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四川会理早侏罗世一新的蜥脚类恐龙[1)]

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摘要:记述了四川会理下侏罗统益门组的蜥脚类化石。经研究,将化石归于马门溪龙科,建立新属新种何氏通安龙 *Tonganosaurus hei* gen. et sp. nov.。通安龙具有进步蜥脚类的特点:颈椎细长、荐前椎发育侧凹、前肢较长,为后肢的0.80等;同时,通安龙也具有原始蜥脚类的特点:脊椎骨组织坚实不中空、肱骨和股骨骨干粗而圆。从国内外已有的资料看,原始蜥脚类主要发现于侏罗纪早期,而进步蜥脚类则主要发现于侏罗纪中晚期。由于通安龙兼具原始蜥脚类和进步蜥脚类的特点,且时代为早侏罗世,因此,通安龙化石材料的发现对中国西南地区早期蜥脚类的系统演化研究具有重要的意义。

关键词:四川会理,早侏罗世,益门组,蜥脚类,通安龙
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四川地区中晚侏罗世的恐龙化石材料相当丰富(董枝明等, 1983; 何信禄,1984; 李奎,1997, 1998a; 欧阳辉、叶勇,2001), 仅在自贡大山铺地区就发现了蜀龙、峨眉龙等多个属种(张奕宏,1988; 何信禄等,1988; 彭光照等,2005)。然而,早侏罗世的蜥脚类恐龙化石相当少,到目前为止,发现并已经正式发表的仅有资中龙 *Zizhongosaurus* (董枝明等,1983)和珙县龙 *Gongxianosaurus* (何信禄等,1998)两属。

2007年,成都理工大学博物馆根据群众提供的线索,对四川省会理县通安镇的恐龙化石点进行了考察和发掘,获得了一批新的蜥脚类恐龙化石材料,包括约20个脊椎、完整的右侧肩带和右前肢、左肩胛骨远端、完整的左右坐骨、左股骨两端及完整的右后肢,以及零散的10多件背椎神经棘、肋骨、跖骨及爪骨等。鉴于化石材料采集于同一个地点,各部位骨骼没有重复,且均成比例,我们推断这些材料代表了同一个蜥脚类个体的不同部位。根据野外地层剖面的追索观察,以及与1∶20万地质图的对比,化石产地的地层层位应为下侏罗统益门组中上部,岩性为紫红色粉砂质泥岩。本文将描述这一川西南新的蜥脚类材料,并建立一新属种——何氏通安龙 *Tonganosaurus hei* gen. et sp. nov.。新材料的发现有助于进一步了解早侏罗世晚期中国西南地区蜥脚类恐龙的多样性。

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1 系统描述

蜥臀目 Saurischia Seeley, 1888

蜥脚形亚目 Sauropodomorpha Huene, 1932

蜥脚次亚目 Sauropoda Marsh, 1878

马门溪龙科 Mamenchisauridae Young & Chao, 1972

通安龙属(新属) *Tonganosaurus* gen. nov.

属征 见属型种的特征。

属型种 何氏通安龙(新属、新种) *Tonganosaurus hei* gen. et sp. nov.。

词源 Tongan, 即通安。化石产地的行政区划属四川省会理县通安镇,故将产地作为化石的属名以资纪念。“saurus”(希腊语),指“蜥蜴”。种名“he”赠予长期从事恐龙研究事业的何信禄先生。

何氏通安龙 *Tonganosaurus hei* gen. et sp. nov.

(图 1–7)

种征 荐前椎均发育侧凹,侧凹大而深,但中间无隔板,结构简单。颈椎细长,神经弓矮,神经棘低、前后延长。后部颈椎及背椎的板状及坑凹构造均发育。前部背椎后凹型,中部平凹型,后部双凹型。前部尾椎双凹型,神经弓矮,神经棘高。脊椎骨组织坚实、不中空。前后肢比例为 0.80。肱骨直而粗壮,其长度为股骨的 0.75, 三角脊发育。股骨直而粗壮,第四转节发育。

正型标本 一具不太完整的蜥脚类成年恐龙个体的骨架。标本保存于成都理工大学博物馆,标本登记号:MCDUT 14454。

产地与层位 四川省会理县通安镇,下侏罗统益门组(J_{1y})。

标本描述 通安龙已复原装架完毕,复原装架后的骨架长度实测为 11.6 m, 故推测活体长度为 12 m。各部位骨骼描述如下。

脊椎:脊椎保存有 5 个颈椎、6 个背椎、8 个尾椎和 3 个零散的背椎神经棘。其中完整的有一个颈椎、一个背椎和两个尾椎。脊椎的测量数据见表 1。

颈椎(图 1, 2A–E):枢椎保存了前半部分,前关节面的下半缘薄且略有扩展,侧视呈铲状。前关节面中间最凹处发育有一个齿突,齿突分前后两节,椎体中部收缩。第三颈椎保存完整,椎体细长,后凹型,椎体参数 R[1)] = 2.94, 属长颈椎型。椎体侧凹发育,横突向前向下倾斜,神经弓和神经棘低矮,神经棘前后延长,斜伏于关节突上,椎体中部收缩。通安龙第三颈椎纤细这一特征,与四川盆地内的长颈蜥脚类峨眉龙相似。

1) 本文用参数 R 来表示椎体的长短程度。表达式为 R = 椎体长/[(后高+后宽)/2],这样处理可以排除由于椎体变形所造成的误差,以后类同。

表1　何氏通安龙(新属、新种)的椎体测量

Table 1　Measurements of vertebrae of *Tonganosaurus hei* gen. et sp. nov.　(mm)

	LC	HV	WC	MH	R		LC	HV	WC	MH	R
Ce. 2		40				Ca. 1	88	153	166		0.55
Ce. 3	168	56	58	105	2.94	Ca. 2	90	170	150		0.56
Ce. 4		55	60			Ca. 3	89	152	140	410	0.61
Ce. 5		65	74			Ca. 4	90	150	140		0.62
Ce. 17	147	130	112		1.21	Ca. 5	97	115	127	305	0.80
						Ca. 6	100	120	111		0.86
D. 2	140	143	133	380	1.01	Ca. 7	106	117	100		0.97
D. 4	118	121	155		0.85	Ca. 8	110	96	80		1.28
D. 8	126	142	166		0.76						
D. 9	114	146	170		0.72						
D. 10	110	163	162		0.67						
D. 11	110	155	160		0.69						

Note: Ce. cervical 颈椎;D. dorsal 背椎;Ca. caudal 尾椎;LC. length of centrum 椎体长;HV. height of centrum 椎体后高;WC. width of centrum 椎体后宽;MH. maximal height of vertebra 椎体全高;R. parameter of centrum 椎体参数。

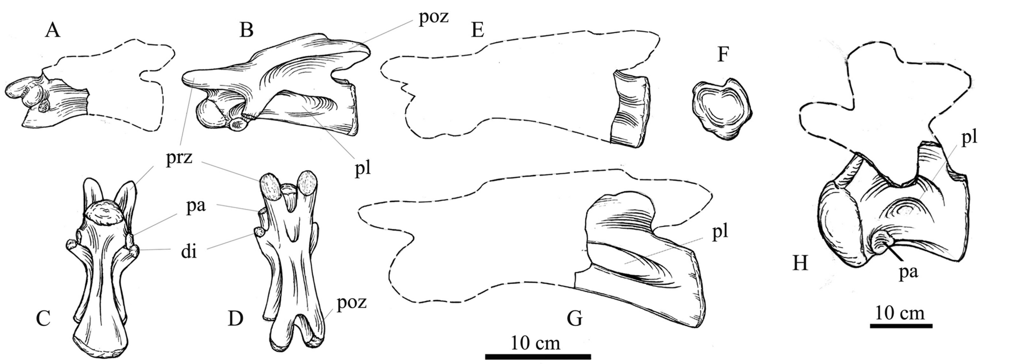

图1　何氏通安龙(新属、新种)的颈椎

Fig. 1　Cervicals of *Tonganosaurus hei* gen. et sp. nov.

