

Redescription of *Gargoyleosaurus parkpinorum*, a polacanthid ankylosaur from the Upper Jurassic of Albany County, Wyoming

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With 20 figures and 3 tables

KILBOURNE, B. & CARPENTER, K. (2005): Redescription of *Gargoyleosaurus parkpinorum*, a polacanthid ankylosaur from the Upper Jurassic of Albany County, Wyoming. – N. Jb. Geol. Paläont. Abh., 237: 111–160; Stuttgart.

Abstract: The polacanthid ankylosaur *Gargoyleosaurus parkpinorum* is described in detail for the first time. The partial skeleton indicates a small individual about 3–3.5 m long. Distinguishing features include a skull longer than wide, with laterally facing nostrils and large postorbital horns slightly overlapping onto the squamosal and a known armor pattern, as the armor was preserved *in situ*. Many features present in *Gargoyleosaurus* are also found in other polacanthids. While controversy surrounds the phylogenetic relationships amongst the polacanthids, it would appear that these taxa are closely related by the number of shared affinities.

Zusammenfassung: Der polacanthide Ankylosaurier *Gargoyleosaurus parkpinorum* wird erstmals detailliert beschrieben. Das Teilskelett gehört zu einem etwa 3–3,5 m langen Individuum. Wichtige Unterscheidungsmerkmale sind ein Schädel, der länger als breit ist, mit seitwärts weisenden Nasenöffnungen und langen postorbitalen Hörnern, die über dem Squamosum etwas überlappen sowie ein Panzermuster, da die Panzerung *in situ* erhalten war. Viele Merkmale von *Gargoyleosaurus* treten auch in anderen Polacanthiden auf. Während die phylogenetischen Beziehungen unter den Polacanthiden umstritten sind, scheinen diese Taxa aufgrund der Anzahl an Gemeinsamkeiten eng miteinander verwandt zu sein.

1. Introduction

Ankylosaur remains from the Upper Jurassic of North America are rare with only two genera known from the Morrison Formation. The first of these discovered, *Mymoorapelta maysi*, KIRKLAND & CARPENTER (1994) comes from the middle of the Brushy Basin Member of the Morrison at Mygatt-Moore Quarry, Mesa County, Colorado. The second taxon, *Gargyleosaurus parkpinorum* CARPENTER et al., 1998, comes from the lower part of the middle Morrison near Bone Cabin Quarry, Albany County, Wyoming (Figs. 1-2).

The partial skeleton of *Gargyleosaurus*, including a nearly complete skull, was recovered by Western Paleontological Laboratories and then donated to the Denver Museum of Nature and Science. CARPENTER et al. (1998) gave a brief and succinct description when they named the taxon, and the skull was shown to possess many common features with the polacanthid *Gastonia*. Upon discovery, a bulldozer damaged the skull, and both quadrate

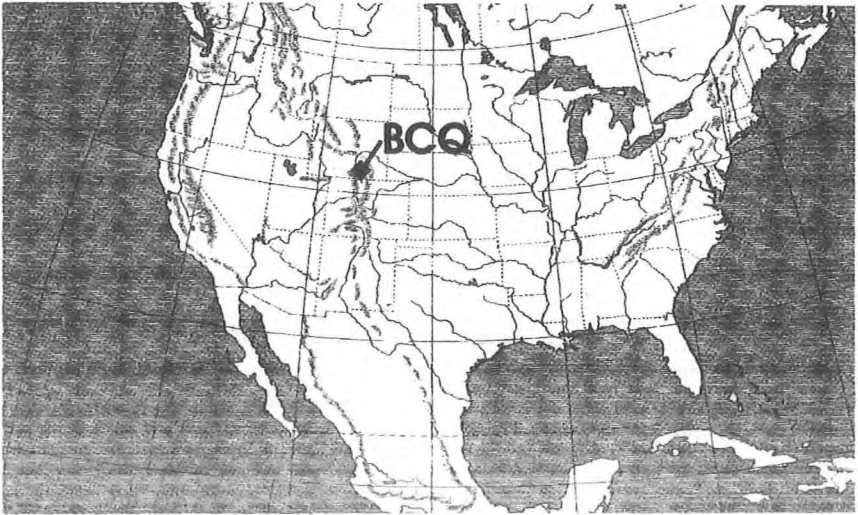


Fig. 1. Map of locality of *Gargyleosaurus parkpinorum*: Bone Cabin Quarry, Wyoming USA.

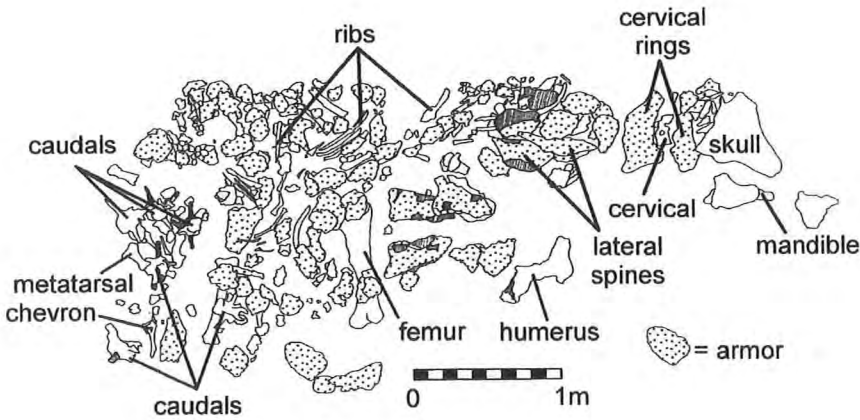


Fig. 2. Quarry map of *Gargoyleosaurus parkpinorum* showing the underside of the skeleton and the distribution of armor. Hatched areas represented armor.

condyles and the entire pterygoid process were lost. Of the postcranial remains, the majority of the left side of the specimen, along with many of the vertebrae, appears to have been lost through taphonomic processes. The remains of *Gargoyleosaurus* shed light upon the Polacanthidae, a family that has only received formal recognition in recent years, and the early origins of the Ankylosauria.

Repository: All elements described reside in the collections of the Denver Museum of Nature and Science (DMNH, formerly the Denver Museum of Natural History), Denver, CO.

2. Systematic Paleontology

- Dinosauria OWEN, 1842
- Ornithischia SEELEY, 1888
- Thyreophora NOPSICA, 1915
- Ankylosauria OSBORN, 1908
- Polacanthidae CARPENTER 2001 a

Gargoyleosaurus parkpinorum

Holotype: DMNH 27726, A nearly complete skull, proatlas, first three cervical vertebrae, six caudal vertebrae, several fragmentary cervical and dorsal ribs, partial right scapula and coracoid, right humerus and femur, fragmentary pubis, several ossified tendons, an abundance of dermal armor including nearly complete cervical rings.

Etymology: Genus name stems from the gargoyle resemblance of the skull in profile, and *sauros*, Greek for lizard. Species name for J. PARKER and T. PINEGAR, the discoverers of the specimen.

Horizon and locality: Upper part of the Morrison Formation, Bone Cabin Quarry, Albany County Wyoming, United States.

Emended diagnosis: Small polacanthid; postorbital horns very large with slight overlap to the squamosal; eight alveoli in premaxillary; transverse ridges dorsally along front of premaxillary; elongated maxillary tooth row; cranial texturing irregular in size, yet a loose pattern exists; a narrow slit between proatlas facets; mandible long and relatively gracile; retroarticular process long compared to other ankylosaurs; centra elongated in comparison to *Mymoorapelta*; anterior caudal ribs project laterally, *Mymoorapelta* ventrolaterally; first ring of cervical armor composed of four partially fused plates and central osteoderm; second cervical ring composed of four elongated partially fused plates.

3. Description

Skull

Much like the skull of nodosaurids (Fig. 3; Table 1) the skull is longer than it is wide, the snout is long and narrow with nostrils facing laterally. Computer axial tomography (CAT-scan) shows that the supratemporal and antorbital fenestrae are closed by the surrounding bones (Fig. 4), as is common to all ankylosaurs; it is not due to covering by armor as suggested by MARYANSKA (1977). The skull is dorso ventrally compressed as is typical of ankylosaurs, and the occiput is inclined anteriorly. The skull shows the ankylosaurid traits of an anterior and posterior secondary palate and an overall triangular shape. The lateral temporal notch is visible in lateral view and larger than in *Animantarx*, but not as prominent as in *Pawpawsaurus*.

Cranial Surface (Fig. 3A) – The overall dorsal surface of the skull is flat; the domed surface that characterizes *Gastonia*, *Euoplocephalus*, and *Ankylosaurus* is absent. Dorsally, the skull is covered by irregularly shaped scutes arranged in asymmetrical pairs of unequal size. The pairs are parallel at the front of the snout but diverge toward the posterior of the nasal. As the pairs diverge, they form two ridges that sweep laterally towards the anterior

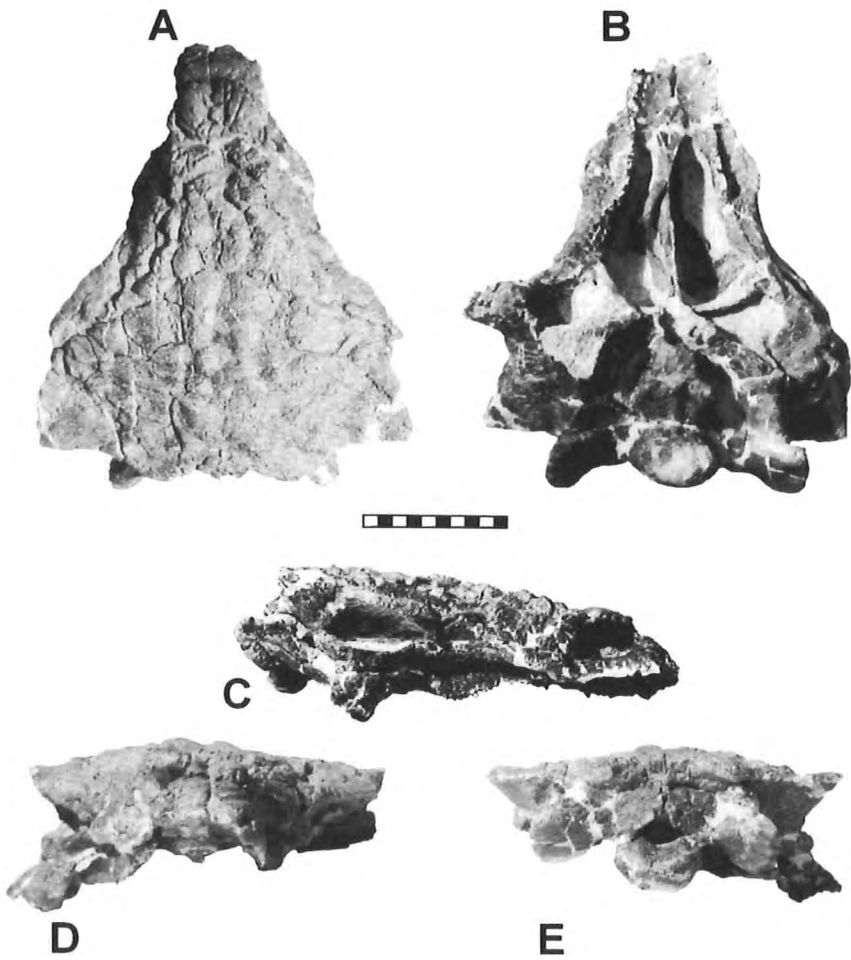


Fig. 3. Skull of *Gargoyleosaurus parkpinorum* (DMNH 27726) in dorsal (A), ventral (B), right lateral (C), anterior (D), and posterior (E) views. – Scale equals 10 cm.

Table 1. Measurements for the skull of *Gargoyleosaurus parkpinorum*

Skull Element	Length (mm)	Width (mm)
Cranium	296	235.5
Orbit	63.8	NA
External Nares	39.4	NA
Maxillary Aveolar Row	126 (Right row)	54.6 (least width)
Foramen Magnum	NA	25
Occipital Condyle	34.5	53
Paroccipital Processes	NA	154
Mandible	209 (incomplete)	30
Dentary Tooth Row	130	NA
Retroarticular Process	38.3	29

corner of the postorbital horns. The general trend of the surface is to be extremely rough anteriorly while gradually smoothing out posteriorly. The most rugose region is the general area of the nasal. Remodeled bone covering the areas of the maxilla and between the orbits is comparatively smoother. Peripheral cranial ornamentation maintains a bilateral symmetry along the skull margin. One set of ornamentation overhangs the anterior rim of each orbit, while another distinct set resides antero-laterally on the maxillae. A large trapezoidal area of ornamentation forms the dorsal margin of the nares, as is common to many nodosaurids (COOMBS & MARYANSKA 1990). An area of bumps and transverse ridges starts at the anterior corners of the orbits between the supraorbital ornamentation. This area continues to the rear of the cranium, covering the parietals and frontals, where it meets with the nuchal shelf. The nuchal shelf extends between the squamosals, beginning immediately above the paroccipital processes. Visible sutures between individual cranial elements are a result of remodeling and sculpturing of the dermatocranium (CARPENTER et al. 2001; VICKARYOUS et al. 2001b). In *Gargoyleosaurus* the sutures between the nasals and the upper margin of the maxilla are clearly visible. Also visible are the sutures between the nasals. It is apparent that the scutes of *Gargoyleosaurus* are at least a partial result of elaboration and sculpturing of individual cranial elements.

