the pterygoid is not developed on skulls of *Inia* and *Lipotes*, thus exposing the entire alisphenoid. On the *Zarhachis* skull the extremity of the alisphenoid is not overspread by the external reduplication of the pterygoid and it appears within the temporal fossa in the same relative position as in *Inia*. In *Platanista* the extremity of the alisphenoid is overspread by the external reduplication of the pterygoid.

The keel of the trough of the vomer is exposed between the nasal passages and the anterior extremity of the external reduplication of the pterygoid. In its shape and relations with the surrounding bones, the vomer does not differ from that on the first skull. It expands horizontally posterior to the nasal passages, but terminates near the anterior margin of the basisphenoid.

The median region of the basicranium is rather broad, bounded on each side, as mentioned above, by a continuous wall formed by the vaginal plate of the pterygoid and the adjoining falcate process of the basioccipital. The surface of the median area between these sloping walls is more or less concave. The basioccipital is a much larger bone than the basisphenoid; the transverse suture between these bones is unusually distinct. The occipital condyles are large and are separated mesially by a deep groove. A deep jugular incisure appears between the internal margin of the exoccipital and the posterior margin of the falcate process of the basioccipital. A small condylar foramen is present on each side between the base of the falcate process of the basioccipital and the condyle.

The body of the squamosal contributes a part of the lateral wall of the brain case and its lateral projection or zygomatic process serves as the articular surface for the condyle of the lower jaw. The glenoid articular surface on the zygomatic process curves upward and forward and is concave from side to side. The external border of the zygomatic process is prolonged downward, forming a thin crest; the internal border is rounded off. The postglenoid process is short and curves forward. A shallow groove for the external auditory meatus traverses the squamosal behind the postglenoid process. A narrow posteriorly directed process of the squamosal is suturally

united with the exoccipital along its external border. To the inside of the postglenoid process and at the origin of the groove for the external auditory meatus, the periotic was attached to the skull. A thin plate-like process of the squamosal which is directed inward and downward contributes the external wall of the tympano-periotic fossa; the internal wall is formed by the falcate process of the basioccipital. Between the glenoid process and the internal margin of the glenoid fossa there is a sharply defined longitudinal depression, which curves forward from the base of the groove for the external auditory meatus to the anterior margin of the squamosal. The contour of the ventral surface of the paroccipital process resembles that of *Inia* and *Platanista*. There are some minor modifications which are not developed on the paroccipital processes in the last-mentioned genera and of these the thin crest on the anterior border is the most conspicuous.

Further comparisons with skulls of the living Iniidae and with *Platanista* show some interesting structural modifications in the region of the orbitosphenoid. In *Inia*, the sphenoidal fissure is relatively large, bell-shaped in contour, and bounded laterally and on the rear by the basisphenoid, and anteriorly by the orbitosphenoid. On their outward course, the trochlearis and the ophthalmic division of the trigeminal nerve follow the groove on the ventral surface of an attenuate process of the orbitosphenoid. This groove is rather deep, with well-marked lateral walls; the process as a whole is directed obliquely outward and forward, terminating near the base of the broad channel on the supraorbital process of the frontal. The most remarkable peculiarity of the orbitosphenoid of *Inia* is the position of the ectal orifice of the optic canal. This orifice appears on the inner wall and about halfway between the anterior and posterior ends of the groove leading forward from the sphenoidal fissure. From this point forward all three nerves occupy the same groove. Within the cranial cavity, the orifice of each optic canal is placed near the inner angle of the sphenoidal fissure and is overhung by a thin platelike process of the orbitosphenoid. The course of the optic canal through the orbitosphenoid parallels the groove leading forward from the sphenoidal fissure. The apex of the process of the orbitosphenoid which contributes the surface of the groove for these nerves is jagged, and projects outward and forward at a lower level than the ventral surface of the supraorbital process.