A. 枢椎左侧视 axis in left side view; B–D. 第三颈椎 the 3rd cervical: B. 左侧视 in left side view, C. 腹视 in bottom view, D. 背视 in top view; E–F. 第四颈椎 the 4th cervical: E. 左侧视 in left side view, F. 后视 in caudal view; G. 第五颈椎左侧视 the 5th cervical in left side view; H. 第十七颈椎左侧视 the 17th cervical in left side view

简字说明 Abbreviations: di. diapophysis lamina 横突板;pa. parapophysis 副突;pl. pleurocoel 侧凹;poz. postzygapophysis 后关节突;prz. prezygapophysis 前关节突

相较于前部颈椎,最后一个颈椎椎体变得壮实,前关节球突略有收缩,神经弓变高,发育有板状及坑窝构造。由于此椎体与背椎有较大的相似性,故推测这是通安龙的最后一个颈椎。

背椎(图2F–L, 3):第二背椎保存完整,后凹型椎体。侧凹发育,其结构简单。副突位于椎体前关节面的上边缘,呈长椭圆形。神经弓高。关节突面呈椭圆形。后关节突上

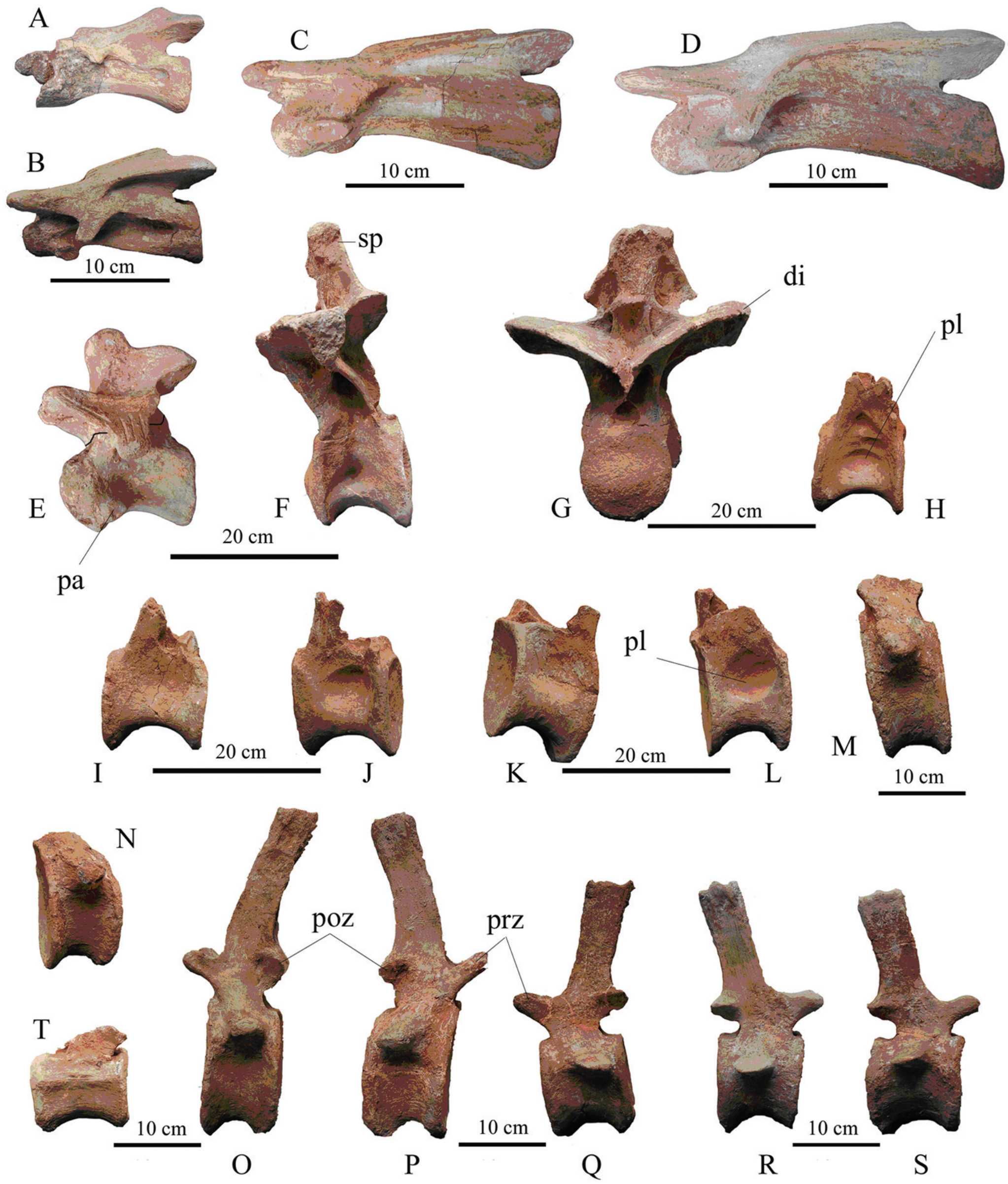

图 2　何氏通安龙(新属、新种)正型标本(MCDUT 14454)

Fig. 2　*Tonganosaurus hei* gen. et sp. nov. (MCDUT 14454, Holotype)

A–E. 颈椎左侧视 cervicals in left side views: A. 枢椎 axis, B. 第三颈椎 the 3rd cervical, C. 第四颈椎 the 4th cervical, D. 第五颈椎 the 5th cervical, E. 第十七颈椎 the 17th cervical; F–G. 第二背椎 the 2nd dorsal: F. 左侧视 in left side view, G. 前视 in anterior view; H–J. 背椎右侧视 dorsals in right side views: H. 第四背椎 the 4th dorsal, I. 第八背椎 the 8th dorsal, J. 第九背椎 the 9th dorsal; K–L. 背椎左侧视 dorsals in left side views: K. 第十背椎 the 10th dorsal, L. 第十一背椎 the 11th dorsal; M, N, P, R–T. 尾椎右侧视 caudals in right side views: M. 第一尾椎 the 1st caudal, N. 第二尾椎 the 2nd caudal, P. 第四尾椎 the 4th caudal, R. 第六尾椎 the 6th caudal, S. 第七尾椎 the 7th caudal, T. 第八尾椎 the 8th caudal; O, Q. 尾椎左侧视 caudals in left side views: O. 第三尾椎 the 3rd caudal, Q. 第五尾椎 the 5th caudal

简字说明 Abbreviation: sp. neural spine 神经棘, 其余简字见图 1 for other abbreviations see Fig. 1

的神经棘支持板相当发育,位于后关节突的中上部、神经棘的侧边,这一支持板使神经棘呈左右宽的长方形宽板状。此外,在神经棘前方的中下部的位置还发育有突起构造,前视面中为一横向的小椭圆(图2G, 3B), 侧视面中为横向长出的粗棱嵴。神经棘的上端面粗糙。横突向两侧水平延伸,端部稍膨大,端面为浑圆三角形。前、后关节突呈叶片状。椎体的板状及坑窝构造相当发育,其中横突支持板及其下方的坑窝尤为发育。

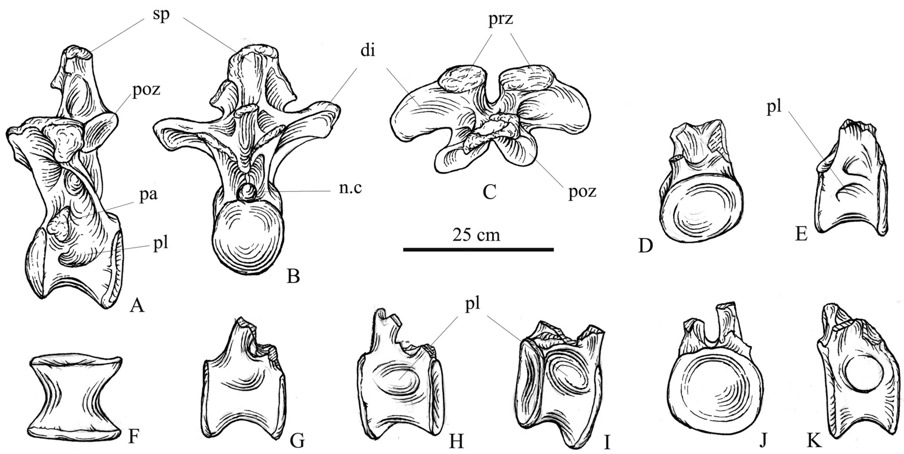

图3　何氏通安龙(新属、新种)的背椎

Fig. 3　Dorsals of *Tonganosaurus hei* gen. et sp. nov.

