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THE LIMBS AND LIMB GIRDLES OF THE SAUROPODS FROM THE TENDAGURU BEDS

by

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WITH PLATES XV-XXIII, APPENDICES A-R AS WELL AS 26 FIGURES AND 19 TABLES IN THE TEXT

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Preface

In previous reports, E. FRAAS reported on the limbs and limb girdles of the sauropods from the Tendaguru Beds in the course of his work on the valuable discoveries made during his expedition to the Tendaguru in 1907. More results were published later in several articles by the present author. The results of the concluding work on the extensive skeletal parts recovered is hereby presented. In addition to illustrating the morphology, the variability of the osteological form within one species will be treated, and, as far as possible, I will try to establish the relationships between the sauropods from the Tendaguru Beds to those of other faunas. The specimens used in this study were prepared on the whole years ago, among them also those that were included in the reconstructions of the skeletons of *Brachiosaurus brancai* and *Dicraeosaurus hansemanni* in the atrium of the Museum of Natural History in Berlin. The head preparators E. SIEGERT and G. NEUBAUER deserve merit for the necessary recent preparations. The description, which started a long time ago, went hand in hand with the production of the figures necessary for this publication, which I owe to the excellent drawing skills of MR. HUGO WOLF, until his health put an end to his work. Gaps in the illustrations that were necessary to continue and complete this study could only be filled by photogramms, which was difficult in the circumstances just after the end of the war.

I am very much obliged to MR. A. OBIEGLO for the special care he dedicated to the photographic tasks. PROFESSOR DR. W. GROSS, the director of the Berlin Paleontological Institute and Museum supported my work in a very generous manner; for this I owe him my heartfelt gratitude.

The occurrence of dinosaurs in the Tendaguru Beds

The remains of dinosaurs (saurischians and ornithischians) are foremost found in the Middle and Upper Saurian Marls, but also in sandstone-like layers that are interspersed between these beds which contain marine fossils. Dinosaur remains are represented but in a much lower number in the Lower Saurian Marl, as confirmed by fieldwork by E. HENNING during his eventful expedition in the year 1934, contrary to doubts from another party. Two sauropod limb bones, the very well-preserved distal part of a femur, and a small claw were found by the Tendaguru Expedition. In addition, six teeth from different types of carnivorous dinosaurs were recovered (JANENSCH 1929), the good preservation of which speaks clearly against the assumption that they had been introduced from superimposed deposits.

The Saurian Marls, which indicate clear signs of redeposition, were probably not built at the open shore, but rather in lagoons or similar protected areas in close proximity of the coastlines. These deposits very rarely contain articulated skeletons, and larger parts of skeletons are uncommon. We predominantly find groups of associated bones that were disconnected from the skeleton, but in particular isolated skeletal elements. A few articulated feet have been found in their life orientation in the marls, indicating that the animals met their death by becoming stuck in the mud.

In some cases bones of smaller or larger herds that perished in a catastrophe were disarticulated but remained spatially together, albeit being taken out of their individual connection; this applies for certain associations of the herbivorous ornithischians *Kenturosaurus* and *Dysalotosaurus*. The occurrence of two or more individuals of the same species, or different species, at the same place, such as the sauropods *Dicraeosaurus hansemanni*, *Barosaurus africanus*, and *Brachiosaurus brancai* and the coelurosaur *Elaphrosaurus bambergi* at trench dd in the Middle Saurian Marl, is probably best explained by these spots having been especially dangerous for getting stuck in the marl mud and therefore representing fossil traps.

The firmer, partially calcareous, sandstone-like layers between the two upper Saurian Marls are often also rich in bones; they include beds with marine fossils, for example *Triennia smeii* and belemnites. In these upper intermediate beds the bones are found much more dispersed and often with abraded ends. These bones were obviously redeposited to a higher degree, probably uncovered by wave action of the westward-advancing surf and transported from the originally marly deposits. Thus it is easily understood that bones in the intermediate beds predominantly include the main bones of the limbs and elements of the limb girdles. Overgrowth of oysters indicate that bones from the intermediate beds came in contact with saltwater. The final deposition of bones in unconsolidated sediment happened probably sometimes only after an unusually churned-up surf, as is caused by violent storms or seismic activity.

Shoulder girdle

The shoulder girdle of sauropods is in particular distinguished by the large surface of its anterior section; this is especially true for the anterior blade-like part of the scapula, which formed, together with the adjacent coracoid, the extensive attachment area for the massive pectoral musculature of these long-necked reptiles. From the extensive anterior part of the scapula grows the much narrower distal blade, on which namely the m. trapezius attaches. The area of the shoulder joint (fossa glenoidalis = glenoid fossa) at the anterior end of the suture between the scapula and coracoid is considerably thickened. Characteristic for sauropods is the ridge that runs transverse to the longitudinal extension of the scapula, upward in a more or less anteriorly open curve on its lateral wall extending from the upper corner of the glenoid fossa along the broadest area of the scapula. In the central section this ridge grades into the surface of the here much narrower blade, and it more or less markedly lowers toward the proximal blade. Apart from presenting an attachment area for the musculature, the significance of this longitudinal ridge probably also consisted in absorbing the gigantic load from the weight that acted onto the shoulder girdle from the anterior trunk and the neck.

A cartilaginous suprascapula was in life certainly attached at the distal end of the blade; the extent of the cartilage was obviously very variable, and probably also different among individuals. The distal width of the blade may be different in species of one genus, as in *Apatosaurus*, and remarkably different also among individuals of the same species, as in *Brachiosaurus brancai* and *Camarasaurus supremus* COPE. A weak muscular crest is sometimes present on the ventral rim of the blade, located slightly in front of the middle of the overall length of the scapula.

The shoulder girdle in sauropods differs from the shoulder girdle in bipedal saurischians and bipedal ornithischians by the much larger surface of the scapula, although it is on the other hand remarkably similar to the heavily burdened shoulder girdle of the quadrupedal stegosaurs. The scapula of the stegosaur *Kentrurosaurus* from the Tendaguru Beds shows a very well-developed longitudinal ridge, as there are remarkable convergent shapes to be found in the limb skeleton.

The differences among the coracoids of sauropods consist essentially in the variable outlines. The suture between the scapula and coracoid is often closed by coossification in older individuals.

Table 1: Measurements of the scapula of *Brachiosaurus brancai*, *Barosaurus africanus*, *Dicraeosaurus sattleri*.

Species	Horizon	Find	Side	Length (glenoid fossa - distal end)		Width along transverse ridge		Width at distal end		Smallest width of blade		Thickness at glenoid fossa	
				cm	%	cm	%	cm	%	cm	%	cm	%
Brachiosaurus brancai	Upper Saurian Marl	Y8	1	154	100	93	61	39.5	25.5	21.5	14	22	14.5
	Upper Intermediate Beds	Ki 24	1	84+	100	44.5	52.4–	–	–	12	14.5 –	11	13–
	Lower Saurian Marl	As 9	r	193	100	100	52	66	35.5	27	14	27	14
Barosaurus africanus	Upper Saurian Marl	k 34	1	134	100	78	58	33	24.5	21	16.5	19	14
		A 4	1	140	100	74	53	30	40.5	23	16.5	14	10
Dicraeosaurus sattleri	Upper Saurian Marl	E 19	1	105+	100	57	54.5–	27	25.5–	19	18–	14	13.5–

Scapula

(Tab. 1)

Brachiosaurus brancai JAN.

The scapula is distinguished by the significantly expanded area of the proximal blade that shows a wide, vertically semicircular outline. The longitudinal ridge that defines the posterior border describes a flat curve, thickens at the dorsal end, and has here a slightly obliquely facing triangular terminal area. It is characteristic that the angle that the central axis of the blade makes with the axis of the upper section of the longitudinal ridge is large, being almost rectangular. The distal blade shows a strikingly variable contour in the available specimens. In the large right scapula Sa 9 (Plate XV, Fig. 1) from the Middle Saurian Marl with a length (glenoid fossa to distal end) of 200 cm, the ventral rim of the blade that extends from the longitudinal ridge runs straight to the distal end, which has a very obtuse-angled contour. The rim of the blade protrudes on the other side in a distinct curvature; thereby widening the distal section of the blade, considerably maintaining the uniformly round contour. The distal width is more than twice the shortest width of the blade. In the smaller scapula Y 8 from the Middle Saurian Marl (Length 154 cm) (Plate XV, Fig. 2) the blade is proportionally shorter. One rim of the blade is also straight, but the other is much more weakly outwardly curved than in scapula Sa 9, as far as the preservation allows a judgment here. In the much smaller, 84.5 cm long scapula Ki 74 (Plate XV, Fig. 3 a, b) from the upper intermediate layer, the blade presents a distinctly different picture, as the vertical rim is not straight but curves clearly outward distally, yet apparently widens at the same time in the opposite direction, too. This deviation from the other scapulae might represent an individual variation. Because of the similar shape of the proximal blade and of the longitudinal ridge there, Ki 74 doubtlessly belongs to *Brachiosaurus*.

The scapula of *Camarasaurus supremus* COPE shows characters similar to *Brachiosaurus* (compare OSBORN & MOOK 1921). These are the overall wide surface area, as expressed especially in the substantially wider blade, which is by the way quite variable, and furthermore in the shape of the longitudinal ridge, which describes a distinct curve, and in the similar angle of the axis of the blade with the longitudinal ridge. These similarities with *Brachiosaurus* have already been pointed out by OSBORN and MOOK (1921). The substantial extent of the scapula of *C. supremus* is especially expressed by the expanded angle between the blade and the cranial end of the longitudinal ridge of the rim.

Barosaurus africanus (E. FRAAS)

The left scapula A 4, Upper Saurian Marl (Plate XV, Fig. 4) is well characterized by the contour of the proximal plate, the proximal rim of which describes a flat curve, by the minimal curvature of the longitudinal ridge, and by the small angle of about half that of a right angle which it encloses with the longitudinal direction of the distal blade. The longitudinal ridge is only moderately developed, it is slightly square in the larger anterior section. The distal blade is quite long, and, in its proximal half it shows a width of almost 1/3 of the length of the longitudinal ridge. The blade widens only slightly distally and almost not at all in ventral direction. The scapula K 34 (Upper Saurian Marl) is in all major characters very similar to scapula A 4.

The scapula of *Barosaurus africanus* is remarkably similar to that of *Diplodocus*, insofar as the longitudinal ridge is also only weakly curved, and its dorsal end forms an angle of only 45° with the longitudinal direction of the distal blade. It differs however in the distal blade being proportionally shorter.

Dicraeosaurus hansemanni JAN.

The right scapula dd 33 from excavation site dd in the Middle Saurian Marl, which was used for the reconstruction of the skeleton, is incomplete in its proximal section and at the distal end of the blade and was restored. The angle between the longitudinal axis of the blade and the axis of the anterior section of the longitudinal ridge comes close to that of a right angle, differing from *Barosaurus africanus* in this respect. The distal blade is relatively wide, it widens only moderately in distal direction; its largest thickness lies in the midline.

Dicraeosaurus sattleri JAN.

The left scapula E 19 (Plate XV, Fig. 5) from the Upper Saurian Marl, which lay together with presacral vertebrae of this species, is complete, except for an anterior piece of the proximal plate; it is quite similar to the scapula of *D. hansemanni*, the longitudinal ridge is distinctly curved and has a very flat rounded cross-section. The distal blade is apparently slightly narrower than in the older species, it is also slightly wider ventrally at the distal end . — Right scapula O 8 (Upper Saurian Marl) (Plate XV, Fig. 6); not preserved. The small scapula is distinctly characterized by a very flat and strongly curved longitudinal ridge.

Coracoid

The coracoid is a low convex plate of slightly different contour. The plate is reinforced enormously towards the shoulder joint. The curved ventral rim is thin, it ends below the shoulder joint, a point at which the rim has become considerably thickened and was probably connected with the anterior end of the sternal plate. The Fo. obturatorium (= obturator foramen) pierces the plate obliquely behind and slightly below the center of the suture between coracoid and scapula it in such a way that its canal approaches the suture medially.

Brachiosaurus brancai
(Fig. 1 a, b)

The right coracoid of the mounted skeleton (S II) from the Middle Saurian Marl has anteriorly been restored to a length of 84 cm, and is 45 cm wide; it must have been like an irregularly broad, oblong extended rhombus. The anterior end of the ventral rim is strongly thickened. The free outer rim of the blade is strongly rugose with the exception of the slightly inwardly curved rim between the facet of the shoulder joint and the anterior end of the ventral rim. The obturator foramen is wide. — In the anteriorly incomplete left coracoid Ki 74 from the Upper Transitional Beds (Plate XV, Fig. 3 a, b), which belongs to scapula Ki 94, the ventral end of the ventral rim is also clearly thickened. The oblong lateral exit of the obturator foramen is ca. 4.5 cm long. The coracoid Ki 74 a is 21.5 cm wide, it is 9.5 cm thick at the glenoid cavity.

Fig. 1 a, b. Right coracoid of *Brachiosaurus brancai* S II. a lateral view, b surface of suture with the scapula. fogl = glenoid fossa. 1/10 of natural size.

Fig. 2. Right coracoid of *Dicraeosaurus hansemanni* dd 181; lateral view. 1/6 of natural size.

Dicraeosaurus hansemanni JAN.
(Fig. 2)

Three coracoids are present from excavation site dd in the Middle Saurian Marl that are of similar size and quite similar to each other, as far as deformation has not altered the shape; they belong most likely to the skeletal remains of *D. hansemanni* that were found at this site. The shape is altogether longish elliptical. In the right coracoid dd 181, the best preserved one, the anterior end of the ventral rim, which projects with an angular contour, is distinctly reinforced. A notch close to the anterior end of the ventral rim is striking. This notch is also present in the second coracoid, although this section is not preserved in the third one. Coracoid dd 181, the anterior end of which was probably elongated by distortion, is 40 cm long, 29.5 cm wide, and it is 14 cm thick at the glenoid cavity.

Sternum

The sternum of sauropods is formed by a pair of plates. The presumed anterior end of the plates is reinforced by thickening, or, as in titanosaurs by a crest; this indicates clearly that a strong cranially directed connection existed here, obviously a connection with the coracoid, namely with the reinforced anterior end of its ventral rim. In agreement with the slightly concave side of the sternal plate, the vault of the plate must be regarded as the dorsal one.

The largest part of the rim of the plate is more or less rough to tuberose, which indicates the attachment of cartilage. It is only on the medial side that the rim is smooth is and curves distinctly inward to an extent that differs within the genera, almost along the overall rim (see Baron VON HUENE 1929).

Only the rim can be considered for a connection with the cartilaginous ventral sections of the dorsal ribs, as long as the rim is rugose and tuberose, not its smooth section. Hence, it can be concluded that the smooth, concavely contoured section of the rim represented the medial side of the plate. A gap that was free of cartilage or bone substance must have existed between both plates. Concerning the question of the orientation of the plates, the position in which the sternal plates of *Monoclonius cutleri* were found in the skeleton, as figured by B. BROWN (1917, Plate 16), has to be considered. According to this position, the thickened and narrowed end of the plates was directed anteriorly, contrary to the conception of HATCHER (1901), who considered for *Diplodocus* the opposite orientation as the correct one.

Fig. 3. Left sternal plate of *Brachiosaurus brancai* S II.
Ventral view. 1/10 of natural size.

Brachiosaurus brancai

(Fig. 3; Tab. 2)

The right sternal plate of the reconstructed skeleton is almost completely preserved, the lateral rim is partially missing in the left one. The ventrally weakly convex plate has to some degree the shape of an ellipse, in which the lateral rim is strongly curved, the medial rim, on the other hand, is rather straight and only slightly curved inwards. The maximum width lies slightly anterior to the center. The medial rim is thin, usually not stronger than 1 cm, the lateral rim is in average as double as thick, it is in the proximal half covered with very strong tuberosities, farther dorsally it is smooth. The posterior rim is wide with a slightly transversely positioned weak swelling, it is slightly tuberose. The proximal end is bend medially and strongly reinforced; here the elongated thickened area is present on the dorsal surface a longish thickening, from which a flat, wide swelling runs almost to the distal end. In proximal view the proximal end forms an obtuse angled triangle, which is about 15 cm high.

Table 2: Measurements of sternal-plates of *Brachiosaurus brancai* (Skeleton S II).

	Greatest length	Smallest width at about mid-length cm	Thickness at proximal end cm	Thickness at rim		
				distal	medial	lateral
Right sternal plate	104(+)	54+/-	15+	4.7	—	1.2
Left sternal plate	110	50	17.5	5.0	1.7	1.5

The about 70 cm long sternum of *Camarasaurus supremus* figured by OSBORN & MOOK (1921, fig. 66) is very similar to the sternum of *B. brancai.* However, it is considerably wider in the juvenile *Camarasaurus lentus* (GILMORE 1925).

The 110 cm long sternal plate of *B. brancai* exceeds significantly in length the one of *C. supremus* which measures only about 70 cm.

Barosaurus africanus
(Fig. 4 a, b)

The completely preserved sternal plate k 35 from the excavation site in the Upper Saurian Marl, which produced remains of *B. africanus*, is on one side clearly flat concave, on the other side mainly flat convex. The circumference of the plate is relatively oval. The narrow anterior end is thick and reinforced by a swelling, which flattens out towards the sides into the dorsal surface. The plate broadens gradually from the anterior end over about 2/3 of the total length towards the wide posterior end; the contour is irregularly rounded in the last third, with two very obtuse-angled corners. The anterior end is covered in very rough tuberosities, a straight tuberose rim continues on the lateral side, which is getting less rugose in posterior direction, but on the right side it is in parts again very tuberose. The medial rim is characterized by being totally smooth over about half of the length, slightly sharpened and concave. The sternal plate is 32.5 cm long, at the narrow end about 12 cm wide and at the wide end 20 cm wide; the anterior end is 6 cm thick; the rim is about 1.3 cm thick in the finely rugose section, at the thicker point about 2 cm.

