Mamenchisaurus

by

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Preface

The text describes the skeleton of *Mamenchisaurus hochuanensis* from Hechuan (formerly Hechuan) County, Sichuan Province excavated from 130 Ma Jurassic sediments. This taxon represents the largest species of dinosaur in China to date, and is the most complete sauropod recovered in the country with a body length of 22 meters, torso height of 3.5 meters, and an estimated living weight of 45 tons. *Mamenchisaurus* was adapted for both terrestrial and aquatic life while subsisting on shoreline vegetation.

The specimen was discovered exposed on the surface by the local populace prior to the Chinese Revolution. But under the leadership of the Chinese Guomindang reactionary party, it was ignored, and as such, this extremely valuable specimen was abandoned and allowed to weather away in situ.

In April of 1957, after the Revolution and under the leadership of Chairman Mao Zedong, the Central Party, and encouraged by the elevated proletariat, and under the guidance of the middle peasantry, the Sichuan Provincial Petroleum Exploration Corps conducted mineral exploration in the impoverished region to rediscover the fossil locality. The Sichuan Provincial Museum immediately dispatched a work team to conduct an excavation with the assistance and support of the local population to expose a nearly complete skeleton lacking the anterior limbs and head. In 1962, after preliminary preparation, the specimen was recognized as a general scientific and educational resource, and subsequently moved to the Chengdu Academy of Geology. In the Spring of 1964 the Chengdu Academy of Geology dispatched two of its personnel to accompany the specimen to the Institute of Vertebrate Paleontology and Paleoanthropology (IVPP) in Beijing where in collaboration with the technical and professional staff, further preparation, reconstruction, and mounting of the skeleton, along with a description, was completed in 1965. This dinosaur skeleton was a product of the efforts of workers in both Beijing and Chengdu and was publicized in the national publications *China Reconstructs* and *China Pictorial* in 1965.

Following the guiding principle as espoused by Chairman Mao: “to advance education through theories of knowledge applied from dialectical materialism,” individuals from several provincial and municipal museums have produced models of *Mamenchisaurus hochuanensis* which will, in the near future, be popularly disseminated as concrete evidence for biological evolutionary development.

Foreword

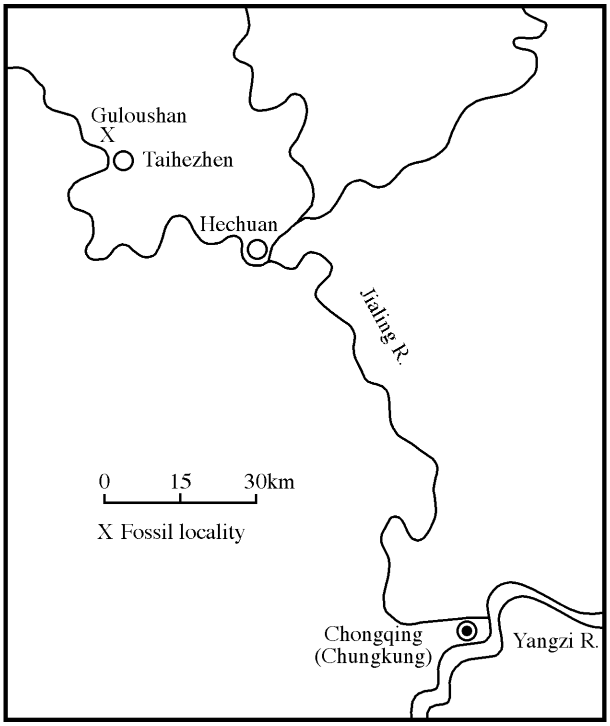

Figure 1. Location of the *Mamenchisaurus* quarry.

The specimen described in this text was produced from Hechuan Co. north of the metropolis of Zhongqing (formerly Chungking) (Fig.1). More specifically, the locality is 200 meters above the Gaochufujiang River on the slope of Mt. Gushushan, by the village of Taihezhen (formerly Taiheba), 35 kilometers from the municipality of Hechuan.

The specimen is preserved in red sediments (Fig. 3, Pl. I) predominantly composed of approximately 250 m of purple-red mudstones, sandy mudstones, and argillaceous sandstones. Calcareous concretions are abundant in the mudstones and sandy mudstones (Fig. 2). Above and below the fossil horizon the sediments are interbedded with dark purple sandstones. Regional geologic data assigns the fluviolacustrine fossiliferous sediments to the Jurassic Upper (Shang) Xiaximiao Fm. within the Zhongqing (Chungking) Group.

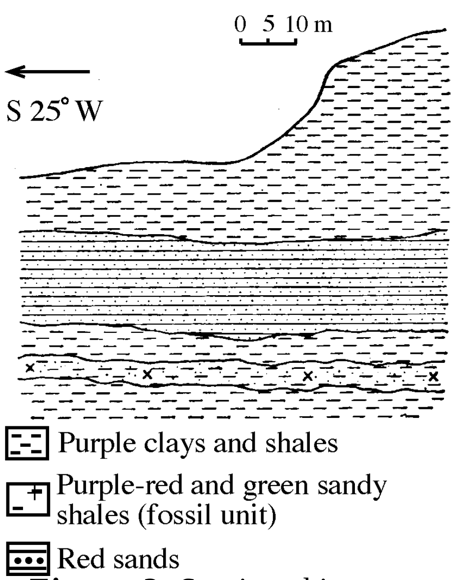

Figure 2. Stratigraphic cross-section at the Gushushan fossil locality.

Preparation of the specimen occurred in two phases: preliminary work was undertaken in Chengdu prior to its transport to Beijing, where the majority of work was undertaken. Difficulty of preparation was compounded by a carbonate rhind that incased the massive bones to create cumbersome blocks. Furthermore, the repeated relocation of the specimen resulted in a certain amount of breakage and shifting creating difficulty piecing back together fragmentary bones. Consequently, it required nearly a years time to complete preparation of the specimen.

This work was conducted through the united efforts of the Chinese people. The discovery and protection of the specimen was undertaken by colleagues in Hechuan County, Sichuan, and the Sichuan Petroleum Research Corps. Colleagues at the Sichuan Provincial Museum provided description of the excavation process, field sketches of the specimen's exposure, and photography of related taphonomic conditions. Colleagues from the Chengdu Academy of Geology provided introductory analysis regarding regional stratigraphic problems and preliminary preparation of the specimen prior to its transportation to IVPP. It was only through the efforts of the aforementioned colleagues that this project was successfully completed.

Description

Saurischia, Seeley, 1878

Sauropoda, Marsh, 1978

Mamenchisauridae fam. nov.

Diagnosis: Extremely long cervical region (19 vertebrae); dorsal, sacral, and caudal vertebrae short and few in number (4 sacral vertebrae); massive and long cervical ribs; pleurocoels not well developed on dorsal vertebrae; anterior dorsal vertebrae with bifid neural spine; medial caudal vertebrae with bifurcated haemal spines; anterior caudal vertebrae procoelous; centrally positioned pubic peduncle on ilium.

Mamenchisaurus (Young, 1954)

Mamenchisaurus hochuanensis sp. nov.

Material: A relatively complete vertebral column including nearly complete cervical, dorsal, sacral, and caudal series, with nearly complete neural arches. Cervical and dorsal ribs are incomplete although cervical ribs are numerous and relatively well preserved. Sacral girdle is represented by the ilium, ischium, and a portion of the pubis. Tibia and fibula are complete but femur is represented only by a right distal end. Hind feet are represented by a pair of astragali and several metatarsals and phalanges, forelimbs are represented only by a fragmentary sternum and proximal end of right humerus. Additional elements include several unidentifiable dorsal vertebrae and fragmentary ribs (see Fig. 4).

Diagnosis: Relatively few dorsals and caudals, but number of cervicals exceeds that in other known species (cervicals 19, dorsals 12, sacrals 4, and caudals 35+). Cervicals are weakly opisthocoelus and constitute nearly half the total body length. Dorsals near the sacral region are distinctly opisthocoelus, 16 anterior caudals are amphicoelus, but the posterior caudals are platycoelus. Cervical neural spines are low and flat, those on the anterior four dorsals are bifid, but those on the five dorsals posterior to these are single with robust terminal ends. Neural spines on the three anterior sacrals are fused, and on the fourth sacral and first caudal are anteriorly convex and posteriorly concave. Caudal haemal spines become anteroposteriorly bifurcated beginning on the ninth caudal. Ilium is robust with a pubic peduncle located centrally. The ischium is gracile. Tibia and fibula are thin and flat, nearly equivalent in length, and the tibia displays a well developed proximal end. Astragalus is relatively well developed with deeply concave articular facets for the tibia/fibula causing the fibular keel to be extremely pronounced. Metatarsals are relatively short and small although the ungual phalanx (claw) of digit I is particularly well developed.

Description

Vertebral column (Pl. III)

Cervicals (Pl. XIV 1,2) (Table 1)

Atlas (Fig. 5): The proatlas is indistinguishable due to fusion. Although the atlas/axis intercentrum is solidly fused to the axis, the general outline of the intercentrum is vaguely discernible. The atlas centrum itself is relatively weak and small with an irregular morphology that lacks a distinct outline. A neural spine is not well developed but is nevertheless distinctly bifurcated and lies posteriorly upon the anterior half of the axis.

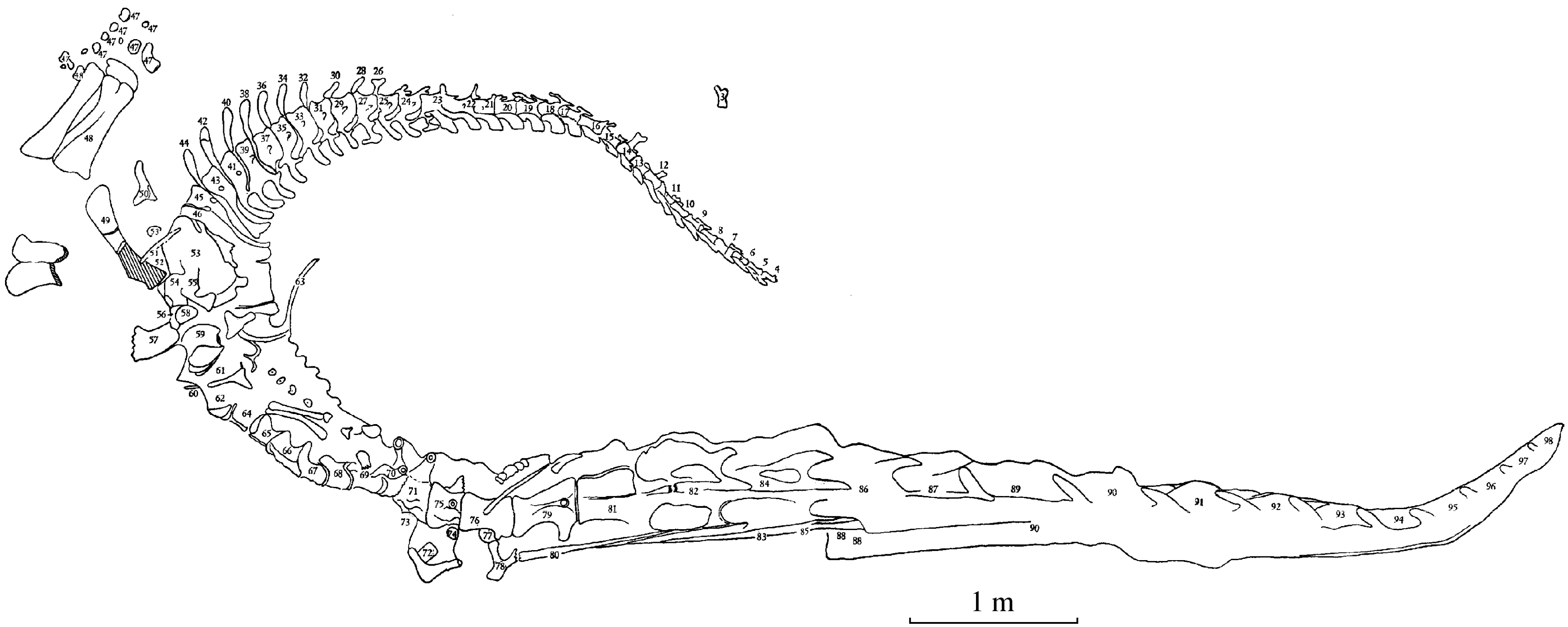

Figure 3. Drawing of the *Mamenchisaurus hochuanensis* specimen as it occurred in the field.