A–C. 第二背椎 the 2nd dorsal: A. 左侧视 in left side view, B. 前视 in anterior view, C. 背视 in top view; D–F. 第四背椎 the 4th dorsal: D. 前视 in anterior view, E. 右侧视 in right side view, F. 腹视 in bottom view; G. 第八背椎右侧视 the 8th dorsal in right side view; H. 第九背椎右侧视 the 9th dorsal in right side view; I. 第十背椎左侧视 the 10th dorsal in left side view; J–K. 第十一背椎 the 11th dorsal: J. 前视 in anterior view, K. 左侧视 in left side view

简字说明 Abbreviation: n. c. neural canal 神经孔;其余简字见图1, 2 for other abbreviations see Fig. 1 and 2

前部背椎为后凹型,中部背椎平凹型,后部背椎双凹型、后关节面较深。所有背椎关节面均为圆形,椎体宽约等于椎体长。后部背椎的椎体长度变短,而关节面面积有所增大。另外,有几个零散的神经棘,其变化趋势是:由前到后神经棘变高变厚,即由原来的板状变为棒状,其端面也渐呈浑圆形。

尾椎(图2M–T, 4):保存完整的两个尾椎应为第三、第五尾椎。前部尾椎为双凹型椎体,前关节面较浅。关节面圆形,脉弧面清晰可见。椎体中部收缩,不发育侧凹,横突位于椎体的上部边缘,向左右两边突出。神经孔位于前关节突的下边缘。神经弓矮。前、后关节突呈叶芽状向前上伸出约30 mm。前关节突与神经棘之间有薄板连接,薄板稍微向上延伸后即与神经棘愈合,由此薄板与两前关节突共同构成一个比神经孔小的坑窝。两个后关节突之间的坑窝则向上延伸到神经棘的中部,因此更像一个纵沟槽。神经棘位于椎体上部中央,稍后倾,高度与椎体近等,中下部呈左右窄、前后长的板状,上部相对膨大,端面呈浑圆形。尾椎的神经棘端面粗糙,凹凸不平的程度比背椎的更为明显。前部尾椎

椎体长小于椎体关节面宽。中前部尾椎双凹型,椎体较之前部尾椎变长变细、关节面变小,前、后关节突收缩,神经棘变矮、前后宽变大。

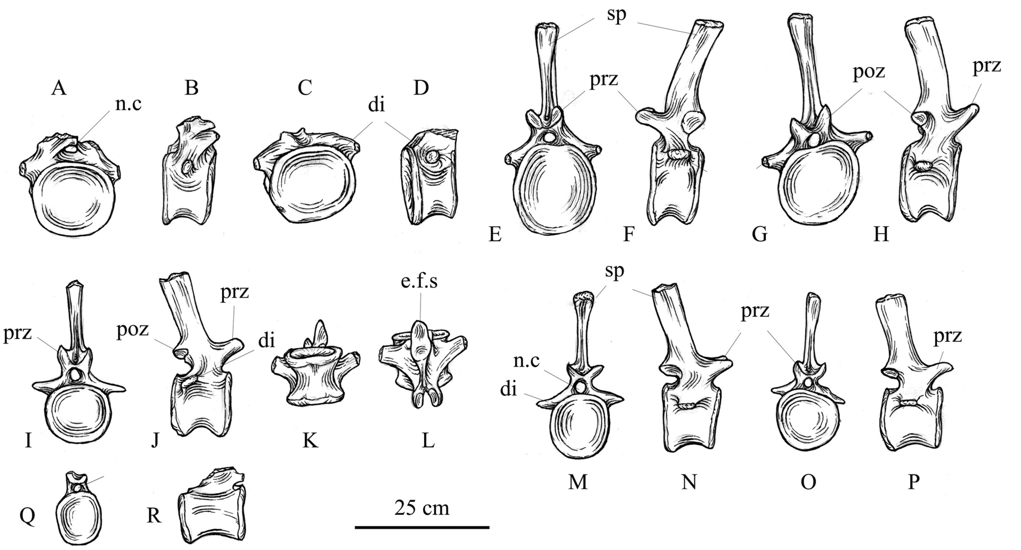

图 4 何氏通安龙(新属、新种)的尾椎

Fig. 4 Caudals of *Tonganosaurus hei* gen. et sp. nov.

A–B. 第一尾椎 the 1st caudal: A. 后视 in caudal view, B. 左侧视 in left side view; C–D. 第二尾椎 the 2nd caudal: C. 后视 in caudal view, D. 右侧视 in right side view; E–F. 第三尾椎 the 3rd caudal: E. 前视 in anterior view, F. 左侧视 in left side view; G–H. 第四尾椎 the 4th caudal: G. 前视 in anterior view, H. 右侧视 in right side view; I–L. 第五尾椎 the 5th caudal: I. 前视 in anterior view, J. 右侧视 in right side view, K. 腹视 in bottom view, L. 背视 in top view; M–N. 第六尾椎 the 6th caudal: M. 前视 in anterior view, N. 右侧视 in right side view; O–P. 第七尾椎 the 7th caudal: O. 前视 in anterior view, P. 右侧视 in right side view; Q–R. 第八尾椎 the 8th caudal: Q. 前视 in anterior view, R. 右侧视 in right side view

简字说明 Abbreviation: e. f. s. end face of neural spine 神经棘端面;其余简字见图 1–3 for other abbreviations see Figs. 1–3

肩带及前肢:右侧的肩胛骨、乌喙骨及前肢完整保存。此外,还保存有右胸骨大部、左肩胛骨远端、左桡骨远端和左尺骨近端。肩带及前肢的测量数据见表 2。

肩带(图 5, 6):肩胛骨的长度介于股骨长和肱骨长之间,近端强烈扩展成一扇状,其最大宽度为肩胛骨全长的一半。近端的上边缘薄,下边缘厚。乌喙骨接触面(图 5C)呈一等腰三角形。肩胛骨的肱骨关节面粗糙,有多个小的凹坑和髁突,其中位于肩胛骨内下边缘的髁突在近端内侧面引出一条浑圆粗嵴,此粗嵴延伸到近端开始扩展处,消失在骨干上。肩胛骨骨干呈板状,横截面呈透镜状。远端略有扩展,而厚度和截面形状与骨干同。乌喙骨高度稍大于宽度,外侧较凸,内侧稍凹,前缘和上缘较薄,下缘较厚,最厚处位于肩臼,其厚度达乌喙骨上下高度的 0.4 倍。肩胛面(图 5D)长,且凹凸不平,其长度约等于乌喙骨宽度。在肩臼面与乌喙骨下边缘之间有一较深的凹沟。乌喙孔洞穿,呈圆形,孔内侧紧靠肩胛边。胸骨较大,呈长卵形,上下高大于左右宽,上下缘厚而窄,中部宽而薄。骨板腹面稍凸,背面略凹,背面中上部有一个水滴状的嵴。乌喙骨的前边缘呈圆弧状。

表 2　何氏通安龙(新属、新种)肩腰带、肢骨及后脚测量

Table 2　Measurements of pectoral and pelvic girdles, limbs and pes of *Tonganosaurus hei* gen. et sp. nov.　（mm）