The sternum of *Diplodocus* is, as the cast of *D. carnegii* shows — especially in the left sternum — very similar to the one of *Barosaurus africanus*, only the anterior end is slightly narrower.

Fig. 4 a, b. Right sternal plate of *Barosaurus africanus* k 35. — a ventral side. b dorsal side. 3/20 of natural size.

Forelimb

Humerus

The humerus of sauropods is formed by a wide, plate-like proximal section with a flat shovel-shaped depression on the adductor side, by a less widened, flattened, and thick distal section, on the abductor side of which extends in a longitudinal, proximally tapering off depression (fossa M. anconeai = M. anconeus fossa), and by a variably long, pillar-like shaft with a roundish to a short-elliptical cross-section. The proximal end is strongly twisted along the vertical axis against the distal end; this twist, which is hardly ever well-preserved because of distortion, can amount up to 45°. The end surfaces of the humerus are usually imperfectly developed due to incomplete ossification of the cartilaginous cap. The proximal articulation of the humerus is distinguished as a roundish swelling, protruding toward the abductor side, which is slightly offset medially from the center of the end surface, and which passes without noticeable border or ledge into the narrow lateral and into the broad and short medial part of the end surface. The lateral rim of the proximal section of the humerus curves medially over a long distance and carries the unusually narrow and long processes lateralis (= lateral process). In particular the particular surfaces are incompletely ossified; usually only the lateral condyle that articulates with the radius is clearly recognizable. The surface is variably ossified in different genera. It can be present on the adductor side as a uniform protrusion which clearly shows the shape of a condyle, but usually the circumference of the bony core is reduced due to incomplete ossification. The cartilage also extends into the ossified center of the lateral condyle and divides it into two parts that are separated by a groove. The condyle consists in the extreme case (*Brachiosaurus*) of two small protrusions, widely separated by a gap located on the adductor side above the distal rim, which signifies most imperfectly a much more extensive, cartilaginous condyle.

The *Brachiosaurus*-like, only 4.5-foot-long humerus of *Pelorosaurus conybeari* MANT. from the Wealden of Tilgate Forest, Sussex (MANTELL 1850, Pl. 21) shows a rare case of good preservation of the smooth surfaces of the joint. Obviously, the lateral condyle of *Titanosaurus australis* LYDEKKER from the Upper Cretaceous of Patagonia (Baron VON HUENE 1929, Pl. 10) and the titanosaur *Magyarosaurus dacus* (v. NOPSA) are also ossified with smooth articular surfaces (Baron VON HUENE 1932, Pl. 54, fig. 5a).

At the distal end of the humerus, a medial condyle is usually not developed. In the cases of complete ossification a facet-like smoothness seems to have been present at the medial corner of the distal end, as in the above-mentioned *Pelorosaurus* or in titanosaurs. A real condyle-like protrusion on the adductor side, as in the lateral condyle, is also not expressed in these cases, but an articulation of the medial condyle with the longer medial wing of the proximal section of the ulna can always be assumed with certainty.

The variable degree of ossification in the articular facets might be connected with the variable constitution of the individuals. It can be assumed that certain ecological factors influenced the degree of ossification in sauropods, for whom an amphibious life style is likely.

Outline of the distal end of the humerus of *Brachiosaurus brancai*.
Fig. 5 right humerus t 7, Fig.. 6. left humerus Y 12. 1/10 of natural size.
col = lateral condyle.

Brachiosaurus brancai
(Fig. 5, 6; Suppl. A Fig. 1a-e; Pl XVI, Fig. 1-4; Tab. 3)

The overall shape of the humerus is characterized by its elongated contour, which is due to the significant length of the shaft, and also by the shortness of the relatively insignificantly widened proximal section. The proximal outline is characterized by its moderate curvature, which drops off short and steep medially. The distal section widens gradually to the thick end of the joint, which, if it was undistorted, has a more or less trapezoidal contour. The smallest cross-section of the shaft is approximately at mid-length, which is, in undistorted specimen, about circular.

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F o r e l i m b s — *Brachiosaurus brancai*

Fig. 1 a-e. Right humerus S II: 1 a Adductor side, 1 b abductor side, 1 c medial view, 1 d proximal view, 1 e distal view.
Fig. 2 a-d. Right ulna S II: 2 a view vertically onto the medial wing, 2 b view vertically onto the lateral wing, 2 c proximal view, 2 d distal view.
Fig. 3 a-d. Right radius S II: 3 a abductor side, 3 d vertical view on the abductor side, 3 c proximal view, 3 d distal view.

col = lateral condyle — all figures are 1/15 of their natural size.

Humeri, proximal and distal sections of which are not, or only somewhat, pressed into the same plane, show an S-shaped curvature. In a very small, ca. 29-cm-long humerus (Ki 130), both ends are twisted against each other at an angle of about 35%.

The head (= head) does not rise above the proximal end surface, it is positioned slightly medial to the midline and overlaps onto the abductor side to a small extend. The lateral process projects steeply from the lateral rim and shows a very tuberose crest, the center of which contributes to about 1/3 of the total length. The rudimentarily developed lateral condyle is very characteristic; it consists of two tuberosities completely divided by a groove; this pair of tuberosities is located slightly closer to the lateral than to the medial rim (Suppl. A Fig. 1 e). The M. anconeus fossa is wide and long.

Table 3: Measurements of the humerus of *Brachiosaurus brancai.*

	Find	Side	Length		Proximal width		Distal width		Smallest width of shaft	
			cm	%	cm	%	cm	%	cm	%
Upper Saurian Marl	No. 4		130	100	42.5	33	32.5	25	16.5	12.5
	I 1	r	169	100	57	33	47	28	23.5	14
	F 2	r	173	100	51.5	30	45	27	12.5	12.5
Upper Intermediate Beds	XV 3		210	100	55+	26+	49+	23-	23	11
Lower Saurian Marl	XX 19	l	69	100	20.5	30	18.5	27	8	11.5
	t 7	r	153	100	48	31	41	27	19	12.5
	J 12	l	170	100	51.5	30	44.5	26	18.5	11
	S II	r	213	100	59	28	51	24	24.4	11.5

In the five humeri from the Middle Saurian Marl, with lengths from 69 cm to 213 cm, the measurements resulted in proximal widths that are 28% to 31% of the length as well as distal widths that are 24% to 27%, in the six humeri from the upper with lengths from 130 cm to 173 cm the measurements show proximal widths of 30% to 33% and distal widths of 25% to 28% of the length. The relation of proximal width to length, which determines eventually the slender or stronger appearance of the humerus, is therefore slightly higher in the humeri from the Upper Saurian Marl than in the ones from the Middle Saurian Marl. Accordingly, the overall skeleton of the geologically older animals should have been built slightly lighter than that of the geologically younger ones.

The humerus of the type species of the genus, *Brachiosaurus altithorax* RIGGS (1904) from the Morrison Beds, is so similar in shape to the broad specimens of *Br. brancai* that a detailed comparison is superfluous; at a length of 204 cm the proximal width is 65 cm, which is 32% of the length. The width of the distal end is not preserved, the smallest width of the shaft, which amounts to 28 cm = 14 % of the total length, is only insignificantly larger than in the East African species. There is no doubt about the generic affiliation, especially as the shape of the associated vertebrae and the shape of the ilium are very similar. — *B. atalaiensis* from the Kimmeridgian of Portugal has been recently erected as the third species of *Brachiosaurus* by A. F. DE LAPPARENT and G. ZBYSZEWSKI (1957). The figure of the proximal half of a left humerus shows the same contour as in the two other species. The authors estimate of the base of the position of the lateral process at a 101 cm long and 55 cm wide right proximal half an overall length of at least 205 cm, which should be close to the original length.

C o m p a r i s o n s : For a recognition of probable relationship between the sauropod faunas from the Tendaguru Beds and those from England, the comparison of the characteristically slender humeri of *Brachiosaurus* with humeri known from there is particularly valuable. A moderate slenderness shows already in the 77 cm long humerus of the older *Centiosaurus oxoniensis* PHILLIPS (HULKE 1869 and Baron VON HUENE 1927) from the Bathonian, however, the distance to *Brachiosaurus* is still significant, and other differences in the development of the limbs and limb girdles do not indicate a closer relationship. But there are also humeri known from England that are quite similar to those of *Brachiosaurus*. Such an extended, but proximally and distally slightly wider humerus, 79 cm long, distally 23 cm (= 29% of length) wide, from the Kimmeridgian of the Dorset coast was named *Pelorosaurus* ("*Ischyrosaurus*") *manseli* HULKE (1869). The division of the ossified center of the lateral condyle into two separate bosses is comparable to the condition in *Brachiosaurus* but is more strongly developed. The medium-sized humerus from the Kimmeridgian of Weymouth (Dorset) described by HULKE (1874) as *Ornithopsis humero-eristatus* [*sic*: *humero-cristatus*] shows the same overall shape; it consists of two pieces and was originally about 1.5 m long. This humerus can probably be considered conspecific with the aforementioned one. — Definitely similar to *B. brancai* because of the remarkably well-developed, smooth medial articular surface mentioned above is the slightly wider type of a right humerus named *Pelorosaurus conybeari*, from the Wealden of Sussex, which MANTELL (1850, Plate 21) illustrated. Because of incomplete preservation the proximal end is not comparable with certainty, but it could belong to a species of *Brachiosaurus*. The similarity of the mentioned English humeri with those of *Brachiosaurus* gains a special significance by the fact that a dorsal vertebra from the English Wealden (J. W. HULKE 1880, Plate 4, fig. 5) shows so much conformity with the corresponding one of *Brachiosaurus*, that I could not exclude a generic assignment to *Brachiosaurus* (JANENSCH 1950, p. 74).

Barosaurus africanus

(Suppl. B. Fig. 1 a–d; Tab. 4)

The humerus of *Barosaurus africanus* VIII 1 from the Upper Saurian Marl (Plate XVI, Fig. 5) is of a moderately short, strong build, especially in its distal section; the anconeal fossa is here long and narrow. The proximal contour shows a rather strong curvature, which descends steeply in the medial direction. The head is positioned slightly closer toward the medial corner than to the lateral, and descends increasingly steeply medially. The lateral process does not extend ventrally to the midlength of the bone. The distal end is clearly characterized by the weakly developed lateral condyle, which is divided by a medial furrow positioned distinctly lateral to the center of the distal contour (Suppl. B Fig. 1b).

Table 4: Measurements of the humerus of *Barosaurus africanus*.

	Specimen	Side	Length		Proximal width		Distal width		Smallest width of shaft		
			cm	%	cm	%	cm	%	cm	%	
Upper	G 91	r	43.5	100	19.5	45	14.5	33	7.5	17.5	
Saurian Marl	k 37	r	97	100	44.5	46	32	33	15	15.5	
	VIII 1	r	97.5	100	43.5	45	31.5	33	16.5	17	
	A 1	r	99	100	44	44	33	33	17	17	
Upper	Ki 130		27	100	10	37	8	30	3.5	13	
Intermediate Beds	IX x9	r	38	100	15.5	40	—		5	13	var.
	Ki 68	l	64	100	24.5	38	19	29	9	14	*gracilis*
	Ki 3	l	75	100	27	36	20.5	27	10	13.5	
	XI a 7	l	80.5	100	32	40	25.5	32	12.5	15.5	

The humeri of *B. africanus* from the Upper Intermediate Beds (Ki 68a, Ki 3 and several more) (Plate XVI, Fig. 6, 7) are distinguished from the one from the Upper Saurian Marl by its slimmer shape, just as the femur, as demonstrated by the ratio of proximal width to total length. For 4 humeri of *B. africanus* from the

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H u m e r u s — *Barosaurus africanus*

Fig. 1 a–d. right humerus k 37: 1 a abductor side, 1 b adductor side, 1 c lateral view, 1 d proximal view.

Tornieria robusta

Fig. 2 a–d. left humerus P 8: 2 a abductor side, 2 b adductor side, 2 c medial view, 2 d proximal view.

Dicraeosaurus hansemanni

Fig. 3 a–d. right humerus Q 11: 3 a abductor side, 3 b adductor side, 3 c lateral view, 3 d proximal contour.
col = lateral condyle — all figures 1/10 of natural size.

Upper Saurian Marl with lengths of 43.5–99 cm, the measurements show proximal widths of 44–46% of the length, distal widths of a regular 33%, and minimum shaft widths of 15.5–17.5%. Among humeri from the Upper Intermediate Beds the measurements from seven specimens with with lengths of 27–88 cm resulted in proximal widths of 36–44%, distal widths of 27–32%, and minimum shaft widths of 13–16% of the length, i.e. distinctly smaller than humeri from the Upper Saurian Marl.

The type of the species, which is distinguished by slimmer limbs, together with those parts of the skull of *B. africanus* found at site Ki, is named var. *gracilis* of this species.

The humerus of *Diplodocus*, which is closely related to *Barosaurus*, is quite similar to that of *B. africanus*, especially when the humeri of the slender type of the African species is compared with the 108-cm-long humerus of *Diplodocus* figured by OSBORN and GRANGER (1901, fig. 3B). The similarity includes the moderate length of the shaft, proximal contour, and also the development of the bony core of the lateral condyle with its notch and its distinctly laterally shifted position.

Dicraeosaurus

The only humeri that can be referred to the genus *Dicraeosaurus* are short; they can be clearly distinguished from the humeri of the other short-shafted genera from the Tendaguru Beds, *Barosaurus* and *Tornieria*, by the uniform lateral condyle, which is wider than in *Barosaurus* and positioned almost exactly above the center of the lower rim of the distal end, and by the anconeal fossa being short and wide above the distal end of the abductor side.

Dicraeosaurus hansemanni

(Suppl. B. Fig. 3 a- d; Pl. 5)

The overall shape of the right humerus Q 11 in the mounted skeleton, and the right humerus St 33 also originating from the Middle Saurian Marl, is short, wide and relatively thick at the proximal end but very wide in the distal part. The shaft is very short, but not as short as in *Tornieria*. The moderately curved proximal contour curves strongly downward medially. The head forms a strong roundish swelling on the midline of the abductor side. The strongly protruding, long lateral process projects ventrally already below the shaft midlength. The anconeal fossa is wide. The lateral condyle is a broad tubercle, it covers almost half the width of the distal end and is only slightly shifted laterally from the center; a division is indicated by a central depression (Suppl. B Fig. 3 b).

The humerus is less robust than that of *Tornieria robusta*, the lateral condyle is more centrally positioned, and the shaft wall lateral to it is not concavely depressed. The shaft is shorter than in *Barosaurus africanus*.

Table 5: Measurements of the humerus of *Dicraeosaurus hansemanni*, *D. sattleri* and *Tornieria robusta.*

Species	Horizon	Specimen	Side	Length		Proximal width		Distal width		Smallest width	
				cm	%	cm	%	cm	%	cm	%
Dicraeosaurus	Upper	O 3	r	61	100	24.5	40	18.5+	30+	8.5	14
sattleri	Saurian Marl	ab 1	l	62	100	26.5	42.5	18.5	30	8	13
Dicraeosaurus	Lower	St 53	r	18.5	100	8	44	6.5	35	3	16
hansemanni	Saurian Marl	Q 11	r	74	100	35	47	26	35	12.5	17
Tornieria	Upper										
robusta	Saurian Marl	P 8	l	89	100	40.5	45.5	32.5	36.5	—	

Dicraeosaurus sattleri

(Tab. 5)

The left humerus ab 1 from the Upper Saurian Marl (Pl. XVI, Fig. 8) and the right humerus O 3 from the same beds are significantly more lightly built than that of *D. hansemanni*; the proximal and distal widths are slightly smaller, the shaft is straighter and thinner (even when taking into account the abrasions by weathering of the present specimen). The proximal profile is uniformly weakly curved. The lateral condyle has a relatively wide circumference, shows a centered notch, and its position is only marginally medial to the center. The wall of the lateral condyle slightly depressed on both sides. The assignment of this humerus to *D. sattleri* is confirmed by the association of vertebrae of the same species at excavation site O in the Upper Saurian Marl. The slender build of the humerus harmonizes definitely with the gracile construction of the whole skeleton of this species, just as the more robust form of the humerus of *D. hansemanni* corresponds well with the stronger built of the skeleton of this species.

Tornieria robusta E. FRAAS
(Suppl. B Fig. 2 a-d; Tab. 5)

Left humerus P 8 from the Upper Saurian Marl, weathered externally but still well preserved in overall shape, is very robustly built in accordance with the habit of the whole limb skeleton. The shape is short and stocky, much bulkier than the humeri of other sauropods from the Tendaguru Beds. The shaft is short, the distal section is very short and broad. The proximal profile in the larger lateral section is almost straight, it drops steeply laterally. The head is positioned slightly medial to the midline. The distal section shows distinct characters: the lateral condyle, divided in two parts, lies almost exactly in the center and protrudes strongly toward the adductor side, more than in other genera from the Tendaguru Beds; the surface next to the condyle is distinctly depressed. The lateral process extends downward almost to midlength of the bone.

Short Humeri in Genera from the Morrison Beds

The short humeri of the very well-known North American genera *Camarasaurus* (= *Morosaurus*) and *Apatosaurus* (= *Brontosaurus*) exhibit no particular morphological traits in their overall shape compared with those genera from the Tendaguru Beds that are also characterized by a short humerus. It should be pointed out that both *Apatosaurus louisae* HOLLAND and *Apatosaurus excelsus* (MARSH) (GILMORE 1936, figs. 11 and 33) possess a lateral condyle divided by a notch, distinctly shifted laterally, and similar to *Diplodocus* and *Barosaurus*. The illustration of the humerus of *Camarasaurus supremus* COPE in OSBORN & MOOR (1921, fig. 83) shows only an indistinct indication of the lateral condyle.