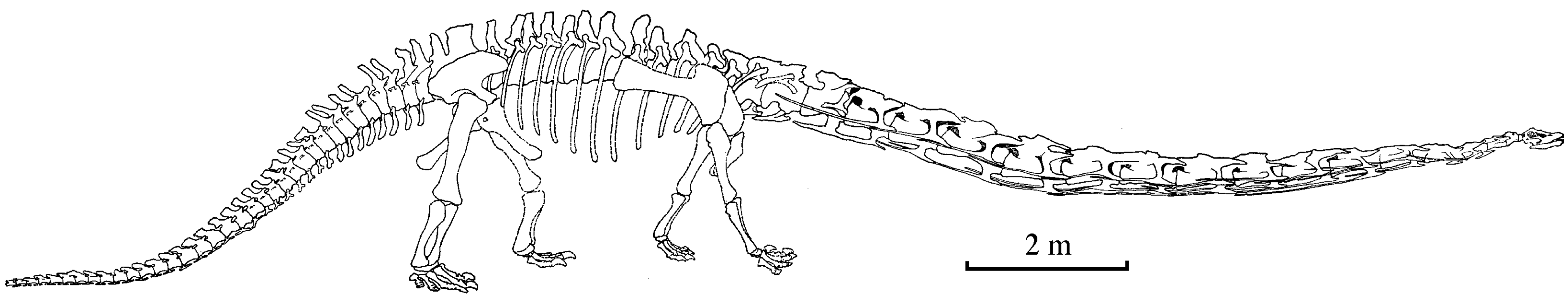

Figure 4. Restoration *Mamenchisaurus hochuanensis* .

Table 1 Vertebral measurements (excluding caudals) (mm).

Sequence	Centrum length	Posterior height	Posterior breadth	Total height
Cv1	60	75	55	85
Cv2	160	80	75	175
Cv3	215	85	85	160
Cv4	320	120	100	195
Cv5	415	150	105	240
Cv6	480	165	110	260
Cv7	580	200	110	340
Cv8	590	220	110	330
Cv9	610	225	130	370
Cv10	660	240	130	390
Cv11	730	255	170	380
Cv12	730	300	140	470
Cv13	690	300	170	510
Cv14	690	325	160	530
Cv15	660	350	200	560
Cv16	640	355	175	580
Cv17	550	375	190	630
Cv18	400	380	220	660
Cv19	325	350	230	660
D1(20)	250	340	170	640
D2(21)	250	315	250	650
D3(22)	240	345	220	740
D4(23)	250	320	220	710
D5(24)	250	350	195	830
D6(25)	230	350	200	890
D7(26)	210	350	200	880
D8(27)	220	305	240	850
D9(28)	210	310	230	890
D10(29)	210	360	230	900
D1130)	190	360	220	870
D12(31)	180	330	215	830
S1(32)	150		225	
S2(33)	170		225	840
S3(34)	210		225	
S4(35)	155	300	225	815

Axis (Fig. 5): The entire element is preserved in tight articulation with the third cervical vertebra (Cv3). Ventrally the axis is very flat and smooth with a depression at its anterior end. The surface of the anteromedial lamina and the very slightly projected posteroventral surface differ from the characters of other cervical vertebrae. The anterior articular surface is indistinct, although as with the other cervicals, it tends to be convex with a centrum that is distinctly opisthocoelus. A small fossa is present on each side anterolaterally. The neural spine is very weakly developed, is more distinctly bifurcated than the atlas, and is penetrated by a rugose fenestra anteriorly.

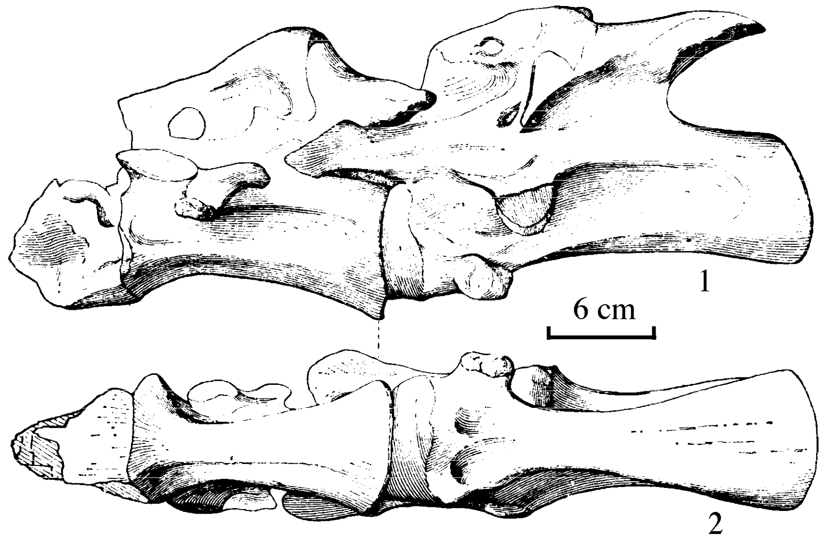

Figure 5. *Mamenchisaurus hochuanensis* cervical vertebrae 1-3.
1. Left lateral view, 2. Ventral view.

The following cervical series will be generally described, unlike the previous two. CV3 (Fig. 5) displays a distinct transitional morphology between that of the axis and CV4. Lengths of the cervicals vary greatly with the longest being CV11 and CV12 (see Table 1). Posterior to these, the lengths progressively diminish to the last cervical, CV19, which is only one-half as long as CV12. All cervicals are distinctly opisthocoelus and are preserved in their original articulation. The prezygopophyses of each cervical articulate extremely tightly with their preceding counterpart. Ventrally, the centra are rather flat and are very slightly flared at their posterior halves. Laterally they are concave with two small elliptical fossae. The midpoint of the centra are more thin and weak than at the articular regions. Two laminar reinforcements lie between the ventral and lateral sides. Anteroposterior neural spines become thin, flat, and distinctly bifurcated laterally. Like *Euhelopus zdanskyi* Wiman, the top of the neural spines are rugose and partially fenestrated. Commonly there is an extremely well developed elliptical canal linking the anterior and posterior neural arches. Parapophyses and diapophyses are well preserved on all cervicals, are positioned rather anteroventrally, and descend strongly to the posterior. From Cv17 parapophyses gradually ascend up the centra such that on the last cervical they are nearly level with dorsal parapophyses. Pneumatisation is well developed on the cervicals (including the neural arches) and in cross-section elaborate honeycombed laminae are infilled with matrix. Breakage has occurred at the midpoint of some cervicals due to being rather gracile at this point.

Cervical ribs (Pl. IV, Nos. 1,2,3): The majority are preserved articulated to the corresponding centra, although several of the distal ends were scattered within the surrounding matrix. The ribs are absent on the atlas/axis, and probably, as with other sauropods, were too delicate for preservation. The degree of fusion gradually weakens beginning with rib 17, where they fundamentally separate from the centra. The most posterior vertebra preserves only the right rib. The best preserved ribs are associated with Cv4,6,10,12, and 15. The longest rib is on Cv14 which attains 2.1 meters (Table 2).

Cervical ribs may be recognized in two forms: anteriorly they are relatively short, spoon-shaped with a sharp terminus, but do not resemble the spoon-shaped morphology of *Mamenchisaurus constructus* Young. Posteriorly, the main shaft is baton-shaped, although several of the posterior ribs are thin and flat ellipses in cross-section. Proximal ends are transversely projected, with relatively short capitula and tubercula that are fused to the opposing centra. It is only at the most posterior three where this fusion is not as complete. These ribs are extremely stout, elongated, and run along the cervical series with hardly any ventral inclination. The cervical ribs of *Euhelopus* are relatively long and extend posteriorly merely to the posterior end of the succeeding vertebra. On *M. hochuanensis* the rib may extend as far as the succeeding third vertebra or even to the anterior portion of the fourth. The posterior cervical ribs gradually become shorter and thicker such that on the most posterior vertebra they do not exceed one-half a meter, or one-quarter the length of the CV14 rib (2.1 m).

Table 2. Preserved lengths of cervical ribs (mm).

Right			Left		
Sequence	Tuberculum to capitulum	Total length	Sequence	Tuberculum to capitulum	Total length
1			1		
2			2		
3			3		
4			4		
5	100	250	5	110	240
6	140	450	6	140	650
7	150	290	7	170	
8	140	310	8	160	1550
9	150	330	9	200	720
10	120	1030	10	200	600
11	120	430	11		
12	200	1090	12	230	670
13	200	940	13	200	290
14	190	990	14	200	2100
15	160	820	15	240	1330
16	170	980	16	190	1200
17			17	190	600
18			18		
19			19		

Dorsal vertebra (Plate XII, Fig. 1) (Table 1): The last cervical and first dorsal vertebrae are generally distinguished by rib morphology. However, a difficulty is posed here by the last cervical's absence of articulated ribs. But other relatively well preserved cervical ribs suggest that the largest cervical rib belongs to the most posterior cervical. The parapophyses facets on the twentieth centrum are the highest positioned in the series and the centrum resembles other dorsals by being extremely short. Therefore, it is determined that centra anterior to and including number 19 are cervical and that centrum 20 is the first dorsal (D1). In this manner *M. hochuanensis* possesses 12 dorsal vertebra (the most posterior dorsal represents the transition from dorsal to sacral) or a total of 31 presacral vertebra which exceeds all known sauropods.

The majority of dorsals, and particularly those anterior to D9, have been shifted in position and suffer compressional distortion, while posterior to D9 the vertebrae are shifted but not to the extent of the anterior series. Rotational distortion has caused the middle of the centrum to become transversely broadened and obliquely inclined dorsally on the right side, which subsequently caused the neural arch to be strongly obliquely distorted with the right side forced dorsally and left side ventrally. In this manner, a perpendicular line drawn from the top of the neural spine would not bisect the median ventral centrum but will traverse the right side. As the distortion is spread among the vertebrae universally, interpretation of the general morphology is basically reliable.

Dorsal centra are relatively robust with weak or undeveloped pleurocoels. Muscular attachment scars are also not well developed and most possess up to four or five laminae that are predominantly dorsoventrally oriented. Parapophyses on the anterior dorsals resemble those on the posterior cervicals and approach the anteroventral angle of the cervicals. Parapophyses on the posterior dorsals migrate dorsally on the centrum. Diapophyses on the anterior dorsals resemble those on the posterior cervicals by being ventrally directed, but posteriorly they gradually become directed dorsally. Dorsal lamina morphology is not well developed and there is a small fossa only anteriorly.

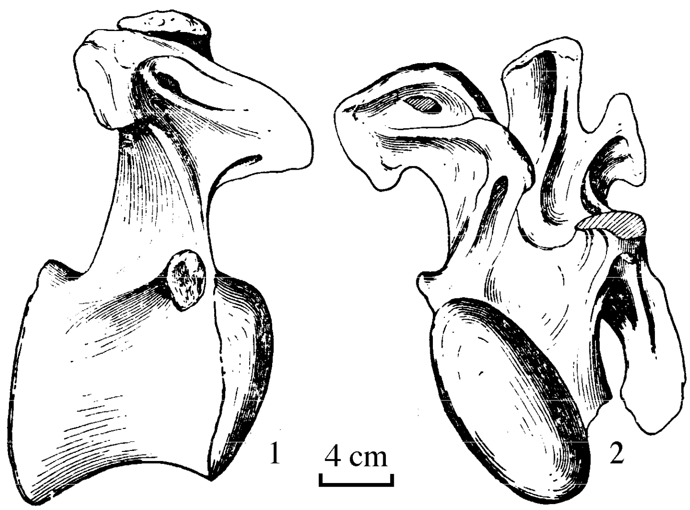

Figure 6. *Mamenchisaurus hochuanensis* dorsal vertebra 2.
1. Right lateral view, 2. Anterior view.