	TL	WP	TP	WD	TD	MWD	TL/humerus
肩胛骨 scapula (r)	760	379	117	215	30	152	1.21
肱骨 humerus (r)	628	283	98	204	124	96	1
桡骨 radius (r)	498	119	76	112	77	61	0.79
尺骨 ulna (r)	520	165	126	63	101	72	0.61
							TL/femur
坐骨 ischium (r)	573	278	80	97	95	64	0.67
坐骨 ischium (l)	570	310	85	110	105	51	0.68
股骨 femur (r)	840	300	122	256	206	147	1
胫骨 tibia (r)	562	226	135	169	120	88	0.67
腓骨 fibula (r)	566	127	61	123	81	47	0.67
跖骨 metatarsal (r-1)	109	59	66	66	39	44	
跖骨 metatarsal (r-2)	166	80	60	67	60	38	
跖骨 metatarsal (r-3)	153	54	65	58	45	33	
跖骨 metatarsal (r-5)	125	108	32	43	36	33	
爪骨 claw (r-1)	170	50	74				
乌喙骨 coracoid (r)	anteroposterior width 208			superoinferior width 344			
	maximum thickness 126			diameter of coracoid foramen 40			
胸骨 sternum (r)	anteroposterior width 300			width of right-and-left 195			

Note: TL. total length 全长;WP. width of proximal end 近端宽度;TP. thickness of proximal end 近端厚度;WD. width of distal end 远端宽度;TD. thickness of distal end 远端厚度;MWD. minimum width of shaft 骨干最小宽度;r. right 右侧的;l. left 左侧的。

肱骨:直而粗壮,其长度为股骨长的 0.75。骨干横截面近椭圆形。三角嵴发育。近端强烈扩展,呈一扇状,最大宽度为肱骨长度的 0.45, 近端面粗糙。近端前侧的附肌凹比较宽阔,后背侧稍隆起。远端扩展也显著,但其程度不如近端强烈,其宽度为骨干最小宽的两倍,远端关节髁分异明显,内髁比外髁大,前侧的髁间沟明显。

桡尺骨:桡骨纤细,为肱骨长的 0.79。近端扩展比远端扩展显著,最大宽度约为骨干最小宽度的两倍。近端端视面呈浑圆形,略凸。远端端视面呈浑圆三角形。桡骨骨干较长,横截面近圆形。尺骨为肱骨长的 0.82。骨干较桡骨粗壮,近端面为异化的三角形,最大宽度为骨干最小宽的 2.30。肘突发育。近端内外侧各为一凹面,内侧凹较深,外侧凹向下延伸较长,前内缘与后内缘较薄。骨干愈往下愈细。下部的骨干稍微向内侧倾斜。远端稍扩展,端面呈长椭圆形,端面粗糙。

坐骨及后肢和后脚:化石材料包括完整的左右坐骨、右股骨、右胫骨、右腓骨、右跖骨Ⅰ, Ⅱ, Ⅲ, Ⅴ和爪骨Ⅰ, 以及左股骨的近端和远端、左腓骨远端。测量数据见表 2。

坐骨(图 6, 7): 近端扩展显著,其宽度为坐骨长度的 0.54, 而远端扩展不明显,整个坐骨呈“Y”字形。耻骨突面与肠骨突面约等大,前者呈三角形,后者呈浑圆形。耻骨突与肠骨突之间即为髋臼窝的后下部分。坐骨骨干纤细,最窄处的宽度仅为近端宽度的0.17, 横截面为圆形。左坐骨因受压变形,骨干后侧变薄,横截面为三角形。

股骨:直而粗壮,近端股骨头向内侧显著扩张,呈一靴状,近端端面为粗糙的长椭圆

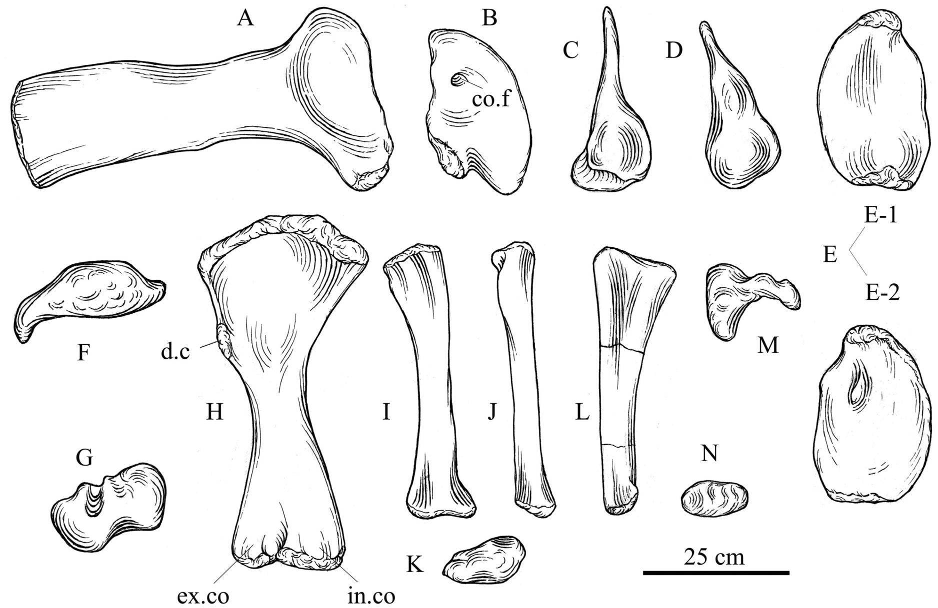

图5　何氏通安龙(新属、新种)的肩带及前肢

Fig. 5　The pectoral girdle and forelimb of *Tonganosaurus hei* gen. et sp. nov.

A–B. 右肩带右侧视 the right pectoral girdle in right side views: A. 肩胛骨 scapula, B. 乌喙骨 coracoid; C. 肩胛骨近端视 scapula in proximal end view; D. 乌喙骨的肩胛面 scapular surface of coracoid; E. 胸骨 sternum: E–1. 前视 in anterior view, E–2. 后视 in caudal view; F–H. 右肱骨 right humerus: F. 近端视 in proximal end view, G. 远端视 in distal end view, H. 前视 in anterior view; I–K. 右桡骨 right radius: I. 前视 in anterior view, J. 内侧视 in inside view, K. 远端视 in distal end view: L–N. 右尺骨 right ulna: L. 前视 in anterior view, M. 近端视 in proximal end view, N. 远端视 in distal end view

简字说明 Abbreviations: co. f. coracoid foramen 乌喙孔; d. c. deltopectoral crest 三角嵴;
ex. co. exocondyle 外髁; in. co. innercondyle 内髁

形。第四转节发育,呈脊状,上下长为股骨全长的0.14, 位于股骨中上部后内侧。远端以内、外髁突向两侧扩展,髁间沟较深,约有70 mm。

胫骨:胫骨粗壮,近端扩展显著,其宽度为骨干最小宽度的2.50,胫骨翼发育。远端略微扩张,端视面为荷叶状,其宽度为骨干最小宽的2.00,骨干前后略扁,内缘中上部呈弧形,内边缘较薄,外边缘直而厚,后侧面上部微凹。胫骨长度为股骨长度的0.67。

腓骨:腓骨比胫骨纤细。近端薄而宽,端视面呈长椭圆形,其宽度为骨干最小宽的2.70,不足胫骨近端宽度的一半。远端略为扩张,宽度为骨干最小宽的2.61, 骨干内外侧较扁,内侧微凸、外侧微凹。骨干上部比下部直,上边缘比下边缘薄,前边缘比后边缘薄。骨干横切面为三角形。腓骨长度为股骨长度的0.67。