Premaxilla (Fig. 3) – The length of the premaxillary scoop is subequal to its width; however, the disparity is not as great as in *Gastonia*. The front of the premaxillary scoop is narrower than the rear, imparting it with a trapezoidal shape. The greatest width across the premaxillae is less than

the span across the caudal end of the maxillary tooth rows. The tomial crest arises at the antero-lateral corners and terminates at the end of the premaxillae. The crest appears to be absent from anterior margin of premaxillae thereby forming a U-shaped notch. A notch appears in *Euoplocephalus*, but it is V-shaped (VICKARYOUS & RUSSELL 2003). Just lingual to the tomial crest are eight alveoli, which are plesiomorphic for ankylosaurs. Premaxillary teeth are common to nodosaurids and *Liaoningosaurus* (XU et al. 2001); however, in the only other known polacanthid skull, *Gastonia burgei*, premaxillary teeth are absent (KIRKLAND 1998). On the dorsal surface are three pairs of ridges that extend dorsolaterally to create shallow chevrons that mark the premaxillae. The ridges lie directly anterior to the rostral margin of the nares. A deep cleft is present on each premaxilla below the lowest of the ridges. Within the cleft a miniscule premaxillary foramen is present. Between the premaxillae, both antero-dorsally and ventrally, lies a deep, elongate interpremaxillary suture. Dorsally, the suture reaches to the rostral-most ornamentation, while ventrally it extends to the diamond shaped sheet formed by the anterior stretch of the vomer. A similar suture occurs in *Gastonia*, *Euoplocephalus*, and *Pawpawsaurus*, present both dorsally and ventrally on the premaxillary, although ventrally it does not reach the tip of the snout in *Pawpawsaurus* (KIRKLAND 1998, VICKARYOUS & RUSSELL 2003). In all of these genera the ventral suture penetrates deeply. The notch bisects the three shallow chevrons formed by the premaxillary ridges. Laterally, the premaxillae form the anterior and ventral margins of the nares, with the premaxillae curving up just above the anterior tip of the maxillae.

Maxilla (Fig. 3) – Near the nasals the maxillae are covered by large ornamentation anteriorly, while the remaining surface is covered by subtle bumps. At the tip of the maxillae, small foramina are present on the lateral surface adjacent to the anterior end of the maxillary tooth row. In ventral view, the maxilla is laterally expanded from the anterior tip to roughly midway along its length. The expansion causes the buccal emargination to appear wide anteriorly despite dramatically narrowing posteriorly. On the lateral surface of the skull, the suture between the maxillae and the nasals is visible. The alveolar ridges are very elongate, extending and diverging posteriorly from the anterior of the maxillae to the suture with the jugal (Fig. 3C). Due to the narrow tip of the snout, the shape of the palate is not that of an hourglass, which is atypical of ankylosaurids and typical of nodosaurids and *Euoplocephalus* (VICKARYOUS & RUSSELL 2003). However, the alveolar ridges, and hence the palate shape, are not nearly as narrow as in *Silvisaurus* (EATON 1960, CARPENTER & KIRKLAND 1998). The length and curvature of the alveolar ridges of *Gargoyleosaurus* contrast markedly with the short and straight ridges in *Gastonia*. In that taxon the row is slightly shorter and straight. Although the caudal half of the left maxillary tooth row is damaged

and missing, it is nonetheless clear that the anterior width across the shelves is less than the posterior width. The lowest point of the tooth row lies directly below the lachrymal. As the alveolar ridges extend vertically, a strong labial curve occurs below the high point of the row, causing the teeth to point slightly lateromedially (Fig. 3B). The anterior end of the maxillary tooth row is nearly continuous with the row of the premaxillary teeth. A short gap separates the premaxillary and maxillary rows; this gap may be a taphonomic artifact. Anteriorly the maxilla meets the vomer and the premaxilla at the lateral corners of the vomer "diamond" to form a short anterior secondary palate. The secondary palate extends to the second maxillary tooth as in *Stegosaurus*. The contact of the maxillae to the secondary palate is very similar to that of *Pawpawsaurus* (LEE 1996, fig. 8).

Nasal (Fig. 3A) – In the approximate area of the nasal, a large trapezoidal area of ornamentation lies anteriorly. The trapezoid is common to nodosaurids but is completely absent in ankylosaurids and *Gastonia* (COOMBS 1978). Two slender flanges project rostro-laterally from the trapezoid, and the most rugose ornamentation of the skull lies posterior to the trapezoid. The latter ornamentation is arranged in asymmetrical pairs of polygons that diverge caudally with two rows on each side. The nasal-premaxillary suture is difficult to determine in *Gargoyleosaurus*, but that suture is still visible in *Gastonia*, the only other polacanthid with a known skull.

Lachrymal (Fig. 3C) – The area of the lachrymal is deeply inset from the rest of the snout. The concave condition of the lachrymal also occurs in *Cedarpelta*, although in *Cedarpelta* the depression does not appear to be nearly as deep. However, the prominence of the concavity may be a result of dorsoventral crushing. The exact position of the depression in relation to *Cedarpelta* cannot be determined, because the texture of the region is gnarled. The depression curves strongly upward dorsolaterally to form a ridge with the dorsal surface of the skull. The ridge extends from the swell of the buccal emargination to the anterior end of a large scute in the supra-orbital region.

Supraorbital (Fig. 3) – *Gargoyleosaurus* is assumed to have supraorbitals, as in *Pinacosaurus*, however, their sutures cannot be determined because of the extensive ornamentation. As in *Cedarpelta*, the anterolateral supraorbital is domed, but this is in part to a large "scute" of ornamentation that may be fused and merged into the rim of the orbit. With the exception of the large "scute", the ornamentation does not appear to be symmetrical between the left and right supraorbitals. The condition of the supraorbitals is very similar in *Pawpawsaurus*. LEE (1996) refers to the distinct ornamentation in *Pawpawsaurus* as 'a rhombic orbital dermal plate.' In both taxa, ornamentation wraps around the curve of the orbit. When viewed dorsally the ornamentation appears to be much shorter in *Pawpawsaurus* than in *Gargoy-*

leosaurus; because this is the orbit of *Pawpawsaurus* is circular in shape while the orbit of *Gargoyleosaurus* is elliptical. Also in *Pawpawsaurus* the supraorbital scute overlaps the anterior portion of the postorbital horn. This feature does not occur in *Gargoyleosaurus*, because the right scute terminates before reaching the right horn, and the left scute just touches upon the left horn. A thickened ridge occurs over the supraorbitals in *Gastonia*; however, a distinct scute is not visible.

Postorbital (Fig. 3) – As compared to *Sauropelta* and *Silvisaurus* the postorbital bar of *Gargoyleosaurus*, as well as *Gastonia*, is extremely narrow laterally, while it is relatively wide posteriorly (EATON 1960 fig. 1, CARPENTER & KIRKLAND 1998, figs. 10, 12). The postorbital is also greatly inclined anteriorly as in *Gastonia*, but unlike *Pawpawsaurus*; however, this may be due to postmortem crushing. In *Euoplocephalus* the postorbital bar articulates with the basicranium near the suture between the basioccipital and basisphenoid (VICKARYOUS & RUSSELL 2003). While the postorbital bar in *Gargoyleosaurus* articulates with the basicranium, the articulation occurs higher than the contact between the basioccipital and basisphenoid. As in *Pawpawsaurus* and other nodosaurids, as well as in *Gastonia*, a large postorbital horn is present. The horn is a three-faced pyramid as in *Pawpawsaurus*; however, it is much larger in *Gargoyleosaurus* and is reminiscent of the squamosal horns of ankylosaurids. The horn stretches from above the posterior half of the orbit to the posterior end of the postorbital. The horn of *Gastonia* has a similar span, and in both taxa the horn slightly overlaps onto the squamosal. The horn is also more tapered than the postorbital horn of either *Gastonia* or *Pawpawsaurus*. CARPENTER (2001b) reported that the postorbital horn of the polacanthid *Hylaeosaurus* is proportional to the postorbital horns of both *Gastonia* and *Gargoyleosaurus*. A suture line is also present in *Gargoyleosaurus* between the postorbital and the jugal, being faintly visible posteriorly on the right side of the skull.

Jugal (Fig. 3) – The left jugal was lost after a bulldozer struck the specimen upon discovery. The right jugal protrudes lateroventrally from below the orbit and is deeply concave on the medial surface as in *Mymoorapelta* and *Gastonia*, but unlike *Euoplocephalus* and *Saichania* (MARYANSKA 1977, VICKARYOUS & RUSSELL 2003). The jugal horn is attached to the lateral surface of the jugal. The only preserved jugal horn of *Gargoyleosaurus* is pathological, so determining its exact length is impossible. It would appear the jugal projection is in fact a horn as the width is greater proximally than distally. This is in contrast to the broad curve of the jugal plate in *Pawpawsaurus*. In *Euoplocephalus* and *Saichania* this horn is also a plate, and in *Euoplocephalus* this horn is attached to the quadratojugal, whereas in *Saichania* the horn only partly covers the jugal (MARYANSKA 1977, VICKARYOUS & RUSSELL 2003). The horn appears to have grown more in line

with the projection of the jugal in *Gargoyleosaurus* than in *Mymoorapelta*. As compared to *Gastonia*, the jugal horn appears to have been more prominent (CARPENTER 2001 a).

Squamosal (Fig. 3 E) – The squamosal forms the caudal half of the dorsal rim of the lateral temporal fenestra. It is small and slanted anteriorly. In dorsal view, a small overhang of the nuchal shelf hides the squamosal. As in nodosaurids, the squamosal, the paroccipital process, and the quadrate all appear to be solidly fused together (COOMBS 1978).

Quadratojugal (Fig. 3 B) – The left quadratojugal was also lost during the discovery, and part of the right. The quadratojugal forms the lower border to the lateral temporal fenestra as in all ankylosaurs. As in *Pawpawsaurus* and *Hylaeosaurus*, the quadratojugal appears to attach high on the quadrate shaft (CARPENTER 2001 b). In *Gastonia* the quadratojugal attaches high on the quadrate shaft, but terminates very low. Where it would terminate in *Gargoyleosaurus* cannot be observed, because the quadrate condyles and the lower half of the quadratojugal were broken off. The quadratojugal does not have an anterior slant nearly as strong as the proximal end of the quadrate and is set almost perpendicular to the quadrate shaft. In advanced ankylosaurids a dermal plate analogous to the jugal horn resides laterally on the quadratojugal jugal (MARYANSKA 1977, VICKARYOUS & RUSSELL 2003).

Vomer (Fig. 3 B) – Anteriorly the vomer is expanded into a diamond-shaped sheet and is fused to the secondary palate portions of the premaxillae and the maxillae. *Gastonia* also has a splay of bone at the anterior end of the vomer, albeit in the shape of a fish tail (KIRKLAND 1998). In *Pawpawsaurus*, the outline of an expanded anterior vomer is visible as well. *Panoplosaurus* also has a diamond-shaped anterior sheet split into wings (RUSSELL 1940 fig. 1). The lateral corners of the diamond lie at the end of the anterior secondary palate. Along the posterior half of the diamond two thin ridges arise and converge at the end of the diamond to form the vomers. The vomers form a thin keel unlike the broad, grooved ridge along the vomers of *Panoplosaurus* (CARPENTER 1990). As compared to *Gastonia* the vomers are much longer. Along the latter third of the vomerine keel, the two ridges again diverge to meet the pterygoid process. Based on CAT-scans of the skull (Fig. 4 A-B), the vomer does not meet the skull roof as it does in *Euoplocephalus* (VICKARYOUS & RUSSELL 2003). Absence of this intersection is common to the Mongolian ankylosaurids *Pinacosaurus*, *Saichania*, and *Talarurus* (MARYANSKA 1977). The ventral margin of the keel reaches just below the ventral margin of the maxillary tooth row. Dorsally, a lateral platform protrudes along the vomers and fuses to the palatines to form the posterior secondary palate.

Palatines (Fig. 3 B) – In contrast to *Pawpawsaurus* the palatines lay in a horizontal plane, and, as in ankylosaurids, the palatines are fused along with

the vomers and the pterygoids to create the caudoventral secondary palate, delineating the posterior margin of the internal naris (VICKARYOUS & RUSSELL 2003). Suture lines are visible between the left palatine and the lateral projection of the left vomer. There is a strong posterior arc in the left palatine as it extends from the posterior half of the vomers along the pterygoid to the caudal end of the maxilla. The front rim of the palatine lies in a vertical plane; while posterior to the rim it is deeply concave, with yet another depression inside it towards the pterygoids.

Supraoccipital (Fig. 3E) – The supraoccipital is a tiny point above the foramen magnum. It lies directly below a small triangular dermal ornamentation on the nuchal shelf. The sutures of the supraoccipital form the outline of an inverted triangle. Below the peak of the triangle is a split that continues down to separate the two proatlas facets. As in *Pawpawsaurus* and *Edmontonia*, on either side of the sagittal ridge lies a shallow depression, but no “subcircular posttemporal foramen” is present (RUSSELL 1940, LEE 1996). The sagittal ridge may branch into the Y-shaped nuchal crest of *Euoplocephalus* and *Pawpawsaurus*, but fusion of the proatlas facets conceals any existence of this feature.

Exoccipital (Fig. 3E) – The exoccipitals bear a strong concavity close to the paroccipital processes. Medial to the concavity, the proatlas facets occur on the exoccipital. The exoccipitals and the proatlas facets contribute to upper margin of the rhomboidal foramen magnum. The paroccipital processes project posterolaterally from the occiput, forming wide, deep lateral temporal notches. In contrast, paroccipitals in *Gastonia* and ankylosaurids project directly laterally (VICKARYOUS & RUSSELL 2003). In *Pawpawsaurus* the lateral temporal notch is roughly 90°, whereas in *Gargoyleosaurus* the notch is closer to 60°. This is due to the fact that in *Pawpawsaurus* the distal end of the paroccipital process is firmly attached to the squamosal. In *Gargoyleosaurus* the distal end of the process is free of the squamosal. The paroccipital processes are short, each one being as about as wide as the occipital condyle. The paroccipital processes are relatively the same length as in *Gastonia*, *Edmontonia*, and *Euoplocephalus*, but proportionally much shorter than those in *Saichania*, *Tarchia*, and *Ankylosaurus*. In their fusion with the quadrates the ends of the paroccipital processes are slanted anteriorly, and such a slant occurs in *Gastonia* as well. The paroccipital process is fused to both the squamosal and the quadrate as in nodosaurids and *Gastonia*. As in *Gastonia*, the exoccipitals contribute to the occipital condyle along with the basioccipital.