The four processes are located on the dorsal portion of the neural arch. This is particularly conspicuous on D8 and 9 (Fig. 7), with diapophyses being the highest, posterior zygopophyses are relatively low, and the anterior zygopophyses are the lowest with their dorsal margin parallel to the midline of the diapophyses. Parapophyses are slightly higher than the centrum. The four processes are linked by laminae, particularly between the anterior zygopophyses and the diapophyses. The medial lamina forms an oblique plane that ascends dorsally on each process to the top of the neural spine. Each process also possesses a small perpendicular lamina, and as such, each side is composed of two parallel planes which intersect the aforementioned two laminae between the anterior zygopophyses for a total of five laminar surfaces.

Dorsal centra are opisthocoelus (Pl. XIII, Fig. 2) with relatively conspicuous prezygopophyses on the anterior series but which become weaker posteriorly. Pleurocoels are not numerous, with only two present on each side. Sediment infilling is not as prominent as on the cervical series although the honeycombed infrastructure is still present.

The dorsal spine is well developed, robust, and very high. As on the cervical vertebrae, the four anterior dorsals have bifid dorsal spines (Pl. XII, XIII), but rotational distortion has extended the right side, leaving the left side short and broad. The longest spine is 15 cm and the greatest angle of divergence is 90°. Among the bifid series, none is complete, D1 displays the most well developed bifid condition in the series, in which bifurcation gradually diminishes posteriorly. The top of D5 neural spine is bluntly rounded with a shallow medial groove that descends ventrally. D6 neural spine is typical in morphology, unbifurcated, and has a thick broadened terminus. All of the spines have rugose surfice texture. Posterior dorsals have relatively thin and flat lateral surfaces with well developed posteriorly directed posterolateral wing-shaped laminae which cause the entire neural spine structure to resemble a projected spoon shaped body that is anteriorly convex and concave posteriorly.

Several vertebrae are relatively well preserved. D2 (Plate XII, Fig. 2) (Text Fig. 6) is particularly robust with four lateral laminae. On one side a lamina extends from the diapophysis to the prezygopophysis, one extends from the diapophysis to the parapophysis, while the other two are basically parallel. Diapophyses are rugose and there are four small fossae, while the posterior centrum is deeply concave (approximately 11 cm), its interior is honeycombed, it has an elliptical cross-section due to compressional distortion, and the right bifid dorsal spine is higher than the left. Two small laminae extend ventrally from the smooth apex of the spines.

D3 (Pl. XII, Fig. 3) is relatively low, flat, and extremely robust, with a particularly large elliptical pleurocoel on the centrum. Neural arch laminae are more well developed than on other dorsals, being thick and broad, are relatively conspicuous at the top of the bifid spine, becoming broadened laterally. The several processes of the neural spines are relatively broad, particularly the posterior zygopophyses.

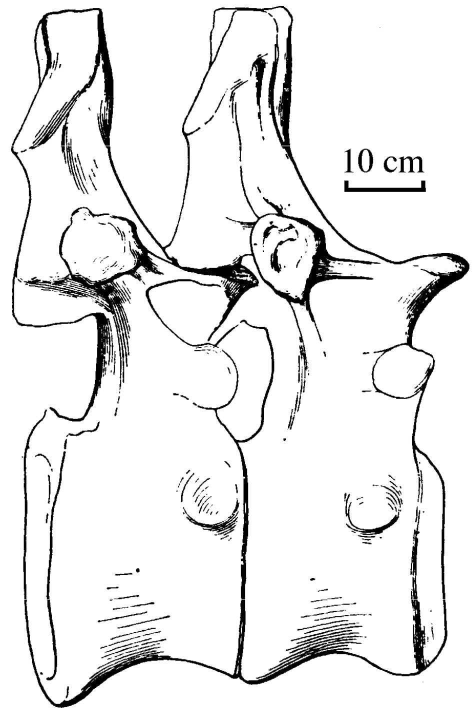

Figure 7. Right lateral view of *Mamenchisaurus hochuanensis* dorsal vertebrae 9 & 10.

The D6 centrum is relatively short and possesses relatively few pleurocoels. Diapophyses are circular with several small irregularly shaped fossae. The neural spine is flattened and not bifid.

Table 3. Dorsal rib measurements (mm).

	Sequence	Length Direct	Length Arced	Tub. to capit. dist.	Prox. breadth	Shaft midpoint
Right	1				145	
	6			200	100	45
	7				100	53
	11	880?	970?	165	85	30
Left	10	1070	1120	120	80	55
	11	905?	940?		75	40

D8 is the smallest dorsal with the lowest neural spine. It has suffered postburial fracturing, and possesses a mammary shaped process.

D9 and D10 are extremely high with tightly articulated pre- and postzygopophyses and tightly fused centra (Text Fig. 7).

Dorsal ribs: (Plate, IV, Figs. 4,5,6,7,8) (Table 3). The very few that are represented are incomplete. The left side preserves only nos. 10 and 11 which are relatively complete, though more are preserved on the right side with no. 11 the most complete. Nos. 1,2,6,7 on the right side are only partially preserved. On the left side dorsal rib 10 is 1.07 m long in a direct line while rib 11 is .905 m in length. On the right side rib 11 is .88 m. These specimens do not display a high degree of curvature except at the neck of the head (approximately 150°). The head is relatively large, tuberculum and capitulum differ in size, and are separated by a 90° angle or sometimes larger. Shafts are relatively straight with undeveloped laminar ridges. Robustness and length gradually reduce anteroposteriorly. Proximal ends are all more robust than distal ends although the posterior ribs tend to have consistent proximal and distal ends.

Sacrum (Table 1): The sacrum is a set of four relatively well preserved and tightly fused vertebrae. Only the most posterior neural spine is not fused with the other three. Centra boundary lines are indistinct with only median depressions discernable. With the exception of the neural spine, the remaining neural arch features are not readily recognizable as the processes and sacral ribs are fused, and it is only possible to distinguish them ventrally. As with the cervicals and dorsals the entire sacrum has undergone compressional distortion but not as intensively as the aforementioned, with the four elements expanded anterolaterally and the posterior two being been slightly contorted. The anterior end of S1 projects anteriorly while the posterior end of S4 projects posteriorly by 8 cm. Both anterior and posterior centra are bisected by a median longitudinal laminar ridge, the largest being 19.5 cm while its counterpart is 9.5 cm. At the anterior end the large hemisphere is on the right side, but posteriorly it is on the left side.

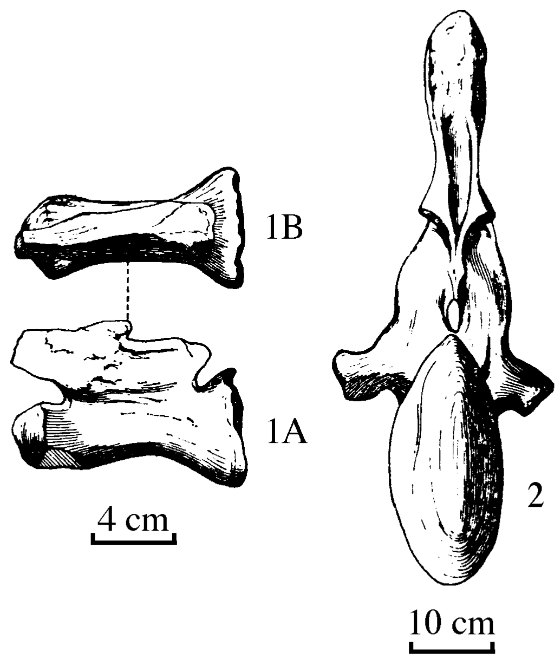

Figure 8. *Mamenchisaurus hochuanensis* caudal vertebrae.
1. Cd35, A. Right lateral view, B.Dorsal view, 2. Posterior view of Cd2.

Sacral centra are fused into a single column which anteriorly is amphicoelus, in opposition to the procoelous caudal vertebrae. As such, the fused centra are exceptionally robust and lack pleurocoels. Intercentrum structure is only visible on the last centrum in ventral perspective as are the relatively distinct longitudinal laminae which connect the diapophyses and parapophyses. Ventrally, it is also evident that the lengths of the four vertebrae differ with S3 being the longest (22 cm), S2 is 18 cm, S4 is 14 cm and S1 is 11.5 cm. S3 possesses vestigial features of rib fusion, while the S4 centrum displays lateral depressions on each side, and a robust posterior margin with a small undulating lamina.

Sacral neural spines are weak and gracile, particularly the spine of S4, which is not fused to the other three and is situated approximately 10 cm distant. Its anterior side is convex, posterior side is concave, and it possesses a longitudinal median lamina. The remaining three fused neural spines possess four lateral longitudinal laminar ridges. The anterior laminar ridge becomes the ventral contact for the prezygopophysis and extends dorsally directly to the anteromedial lamina of S1. On the right side this is conspicuous but on the left side is indistinct. This feature is not present on S2, although dorsally on S2 and 3, not only are laminar ridges well developed, but there exist distinct small flat dorsal and ventral processes which may represent vestiges for rib attachment. S4 postzygopophyses are indistinct. The posterodorsal end of the three fused neural spines is cap-shaped. At the base are two irregularly spaced small fossae and an anteroposteriorly rugose narrow surface, the posterior of which is depressed and spoon shaped. S1 and S2 neural spines possess a fenestration between them.

Table 4. Caudal vertebrae measurements (mm).

Sequence	Centrum length	Post. height	Post. breadth	Total height
Cd1(36)	120	335	200	800
Cd2(37)	150	350	150	710
Cd3(38)	140	335	150	700
Cd4(39)	145	320	150	665
Cd5(40)	150	310	135	630
Cd6(41)	160	295	135	600
Cd7(42)	150	285	150	570
Cd8(43)	160	265	140	495
Cd9(44)	160	255	165	455
Cd10(45)	150	240	170	455
Cd11(46)	150	220	155	450
Cd12(47)	160	200	160	400
Cd13(48)	160	185	165	380
Cd14(49)	160	180	170	370
Cd15(50)	160	165	165	360
Cd16(51)	160	160	135	355
Cd17(52)	160	150	140	330
Cd18(53)	170	145	130	305
Cd19(54)	170	135	130	275
Cd20(55)	175	130	120	175
Cd21(56)	170	130	120	245
Cd22(57)	165	120	110	225
Cd23(58)	165	115	110	210
Cd24(59)	165	100	105	210
Cd25(60)	150	100	95	175
Cd26(61)	150	95	95	175
Cd27(62)	150	95	90	160
Cd28(63)	150	90	90	145
Cd29(64)	150	85	85	150
Cd30(65)	140	75	80	135
Cd31(66)	145	75	80	120
Cd32(67)	130	70	75	120
Cd33(68)	130	55	65	100
Cd34(69)	110	55	60	95
Cd35(70)	115	55	60	90

Sacral ribs: None is complete although there are several distal ribs fused solidly to the dorsal ilia, and particularly on the left side, where proximal ends are solidly fused with the sacral centra. In addition there are several capitular pedicels. One relatively large (20 cm in length) piece may represent a proximal rib. It is relatively robust with several solid surficial transverse laminae. The end is missing prohibiting further description.