In *Lipotes*, the sphenoidal fissure is narrower, bounded on the rear and on the outside by the alisphenoid, and on the inside and in front by the orbitosphenoid. The orbitosphenoid of *Lipotes* has the same general shape as that of *Inia* and is likewise characterized by a narrow attenuate process which is grooved for the passage of nerves. The course of the optic nerve is slightly modified in comparison with *Inia*. This nerve does not pierce the orbitosphenoid,

but follows the groove on the ventral face of the attenuate process of the orbitosphenoid in company with the trochlearis and the ophthalmic division of the trigeminal. This groove is much wider than in *Inia*, and that portion of the orbitosphenoid which separated the optic canal from the above-mentioned groove has disappeared on the skull of *Lipotes*.

The observations of Anderson on the peculiarities of the orbitosphenoid in the skull of *Platanista* have been found to agree with specimens in the United States National Museum. This description⁷ can be consulted for a more detailed discussion. In *Platanista*, the sphenoidal fissure is almost closed and the orbitosphenoid is pierced by an extremely small foramen for the optic nerve. The orbitosphenoid has been depressed and thrust backward so that its posterior border slides backward above the anterior margin of the alisphenoid. The ventral surface of the orbitosphenoid is broadly and deeply grooved for the trochlearis and the ophthalmic division of the trigeminal nerve which pass out through the sphenoidal fissure and continue forward along this canal-like continuation of the fissure. As viewed through the foramen magnum the cranial orifice of each optic canal is overhung by a thin platelike process of the orbitosphenoid. The minute ectal orifice of the orbitosphenoid portion of the optic canal appears on the inner wall of the canal-like continuation of the sphenoidal fissure near the level of the anterior border of the alisphenoid. The upper border of the external reduplication of the pterygoid and a thin platelike process of the frontal which slides forward under the maxilla, as viewed from in front, enclose the passage for the optic nerve from below as it curves forward and outward; the ectal orifice of the optic canal appears near the internal extremity of the lachrymal. The optic canal, as it passes outward along the supraorbital process, is bounded on three sides by the thin plates of the frontal and roofed over by the maxilla. This thin plate like anteriorly directed process of the frontal also conceals the basal half of the supraorbital process from a ventral view. The canal-like continuation of the sphenoidal fissure for the passage of nerves is concealed by the pterygoid. Imperfections in the ossification of the walls of the optic canal occur in most skulls of *Platanista*.

In *Zarhachis*, the course of the optic nerve from the point where it issues from the cranial cavity to the base of the supraorbital process is concealed by the external reduplication of the pterygoid. The edges of the bones surrounding the ectal orifice of the optic canal are broken and jagged on the second skull and no attempt has been made to remove the matrix from this region on the first skull because of its

⁷ Anderson, J., Anatomical and Zoological Researches: Comprising an account of the Zoological Results of the Two Expeditions to Western Yunnan in 1868 and 1875. London (1878), pp. 511-512. 1879.

fragile condition. Hence one can not be certain what modifications were present around the ectal orifice of the optic nerve near the base of the supraorbital process of the frontal. Both frontals appear to have developed thin plates. It is possible that they may have curved below the optic nerve in the same manner as in *Platanista*. This point can not be settled on the basis of these two skulls alone.

In the preceding paper⁸ attention was called to the presence of a peculiar shelf in the temporal fossa above the upper margin of the squamosal. It is now apparent that this shelf was the result of crushing and the consequent buckling of the bones involved and that it is not comparable with a similar groove on the skull of *Platanista*. The second skull has suffered in the same way on the right side, but to a lesser degree.

At the base of the falcate process of the basioccipital and near the posterior margin of the alisphenoid is the partially closed ectal orifice of the canal for the carotid artery. The mandibular branch of the fifth cranial nerve issues through a cleft on the posterior border of the alisphenoid at a point 11 mm. external to the orifice of the carotid canal and on its forward and outward course crosses the ventral face of this bone, finally emerging in the temporal fossa through the foramen ovale.