后脚:跖骨Ⅰ短而粗壮,跖骨Ⅰ长与近端高的比值为1.65, 近端面为浑圆矩形,骨干腹部收缩,表面光滑。跖骨Ⅱ与跖骨Ⅲ相似,均较纤细,骨干长与近端高的比值分别为2.51和2.35, 近端面呈梯形,远端面呈浑圆形。骨干表面光滑,中部收缩明显。跖骨Ⅴ背视呈

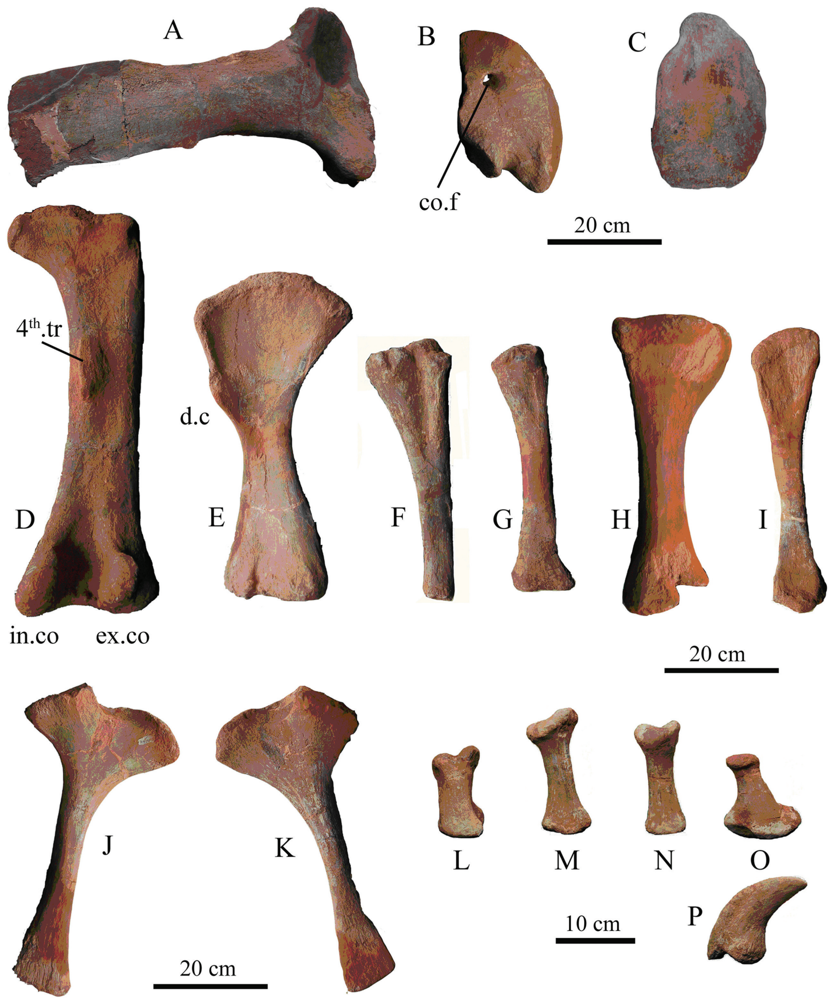

图 6　何氏通安龙(新属、新种)正型标本(MCDUT 14454)

Fig. 6　*Tonganosaurus hei* gen. et sp. nov. (MCDUT 14454, Holotype)

A. 右肩胛骨右侧视 right scapula in right side view; B. 右乌喙骨右侧视 right coracoid in right side view; C. 右胸骨背视 right sternum in top view; D. 右股骨后视 right femur in caudal view; E. 右肱骨前视 right humerus in anterior view; F. 右尺骨后视 right ulna in caudal view; G. 右桡骨后视 right radius in caudal view; H. 右胫骨后视 right tibia in caudal view; I. 右腓骨后视 right fibula in caudal view; J. 左坐骨左侧视 left ischium in left side view; K. 右坐骨右侧视 right ischium in right side view; L-O. 右跖骨Ⅰ, Ⅱ, Ⅲ, Ⅴ背视 right metatarsals Ⅰ, Ⅱ, Ⅲ and Ⅴ in dorsal views; P. 右爪Ⅰ侧视 right claw Ⅰ in lateral view

简字说明 Abbreviation: 4^{th}. tr. fourth trochanter 第四转节;其余简字见图 5 for other abbreviations see Fig. 5

扇形。近端扩展强烈,左右宽为跖骨 V 长度的 0.86,近端背部中央有一粗嵴,往下稍有延伸即后消失。骨干最小宽仅为近端宽度的 0.30, 位于骨干中下部。远端略微扩展。跖骨 V 腹部粗糙、微凹。爪骨 I 近端面呈多边形,关节面内凹,近端外侧有一纵长的沟槽,近端外侧下方呈髁状。背视呈锥型。爪尖弯曲,爪尖截面粗圆。

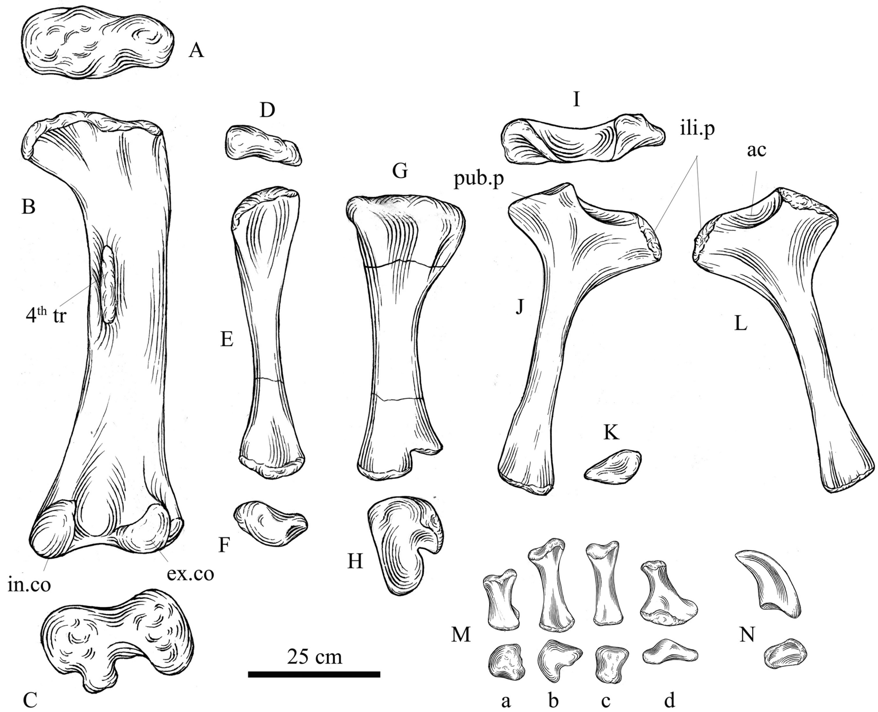

图 7　何氏通安龙(新属、新种)的腰带、后肢和后脚

Fig. 7　Pelvic girdle, hindlimb and pes of *Tonganosaurus hei* gen. et sp. nov.