Basioccipital (Figs. 3E, 4) – The basioccipital contributes to both the posterior floor of the braincase and the ventral margin of the ventrally sloped foramen magnum. The basioccipital also contributes the main body of the occipital condyle. The dorsoventrally compressed condyle is oval in cross

section and slightly concave dorsally. The convex occipital condyle sits on a short neck and is marginally wider than the rest of the basioccipital. A distinct lip is present on the anteroventral surface of the condyle. The condyle is very similar to that of *Gastonia* not only in size and shape, but also by being composed of both the exoccipitals and the basioccipital. In lateral view the occipital condyle of *Gastonia* extends far past the paroccipital process, while the occipital condyle does not project past the paroccipital process in *Gargoyleosaurus*. This is due to the distinct posterolateral slant of the paroccipitals in *Gargoyleosaurus*. Both the basisphenoid and the basioccipital form the backwards-projecting basitubera. Each tubera has a distinct point and is not as swollen as in *Gastonia* and *Pawpawsaurus*. On the occiput, a sharp crest arises sagittally between the basitubera. Alongside the right face of the basioccipital, the right stapes emerges from the inner ear and curves dorsally to closely approach the quadrate.

Basisphenoid (Fig. 3B, 4) – The basisphenoid is a short block of bone anterior to the basioccipital. A short keel that extends across the basioccipital to the occipital condyle follows the crest. The sagittal crest and keel are absent in *Gastonia*, *Edmontonia*, and *Euoplocephalus*, but present in *Pawpawsaurus*. Of the two short basiptyergoid processes, only the right one is intact. In *Gastonia* the basiptyergoid processes are more than twice as long. VICKARYOUS & RUSSELL (2003) report that the basiptyergoids of *Euoplocephalus* do not directly fuse to the pterygoid process. As in all dinosaurs the basisphenoid harbors a large foramen for the carotid artery.

Quadrate (Fig. 3) – The distal condyles of both quadrates were broken off during discovery. A distinct suture lies between the proximal end of the quadrate and the paroccipital process. The suture sheds doubt upon whether

Fig. 4. Computer Axial Tomography of the skull of *Gargoyleosaurus parkpinorum* (DMNH 27726) showing the difference in density (dark regions are mostly bone). A, skull in dorsoventral view showing location of cross-sections. B, cross section across the snout (b-b'), view is towards front of snout; note the nasal chamber is not divided in half. C, cross section across rear of the skull (c-c'), view is towards the front of the snout. D, sagittal section of the skull just off midline (d-d'). Abbreviations: af – adductor fossa; bo – basioccipital; bs – basisphenoid; ch – choana (internal nares), ec – endocranial cavity; en – external nares; fm – foramen magnum; fo – fenestra ovalis; ltf – lateral temporal fenestra; mx – maxilla; mxs – maxillary sinus; nc – nasal chamber; oc – occipital condyle; pal – palatine; pm – premaxilla; pop – paroccipital process; pro – prootic; pt – pterygoid; qu – quadrate; sos – supra-occipital shelf; t – telescoped maxilla from crushing; v – vomer.

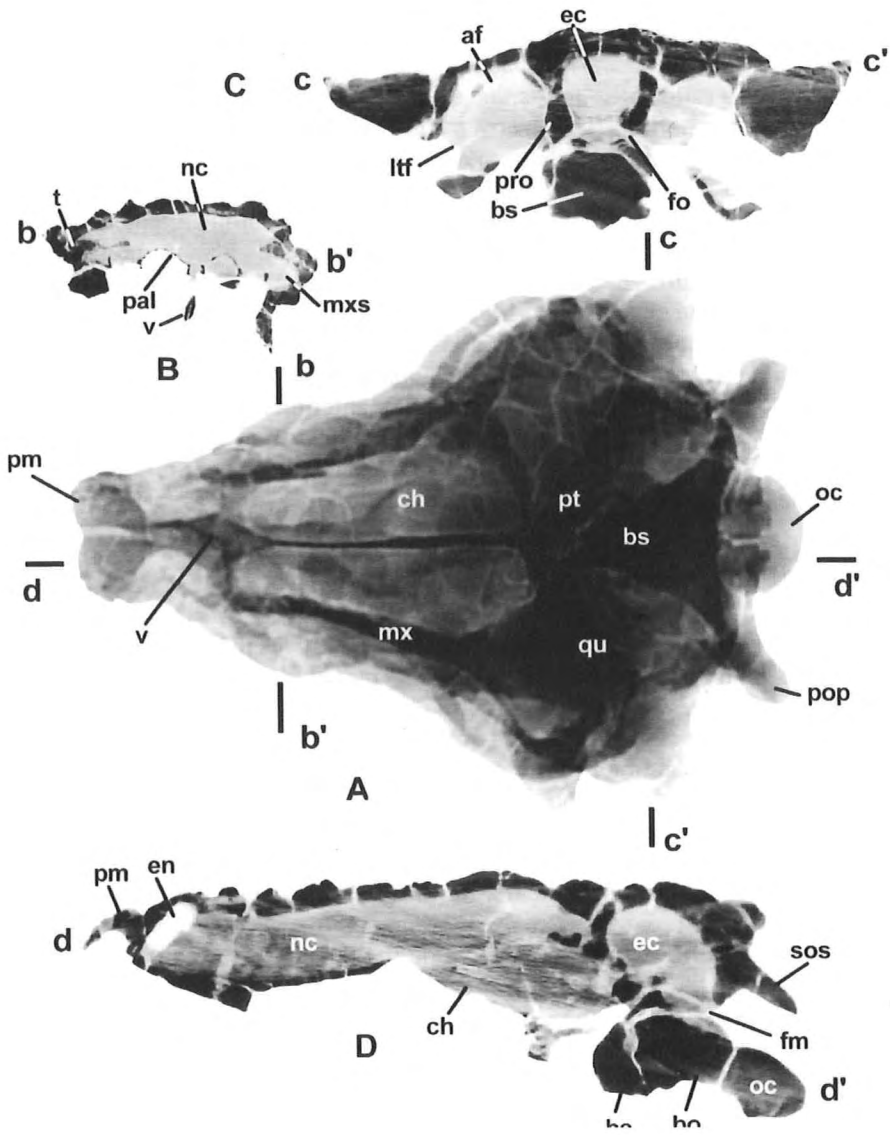


Fig. 4 (Legend see p. 122)

these two elements are firmly fused. The quadrates have strong curves along the medial margins as in *Hylaeosaurus*, *Gastonia*, and nodosaurids, as well as a groove along the lateral side of quadrate (CARPENTER 2001b). CARPENTER (2001b) suggests that this groove marks the anterior edge of the tympanic membrane. The groove, however, is a common feature to most dinosaurs. The quadrate shafts have a tremendous anterior slope, which is common to *Gastonia* and *Pawpawsaurus*. However, in *Pawpawsaurus* only the proximal end of the quadrate dorsal to the quadratojugal has an anterior slant. In *Cedarpetta* the quadrate is largely perpendicular to the horizontal plane of the skull. The proximal ends of the quadrates (Fig. 3E) are far more slender than the quadrates of *Ankylosaurus*, *Saichania*, and *Euoplocephalus*. In relative shape, the proximal ends of the quadrates are more similar to *Gastonia*, *Pawpawsaurus*, and *Edmontonia*. A strong anterior slant is also present in *Sauropelta*, but the quadrate is anteriorly bowed (CARPENTER & KIRKLAND 1998). Although the distal condyles of *Gargoyleosaurus* have been broken off, it seems plausible that the condyles would have a ventral orientation so as to articulate with the mandible.

Mandible

The mandible is long and low for an ankylosaur (Fig. 5; Table 1). While the jaw displays the typical sigmoidal shape, it resembles more the jaws of nodosaurids than ankylosaurids. On the right mandible the dorsal margin of the coronoid process is broken, and the anterior tip of the dentary and the prementary are missing. Only a small piece of the dentary was recovered from the left mandible. As is common in all ankylosaurs, a growth of ornamentation is located on the angular, although the exact margins of the scute are illdefined. The retroarticular process is elongate for an ankylosaur. The suture between the dentary and the angular is obliterated, while sutures along the splenial and the retroarticular process are still visible.

Dentary (Fig. 5) – The dentary is similar to that of *Animantarx* as the dorsal margin is strongly convex while maintaining an elongate profile. In both genera the anterior part of the dentary has a strong medial curve. Despite this similarity the symphysis of *Animantarx* was vertical, while the symphysis of *Gargoyleosaurus* was apparently horizontal as inferred from the medial curvature of the ventral margin of the dentary. Where the dentary forms this curve, the alveolar margin curves labially. As in *Edmontonia* and *Animantarx*, the posterior half of the alveolar margin is deeply inset medially. Between twenty-six and twenty-seven teeth would have been present on the dentary. On the medial surface of the dentary, below each alveolus lies a small foramen with replacement teeth. On the lateral surface of the dentary are four to five nutrient foramina that decrease in size towards

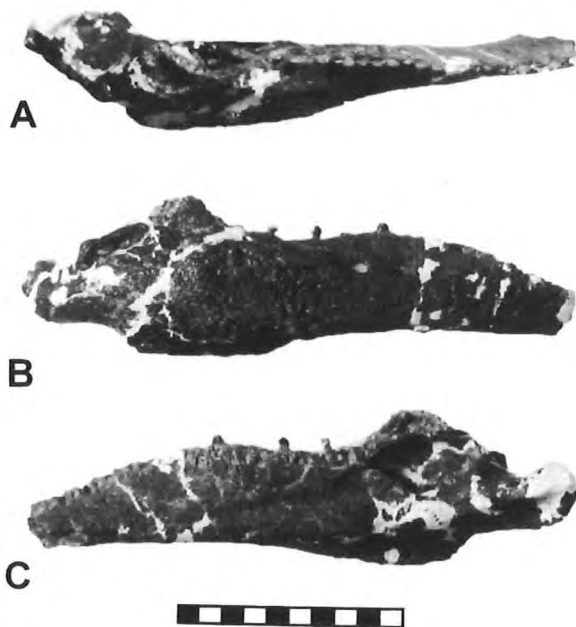


Fig. 5. Right mandible of *Gargoyleosaurus parkpinorum* (DMNH 27726) in dorsal (A), lateral (B), and medial (C) views. – Scale equals 10 cm.

the symphysis. The Meckelian groove is completely covered by the splenial, in contrast to *Sauropelta* and *Euoplocephalus* (CARPENTER et al. 1999, VICKARYOUS & RUSSELL 2003).

Splenial (Fig. 5C) – As in *Edmontonia* and *Euoplocephalus* the splenial is a thin sheet of bone anterior to the adductor fossa and prearticular and ventral to the coronoid and dentary (VICKARYOUS & RUSSELL 2003). Along the ventral surface of the mandible, the splenial meets the angular scute. The suture between the splenial and the dentary is partially visible and similar to the one seen in *Animantarx* (CARPENTER et al. 1999, fig. 3C). Any other sutures between the splenial and other elements have been obliterated by fusion. A shallow depression extends across the splenial anterior to the adductor fossa. No intermandibular foramen is present as in *Euoplocephalus*

and *Edmontonia* (VICKARYOUS & RUSSELL 2003). A small foramen is present on the ventromedial surface of the splenial opposite from the rostral end of the angular ornamentation. Similar foramina occur in *Edmontonia* and *Animantarx*.

Angular (Fig. 5B) – The angular's suture with the dentary and the surangular is lost due to extensive fusion. As in many ankylosaurs, osteoderms cover the angular. The exact perimeter of the ornamentation cannot be determined since the area is extremely rugose, which resembles the condition in *Animantarx*. As in *Animantarx*, the armor covers only the posterior half of the mandible, unlike the greater coverage in *Panoplosaurus* and *Edmontonia* (CARPENTER et al. 1999). The ornamentation extends below the bottom of the mandible in both lateral and medial views. A similar situation is seen in *Edmontonia*, although the scute does not have a strong caudal protrusion as in *Gargoylesaurus*. A deep gouge extends ventrally along the length of the ornamentation. A distinct keel runs from the dorsal margin of the ornamentation to the dentary where it loses its edge.

Surangular (Fig. 5) – The dorsal edge of the surangular appears to have been damaged. The surangular forms the highest point of the mandible and together with the coronoid forms the coronoid process. Along the posterior upper margin of the surangular runs a thick, distinct, ventrolaterally concave ridge. This ridge is also present in *Edmontonia*. Three to four tiny foramina lie laterally beneath the ridge of the surangular, but it is unclear if these are natural or taphonomic artifacts.

Coronoid (Fig. 5C) – The coronoid has the shape of a small crescent as in *Euoplocephalus* (VICKARYOUS & RUSSELL 2003, fig. 15E). As in most ankylosaurs it is on the medial face of the alveolar margin and in front of the adductor fossa.

Preaticular (Fig. 5) – The prearticular and the articular form the retroarticular process. The prearticular appears to wrap around to the lateral side of the mandible, but the sutures cannot be clearly discerned. The boundary between the articular and the prearticular is still visible. The prearticular forms a transverse wall posterior to the adductor fossa. A posterior wall also occurs in *Edmontonia* and *Panoplosaurus* (CARPENTER et al. 1999).

Articular (Fig. 5) – The articular lies at the posterior-most position of the mandibular ramus. In lateral view the articular is unciform in shape with a deep depression in the anterior surface. Anteriorly, the articular contacts the posterior part of the prearticular to form the glenoid. As is common in ankylosaurs, ventromedially along the retroarticular process, a concavity is created by the medial expansion of the glenoid. Contrary to most ankylosaurs though, the retroarticular is longer than deep.

