

A new species of sauropod from the Late Jurassic of the Sichuan Basin (*Mamenchisaurus jingyanensis* sp. nov.)

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Abstract

The text describes new specimens of a large sauropod collected from the Upper Jurassic Upper Shaximiao Fm. in the Sichuan basin erected as *Mamenchisaurus jingyanensis* sp. nov. The new species further substantiates the genus *Mamenchisaurus* Young, 1954 and the inclusion of the family Mamenchisauridae within the superfamily Bothrosauropodoidea.

Introduction

At the end of the 1970's and beginning of the 1990's, the Chongqing (Chungking) Natural History Museum in collaboration with the Jingyan County Management Office of Cultural Relics conducted a series of sauropod excavations in the Upper Jurassic Upper (Shang) Shaximiao Fm. from the localities of Sanjiang and Meiwang, Yanxian Co. and Dujia, Rongxian Co. The humerus collected from Dujia was previously identified by Zhiming Dong as belonging to *Mamenchisaurus* (Dong et al., 1983), the remaining specimens were long since left unidentified due to the absence of diagnostic comparative specimens. Recent publications on more diagnostic data resulting in the erection of *M. youngi* and *M. anyuensis* allows the Rongxian and Jingyan specimens to be reevaluated for diagnosis. This text provides brief descriptions of these specimens for future reference.

Description

Saurischia Seeley, 1888

Sauropodomorpha Huene, 1932

Sauropoda Marsh, 1878

Bothrosauropodoidea Young, 1958

Mamenchisauridae Young and Chao, 1972

Mamenchisaurus Young, 1954

***Mamenchisaurus jingyanensis* sp. nov.**

Species etymology: "Jingyan" being Pinyin romanization for the county in which the predominance of specimens for the new species were excavated.

Diagnosis: The species is enormous in size with a body length of 20-26 m, skull is delicately constructed and moderate in height and length, external nares are small and anteriorly positioned, mandible is relatively slender and elongated, and dentition is spoon-shaped with anterior and posterior serrations. Dental formula is: Pm: 4, M: 14-16, D: 17-19. Cervical vertebrae are elongated with low neural spines, well developed pleurocoels, and lack a ventral keel. Dorsal vertebral pleurocoels are not well developed and anterior neural spines are bifid. Four completely fused sacral vertebrae are present. Anterior caudal vertebrae are strongly procoelous. Humerus is straight and robust.

Type: All specimens are housed in the Chongqing Museum of Natural History. A relatively complete skull (included in the surrounding matrix were several loose maxillary teeth and a hyoid bone), an incomplete scapula with complete coracoid, a right humerus, semicomplete left radius, ulna, and a complete left ischium. Specimen #CV00734 from Meiwang.

Paratype: Two isolated teeth, three anterior cervical vertebrae, several extremely weathered dorsal vertebrae, a column of nearly articulated anterior caudal vertebrae, medial and posterior caudals, and relatively complete hind and forelimbs. Specimen #JV002 from Sanjiang.

Hypodigm: Two isolated teeth, a column of medial and posterior cervicals with articulated ribs, four fused sacrals, several medial and posterior caudals, a complete right scapula-coracoid, two complete humeri, one distal femur, and semi-complete tibia and fibula. Specimen #CV00219 from Dujia.

Localities: The type specimen was collected approximately 200 m from the administrative headquarters of the town of Meiwang, Jingyan Co., Sichuan Province. The paratype was collected from Liuzu, at the hamlet of Yuebocun, village of Sanjiang (Sanjiangzhen), approximately 10 km from the town of Meiwang. The hypodigm was collected from the hamlet of Yanwang (Yanwangcun), by the village of Dujia, in Rongxian Co. approximately 10 km from Sanjiang.

Age and stratigraphic position: The stratigraphic horizon of all three specimens is generally consistent, being collected from the Upper Jurassic Upper (Shang) Shaximiao Fm. Stratigraphic positions were between 100-200 m above the conchostracan zone recognized as the boundary between the Upper and Lower Shaximiao formations. Age is recognized as early Late Jurassic.

Description: The left side of the occipital region is damaged. All the principle cranial elements are represented with the exception of the nasal and jugal. Cranial reconstruction was conducted by the authors following the complete preparation of the specimens (Fig. 1).