Caudal vertebrae (Plate V, Figs. 6,7,8,9,10, Text Fig. X) (Table 4): Thirty-five caudal vertebrae are preserved comprising complete centra, neural spines, and haemal arches. Posterior caudals are distorted although distortion and shifting is not evident anteriorly, with the exception of a slight amount at the anterior end in the opposite direction of the aforementioned vertebrae, or with the processes of the right side inclined posteroventrally, but with the left side preserved normally. Anteriorly the vertebrae are higher than long but gradually diminish in height posteriorly. Caudal 12 is nearly equivalent in height and length and beginning with Cd13, length gradually increases relative to height. Most posteriorly, centra and neural spines become extremely low and flat.

The most anterior caudals are distinctly procoelous but this condition diminishes gradually posteriorly. Lengths of postzygopophyses on the anterior caudals are nearly equivalent to the centra lengths, but by Cd15 or 16 the postzygopophyses are barely visible and the procoelous condition has become weakened to the point of being nearly absent. From Cd17 posteriorly the vertebral condition approaches amphiplatyan and further posteriorly becomes very slightly platycoelus. However at Cd35 the procoelous condition reappears (although not in its typical state) with a hemispherical posterior end.

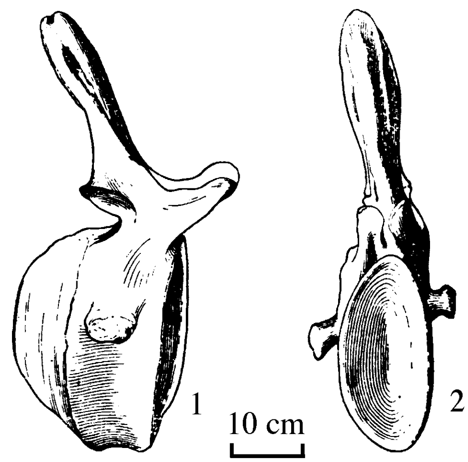

Figure 9. *Mamenchisaurus hochuanensis* Cd7
1. Right lateral view,
2. Anterior view

Transverse processes on the anterior caudals are relatively well developed and particularly on Cd1 with a length of 11 cm. They are relatively thin and flat dorsally and ventrally, and are anteroposteriorly broadened, but this condition gradually diminishes posteriorly and by Cd16 the transverse processes are completely lost. Cd1 is transitional, as there appears to be vestiges for rib fusion. The neural spine also resembles the sacral condition by being anteriorly projected and posteriorly concave and as such it could be regarded as a sacral vertebra

Caudal centra are relatively robust and lack distinct pleurocoels. Anterior caudal centra are laterally concave. Anterior and posterior margins display laminar ridges with the anterior being more well developed. The ventral centra are narrow and also concave. Pre- and postzygopophyses are extremely well developed and are in tight articulation. Diapophyses or parapophyses are not well developed with only a single vestigial process (Table 4).

Whether or not Cd35 is the terminal vertebra is subject for discussion. It is the smallest within the vertebral sequence with the rate of size reduction extremely rapid. Cd31 is 14.5 cm in length while Cd35 diminishes to 11.5 cm and is distinctly procoelous with an apparently genuine hemispherical posterior terminus (refer to text fig. X,2) that is not the result of pathology or weathering conditions. Although Cd35 was the last vertebra to be excavated it is not necessarily the last element in the sequence, for it is possible that there was a cartilaginous terminal shaft, but one which could not be too long as the length of the individual nodes could not exceed the length of Cd35. The anterior ends of these elements were probably concave and in tight articulation with the terminal caudal. Additionally, Cd35's neural spine and arch are extremely low, do not display thin and flat sides as do the other caudals, and are flattened dorsoventrally, particularly at their posterior end, which may reflect its relationship to additional flattened cartilaginous nodes. It should also be noted that the Hechuan specimen is distinct from the gracile and long terminal caudals on *Diplodocus* which do not gradually diminish in size and shorten, but in contrast gradually lengthen and become more slender with neural arches and spines nearly absent. On *Mamenchisaurus* these elements gradually shorten and thicken while becoming dorsoventrally compressed. This tendency of rapid morphological change suggests that there may have been one more meter of cartilage articulated with Cd35 (Fig. 8,1).

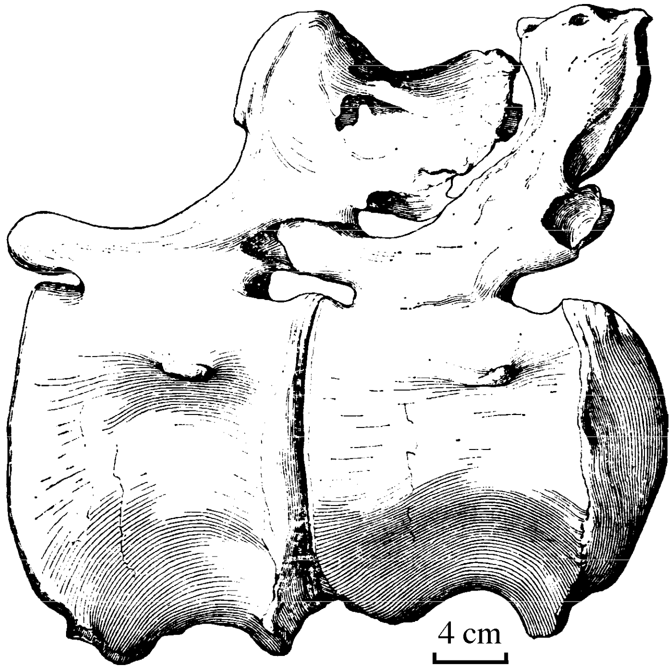

Figure 10. Left lateral view of *Mamenchisaurus hochuanensis* caudals 12-13.

Caudal neural spines are still well developed, with the spine on Cd1 resembling the sacral condition. Cd2 neural spine resembles Cd1 but is not as distinctly concave. These spines gradually become more baton-shaped from Cd3-10 with an inflated terminal end and a thickly rounded posteromedial lamina. There is also a very slender rugose longitudinal ridge on each side of the posterior surface to facilitate caudal musculature. Beginning with Cd30 the dorsal spines become laterally compressed, anteroposteriorly extended, plate-shaped, and undistorted, as opposed to the anterior caudals. Height and breadth decrease rapidly posteriorly. The spines are widest posteromedially, some being 10 cm in breadth. Beginning with Cd20 the neural spine straightens to becomes basically anteroposteriorly aligned. On the posterior caudals the nerual spines are basically complete with only a small amount of dammage on #15, 19, 20, 24, 26, 27, 28, and 33). Additionally, some of these centra and spines are fused.

Haemal arches are relatively well preserved (arches 1-8 are complete) (Pl. V, Figs. 1,2,3,4,5) with their inception occurring between Cd1 and 2. Arch 1 is shorter than arch 2 and is laterally compressed with a slightly medially thickened lamina. It is rather long dorsoventrally rather long but extremely thin anteroposteriorly. Arch 4 is the longest at

33.5 cm, arch 1 is broadest at 16 cm, and arches 3 and 4 are the widest anteroposteriorly, but as opposed to arch 1 are the narrowest laterally. The first eight anterior haemal spines display a certain degree of posterior curvature with spine 2 as the most curved, which occurs not at its midpoint but more ventrally. From anterior perspective the proximal end of the arch appears to be tightly fused along a suture which is ventrally concave and on arch 1 is distinctly laterally butressed. Many of the haemal spines' termini are bluntly rounded with the exception of spines 1 and 2, which are more acute, and spine 8 which is more inflated at its terminus. The haemal canal is a dorsally broad and ventrally narrow ellipse that is largest at the first haemal arch and which gradually attenuates posteriorly. Most noteworthy are the anteroposterior bifurcations of the haemal arches in lateral view at the midpoint of the caudal series, which initiates at Cd9 and is transitional in morphology to the following spines. The transition initiates as a small opening on the bluntly rounded distal end of Cd9, although this spine is broken. On spine 10 this opening is futher enlarged, and further posteriorly becomes quite prominent. At spine 14 the divergence angle of the bifurcated spine has not attained 90° but at spine 15 attains a right angle. By spine 17 the divergence angle approaches 180° and at spine 19 becomes a completely straight profile which continues to the terminal caudal. Distal ends are relatively sharp and gracile and the haemal canal becomes a dorsal broadened ventrally narrowed triangle. From a lateral perspective the anterior branch of the spine is shorter than the posterior branch with an anterior external angle smaller than the external angle of the posterior branch. Posterior to haemal arch 19, where the spines are completely straightened, the anterior and posterior branches are in contact due to the close proximity of the arches while the haemal arch openings become extremely close, providing protection for the haemal canal. This is particularly noticeable at the most posterior haemal arches where they have basically formed a canal that is tightly fused to the centra. Ventrally these arches appear gracile and long to resemble a transversely broadened "cross," although the intersection is not always at the midpoint, it is more noticeable on *Mamenchisaurus constructus,* but is indistinct on the Hechuan specimen (Tables 5a,b).

Several caudals are described in more details as follows:

The centrum of Cd1 is the most procoelous, robust, and tallest in the caudal sequence, and is anteroposteriorly compressed with relatively well developed laminae between the centrum and neural arch. The rugosely textured neural spine is particularly well developed, with nine foramina and distinct vertical ridges on it. The postzygopophyses are tightly articulated with the prezygopophyses of Cd2. The right half of the anterior sulcus is five cm deep on the right side due to compressional distortion. Diapophyses intersect lateral laminae.

Table 5a. Anterior haemal arch measurements (mm).

Sequence	Length	Horiz. breadth	Vert. breadth
1*	300	160	55
2	310	125	75
3	330	110	75
4	335	115	80
5	330	110	75
6	285	105	70
7	235	105	75
8	225	100	70

* Arch is between centra of Cd1 and Cd2

Cd2 centrum is lower but longer than Cd1 with relatively small pleurocoels and undeveloped lateral laminae. Small foramina are only on the rugose neural arch. The centrum has undergone anteroposterolateral distortion which has created median laminae on the processes. Articular surfaces are smooth and glossy, the length of the arc on the left side of the median lamina is 19 cm, and the slightly medially concave diapophyses are not parallel but are ventrally oblique at a 70° angle. The medial sides of the postzygopophyses extend ventrally to intersect directly with the neural canal, which is a thinly tapered ellipse ventrally. The centrum is laterally flattened with a smooth ventral surface (Fig. 8, 2).

Cd3 and 4 are tightly articulated. Cd3 is typical in caudal morphology with relatively smooth and glossy lateral sides. The centrum of Cd4 is relatively well developed, being 15 cm in length and with a neural arch that is comparable to Cd1 although distinctly more gracile.

Table 5b. Posterior haemal arch measurements (mm).

Sequence	Length	Horiz. breadth	Vert. breadth
9***	280	90	65
10**			
11*			
12*		100	
13**			
14*			
15	140		90
16*			
17	62	70	180
18		70	178
19	65	80	165
20	65	75	170
21			165
22	65	90	170
23			172
24			160
25*			
26	48	77	150?
27		65	150?
28*			
29	40	75	150
30*			
31**			
32*			

* Fragmentary
** Not Preserved
*** Initiates bifurcation transition phase

Cd7 is relatively well developed (Fig. 9) with a high rather smooth and glossy centrum, but is shorter than Cd6. Pre- and postzygopophyses are extremely well developed, the latter of which articulate tightly with Cd8. In cross-section, the ventrally directed diapophyses are anteroposteriorly elongated ellipses that still maintain small rectangular foramina at their center. The neural spine is rather high with a small foramen on each side and differs from the other caudals with an apex that is not inflated but to the contrary is a gracile baton. The neural spine is distinctly anteriorly convex and posteriorly concave and has irregular lateral laminar ridges. Several of the ridges are separated by fossae which may reach 5 cm.

Cd12 and 13 are tightly articulated (Fig. 10). The centra are rather low and elongated with a combined length of 320 cm. Diapophyses are not as conspicuous as those on the anterior caudals with their terminal ends inclined ventrally while gradually attenuating laterally. Dorsoventrally they are thin and flat but are the same anteroposterior length as on the anterior caudals. Centra are distinctly medially concave, ventrally smooth, but laterally, and particularly dorsolaterally, are rather rugose in texture.