Adductor fossa (Fig. 5C) – The adductor fossa is walled in by the prearticular (described above) and the surangular. A thin lamina of the

surangular folds in medially to wall off the fossa posteromedially. The coronoid process caps the adductor fossa dorsally. The dorsal closure of the adductor fossa is absent in *Edmontonia*, *Animantarx*, and *Euoplocephalus*. The adductor fossa faces medially rather than caudally. This trait is present in the nodosaurids *Animantarx* and *Edmontonia*; however, it is absent in the ankylosaurids *Tarchia* and *Saichania*.

Dentition

The premaxillary and anterior dentary teeth appear very similar to maxillary teeth in *Ankylosaurus* (BROWN 1908, figs. 4-5). The overall shape is lanceolate. Unlike nodosaurids, a distinct cingulum is not present, but lingually the crown slightly swells proximally. Each tooth is labially-lingually compressed, with approximately seventeen denticles of varying size. On the best preserved premaxillary teeth, there are eight denticles on the anterior carina and six denticles on the posterior carina; however the tip of the tooth is broken off. On an isolated tooth from the anterior dentary, eight denticles are present on either side of the apical denticle. The teeth of the posterior maxillae and dentaries have fewer denticles and some teeth show considerable wear along the posterior (distal) edge. As in *Ankylosaurus* the apical denticle is slightly offset posteriorly from the vertical axis of the root, causing the tooth to be curved. The maxillary and posterior dentary teeth resemble the teeth of the nodosaurids *Sarcolestes*, *Edmontonia*, and *Panoplosaurus*. The heavy, distinct fluting of *Silvisaurus* and *Euoplocephalus* is faint on the premaxillary teeth and barely noticeable, if at all present, on any other teeth, except those of the anterior dentary. The fluting is so faint, that it appears as vertical striations. From what remains of the maxillary teeth it appears that all the maxillary teeth are roughly the same size, while the premaxillary teeth are considerably larger. Similarly, anterior teeth of the dentary are larger and more blade-like than the posterior teeth of the dentary. The teeth have long, cylindrical roots that are oval in cross section. The denticles appear as small cones noticeably, smaller than the denticles of *Silvisaurus*, *Edmontonia*, and *Texasetes* (COOMBS 1995, fig. 1). The smaller denticles allow for a greater number of denticles per carina.

Axial Skeleton

Of the vertebral column only the proatlas, the first three cervical and seven caudal vertebrae were recovered (Table 2). Several fragments of cervical and dorsal ribs were retrieved as well as five chevrons. Only proximal chevrons were found. Also, various fragments of ossified tendons were found.

Proatlas (Fig. 6A) – The proatlas comprises two thin, elongate pieces of bone less than 50 mm long. The proatlas members appear crescentic in

dorsal view. The medial edge is either convex or straight while the lateral edge is strongly concave. The anterolateral margin is slightly thick. The posteromedial edge is thin distally, but about as thick as the opposite edge proximally. Proximally, a short ridge arises on the ventral surface. The ridge forms the ventral edge of the articular face. The dorsal edge of the articular face derives from the anterolateral edge. The proatlas projects slightly below and parallel to the dorsal margin of the paroccipital process. A deep groove exists between the articular face and the posteromedial edge.

Atlas (Fig. 6B-D) – The neural arches are not fused to the centrum despite evidence indicating that the individual was an adult; the neural arches and the centra of all the other known vertebrae are solidly fused together. The sutural surface for the neural arches on the intercentrum face anterodorsally. The anterior face of the intercentrum is cupped and sloped anteriorly to receive the occipital condyle. The dorsal surface of the intercentrum is notched to receive the odontoid process. The posterolateral corners of the odontoid notch have a mediolaterally elongate facet for comparable facets below the odontoid process of the axis. The posterior surface of the atlas intercentrum is a smooth crescent with two circular articular faces for the cervical ribs at the ventrolateral corners. A low lip is present at the anterior margin of each of the faces for the cervical ribs.

The neural arches of the atlas are fused along the midline, with a slight raised area functionally comparable to the neural spine of the other cervicals.

Table 2. Measurements of the vertebra of *Gargoyleosaurus parkpinorum*

Vertebral Element	Length (mm)	Width (mm)
Proatlas	48.9 (Left) 43.9 (Right)	29.6 (Left) 29.4 (Right)
Atlas	25.7	72.1
Axis	61.7	44.4
3 rd Cervical	52.6	46.3
1 st Sacral Vertebrae	66.5	55
1 st Caudal Vertebrae	54.5	60.75
2 nd Caudal Vertebrae	57	62
3 rd Caudal Vertebrae	59.5	59.5
4 th Caudal Vertebrae	62.5	61.5
5 th Caudal Vertebrae	68.5	60.75
6 th Caudal Vertebrae	69	52.5

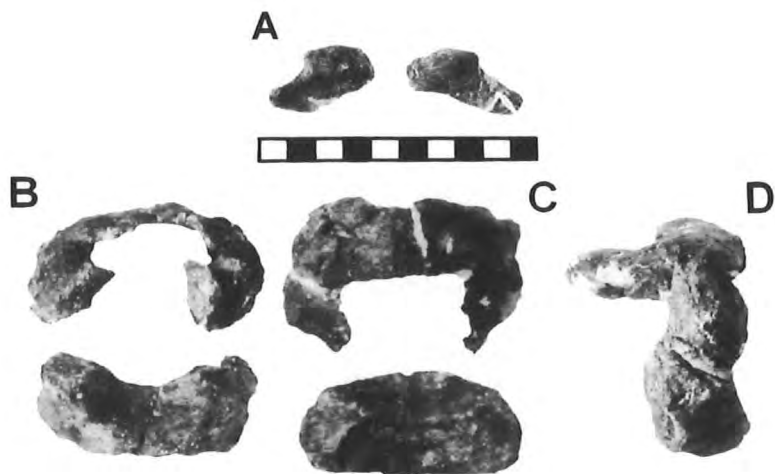


Fig. 6. Atlas and proatlas of *Gargyleosaurus parkpinorum* (DMNH 27726). Proatlas in ventral view (A). Atlas in anterior view (B). Atlas in dorsal view (C). Atlas in right lateral view (D). – Scale equals 10 cm.

The upper half of the atlas is the neural arch with no neural spine or prezygapophyses. The neural arch pedicels are thickened. The dorsal surface of the neural arch is very thin. Along the anterior margin of the neural arch is a pair of projecting facets for articulation with the proatlas. The postzygapophyses are long and strongly turned in medially, with the distal end being somewhat thinner than the proximal end. The postzygapophyses protrude directly posterior to, and within the same plane as, the neural arch. A small flange, continuous with the dorsal surface of both the neural arch and postzygapophyses, projects ventrolaterally from the postzygapophyses.

Axis (Fig. 7A-B) – The axis is deeply amphicoelus and lacks a notochordal prominence. It is somewhat damaged, missing the left transverse process and postzygapophysis. The height of the centrum is subequal to the height of the neural arch. The transverse process projects slightly upward and is short, barely extending past the parapophyses. As in *Sauropelta* and *Edmontonia* the postzygapophyses project from the neural spine, and the

postzygapophyses dwarf the prezygapophyses (GILMORE 1930, OSTROM 1970). The reduced prezygapophyses barely protrude past the neural arch. While the postzygapophyses extend over the posterior face of the centrum, they do not protrude as far caudally as in *Sauropelta* (OSTROM 1970, pl. 22G). The articular faces of the preand postzygapophyses are ellipsoid. The neural spine is shallowly sloped anteriorly and is scarcely longer than the centrum. The neural spine is laterally compressed, flaring where the postzygapophyses fuse to the spine. The anterior tip of the neural spine has a triangular expansion and below that is another tiny protrusion. As in *Sauropelta* the pedicels are high and form the lateral walls to a large, oval neural canal (OSTROM 1970).

The odontoid process is roughly sixty percent of the width of the centrum, and the length of the odontoid is 75 % the length of the centrum. As in *Shanxia*, the odontoid is concave dorsally, while ventrally it is convex (BARRETT et al. 1998). The odontoid is very similar to that of *Sauropelta*, but it tapers neither dorsally nor laterally (OSTROM 1970). The dorsal surface of the odontoid is grooved for the spinal cord and this continues posteriorly across the centrum. Ventrally, the odontoid has a neck or groove. The articular face to the atlas is a groove that is divided vertically immediately below the odontoid by a low ridge. As in *Sauropelta* the axis centrum is low and horizontally ovate, albeit shorter, and the "thin, sheetlike lamina of bone" extending caudally from the anterior edge is absent (OSTROM 1970). The parapophyses are large and extend from the anterior end of the centrum to roughly halfway along the longitudinal axis. The posterior lateral edges of the centrum are deeply concave, bordered by robust parapophyses anteriorly and the wide posterior face of the centrum posteriorly. A rounded keel stretches ventrally along the centrum.

Third Cervical (Fig. 7C-D) – The left side of the third cervical is badly damaged: the left half of the neural arch is missing as is the neural spine, and the left side of the centrum is damaged. The anterior face of the centrum is higher than the posterior face, and both faces are deeply amphicoelus as in *Edmontonia*, contrary to the amphiplatyan faces of *Ankylosaurus* (BROWN 1908, GILMORE 1930). The centrum faces of *Saichania* are amphicoelus as well, but the anterior face is lower than the posterior face (MARYANSKA 1977). In *Shanxia* the centrum is also amphicoelus and, as is the case in *Gargoyleosaurus*, bears a midline keel (BARRETT et al. 1998). In lateral view, the ventral surface is weakly concave due to disposition between the centrum faces. The centrum is shorter than the centrum of the axis. A notochordal prominence is not present on either face, although notochordal prominences are common to *Shanxia* and *Edmontonia* (GILMORE 1930, BARRETT et al. 1998). Transversely the bottom of the centrum is rounded, while the lateral surface between the parapophysis and posterior face of the centrum is

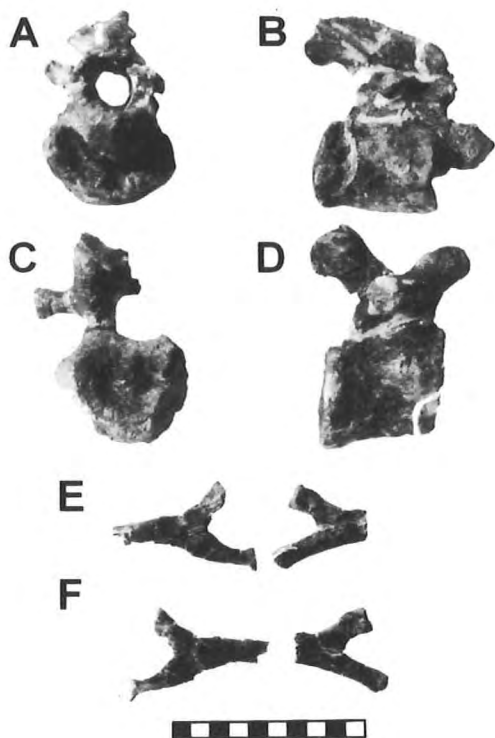


Fig. 7. Axis, third cervical vertebra, and cervical rib of *Gargoyleosaurus parkpinorum* (DMNH 27726). Axis in anterior (A) and right lateral (B) Views. Third cervical vertebra in anterior (C) and right lateral (D) views. Cervical ribs in lateral (E) and medial (F) views. – Scale equals 10 cm.

slightly concave. The the right parapophysis is located at mid-height of the centrum, as in *Niobrarasaurus* and *Shanxia* (MEHL 1936, CARPENTER et al. 1995, BARRETT et al. 1998). It lies just posterior to the anterior centrum face. A distinct keel extends directly caudal from the parapophysis to the posterior face of the centrum. The neural canal would have been ovate, and a deep gouge is excavated into the centrum along the bottom of the canal. The right pedicel is thickened. A depression is located opposite the area just below the

transverse process. The transverse process protrudes slightly beyond the parapophysis and is dorsoventrally compressed, but still thickened. The distal end of the transverse process is flared, and in distal view it is circular. The transverse process is $3/4$ the length of the prezygapophyses. The pre- and postzygapophyses are short, thick and oval in shape. The postzygapophyses are slightly longer than prezygapophyses, and all the zygapophyses are markedly convex opposite to their articular surface.

Cervical Ribs (Fig. 7E-F) – Although several fragmentary pieces of cervical ribs were found with the specimen, only the right rib of the second vertebra was found nearly complete. The distal portion of the shaft was broken off. The rib is Y-shaped, with the capitulum longer and more slender than the tuberculum. In *Silvisaurus*, the capitulum is also longer than the tuberculum, but in contrast a strong curve exists between the capitulum and rib shaft (EATON 1960, CARPENTER & KIRKLAND 1998). The entire rib is extremely laterally compressed. The rib shaft is shallowly concave on the medial side while the lateral side is equally convex. The curvature indicates that the dorsal margin of the shaft twists medially. In *Silvisaurus* the tuberculum is slightly larger at the tip than the capitulum; however, in *Gargoyleosaurus* the opposite occurs although this may be a result of taphonomic deformation (EATON 1960, CARPENTER & KIRKLAND 1998). Based on other fragments, it is clear, though, that the shaft of the tuberculum is crushed. The rib is similar to *Hylaeosaurus* (OWEN 1858). The anterior ribs are very thin, but fragments of distal cervical ribs indicate that caudally through the series, the ribs are slightly thickened.