A–C. 右股骨 right femur: A. 近端视 in proximal end view, B. 后视 in caudal view, C. 远端视 in distal end view; D–F. 右腓骨 right fibula: D. 近端视 in proximal end view, E. 前视 in anterior view, F. 远端视 in distal end view; G–H. 右胫骨 right tibia: G. 后视 in caudal view, H. 远端视 in distal end view; I–K. 左坐骨 left ischium: I. 近端视 in proximal end view, J. 左侧视 in left side view, K. 远端视 in distal end view; L. 右坐骨右侧视 right ischium in right side view; M. 右跖骨背视及近端视 right metatarsal in top and proximal end view, a–d. Me. Ⅰ, Ⅱ, Ⅲ and Ⅴ respectively; N. 右爪骨Ⅰ背视和侧视 right claw Ⅰ in dorsal and lateral views

简字说明 Abbreviations: ac. acetabulum 髋臼; ili. p. ilium peduncle 肠骨突; pub. p. pubic peduncle 耻骨突; 其余简字见图 5,6 for other abbreviations see Fig. 5 and 6

2　比较与讨论

如下通安龙与国内外的蜥脚类恐龙的比较讨论,均在科级和属级水平上进行。

2.1　与晚三叠世蜥脚类的比较

晚三叠世的蜥形类(sauropodomorpha)多属原蜥脚类(Yates, 2003), 蜥脚类仅有一例,为出土于泰国东北部 Nam Phong 组的伊森龙 *Isanosaurus* (Buffetaut et al., 2000, 2002)。伊森龙属于原始蜥脚类,区别于通安龙的特点有:颈椎椎体短,背椎神经弓高、神

经棘的前后长大于左右宽。肱骨近端宽为长度的 0.34, 远端宽为长度的 0.29, 股骨长、呈棒状,第四转节长而尖、呈 S 形。通安龙的颈椎椎体细长,背椎神经弓低矮,神经棘的左右宽大于前后长,肱骨末端的扩展比伊森龙更强烈,股骨的第四转节发育,但为稍微隆起的粗嵴,也不呈 S 形。因此,二者区别较大。

2.2　与早侏罗世蜥脚类的比较

国内已公开发表的早侏罗世的蜥脚类有 3 属:产于云南的昆明龙 *Kunmingosaurus*, 产于四川的珙县龙 *Gongxianosaurus* 和资中龙 *Zizhongosaurus*。

昆明龙(Young, 1940; 李奎,1998b;方晓思、李佩贤,2008)与通安龙明显不能归于同一类,原因是:昆明龙的颈部和颈椎均较短,背椎椎体无侧凹,股骨的第四转节不发育, 肱骨的三角脊不发育。珙县龙(何信禄等,1998)与通安龙不同特点表现在:椎体两侧无侧凹,脊椎的板状构造极不发育,颈椎平凹型,构造简单,神经棘小,前肢为后肢长度的 0.70 ~0.75, 乌喙骨无乌喙孔。资中龙的脊椎无侧凹,脊椎神经棘较低,股骨头不发育,肱骨的三角脊不发育。通安龙与之对应的特点表现为:椎体侧凹和板状构造发育,并且板状构造复杂,颈椎后凹型,前后肢比例为 0.80, 股骨头发育,肱骨的三角脊发育,乌喙孔发育且洞穿。鉴于这些区别,通安龙与昆明龙、珙县龙和资中龙不属于同一类。

迄今为止,国外已正式发表的早侏罗世的蜥脚类恐龙共有 6 属:津巴布韦的火山齿龙 *Vulcanodon* (Raath, 1972), 印度南部科塔组(Kota Formation)的巴拉帕龙 *Barapasaurus* (Jain et al., 1975, 1979)和科塔龙 *Kotasaurus* (Gillette, 2003), 印度南部 Upper Dharmaram 组的莱姆帕拉佛龙 *Lamplughsaura* (Kutty et al., 2007), 非洲摩洛哥的塔邹达龙 *Tazoudasaurus* (Ronan et al., 2004)和德国的欧姆登龙 *Ohmdenosaurus* (Wild, 1978; Gillette, 2003)。

国外早侏罗世蜥脚类恐龙与通安龙相区别的特点为:火山齿龙的荐前椎缺乏侧凹,股骨纤细;巴拉帕龙的颈椎椎体短,肱骨和股骨较纤细,肱骨的近端和远端扩展程度相等,尺骨比桡骨短;科塔龙的背椎结构简单,肱骨两端略有扭曲、并且扩展不明显;莱姆帕拉佛龙的颈椎粗短,第三颈椎的长高比仅为 1.65, 肩胛骨近端与远端的扩展程度近等,前肢为后肢长度的 0.74, 肱骨远端没有髁突,肱骨三角脊和股骨的第四转节相当发育;塔邹达龙颈椎和背椎的神经弓高、与椎体等高,并且椎体无侧凹,神经棘矮,背椎的副突向外伸出较长,神经棘向后倾斜的程度大,后下肢短,腓骨不足股骨长度的 0.65; 欧姆登龙的荐前椎没有发育侧凹,而且股骨纤细。

2.3　与国内中–晚侏罗世蜥脚类的比较

中国的中侏罗世的蜥脚类恐龙相当繁盛,四川盆地有 6 属:原颌龙 *Protognathosaurus* (张奕宏,1988), 蜀龙 *Shunosaurus* (董枝明等,1983), 酋龙 *Datousaurus* (董枝明、唐治路,1984), 大山铺龙 *Dashanpusaurus* (彭光照等,2005), 秀龙 *Abrosaurus* (欧阳辉,1989)和峨眉龙 *Omeisaurus* (Young, 1939, 1958; 何信禄等,1988; 唐烽等,2001);云南地区有 3 属:蜀龙 *Shunosaurus* (付丽娅、张加华,2004), 川街龙 *Chuanjiesaurus* (方晓思等,2004)和元谋龙 *Yuanmousaurus* (吕君昌等,2005); 新疆有 3 属:巧龙 *Bellusaurus* (董枝明,1990), 克

拉美丽龙 *Klamelisaurus*（赵喜进,1993）和拉伯龙 *Lapparentosaurus*（Farida et al., 2005）。

原颌龙和蜀龙归于鲸龙科 Cetiosauridae Lydekker, 1888, 该科的科征为:颈椎椎体短,背椎神经棘高,荐前椎不发育侧凹,前后肢比例小,仅为 0.67。酋龙、大山铺龙和秀龙归于圆顶龙科 Camarasauridae Cope, 1877, 该科的科征为:颈椎椎体短,后部颈椎和前部背椎的神经棘分叉,前部尾椎前凹。由于通安龙的颈椎椎体细长,荐前椎发育侧凹,脊椎的神经棘不分叉,前后肢比例为 0.80,因此,不宜将通安龙归入鲸龙科和圆顶龙科的各属蜥脚类中。通安龙与峨眉龙有较多相同特点,表现在:它们都有细长的颈椎,神经棘低而长,颈椎的腹嵴、副突发育,荐前椎侧凹发育,椎体中部收缩,后部颈椎及背椎的板状构造及坑窝构造发育;前后肢比例为 0.80, 肱骨和股骨均直而粗壮。然而,峨眉龙与通安龙的不同点也较为明显:峨眉龙的侧凹结构复杂,椎体内部有蜂窝构造,尾椎的神经弓较高。元谋龙和川街龙是大型的蜥脚类恐龙,与通安龙不同的特点是:元谋龙和川街龙的后部颈椎和前部背椎的神经棘分叉,其上的板状及坑窝构造相当复杂。巧龙的颈椎椎体短、神经棘高,尾椎前凹型。克拉美丽龙的神经棘很高,荐前椎呈后凹型, 后部颈椎和前部背椎神经棘分叉,前部尾椎为前凹型。拉伯龙的中前部背椎双凹型,背椎的神经棘末端向后延伸,板状构造相当发育,在前关节突上只有一个神经棘支持板。

国内晚侏罗世的蜥脚类分布较为分散,共有 6 属:四川的大安龙 *Daanosaurus*（叶勇等, 2005）, 四川、云南、甘肃和新疆等地的马门溪龙 *Mamenchisaurus*（Young, 1954; 杨钟健、赵喜进,1972; Russell and Zheng, 1993; 李奎、蔡开基,1997; 张奕宏等,1998; 王正新等,2003; 欧阳辉、叶勇,2001; 方晓思等,2004）, 新疆的天山龙 *Tienshanosaurus*（Young, 1937）、蝶龙 *Hudiesaurus*（Dong, 1997）, 山东的盘足龙 *Euhelopus*（Wiman, 1929）, 以及甘肃和新疆的嘉峪龙 *Chiayusaurus*。大安龙与通安龙不同的特点表现在:大安龙的颈椎粗短、无腹嵴,背椎神经孔呈椭圆形。马门溪龙是进步的蜥脚类,其明显区别于通安龙的特点表现在:荐前椎椎体侧凹的结构复杂,后部颈椎及前部背椎的神经棘分叉,前部尾椎前凹型,椎体内部的蜂窝构造相当发育。天山龙、蝶龙、盘足龙和嘉峪龙共同区别于通安龙的特征是:后部颈椎和前部背椎的神经棘分叉,前部尾椎前凹型。此外,天山龙的前肢较短。