The skull is relatively low and flat with a rather gently rounded rostrum. The highest point on the skull is at the parietal-frontal suture and the broadest point on the skull is at the lateral margin of the frontal, or the orbital region. From the anterior end of the frontal the skull descends at an oblique angle and from the maxilla-jugal suture it gradually becomes constricted causing the rostral region to become relatively anteriorly convex. Cranial height/length index (including mandible) is 1:1.6. The occipital region is relatively broad and spacious, and the plane of the occiput is posteriorly oblique.

Table 1. Cranial and mandibular measurements of *Mamenchisaurus jingyanensis* sp. nov. (CV00734) (cm)

Maximum length after restoration	55.0
Maximum breadth	25.0
Breadth between paroccipitals	24.0
Dorsal margin of foramen magnum to dorsal margin of supraoccipital	5.5
Breadth between supraoccipitals	11.0
Maximum ventral breadth of premaxilla	14.2
Ventral length of maxilla	27.0
Quadrate height	16.5
Dorsal margin to ventral process of lacrimal	12.4
Mandible length	54.1
Dentary length	35.8
Maximum anterior dentary height	12.1

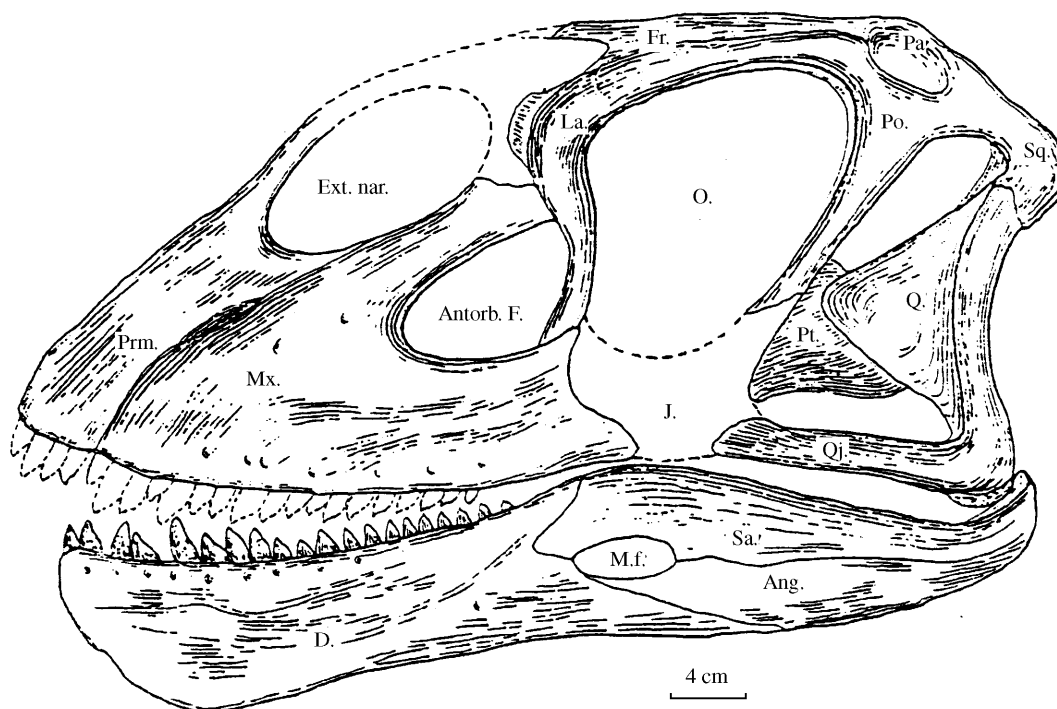


Figure 1. Left lateral view of *Mamenchisaurus jingyanensis* sp. nov. reconstructed skull (CV00734).

The right mandible has been damaged but the left is relatively well preserved, lacking only the articular. The mandible is distinctly slender and elongated, quite unlike the robust form on *Omeisaurus tienfuensis* or *Bashunosaurus*. The mandible is slightly expanded at its suture zone, at its midsection it is slightly constricted, and its highest point occurs at the contact of the dentary, angular, and surangular, where there is also a small elliptical mandibular foramen. The articular fossae is determined to lie ventral to the dentition based upon the configuration of the prearticular and surangular. Compared to *Camarasaurus* and *Omeisaurus tienfuensis* the dentary is distinctly longer, constituting nearly two-thirds the length of the mandible, and its anterior end is slightly high with a straight lingually oblique suture line. The angle between the anterior and ventral margins is approximately 120° and the ventral margin is dorsally embayed at its midsection. At the posterior dentary there is an aperture that represents the anterior margin of the mandibular fenestra, the lateral surface of the dentary is roughened, and on the dorsal margin in the vicinity of the dental trough, there is a distinct row of approximately 18 nutrient foramina. The medial side of the dentary is relatively smooth and glossy. On the dorsal margin approaching the posterior dental trough there is a row of alveoli containing replacement teeth. Ventrally there is a relatively deep Meckelian groove. Both mandibles possess 17-19 teeth.