Dorsal Ribs – No complete dorsal ribs were recovered. Most of the fragments recovered are from the mid to distal end of the rib shaft. As in the polacanthids *Mymoorapelta* and *Hoplitosaurus* the ribs are triangular in cross section; however, this occurs only distally in the rib shaft of *Gargoyleosaurus* (GILMORE 1914, KIRKLAND & CARPENTER 1994). Proximally the dorsal ribs are T-shaped, with flanges projecting both anteriorly and posteriorly from the shaft, or L-shaped, with a single flange projecting posterior to the shaft; this is also the case for *Polacanthus*, and many other ankylosaurs (EATON 1960, COOMBS 1978, BLOWS 1987, KIRKLAND & CARPENTER 1994). Distally the flanges taper, eventually merging with the rib shaft. As the flanges merge, the rib shaft inversely grows thicker and triangular in cross section.

Sacral vertebrae (Fig. 8A-B) – The first sacral centrum is present. The articular faces indicate that fusion of the sacrals had not occurred, nor of the dorsals into a synsacrum. It is possible, although not proven at this time, that a synsacrum was not present in this primitive polacanthid. The centrum is rectangular in profile, and is laterally and ventrally concave. The ventral surface is nearly flat transversely. The facets for the sacral rib and neural arch

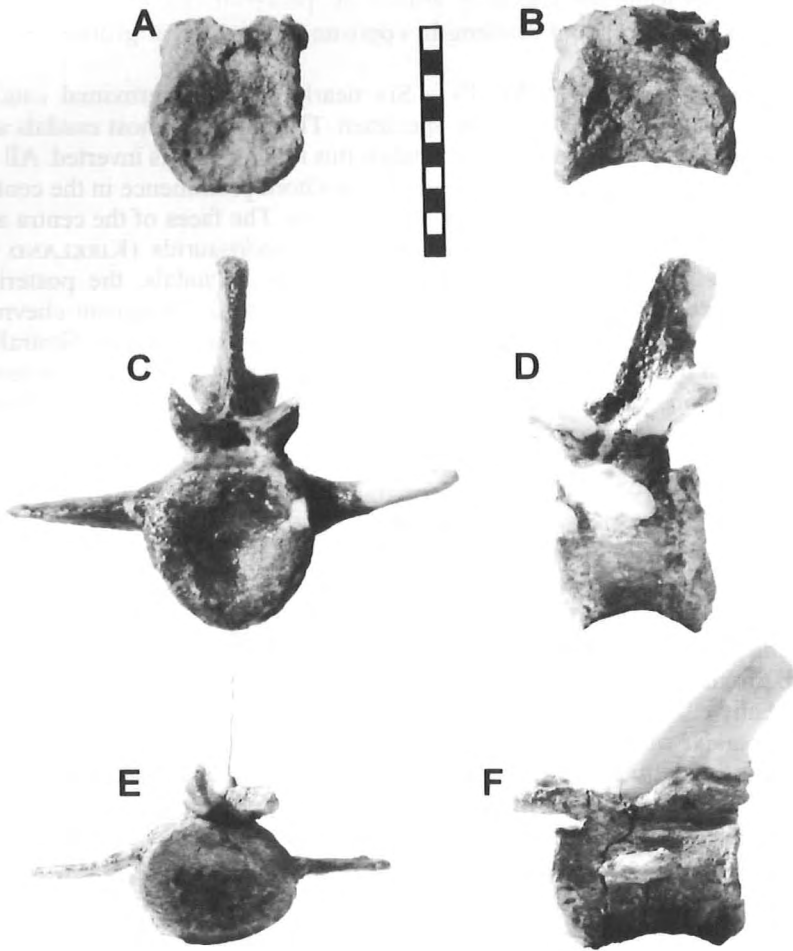


Fig. 8. Sacral and caudal vertebrae of *Gargyleosaurus parkpinorum* (DMNH 27726). First sacral centrum in anterior (A) and left lateral (B) views. Proximal anterior caudal vertebra in anterior (C) and left lateral (D) views. Distal anterior caudal vertebra in anterior (E) and left lateral (F) views. – Scale equals 10 cm.

extend posteroventrally and wrap around the posterior side of the centrum; the facets begin at about midlength, opposite a deep dorsal groove for the neural canal.

Caudal vertebrae (Fig. 8C-F) – Six nearly complete proximal caudal vertebrae were recovered with the specimen. The proximal-most caudals are wider than long; in the more distal caudals this relationship is inverted. All of the centra are amphicoelus, with a small notochord prominence in the center of the anterior faces of the anterior-most caudals. The faces of the centra are mildly heart-shaped as in *Mymoorapelta* and nodosaurids (KIRKLAND & CARPENTER 1994). On two of the most proximal caudals, the posterior centrum face extends below the anterior centrum face. Prominent chevron facets are present at the ventral margins of the articular surfaces. Ventrally, the centrum of the anterior-most caudals is flat. Distally through the series a sulcus develops ventrally, extends the length of the centrum and is bordered by two ridges that connect the chevron facets. As in *Edmontonia* and *Mymoorapelta* the centrum is moderately excavated beneath the caudal ribs (GILMORE 1930). The caudal ribs are not as thick as in *Silvisaurus*, *Edmontonia*, and *Sauropelta* (GILMORE 1930, EATON 1960, OSTROM 1970, CARPENTER & KIRKLAND 1998). While the caudal ribs approach the thickness of those in *Mymoorapelta*, the ribs project directly laterally and do not possess the ventral curve of *Mymoorapelta* and ventral inclination of *Silvisaurus* (EATON 1960, CARPENTER & KIRKLAND 1998). In one of the more proximal caudals in which both caudal ribs have been preserved, the ribs gently curve anteriorly at the tip. In the anterior-most caudals, the width of the caudal ribs is half the entire length of the centrum. In more distal caudals, the width of the caudal rib is scarcely more than a third of centrum length. In all the caudals, the prezygapophyses are elongate, although they are broader in more proximal caudals. From the neural arch, the prezygapophyses diverge to form a U-shaped gap between them in dorsal view. The postzygapophyses terminate proximal to the neural arch and do not extend past the neural spine. As in *Mymoorapelta*, the neural canal is circular, rather than the vertical oval of *Edmontonia* and *Sauropelta* (GILMORE 1930, OSTROM 1970). In the most proximal caudals, in which the neural spine is preserved, the anterior edge flares distally while overall the neural spine is a laterally compressed blade. The neural spines lack the distal flaring characteristic of *Mymoorapelta*, *Silvisaurus*, and *Sauropelta* (EATON 1960, OSTROM 1970, KIRKLAND & CARPENTER 1994, CARPENTER & KIRKLAND 1998). Caudally, the neural spine is preserved in only the most distal caudal. The spine is more blade-like and far more flat than in the more proximal caudals. The spine is also sloped posteriorly, and does not rise as high as in the proximal caudals. As the series progresses distally, centrum length increases while the neural spine and caudal ribs decrease in size proportionally as in

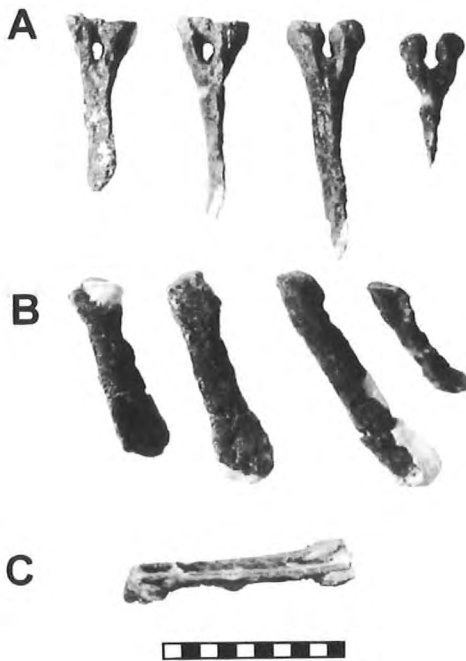


Fig. 9. Chevrans and ossified tendons of *Gargoyleosaurus parkpinorum* (DMNH 27726). Four proximal chevrons in anterior (A) and left lateral (B) views. Ossified tendons (C) in lateral(?) view. – Scale equals 10 cm.

Gastonia (KIRKLAND 1998). In the more distal of the anterior caudals, the chevron facet does not extend onto the articular surface; the posterior chevron facets protrude ventrally as in *Silvisaurus* (EATON 1960, CARPENTER & KIRKLAND 1998). Longitudinal ridges extend between the anterior and posterior chevron facets as in *Sauropelta*; however, the greater majority of the ridges are weak and hardly observable (OSTROM 1970).

Chevrons (Fig. 9A-B) – Four chevrons were recovered with the specimen. The chevrons are free of the centra, in contrast to the fusion that occurs in *Ankylosaurus* and *Mymoorapelta* (BROWN 1908, KIRKLAND & CARPENTER 1994). Free chevrons are characteristic, though, to *Polacanthus* and *Hylaeo-*

saurus (PEREDA-SUBERBIOLA 1994). All the chevrons have the blade shape characteristic of anterior to mid-caudal elements instead of the crescentic shape of distal chevrons. A bridge exists across the oval haemal canal connecting the articular ends of the most proximal chevrons as in *Edmontonia* (GILMORE 1930). In the other two chevrons, the longest and the shortest of those recovered, the bridge is absent. Among all of the caudals the shaft is very thick proximally and tapers to a thin blade distally. Along the posterior surface of the chevrons a variably developed keel arises. The keel eventually merges with the flattened distal end.

Ossified Tendons (Fig. 9C) – The ossified tendons are mostly thin, rod-like structures. The longest piece recovered is 139.8 mm, but it appears to be fragmentary. Most tendons are 9.5 mm wide. The anatomical position of the tendons is difficult to determine. Tendons were found associated with the dorsal and caudal vertebrae in *Sauropelta* and *Minmi*, with the caudal vertebrae in *Polacanthus*, and with the dorsal and distal caudal vertebrae in *Ankylosaurus* (BROWN 1908, OSTROM 1970, BLOWS 1987, MOLNAR & FREY 1987). OSTROM (1970) suspected that the tendons extended from the anterior or middorsals to at least the midtail.

Appendicular Skeleton

Of the appendicular remains (Table 3), both the pectoral girdle and the pelvic girdle are very fragmentary. The only parts recovered are a partial right scapula and coracoid and the right pubis. Of the limbs, only the right humerus, the right femur, two tarsals, a carpal, and several phalanges were recovered.

Scapula and Coracoid (Fig. 10) – Only two large pieces of the right scapula and coracoid were recovered: the coracoid and the distal end of the scapular blade. The anterior edge of the coracoid has been broken off, making its exact size and shape impossible to determine. The coracoid lacks the strong medial bend characteristic of *Saichania* (MARYANSKA 1977). The posteroventral margin of the coracoid is straight in *Hoplitosaurus* (GILMORE 1914) whereas in *Gargoyleosaurus* a sharp, deep anterior arch is present just below the glenoid. On the medial surface a distinct groove is medial to the all but obliterated scapula-coracoid suture. Within the apex of the arch a deep concavity is present. The coracoid is relatively flat, but the ventro-medial edge is thickened on the anterior surface. In comparison to *Sauropelta* (OSTROM 1970) the coracoid is much thinner, being only 44.5 mm at its thickest point in *Gargoyleosaurus*. As in *Texasetes* the ventral tip of the coracoid forms the typical nodosaurid right angle (COOMBS 1995). Also as considered diagnostic for nodosaurids by COOMBS & MARYANSKA (1990), the cranial edge of the coracoid curves smoothly to the ventromedial edge.

Table 3. Measurements of the appendicular skeleton of *Gargoyleosaurus parkpinorum*

Element	Length(mm)	Width(mm)	Least Breadth(mm)	Greatest Breadth(mm)	Circumference (mm)
Scapula	NA	157 (Across posterior flange)	NA	NA	NA
Coracoid	154.75 (Greatest length)	NA	NA	NA	NA
Humerus	292	NA	69.5	Undeterminable	175
Metacarpal	58	NA	18	37.5	~67
Pubis	107.5	31	NA	NA	NA
Femur	465	NA	70	176	193
Meta-tarsals*	107	NA	28	44	97

*Measurements taken from longest metatarsal

The coracoid also forms the lower tip of the lower articular face of the glenoid cavity.

Only the distal end of the scapula was preserved. The posterior end of the scapular blade tapers to a thin, rounded tip as BROWN (1908) described in *Ankylosaurus*. The shaft of the scapula is oval in cross section. The medial surface of the scapula is greatly flattened, while the lateral surface is convex, decreasing the spine's thickness to form a flattened posterior end. The flattened portion of the scapula forms a distinct lobe that extends postero-ventrally to the end of the scapular shaft. A short crest lies atop the lobe proximally and eventually merges with the thinned top of the scapular shaft.

Humerus (Fig. 11) – As in all ankylosaurs the humerus is short and massive. Much of the proximal third is damaged or missing. The exact point at which the deltopectoral crest terminates relative to the length of the humeral shaft is difficult to determine, because the distal end of the humerus is distorted. The deltopectoral crest is nearly perpendicular to the transverse axis through the distal condyles. This is similar to the condition in *Gastonia*, but contrasts with to the crest being parallel to the axis in *Polacanthus* and *Liaoningosaurus* (PEREDA-SUBERBIOLA 1994, XU et. al 2001). As in

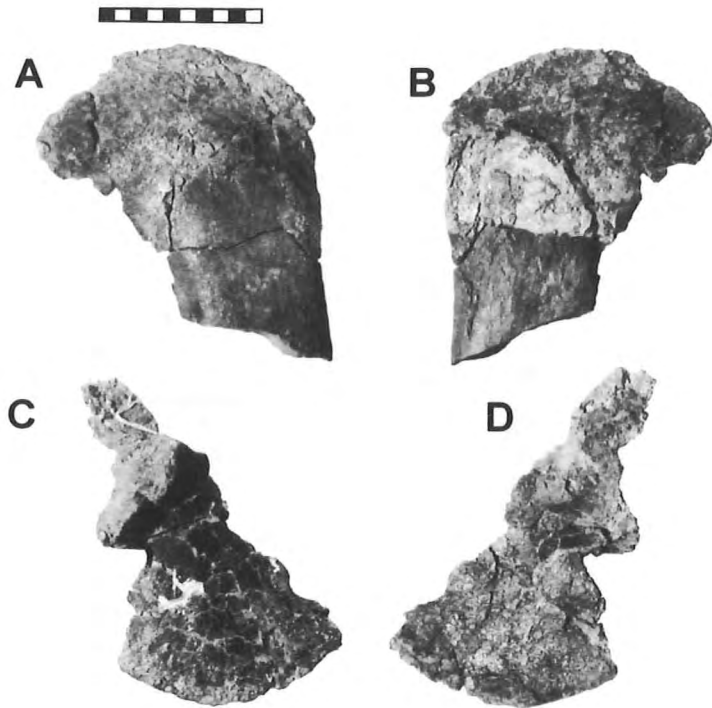


Fig. 10. Right scapula and coracoid of *Gargoylesaurus parkpinorum* (DMNH 27726). Scapula in lateral (A) and medial (B) views. Coracoid in lateral (C) and medial (D) views. – Scale equals 10 cm.