综上所述,通安龙与国内中、晚侏罗世的蜥脚类皆有不同。因此,通安龙不能归于以上的任何一属。

2.4 与国外中-晚侏罗世蜥脚类的比较

国外中-晚侏罗世的蜥脚类恐龙(McIntosh, 1990; Upchurch, 1995, 1998; Wilson and Sereno, 1998; Myers and Fiorillo, 2009)可归于如下 5 科:鲸龙科 Cetiosauridae, 圆顶龙科 Camarasauridae, 梁龙科 Diplodocidae, 腕龙科 Brachiosauridae 和巨龙科 Titanosauridae。

通安龙与鲸龙科和圆顶龙科的不同特点见上一节(2.3)。梁龙的前部尾椎前凹型,前肢较短, 仅为后肢长的 0.67 左右。而通安龙的前部尾椎双凹型,前后肢比例为 0.80。腕龙科(Monbaron et al., 1999; Rauhut, 2001)与通安龙最大的不同点表现在:腕龙的前肢比后肢长,而且后部颈椎和前部背椎的神经棘分叉;而通安龙的后肢比前肢长,所有脊椎的神经棘均不分叉。巨龙科与通安龙的不同特点是:背椎神经棘向后延伸,背椎横突向侧

上方延伸,近端尾椎为典型的前凹型。

综上所述,通安龙与国外中、晚侏罗世的各属蜥脚类皆具有不同特点,因而不能归于以上的任何一属。

3 结　论

晚三叠世到晚侏罗世的国内外蜥脚类恐龙皆具有与通安龙明显不同的特点,通安龙不应归入其中任何一属中。通安龙发现于下侏罗统,并且与中侏罗统出土的峨眉龙有较多相似性:颈椎细长,前部颈椎神经棘低长,颈椎的腹嵴、副突发育,荐前椎侧凹发育,椎体中部收缩,后部颈椎及背椎的板状构造及坑窝构造极为发育,前后肢比例为0.80, 肱骨和股骨均直而粗壮。董枝明、唐治路(1984)、何信禄等(1988)和李奎(1998a)等均将峨眉龙归入马门溪龙科。因此,笔者也暂将通安龙归于马门溪龙科 Mamenchisauridae Young & Chao, 1972, 建新属通安龙属 *Tonganosaurus* gen. nov.,其特点比峨眉龙属原始。通安龙对四川盆地早期蜥脚类恐龙的演化意义将另文阐述。

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A NEW SAUROPOD FROM THE LOWER JURASSIC OF HUILI, SICHUAN, CHINA

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Key words　Huili, Sichuan; Early Jurassic; Yimen Formation; Sauropoda; *Tonganosaurus*

Summary

A new sauropod, *Tonganosaurus hei* gen. et sp. nov. from the Yimen Formation (Lower Jurassic) of southern Sichuan, China, is described on the basis of a collection of bones. These fossils include about 20 vertebrae, a complete right pectoral girdle and right forelimb, the distal end of a left scapula, a pair of complete ischia, a complete right hindlimb, the proximal and distal ends of a left femur, right metatarsals (mt. I, II, III and V), a right pedal ungual, and ten neural spine and rib fragments. The third cervical and anterior caudals are most similar in shape to those of the mamenchisaurid *Omeisaurus* (from the Middle Jurassic, Sichuan Basin), and quite different from those of other sauropods. The material was therefore assigned to the Family Mamenchisauridae Young & Chao, 1972 and a new genus and species were established. This represents the first discovery of a sauropod in the Lower Jurassic of China since *Gongxianosaurus* was found in Sichuan Basin. The *Tonganosaurus* material is of great importance for understanding the phylogenetics of the early Sauropoda.

Saurischia Seeley, 1888
Sauropodomorpha Huene, 1932
Sauropoda Marsh, 1878
Mamenchisauridae Young & Chao, 1972
***Tonganosaurus* gen. nov.**

Diagnosis As for the type and only known species.

Type species *Tonganosaurus hei* sp. nov.

Tonganosaurus hei sp. nov.

(Figs. 1–7)

Etymology The generic name is from the type locality of *Tonganosaurus*, Tong'an, Huili, Sichuan. The specific name, *hei*, refers to He Xinlu, who spent a lifetime in dinosaur research.

Diagnosis Pleurocoels are developed in all presacral vertebrae, and the bone texture is solid. Pleurocoels are large and deep. Cervical centra are slender. A ventral keel is present on each cervical centrum. Posterior cervical centra have well developed laminae and cavities. Both laminae and pleurocoels are well developed in the dorsal vertebrae. Cervical and anterior dorsal centra are opisthocoelous, middle dorsal centra are platycoelous, posterior dorsal and anterior caudal centra are amphicoelous. Centra lack a cancellous structure. Forelimb length is 0.80 of hindlimb length. Humerus is straight and robust, and deltopectoral crest is well developed. Femur is straight and robust with a well developed 4^{th} trochanter.

Holotype An incomplete skeleton of a long-necked sauropod (MCDUT 14454).

Locality and horizon The town of Tong'an in the south of Sichuan Province, China. The Lower Jurassic Yimen Formation.

Remarks The cervical centra are slender, with well-developed parapophyses and ventral keels. The pleurocoels are simple in structure, each having a deep anterior part and a shallow posterior part. The neural arches are low, and the middle part of each vertebra is constricted. The neural arches of the posterior cervicals bear well developed laminae.

The anterior dorsal centra are opisthocoelous, and are longer than wide. The terminal surface of each parapophysis is elliptical. The neural spines in this region are high and plate like, and the parapophyseal laminae expand horizontally on both sides. The neural arches are complex, with well-developed laminae and pleurocoels. The mid-dorsal centra are platycoelous. The posterior dorsal centra are amphicoelous, and more slender than the middle and anterior dorsal centra. Pleurocoels, laminae and cavities are developed on all dorsal centra, and the pleurocoels are simple in structure. The middle part of each dorsal centrum is strongly constricted.

The anterior caudal centra are amphicoelous, and the middle part of each centrum is constricted. The width of each centrum exceeds its length, but the length is approximately equal in each case to the height of the centrum at its midpoint. The neural arches are equivalent in height to their centra. The plate-like neural spine is centrally positioned on the centrum and inclined slightly posteriorly, with a rounded terminal face. The prezygapophyses and postzygapophyses are constricted and attenuated.

The forelimb to hindlimb length ratio is 0.80, whereas the length ratios of the radius to the humerus and of the tibia to the femur are 0.79 and 0.67 respectively. The humerus is straight and robust. The proximal surface is larger than the distal surface, and the deltopectoral crest is well developed. The femur, which bears a well developed 4^{th} trochanter, is also straight and robust, and the proximal surface exceeds the size of the distal one as in the humerus. The diaphysis of the ischium is moderately slender, and the iliac peduncle is identical to the pubic peduncle in shape and size. The proximal end of the scapula is broad and thick, whereas the scapular blade is narrow and thin.

Comparison and discussion Well-preserved sauropodomorph skeletons are relatively uncommon in the Late Triassic, and most of the ones that have been recovered belong to prosauropods. A major exception is the primitive sauropod *Isanosaurus*, from the Nam Phong Formation of Thailand (Buffetaut et al., 2000, 2002). *Isanosaurus* has a rather short neck, and the 4^{th} trochanter on the femur is S-shaped. By contrast, *Tonganosaurus* has gracile cervical centra and a long neck, and the 4^{th} trochanter is low and straight.