In summary, the Hechuan specimen has 70 vertebrae composed of 17 cervicals 9.8 m in length, 20 dorsals 3.26 m in length, four sacrals .7 m in length, and 35 preserved caudals that are six meters in length. It is estimated the skull was a half meter long and the cartilagineous posterior tail is estimated to be 1.6 m for a total body length of 21.86 m. This is the first sauropod discovered in China with such a length, and of particular interest is the length of the neck which is unprecedented by constituting one-half the total body length.

Appendicular skeleton:

Forelimbs and pectoral girdle:

Due to the affects of heavy weathering, there are only three fragments that may represent a portion of the scapula. These dark purple striated elements are thin and flat with a thicknesses of over one cm. One surface is relatively smooth while the opposing side is rather rugose. It is presumed the smooth portion was anteriorly directed due to its slight convexity. Restoration of the dorsoventral alignment is based principally upon the striations and it is regrettable that the largest piece does not exceed 15 cm, hence a determination of which portion of the scapula they represent is difficult, but it is assumed they represent the midportion based upon their thicknesses.

The forelimbs are represented only by a humeral head, which is relatively robust, approximately 15 cm in thickness, and it closely resembles the Yongdeng County specimen, and hence is estimated to be nearly equivalent in length. The posterior process of the articular head is well developed, while the articular surface itself is rugose. Ventrally there are several rounded laminae that lie perpendicular to the axis of the shaft. It is well preserved with glossy dermal bone, while gray-white endochondral bone is noticeable where it is broken.

Hindlimbs and pelvic girdle (Fig. 6):

These are basically complete and relatively well preserved, particularly the pelvic girdle. Two ilia are present, although the anterior portion of the left ilium is damaged; there are two relatively complete ischia but the right proximal end was not preserved; there is slight damage to the left pubic peduncle, and only two distal ends of the pubes are represented.

Ilium (Pl. VI, Fig. 1; Pl. VIII, Fig. 1): This is massive, robust, and concpicuously elongated anteriorly, being nearly twice the size as the Yongdeng specimen. A right angle is formed between the ventral margin and the anterior margin of the pubic peduncle. Posteriorly it is also very robust but does not project excessively posteriorly. A shallow depression lies along the median iliac plate. The margin of the posterior end (ischiac process) descends abruptly. The pubic peduncle is robust and positioned centrally, or nearly traversing the sutures of the ilia, in which character it is more distinct than on any other sauropod. The anterior surface of the pubic peduncle is relatively rugose with a dorsoventral fossa. Half of the acetabulum is surrounded by the ilium due to the extreme development of the pubic peduncle. Dorsoventrally the peduncle is composed of three surfaces, the largest of which faces the acetabulum. The iliac surface is curved and rugose with visible basal processes and fossae. Shallow fossae on the iliac blade are directed medially in the standard condition. There is an extremely thick marginal lamina on the dorsal iliac blade which increases the pelvic robustness. Solid vestigial nodes for sacral rib attachment lie medially but are not in alignment and appear to represent paired series. The dorsal set is rather numerous and robust but the ventral set is poorly developed. Most interestingly are the presence of 2-3 cm thick projections along the dorsal margin of the left ilium which may be to strengthen the element. Both right and left ilia resemble each other in morphology (measurements provided in Table 6).

Pubis: (Plate VI, Fig. 3): Only the distal ends are preserved with the right one more complete than the left. The distal end of the right pubis is thickly expanded, being 32 cm in breadth and 16 cm thick, with a relatively flat medial surface, an extremely rugose lateral surface, and a rounded laminar ridge that lies most dorsolaterally . In vertical cross-section it is a bluntly rounded quadrangle. The left pubis is damaged prohibiting measurements, but it appears to have a more smooth surface than its opposing element.

Table 6. Hindlimb and sacral girdle measurements (mm).

	Place of measurement			
Right	Ilium	Length		900
		Height	Top-isc. proc.	500
	Ischium	Breadth	Medial	130
			Ventral	120
	Pubis	Ventral breadth		230
	Femur	Ventral breadth		415
	Tibia	Length		860
		Dorsal breadth		335
		Ventral breadth		280
		Medial breadth		170
	Fibula	Length		880
		Dorsal breadth		250
		Ventral breadth		190
		Medial breadth		110
	Astragalus	Length		180
		Breadth		300
		Height		150
Left	Ilium	Length		920
		Height	Top-pub. ped.	700
			Top-isc. proc.	420
	Ischium	Length		930
		Breadth	Medial	110
			Ventral	130
	Astragalus	Length		190
		Breadth		310
		Height		140

Ischia (Pl. VI, Fig. 2; Pl. VIII, Fig. 2): These are relatively well preserved and smaller than the pubes. The left side is the most complete with slight damage only at the anterior side. It is “Y” shaped, medially thin and flat, and laterally projected to compose a robust medial lamina. Its midportion is extremely thin but thickens distally, curves laterally, and curves from its midportion dorsally. The proximal end composes the posteroventral margin of the acetabulum and is smooth both medial and laterally. Compressional distortion has created several small angular fissures that run along the axis of the shaft, and hence the left and right ischia equal in shape for the left side is large with a bluntly rounded distal end while the right side’s distal end is bluntly angular. In cross section they differ with the right side being a compressed ellipse and the left side being a compressed triangle. Both rugose distal ends reflect massive musculature attachment. Although the distal end of the right ischium is inflated, it is not very prominent (Table 6).

The hindlimb is relatively well represented, however the left side is only represented by an astragalus.

Femur (Pl. VII, Fig. 3): Only the distal end is represented which is flat and smooth anteriorly as are both sides, but the posterior surface is rugose. Anteroposteriorly the element is rather thin and flat with an extremely deep trochlea between the two condyles, but anteriorly this depression is relatively shallow. From an anterior perspective, the tibial condyle is relatively large, as is the fibular condyle from a posterior perspective. A vertical groove runs dorsal to the condyles which becomes rugose at the articular contacts with the tibia and fibula. A posterior view of the tibial condyle reveals a posteriorly curved vertical lamina that penetrates the entire condyle. Based upon the morphology of the distal end, it is presumed that the femoral shaft distal to the fourth trochanter was relatively thin. Compared to the Yongdeng specimen this element is distinctly larger and consequently restored as longer, although its breadth is indeterminate.

Tibia (Pl. VII, Fig. 3): Completely preserved, the tibia is thin and flat, rather robust with smooth lateral sides, extremely broad proximally, and expanded distally. The dorsal margin is straight but distally the margin is concave at its midpoint to facilitate articulation with the astragalus. The thinnest portion of the shaft is ventral to the midpoint, the medial side is nearly straight, but the lateral side is curved. Compressional distortion has created several mud fulled longitudinal fissures upon the anterior and posterior surfaces which are largest anteriorly. The medial side is thin, narrow, and resembles a gently expanded lamina while laterally there lies a very fine laminar ridge with a slightly undulating margin. The proximal end broadens to the same width as the distal femur. A deep vertical fossa lies posterodorsally that is broad dorsally and narrow ventrally with a gentle lamina flanking each side. Posteroventrally there is an elliptical depression that lies very close to the medial margin. The distal articular surface is composed of two projections divided by a sulcus to facilitate the fibular hinge of the astragalus and articulation with the fibula.

Fibula (Pl. VII, Fig. 2): Completely represented and subjected to less distortion than the tibia this element is robust, thin, flat, and 20 cm longer than the tibia, which is a rare phenomenon among other species of sauropods. It is dorsally broad, thin, and flat while ventrally narrow, and especially thickly rounded with a hemispherical astragalar articular facet. The anterior side is concave medially to compose a vertically straight fossa, while the posterior side is laterally projected as a thick and gently rounded ridge. The entire element is curved with the medial margin rather embayed and with several undulations at its midpoint. As on the tibia, the fibula’s lateral margin is extremely thin while the medial margin is broader. Posterodorsally the entire shaft is a very slightly depressed dorsally broadened triangle which attenuates to becoming flat and smooth. The proximal articular surface for the femur is not entirely flat while the distal articular surface for astragalus is extremely smooth on the medial side and posterior side for tight articulation with the fibular hinge of the astragalus. The entire element is posteriorly curved, which is another feature rarely observed within other sauropods.

Astragalus (Plate VII, Figs. 4 and 5; Pl. XIV, Fig. 3; Text Fig. 11): The lateral sides of this robust element are completely preserved. The left astragalus is 19 cm wide, or one cm wider than the right, but one cm shorter in addition to being slightly thicker. It is also not as robust and is rather rugose. From a ventral perspective its outline is a scalene triangle with the anterior margin as the longest side. The medial half is relatively smooth but the lateral half has many curved laminar ridges. The anterior surface is relatively flat and is not subdivided into three nodes as on the right astragalus, however, a slight anterior projection is visible in the center. The posterior surface is particularly rugose. A three cm deep rectangular fossa surrounded by several projections lies on the anteromedial side of the fibular keel which inclines toward the fibula. On the right astragalus there are two large well developed fossae, but on the left specimen these are not conspicuous.

The right astragalus in ventral perspective is rectangular, flat, and has a few small fossae on its lateral side. Ventrally, a sulcus is visible at the posteromedial portion. Three small projections occur on the anterior margin which is rather rugose and displays an anterior projection that is concave on two sides at its midpoint, which causes the entire facet to be subdivided into three sections. The entire posterior side is rather flat, depressed at the center, and contains vertical cracks due to compressional distortion. Two large fossae, the medial being larger than the lateral, are observable on the dorsal surface which lie on either side of the well developed slightly laterally positioned fibular keel. Within the larger fossa lies a series of semiradiating laminar ridges, and it is in juxtaposition to the tibia while the smaller fossa opposes the fibula. A vertical medial fibular keel such as this is not observed on other sauropods, and the fact that the two astragali are asymmetrical is a very strange and a unique character for this specimen.

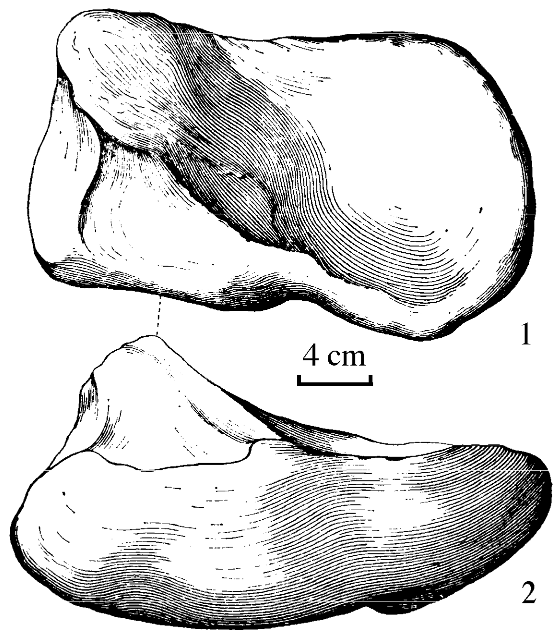

Figure 11. *Mamenchisaurus hochuanensis* right astragalus. 1. Dorsal view, 2. Anterior view

Metatarsal IV: Preserved relatively completely, this robust rectangular element has expanded proximal and distal ends. The shaft is curved lateromedially, the rugose textured larger proximal end is laterally projected for articulation with the astragalus. The distal end is relatively smooth with a very slight medial depression suggesting rather tight articulation with the first phalanx on the dorsomedial side, while on the lateral side there is a gentle laterally projected lamina. The midpoint of the ventral side is relatively thin and ventral curvature is rather pronounced at this point where there is a relatively well developed depression. In summary, MtIV is short, broad, and dorsoventrally thin and flat to facilitate plantigrade locomotion.