Upper and lower teeth are all moderate in size, typically spoon-shaped, and the dentition is relatively numerous. Dental formula is Pm: 4, M.: 14-16, D.: 17-19.

A relatively well preserved right premaxilla preserves four distinct alveoli with all functional teeth missing, but four replacement teeth in various stages of eruption are present. These teeth and the anterior maxillary teeth proximal to them indicate that the premaxillary dentition was straight and robust with a maximum length of 9 cm, approximate crown height of 4 cm, and approximate breadth of 1.8 cm. Anterior and posterior margins are nearly symmetrical, and six to eight anterior and posterior serrations are present on the unworn teeth, the labial side of the crown

is convex, and lingual side is shallowly concave. There is a weak medial ridge approaching the apex.

The completely preserved left maxilla displays over 14 alveoli, isolated teeth in the matrix surrounding the maxilla indicate that the anterior maxillary teeth basically resemble the premaxillary teeth in morphology, but tooth crowns gradually become lower and more asymmetrical posteriorly along the dentition. Unworn teeth are distinctly serrated on their anterior and posterior margins, the labial sides are convex, and the apices are very slightly lingually curved.

The left mandible bears 19 teeth and the right 17, with dental morphology resembling the maxillary teeth. Anterior teeth are robust, and although crowns are relatively straight they are more posteriorly asymmetrical than the premaxillary teeth. Crowns are rather distinctly spoon-shaped, anterior and posterior margins are both serrated, although those on the anterior margin are frequently more pronounced than the posterior margin, the tooth crowns diminish in size and height posteriorly along the series, and apices become more curved. A medial crest also becomes more distinct on the posterior teeth. The most terminal tooth is the smallest and most laterally compressed.

An approximately 30 cm long piece of the hyoid apparatus is present which has no appreciable characteristic morphology.

Postcrania on the type is represented only by a fragmentary scapula, complete coracoid, damaged humerus, complete radius and ulna, a relatively complete ischium, and several fragmentary ribs.

The glenoid region of the scapula is relatively broad and spacious and the scapular crest is relatively high, resembling the morphology of the hypodigm scapula excavated from Dujia, Rongxian Co. (CV00219). The coracoid is large and circular, also similar in size and morphology to the Dujia specimen. Coracoid diameter may exceed 50 cm.