In China, Early Jurassic sauropods are less. There are only three previously recorded genera: *Kunmingosaurus* from Yunnan Province, and *Gongxianosaurus* and *Zizhongosaurus* from Sichuan Province. *Kunmingosaurus* lacks pleurocoels in the dorsal vertebrae and a clearly developed 4^{th} trochanter on the femur, while in *Tonganosaurus* the dorsal centra have pleurocoels and the 4^{th} trochanter of the femur is well developed. *Gongxianosaurus* and *Zizhongosaurus* also lack pleurocoels, and their neural arches are without well developed diapophyseal laminae and cavities. As a result, *Tonganosaurus* cannot be synonymous with any of these previously described Early Jurassic Chinese sauropod taxa.

Well-preserved sauropod skeletons from Lower Jurassic strata outside China include specimens of *Vulcanodon* from Zimbabwe, *Barapasaurus* and *Kotasaurus* from the Kota Formation of India (Jain et al., 1975, 1979; Gillette, 2003), *Lamplughsaura* (Kutty et al., 2007) from the Upper Dharmaram Formation of India, *Tazoudasaurus* from Morocco, and *Ohmdenosaurus* from Germany. These dinosaurs differ from *Tonganosaurus* as follows. *Vulcanodon* lacks pleurocoels and has a gracile femur, in contrast to the presence of presacral pleurocoels and a robust femur in *Tonganosaurus*. In *Barapasaurus* the humerus and femur are moderately gracile with the proximal and distal ends about equally expanded, so that there is no particularly strong expansion of the proximal end of the femur. We can distinguish *Kotasaurus* from *Tonganosaurus* on the basis of osteological details including simple dorsal vertebrae and less expanded humerus with slight twist at both ends. The forelimb to hindlimb length ratio is 0.74 in *Lamplughsaura*, and in lateral view the deltopectoral crest of the humerus appears so large that its width exceeds that of the humeral shaft. However, *Tonganosaurus* has a moderately long forelimb that is 0.80 as long as the hindlimb, and the deltopectoral crest is comparatively small. *Tazoudasaurus* differs from *Tonganosaurus* in lacking pleurocoels on the dorsal centra, and the dorsal vertebrae of the former taxon have high neural arches but low neural spines. *Ohmdenosaurus* differs from *Tonganosaurus* in lacking pleurocoels on the cervical and dorsal vertebrae and in having a gracile femur.

Sauropods from the Middle Jurassic of China are abundant. Described taxa include *Protognathosaurus*, *Shunosaurus*, *Datousaurus*, *Dashanpusaurus*, *Abrosaurus* and *Omeisaurus* from Sichuan Province; *Shunosaurus*, *Chuanjiesaurus* and *Yuanmousaurus* from Yunnan Province; and *Bellusaurus*, *Klamelisaurus* and *Lapparentosaurus* from the Xinjiang Autonomous Region. *Protognathosaurus* and *Shunosaurus* are members of Cetiosauridae Lydekker, 1888. In cetiosaurids the cervical centra are short, the dorsal centra lack pleurocoels, and the forelimb to hindlimb length ratio is 0.67. *Datousaurus*, *Dashanpusaurus* and *Abrosaurus* belong to the Camarasauridae Cope, 1877. Camarasaurids also have short cervical centra, and the neural spines of the posterior cervicals and anterior dorsals are bifurcate, whereas the anterior caudals are procoelous. *Omeisaurus*, *Yuanmousaurus* and *Chuanjiesaurus* have several derived characteristics, such as complex pleurocoels and the development of cancellous structure throughout the cervical part of the column. In addition, *Omeisaurus* and *Tonganosaurus* share numerous characteristics: long, thin cervical vertebrae with low and long neural spines; well developed ventral keels and parapophyses on the cervical centra; pleurocoels on the presacral centra are developed; presacral centra are constricted near the midpoint; many well-developed laminae and cavities in the neural arches of the posterior cervicals and anterior dorsals; a forelimb to hindlimb ratio of about 0.80, and a robust, straight humerus and femur. However, many details of the osteology of *Omeisaurus*, including complex pleurocoels of presacral centra, the cancellous bone texture of centra, anterior caudals with high neural arch, indicate that we can not attribute *Tonganosaurus* and *Omeisaurus* to the same genus. *Bellusaurus* has wide cervical centra with high neural spines, and the anterior caudal vertebrae are procoelous. The presacral centra of *Klamelisaurus* are opisthocoelous, the posterior cervical and anterior dorsal neural spines are bifurcate, and the anterior caudals are procoelous. The architecture of the dorsal neural arches is more complex in *Lapparentosaurus* than in *Tonganosaurus*.

Six genera of Late Jurassic sauropods are known from China: *Daanosaurus* from Sichuan Province, *Mamenchisaurus* from Sichuan, Yunnan, Gansu and Xinjiang, *Tienshanosaurus*, *Hudiesaurus* and *Chiayusaurus* from Xinjiang, and *Euhelopus* from Shandong. The cervical centra of *Daanosaurus* are short. *Mamenchisaurus* is the most derived sauropod known from the Sichuan Basin, and derived characteristics that differentiate this taxon from *Tonganosaurus* include: complex pleurocoels, well-developed cancellous structure in all cervicals, anterior caudals that are typically procoelous, and bifurcate posterior cervical and anterior dorsal neural spines. *Tienshanosaurus*, *Hudiesaurus*, *Chiayusaurus* and *Euhelopus* are also more derived than *Tonganosaurus* in that their posterior cervical and anterior dorsal neural spines are bifurcate, and in that their anterior caudals are procoelous. In *Tienshanosaurus* the forelimb is also comparatively short.

Sauropod dinosaur remains, which have been discovered and collected from the Mid-Late Jurassic of other countries (McIntosh, 1990; Upchurch, 1995, 1998; Wilson and Sereno, 1998; Myers and Fiorillo, 2009), belong to five families: Cetiosauridae, Camarasauridae, Diplodocidae, Brachiosauridae and Titanosauridae.

Features distinguishing *Tonganosaurus* from cetiosaurids and camarasaurids were enumerated above.

In diplodocids the anterior caudals are procoelous, the forelimbs are comparatively short, and the forelimb to hindlimb length ratio is 0.67. By contrast, the anterior caudals of *Tonganosaurus* are amphicoelous, and the forelimb to hindlimb length ratio is 0.80.

Brachiosaurids (Monbaron et al., 1999; Rauhut, 2001) can be easily distinguished from *Tonganosaurus* on the basis of their numerous unique characteristics: for example, the forelimb is longer than the hindlimb and the neural spines of the posterior cervical and anterior dorsal vertebrae are bifurcated. Titanosaurids Sternfeld, 1911 differ from *Tonganosaurus* in typically having procoelous anterior caudals and posteriorly inclined dorsal neural spines.

In conclusion, *Tonganosaurus* is different from all other sauropods currently known from the Late Triassic to the Late Jurassic, both in China and abroad. Among the sauropods mentioned above, *Omeisaurus* from the Middle Jurassic of Sichuan is most similar to *Tonganosaurus*. The similarities are as follows: thin and long cervical vertebrae, low and long neural spines, well developed ventral keels and parapophyses on the cervical vertebrae, well developed pleurocoels on the presacral centra, presacral centra are constricted near the mid-point, extremely well-developed laminae and cavities in the posterior cervical and dorsal vertebrae, a forelimb to hindlimb length ratio of 0.80, and a straight and robust humerus and femur. However, *Tonganosaurus* has simply constructed presacral centra, while *Omeisaurus* has complex presacral centra. Furthermore, the ratio of humeral length to femoral length in *Tonganosaurus* is 0.75, compared to 0.80 in *Omeisaurus*. Dong and Tang (1984), He et al. (1988), Li (1998a) and others have attributed *Omeisaurus* to the Family Mamenchisauridae Young & Chao, 1972, so we attribute *Tonganosaurus* to this family as a newly established genus. This new genus is more primitive than *Omeisaurus* in its characteristics.

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