Forearm

The forearm in sauropods has a characteristic mode of articulation between the ulna and radius. The pillar-like, more or less strongly backward-curved distal section of the ulna is reinforced proximally by two thick walls, extending higher on the adductor side, and these are positioned at a right angle or less toward one another and enclose an extensive longitudinal groove. This groove becomes deeper and wider proximally and can extend beyond the midlength. The proximal end of the radius fits exactly into this longitudinal groove, so that the ulna and radius form a united, strong pillar. The medial wing of the ulna always protrudes farther than the lateral one, its flat upper rim is more or less distinctly depressed longitudinally, the shorter upper rim of the lateral wing, on the other hand, is always continually slightly arched transversely. As the concavity of the upper rim of the medial wing appears to be found continually, it must be of importance. It is postulated that this flatly depressed section represents the sliding surface articulating with the medial corner of the distal end of the humerus, as already discussed in the description of the humerus. On the radial side, above the pillar-like distal section, an insertion area for ligamentous or also muscular tissue which connected the radius and ulna is visible; this area is developed as a more or less rugose swelling or only as a set off surface. The posterior ascending edge of the proximal section is always broadly rounded, an olecranon at its proximal end is hardly ever even indicated. The narrowest area of the shaft lies below midheight and the exact position varies in the genera.

The radius is pillar-shaped, distinctly thickened at both ends, at the distal end more than the ulna; the proximal end surface is more or less distinctly concave for the articulation with the lateral condyle of the humerus. The distal end surface, on the other hand, is always strongly convex. On the medial side a strong, longitudinal bulge lies above the distal end, there it served as the insertion area for the tissue that connected the radius and ulna.

The robustness of the forearm bones changes considerably in accordance with the different physical construction of the animals, as demonstrated by e.g. a comparison of these bones in the gracile *Barosaurus africanus* with the very robust ones of *Titanosaurus australis* LYD. and *T. robustus* V. HUENE.

Ulna

(Tab. 6)

Brachiosaurus brancai

(Suppl. A. Fig. 2 a- d)

The proximal section positioned above the thinnest part of the shaft is more than 2.5 times as long as the distal section. It curves only indistinctly backward. The radial groove is very wide. The cross-section of the shaft is more or less triangular at the thinnest point. The medial wing protrudes in a characteristic fashion much farther than the lateral wing and encloses a right angle with the latter; its proximal rim is distinctly longitudinally concave, the end surface of the lateral wing is clearly transversely curved. The distal end surface shows a high, semicircular outline and is only weakly convex.

Table 6: Measurements of the ulna in *Brachiosaurus brancai*, *Barosaurus africanus*, *Dicraeosaurus hansemanni*, *D. sattleri*, and *Tornieria robusta.*

Species	Horizon	Specimen	Side	Length		Proximal width				Distal width	
						medial wing		lateral wing			
				cm	%	cm	%	cm	%	cm	%
Brachiosaurus brancai	Middle Saurian Marl	S II	r	130	100	44.5	34	37.5	29	22.5	17
Barosaurus africanus	Upper Saurian Marl	k 38	l	74	100	25.5	34	21.5	29	15.5	21
	Upper Intermediate Beds	Ki 69	6	43.5	100	15	35	13	30	—	—
	Upper Intermediate Beds	Ki 63	r	47.5	100	16.5	38	14	30	—	—
Dicraeosaurus sattleri	Upper Saurian Marl	O 7	r	40.5	100	15.5	38	12.5	31	8	20
Dicraeosaurus hansemanni	Middle Saurian Marl	Sa 27	l	47	100	15.5+	33+	—	—	8.5	18
Tornieria robusta	Upper Saurian Marl	P 12	l	67	100	32.5	48	28.5	42	—	—

Barosaurus africanus

The thinnest part of the shaft lies in the robust type k 38 (Pl. XVII, Fig. 1 a-c) at about 1/4 of the height, in the gracile type var. *gracilis* (Pl. XVII, Fig 2 a, b; 3) at about 1/3 of the height, and is here flattened on the radial side of the shaft. Only the moderately reinforced distal section is distinctly bent backward. The proximal end surface of the more robust type (Pl. XVII, Fig. 1 c) is heavily grained and is much more expanded than in the more gracile type. In both cases the medial wing does not protrude considerably farther than the lateral one. The proximal end surface shows that the wings were much thicker-walled and the longitudinal groove deeper in the robust type (Ki 63; Pl. XVII, Fig. 3). The end surface of the gracile type is shaped as an equilateral triangle and is narrower.

Dicraeosaurus sattleri

The total shape of ulna 07 (Pl. XVII, Fig. 5 a–e) is relativly strong, the narrowest point lying at about 1/3 of the height. The ventralmost section of the shaft curves distinctly backward over a short distance. The proximal end surface is similar to that of *Barosaurus africanus*, but the longitudinal groove is very shallow (Pl. XVII, Fig. 5 c). The distal end surface exhibits almost exactly the contour of an equilateral triangle.

Tornieria robusta

The proximal section of the left ulna P 12 (Plate XVII, Fig. 7 a, b), the shaft of which is thinned due to severe weathering, is very stocky; the proximomedial wing is strongly longitudinally concave and does not protrude farther, but is thicker than the lateral wing, the end surface of which is distinctly transversely convex. Both wings together enclose nearly a right angle; the radial groove is moderately deep. The thick shaft has a rather flat distal end surface with a semicircular contour, which is slightly indented on the adductor side. The proximal section is 32.5 cm wide above the medial wing, dorsal to the medial [*sic*, *lapsus viz*. lateral] wing 28.5 cm wide. The length of the ulna is 67.5 cm. The ulna of titanosaurs, by the way, exceeds the stockiness of this specimen by far.

Radius

(Plate 7)

Brachiosaurus brancai

(Suppl. A Fig. 3 a-d)

The radius is slim, the shaft is continually broad up to the short, widened proximal and distal end sections. The thinnest point of the 124 cm long right radius of skeleton S II lies about 43 cm distal to the proximal end and is here 13.5 cm wide and 10.5 cm thick. The distinctly concave proximal end surface is oval, extended into an acute angle 30.5 cm long and 21.5 cm wide, the distal end surface is slightly concave, elliptical, 26.5 cm long and 16.5 cm wide.

Table 7: Measurements of the radius of *Brachiosaurus brancai*, *Barosaurus africanus Tornieria robusta.*

Species	Horizon	Specimen	Side	Length		Proximal width		Distal width		Smallest width of shaft	
				cm	%	cm	%	cm	%	cm	%
Brachiosaurus brancai	Upper Saurian Marl	S II	r	124	100	30.5	24.5	26.5	21.5	13.5	11
Barosaurus africanus	Upper Intermediate Beds	Ki 70	l	49.5	100	9.5	19	9.5	19	5	10
Dicraeosaurus sattleri	Upper Saurian Marl	G 83	l	45.5	100	11	24.5	10	22	6.5	14.5
Tornieria robusta	Upper Saurian Marl	P 11	l	62	100	18.5	30	20.5	33	—	—
	Upper Intermediate Beds	IX v 3	l	48.5	100	14	29	12	25	6.5	13

Barosaurus africanus

The radius Ki 70 from the Upper Intermediate Beds (Pl. XVII, Fig. 4), the only available radius representing the gracile type, is very slim, it widens over a short distance toward the proximal end and very gradually toward the distal end. The proximal end surface has the contour of an irregular right-angled triangle, the overall cross-section of the proximal part of the radius is similar. Three definite main edges can be distinguished, one on the abductor side below the proximal end, one in the central section of the shaft on the lateral side, a third one medially on the proximal half of the shaft; in the distal third is the insertion area for the ligaments or musculature respectively that connected the bone with the ulna.

Dicraeosaurus sattleri

Radius G 83 from the Upper Saurian Marl (Pl. XVII, Fig. 6) probably belonging to *D. sattleri* exhibits a strong shaft that has an elliptical cross-section in its middle section (67 x 41 mm), and which strengthens only moderately toward both ends. The relatively narrow oval proximal end surface is slightly concave, the longish oval distal end surface is somewhat convex. The edges are poorly developed, and an insertion area for the ligament attachments is also not recognizable.

Tornieria robusta
(Pl. XVII, Fig. 8)

The proximal end surface of the left radius P 13 from the Upper Saurian Marl, of which only in the end sections are well preserved, is strongly concave with a triangular contour. The strongly concave distal end surface, especially on the medial side, shows a rounded rectangular, medially slightly wider contour.

The small, strongly curved left radius IX v 3 from the Upper Intermediate Beds is considerably slimmer, it shows on its proximal, very strongly reinforced end a distinctly concave end surface; the distal third is thickened to a club by the extensively developed rugose ligament insertion area. In the middle section of the radius, three rather characteristic sharp slanting edges are accentuated on the abductor side.

Manus

The architecture of the manus in sauropods is characterized as a variably high, steeply positioned pillar, which had the function of supporting the weight of the body, but, in contrast to the pes, partook less in the task of moving the body forward. Connected with this special function is the fact that the phalanges are in the majority strongly reduced. The first digit always still has the normal number of two phalanges, the other digits having been reduced to the first phalanx in *Brachiosaurus* and *Diplodocus*, but the second toe in *Tornieria* shows still a rudimentary second phalanx, as do the second and third digit in *Apatosaurus louisae* GILMORE (1936). Only the second phalanx of the first digit is developed as a strong claw, but it may also be reduced in size (*Brachiosaurus*); however, the first phalanges of the lateral digits can be reduced in size and shape, as is the case in *Tornieria*. The way the stress of body weight is distributed in the manus is expressed in the different strengths of the metacarpals, although the size of the end surface of the metacarpals represents approximate and certainly not exact sizes. The comparison of these end surfaces in different genera suggests not inconsiderable differences in stress distributiona. Mc I to Mc IV are relatively equal in *Brachiosaurus*, whereas Mc V is considerably weaker. Mc I and Mc III are relatively strong in *Diplodocus*, but Mc V is stronger. Differing from these genera, Mc I and Mc V are strong in *Tornieria*, and Mc III and Mc IV are distinctly weak.

The first two Mc are the strongest in *Apatosaurus louisae*, the last two are distinctly weaker, and Mc III is still weaker. Among titanosaurids, the first three Mc show relatively equal proximal end surfaces, and Mc IV and Mc V are not much smaller in *Antarctosaurus wichmannianus* (Baron VON HUENE 1929, Fig 1. Pl. 34). The proximal end surfaces of Mc I to Mc IV are of similar size in *Laplatosaurus* [*sic*: *Laplatasaurus*] *araukanicus* VON HUENE (1929, Pl. 25, fig. 1 and 10) .

Carpus

In some sauropod genera the carpus apparently includes only one ossified element. This is true for *Brachiosaurus* and *Tornieria*, as well as for *Apatosaurus* from the Morrison Beds. Both cases are documented for *Diplodocus* and *Camarasaurus*. Although GILMORE (1936, p. 219) assumes only one carpal bone for *Diplodocus*, O. ABEL (1910) reconstructed earlier a manus skeleton with two carpals, as did H. F. OSBORN & W. GRANGER (1901). E. S. RIGGS (1901, Pl. 40) found only one plate-like carpal in a manus skeleton of *Camarasaurus grandis*, but reconstructed two of these in a mounted limb skeleton (1901, Pl. 41; ? different specimen). Baron VON HUENE (1929) described two carpals for the titanosaurid *Argyrosaurus superbus* LYDEKKER from the Upper Senonian of Patagonia. In contrast to the flat plate-like shape in *Brachiosaurus*, the thick plate-like shape in *Diplodocus*, and the irregularly plate-like form in *Tornieria*, the carpal bone in *Apatosaurus louisae* (GILMORE 1936) is distally flat, but proximally irregularly raised to a low cone; according to HATCHER (1902) in *Apatosaurus excelsus* the carpal bone is disc-shaped, anteriorly sharply edged, posteriorly considerably thickened; of two shallow concave depressions the larger one would have articulated with the radius, the smaller one with the ulna. The carpal of *Tornieria* (Pl. XXIII, Fig. 5 a, b) shows also a corresponding partitioning into two planes for ulna and radius, arguing for a single carpal.

It might be possible that in these cases in which a single carpal occupies only a limited part of the width of the manus, a second carpal was present, the existence of which has either so far not been proven, or it was only cartilaginous. It has to be assumed that the carpal bone probably developed by fusion of several small elements; but from which elements is not yet clear. OSBORN & GRANGER (1901) assumed that three small bones found together with a carpal bone in a manus skeleton of *Apatosaurus* (No. 276 of the Amer. Mus. Nat. History) represent elements from the distal row of the carpus.

Brachiosaurus brancai

No carpal bone was found with the manus of skeleton S II, but at excavation site R right and left carpal bones were found among the remains of a *Brachiosaurus*; however, these are lost.

"Both specimens essentially match each other. These are flat bones with the contour of an almost equilateral triangle with rounded corners and a diameter of 12 to 13 cm perpendicular to the sides. The maximum thickness of about 5.5 cm is at one corner, otherwise the average thickness is 4 cm. The rims are pitted, only at the thickest corner the vertical wall is more or less smooth over a distance of 6 cm. One of the main surfaces is sculptured in a pitted pattern, especially coarse in a zone along one side; the other surface is smooth with a flat bulge in the center." (after W. JANENSCH 1922, p. 475).

Tornieria robusta

The almost complete left carpal P 11 (Pl. XXIII, Fig. 5 a, b), from the Upper Saurian Marl was found at excavation site P among a lot of the predominately strongly weathered limb bones of two individuals, namely spatially close to phalanges of a left manus.

The carpal represents a wedge-shaped plate of weakly oval contour, which is 16 cm long and 11 cm broad. One end is 7.5 cm thick and shows a coarse-pitted rim; it flattens out to 3 cm towards the opposite end. The longitudinal rim that is closer to the thick end protrudes in a slightly obtuse-angle. Although one main surface is relatively level, the other one shows over two thirds of its length a shallow, bipartite depression, which articulated with one of the forearm bones and therefore indicates the proximal side; the other third is slightly convex, the pitted surface spreading onto it from the rim.

M a n u s — *Brachiosaurus brancai*

Fig. 1 a–c. right manus S II (after W. JANENSCH 1922, fig. 5–7): 1 a view of the four inner digits, 1 b view of the four outer digits, 1 c contours of the proximal surfaces of the metacarpals.

Tornieria robusta

Fig. 2 a–d. right manus No. 5 (after W. JANENSCH 1922, fig. 1–4); 2 a view of the four inner digits, 2 b view of the three outer digits, 2 c contours of the proximal surfaces of the metacarpals, 2 d cross-section through the metacarpals distally to mid length.
Fig. 1 a- c 1/8 natural size, Fig. 2 a–d 1/5 natural size.

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Explanations to the figures see page 194 bottom.

Metacarpus and toes

Brachiosaurus brancai
(Tab. 8)

Right manus of skeleton S II
(Suppl. C Fig. 1 a–c)

The manus belongs to the larger of the two individuals of the species, of which associated remains were found at excavation site S in the Middle Saurian Marl. The manus has already been described in my earlier publication (JANENSCH 1922); this description is hereby referred to, but the relevant figures are reproduced here; they are supplemented by figures of the individual phalanges from the same manus (Pl. XVIII, Fig. 8–13).

Table 8: Measurements of the metacarpus of *Brachiosaurus brancai* S II and R.

	Mc I				Mc II				Mc III				Mc IV				Mc V			
	S II		R		S II		R		S II		R		S II		R		S II		R	
	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%
Length	59.5	100	36.5	100	63.5	100	40	100	59.5	100	39.5	100	57	100	36.5	100	49	100	31	100
Proximal width	21.5	36.5	15	40.5	12	19	82	20.5	16.5	27.5	(12±	33±)	14.5	25.5	—	—	7.5	15.5	5.5	17.5
Distal width	11	19	11	29.5	17	27	11	28	16.5	26	10.5	27	15	26	10.5	29	14	29	8.5	28

An additional contribution to the understanding of the manus delivers the almost complete right manus from excavation site R in the Upper Saurian Marl (Fig 7; Pl. XVIII, Fig. 1-17), in which right and left carpals were found, as has already been mentioned.

Fig. 7. Proximal view of the left metacarpus of *Brachiosaurus brancai* R. 1/5 of natural size.

The comparison of the measurements of the metacarpals of specimens S II and R show that the proportions of the length of the five Mc in R to the length of the corresponding Mc in S II is quite equal, amounting to 63% and 67%. The proximal width of the individual Mc in proportion to their lengths are, as the table of measurements shows, remarkably larger in R than in S II; the proportional figures are 40½% and 36½% for Mc I, 28% and 19% for Mc II, 33% and 27½% for Mc III (indeterminable for Mc IV), 17½% and 15½% for Mc V. These figures show that the metacarpals of manus S II from the Lower Saurian Marl are considerably slimmer than the Mc of manus R from the Upper Saurian Marl. The picture presented by the comparison of the distal widths of the Mc of both hand skeletons is more heterogeneous. Mc 1 of R shows a considerably larger width, the distal width is barely larger in Mc II and Mc III as in S II, Mc IV is again considerably wider, and Mc V, on the other hand, is considerably narrower than in S II. However, the proportional figures of the distal widths cannot change the fact that the Mc in S II are significantly slimmer in build than in R.