Gastonia, a large tubercle is present on the posterior surface of the deltopectoral crest. In *Gastonia*, a thin ridge of bone protrudes from the proximal end of the outer tubercle, extending upward parallel to the humeral shaft. This ridge is absent in *Gargoylesaurus*. Despite some similarities with *Gastonia* the outermost extension of the deltopectoral crest is higher and protrudes farther in *Gargoylesaurus*. The deltopectoral is tined in more medially in *Niobrarasaurus* than in *Gargoylesaurus* (CARPENTER et al. 1995, fig. 8). The shaft is subtriangular in cross-section. There is a slight

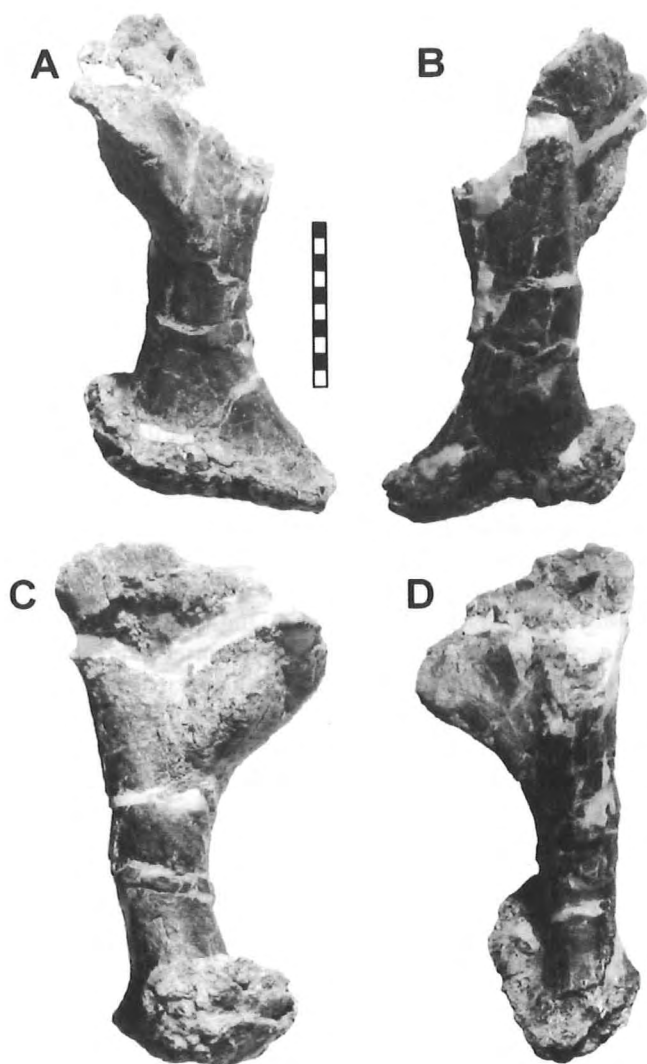


Fig. 11. Right humerus of *Gargoylesaurus parkpinorum* (DMNH 27726). Humerus in anterior (A), posterior (B), lateral (C), and medial (D) views. – Scale equals 10 cm.

twisting between the proximal and distal ends of the humerus, but much less so than in *Gastonia* and unlike the lack of twisting in *Sauropelta* (OSTROM 1970). Although the distal end of the humerus is grossly distorted, it is clear that the distal end of the humerus is more lateromedially expanded than in *Gastonia* and *Animantarx* but similar to *Polacanthus*, *Talarurus*, and *Saichania* (MARYANSKA 1977, PEREDA-SUBERBIOLA 1994). As in *Shanxia* there is a weak concavity, the ulnar fossa, on the posterior surface of the distal end of the humerus; however, the thick buttress of bone that borders this concavity in *Shanxia* is absent (BARRETT et al. 1998). The ulnar and radial condyles are deformed in such a manner as to suggest a pathology. Using differential diagnosis the most likely diseases would be arthritis, infectious arthritis, or neoplasm (MCWHINNEY, pers. comm., 2003). It seems doubtful that the distortion is due to crushing, because of the absence of displaced bone fragments and the condyles still retain their overall shape. The intercondylar notch is very poorly developed. On the posterior side, the olecranon fossa has a moderately developed, asymmetrical shape.

Carpal – A single, small, wedge-shaped carpal has been found that may belong to *Gargoyleosaurus*. Its dorsal (?) surface is lateromedially arcuate, whereas its ventral(?) surface is slightly concave. The posterior side is thicker than the anterior edge.

Manus – Only a single metacarpal and a single phalanx were recovered with the specimen. The metacarpal is slightly distorted. The anterior margin is damaged, exposing the trabecular bone. The metacarpal is more proximally flared than in *Mymoorapelta* and *Edmontonia* (CARPENTER 1990, KIRKLAND & CARPENTER 1994). On the posterior surface of the metacarpal is a distinct depression that is unmatched on the anterior side. A transverse keel lies dorsally across the proximal end of the metacarpal; however, this may be in part due to crushing. The lateral and medial surface of the proximal end each bear a depression. The lateral depression is the larger of these two. Distally two condyles extend from the anterior surface, with the medial condyle being by far the larger. The proximal end is twisted with respect to the distal end so that the distal end is 45° to the plane of the proximal end of the metacarpal.

The single manus phalanx is relatively long for its width and dorsoventrally compressed. In contrast, the pes phalanges are very short relative to their width and not dorsoventrally compressed. The proximal end is ovate and has an undivided concave articular surface. Dorsally, between the base of the distal condyles, is a small depression. Right above the concavity the proximal end of the phalanx flares anteriorly. The distal end is slightly distorted. On both the lateral and medial surfaces, a collateral ligament pit is present.

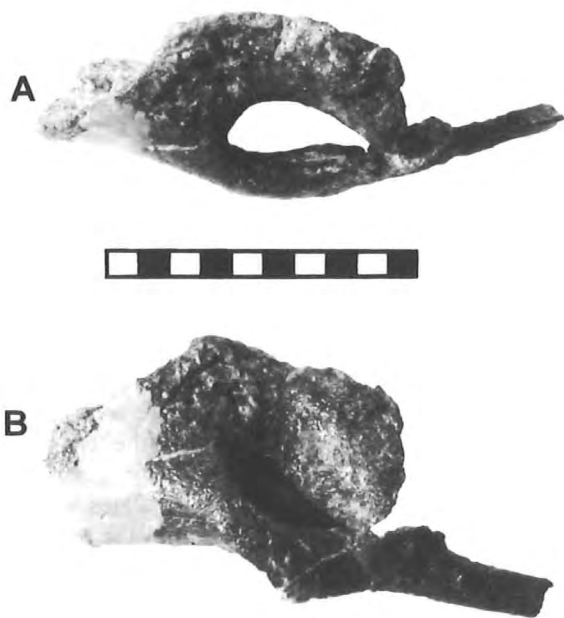


Fig. 12. Right pubis of *Gargoyleosaurus parkpinorum* (DMNH 27726) in dorsal (A) and medial (B) views. – Scale equals 10 cm.

Pubis (Fig. 12) – Only a nearly complete proximal part of a right pubis is preserved. The pubic body is elongate and compressed, whereas it is a block-like in *Gastonia*. As in *Sauropelta* the lateral surface is very rugose while the medial surface is smooth (OSTROM 1970). The pubis of *Gastonia* is much smoother on the lateral surface than is the pubis of *Gargoyleosaurus*. The articular surface for the ilium is a dorsally facing rugose depression. Posterolaterally, the rugose surface is continuous with the rugose surface of the acetabulum. The articular surface for the ilium is by far the most rugose area of the entire lateral surface. OSTROM (1970) describes a similar articular surface in the pubis of *Sauropelta*. In *Gastonia* no excavation is present for articulation with the ilium and the articular surface is considerably smoother. The pubic body of *Sauropelta* and *Edmontonia* is longer and rostrally

narrower than in *Gargoyleosaurus*. Furthermore, the entire pubes of *Sauropelta* and *Edmontonia* bear a distinct dorsal arch which is absent in *Gargoyleosaurus* (GILMORE 1930, fig. 16, OSTROM 1970, pl. 25). Roughly halfway along the length of the pubis, the postpubic process projects caudo-ventrally. It is incomplete, so its original length is unknown. A small, triangular flange projects ventrally from the postpubic process, opposite to the dorsal expansion of the postpubic process reported in *Edmontonia* (GILMORE 1930). In *Gargoyleosaurus* the postpubic process is triangular in cross section, less broad, and less curved than in *Edmontonia*. The more strongly curved and laterally projected postpubic process causes the obturator foramen in *Gastonia* to be circular. In contrast, the shape and the projection of the postpubic process causes the obturator foramen to be elliptical in *Gargoyleosaurus*. The medial surface of the pubis opposite the postpubic process is markedly concave, more so than in *Gastonia*. The posterior end of the pubis is curved so that the external surface faces posteriorly. This is similar to the condition in *Mymoorapelta*, in which the curvature of the posterior end of the pubis articulates with the ischium. An ellipsoid facet is present on the dorsal surface of the postpubic process that articulated with the ischium; a similar facet is present in *Gastonia*.

Femur (Fig. 13) – The femur is slightly sigmoidal in lateral view, however, the shape is due to fractures and displacement of bone. Without these breaks, the shaft would probably be straight. The femoral head is elliptical in shape as in *Sauropelta* and strongly curves ventrally to join with the femoral shaft (OSTROM 1970). The femoral head extends nearly as far medially as the tibial condyle, and is almost at right angles to the femoral shaft; in more derived ankylosaurs, the head is angled dorsomedially. The curvature beneath the head is sharper than in *Gastonia*, *Ankylosaurus*, *Euoplocephalus*, and *Polacanthus* (COOMBS 1978, PEREDA-SUBERBIOLA 1994, KIRKLAND 1998). In proximal view, the femoral head is anteroposteriorly expanded as BARRETT et al. (1998) reported in *Shanxia*. The femoral head in *Polacanthus* lacks such expansion (PEREDA-SUBERBIOLA 1994). The top of the femoral head is also taller than the greater trochanter, as is the case in *Shanxia*, *Polacanthus*, *Hoplitosaurus*, and *Sauropelta* (GILMORE, 1914, OSTROM 1970, pl. 26, PEREDA-SUBERBIOLA 1994, fig. 3, BARRETT et al. 1998). The anterior trochanter is large, but not as massive as in *Cryptodraco* (GALTON 1983). The lower part of the greater trochanter is damaged due to crushing on the posterior face of the femur. Despite this, it appears that the greater trochanter may have been of similar proportions to that in *Hoplitosaurus*, though slightly smaller (GILMORE 1914). In proximal view the anterior trochanter lies directly against the greater trochanter as in *Polacanthus* and *Hoplitosaurus*, but unlike *Cryptodraco* (GILMORE 1914, fig. 69, GALTON 1983, fig. 2, PEREDA-SUBERBIOLA 1994, fig. 3). Laterally, a

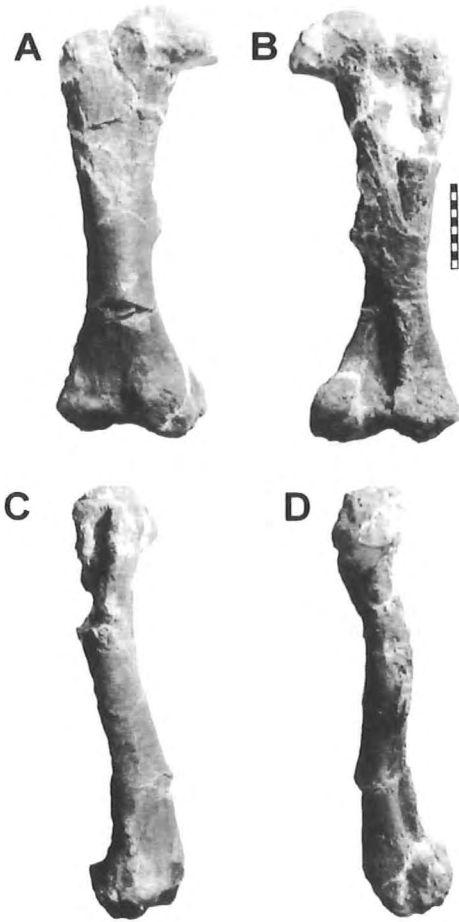


Fig. 13. Right femur of *Gargyleosaurus parkpinorum* (DMNH 27726) in anterior (A), posterior (B), lateral (C), and medial (D) views. – Scale equals 10 cm.

deep groove separates the anterior and greater trochanters. A broad U-shaped notch separates the anterior trochanter from the femoral head, but this may be an artifact of preparation. *Hoplitosaurus* also has a distinct anterior trochanter with a U-shaped notch (GILMORE 1914, fig. 69). In *Shanxia* and

Pinacosaurus the anterior trochanter is probably completely fused into the greater trochanter as in *Stegosaurus* (BARRETT et al. 1998). In *Sauropelta* the anterior trochanter is largely fused into the femoral head leaving a very minute trochanter (OSTROM 1970). The femoral shaft is bowed, with the center being placed anteriorly as in *Hoplitosaurus* (GILMORE 1914). The shaft of the femur is wider than deep as in *Hoplitosaurus*, but instead of being anteroposteriorly flattened, the anterior face of the shaft is convex (GILMORE 1914).