A postero-external process of the alisphenoid projects backward, meeting the squamosal along its external border, abutting against the exoccipital posteriorly, and uniting with the underlying process of the basioccipital internally. The alisphenoid and the above mentioned bones form the fossa in which periotic and tympanic bones are lodged. A small foramen pierces the alisphenoid above the anterior process of the periotic. Two large foramina appear in this fossa above and internal to the jugular incisure. The ectal orifice of the internal foramen is situated internal to the jugular incisure; it opens at the base and near the posterior margin of the falcate process of the basioccipital. This foramen probably represents the compartment for the nerves in the *foramen lacerum posterius*. The external foramen is partially inclosed by the exoccipital and may afford a passage for the jugular vein. The foramina within the tympano-periotic fossa have the same general arrangement as on one skull of *Eurhinodelphis bossi*⁹ which was also obtained from the Calvert formation. In skulls of *Platanista*, *Inia*, and *Lipotes*, a large fissure occupied the area corresponding to the tympano-periotic fossa on the *Zarhachis* skull.

⁸ Kellogg, R., Proc. U. S. Nat. Mus., vol. 63, pp. 18-19. 1924.

⁹ R. Kellogg, On the occurrence of remains of fossil porpoises of the genus *Eurhinodelphis* in North America. Proc. U. S. Nat. Mus., vol. 66, publ. 2563, pl. 5. 1925.

MEASUREMENTS FOR THE SKULL (in millimeters)

Breadth of rostrum at base (between antorbital notches).....	163
Greatest breadth of skull across supraorbital processes.....	260
Greatest breadth of skull across zygomatic processes of squamosals.....	260
Vertical height of skull (between tips of falcate processes of basioccipital and frontals on vertex of skull).....	165.5
Vertical height of skull (basisphenoid to frontals on vertex of skull.....)	128
Greatest depth of rostrum at level of antorbital notches.....	89
Greatest distance between outside margins of premaxillae at level of anterior margin of porous pluglike presphenoid.....	93
Greatest distance between outside margins of premaxillae at level of anterior margin of nasals.....	130
Greatest breadth of right premaxilla in front of nasal passages.....	44
Length of frontal plate of right maxilla (antorbital notch to supraoccipital).....	141.5
Greatest breadth of exposed surface of frontal plate of right maxilla behind supraorbital process.....	66
Least distance across vertex of skull between inner margins of maxillae..	39
Greatest antero-posterior diameter of supraorbital process of right frontal..	96
Greatest dorso-ventral depth of supraorbital process of right frontal.....	63.5
Greatest thickness of "upended" portion of supraorbital process of right frontal.....	40
Least breadth of braincase between temporal fossae.....	120
Least distance between temporal fossae as measured between lambdoid crests.....	141.5
Distance from center of transverse crest of supraoccipital to upper margin of foramen magnum.....	104.5
Greatest breadth of supraoccipital.....	151
Breadth of foramen magnum.....	42.5
Greatest distance between outside margins of occipital condyles.....	105
Greatest dorso-ventral diameter of right condyle.....	53
Greatest transverse diameter of right condyle.....	42
Greatest distance across skull between outside margins of exoccipitals..	212
Depth of left exoccipital at extremity.....	72.5
Distance from anterior margin of foramen magnum to right nasal passage..	122
Distance from horizontal plate of right maxilla to extremity of right paroccipital process.....	127+
Greatest antero-posterior diameter of zygomatic process of right squamosal.....	101
Distance between anterior margin of apophysis of right maxilla and posterior face of right condyle.....	215
Greatest breadth of basioccipital across tips of the falcate processes.....	101
Distance between anterior margin of foramen magnum and anterior margin of basisphenoid.....	86
Greatest length of right nasal.....	14
Greatest breadth of right nasal.....	26
Greatest length of exposed portion of right frontal on vertex of skull.....	34
Greatest breadth of exposed portion of right frontal on vertex of skull...	28

. EXPLANATION OF PLATES

Zarhachis flagellator Cope. Cat. No. 10,911, division of vertebrate paleontology, United States National Museum. Calvert formation, western shore of Chesapeake Bay, about $3\frac{2}{5}$ miles south of Chesapeake Beach, Calvert County, Md. Collected by Norman H. Boss, December 30, 1923.