The overall cubic shape of phalanx I 1 (Fig. 8 a, b) is very characteristic for *Brachiosaurus*, as opposed to other genera. A small claw from excavation site XX in the Middle Saurian Marl (Pl. XXII, Fig. 4) is much more elongate, which might be considered as a juvenile character; it shows a short groove on each side of the distal section. The overall shape of II 1 is shorter in R, the two very unequally sized condyles arch considerably further proximally onto the dorsal wall in S II, and are also sharply separated on the plantar face. III 1 is significantly more elongate in S II than in R, the proximal surface is slightly lower. The distal facet shows a constant rounded profile, whereas it is very different in R, in showing a centered saddle-shaped depression, which results in the development of two condyles.

Fig. 8 a–c. right distal phalanx I 1 of *Brachiosaurus brancai* dy 52. 1/3 natural size.

IV 1 is not preserved in R, it is in S II definitely similar to III 1; the end facet is poorly differentiated, the condyles are hardly indicated. Phalanx V 1 is characterized by its distal curve, which gets narrower laterally and extends onto the narrow lateral end of the oval proximal surface, resulting in the laterally slanting distal profile. The phalanx is clearly in both manus skeletons similar, except that V 1 is much shorter in R and laterally more compressed in S II.

Claw No. 14 from the Lower Saurian Marl

The 4.5-cm-long small claw, which is very remarkable because of its low stratigraphic position, is low, proximally only 2.6 cm high and 1.8 cm thick. The claw gets only slightly dorsoventrally shorter and narrower toward the tip, which is abraded by weathering. The somewhat obliquely positioned proximal

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R i g h t m a n u s of *Tornieria robusta*

Metatarsals [*lapsus*: metacarpals]

Fig. 1 a–c. Mc I: 1 a dorsal view, 1 b lateral view, 1 c distal view.
Fig. 2 a–c. Mc II: 2 a dorsal view, 2 b lateral view, 2 c distal view.
Fig. 3 a–c. Mc III: 3 a dorsal view, 3 b lateral view, 3 c distal view.
Fig. 4 a–c. Mc IV: 4 a dorsal view, 4 b lateral view, 4 c distal view.
Fig. 5 a–c. Mc V: 5 a dorsal view, 5 b lateral view, 5 c distal view.

Phalanges

Fig. 6 a, b. I 1 : 6 a dorsal view, 6 b distal view.
Fig. 7a, b. I 2: 7 a lateral view, 7 b proximal view.
Fig. 8 a, b. II 1: 8 a dorsal view, 8 b distal view.
Fig. 9 a, b. II 2: 9 a dorsal view, 9 b distal view.
Fig. 10 a, b. III 1: 10 a dorsal view, 10 b distal view.
Fig. 11 a, b. IV 1: 11 a dorsal view, 11 b distal view.
Fig. 12 a, b. V 1: 12 a dorsal view, 12 b distal view.

All figures 3/10 of natural size.

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Explanation of the figures see page 196 bottom.

surface is slightly concave. On the slightly vaulted lateral wall extends a distinct curved, long groove at mid-height in the anteroventral direction, on the other flatter wall extends a shorter groove at the same height. This claw could be interpreted as the forelimb of a small sauropod, perhaps a juvenile *Brachiosaurus*.

Tornieria robusta
(Suppl. C. Fig. 2 a–d; Suppl. D Fig. 1–12)

The complete right manus without carpus. Isolated find specimen No. 5 from the Upper Saurian Marl. The manus was already described by me in an earlier publication (JANENSCH 1922). It is hereby referred to in this work. The figures are here reproduced; they are supplemented by illustrations of the individual elements of the manus skeleton.

Pelvis

Characteristic for the pelves of saurischian dinosaurs are the medially wide open acetabulum, the articular surface for the femoral head, which is developed like a ring a cut out of a spherical surface, formed by three elements. The pelvis was differentiated into various shapes due to variable stress from musculature and the demands of different habitats of the various subgenera. Therefore, the pelvic bones of sauropods are definitely characteristically developed, and are easily distinguishable from the pelves of other saurischians.

The ilium of sauropods is characterized by the considerable surface development of the dorsally steeply positioned blade, the height of which is variable in different genera and can be proportionally expanded in the preacetabular section (*Brachiosaurus*) due to the considerabe length of the drooping and curved proc. pubicalis (= pubic process) and of a proc. ischiadicus (= ischial process), the latter being developed as a flat, plate-like reinforced contact area behind the acetabulum. In the typically bipedal coelurosaurs and bipedal carnosaurs, on the other hand, the postacetabular section of the ilium is especially extensive. In contrast to sauropods the ischial process is more developed as a bulge or tuber, posterior to which along the ventral rim of the dorsal wing runs a ventrally concave lamella. The lamella may have several insertions for the origins of very strong musculature (M. coccygeo-femoralis-brevis after ROMER), which was a match for the stress to the demands of a fast run in bipedal posture.

The ilium of the prosauropod *Plateosaurus* is characterized by the less expanded preacetabular section of the blade, but a high caudal section that also extends far posteriorly over the ischiadic process. Therefore plenty of surface area is generated for the origin of M. coccygeo-femoralis-brevis, as in coelurosaurs and carnosaurs but in a different fashion. The ilium of the sauropods is remarkably similar to that of crocodilians but even to the ilium of further-removed genera such as *Euparkeria* and *Erythrosuchus*. The position of the origins of M. ilio-femoralis and M. ilio-tibialis, which are as important for the movement of the hind limbs as the shape of the femur, is still considerably more primitive in prosauropods than in sauropods.

In saurischians, both ventral pelvic elements, pubis and ischium, show a distinct division into proximal and distal sections. The pubis and ischium together form the ventral rim of the acetabulum. Among sauropods with a narrower ischium, as for example *Brachiosaurus*, the contribution of the ischium to the ventral rim of the acetabulum is smaller than the contribution of the pubis, both elements contribute equally to the acetabulum in *Camarasaurus* and *Ornithopsis*, but in genera with a wider ischium the bone forms a larger section of the acetabular ring than the pubis, as in *Barosaurus*, *Diplodocus*, *Dicraeosaurus*, and *Haplacanthosaurus*. The proximal parts of the pubis and ischium form a more or less laterally curved wall, and these proximal sections articulate in a suture, which is sometimes probably fused in older individuals, and in addition in some rare cases the bones are also fused with the processes of the ilium. The distal sections of the pubis and ischium are, depending on their width, strap-shaped to distinctly plate-like. In the development of their surface area, they are positioned transverse to the wall of the proximal section and are also to a variable degree connected medially with the corresponding partner from the other side, but their distal ends are always in contact with one another. The pubic parts thereby connected drop anteriorly, the parts of the ischia drop ventrally.

Contour of the distal end of the ischium.
I Bothrosauropodidae
Fig. 9. *Brachiosaurus brancai* J 3, 1/5 natural size. — Fig. 10. *Brachiosaurus brancai* T 2, 1/5 natural size.
II Homalosauropodidae
Fig. 11. *Barosaurus africanus* K 44, 3/20 natural size. — Fig. 12. *Dicraeosaurus sattleri* M 7, 2/13 natural size.
Fig. 13. *Tornieria robusta* G 77, 1/5 natural size.

The proximal sections of both pubes form the lateral wall of the anterior part of the pelvic cavity up to the level of the acetabulum. The plate-like distal sections of both pubes delimit the abdominal cavity caudally below the passage into the pelvic cavity. Therefore the shorter the proximal section and the longer the distal section of the pubis, the larger the extent to which the pubis delimits the abdominal cavity caudally and the narrower the abdominal cavity becomes at the passage into the pelvic cavity, which in a morphological sense should be considered a separate cavity. The proportions of the length of the distal section of the pubis to its proximal section is smaller in sauropods than in other saurischian groups. Among prosauropods, the distal section covers about 3/4 of the entire length in *Plateosaurus*, and the proportion is similar in coelurosaurs and carnosaurs. On the other hand, the distal section measures only 1/3 of the entire length in *Brachiosaurus*, about equally little in *Camarasaurus*, slightly less than half the entire length in *Barosaurus*, about the half the entire length in *Tornieria*, slightly more in *Dicraeosaurus*. The distal section of the pubis is variably broad in sauropods, thickened at the distal end, and the symphyseal surface varies in extent and contour.

The distal section of the ischium is rod-shaped to plate-like. A terminal reinforcement of the ischium, by widening and thickening, is distinctly expressed in most genera, but it is almost entirely missing in genera in which the ischium forms a more or less thin plate in its distal section, as in the bothrosauropodids *Brachiosaurus*, *Camarasaurus*, *Cetiosauriscus*, *Bothriospondylus*, and further also in *Titanosaurus*.

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I l i u m of *Brachiosaurus brancai*
Fig. 1 a, b. Right ilium Aa 13: 1 a lateral view, 1 b dorsal view.
Fig. 2. Left ilium J 1: lateral view.
1/9 natural size

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I l i u m — *Barosaurus africanus*
Fig. 1. Right ilium A 4: lateral view.
Fig. 2. Right ilium St 234: lateral view.

Dicraeosaurus hansemanni
Fig. 3 a, b. Right ilium m 62: 3 a medial view, 3 b lateral view.

Dicraeosaurus sattleri
Fig. 4. Right ilium M 4: lateral view.
Figs. 1, 3 a, 3 b, 4 = 1/10 natural size; Fig. 2 = 1/5 natural size

This difference is evident in the view of the terminal end of the paired ischia, as already illustrated by O. MARSH (1896) and THEVENIN (1907). In the first group, the contour is formed by two narrower or wider triangles that are connected at the symphysis; the end surfaces of the ischia in the second group are connected over a short distance and form an almost continuously narrow band (Figs. 9–13). The function of the ilium, to support the posterior section of the body when resting, is very well expressed in the first group which includes e.g. *Apatosaurus*, *Diplodocus*, *Tornieria*, and *Dicraeosaurus*, by contrast to the second group, in which this function is less well expressed.

Prosauropods possess extremely extensive distal sections of the pubes, which are terminally hardly reinforced, in contrast to the more rod-like distal sections of the ischia with fortified ends. These appear therefore to be well-suited to support the body at rest, although the terminally thin, plate-like, obliquely positioned pubes were less well equipped for this purpose. In the proximal section of the pubis, the obturator foramen opens obliquely laterally and at the same time more or less caudally.

At the cranial rim of the pubis, below the contact area of the pubic process of the ilium lies the origin of the M. ambiens, as A. ROMER (1923 a, b) concluded from the condition in crocodiles. This area is in the family group of homalosauropodids (comp. JANENSCH 1929 and von HUENE 1956) often developed as a sharply protruding projection or trochanter ("Tr. ambientis"), as in *Dicraeosaurus*, *Barosaurus* and *Diplodocus*, more rarely indistinct as in *Apatosaurus*. In the family group of bothrosauropodids there is no real projection in this area, at best a swollen callous or rugosity, as in *Brachiosaurus*, *Camarasaurus,* or *Haplacanthosaurus* [*lapsus: Haplocanthosaurus*]. In the Chinese genera of this family group *Helopus* (WIMAN 1929), from the Lower Cretaceous, and *Omeisaurus* (YOUNG 1958), questionably from the Upper Jurassic, an ambiens trochanter was apparently not developed.

Table 9. Measurements of the ilium of *Brachiosaurus brancai*, *Barosaurus africanus*, *Dicraeosaurus hansemanni*, *D. sattleri.*

Species	Horizon	Find	Side	Greatest length of blade		Entire height at pubic process		Height of blade above acetabulum	
				cm	%	cm	%	cm	%
Brachiosaurus brancai	Upper Saurian Marl	J 1	l	105.5	100	81.5	77	—	
	Upper Intermediate Bed	A a 13	r	119	100	89	75	45	38
	Middle Saurian Marl	Ma 2	r	128+	100	96	75	48	38
Barosaurus africanus	Upper Saurian Marl	A 4	r	106	100	77	73	—	
	Middle Saurian Marl	St 234	r	41	100	29.5	71	15.5	38
Dicraeosaurus sattleri	Upper Saurian Marl	M3	l	81	100	56.5	70	37.5	46
Dicraeosaurus hansemanni	Middle Saurian Marl	m	r	84	100	62	74	36	43

Ilium

(Tab. 9)

Brachiosaurus brancai

(Suppl. E. Figs. 1, 2)

As the left ilium J 1 from the Upper Saurian Marl and the right ilium Aa from the Upper Intermediate Beds show, the ilium is in particular characterized by the substantial extent of the anterior wing of the blade, which is broadly rounded and protrudes far anteriorly; the thick posterior wing that tapers off pointedly extends only moderately or almost not at all over the proc. ischiadicus. The greatest height of the blade is in front of the proc. pubicalis, and the entire anterior half of the blade curves very strongly laterally. Below the upper rim a moderate, not knob-shaped swelling lies close to the end. The pubic process extends far ventrally, it is characterized by a narrow cross-section, which widens moderately distally. The ischiadic process projects freely caudally as a very thick, short plate.

The ilium of *Brachiosaurus altithorax* RIGGS corresponds so well with the ilium of the African *Brachiosaurus* in characteristic features, such as the strong development of the anterior wing of the blade and the compressed shape of the pubic process, that the assumption of generic identity is well supported. The differences are insignificant. In the American species, the posterior wing of the blade, which does not reach beyond the ischiadic process, is less pointed, and the anterior wing somewhat higher.

Being closely related to the highly specialized *Brachiosaurus, Camarasaurus* with a shorter neck and lower forelimbs has a normally formed ilium with a shorter anterior wing and a thicker pubic process.

Barosaurus africanus
(Suppl. F. Figs. 1-3)

The blade of the ilium shows only a moderate surface development in the anterior section, which becomes pointed anteriorly; the very strong and low posterior section extends considerably far beyond the ischiadic process, but rises more briefly and steeply above this projection in two juvenile specimens (St 234 and St 243) from the Middle Saurian Marl than in the large ilium (A4) from the Upper Saurian Marl. The greatest height of the blade is approximately above the pubic process. Just in the front of the posterior end, a knob-like swelling lies on the lateral wall for the attachment of a tendon. The relatively long ischiadic process is stocky and thickens considerably, especially towards the lower rim. The ischiadic process forms a plate, the rim of which protrudes as a bulge laterally and posteriorly.

The ilium of the North American *Barosaurus lentus* LULL, as reconstructed by R. S. LULL (1919, pl. 7), is according to this author very incompletely preserved, and therefore not suitable for comparison. There is a marked correspondence in all essential features between the ilia of *Barosaurus africanus* and that of *Diplodocus*, which is closely related to *Barosaurus*. Somewhat different is also the slightly larger height of the posterior section of the blade.

Dicraeosaurus hansemanni
(Suppl. F fig. 3)

The blade of the ilium in the mounted skeleton m is relatively high, its largest height lies approximately at mid-length; anterior and posterior halves are similar in contour, the posterior end extends to a moderate degree beyond the ischiadic process. A knot-like protuberance lies below the upper rim lies on the lateral side, closely to the posterior end. The pubic process is strong, ventrally thick, the ischiadic process barely stands out as a bulge- to plate-shaped structure posteriorly against the strong ventral rim of the blade.

Dicraeosaurus sattleri
(Suppl. F. Fig. 4)

The entire shape is very similar to *D. hansemanni;* remarkable differences that are not the result of preservation are hardly noticeable. The entire ilium is in accordance with to the overall construction of the younger species, distinctly more weakly built.

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P u b i s , i s c h i u m — *Brachiosaurus brancai*

Fig. 1. Both pubes S II: anterior view.
Fig. 2 a, b. Left pubis J 2: 2 a lateral view, 2 b medial view.
Fig. 3 a, b. Right ischium J 3: 3 a lateral view, 3 b medial view.

All figures 1/10 natural size.

Tornieria robusta

E. FRAAS (1908, fig. 11) figures a very large ilium referred to this taxon, with a length of 110 cm as preserved; it shows only a very imperfect contour and in particular such a low blade that the height cannot be considered original. A more detailed description and identification are therefore not possible.

Pubis

(Tab. 10)

Brachiosaurus brancai

(Suppl. G Figs. 1, 2)

The pubes of S II from the Middle Saurian Marl and the left (?) pubis J2 from the Upper Saurian Marl are robustly built and show a very wide surface, especially in the proximal section. The suture between the pubis and the ilium is very long, and thus the laterally bulging proximal section forms together with that of the ischium a very high laterally curved wall of the pelvic cavity. The distal section of the pubis, by contrast, is short, about 1/3 as long as the proximal section; it widens considerably distally and becomes a thick plate. The median rim that curves in its proximal half is particularly reinforced at the distal inner corner. The anterior contour of the pubis is altogether only weakly curved inward, the origin of M. ambiens is indicated only by a weakly protruding tuberosity below the proximal end. The contact area for the narrow pubic process of the ilium is accordingly less extensive, but the contribution to the acetabulum is, on the other hand, much longer. The fo. obturatorium (= obturator foramen) is wide, it is open against the puboischiadic suture in the pubis (T 28) of a juvenile individual.

Table 10: Measurements of the pubis of *Brachiosaurus brancai*, *Barosaurus africanus*, *Dicraeosaurus hansemanni*, *D. sattleri* and *Tornieria robusta*.