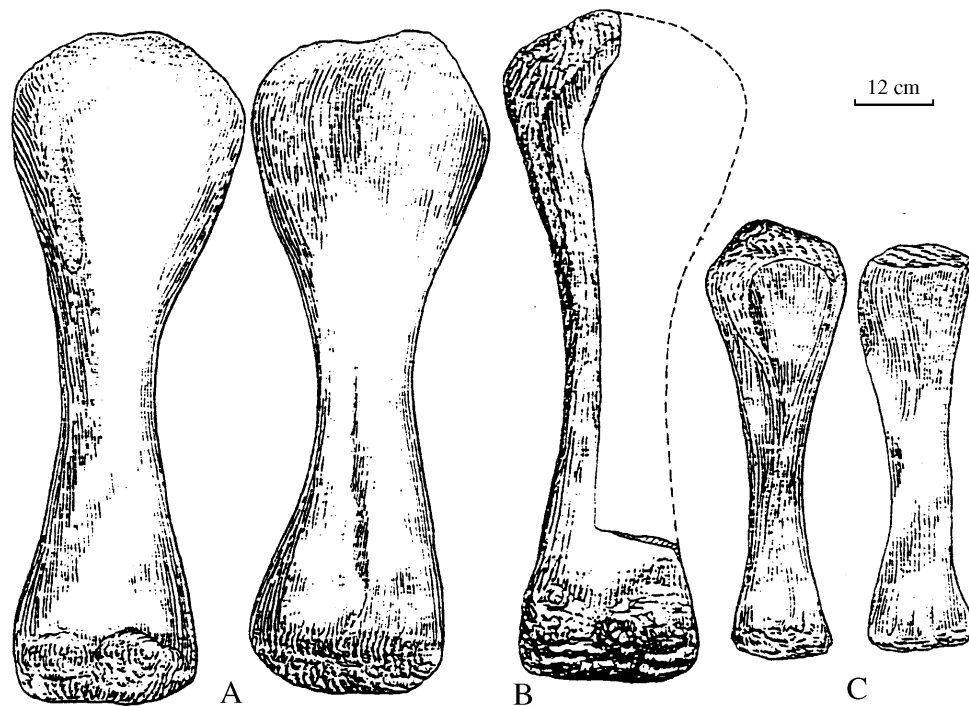


Figure 2. Forelimb of *Mamenchisaurus jingyanensis* sp. nov.

Humerus morphology is based upon its impression in the matrix in addition to the presence of a majority of a specimen. It is a relatively robust element with a straight shaft, a length of approximately 110 cm, and a morphology similar to the Dujia specimen. It also resembles the paratype specimen JV002 excavated from Sanjiang, Jingyan Co.

The ulna and radius are straight, relatively short, and have a morphology as illustrated in Figure 2.

A. Anterior and posterior views of right humerus (CV00219), B. Anterior view of right humerus (CV00734), C. Anterior view of right ulna and radius (CV00734).

The ischium is comparable in size and morphology to *M. hochuanensis*, with a maximum length of 93 cm. Near the proximal end its minimum breadth is 20 cm and its distal maximum breadth is 18.2 cm.

The paratype (JV002) fossil locality of Sanjiang is 10 km from the Meiwang locality and approximately 20 km from the Dujia locality. All three localities are regarded as representing the same stratigraphic horizon. Not only do the paratype and hypodigm localities produce teeth with identical morphology, they also produce elements directly comparable to *M. hochuanensis* from Hechuan Co. and the type specimen CV00734 from Meiwang, including cervical, dorsal, a large quantity of caudals, pectoral and limb elements.

Among the three paratype cervical vertebrae, only a Cv5 is completely preserved (Fig. 3) with a length of approximately 40 cm, pleurocoels are well developed, centrum is opisthocoelous, diapophyses and parapophyses are low, a ventral keel is absent, neural arch and spine are relatively low, centrum posterior height is approximately 15.2 cm, breadth is 10.3 cm, and maximum height is 25.0 cm. It is completely consistent in morphology with the anterior cervicals on *M. hochuanensis*.

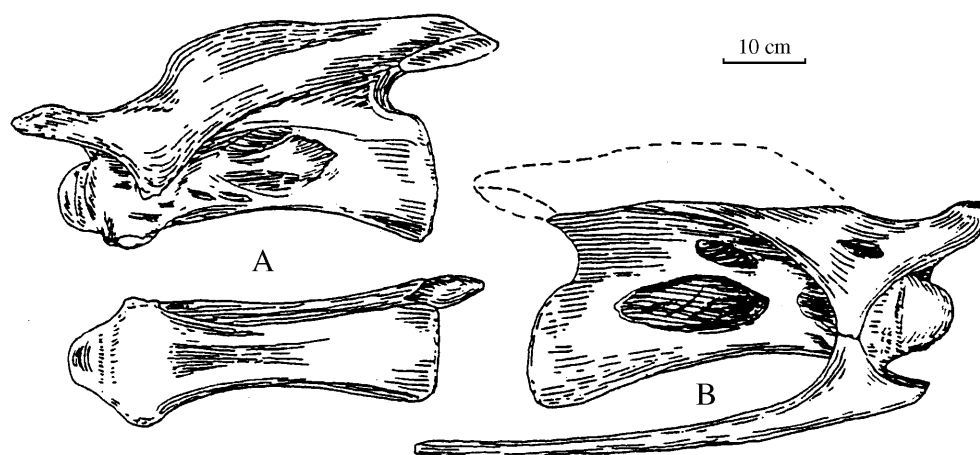


Figure 3. *Mamenchisaurus jingyanensis* sp. nov. cervical vertebrae. A. Lateral and ventral view of CV5 (JV002), B. Lateral view of CV6 and associated rib (CV00219)

Dorsal vertebrae are opisthocoelous, short, and high with undeveloped pleurocoels. Anterior neural spines are bifid.