PLATE 1

Dorsal view of skull of *Zarhachis flagellator* Cope. About $\frac{2}{5}$ natural size. The following abbreviations are used on plates 1 to 5. *Bo.*, basioccipital; *Bs.*, basisphenoid; *C.*, condyle; *Cr. l.*, lambdoid crest; *Cr. max.*, maxillary crest; *Ect.*, ectethmoid; *Ex. oc.*, exoccipital; *Ex. pt.*, external reduplication of the pterygoid; *Ex. aud. M.*, groove for external auditory meatus; *Fal. pr.*, falcate process of basioccipital; *F. m.*, foramen magnum; *Fo. c.*, condylar foramen; *Fo. inf.*, ventral orifice of infraorbital canal; *Fo. l. p.*, foramen lacerum posterius, compartment for vein; *Fo. max.*, maxillary foramen at posterior extremity of the premaxilla; *Fo. ov.*, foramen ovale; *Fo. pmx.*, premaxillary foramen; *Fr.*, frontal; *J. inc.*, jugular incisure; *Max.*, maxilla; *N. A.*, left nasal passage; *Na.*, nasal; *Pa.*, parietal; *Pmx.*, premaxilla; *Poc. pr.*, paroccipital process of exoccipital; *P. pr.*, postglenoid process of squamosal; *Prs.*, presphenoid; *Pt.*, vaginal process of pterygoid; *S. oc.*, supraoccipital; *S. or. pr.*, supraorbital process of frontal; *Sq.*, squamosal; *Vo.*, vomer; *Zyg.*, zygomatic process of squamosal; *1*, foramen in alisphenoid above the anterior process of the petiotic; *2*, passage for mandibular branch of trigeminal nerve in a cleft on posterior border of alisphenoid; *3*, foramen lacerum posterius, compartment for nerves.

PLATE 2

Frontal view of skull of *Zarhachis flagellator* Cope showing position of the crescentic foramina. About $\frac{3}{5}$ natural size.

PLATE 3

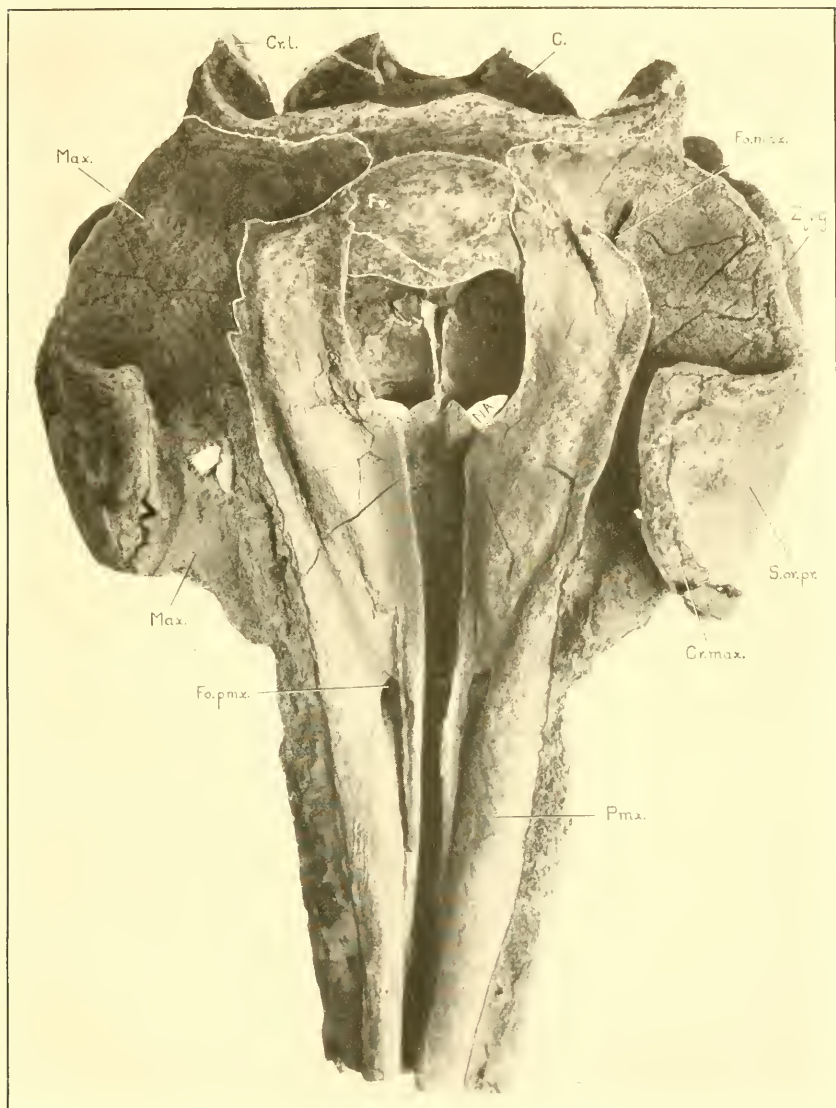
Posterior view of skull of *Zarhachis flagellator* Cope. About $\frac{3}{5}$ natural size.