Species	Horizon	Find	Side	Greatest length		Width at acetabulum		Width at distal end		Smallest width of distal section	
				cm	%	cm	%	cm	%	cm	%
Brachiosaurus brancai	Upper Saurian Marl	T 28		74	100	22	28.5	19.5	26.5	11.5	15.5
	Upper Saurian Marl	R 21		83	100	29.5	35	27	32	16.5	20
	Upper Saurian Marl	J 2	l	89	100	31.5	35.5	27	30	—	
	Middle Saurian Marl	S II 8	r	121	100	42.5	35	37.5	31	—	
Barosaurus africanus	Upper Saurian Marl	XI 10	r	69.5	100	28	40	47.5+	25+	9	13
	Upper Saurian Marl	E 6	r	72	100	29	40.5	20.5+	28.5	9.5	13
	Upper Intermediate Beds	Ki 13	r	68.5	100	25.5	37	15.5+	22.5	9.5	14
Dicraeosaurus sattleri	Upper Saurian Marl	M 6	r	74	100	27	36.5	23.5	32	12.5	17
Dicraeosaurus hansemanni	Middle Saurian Marl	m	r	79.5	100	30.5	38	25+/-	32	14	17.5
Tornieria robusta	Upper Saurian Marl	B 8	l	94	100	29.5+	31.5+	30	32	—	

Comparison: The pubis of *Camarasaurus supremus* COPE is very similar to that of *Brachiosaurus* it coincides in so far that the proximal section is very wide and long that the distal section is much shorter, and at the same time plate-like and very wide, and that the origin of the M. ambiens is only represented by a rugosity (comp. the figures in OSBORN & MOOK 1921).

The pubis of *Camarasaurus lentus* MARSH [GILMORE 1925] is of very much the same type as that of *C. supremus* and *Brachiosaurus*. The obturator foramen opening toward the puboischiadic suture is certainly a juvenile feature (U.S.G.S. pl. 69). It is quite possible that *C. lentus* represents a juvenile individual of a larger species of the same genus. The pubis illustrated by CH. G. MOOK (1917) as *Apatosaurus minimus* together with the associated ischium is of the *Camarasaurus* type, and this also applies clearly to the ischium. — The pubis of *Cetiosauriscus leedsi* (HULKE) from the English Oxford (Baron VON HUENE 1932, fig. 22, and HULKE 1889) definitely represents the *Brachiosaurus* type; the proximal section is very broad and long. — The pubis has no distinct ambiens trochanter in *Ornithopsis*, a genus related to *Brachiosaurus*, as shown by the illustration of a pubis of *O. hulkei* with an attached ischium provided by H. G. SEELEY (1889, fig. 1). The proximal section of the pubis in this illustration is, in proportion to the entire element, much less extensive than in *Brachiosaurus* but is obviously incompletely preserved, as can be concluded from the position of the obturator foramen. The attached ischium is wider that of *Brachiosaurus*. — Finally, the pubis of *Bothriospondylus madagascariensis* LYD. (THEVENIN 1907, pl. 2, fig. 6) from the "middle Jurassic times" exhibits strong similarities with that of *Brachiosaurus*. The proximal part is very wide, with a long contact for the ischium, the distal section is short and wide.

Barosaurus africanus

Left pubis E 6, Upper Saurian Marl (Pl. XIX, Fig. 1); right pubis XI a 10, Upper Intermediate Beds (Plate XIX, Fig. 2); left pubis Ki 13, Upper Intermediate Beds (pl. XIX, Fig. 3). There are no characteristic features expressed in the pubis of *B. africanus* that distinguish it from those of other genera of the family Homalosauropodidae, such as *Dicraeosaurus* and *Diplodocus*. The overall build is relatively strong in E 6 and XI a 10, especially the proximal section is rather wide and altogether much more extensive than the slightly shorter distal section. The latter is relatively narrow, but the distal end protrudes considerably in a point anteriorly. The ambiens trochanter juts out strongly anteriorly and is considerably high, being more strongly developed than in *Dicraeosaurus*. The obturator foramen lies in a wide depression, which extends toward the rim of the acetabular facet. The left pubis Ki 13 (pl. XIX, Fig. 3) is much more slenderly built than both described pubes, as are the other skeletal elements of the gracile variety of this species from the same excavation site, but it obviously corresponds with these in overall shape.

Dicraeosaurus hansemanni
(Suppl. H Fig. 1 a- c)

The proximal section of the pubis of the reconstructed skeleton (m) is moderately wide, relatively thick, and only slightly arched laterally. The acetabular facet is only moderately long and considerably shorter than the contact area for the pubic process of the ilium. The obturator foramen lies very close to the proximal end. The ambiens trochanter is strongly developed, it protrudes about 10 cm high with a sharp outline. The distal section occupies slightly more than half of the entire length of the bone, it is relatively wide, and is still widest at its distal end, which is apparently caused by compression.

Dicraeosaurus sattleri
(Suppl H Fig. 1 a–c)

P u b i s , i s c h i u m — *Dicraeosaurus hansemanni*
Fig. 1 a–c. Right pubis m 30: 1 a lateral view, 1 b medial view, 1 c posterior view.
Fig. 2 a–c. Right ischium m 33: 2 a lateral view, 2 b medial view, 2 c posterior view.

Dicraeosaurus sattleri
Fig. 3 a–c. Left pubis M 5: 3 a lateral view, 3 b medial view, 3 c posterior view.
Fig. 4 a–c. Left ischium M 7: 4 a lateral view, 4 b medial view, 4 c anterior view.
All figures 1/10 natural size.

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Explanation to the figures, see page 202 below

The pubes of skeleton M (Upper Saurian Marl) are, in accord with the overall construction of the species, much slimmer and more gracile than in the older *D. hansemanni*. The proximal section is narrow and only moderately arched laterally. Its length to the end of the puboischiadic contact amounts to somewhat less than half of the entire length. The anterior longitudinal contour curves only weakly inward. The acetabular facet is about as long as the contact area for the pubic process of the ilium. The distal section is narrow and extended, the distal end is considerably widened and also reinforced, with a longish, three-sided symphyseal surface. The ambiens trochanter protrudes strongly and nose-like; the obturator foramen lies close to the distal and posterior rim.

The pelvis including pubis and ischium illustrated by J. PARKINSON (1930, fig. VI) should be referred to *Dicr. sattleri*.

Tornieria robusta

The left pubis B 8 from the Upper Saurian Marl (Pl. XIX, Fig. 4) is characterized by its stocky build. The very thick proximal section is only moderately wide, its length amounts to about half of the length of the entire bone. The distal section starts out moderately wide, but widens distally and is also gets much thicker, showing an extensive contact area for the corresponding pubis in the shape of an equilateral triangle with the sides about 20 cm long. A not very distinctly preserved ambiens trochanter is present. The relatively uniform inward curvature of the anterior contour of the element is characteristic.

Table 11: Measurements of the ilium of *Brachiosaurus brancai*, *Barosaurus africanus*, *Dicraeosaurus hansemanni*, *D. sattleri*, *Tornieria robusta*.

Species	Horizon	Find	Side	Greatest length		Width at acetabulum		Width at distal end		Smallest width of distal section	
				cm	%	cm	%	cm	%	cm	%
Brachiosaurus brancai	Upper Saurian Marl	J 3	r	92.5	100	20.5	22	21	23	13.5	15
	Upper Saurian Marl	T 2	l	71.5	100	16	22	13.5	22	6.5	9
Barosaurus africanus	Upper Saurian Marl	k 44	l	88	100	26.5	30	26	30	14.5	16
Dicraeosaurus sattleri	Upper Saurian Marl	M	l	79	100	23	28	24.5	31	10.5	13
Dicraeosaurus hansemanni	Middle Saurian Marl	m	r	75	100	23	33	23.5	31	11	14.5
Tornieria robusta	Upper Saurian Marl	G 77	r	65.5	100	21	32	19	24.5	11.5	18
	Upper Saurian Marl	B 13	r	91.5	100	31	100	24+	27+	—	

Ischium

(Pl. 11)

Brachiosaurus brancai

(Suppl G. Fig. 3 a, b; Plate XIX, Fig. 5 a, b)

The left ischia T2 (Upper Saurian Marl) and J3 (Upper Saurian Marl) are very narrow in their proximal section with a very short contribution only to the acetabulum; the puboischiadic suture is long. The distal section is a thin, relatively narrow plate showing a uniform width and an even, weak curvature of the surface, it is not reinforced at the distal end and has a long symphysis. The whole posterior contour of the ischium is evenly and weakly curved inward. The contribution to the acetabulum is very short. Both terminal surfaces form together a rather uniform, narrow, and more or less curved band. The lateral third is slightly widened and strongly curved upward in the juvenile T2 (Plate XIX, Fig. 5 a, b), in J3 the distal end surface is only insignificantly curved, and slightly widened medially and laterally (Figs. 9, 10).

A right ischium illustrated by OSBORN & MOOK (1921, fig. 94) and identified as *Camarasaurus supremus* COPE, harmonizes so much with that of *Br. brancai* with respect to the contour and also the distal end, that it must be most likely assigned to *Brachiosaurus*, i.e. probably to the North American *Br. altithorex* [*Lapsus calami = altithorax*] RIGGS. The illustrations of *Camarasaurus supremus* by OSBORN & MOOK (1921) show that the proximal section of the ilium represents a moderately wide plate of approximately trapezoidal outline, the posterior contour line and the puboischiadic suture being parallel. As the latter is long, about 2/5 of the total length of the ischium, and as the acetabular facet is shorter than that of the pubis, the proximal section is remarkably similar to the same section in *Brachiosaurus*; the distal section is also similar, in as much it is uniformly narrow and plate-like, and the distal end is not reinforced; very different, but altogether highly characteristic for *Camarasaurus* is the entire distal section being strongly curved downward posteriorly. — The ischium as well as the pubis of *Cetiosauriscus leedsi* (HULKE) from the English Oxfordian are of a distinct *Brachiosaurus* type (see HULKE 1889 and Baron VON HUENE 1932, fig. 22); the proximal section is narrow, the distal one is a narrow, thin plate with a correspondingly narrow terminal surface. — In contrary to that differs the proximally much wider ischium of *Ornithopsis eucamerotus*, illustrated by J. W. HULKE (1892), which has been associated with a pubis, very unlike the ischium of *Brachiosaurus*, although the pubis would probably be similar to that of *Brachiosaurus* were it completely preserved. *Bothriospondylus madagascariensis* LYD. has, like *Brachiosaurus*, a narrow, weakly curved distal end surface of the ischium; it widens slowly in the median direction. In *Haplacanthosaurus priscus* HATCHER the terminal surfaces of both ischia apparently form a narrow band, similar to *Brachiosaurus*, according to HATCHER'S description and illustration (HATCHER 1903).

Barosaurus africanus

Ischium K 44 from the Upper Saurian Marl (Plate XIX, Fig. 6). The proximal section is moderately narrow, the rim of the puboischiadic contact is relatively short, and slightly convex. The process that is directed towards the ischiadic process of the ilium protrudes strongly caudally. The acetabular facet is relatively long.

Toward the distal section, the anterior contour is almost straight, the posterior contour is only weakly curved inward. The distal posterior section widens only moderately and is relatively thick. The narrow three-sided distal end surfaces of the ischia are uniformly curved; they become narrower laterally. They contact each other along the one very short side of the triangle medially, in such a way that the longitudinal axis of both triangles encloses a very acute angle (see Fig. 11). (The view of the distal ends of the ischia of *Barosaurus africanus*, which E. FRAAS [1908, fig. 12] illustrates, show apparently slightly weathered contours.)

The strong ischium of *Diplodocus* is of the same type as *Barosaurus africanus*, characterized by a strongly developed ambiens trochanter and a considerably widened distal end, the terminal surface of which is triangular; this is shown by the cast of *Diplodocus longus carnegiei*.

The terminal view of the ischia of *Diplodocus longus* illustrated by O. MARSH (1896, pl. 28, fig. 3) must present another genus; the narrow, band-shaped contour is very similar to that of *Brachiosaurus brancai*.

Dicraeosaurus hansemanni
(Suppl. H Fig. 2 a–c)

Right ischium m 33 from the skeleton of *D. hansemanni*, Middle Saurian Marl. The proximal section is relatively wide, the contribution to the acetabulum is quite long, the puboischiadic suture is moderately long. The distal section is moderately thick, at first narrow but strongly widened distally, although only moderately thickened. The distal end surface is three-sided. The symphysis between both ischia is restricted to a short distal part. The overall posterior contour is uniformly bent inward, the anterior contour is very strongly constricted immediately below the puboischiadic suture.

Dicraeosaurus sattleri
(Suppl. H fig. 4 a–c)

Right ischium M 7 of skeleton M, Upper Saurian Marl. The ischium is very similar to that of the older species, and in accord with the overall cosntruction of the species; the distal end is slightly less widened, the contour is not so strongly bent inward. The distal end surface is shaped as a narrow, strongly curved triangle; both end surfaces of the ischia touch along a relatively short symphysis in such a way that their longitudinal axes enclose a pointed angle (Fig. 12).

The pelvis and pubis illustrated by J. PARKINSON (1930, fig. VI) must be referred to *Dicr. sattleri*.

Tornieria robusta

Right ischium B 13, Upper Saurian Marl; right ischium G 77, Upper Saurian Marl (Plate XIX, Fig. 7). Overall shape relatively robust. The process directed toward the ischiadic process of the ilium is very thick, it protrudes only moderately posteriorly. The puboischiadic suture is relatively short. The shaft is wide, it flattens considerably anteriorly. The distal section widens considerably, its profile runs from the posterior lowermost corner in a strong curve anteroproximally. The distal end surface of ischium G 77 has almost the shape of an equilateral triangle that is of a larger extent than in other Tendaguru sauropods, and agrees with its robust build (Fig. 13).

Hind limb

Femur

The head extends from the straight shaft that has an elliptical to oval cross-section without the development of a neck medially, although the distal end widens considerably medially and laterally. The proximal section is weakly curved upward on the abductor side, the distal section is slightly bent downward on the adductor side; the S-shaped curvature of the entire bone is minimal and, in additional, often obliterated by distortion. It is characteristic that the proximal and distal ends are not twisted relative to one another to the slightest degree.

The head, only parts of which fit into the not very deep, medially open acetabulum, resembles often more a slightly medially inclined pillar than an irregular sphere. It is distinguished more or less clearly form the rough, transversely curved proximal end surface of the femur, often by a slightly coarse sculpture. The low-domed, proximal area of the head is not situated exactly terminally on the end surface, but the apex of the dome is shifted toward the adductor side. Below the distal rim a fluted zone at which the ligamentuous joint capsule was attached runs all around the proximal end surface.

Of the distal condyles, which are separated by a well-developed intercondyloid fossa, the medial one is more extensive than the lateral, their vault curving strongly proximally toward and onto the adductor side of the shaft. An epicondyle is developed as a shelf lateral to the lateral condyle. The femora of the different genera and species are more or less distinctly characterized by differences in the extent of the condyles, in the proportions between the medial and the lateral condyles, in the width of the intercondyloid fossa, and in the width of the epicondyle. The coarsely pitted surface of the terminal end of the femur argues for the presence of a thick layer of cartilage that is not preserved, as has already often been pointed out. The actual joint surfaces of the condyles were obviously better ossified, and exhibit the character of sliding surfaces.

Of the trochanters, only the fourth trochanter is distinctly developed, sitting as a strong crest on the shaft, approximately along the line at which the adductor side grades into the medial side; it is usually closer to the proximal than to the distal end.

A lesser trochanter is not developed on the proximal section of the femur of sauropods. However, it is perhaps indicated by a ridge-like reinforcement below the edge on the adductor side (ventral) of the proximal end surface, close to the lateral end, as for example in *Brachiosaurus brancai*, and apparently especially distinct as a protrusion in the Australian *Rhoetosaurus browni* LONGMAN (1917, plate 5). Here, the insertion of the M. ilio-femoralis externus could be assumed, which ROMER hypothesized on the lesser trochanter in *Thescelosaurus*.

Regarding the characters discussed above, the differences among sauropods are basically not very distinct, but the proportions between the width of the end section to the length of the entire bone fluctuates within a broad rage; extreme robustness is found in titanosaurids, as for example in *Titanosaurus indicus* LYD. (VON HUENE & MATLEY 1933, fig. 25), extreme slenderness in *Amphicoelias altus* COPE (OSBORN & MOOK 1921, figs. 125 and 126); remarkable differences in strength of the femur occur not only between genera but also between species.

Figs. 14–22. Contour of the distal end of the femur.
Fig. 14. *Brachiosaurus brancai* St. 134. — Fig. 15. *Br. brancai* t 6. — Fig. 16. *Br. brancai* No. 34. — Fig. 17. *Tornieria robusta* modified after E. FRAAS (1908). — Fig. 18. *Barosaurus africanus* e 2. — Fig. 19. *B. africanus* var. *gracilis* Ki 71. — Fig. 20. *B. africanus* var. *gracilis* Ki 4. — Fig. 21. *Dicraeosaurus hansemanni* m 1. — Fig. 22. *D. sattleri* M 1. — col = lateral condyle, com = medial condyle, ecl = lateral epicondyle, foi [in fig.: foc] = intercondyloid fossa.
All figures c. 1/10 natural size.

The pillar-shaped, almost straight overall shape of the femur, furthermore the position of the head and the condyles, resemble the femur of proboscidians; this indicates very strongly that the femur in sauropods was swung in a sagittal plane; this assumption is in accordance with the North American sauropod tracks that indicates a narrow-gauge gait.

The femur of sauropods resembles in its entire shape that of the heavy and secondary quadrupedal ornithischians, and especially corresponds strikingly with the femur of stegosaurs. Only the weak anterior curvature of the distal condyles on the adductor side is slightly different, which indicates a steep orientation of the hind limbs. The stocky femur of large ceratopsids resembles in its overall form also that of sauropods; the proximal section differs slightly by the more clearly set off head and by the very distinct reinforcement of the lateral part of the proximal section which represents the greater trochanter; the distal joint, however, corresponds in the development of the condyles, of the intercondyloid fossa, and of the lateral epicondyle absolutely with the distal femur of sauropods. These ornithischians differ from sauropods in the fact that a lesser trochanter is more or less clearly developed at the femur.