There are eight articulated anterior caudals with high and enlarged procoelous centra, posterior articular surfaces are strongly convex, and neural spines are high and claviform. Medial caudals are gently procoelous and not conspicuously posteriorly convex.

The humerus is basically consistent with those on specimens CV00734 and CV00219. The maximum femur length of *M. anyuensis* is approximately 1.7 m, providing an estimated maximum body length of 23 m. The Jingyan femur is approximately 2.0 m in length providing an estimated body length of 26 m. The tibia and fibula in size and morphology approach those of CV20019. The size and morphology of the pes elements are completely consistent with *M. hochuanensis*.

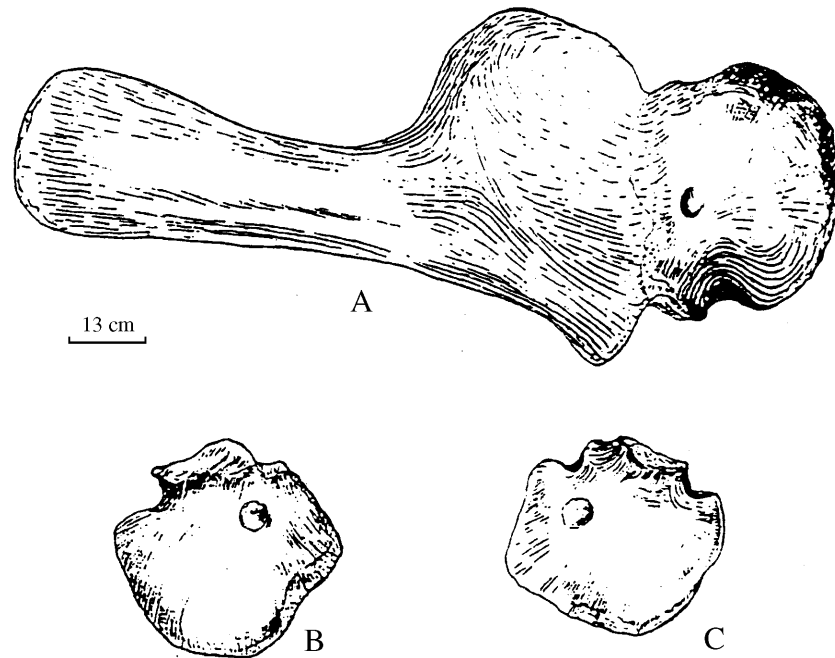


Figure 4. *Mamenchisaurus jingyanensis* sp. nov. scapula-coracoid. A. Lateral view of right scapula-coracoid (CV00219). B. Lateral view of right coracoid (CV00219). C. Lateral view of left coracoid (CV00734).

The hypodigm specimen CV0019 consists of spoon-shaped teeth, a column of cervical vertebrae with articulated ribs, four fused sacrals, a portion of caudals, and limb bones, all of which may be compared to *M. hochuanensis* and the paratype from Sanjiang. It may also be compared to the type (CV00734) scapula-coracoid and humerus. There is a column of medial to anterior cervicals with intensely weathered neural spines, centra are opisthocoelous and elongated, neural arches and spines are relatively low, diapophyses and parapophyses are relatively low, and the posterior laminae supporting the parapophyses form the boundary between the lateral and ventral centrum. A ventral keel such as present on *O. tienfuensis* is absent, consequently, their morphology resembles the medial and anterior cervicals on *M. hochuanensis*.

Four fused sacral vertebrae are represented, the first and last of which are large, rounded, and very slightly opisthocoelous. In contrast, the second and third sacrals are constricted. The first three neural spines are fused and separated from the fourth. Size and morphology are basically consistent with *M. hochuanensis*. The medial caudals are gently procoelous, nearly cylindrical, and their caudal haemal arches begin to become bifurcated. Posterior caudals are amphicoelous with elongated, slightly laterally compressed, and medially constricted centra.

Scapula and coracoid are relatively robust with a broad, spacious, oblique glenoid fossa, the medial side of which is simple in configuration. The scapular crest is relatively high, the blade is relatively short and narrow, is convex at its lateral midsection, and its distal end is a rather flattened plate but is not excessively expanded. Length is approximately 110 cm. The coracoid is relatively large, subcircular, and rather laterally convex (Fig. 4).