PLATE 4

Lateral view of skull of *Zarhachis flagellator* Cope. About $\frac{1}{2}$ natural size.

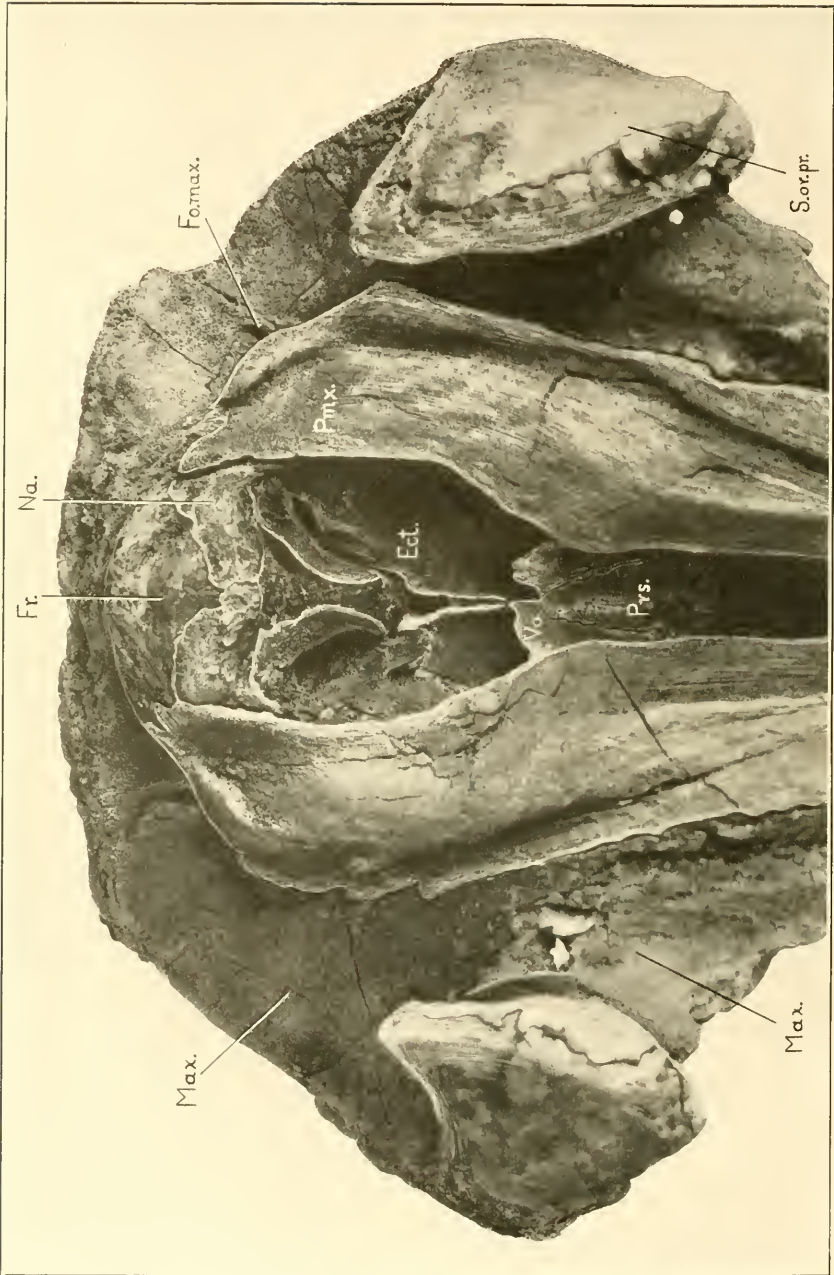
PLATE 5

Ventral view of skull of *Zarhachis flagellator* Cope. About $\frac{2}{5}$ natural size.