Brachiosaurus brancai
(Suppl. J Fig 1 a–c; Figs. 14 - 16; Pl. XX, Fig. 13)

The overall shape is rather robust (Pl. XX, Figs. 1–3). The proximal section is wide and the head curves considerably outward medially. The distal section is widened not only by a medial extension, but in a characteristic fashion particularly laterally, in connection with the strong development of the lateral epicondyles.

The distal end surface is relatively low in top view; it is characteristic that both condyles are short, roundish, and low; the medial condyle is slightly wider than the lateral, being almost as wide as the intercondyloid fossa; the lateral epicondyle is remarkably wide, it extends slightly above the bottom of the intercondyloid fossa. The fourth trochanter lies above mid-height at the medial rim of the adductor side.

Table 12: Measurements of the femur of *Brachiosaurus brancai*.

	Find	Side	Length		Proximal width		Distal width		Smallest width of shaft	
			cm	%	cm	%	cm	%	cm	%
Upper Saurian Marl	II 27c	r	169	100	50.5	30	52	31	27.5	16.5
	IX 1	l	88	100	25	28	22.5+	26+	13.5	15.5
Upper Intermediate Beds	XV 1	r	214	100	56	26	55	26	32.5	15
	Ng 21	r	37.5	100	10.5	28	9.5	25	5	13.5
Middle Saurian Marl	St 134	r	74	100	20	27	20.5	28	11.5	15.5
	XX	r	84	100	26	31	25	30	14.5	17.5
	No. 12	r	149	100	44.5	30	41.5	28	22.5	15
	t 6	l	160	100	42	26	42	26	25.5	16
	St 291	r	183	100	54	30	53.5	29	31	17
Lower Saurian Marl	No. 37	r	—		—		45.5	—	—	

It is remarkable that in all femora the distal and proximal width is almost identical. Measurements taken from well-preserved femora resulted in the following proportions of proximal and distal width to the entire length: In eight femora of *B. brancai* from the Middle Saurian Marl, the length of which ranges from 37.5 cm to 189 cm, the measurements of the proximal width represent 26 % to 31% of the length, the measurements of the distal width 25% to 30%; in 3 femora from the younger beds with lengths between 88 cm and 214 cm, the indices for the proximal width amounts to 26% to 30%, for the distal width to 26% to 31%. There were practically no differences in all these proportions between the femora from the Middle Saurian Marl and of the femora from the younger beds. The considerable differences in the figures for the smallest width of the shaft, as shown in the table, might partially be due to the different degrees of distortion.

The distal section of the right femur No. 34 (Pl. XX, Fig. 3) from the Lower Saurian Marl deserves a separate discussion because of its low stratigraphic position. The well preserved, c. 60 cm long and 45 cm wide distal fragment of a large femur belongs obviously to the genus *Brachiosaurus*, but the co. medialis differs from the normal one in *B. brancai* extending further proximally on the adductor side of the femur and in becoming narrower at the same time. This difference might have been caused by distortion, perhaps in combination with weathering, and there is no good reason to erect a distinct variant.

Brachiosaurus altithorax (RIGGS 1904). The contour of the 2.03 cm [sic] long femur of the type species of the genus is very similar to that of *B. brancai*. The exact shape of its distal articulation and its condyles is not illustrated, and can therefore not be compared.

C o m p a r i s o n s : As with other elements, a comparison of the femur with that of *Camarasaurus* is justified. For this genus, a femur identified as *Morosaurus grandis* MARSH (U. S. G. SURVEY, Plate 72) is important. The overall shape is slightly more robust than in *Brachiosaurus*, the proximal section is less far curved medially. The obviously obliquely distorted distal joint resembles strongly that of *B. brancai*; both condyles have the same width, only the medial condyle is slightly longer, as is the case in the femur originating from the Lower Saurian Marl. The lateral condyle seems to be slightly narrower, but is also in the same position regarding the height as the intercondyloid fossa. — *Cetiosaurus oxoniensis* PHILL. (PHILLIPS 1871, diagram 108) from the "Great Oolite" of Oxford harmonizes well with *Brachiosaurus* regarding the overall shape. It seems, as far as can be concluded from the illustration by PHILLIPS, that the distal joint shows no distinct differences when compared to *Brachiosaurus* with respect to the rather similar widths of the medial and lateral condyles, and also to the wide lateral epicondyle. — The femur of *Bothriospondylus madagascariensis* LYDD. [*sic*] (THEVENIN 1907, fig. 13) from the Bathonian is very similar to that of *B. brancai*, albeit somewhat slimmer. The distal joint resembles most of all that of *B. brancai* from the Lower Saurian Marl, because in both specimens the medial condyle is longer than in *B. brancai* and becomes narrower proximally. Furthermore, the wide lateral epicondyle and the wide intercondyloid fossa are similar.

Barosaurus africanus

(Suppl. 18–20; Plate XX, Fig. 4, 5; Tab. 130)

The overall shape is moderately robust to slender, varying considerably in strength. The proximal section curves medially only posterior to mid-length. The head protrudes only moderately medially. The inward curve of the lateral contour extends proximally beyond mid-length. The distal end widens only weakly laterally (in contrast to *Brachiosaurus*). The fourth trochanter lies somewhat closer to the proximal end than to the distal end. The distal end surface is relatively high. The lateral condyle is slightly narrower, lower, and shorter than the medial condyle, which drops characteristically strongly obliquely toward the intercondyloid fossa. The lateral epicondyle is narrow and extends only a little over the bottom of the intercondyloid fossa.

Table 13: Measurements of the femur of *Barosaurus africanus*.

	Find	Side	Length		Proximal width		Distal width		Smallest width of shaft	
			cm	%	cm	%	cm	%	cm	%
Upper	XV 7	l	79	100	22.5	28	20	25	11	14
Saurian Marl	no 1	r	117	100	31	26	30.5	26	15.5	13
	e 2	l	135	100	39.5	29	36.5	27	21	15.5
	No. 76	l	135	100	41.5	31	36	27	19.5	14.5
Upper	Ki 71 a	l	102	100	24.5	24	21.5	21	12	11.5
Intermediate Beds	Ki 8	l	108	100	26	23	24	22	13	12
	Ki 2	r	119	100	33	28	29	24	15.5	13
	H 4	l	129	100	36	27	31.5	24	17.5	13.5
Middle Saurian Marl	Sa 29	l	92	100	23	25	22	24	12.5	13.5

The differences in the contour of the distal end surface in the femur that FRAAS (1908, fig. 13) illustrated are due to the fact that the medial condyle is almost entirely missing in this femur.

The measurements of the femora of *B. africanus* resulted in quite significant differences in the proportions of width and length (e.g., Pl. XX, Figs. 4 and 5). In 5 femora from the Upper Saurian Marl with lengths from 79 cm to 138 cm, the proximal width amounts to 26% to 31% of the length; in 7 femora from the Upper Intermediate Beds with lengths from 102 cm to 129 cm it amounts to 23% to 28%; the distal width amounts in the femora from the Upper Saurian Marl to 25% to 30%, in those from the Intermediate Beds to 21% to 24%. The comparison shows that, regarded as a whole, the femora from the Upper Saurian Marl are proximally and distally wider in proportions to their length than those from the Intermediate Beds.

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Femur — *Brachiosaurus brancai*

Fig. 1 a–e. Right femur St 291: 1 a adductor side, 1 b abductor side, 1 c medial view, 1 d proximal view, 1 e distal view.

Dicraeosaurus hansemanni

Fig. 2 a–g. Right femur m 1: 2 a adductor side, 2 b abductor side, 2 c medial view, 1 d proximal contour, 2 e–g cross-sections.
col = lateral condyle, com = medial condyle, ecl = lateral epicondyle, fic = intercondyloid fossa.
Fig. 1 a–e 1/15 natural size; Fig. 2 a–g 1/12 natural size.

Among the latter, some femora from excavation site Ki stand out due to their slender shape, and their distal end surface being narrower and higher than in the femora from the Upper Saurian Marl. The narrower type of femur, for example Ki 71 a (Pl. XX, Fig. 5), is hereby named var. *gracilis*.

Only a very massive proximal fragment is preserved of the femur of *Barosaurus lentus* LULL (1919), which does not justify a comparison.

The slender femur of *Diplodocus longus carnegiei* HATCHER (HATCHER 1901, pl. 11, fig. 3) with respect to its contour very much resembles the slender femora of *B. africanus*. The distal surface of the femur of the skeleton from the Carnegie Museum is furthermore very similar to that of *B. africanus*: the lateral condyle is shorter and narrower than the medial condyle, which slopes obliquely towards the intercondyloid fossa. The lateral epicondyle reaches only a little bit above the intercondyloid fossa, it is only slightly wider than in *B. africanus*.

For a comparison of the range of variation of the length-to-width proportions of the femur, as determined for *Brachiosaurus brancai* and *Barosaurus africanus*, measurements of three skeletons of *Diplodocus* are available, compiled by C. W. GILMORE (1932). In the skeleton of *Diplodocus longus* from the U. S. Nat. Mus., as the calculation shows, the proximal width measures 22% of the length, the distal width 18.5% of the length; the corresponding figures from the two skeletons of *D. carnegiei* at the Carnegie Museum are in No. 84 32.5% and 26%, in No. 94 26% and 25%. These measurements show that the femur of the skeleton of *D. longus* is a lot more slender than the femora in the two skeletons of *D. carnegiei*. Both these specimens also differ from each other by a very different proximal width, although the distal width differs only slightly.

GILMORE leaves the question open whether all these skeletons attributed to different species should be regarded as conspecific; were this the case, the proportions of femur widths would be extraordinary variable within one species, far more variable than in *B. brancai* or in *B. africanus*.

Table 14: Measurements of the femur of *Dicraeosaurus hansemanni, D. sattleri, Tornieria robusta*.

	Horizon	Find	Side	Length		Proximal width		Distal width		Smallest width of shaft	
				cm	%	cm	%	cm	%	cm	%
Dicraeosaurus sattleri	Upper Saurian Marl	M 2	l	112.%	100	33	29.5	26.5	23.5	16.5	14.5
	Upper Saurian Marl	O 2	r	98	100	—		24	24.5	13.5	14
Dicraeosaurus hansemanni	Middle Saurian Marl	m 5	r	122	100	34	28	32.5	26.5	19.5	16
Tornieria robusta	Upper Saurian Marl	No. 22	l	128	100	—		38.5+	30+	—	
	Upper Intermediate Beds	IX l i	r	133	100	50	30	44.5	30	36.5	24.5

Dicraeosaurus hansemanni

(Fig. 21; Suppl. J Fig. 2 a–g; Pl. 14)

The overall shape of the mounted skeleton m from the Middle Saurian Marl is rather straight and elongate. The proximal section is quite thick, it is weakly extended in a comparatively short curve medially, and curves laterally in a weak curve outward. The head is relatively high; the lateral third of the proximal profile is clearly offset by a flat step. The shaft widens strongly toward the distal end, but in a characteristic way only very little on the lateral side. The fourth trochanter lies closer to the proximal end. The cross-section at the height of the fourth trochanter shows the shape of a slightly raised semicircle; the cross-section shows, a considerably flatter, narrow-oval contour above the trochanter, it becomes significantly narrower and more triangular below the trochanter. In dorsal view the coarsely pitted distal end surface has a high contour relative to the width. The medial condyle is particularly thick and moderately high, and in both these respects it exceeds considerably the lateral condyle which leans slightly laterally. The lateral epicondyle extends distinctly above the bottom of the intercondyloid fossa, which is deep and narrow.

Dicraeosaurus sattleri
(Fig. 22; Pl. XX, Fig. 6 a, b; Tab. 14)

The femora of skeleton M from the Upper Saurian Marl are more slender (Pl. XX, Fig. 6 a, b) than those of *D. hansemanni*, but are very similar in all other essential features. The distal articulation is slightly more lightly built, the intercondyloid fossa is deeper, the lateral condyle is lower in the right femur M 1 because of abrasion. The smaller femora of the same species from the excavation site O are due to weathering even more slender than those of skeleton M.

Tornieria robusta
(Fig. 17; Pl. XX, Fig. 7 a, b; Tab. 14)

The overall shape of the right femur IX c 1 from the Ipper Intermediate Beds (Pl. XX, Fig. 7 a, b) is very stocky. The proximal section curves very strongly medially, the lateral contour bulges very far, which results in the characteristically massive nature proximal end. The head is lower, its medial wall recedes remarkably in the distal direction. The shaft shows a moderate S-shaped curvature, it has a relatively wide elliptical cross-section. The distal section protrudes strongly medially and also distinctly laterally. The distal end surface is high, the medial condyle wide and high, the lateral condyle narrower and lower; the intercondyloid fossa is narrower than the medial condyle is wide. The lateral epicondyle projects remarkably weakly in the lateral direction; the fourth trochanter lies only slightly toward the proximal end.

Tibia
(Tab. 15)

The tibia is a pillar that strengthens considerably proximally and less strongly distally, the middle section of which is moderately curved laterally and flatter medially. The proximal end surface, which is in most cases sculptured by grooves, shows a more or less wide rhomboidal to elliptical contour, it is usually relatively level, but shows also often a distinct shallow depression for the contact with the medial condyle of the femur; such a structure is only rarely recognizable for the lateral condyle.

In accordance with the configuration of the proximal surface of the astragalus, the tibia extends on the lateral side less far distally than on the medial side. This results in a more or less distinct step on the rear edge of the distal end surface. From this step a distinct groove extends proximally that is very variable in different genera. It is very likely that a tendon connecting the tibia and tarsus ran in this groove (M. anconeus tendon).

At the proximal section of the tibia, the medial wall projects far anteriorly and forms the tuberosity, which extends variably far distally; it served as the insertion area for important muscles, such as M. sartorius, M. ilio-tibialis, and M. femoro-fibialis.

A specially shaped form developed in the titanosaurids *Titanosaurus* and *Laplatasaurus*. The tuberosity is very extensive and its tip is in both genera positioned very low on the tibia that differs strongly in robustness in those genera, the distal end, however, is only slightly reinforced (Baron VON HUENE 1929).

T i b i a ,   f i b u l a — *Brachiosaurus brancai*
Fig. 1 a–e. Right tibia St 148: 1 a lateral view, 1 b medial view, 1 c anterior view, 1 d proximal view, 1 e distal view.
Fig. 2 a–e. Right fibula St 148: 2 a lateral view, 2 b medial view, 2 c anterior view, 2 d proximal view, 2 c distal view.

Barosaurus africanus
Fig. 3 a–c. left tibia K1 a: 3 a lateral view, 3 b medial view, 3 c anterior view, 3 d proximal view, 3 e distal view.
All figures 1/10 natural size.

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Explanation of figures see page 210 below

Table: 14. Measurements of the tibia of *Brachiosaurus brancai, Barosaurus africanus, Dicraeosaurus hansemanni, D. sattleri, Tornieria robusta.*

Species	Horizon	Find	Side	Length		Proximal width upper tuberosity		Distal width		Smallest width of shaft	
				cm	%	cm	%	cm	%	cm	%
Brachiosaurus brancai	Upper Saurian Marl	J 15	r	95	100	36	38	32	33.5	17	18
	Middle Saurian Marl	St 148	r	107	100	46.5	43.5	34	32	18	17.5
	Middle Saurian Marl	B o 1	r	112	100	40	35.5	38.5+	34.5+	19.5	17.5
Barosaurus africanus	Upper Saurian Marl	K 41	l	86	100	32.5	38	25.5	30	14	16.5
	Upper Saurian Marl	K 1 a	r	87	100	—		22.5	26	13.5	15.5
	Upper Saurian Marl	C 13	r	89	100	3.5	35	26	29	15.5	17.5
var. *gracilis*	Upper Intermediate Beds	Ki 72a	l	67	100	17.5	26	14	22	8.5	12.5
	Upper Intermediate Beds	Ki 11	l	84	100	23	27	19	21	11.5	13.5
Dicraeosaurus sattleri	Upper Saurian Marl	O 4	r	59	100	18+	31+	15.5+	26.5+	—	
Dicraeosaurus hansemanni	Middle Saurian Marl	Q 12	r	71	100	—		20+	28+	12.5	18
	Middle Saurian Marl	m 1	l	76	100	30	39	24.5	32	13.5	18
Tornieria robusta	Upper Saurian Marl	E. Fraas (1908)	r	78	100	33	42.5	25	32	15.5	20
	Upper Saurian Marl	P 5	l	85	100	30	35.5	31	36.5	14.5	17

Brachiosaurus brancai
(Suppl. K Fig. 1 a–e)

The overall shape is rather robust, as in St 148 from the Middle Saurian Marl. The extensive tuberosity projects far anteriorly with a roundish, obtuse-angled profile. The proximal section of the tibia shows on the lateral side a obtuse-angled to almost rectangular longitudinal edge, into which the groove between the tuberosity and the actual body of the tibia is steeply cut. It is characteristic for *Brachiosaurus* that the wall in front of the longitudinal edge is half as narrow as that behind this edge. The proximal end surface has a moderately wide oval contour, which is laterally obliquely truncated; it is almost planar. The distal end surface shows a slightly oblong-triangular contour. The notch for the astragalus in the edge of the distal end forms a very obtuse angle. The furrow for the tendon above the distal edge is very flat and short.

The slightly wider proximal and distal end surfaces of a tibia referred to *Morosaurus* (= *Camarasaurs*) *grandis* (U. S. Geol. Surv., pl. 76, fig. 1 a, and pl. 75, fig. 1 a) are remarkably similar.