The pair of humeri are approximately 115 cm long and are robust with straight shafts. The distal end of each is rather expanded, the deltopectoral crest is well developed and near the medial side there is a relatively conspicuous pectoral crest. Both distal condyles are relatively well developed (Figure 2).

Only a distal end of a femur is preserved. It is exceptionally robust with a transverse breadth of 42 cm. The tibia and fibula are thick and straight, unlike the laterally compressed morphology of *M. hochuanensis*. Tibia length is 85 cm, articular surface is subcircular with a breadth of 33 cm, and the maximum distal breadth is 27 mm. Fibula length is 87 cm, proximal breadth is 25 cm, and distal breadth is 18 cm. The unguals on digits one and two are particularly robust with lengths exceeding 15 cm.

Diagnosis and discussion: Specimens CV00734, CV00219, and JV002 were produced from the same region and stratigraphic horizon. The localities of Meiwang and Sanjiang, Jingyan Co. and Dujia, Rongxian Co. are not more than 20 km apart and lie in the Upper Shaximiao Fm. between 100 to 200 m above the conchostracan unit recognized as the boundary between the Upper and Lower Shaximiao Formation. The specimens from these three localities are completely consistent in morphology and are thus considered to belong to a single species. The principle characters include a typically spoon-shaped dentition, elongated cervicals with low elongated neural spines, anterior dorsal neural spines are bifid, and anterior caudals are procoelous, assigning them unquestionably to the genus *Mamenchisaurus* Young, 1954.

This genus is characteristic of the Late Jurassic of East Asia. To date there are seven species recognized (Li et al., 1997). With the exception of *M. sinocanadorum* Russell and Zheng, 1993, the type specimens for the remaining species are all produced from the Sichuan Basin.

M. sinocanadorum is represented only by a left mandible and first through third cervicals. Its estimated body length is 26 m. The size of the Jingyan and Rongxian specimens is equivalent to this species and the mandibular morphology and dentition are basically consistent. However, specimens representing *M. sinocanadorum* are extremely restricted, the reliability of its diagnosis is questionable, and the type locality is 2,000 km from the other species. Thus the probability of the current specimens belonging to this species is not very high.

The four species *M. constructus* Young, 1954, *M. fuxiensis* Hou et al., 1976, *M. guanyuanensis* (unpublished), and *M. youngi* Pi et al, 1996, have body size ranges of 14-16 m, being much smaller than the 20-26 m body size of the Jingyan and Rongxian specimens. Furthermore the pleurocoel and butressing on the presacral vertebrae is much more well developed on *M. jingyanensis*, distinguishing it from these four species.

M. hochuanensis Young and Chao, 1972 compares closely in both size and morphology but there are relatively clear distinctions as the Jingyan and Rongxian cervicals have better developed pleurocoels and the tibia is thick and linear, whereas on the former the tibia is laterally compressed.

The body length of *M. anyuensis* He et al., 1996 is 21.5-23 m, which is within the range of the Jingyan and Rongxian specimens, but there are numerous character distinctions with the former possessing teeth with only anterior serrations whereas on *M. jingyanensis* serrations are present on both anterior and posterior margins. Furthermore, cervical pleurocoels on

M. anyuensis are not well developed but dorsal pleurocoels are relatively well developed in direct contrast to the new species which has well developed cervical pleurocoels but weak dorsal pleurocoels. Additionally, *M. anyuensis* has five sacral vertebrae in contrast to the four on *M. jingyanensis*.

These comparisons justify the erection of the new species *Mamenchisaurus jingyanensis*. This species further substantiates the erection of the family Mamenchisauridae Young and Chao, 1972 and its undisputed assignment to the superfamily Bothrosauropodoidea Young, 1958.

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Explanation of plates

Plate I

1. Occipital view of skull (CV00734), x1/2.
2. Lateral view of cranial wall (CV00734), x 1/2.
3. Lateral view of right mandible (CV00734), x1/2.
- 4.. Medial view of maxilla (CV00734), x1.

Plate II

1. Lateral view of left maxilla (CV00734), x1/3.
2. Lateral view of right premaxilla and maxilla (CV00734), x1/4.
3. Medial and lateral view of maxillary tooth (JV002), x2/3.
4. Medial and lateral view of mandibular tooth (JV002), x1.
5. Lateral view of coracoids. Right coracoid (CV00219) and left coracoid (CV00734), x1/8.