DORSAL VIEW OF SKULL OF ZARHACHIS FLAGELLATOR

FOR EXPLANATION OF PLATE SEE PAGE 13



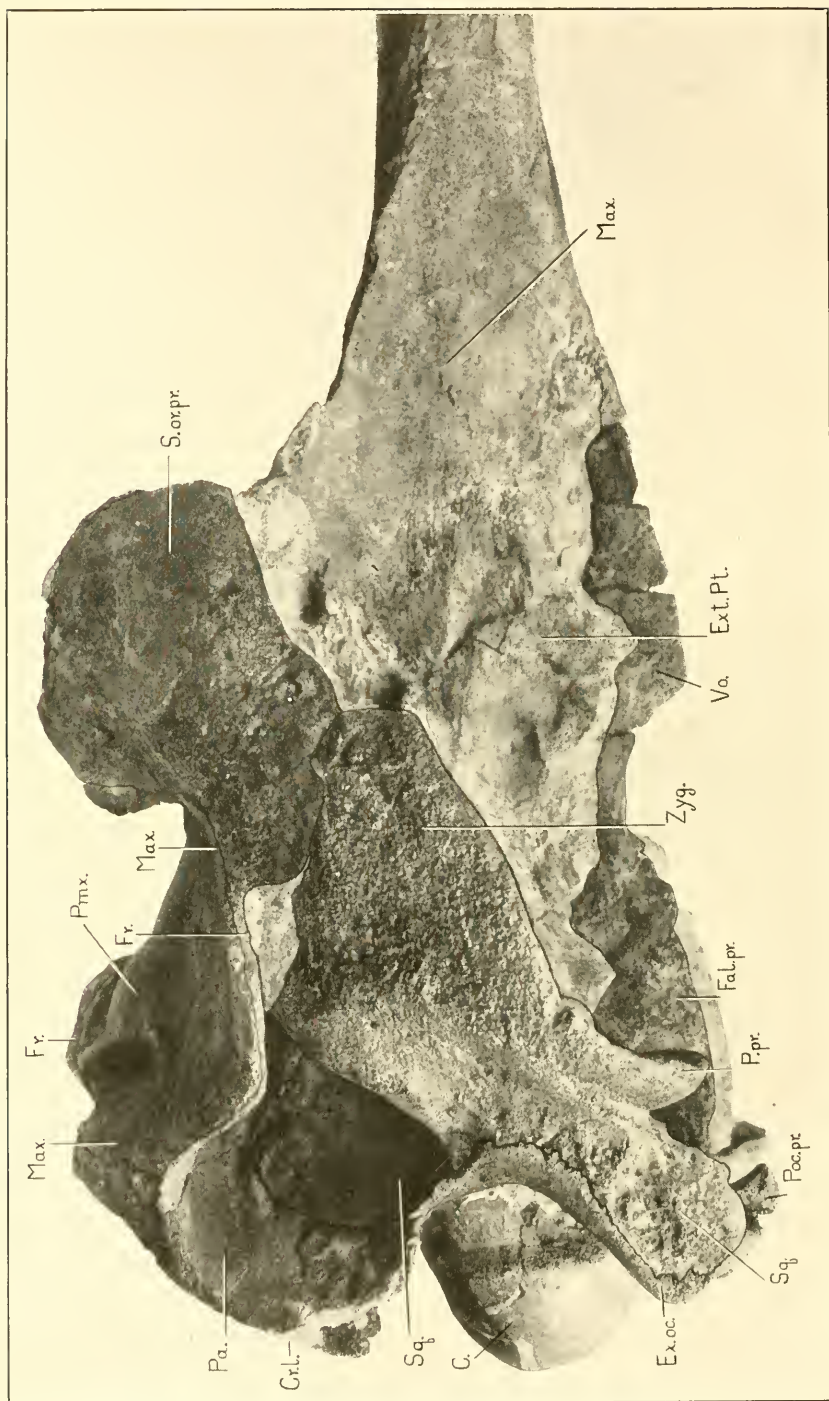
FRONTAL VIEW OF SKULL OF ZARHACHIS FLAGELLATOR

FOR EXPLANATION OF PLATE SEE PAGE 18



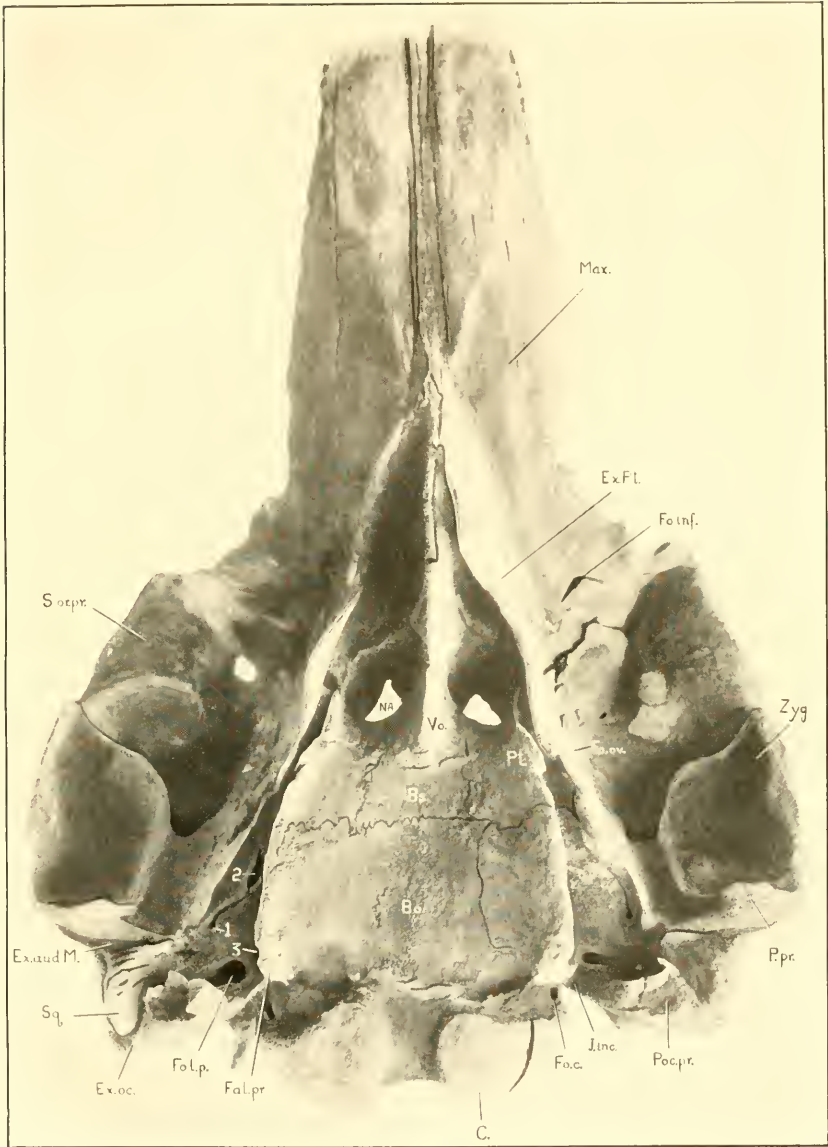
POSTERIOR VIEW OF SKULL OF ZARHACHIS FLAGELLATOR

FOR EXPLANATION OF PLATE SEE PAGE 18



LATERAL VIEW OF SKULL OF ZARHACHIS FLAGELLATOR

FOR EXPLANATION OF PLATE SEE PAGE 18



VENTRAL VIEW OF SKULL OF ZARHACHIS FLAGELLATOR

FOR EXPLANATION OF PLATE SEE PAGE 18