Barosaurus africanus
(Suppl. K fig. 3 a–e)

The overall shape of the tibiae form the Upper Saurian Marl, such as C 13 (Pl. XXI, Fig. 1) and K 1 a (Pl. XXI, Fig. 2 a–e), is relatively strong, but it is more slender in smaller tibiae from the Upper Intermediate Beds, as in K1 11 (Pl. XXI, Fig. 4). The proximal section is distinctly stronger than the distal end. The very obtuse-angled longitudinal edge on the lateral wall below the proximal end divides the wall in approximately similar halves, in contrast to *Brachiosaurus*. The depression between the tuberosity and the lateral wall is wide and shallow. The tuberosity projects anteriorly relatively far with an obtuse-angled profile. The proximal end surface (Pl. XXI, Fig. 2 d) is a wide rhombus; a flat and broad depression extends on its surface from the anterior end until far over the center. The distal end develops a triangular cross-section distally. The distal end surface (Pl. XXI, Fig. 2 e) is three-sided, its medial end forms a rounded angle; it is narrower in slender tibiae (excavation site Ki). The notch for the astragalus is characteristic for the genus in the lateral distal edge. It forms a right angle with the apex lying considerably behind the center of the edge, and the short side approximately paralleling the longitudinal axis of the bone. In tibia K 1 a (Pl. XXI, Fig. 2 a), this furrow is developed as a deeply depressed canal. The furrow for the tendon that arises from the apex of the angle is distinctly developed, especially in very slender tibiae.

Regarding the tibia of *Barosaurus lentus* MARSH, only a very incomplete, not comparable distal fragment of very large size is known (LULL 1919).

The tibia of *Diplodocus longus* (and *carnegiei* respectively) is quite similar to that of *B. africanus;* this is true for the shape of the proximal section and its end surface, which is slightly wider, and as the edge of the lateral wall of the proximal section is only weakly developed and therefore flat, and it is also true for the distal end concerning the strongly developed furrow for the tendon of the M. anconeus.

Dicraeosaurus hansemanni

(Suppl. L Fig. 1 a–d)

The overall form of the tibia of skeleton m 2 from the Middle Saurian Marl is relatively strong. The proximal surface has a regular rhomboid contour; its surface is relatively level. The edge on the lateral wall of the proximal section is very flat. The tuberosity is weakly developed, however it extends rather far distally. It does not protrude with an angular, but with a straight-lined profile, and forms together with the lateral wall of the proximal section a weakly expressed groove. The distal section is strong, it has a triangular cross-section with a distinct, barely rounded edge on the medial side, which lends the end surfaces a longer contour in comparison with *Barosaurus*. The notch in the posterior edge of the distal end surface shows an approximately right angle. The furrow for the tendon above the distal rim is completely flat. The slightly smaller tibia Q 12 is very similar to the previous one.

Dicraeosaurus sattleri

(Suppl. L Fig. 4 a, b)

The entire tibia of the juvenile o 4 from the Upper Saurian Marl is somewhat more slender than than of *D. hansemanni.* The edge on the lateral wall of the proximal section is more distinct, the groove between it and the tuberosity is completely flat. The distal end surface is apparently considerably narrower than in *D. hansemanni*. The state of preservation of the present specimen does not allow to distinguish further details.

Tornieria robusta

(Suppl. L Fig. 6 a–e)

The shaft of the tibia P 5 from the Upper Saurian Marl is strong, very much reinforced toward both ends. On the wide-rhomboid proximal end surface is developed, according to E. FRAAS (1908, fig. 15), apart from the extensive socket for the medial condyle of the femur, also half of the much smaller socket for the

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T i b i a ,   f i b u l a — *Dicraeosaurus hansemanni*

Fig. 1 a–d. Left tibia m 2: 1 a lateral view, 1 b medial view, 1 c proximal contour, 1 d distal contour.
Fig. 2 a–c. Left fibula m 3: 2 a lateral view, 2 b proximal contour, 2 c distal contour.
Fig. 3. Right tibia Q 12: lateral view.

Dicraeosaurus sattleri

Fig. 4 a, b. Right tibia O 4: 4 a lateral view, 4 b distal contour.
Fig. 5 a, b. Right fibula O 5: 5 a lateral view, 5 b distal contour.

Tornieria robusta

Fig. 6 a–e. Left tibia P5: 6 a lateral view, 6 b medial view, 6 c anterior view, 6 d proximal view, 6 e distal view.
All figures 1/10 natural size.

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Explanation of figure see page 212 below lateral condyle. The tuberosity protrudes only moderately far along a curved profile. The edge on the lateral wall below the proximal end surface lies very characteristically at the anterior end of this wall, between it and the tuberosity runs a very narrow groove. The distal end widens considerably, its end surface has an elongate three-sided contour, corresponding to the long contour of the astragalus, which cuts in very low at a very obtuse angle in the lateral edge of the end surface.

The tibia, illustrated by E. FRAAS (1908, pl. XI, fig 2—reproduced on pl. XXI, Fig. 7) is more slender than tibia P5.

Fibula

(Tab. 16)

The fibula of sauropods is usually a slender rod of bone, the flatter and slightly transversely curved proximal section of which is extended to the rear and becomes thinner to the front. At the anterior section of the medial wall, an extensive, distally sharp-angled area is delimited, the rear rim of which rises in a straight line toward the rear end of the proximal end surface of the fibula, and the surface of which is longitudinally fluted and rugose. It is assumed that from this rough surface arose a ligamentous connection with the tibia. The medial wall of the central main part of the shaft is almost level, its lateral wall is curved to different degrees. The distal end is reinforced and the medial edge is more or less extended forward toward the astragalus. A facet for the contact with the lateral rim of the astragalus is not developed. In the middle section a muscle insertion area runs obliquely distally and posteriorly on the lateral face, which is variably developed in different genera; it is regarded as the insertion of M. anconeus.

Table 16: Measurements of the fibulae of *Brachiosaurus brancai*, *Barosaurus africanus*, *Dicraeosaurus hansemanni*, *D. sattleri*, *Tornieria robusta.*

Species	Horizon	Find	Side	Length		Proximal width		Distal width		Smallest width of shaft	
				cm	%	cm	%	cm	%	cm	%
Brachiosaurus brancai	Upper Saurian Marl	J 11	r	96	100	24.5	25.5	21	22	9	9.5
	Upper Intermediate Beds	XV 2	r	134	100	33+	25+	22+	16.5+	15	11
	Middle Saurian Marl	XX 7	r	41	100	11.5	28	8	19.5	4.5	11
	Middle Saurian Marl	St 149	r	109	100	29	27	23	21	12.5	11.5
	Middle Saurian Marl	S II 3	r	119	100	30.5	26	23.5	20	12.5	10.5
Barosaurus africanus	Upper Saurian Marl	K 1 b	r	87	100	20.5	23	16.5	18.5	9	10.5
	Upper Saurian Marl	H 3	l	92	100	20	22	16	17	8.5	9.5
	Upper Intermediate Beds	Ki 65		75	100	13.5	17	12	16	7	9.5
	Upper Intermediate Beds	F 4	l	95	100	17.5	18	15.5	16	8.5	9
	Middle Saurian Marl	St 61	r	88	100	15	17	13	15	9	9.5
Dicraeosaurus sattleri	Upper Saurian Marl	O 5	r	62	100	—		11	18	—	
Dicraeosaurus hansemanni	Middle Saurian Marl	m 3	l	80	100	21	26	17.5	22	9.5	11.5
Tornieria robusta	Upper Saurian Marl	E. FRAAS (1908)	r	84	100	20	24	14	17	10	12

The topographic relationships of the distal end of the fibula with the tibia and the tarsus is only very indistinctly marked; the areas that were probably in contact were obviously so completely covered in cartilage that their bony surfaces show no differentiated contact areas.

Brachiosaurus brancai
(Suppl. K Fig. 2 a–e)

The fibula St 149 that belongs to tibia St 148 is nearly straight, variably slender, it widens from mid-length rather uniformly in the proximal direction. The roughened area on the medial wall is much shorter than wide, and finely fluted longitudinally. The proximal end is thick and strongly arched in lateral direction, it is extended as a thin structure anteriorly. The proximal contour slopes in a curve in anterior direction. The proximal end surface describes a flat arch and becomes strongly narrow anteriorly. In its middle section the shaft is strongly curved laterally and shows a rounded, high-triangular cross-section. The distal end surface has a rounded triangular to rounded trapezoidal contour. Highly characteristic is the medial edge of the distal end surface, which projects as a wide bulge. The insertion area for the M. anconaeus is only weakly developed as an irregularly broad and bulgy structure at mid-length .

The fibula XV 2 from the Upper Intermediate Beds is distinguished by the extreme length of 134 cm. The fibula illustrated by E. FRAAS (1908, pl. 10, fig. 3, 4) as *Gigantosaurus africanus* belongs to *Brachiosaurus*.

Barosaurus africanus

Overall shape slender (Pl. XXI, Fig. 3) especially in the fibulae from the upper interspersed layers, as Ki 65 (Pl. XXI, Fig. 5). (K 1 b [Pl. XXI, Fig. 3 a–c] from the Upper Saurian Marl belongs to tibia K 1 a.) A distinct S-shaped curvature is characteristic. The somewhat posteriorly inclined proximal section is only slightly widened in proximal direction, as the anterior contour is also distinctly inclined posteriorly. The proximal end surface is weakly curved, the distal end surface, which rises often slightly in posterior direction, is irregularly elliptical (Pl. XXI, Fig. 3 b, c). Its medial rim projects slightly in medial direction. The whole insertion area for the muscle lies above mid-length and is well-developed. The rugose medial triangular area extends slightly distally farther than in *Brachiosaurus*. In its middle section the shaft is weakly arched laterally, the cross-section is low.

The fibula of *Diplodocus carnegii* HATCHER is similar to that of *Barosaurus africanus*, being slender and S-shaped. The insertion area for the muscle lies here also above mid-length.

Dicraeosaurus hansemanni
(Suppl. L fig. 2 a–d)

Overall shape of the fibula of skeleton m from the Middle Saurian Marl rather strong, straight, posterior contour is rising very straight; the proximal end is wide, posteriorly extended. The anterior end surface is moderately narrow, curved; the distal end is particularly strong, with wide elliptical end surface. The medial rugose area, below the proximal rim is slightly shorter than in *Barosaurus*. The insertion area for the muscle lies approximately at mid-length and is only weakly developed.

Dicraeosaurus sattleri
(Suppl. L Fig. 5 a, b)

The entire shape is very similar to that in *D. hansemanni*, and may be only somewhat more slender. The shaft is in the middle section weakly arched on the lateral side, and the cross-section is therefore narrow.

Tornieria robusta

Moderately slender, proximal section strongly widened in posterior direction, proximal end surface very narrow, in harmony with the weak development of the epicondyle lateralis of the femur. The distal end is medially thickened and bulging. The proximal section of FRAAS's specimen (E. FRAAS 1908, pl. 11, figs. 3, 4, text figs. 15, 16—here reproduced as Pl. XXI, Fig, 8) is probably narrower toward the anterior rim due to erosion. The fibula P 3 is considerably wider distally.

Pes

Although the sauropod manus mainly experienced static loads with its steeply positioned metacarpals, the pes was also subject to strong kinetic forces, in as much as the capability for flexion existed between the lower leg and the tarsus, and the toes also were capable of a real rolling movement, as far as such a movement was not limited by the reduced number of phalanges and an degeneration of their form. The five-toed pes of sauropods is characterized by relatively short metatarsals, of which the first is particularly strong, but shorter than the second. The first three toes end mostly in claws, such as in *Camarasaurus*, *Apatosaurus*, *Tornieria*, and probably also in *Dicraeosaurus*; the third claw is absent in *Barosaurus africanus*. The first claw is always the longest and strongest, the second is considerably shorter and weaker, the third claw is still significantly weaker and shorter. A shortening of the toes is caused by reduction of the normal number of phalanges, but it can also take place in the claw-bearing toes by a shortening and reduction of the penultimate phalanx. The strong claws of at least the first two toes are positioned obliquely laterally due to the tilt of the distal joint facets relative to the longitudinal axis of the pertinent metatarsals. All in all, it is evident that within sauropods the morphology of the pes is more homogenous than that of the manus. Only with respect to one element, metatarsal V, is a certain differentiation of the genera visible.

Tarsus

The tarsus consists of the medially extensive astragalus and the small lateral calcaneum. A calcaneum is not identified even for the well-known older genera such as *Camarasaurus*, *Apatosaurus*, and *Diplodocus*. Baron VON HUENE (1929) found it in titanosaurs of Early Cretaceous age. Whether the rare evidence of a calcaneum is due to the fact that it just has not been found in the majority of genera, or that it was not ossified, or even that it was not developed at all must remain an open question.

Astragalus

(Tab. 17)

The astragalus connects the tibia with the metatarsus as an extensive, mostly wedge-shaped medially flattened block. Hence, the shape of the proximal wall fits perfectly on the distal end of the tibia. The width—the extent in the mediolateral direction—exceeds the length, that is the extent transverse to the width, to a highly variable degree. The entire lateral wall of the astragalus exhibits a very strong bulge with a mediolateral axis; the bulge is strong on the lateral side but becomes flatter medially. The proximal end surfaces of Mt I–III and probably also in part Mt IV articulated with the anteriorly directed, poorly differentiated area of the bulge, although the posteriorly directed area of the bulge was probably covered with a thick sole cushion. The contour of the flatter medial section of the astragalus is narrower or wider in the different genera. Laterally a more or less concave depressed wall is developed on the astragalus; the degree to which the wall is obliquely positioned is variable and the central part is usually relatively smooth.

Table 17: Measurements of the astragalus of *Brachiosaurus brancai, Barosaurus africanus, Dicraeosaurus hansemanni*, *D. sattleri*, *Tornieria robusta*.

Species	Horizon	Find	Side	Width		Length		Height	
				cm	%	cm	%	cm	%
Brachiosaurus brancai	Middle Saurian Marl	St 150	r	28.5	100	18.5	64	17.5	61
	Middle Saurian Marl	Y 25	r	29.5	100	16	55	17	56
	Upper Saurian Marl	Z 68	l	24.5	100	16	64	12.5	52
	Upper Saurian Marl	X 24	l	30.5	100	21	69	19	62
	Upper Saurian Marl	XII 7	l	31	100	18.5	60	19	62
Barosaurus africanus	Upper Saurian Marl	No 79	r	24.5	100	18	72	16	66
	Upper Saurian Marl	K 1 c	r	22.5	100	15.5	69	14	64
	Upper Saurian Marl	K 23	l	22	100	14.5	69	14.5	65
	Upper Saurian Marl	TL 31	l	10.5	100	7.5	70	7	68
Dicraeosaurus sattleri	Upper Saurian Marl	XIV 4	l	10	100	8.5	83	6.5	68
	Upper Saurian Marl	ab 18	r	15	100	14	91	10	65
Dicraeosaurus hansemanni	Middle Saurian Marl	m	l	21.5	100	16.5	77	14	66
Tornieria robusta	Upper Saurian Marl	E. FRAAS (1908)	r	27	100	16	59		
	Upper Saurian Marl	P 4	l	30.5	100	21	68	13	43

A strong pillar that rises on the rear side between the distal and the proximal wall is of a remarkable form; it is smooth on the outside, variably wide throughout the genera, and more or less angular. The significance of this pillar was certainly to absorb the load from the tibia and transmit it onto the metatarsus, the pillar lies more or less in the center of the width of the metatarsus. Medial to this pillar, a groove runs along the ventral rim of the lateral wall. This groove can be very flat (as in *Brachiosaurus*), but can often also be deeply cut in with a rounded or sharp rim. This groove lies ventral to the area where the distal rim of the tibia shows an indentation—probably for the passage of a strong tendon that runs toward the pes. At the bottom of the groove often one or two remarkably wide foramina are visible. On the concave lateral wall of the astragalus are sometimes larger foramina, but by far not as large as the previously mentioned ones. It can be naturally assumed that large blood vessels, perhaps together with nerves, penetrated the astragalus through these large foramina. The question about the content of the groove on the posterior wall, in most cases really remarkable, devoid of all bone tissue, is hard to answer. It can only be stated, as the preparation kindly executed by Senior Preparator NEUBAUER shows, that the large foramina turn laterally at some depth of the grooves, the foramina of the lateral wall turn medially. A cross-section of one of the large foramina in the lateral wall shows that it ends blindly and therefore does not branch out.

Three different types of surfaces can be distinguished on the astragalus. There are areas with a smooth surface, i.e. the posterior wall of the pillar, followed by the concave lateral wall, and the more or less depresed area medially adjacent to the pillars, which mostly exhibits large foramina. The edge of the entire large bulge of the astragalus is characterized by a coarse tubercular sculpture, especially at its medial rim and the ventral rim of the lateral wall, and here in particular at the anterior corner. The remaining surfaces of the astragalus are covered with low tubercles and are undulating; small pores which are mostly filled with matrix are visible in the very weakly sculptured areas. The width of the pores depends on the size of the astragalus, the diameter at their mouth may range from 1 mm to more than 4 mm in the same specimen. It is certain that th, with the exception of the smooth areas, e astragalus wascovered with cartilage, especially in the highly tuberose marginal areas.

It has been reported for the sauropods of the Morrison Beds that the astragalus may fuse with the tibia; it can therefore be assumed that, even if—as it is usually the case—both parts are unfused, no flexibility worth mentioning existed in this area. The astragalus is in some cases compressed flat; it was probably due to its mostly cartilaginous constitution not very resistant to the pressure from the surrounding matrix.