Metatarsal V (Fig. 12.1): This is the smallest element in the metatarsal series, shorter than MtIV and thin and flat with an exceptionally broadened proximal end. It is umbrella-shaped with a raised proximal end and lowered distal end. Its length is 18 cm and width is 15 cm. The laterally flattened hemispherical proximal end is rugose. At its midpoint there is a slight lateral projection. The distal end is smooth with a straight lateral margin for tight articulation with the first phalanx. The proximal end is twice as large as the distal end and the midpoint of the shaft is extremely slender with a significant depression on the medial side. Curvature is more pronounced than on MtIV and directed distomedial-proximalaterally. A gentle dorsal lamina runs along the axis of the shaft which is smooth dorsally but rugose ventrally.

Phalanges: Numerous of these elements are preserved including the ungual (claw) of digit I, phalanges 2 and 3 of digit II, phalanges 1,2,3 and 4 (claw) of digit III, phalanges 1,2, and 3 (claw) of digit IV, and the ungual (claw) of digit V. Phalanges are all relatively rugose with a wide range of morphological variation. The largest is Ph1 of digit III with its proximomedial side composed of a medial projection flanked by two flat depressions. The dorsal surface undulates while the lateral side displays a small foramen at its midpoint. Other characters resemble Ph1 of digit II and Ph1 of digit IV which are relatively large, thin, and flat. Remaining phalanges are comparatively small and represent simple flattened bony plates.

Ungual morphology varies with that of digit I the largest (Fig. 12.2, length 16 cm, height 14 cm), laterally flattened, crescentic, and with a distinct groove suggesting cutaneous sheathing. A relatively smooth well developed laminar ridge runs along the midline. The apex of the claw is broken approximately one-sixth the distance from the terminus. Posteriorly, it is dorsally projected and ventrally concave with a smooth articular surface that represents tight articulation with distal MtI. In summary the first claw is particularly robust for facilitating locomotion of a cumbersome body on muddy or sandy substrate.

Digit III's ungual is gracile, weak, and long. It is slightly thin and conical but terminates in a blunt apex. Both sides are well-grooved with the lateral side possessing two well developed shallow grooves, one being anteroposteriorly directed and the other vertically directed such that posteriorly they intersect to form a right angle. Dorsally there is a gently rounded lamina while ventrally there is a curved rugose surface. The posterior end is extremely flat with a slight sulcus for articulation with its opposing phalanx.

The ungual of digit IV is extremely simple in morphology with a bluntly rounded apex. The ventral surface is inclined and rugose, a fossa lies dorsally, while there is no distinct boundary between the dorsal and lateral sides which gradually phase into each other. The medial surface undulates with an indistinct outline.

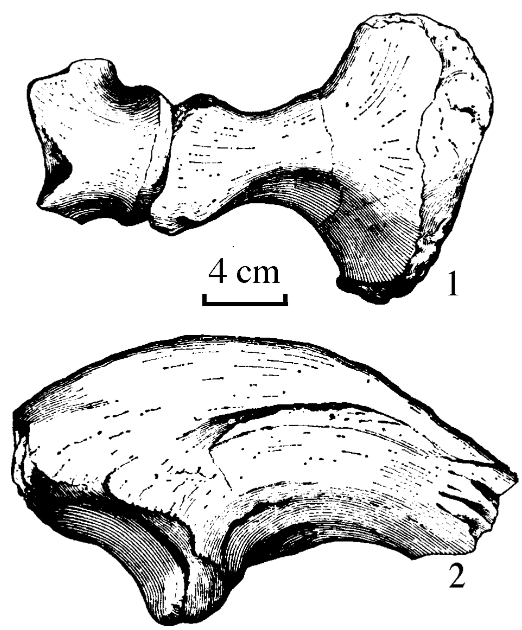

Figure 12. *Mamenchisaurus hochuanensis* right hindlimb elements. 1. Dorsal view of pes digit V. 2. Lateral view of pes digit I ungual.

The ungual of digit V is particularly distinct by being extremely long with a pentagonal dorsal surface which terminates in a thin and gracile flattened lamina. The medial side is less developed as is the anterolateral margin and lateral side which are extremely short. A small round foramen lies anterodorsally, while the proximal end is flat and slightly projected for articulation with its opposing phalanx. The distal end is a gracile and thin flattened lamina. The ventral surface is saddle shaped with two rugose sides. It appears as though this element seldom made contact with the ground.

Phalanx 1 of digit II has an extremely odd morphology as the outline of the dorsal surface is trapezoidal and the posterior end is smaller than the anterior end. But the posterolateral side is 10 cm thick while the anterior end is 4 cm thick. The medial side is small, narrow, and rugose, while the lateral side is expanded with three vertically aligned depressions. The anterior articular surface is projected but smooth, although the dorsal surface is inclined and rugose with a shallow horizontal groove in the center.

Phalanx 2 of digit II is extremely thin, being, anteroposteriorly shortened to 3 cm, but it is extremely high laterally with an anterior end that is slightly concave. Its four sides are all rugose, the proximal end is concave, or saddle shaped, and smooth with a well developed articular surface reflecting tight articulation.

Phalanx 1 of digit III has been slightly compressionally distorted such that the dorsal and lateral sides are nearly the same surface. Both lateral and medial sides possess a large fossa for musculature attachment. The anterior margin has a projected ridge and the ventral surface is crescentic.

Phalanx 2 of digit III is anteroposteriorly shortened with a medial side larger than the lateral side. Dorsally it is very uneven with a shallow sulcus in the center. The ventral surface is narrow, and rugose. From the perspective of digital sequence this phalanx appears to have been enclosed within its anterior and posterior counterparts.

Phalanx 3 of digit III is smaller than the previous, uneven anteroposteriorly, and has a small foramen on its dorsal surface. The medial and lateral sides are equivalent shapes; the distal end is thin, narrow, and moderately rugose; and the proximal end is flat and smooth with a relatively well developed articular surface.

Phalanx 1 of digit IV is anteroposteriorly flattened with anterior and posterior ends that are thin, flat, rugose, and lack any foramina or projections. The medial side possesses a small and shallow groove that is bisected by a small basal projection. Ridges on the dorsal or lateral sides are also indistinct. Both proximal and distal articular surfaces are not well developed, which may indicate the presence of cartilage between phalanges and suggests that the digit was relatively weak or did not frequently make contact with the ground unless traversing soft substrate.

Phalanx 2 of digit IV is simple, weak, and gracile but differs from its preceeding counterpart by being anteroposteriorly larger. It is dorsoventrally thin and flat with a relatively smooth and flat rhomboid shaped dorsal surface. There are relatively few foramina, the anterior end is smaller than the posterior end, a slightly concave proximal articular surface is not well developed, and the distal end is also slightly concave. The ventral surface is rugose and the lateral surface possesses a shallow groove to facilitate musculature attachment.

In summary, the reduced digits IV and V suggest that *Mamenchisuarus* probably relied on digits I, II, and III for the majority of its support.

Table 7. Right pes measurements (mm).

Element	Length	Width	Height
Digit I, ungual	160	75	140
Digit II, phalanx 1	60	85	90
Digit II, phalanx 2	40	75	55
Digit III, phalanx 1	70	110	95
Digit III, phalanx 2	40	85	60
Digit III, phalanx 3	25	60	40
Digit III, ungual	115	40	50
Metatarsal IV	200	150	75
Digit IV, phalanx I	60	95	70
Digit IV, ungual	40	72	35
Metatarsal V	180	150	75
Digit V, ungual	75	75	60

III Diagnosis and discussion

The Hechuan specimen is recognized as a member of the family (super family) Homalosauropididae rather than the Bothrosauropidae due to characters including its opisthocoelus cervical and dorsal vertebrae; the anterior and posterior extension of the sacrals; procoelous anterior caudal vertebrae; and the anterior and posterior bifurcation's of the haemal spines on the mid to posterior caudals. Cranial and dental remains are not preserved but based upon the postcranial evidence, its phylogenetic position is recognized as follows:

Sauropoda
- Bothrosauropodidae-Spoon shaped dentition with platycoelus caudals
- Homalosauropodidae-Pedicilate dentition with procoelous anterior caudals.
  - Titanosauridae
  - Apatosauridae
  - Diplodocidae
  - Dicraeosauridae
  - Mamenchisauridae fam. nov.
    - *Mamenchisaurus*
      - *Mamenchisaurus hochuanensis* sp. nov.
      - *M. constructus*

The description provided above clearly demonstrates extremely autapomorphic characters on the Hechuan specimen which justify the erection of a new sauropod family. These include: the increased cervical count to 19 with each cervical unusually elongated and associated with cervical ribs over two meters in length; four fused sacral vertebrae (with fusion of the three anterior neural spines), the increased number of procoelous caudal vertebrae (16); the terminal vertebra being procoelous with a posterior projection; the bifurcation of medial and posterior caudal haemal spines; and well developed lateral processes on the caudals.

The locality of the Hechuan specimen is very close to that of the type specimen for the genus. In addition, characters shared with the type include the distinctively long neck to body size ratio; opisthocoelous cervical vertebrae, procoelous anterior caudal vertebrae; the anteroposterior bifurcation of a portion of the haemal spines; and the condition of the pleurocoels on the dorsal vertebrae. It is important to note, however, that the Hechuan specimen is much more complete than the Type and greatly supplements C.C. Young's 1958 description. The Type specimen from Yibin County was poorly preserved with many characters indistinct, such as the precise vertebral count within several sections of the torso, characters of the cervical vertebrae and ribs, the condition of sacral centra fusion, and the morphology of the terminal caudal vertebrae. But it is unclear whether the Hechuan and Yibin specimens are conspecific as the Type is smaller and the Hechuan specimen possesses 19 cervicals with relatively long cervical ribs that have dagger-shaped rib heads. Furthermore, the condition of sacral neural spine fusion differs, there are 16 procoelous caudals, and the astragalus is relatively low. The type appears to have fewer cervical vertebrae and shorter cervical ribs with spoon-shaped rib heads. Sacral neural spines are unfused, there are fewer than 16 procoelous caudals, and the astragalus is higher. Hence the erection of *Mamenchisaurus hochuanensis* sp. nov. is warranted and an additional specimen recovered from Yongdeng, Gansu Province, that was described in 1958 as *M. constructus* is reassigned to this new species.

Other Chinese specimens that can be compared to include *Tienshanosaurus chitaiensis*, *Euhelopus zdanskyi*, and *Omeisaurus changshouensis*, which are three distinct genera of bothrosauropods distinguished by the following characters:

Omeisaurus displays extremely well developed pseudospinous vertebral processes, possesses three sacral vertebrae, the first caudal vertebra articulates with a fan-shaped, thin, and flat caudal rib, and the proximal ends of the pubis and ischium are expanded, all of which clearly differ from *M. hochuanensis*.

Tienshanosaurus chitaiensis has relatively well developed pleurocoels, vertebrae are relatively short and particularly the caudal centra, haemal spines are unbifurcated, and generally the species is relatively small as the ilium is 57 cm compared to 92 cm for the ilium of *M. hochuanensis*. From the dorsal margin of the ilium to the pubic peduncle is 79 cm on the Hechuan specimen while on *T. chitaiensis* this measurement is 48 cm. The pubic peduncle on the former is rather central while on the latter it is anterior to the midline.

The vertebral count of *Euhelopus* is: cervicals-17, dorsals-15, and sacrals-3. The entire column is procoelous, robust, hemispherical in morphology, and the hindfeet are more plantigrade. These characters are sufficient to distinguish it from *M. hochuanensis*.

A comparison to the remaining known sauropods in China is not possible here due to their fragmentary nature, poor preservation, and their chronological disparity. In addition, it is doubtful whether some taxa are legitimate, including *Chiayusaurus lacustris* (Bohlin, 1953) from the Cretaceous of Gansu Province, and *Mongolosaurus haplodon* (Gilmore, 1933) from the Lower Cretaceous of Huru Ulan, Inner Mongolia.