The fourth trochanter (Fig. 13A-B) was broken off the femur; however, its placement on the femur can still be determined. The fourth trochanter extends past the midlength of the femur, as opposed to being above the midlength of the shaft in *Sauropelta* (OSTROM 1970). The placement of the fourth trochanter is similar to the position in *Hoplitosaurus* and *Polacanthus* (GILMORE 1914, fig. 69, PEREDA-SUBERBIOLA 1994). A slight concavity lies on the anterior surface of the distal femur directly opposite to the intercondylar groove. On the posterior face a thick buttress of bone arises from the outer condyle; however, in *Shanxia* buttresses of bone arise from both the distal condyles (BARRETT et al. 1998). On the distal end of the femur, the intercondylar notch between the distal condyles is shallow. It wraps around to the popliteal fossa on the posterior side. However, a short "lip" separates the two. Of the two condyles, the inner, or tibial, condyle is the larger, and both the fibular and tibial condyles project posteromedially, possibly due to distortion. In lateral and medial views, the distal condyles are unciform.

Tarsal (Fig. 14B) – A single distal tarsal is present partially fused to the proximal surface of metatarsal III. It is wedge-shaped, tapering anteriorly into a cup-shaped articular surface. In distal or proximal view, it is subrectangular. Tarsals, except for the astragalus, are rare in ankylosaurs. Save for an astragalus and calcaneum in *Niobrarasaurus*, the tarsus is unknown in adult ankylosaurs.

Pes (Fig. 14) – Two nearly intact metatarsals, III and IV, were found along with several phalanges and two unguals. Metatarsal III is not flared at the proximal end; however, anteriorly a slight overhang is present. As a result the anteroposterior length of the proximal end is about the same size as the distal end. In anterior view the shaft of the metatarsal is bowed laterally. From the proximal end to roughly midlength, the medial side of the metatarsal has an inverted triangular patch that is greatly roughened marking the sutural surface for metatarsal II. On the posterior side of the proximal third of the shaft is a rugose area for insertion of the tendon for the foot flexor musculature. Distally, on both the shorter and longer metatarsals is a pair of concavities, pits for the collateral ligaments, one on either side of the distal condyles. The lateral concavity is smaller than the medial concavity.

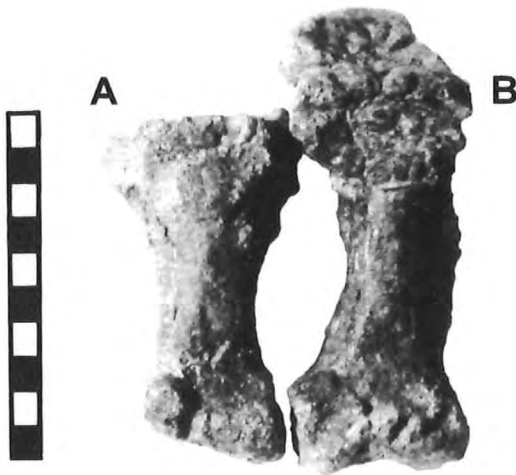


Fig. 14. Metatarsals of *Gargoyleosaurus parkpinorum* (DMNH 27726). Metatarsal IV in anterior view (A). Metatarsal III with fused tarsal in anterior view (B). – Scale equals 10 cm.

The shorter of the two metatarsals, metatarsal IV, is anteroposteriorly compressed, though convex on the anterior side, giving the shaft a D-shaped cross section. The proximal end is flared so that it has a trapezoidal shape in proximal view. The base of the trapezoid is the posterior margin of the dorsal surface. The distal end of the metatarsal is slightly askew so that the medial side is placed more anteriorly and ventrally than the lateral side. A tear-drop shaped pit for the collateral ligament is developed on the medial ginglymus. The ginglymoid notch is only developed on the posterior side. It resembles the metatarsal of *Sauropelta* (OSTROM 1970, pl. 26).

Phalanges – Several phalanges were found with the specimen, and their large sizes suggest they belong to the pes. The phalanges are short and thick, and the majority are ovate in proximal view. Many, but not all, of the phalanges bear midline keels on the proximal articular surface to articulate with the condyles of the metatarsals or other phalanges. In some of the phalanges the posterior side of the proximal end is extended caudally. Such flaring occurs in *Gastonia*. At the distal end of each phalanx is a pair of pits

for the collateral ligaments, similar to the ones in the metatarsals, but of equal size.

Two ungual phalanges were also recovered. The unguals are two dorsoventrally compressed cones with flattened, blunt tips. They are dorsally convex and ventrally concave. On the better preserved of the two unguals, a distinct notch on either side of the articular face is a distinct notch. A similar pair of notches is set in the phalanges of *Silvisaurus* (EATON 1960, fig. 17A, CARPENTER & KIRKLAND 1998). The unguals resemble those described of *Sauropelta* and *Edmontonia* (RUSSELL 1940, pl. 3, OSTROM 1970, pl. 26). As in *Edmontonia* the surfaces of the unguals are lined with nutrient furrows (RUSSELL 1940).

Dermal armor

The armor of *Gargoyleosaurus* consists of four types: thick, elongated spines; thin, triangular plates with hollow bases; individual flat, keeled, ovate scutes; and scutes and ossicles fused into a single sheet. The smaller solid-based, bladelike plates found in *Mymoorapelta* are not present in *Gargoyleosaurus* (KIRKLAND et al. 1998). Most of the dermal elements appear to come from right side of the body, and the armor was found *in situ*. Many of the elements resemble those in *Gastonia* (KIRKLAND 1998, GASTON et al. 2001), but the sacral shield is fragmentary.

Cervical Armor – The cervical armor consists of two half rings composed of keeled plates and ossicles coossified together. The first ring (Fig. 15A) consists of a central single dominant scute, wider than anteroposteriorly long, which has a low conical point towards its posterior. Along the posterior base of the central cone are numerous smaller nodes, of which the lateral-most are the most prominent. The scute is ventrally flat so as to rest directly on top of the neck. The scute is flanked on each side by a quarter-ring that is ventrally concave so as to conform to the neck. Each quarter-ring is composed of a laterally projecting, dorsoventrally compressed, triangular plate coossified to a tall-peaked scute. The base of the triangular plate is thickest. The anterior edge is posterolaterally convexly arcuate, and the posterior edge concavely arcuate. The tall-peaked scute is higher than the solitary median scute. The tall-peaked scute has a longitudinal sharp keel and is also swollen medially. Clustered along the suture between the lateral triangular plate and the tall-peaked scute are coossified ossicles. Similar ossicles occur on the medial side of the quarter-ring. The base of the armor markedly thickens posteriorly so that the quarter-ring is wedge-shaped in cross-section. Of these two quarter-rings, only the right ring is completely preserved, and only the medial scute of the left ring is preserved.



Fig. 15. Cervical armor of *Gargyleosaurus parkpinorum* (DMNH 27726). The first cervical ring in dorsal view (A). The right quarter-ring of the second cervical ring in dorsal view (B). The left quarter ring in the first cervical ring has been partially reconstructed. – Scale equals 10 cm.

The second half ring (Fig. 15B) is composed of only two sets of three plates and scutes arranged in an arcuate pattern. Only the right quarter ring is preserved. In dorsal view, the ring arcs posteriorly. The base of the plates is thick and a large swelling is present ventrally along the sutures of adjacent plates. At the lateral end of the quarter-ring is a large triangular plate. It resembles the triangular plate from the first ring, but is larger and bears a straight anterolateral edge. It is anteroposteriorly longer than the adjacent keeled scute. The posterior edge of the plate has been partially broken off. Ventrally there is a U-shaped notch, which is pathological, located at the posterior along the sutural margin. The triangular plate is coossified to a large scute. The sutural zone is marked by a groove that is flanked by several coossified ossicles. The scute has a distinct longitudinal keel that spans the longitudinal width of the ring. Medially the dorsal surface of this scute is convex while laterally it is flattened. The medial margin of the scute is significantly narrower than the lateral margin. The posteromedial edge is

oblique and has several coossified ossicles along its dorsal margin; co-ossified ossicles also occur along the suture to the smaller, medial scute. The medially adjacent smaller scute is located at the very proximal-most end of the ring. It is comparable in size to the keeled conical scute of the first ring. Laterally this scute is also flattened while medially it is convex. In *Gastonia* the second cervical ring consists of two large, firmly rooted plates and large separate scute; without any coossification (GASTON et al. 2001).

Lateral Armor – The shoulder armor consists of two pairs of spines (Fig. 16B) that projected posterolaterally from the body, as opposed to the forward projection of the shoulder spines in *Edmontonia* (GILMORE 1930). Only the right members of each pair were recovered. The first pair of these spines is greatly tapered, much more so than the next pair. The spines have hollow bases with asymmetrical margins. This also occurs in *Mymoorapelta* and *Gastonia*, and as in *Mymoorapelta* the dorsal surface is flat while the ventral surface is concave (KIRKLAND et al. 1998). The dorsal margin is deepest posteriorly while the ventral margin is deepest anteriorly. The same condition occurs in *Mymoorapelta* (KIRKLAND et al. 1998). The spines are triangular in cross section with a pronounced groove on the posterior surface. Distally the groove becomes shallower, terminating just prior to the tip as in *Gastonia* and *Mymoorapelta* (KIRKLAND 1998, KIRKLAND et al. 1998). The ventral margin of the groove protrudes farther than the dorsal margin. Nutrient foramina are present within the hollow base, as in *Mymoorapelta* (KIRKLAND et al. 1998). The prongs described by KIRKLAND et al. (1998) are absent in *Gargoyleosaurus*, but the depression posterior to these prongs is present. In contrast to *Mymoorapelta* the base of the spine is longer, and the spine from the posterior end of the base to its tip is shorter. Also the spine of *Mymoorapelta* is thicker, making the keel of *Gargoyleosaurus* appear more acute in comparison. The second pair of spines is very similar to the first except it is much wider and shorter. In comparison to the anterior-most shoulder spine, the ventral edge of the posterior groove extends farther posteriorly, while anteriorly the margins of the base have nearly equal depths. The keel of both sets of spines faces anterolaterally contrary to the twisted posterodorsal keel of *Edmontonia* (GILMORE 1930).

Only seven spines of lateral dorsal armor caudal to the shoulder spines were recovered (Fig. 16A). These spines consist of dorsoventrally compressed triangular plates with a hollowed base. The plates are shaped like right triangles. None of these plates exhibit a posterior groove as seen on the shoulder spines. The basal length of these plates is greater than the width. While one of the spines appears to be greatly distorted, it appears that the spines were flat dorsally and concave ventrally. In these spines, the base is asymmetrical, with the ventral edge being deepest anteriorly and the dorsal edge being deepest posteriorly. The points of these spines are far more

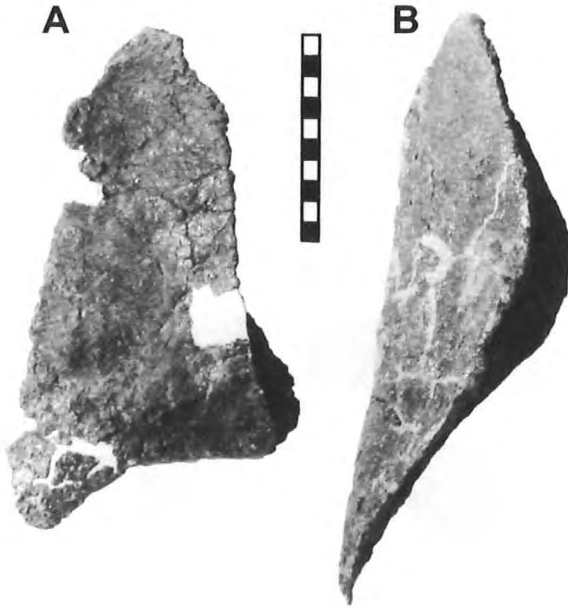


Fig. 16. Lateral armor of *Gargoyleosaurus parkpinorum* (DMNH 27726). Lateral triangular plate in ventral view (A). Shoulder spine in ventral view (B). – Scale equals 10 cm.

rounded than the points of those on the shoulder. The lateral spines appear to be relatively longer and narrower than in *Gastonia* (GASTON et al. 2001).

The general trend of the caudal plates is to decrease in size distally through the series. The first of the caudal plates is very thick proximal to the base and is the thickest of the caudal plates. The plate is concave ventrally and the peak of the plate is towards its posterior end, but it is more rounded than pointed. Much of the base of the first plate was lost during fossilization, but since the dorsal side of the posterior end is deeper than the ventral side it is evident the base was asymmetrical. A similar thickened plate is observed in *Mymoorapelta* (KIRKLAND et al. 1998, fig. 7D). In contrast to *Gargoyleosaurus* the plate of *Mymoorapelta* is less ventrally curved, far more pointed, and is marked with furrows extending posterolaterally. The plate of *Mymoo-*

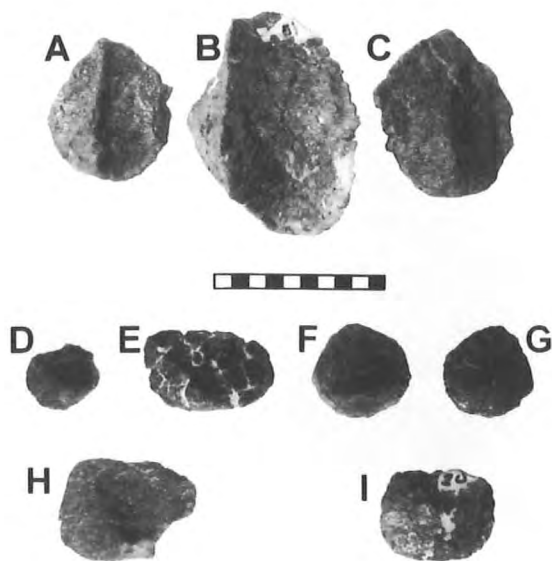


Fig. 17. Dorsal armor of *Gargyleosaurus parkpinorum* (DMNH 27726). Keeled scutes in dorsal view (A-C). Smaller scutes in dorsal view (D-I). – Scale equals 10 cm.

rapelta also arcs anteriorly along the posterior edge. The two lateral caudal plates posterior to the first caudal plate resemble plates along the trunk margin.