Table 8 displays the principle characters among the type specimens for the various families within the superfamily (or family) Homalosauropodidae:

There are five genera in Table 8, with the exception of *Mamenchisaurus*, of which four represent families within the Homalosauropodidae. Here, a discussion of the derived taxon *Euhelopus* is warranted, which was erected in 1929 by the Swedish paleontologist C. Wiman, although he did not propose a precise phylogenetic position. More recently, several workers have placed this genus within the Bothrosauropodidae (Huene, 1932;

Two more recent taxa of bothrosauropods were discovered in 1964 from the Tugulu Group of Wurhe, Xinjiang

Romer, 1956). But Piveteau (1955) assigned *Euhelopus* to the Titanosauridae, which is regarded here as inappropriate, for titanosaurs have a relatively short cervical series, the first caudal centrum is biconvex while remaining vertebrae are procoelous, anterior dorsal neural spines are relatively low, and they possess six sacral vertebrae. *Euhelopus* has an extremely long cervical series with relatively elongated vertebrae, three sacral vertebrae, undeveloped pleurocoels, and relatively high neural spines on the anterior dorsals. More importantly, the teeth of *Euhelopus* are spoon-shaped, which is characteristic for the Bothrosauropodidae. Consequently the taxonomy erected by Huene et al. is used, which places *E. zdanskii* as an independent family within the Bothrosauropidae.

Mamenchisaurus displays several characters that approach *Euhelopus* in the cervical and dorsal region, however, from cranial and dental evidence, the latter genus is excluded from the Homalosauropodidae. It would also be appropriate here to mention that some workers recognize the age of the sediments which produce *Euhelopus* to be Late Jurassic while others recognize it as Early Cretaceous. This text recognizes the former age based upon the taxon's characters and its associated fauna.

With the exception of some questionable character conditions, the other four families within the Homalosauropodidae all share characters including procoelous anterior caudal vertebrae, relatively low and long gracile skulls with pedicilate toothed maxillae, and extremely small nostrils posteriorly positioned between the orbits.

A brief description of each of these families and a comparison to *Mamenchisaurus* follows :

Table 8 illustrates that the Apatosauridae possess 15 cervicals with well developed neural spines and 10 dorsals with weakly developed pleurocoels, six of which have bifid neural spines. Five amphicoelous sacrals are present but only three of these are fused. Anterior caudals are gently procoelous, cervical ribs are extremely short, and haemal arches are very weakly bifurcated. These characters all differ from *Mamenchisaurus hochuanensis* excluding it from this family.

Dicraeosaurus is incompletely known and the sole representative for this East African family. It displays bifid dorsal spines; a count of 12 for both cervicals and dorsals which constitutes a relatively short neck; and dorsals that are not strongly opisthocoelous, relatively simply constructed, and do not have well developed pleurocoels. These characters approach those for the Diplodocidae and distinguish it from *Mamenchisaurus.*

Two other families in Table 8 share characters with *Mamenchisaurus*, the Titanosauridae and Diplodocidae, although neither of these families are completely consistent with the Chinese form. Although the Titanosauridae share characters such as procoelous centra (with the exception of the first caudal which is biconvex), numerous other characters are inconsistent and hence the family is regarded as exclusive.

The Diplodocidae also share several characters including bifid dorsal neural spines, gently procoelous anterior caudals, bifurcated haemal spines and rather extended neural spines on the dorsals and caudals. However, distinguishing characters are predominant with the diplodocids possessing 15 cervicals, 10 dorsals and merely two fused sacrals. The cervical ribs are short, the tail is long, and the pubic peduncle is situated more anterior, which are clearly distinct from *Mamenchisaurus.*

Consequently, the erection of the new family Mammenchisauridae is justified. To date there are two species recognized for the family, *M. constructus* and *M hochuanensis.*

M. hochuanensis is currently the largest sauropod known from China and it is regretable that neither skull nor teeth are known for the family and hence the conclusions offered here may be subject to some revision. Regardless, the taxonomic status based upon the appendicular skeleton is considered reliable.

With the exception of *Euhelopus* the remaining Chinese sauropods, including *Tienshansaurus* and *Omeisaurus* are known solely from their post crania* which are all assignable to the Homalosauropodidae and relate to *Euhelopus*. Finally, it is necessary to clarify that at numerous Chinese localities (including Guangyuan and Nanxiong) both spatulate and pedicilate sauropod teeth have been recovered indicating that both the Bothrosauropodidae and Homalosauropodidae were widely distributed in China and that the Chinese forms are probably associated with the euhelopids and mammenchisaurids.

4. Rediagnosis of the sauropod from Yongdeng, Gansu.

In the Haishiwan region of Yongdeng, Gansu Province, sauropods are relatively abundant. Between 1947 and 1956, staff members from IVPP made over four expeditions to the region and subsequently diagnosed the material as *Mamenchisaurus constructus* (*Vertebrata PalAsiatica* Vol. 2, No.1, 1958). This material was referenced during the study of *M. hochuanensis*, but in 1958 comparative material was relatively rare creating several discrepancies in osteological diagnoses, and hence a revision is hereby undertaken: The radius and ulna initialy attributed to the right side is now recognized to be on the left. Metacarpal and tarsal reconstruction has also been revised: the left forefoot is not preserved but the right foot preserves McII and V, the right hindfoot preserves Mt II and III, and the left hindfoot preserves MtII and V. Vertebral revisions are not extensive, but the second caudal is now recognized as CdI and CdXI is recognized as CdV. In addition, the ilium initially associated with the specimen is now recognized as being 1/3 too small such that the specimen probably represents a juvenile.

A comparison of the Yongdeng and Hechuan specimens indicates that they are more similar to each other than to the Yibin specimen. The former two, however, lack certain elements such that it is only possible to compare the caudal vertebrae, posterior limbs, and pelvic girdle.

The Hechuan specimen is slightly larger than the Yongdeng specimen and the Yongdeng specimen is much larger than the Yibin specimen. Hence, the closer similarity of former two.

The morphology of the ilia are very similar, with the pubic peduncle descending centrally. The lateral side of the iliac plate is concave and extends anteriorly such that the pubic peduncle forms a 90° angle with both the antero- and posteroventral margins. The two specimens differ as the Hechuan ilium is more robust while the Yongdeng specimen is smaller and more gracile. Ischia also display minor differences as the pubic peduncle is larger than the ischiac peduncle which thickens distally on the Yongdeng specimen, whereas there is no appreciable difference of peduncle size on the Hechuan specimen. Particularly noteworthy is that the Yongdeng ischia are also distinctly asymmetrical.

Femora are distinctly similar and are robust with a fibular condyle divided by a depression andwith the lateral side larger than the medial. On the Yongdeng specimen this depression is deeper. The fibulae are both proximally expanded and extremely thin and flat on both specimens, although the tibia differ with the Yongdeng specimen being relatively

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* In 1966 several spatulate teeth and potential cranial fragments were collected from the Turpan Basin of Xinjiang Autonomous Region.

thickly rounded and elliptical in cross section but not broadened proximally while the Hechuan specimen is thin and flat with a noticeably broadened proximal end. The fibula is longer than the tibia on both specimens.

The proximal articular surface of the Yongdeng humerus resembles the Hechuan specimen by being relatively well developed and rugose, but the Hechuan specimen differs by possessing several transverse laminae.

The astragali are nearly identical in morphology. From a dorsal perspective, the Yongdeng specimen is also quadrilateral but it is slightly taller than the Hechuan specimen. Lateral metatarsals are relatively thin and flat although the Yongdeng specimen's are slightly shorter with thicker proximal and distal ends, thinner shafts, and more rugose articular surfaces. The Yongdeng first claw is sharper, very laterally compressed, and has a gently rounded dorsal laminar ridge. Proximally it is slightly concave, ventrally it is crescentic, and on the medial side there is a strong groove that extends along the entire arc. Consequently, this specimen differs only in size, being 18 cm in length, 5.5 cm in breadth, and 10 cm high, while the equivalent measurements for the Hechuan specimen are 16, 7.5, and 14 cm. Remaining limb elements are similar with the Yongdeng specimen being smaller but morphologically similar.

Fourteen of the Yongdeng caudal vertebrae are extremely procoelous while this number is 16 on the Hechuan specimen. Parapophyses continue distally on the caudals until Cd18 while on the Hechuan specimen this number is 16. Posteriorly, vertebral centra shorten equivalently and caudal neural spines are anteriorly projected and posteriorly concave. The first haemal arch is slightly smaller than the second, and the tenth haemal spine is very slightly bifurcated. All of these features closely resemble the Hechuan specimen. The Yongdeng specimen preserves only 27 caudals but it is estimated from the measurements of Cd26 (length 15 cm and breadth 9 cm) and Cd27 (length 14 cm and breadth 8 cm) that the Yongdeng specimen caudal count is also probably over 30 and at most does not exceed 40, and that both would have similar tail lengths.

Ribs are extremely similar as being thin and flat with weathered glossy surface texture.

It is evident from the comparisons made above that these specimens are much more alike than distinct from each other and that both differ a bit more from the Yibin specimen, which is difficult to compare due to its poor state of preservation. Consequently, the Yongdeng specimen *Mamenchisaurus constructus* Young is synonymized with *M. hochuanensis* Young and Chao with the Hechuan specimen now recognized as the type for the family and which is housed in the Chengdu Institute of Geology. The Yongdeng paratype is at the Institute of Vertebrate Paleontology and Paleoanthropology in Beijing.

Table 8: Comparison of six sauropod taxa.

	M. hochuanensis	*M. constructus*	Titanosauridae	Diplodocidae	Apatosauridae	Dicraeosaur-idae	*Euhelopus*
Cervicals	19, extremely long. 33.5*	?May be very long	Short	15, relatively long, 55*	15, relatively long, 54*	12,?	17, long 36*
Dorsals	12, anterior 4 bifid	------------------	?	10, numerous bifid	10, anterior 6 bifid	12	15, at least 8 bifid
Presacral	opisthocoelous very weak pleurocoels	opisthocoelous very weak pleurocoels	weak pleurocoels	strong pleurocoels	weak pleurocoels	weak pleurocoels	more concave
Sacrals	4, both ends convex, anterior 3 fused	?	6	3, ? 2 fused	5, amphicoelous, medial 3 fused	?	3
Caudals	35, anterior 16 procoelous	Anterior 12 procoelous (2)	Cd1 biconvex, others procoelous	?	ant. caudals distinctly procoelous	?	------------------
Cervical ribs	Medials extremely long	Short and acute	------------------	Short	Short	?	Long
Haemal arches	Medials bifid	Medials bifid	?	Bifid	Not bifid	?	?
Ilium	Centrally positioned	?	?	Not anteriorly extended	Anteriorly extended	?	?
Ischium	Distally rounded	?	?	Inclined	?	?	Inclined

*Ratio to dorsal vertebrae

5. The reconstruction of the two *Mamenchisaurus hochuanensis* specimens.

Reconstruction of the Hechuan specimen (Pl. IX).

A reliable skeletal reconstruction is possible due to the complete and articulated nature of the Hechuan specimen. Within the process of its reconstruction, missing portions of the skeleton were supplemented from data derived from the Yongdeng specimen. In the reconstruction of the skull, a diplodocid model was applied due to the resemblance of the postcranial skeleton, or particularly the long and narrow necked feature of homalosauropods. Prior to the sculpting of the 50 cm long cranial model, strict attention was paid to diplodocid cranial measurements and other aspects. Particular attention was paid to the characters of the cervical vertebrae. Pedicilate teeth were implanted according to the character for the superfamily. The proportionate size and outline of the skull is probably consistent with the original, though further evidence is required to verify its accuracy. The skull model was based on the principle that in general sauropod cranial lengths are equivalent to half the length of the first two cervicals (including the atlas).