The most distal caudal plate is intact and differs from the lateral plates anterior to it. While it is flattened as in the second and third caudal plates, the apex is extremely rounded and blunt. The base is greatly asymmetrical, and is an exaggerated likeness of the bases of more anterior plates. The base is dorsoventrally compressed and no nutrient foramina are discernable.

Dorsal Armor (Fig. 17) – Along the back of *Gargyleosaurus* are longitudinal rows of ovate to comma shaped scutes arranged in alternating order. The keels extend longitudinally and are on the medially off-set as in *Gastonia* (GASTON et al. 2001). These scutes are similar to those in *Mymoorapelta* and many ankylosaurids in that they are very thin (KIRKLAND et al.

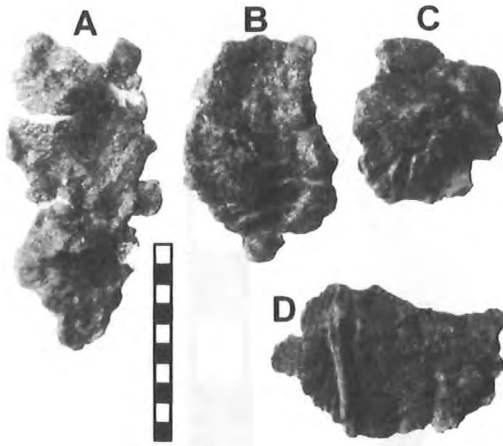


Fig. 18. Sacral armor of *Gargoyleosaurus parkpinorum* (DMNH 27726). Three fragments of sacral armor in dorsal view (A-C). Fragment 'B' in ventral view with attached ossified tendons visible (D). – Scale equals 10 cm.

1998). As in *Mymoorapelta*, the scutes are flattened or slightly concave ventrally, and the keel rises to a low posterior peak (KIRKLAND & CARPENTER 1994). Posterior to the cervical armor, a transverse band of four scutes lies between the first pair of shoulder spikes. The scutes range from large (approx. 138 mm long) to tiny (approx. 30 mm long), with rows of large scutes being set more towards the lateral margin of the trunk, as in *Gastonia*, and rows of small scutes being set medially (GASTON et al 2001). Each individual row contains scutes of roughly the same size. The large, solid spines in the anterior dorsal region of *Gastonia* and *Polacanthus* are absent in *Gargoyleosaurus* (BLOWS 1987, GASTON et al. 2001).

A single anterior dorsal scute of the tail is ovate and deeply hollowed within the base. The peak of this scute is thick and a keel longitudinally extends across the scute. At the anterior end, the medial side of the scute is more swollen than the lateral side. Similar scutes are found in *Gastonia* (KIRKLAND 1998, CARPENTER et al. 1999).



Fig. 19. Unidentifiable bone in the palatal region of *Gargoyleosaurus parkpinorum* (DMNH 27726). – Scale equals 10 cm.

Sacral Armor (Fig. 18) – Numerous fragments of the sacral shield were found with the specimen. The remains of the sacral shield are composed of larger scutes and smaller scutes fused into a continuous sheet. Across their greatest lengths the larger scutes and the smaller scutes range between 48-74 mm and 11-28 mm, respectively. Two variations occur among the larger

Fig. 20. Mounted skeleton of *Gargoyleosaurus parkpinorum* (DMNH 27726). Much of the left half of the skeleton has been reconstructed.



Fig. 20 (Legend see p. 152)

scutes. Some scutes are keeled and laterally compressed, but most are squat cones. As in *Polacanthus* and *Mymoorapelta* the peak of the larger scutes is placed posteriorly (HULKE 1887, KIRKLAND et al. 1998). HULKE (1887) described keeled scutes placed in lateral rows across the shield whereas the short conical scutes were placed over the vertebral column in *Polacanthus*. The sacral shield of *Mymoorapelta* consists of ovate, low keeled scutes (KIRKLAND et al. 1998). Ventrally, all the scutes of *Gargoyleosaurus* bear slight depressions which are deepest below their peaks. In the larger scutes the hollow is deepest transversely below the peak. On none of the fragments do any of the larger scutes appear to be adjacent to one another. The larger scutes are bordered by smaller scutes or by a flat stretch of bone. This is similar to the shield fragment described by KIRKLAND & CARPENTER (1994) for *Mymoorapelta*. In *Polacanthus* the sacral shield is composed of both larger and smaller scutes, but these elements are more distinct in the shield of *Polacanthus* (BLOWS 1987, fig. 9). On two fragments of sacral armor of *Gargoyleosaurus* ossified tendons are fused to the ventral surface (Fig. 18D).

Miscellaneous elements

Alongside *Gargoyleosaurus* were found many pieces of bone that are, at this time, unidentifiable. Part of the problem in identifying this material is that as many as twelve taxa come from Bone Cabin Quarry, instead of an isolated specimen. Most of these fragments are severely worn and weathered so that no distinct features are visible. Out of this jumble of bones one element is distinct and worthy of description.

In the palatal region of the skull, one of these bones is located in the left choana, resting on the caudoventral secondary palate (Figs. 2B, 19). This bone is thin and narrow and crescentic in shape, and extends towards the snout and towards the back of the skull. The concave side of this bone faces the vomer. The rostral extension of this bone is flat, while the caudal extension of the bone appears to be rounded in cross section. The distal end of the caudal extension of this bone is flared and is marked with small grooves and fossae. On the convex side between the two extensions is a short flange. The uneven, rough margin of this flange indicates that this bone is broken off a larger piece of bone and independently came to rest in the skull of *Gargoyleosaurus*, to which it may or may not belong.

At least it was possible to reconstruct a skeleton of *G. p.* on the base of the fossil remains of the specimen described herein (Fig. 20).

4. Discussion

As is characteristic of all other polacanthids known from adequate material, *Gargoyleosaurus* shows a mixture of ankylosaurid and nodosaurid features. Among the ankylosaurid features are an anterior and posterior secondary palate, jugal horns, two cervical rings, and hollow based spines and scutes. The nodosaurid features include a narrow snout and the rostral projection of the deltopectoral crest. Postorbital horns occur in *Gargoyleosaurus*, *Hylaeosaurus*, and *Gastonia* and are also common to some nodosaurids. However, these horns are large and reminiscent of the squamosal horns of *Euoplocephalus*.

There are, however, many autapomorphies within the Polacanthidae, and these traits could potentially be diagnostic for the group. The aforementioned postorbital horns occur in the genera of polacanthids that have known cranial material. CARPENTER (2001 b) reported that a partial skull of *Hylaeosaurus* has a right postorbital horn of similar proportions to *Gargoyleosaurus* and *Gastonia*. Also diagnostic of the Polacanthidae is a sacral shield composed of smaller ossicles and larger scutes fused into a single sheet (CARPENTER 2001 a). Unfortunately the sacral shield of *Gargoyleosaurus* is in fragments, which makes any discernable pattern amongst the scutes impossible to see. The shoulder spines characteristic of *Gargoyleosaurus* are found in many members of the Polacanthidae, including *Mymoorapelta* and *Hoplitosaurus* among others (GILMORE 1914, pl. 29). The spines are thick and in life projected posterolaterally. Along the back of these spines is a distinct posterior groove that connects with a hollow asymmetrical base. In anterior or posterior view it can be seen that the spine slightly curves ventrally. The only peculiarities amongst the polacanthid spines occur in *Polacanthus* and *Hylaeosaurus*. In *Polacanthus* the base of the spine has a pronounced, medially facing keel (BLOWS 1987, fig. 7A-B). BLOWS (1987) originally refers to this spine as a caudal plate but KIRKLAND & CARPENTER (1994) suggest it may be a shoulder spine. In *Hylaeosaurus*, the posterior groove appears to be lacking (OWEN 1858, pl. 9, PEREDA-SUBERBIOLA 1993). In *Gargoyleosaurus*, *Gastonia*, *Mymoorapelta*, and *Polacanthus* lateral armor posterior to the shoulder spines consists of flattened triangular plates (BLOWS 1987, fig. 5). However in *Polacanthus* some of the plates are fused to separate strips of basal bone (BLOWS 1987). The triangular plates of the caudal armor are also clearly common to all known polacanthids.

In a preserved skull roof of *Gastonia*, a clear suture can be seen on the ventral surface between the nasals. This would indicate that the vomer did not extend to the skull roof. This condition is also present in *Gargoyleosaurus*. However, this is a primitive condition found in both nodosaurids and ankylosaurids, as well as most other dinosaurs. At the moment it is

impossible to ascertain if a more derived condition occurred in any polacanthid.

Currently there is debate about the validity of the Polacanthidae as a monophyletic clade. CARPENTER (2001a) used a rather unorthodox "compartmentalization" method to derive a cladogram for the Polacanthidae. In this analysis CARPENTER determined that the Polacanthidae are monophyletic, and that two divisions within the Polacanthidae exist. In one mini-clade *Gargoyleosaurus*, *Hylaeosaurus*, and *Mymoorapelta* are grouped together. A shared trait in this group is the anatomy of the shoulder spines. All of these taxa exhibit a "pocket" towards the posterior of the base in the largest of the shoulder spines. In *Mymoorapelta* the pocket is pronounced and deep while in *Gargoyleosaurus* it is very shallow. Based upon OWEN's plates it would appear that *Hylaeosaurus* also exhibits a pocket. Another characteristic of the clade is the prominence of the jugal horn. The jugal horns within this group are more prominent than in *Gastonia*. Jugal horns are known for all species within this group. In *Gargoyleosaurus* premaxillary teeth are present, and the snout is narrow with laterally facing nares. In this clade *Gargoyleosaurus* is the only species with a known skull so it is currently impossible to know if these features are characteristic of all members in this clade.

The other proposed clade consists of *Gastonia*, *Hoplitosaurus*, and *Polacanthus*. One of the autapomorphies of this clade includes the presence of elongate, dorsolaterally projecting spines. These spines have solid bases and are known for all taxa in this clade. In *Hoplitosaurus* the spines appear to be much wider than in either *Polacanthus* or *Gastonia* (GILMORE 1914, fig. 71). Another feature common to these species is spined plates (BLOWS 2001, fig. 17.7, CARPENTER 2001a). The bases of these spines are greatly flattened, and the spines are situated just anterior to the sacral shield. Similar spines are present in *Hoplitosaurus* and *Polacanthus*; however, they are absent in *Gastonia*. In *Gastonia* and *Polacanthus* the acromion flange projects down to the middle of the blade; in *Hoplitosaurus* the acromion is shorter (CARPENTER 2001a).

In studies by VICKARYOUS et al. (2001a) and HILL et al. (2003), the Polacanthidae were found to be paraphyletic, rather than a monophyletic group. The "compartmentalization" method of CARPENTER (2001a) was not used, and a more "traditional" procedure of systematics was undertaken. VICKARYOUS et al. (2001a) ran three analyses. In the first cladogram both *Gargoyleosaurus* and *Gastonia* were found to be "traditional ankylosaurids." In the second two cladograms *Gargoyleosaurus* and *Gastonia* were found to be paraphyletic. HILL et al. (2003) also concluded that *Gargoyleosaurus* and *Gastonia* are in fact members of the Ankylosauridae and that both taxa serve as separate outgroups to the remaining genera of the Ankylosauridae. Thus,

in this study, *Gargoyleosaurus* and *Gastonia* are again paraphyletic. An area of concern in these two studies is the fact that both studies only used cranial features to determine their results. As many of the features that link polacanthids together are postcranial, and many polacanthid taxa are only known from postcranial material, another analysis using both cranial and postcranial features could potentially have drastically different results.

5. Conclusions

Gargoyleosaurus parkpinorum shows a mix of ankylosaurid and nodosaurid features that are common to all members of the Polacanthidae. Furthermore the features shared by the Polacanthidae include the sacral shield; large postorbital horns; jugal horns; posteriorly grooved shoulder spines; and asymmetrically based, hollow triangular plates lining the lateral margins of the body. While the exact nature of the relationship between the members of the Polacanthidae is still largely debated, the many shared features of these taxa suggest that they are closely related.

Acknowledgments

We thank the Radiology Department at Kaiser Permanente for the Computerized Axial Tomographic images of the *Gargoyleosaurus* skull and Western Paleontological Labs for donating the specimen. In addition, B.M.K would like to deeply thank JUDITH SCHIEBOUT, RAY WILHITE, and KENNETH CARPENTER, for without their instruction, aid, and encouragement my involvement in this study may not have been possible. For their assistance in helping the final version of this manuscript come to fruition, I thank MARYBETH LIMA, GRANT FRIDAY, and YIN-LIN CHIU. I also thank SUYIN TING, MIKE WILLIAMS, MARYBETH LIMA, MELINDA MANGHAM, LAURIE GODSHALL, DIANE TOUCHET, DONNA KRIPPSE and too many others to name for their support and encouragement of my pursuit of vertebrate paleontology. Lastly, B.M.K. would like to thank his parents Donald and Jacquelyn for their support.

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Manuscript received: October 7th, 2003.

Revised version accepted by the Stuttgart editor: November 17th, 2004.

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