The vertebral column is the most completely preserved section of the specimen although meticulous details, such as sacral ribs and the proximal end of the humerus, were not reconstructed. Reconstruction was primarily applied to the pectoral girdle, anterior limbs, and dorsal vertebrae. Within the mounting process reference was made to various foreign sauropods. To reconstruct the scapula/corocoid, reference was made to several species of homalosauropods in addition to species of bothrosauropods including *Brontosaurus, Camarasaurus , Euhelopus,* and titanosaurs in addition to endemic taxa including *Tienshanosaurus, Omeisaurus,* and the former *Mamenchisaurus constructus.* Finally the shoulder was reconstructed on the basis of the general characters for the superfamily. The sternum fragments were included in the reconstruction which was modeled after *Diplodocus* with further reference made to *Camarasaurus.* No further vertebrae or cartilaginous appendages were attached posterior to caudal vertebra 35 as an additional meter of tail would be superfluous. However, the reconstructed fleshy model will take this factor into account.

Forelimb reconstruction was based upon the Yongdeng specimen, although it is proportionately longer than the Hechuan specimen. Further reference was made to *Camarasaurus, Brontosaurus*, and *Diplodocus.* Phalangeal formula and ungual phalangeal morphology were based upon *Diplodocus.*

Posterior limb reconstruction is relatively accurate (Plate XI) as the mounting of the pelvic girdle was facilitated by the complete ilium and the known length of the ischium. Only the pubis is incomplete, but based upon the two preserved distal ends and reference to the proportionate size of the *Diplodocus* pubis, it is possible to reconstruct this element. Femur length was based upon the proportions of related taxa. The Yongdeng specimen provided data for the proximal end and since the distal end is robust the shaft and proximal end was also reconstructed accordingly with a fourth trochanter situated slightly dorsally and with a morphology that resembles the Yongdeng specimen. Tibia, fibula, and a majority of the pes is known from the right hindlimb. Both left and right astragali are simple in morphology. Ungual phalanges and missing metatarsals were based upon *Diplodocus* and deductions from the material at hand. Phalangeal formula is thus I-2, II-3, III-4, V-1.

Mounting of the specimen occurred concurrently with its study. Soldering was utilized to replace the previous rivets, as this method is more appropriate to the construction of a massive specimen as heavy as *Mamenchisaurus,* consisting of 1,765 kg of fossil bone, 404 kg of supporting steel, and 369 kg of plaster. Since the massive sauropod skeleton was not readily mobile but required transportation after its completion, the supporting structure was designed to be modular. Construction of the supporting frame occurred in two phases: firstly a beam was suspended 1.5 meters above the ground, the dorsal vertebrae aligned upon it, and then elevated to its required height. A double intervertebral beam inserted through the center of the 10 m long 690 kg cervical series was the most suitable method to make this section mobile. Next the erection of the four limbs was undertaken to establish the posture of the mount. Since only a small amount of anterior limbs was preserved, reconstruction occurred as the mount was erected, such that the final morphology of the anterior and posterior limbs were adjusted and corrected for a mobile posture and the cervical series and head was lowered to give the impression of slow and graceful foraging. The angle of the neck was based upon its relationship to the rest of the skeleton as it was excavated. Although the vertebrae (particularly the cervical and dorsal series) had been subjected to compressional and rotational distortion, no attempt was made to recorrect the series which would only have hampered the procedure of mounting. The skeletal height and height of the forelimbs are estimated, but the hind limbs and sacral girdle are based upon conventional standards and references to related taxa. The mounting of the modular skeleton took over three months. It subsequently took the Shanghai Museum of Natural History one month to reassemble the specimen after its transportaion.

Restoration and mounting of the Yongdeng specimen.

Subsequent to the experience of mounting the Hechuan specimen, work began upon the Yongdeng specimen, which occurred rather rapidly. Paper mache supplemented skeletal reconstruction which was completed in just over one month due to its lightness and portability.

To reiterate, the Yongdeng specimen was initially the type for *Mamenchisaurus constructus* Young, but is now referred to as the paratype for *M. hochuanensis.* Reconstruction was readjusted based upon the Hechuan specimen in the regions of the cervical, dorsal, sacral vertebrae, the ilia and a portion of the ribs. Further skeletal revisions must await later discoveries as the specimen is a composite. Regardless, this specimen is one of the better representations of the Sauropoda in China to date.

The caudal region of the Yongdeng specimen is slightly smaller than the Hechuan specimen but other aspects are either comparable or slightly smaller. The ilia associated with the Yongdeng specimen are indeed too small, and as such are replaced by those the size of the Hechuan specimen. The scapula, coracoid, and sternum are not represented and are reconstructed based on comparisons with taxa including *Apatasaurus* and *Diplodocus*. Reconstructed length is nearly equivalent to the Hechuan specimen. Anterior limbs of the specimen are slightly long (compared to the posterior limbs and particularly the length of the ventral elements) and as such the anterior scapular girdle is a robust feature that is turned dorsally to form a 10° angle with the vertebrae. The neck and head are reconstructed as looking posteriorly.

VI Discussion

Discussion of the age of the sediments containing *Mamenchisaurus hochuanensis.*

Sediments consist of red-beds equivalent to the Jurassic Zhongqing (Chungking) Group’s Upper Shaximiao Fm. which consist predominantly of purple-red mudstones, sandy mudstones and sandstones.

Within the evolutionary stages of the Dinosauria, the Sauropoda emerged in the early stages of the Jurassic and persisted into the Late Cretaceous. Table 9 displays a simplified Jurassic geologic correlation chart to assist in the chronological interpretation of the *Mamenchisaurus* beds.

Table 9 is basically consistent with that of the Sichuan Provincial Office of Geology, which considers the Xiangxi Group as Late Triassic to Early Jurassic (Rhaetic-Liassic) and the Ziliujing Group as Jurassic. But there is not complete consensus about the age of the Zhongqing Group and particularly its lower section (notably the Upper and Lower Xiaximiao Fms.) which may be Middle or Late Jurassic.

Considering *Mamenchisaurus* itself, the vertebrae (particularly the dorsals) are extremely primitive in the condition of the pleurocoels, which is primitive for the Sauropoda. On more derived taxa dorsals possess laminar plates for robust muscular attachment and extensively developed pleurocoels for the diminishment of vertebral weight. Also on derived taxa, the pubic peduncle is strongly extended anteriorly but this is not so on *M. hochuanensis*, although the Hechuan specimen does possess the derived character of an enlarged and elongated cervical series. Consequently, derived characters of this taxon include the increased number of elongated cervicals, the increased amount of bifurcated haemal spines, and the relatively thin and flattened pubis. This implies that *M. hochuanensis* possessed a mosaic of primitive and derived characters and is in a medial phase of the evolutionary sequence. As the sauropods entered their most prolific phase in the Late Jurassic, it may be determined from the evolutionary possition of this taxon that its age should be a little older. Consequently, the Upper Shaximiao Fm. should be regarded as early Late Jurassic, and as such the entire Zhongqing Group cannot be recognized as being entirely Late Jurassic. At least the lower section of the group (the Lower Xiaximiao Fm.) is late Middle Jurassic. Thus on the basis of fossil vertebrates a distinction may be made between the Middle and Upper Jurassic. It is hereby recognized that the Lower Xiaximiao Fm. (300-770 m in thickness) is readily distinguished from the Late Jurassic Upper Xiaximiao Fm. (200-1200 m in thickness) which is diagnosed by the presence of *Mamenchisaurus hochuanensis*. The overlying Suining and Penglaizhen fms. are completely Upper Jurassic. Further circumstantial evidence lies in the angular unconformity between the Upper and Lower Xiaximiao with the basal contact of the Upper Xiaximiao as a rudaceous sand or argillaceous conglomerate.

In conclusion this taxon is chronologic evidence for the rather sparsely fossiliferous Zhongqing Group of Sichuan and which extends into the red beds of Yunnan Province.

Table 9. Middle and Upper Jurassic stratigraphic table of the central Sichuan Region.

Period	Group	Formation
U. Jurassic	Zhongqing	Penglaizhen
		Suining
		U. Shaximiao *Mamenchsaurus* beds
L. Jurassic	Ziliujing	L. Shaximiao
		Lianggaoshan
		Daanzhai
		Dongyuemiao

Bibliography

Bohlin, B., 1953; Fossil Reptiles Mongolia and Kansu. *Pal. Sin.* (no serial number), 1-113, I-IX Plates.
Gilmore, C.W., 1925; A nearly complete articulated skeleton of *Camarasaurus. Mem. Carnegie Mus.,* 10(3), Pittsburgh.
Gilmore, C.W., 1932; On a newly mounted skeleton of *Diplodocus* in the United States National Museum. *Proc. U.S. Nat. Mus.,* **81**(18), 1-21.
Gilmore, C.W., 1933; Two dinosaurian reptiles from Mongolia with notes on some fragmentary specimens. *Amer. Mus. Novit.,* (679), 1-20.
Gilmore, C.W., 1936; Osteology of *Apatosaurus,* with special reference to specimens in the Carneige Museum. *Mem. Carneige Mus.* **11**(4) Pittsburgh.
Holland, W.J., 1906; The osteology of *Diplodocus marshi*. *Mem. Car. Mus.* **II**(6), 225-264.
Holland, W.J., 1924; The skull of *Diplodocus. Mem. Car. Mus.* **IX**(3), 379-403.
Huene, v.F., 1932; Die fossil reptil-Ordrung Saurischia, ihre Entwicklung und Geschichte. *Mong. Geol. Pal.,* (1) 4, Pts. 1 and 2, VIII 361 pp. 41. figs., 56 pls.
Huene, v. F., 1948; Short review of the lower tetrapods. Special publication of the lower tetrapods. *Special Publication of the Royal Society of South Africa,* 65-106.
Huene, v. F., 1956; Palaontologie und Phylogenie der Niedern Tetrapoden. *Jena.* 470-576.
Osborn, H.F. and Mook, C.C., 1921; *Camarasaurus, Amphicoelis* and other Sauropods of Cope. *Mem. Amer. Mus Nat. Hist.,* N.S. III, New York.
Piveteau, J., 1955 Traite de Paleontologie. **V.** 818-828.
Romer, A.S., 1956: Osteology of the Reptiles.
Rozhdestvnskii, A.K. I dr.,
Si, H.J., and Zhou, Z. Y., 1962; Mesozoic terrestrial stratigraphy of China. *Collected Papers from the National Geological Congress.* 140-156 (in Chinese).
Wiman, C., 1929; Die Kreide-Dinosauria aus Shantung. *Pal. Sin.,* Ser. C., **4**, (1), Peking.
Young, C.C., 1935; Dinosaurian remains from Mengyin, Shangtung. *Bull. Geol. Soc. China,* **14**(4), 519-533.
Young, C.C., 1935; Fossil Reptiles in China. *Mem. Geol. Survey China,* Ser. B, (8), Peking.
Young, C.c., 1937; A new dinosaurian from Sinkiang. *Pal. Sin.* New Ser. C. (2).
Young, C.C., 1939; On a new sauropod with notes on other fragmentary reptiles from Szechuan. *Bull. Geol. Soc. China.* **19**, 279-315.
Young, C.C., 1942; Fossil vertebrates from Kwangyuan, N. Szechuan, China. *Bull. Geol. Soc. China,* **22,** 293-309.
Young, C.C., 1948; Notes on the occurrence of sauropod remains from N. Kweichow, China. *Sc. rec.* **2**(2), 200-206.
Young, C.C., 1948; Fossil crocodiles in China with notes on dinosaurian remains associated with the Kansu Crocodiles. *Bull. Geol. Soc. China,* **28**, 255-285.
Young, C.C., 1954; On a new sauropod from Yiping, Szechuan, China. *Scientia sinica,* **III**(4), 481-514.
Zhu, D.K., 1957; Qingli "Dinosauria," a report on paleontological work (unpublished data) (in Chinese).