Brachiosaurus brancai

Left astragalus X 24 from the Upper Saurian Marl (Pl. XXII, Fig. 1). Right astragalus St 150 from the Middle Saurian Marl (Pl. XXII, Fig. 2 a, b). The lateral section of the robust astragalus is almost rectangular, the contour becomes narrower medially and ends broadly rounded. The lateral wall, with rather roundish outlines is characterized by the perpendicular orientation to the wide axis of the entire bone and the low depression. The pillar is exceptionally wide and massive. The groove medial to the depression is moderately well-developed and flat, it includes one or two large foramina, which are up to 29 mm wide. Two much smaller foramina are visible on the lateral wall of one of the astragali.

An astragalus of *Brachiosaurus atalaiensis* from the Kimmeridgian of Portugal, which A. F. DE LAPPARENT and G. ZBYSZEWSKI (1957, pl. 28, fig. 103) illustrated, corresponds well with that of *B. brancai*. Illustrations of a deformed astragalus of *Camarasaurus supremus* by OSBORN & MOOK (1921, fig. 116) show distinct similarities with the astragalus of *Brachiosaurus* namely in the shape of the entire contour, in the perpendicular position of the lateral wall, and in the width and the position of the pillar.

Barosaurus africanus

Left astragalus K 23 from the Upper Saurian Marl (Pl. XXII, Fig. 3 a–c). The contours of several differently large astragali have, as also FRAAS's (1908, plate 9, fig. 4) illustration shows, approximately the shape of a high, equilateral triangle, the sides of which are slightly curved and the tip of which is short and rounded. In contrast to *Brachiosaurus* the lateral wall rises, inclined in medial direction and is strongly depressed. The pillar is here considerably lighter built and more irregularly differentiated. The groove next to its medial edge is moderately sharp delineated and contains one or two large foramina, which are up to 24 mm wide. The bulge of the distal wall increases especially strong towards the lateral wall.

Two remarkable parallel grooves are found on the distal wall of astragalus K 23, which probably represent fractures suffered in life, which later healed. The incomplete right astragalus of *Diplodocus carnegiei* HATCHER (1901, fig. 20) apparently does not differ considerably from that of *Brachiosaurus africanus*.

Dicraeosaurus hansemanni
(Fig. 23)

The astragalus has, in contrast to the other genera from the Tendaguru Beds, a more short trapezoidal contour, the posterior rim of which is considerably shorter than the anterior one. The lateral wall is clearly obliquely positioned and distinctly concave. The pillar is relatively weak, forming more a plate positioned oblique to the longitudinal axis. The longish groove next to the pillar is extensive, with sharp edges, but does not show a large foramen.

Fig. 23. Left astragalus of *Dicraeosaurus hansemanni* m 4 in posterior view, 1/4 natural size. — Gr. = groove, lat = lateral side, med = medial side, Pf = pillar.

Dicraeosaurus sattleri

Left astragalus ab 18 from the Upper Saurian Marl (Pl. XXII, Fig. 4 a, b). Right astragalus IV 4 from the Upper Saurian Marl (Pl. XXII, Fig. 5 a, b). The available astragali, which according to the stratigraphic position of the sites belong to the younger species of *Dicraeosaurus*, show no distinct differences when compared to the astragalus of *D. hansemanni*.

Tornieria robusta

The astragalus differs completely from those of the genera discussed. From excavation site P (plate XXII, Fig. 6) in the Upper Saurian Marl two left specimens correspond well with the right astragalus described and illustrated by E. FRAAS (1908) (reproduced on Pl. XXII Fig. 7). The bone represents a low plate; this is particularly true for its medial section, which becomes much narrower medially; the entire distal wall is only slightly curved. The lateral wall is very weakly concave and shows in P4 one very large and two smaller foramina below the proximal rim. The pillar, which is strongly eroded in P4 and P7, becomes very wide distally according to E. FRAAS's illustrations and reaches far laterally. Two more foramina appear medially to the pillar.

Calcaneum

The lateral element of the tarsus, the calcaneum, is a nearly semispherical, compact structure with a rather smooth curve and a flat, slightly tubercular proximal wall. The spatial position of astragalus and calcaneum cannot be determined by the distinct contact areas on both elements. It may be assumed that the curved zone of the distal wall of the astragalus, which lay opposite the larger medial section of the metatarsus, continued into the curved distal wall of the calcaneum, and that this distal wall lay opposite the less extensive lateral section of the metatarsus. The contact surface of the calcaneum, together with the distal end surface of the fibula, must have formed a flat, somewhat tubercular wall. A non-rigid articulation might have existed between the exceptionally rough and tuberous distolateral corner of the astragalus and the equally coarse tubercular side of the calcaneum.

Metatarsals — *Brachiosaurus brancai*

Fig. 1. left Mt I S II 117: distal view.
Fig. 2 a–d. left Mt I Jg 415: 2 a dorsal view, 2 b medial view, 2 c distal view, 2 d proximal contour.
Fig. 3 a, b. left Mt II S II 118: 3a dorsal view, 3 b proximal contour.
Fig. 4 a, b. Left Mt III W 4: 4 a dorsal view, 3 b proximal contour.
Fig. 5. Right Mt IV Q14: dorsal view.

All figures 1/3 of natural size.

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Explanation to figures see page 218 below

It is obvious to assume that the bulging, more or less protruding medial rim of the distal end of the fibula was related to the smooth concave lateral wall of the astragalus, as already supposed by OSBORN & MOOK (1921). However, the different characteristics of the surfaces of both areas indicate that there was no immediate contact between them and that they might have been separated by perhaps a considerable distance. It might be assumed that an extensive bursa was inserted between them.

Fig. 24 a, b. Left calcaneum of *Brachiosaurus brancai* Bo 4.
a proximal view. b posterior view? 1/4 natural size.

Brachiosaurus brancai
(Fig. 24 a, b; Pl. XXIII, fig. 1 a–c)

The calcaneum of *Brachiosaurus brancai* St 149, Middle Saurian Marl (Pl. XXII, Fig. 1 a–c) is represented by an almost complete hemisphere. The distal wall shows a very flat ridge that runs along the slightly longer axis. The proximal wall is slightly depressed and strongly tubercular; one of the rims, presumably the medial one, is particularly tubercular. A similar, but smaller calcaneum (I R 24) is not concave proximally. Whether this bone also, too, belongs to *Brachiosaurus* cannot be decided.

The calcaneum of *Titanosaurus australis* LYD. resembles in the overall shape quite that of *Brachiosaurus* (Freiherr von HUENE 1929, pl. 17, fig. 2)

Metatarsus and toes

Brachiosaurus brancai

The available material of elements of the foot skeleton includes:

a) Left metatarsal I and II, one claw, one phalanx of S II, Middle Saurian Marl. According to their size these remains must be referred to the larger of the two specimens from this excavation site.

b) Pes bones from trench XX, Middle Saurian Marl, all of them from not fully grown individuals. One Mt I from a larger animal; two and a half metatarsals, four phalanges, among them two identical ones of exactly the same size, apparently from two smaller, but similar sized animals; a very small claw of a fourth individual.

c) A number of mostly isolated foot elements from different excavation sites in the middle and Upper Saurian Marl.

As a completely articulated pes of *Brachiosaurus* is not present, the individual specimens of foot bones will be discussed in more detail to understand the essential characters of the general morphology of the foot skeleton.

M e t a t a r s a l I (Suppl. M Figs. 1, 2 a–c; Suppl. N Fig. 1a–c)

Left Mt I Jg 415; Middle Saurian Marl. Overall shape rather robust. The cross-section of the bone narrows strongly medially, it is distally hardly narrower than proximally, but transversely it is only slightly more than half as wide. The contour of the extensive proximal end surface is a somewhat oblique semicircle, being straight laterally. Immediately below the center of the lateral wall lies a narrow rugosity. The medial wall is rather narrow, below its proximal rim lies a low rugosity. The tubercular distal end surface bulges dorsally, a wide depression separates the two almost similarly thick condyles. — Left Mt I "S II 117". The proximal and distal sections are incompletely preserved, but they are in contact with one another, and therefore the total length is present. The reconstructed M I [*lapsus*: Mt I] might not have been restored extensively enough in its proximal section, but it is similar to the previous one with respect to the essential characters. — Right Mt I "XX 11"; Middle Saurian Marl. The overall shape is slightly more elongate than in Jg 415. At the distal end the thicker medial condyle extends further onto the dorsal area than the narrower lateral condyle. A notch on the lateral side of the condyle is well developed. — Left Mt I "TL 33"; Upper Saurian Marl. The small Mt 1 is very similar to XX 11, the previously described one.

M e t a t a r s a l II (Suppl. M Fig. 3 a, b; Suppl. N Fig. 2 a–c).

Left Mt II "Lw 4"; Middle Saurian Marl. The overall shape is slightly elongate, the distal end is slightly wider than the proximal. The proximal end has a more or less rectangular cross-section, with dorsal and plantar edges, between which lies an extensive longitudinal groove. Both distal condyles are weakly developed and are not expressed at all on the dorsal side; the medial condyle is slightly thicker than the lateral and extends further proximally on the plantar side. — Right Mt II "XX 12". This small Mt is very similar to the larger Lw 4, only noticeably more slender. The shaft has a square-rounded cross-section in its middle section. — Left Mt II "S II 118". There are no remarkable differences to the other Mt II.

M e t a t a r s a l III (Suppl. M Fig 4 a, b; Suppl. N Fig. 3 a–c)

Right Mt III XX 13. Overall shape slender. The flat proximal end surface is irregularly trapezoidal; the dorsal rim in much longer than the plantar. Ventral to the lateral rim of the proximal end surface lies a ca. 2 cm wide area with transverse fluting. The longitudinal groove on the lateral wall is absent, in contrast to Mt II. Below the mid-length, the shaft has a rather square cross-section. The condyles are only very weakly indicated. Mt III XX 13 probably originated from the same pes as Mt II XX 12. — Left Mt III W 4; Middle Saurian Marl. The overall shape of this large metatarsal is considerably more robust than the small metatarsal XX 13. Overall, there is such a good agreement that both metatarsals must be regarded as the same Mt from two very differently sized individuals.

M e t a t a r s a l I V (Suppl. M Fig. 5; Suppl. N Fig. 4 a, b)

Right metatarsal Mt IV Q 14; Middle Saurian Marl. Surface weathered. Because of its size the Mt can only belong to *Brachiosaurus*. The overall shape is similar to Mt III W 3 but more slender. In contrast to the latter the shaft has a cross-section that is rounded on the plantar side and acutely angled at mid-length, whereas it shows an obtuse angle in Mts III W 4 and XX 13. As the same difference between Mt III and Mt IV is developed in pes XIII of *Barosaurus africanus*, Q 7 should also be regarded as Mt IV. — Right Mt IV GD 18; Upper Saurian Marl. The 6 cm long distal section has an egg-shaped, 3.4 cm long and 2 cm wide cross-section at the obliquely proximally running fracture surface. The width increases toward the 6.5 cm wide distal surface very quickly. This end surface is medially ca. 5 cm high, laterally narrower and flatly arched.

M e t a t a r s a l s — *Brachiosaurus brancai*

Fig. 1 a–c. Left Mt II Lw 4: 1 a dorsal view, 1b distal view, 1c proximal contour.
Fig. 2 a–c. Right Mt II XX 12: 2 a dorsal view, 2 b distal view, 2 c proximal contour.
Fig. 3 a–c. Right Mt II XX 13: 3 a dorsal view, 3 b distal view, 3 c proximal contour.
Fig. 4 a, b. Right Mt IV GD 18 (distal section): 4 a dorsal view, 4 b distal view.
Fig. 5 a, b. Right Mt V XX 14 (proximal section) 4 a dorsal view, 4 b proximal contour.
Fig. 6 a, b. Right Mt V GD 19 (distal contour): 6 a dorsal view, 6 b distal view.
Fig. 7. Reconstruction of Mt V.

All figures 1/2 natural size.

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Explanation of figures see page 220 below

The condyles are hardly indicated. On the dorsal surface, a wide, rough swelling lies medially, immediately in front of the end surface. The fragment, which was found similarly together with the obliquely cut-off distal section of a Mt V, might originate from a right Mt IV because of its narrow shaft.

M e t a t a r s a l V (Suppl. N Fig. 5 a, b; fig. 6 a, b; Fig. 7)

Right Mt V XX 14. Only the proximal, 8 cm long half is preserved, which allows only the identification as the proximal section of a Mt V. The proximal end surface has a very low, isosceles outline, 7.2 cm wide and 2.8 cm high contour; the medial edge is characterized by a narrow, longitudinally extended contact area for the Mt IV. The wide proximal section narrows very rapidly and is transformed into a slender shaft, the distal fracture of which forms a 2.5 cm long and 1.8 cm wide ellipse. — Right Mt V GD 19; Upper Saurian Marl. Only 7 cm of the distal half is preserved. The very thin shaft with a roundish cross-section showing a diameter of 2.5 cm extends into a wide, rather flat, 7.2 cm wide and 4.4 cm thick distal end. On the one lateral side the distal end shows a ca. 3.5 cm high nose-like ledge. The curved end surface shows a long elliptical contour, it is strongly pitted on the plantar side and extends on to the outer surface of the ledge, which is most probably directed laterally. An interpretation other then a distal section of a Mt V, which originates together with Mt IV G D 18 from the same pes, is hardly possible; furthermore, it can only be referred to *Brachiosaurus*, as the Mt V in other genera of sauropods from the Tendaguru Beds shows a much wider shaft. The very slender shaft corresponds well to the proximal end of Mt V “XX 14.” A combination of both specimens results approximately in the reconstructed contour in Fig. 7, the measurements of which are of course uncertain.

T o e s (Suppl. O)

1. Toe

I 1: i 7 (right); Upper Saurian Marl. The phalanx is short and cylindrical and, as in other sauropods, is considerably shorter laterally than medially. The lateral wall is set off by a dorsal ridge. The plantar surface encloses with the irregularly circular proximal surface an angle of only ca. 55°. Both vaulted condyles are low; the lateral condyle is characteristically indented laterally by a concave surface. The significantly oblique position of the plantar surface identifies the phalanx as phalanx I 1. The greater length of the phalanx and the lower height of the distal joint surface distinguish this phalanx from those of *Brachiosaurus*, *Tornieria*, and *Dicraeosaurus*. Several bones of *Brachiosaurus* were found at the excavation site. — IR 19 (right); Upper Saurian Marl. corresponds well with i 7, but is significantly shorter and shows a higher distal end surface.

I 2 (claw): S II 119 (right). The entire distal half of the claw and corners of the proximal end are missing. The sharply edged back is particularly characteristic. The dorsally acute cross-section of the proximal section widens strongly toward the sole. — G 90 (left). Completely preserved; large (Pl. XXIII Fig. 2 a, b). — XX 2 (right) as far as it can be compared, corresponds very well with the previously described claw S II. The contour tapers uniformly into the rounded pointed distal end; the overall shape induces a minor extension. The weak curve of the entire medial wall is characteristic. A sharp edge extends on the palmar side straight to the distal end. The groove on the lateral side starts about 4 cm from the proximal end, approaches the dorsal edge distally, extends onto it, passes over the edge and curves close to the distal end downward to the palmar edge. The area surrounding the groove is distinctly vaulted. The groove approaching the dorsal rim, as well as the weak curvature of the dorsal contour, represent the distinguishing characters for pedal claw I 2 of *Brachiosaurus*. — G 90 (left); Upper Saurian Marl (Pl. XXIII, Fig. 2 a, b). It resembles essentially the already described claw XX 2, the only difference is in the course of the lateral groove staying consistently more lateral, next to the dorsal edge. — i 19 (left); Upper Saurian Marl. The claw is distinguished from the previous ones by a slightly lower shape, the almost completely reduced concavity of the proximal end surface, and a slightly rounded back. Theses differences seem to be essentially the result of weathering. The claw belongs probably to the same animal as claw I 2 i 7.

2. T o e

II 1: XX 17 (right) and XX 15 (right). Overall shape flat and cylindrical, laterally flattened, slightly longer medially than laterally, higher than in III 1. Proximal surface is a wide oval. The distal facet is slightly indented in its center; a notch in the distal rim separates the condyles; the lateral condyle is indented above the plantar rim.

II 2: Not identified.

II 3 (claw): XIV 24 (left) (Pl. XXIII, Fig. 3); Upper Saurian Marl. The claw differs from claws of the first toe by the shorter shape, it resembles them in the very weakly curved plantar contour. The groove starts slightly in front of mid-length and trails in a distinct curve toward the dorsal rim and further on closely below the rim. The claw might be regarded as that of the second toe more likely than the third, it is 8.9 cm long, 5.8 cm high, and proximally 3 cm wide.

3. T o e

III 1: XX 16 (right). Overall shape low, flatter than II 1; in dorsal view rectangular, strongly flattened laterally. The proximal end surface is oval-triangular with rounded corners. The distal facet is low, slightly indented, the medial condyle is somewhat extended in the plantar direction. — TL 4 (left); Upper Saurian Marl. The phalanx is very similar to the previous one, much larger. — U 11 (left); Middle Saurian Marl. The distal end is remarkably lower laterally than in the two previous III 1, and also curved ventrally.

III 2: Not identified.

III 3: Not identified.

4. T o e

IV 1: SII 120 (left). The rim on the proximal end surface is for the most part missing. Overall shape shorter than in III 1, flat cylindrical, less flattened laterally; proximal end surface semicircular. The distal end is distinctly indented in the center, the lateral condyle is slightly more extensive than the medial. A rugose tubercle lies directly in front of the plantar medial corner. The short shape argues for a IV 1. — XX 18 (right). Overall shape short, shorter than III 1 and rather flat, slightly pointed medially. The proximal end surface is oval, the distal end wide and distinctly indented; the medial condyle is more voluminous than the lateral, the facet of the latter is extended laterally on the plantar side. — JR 20 (right); Upper Saurian Marl. The phalanx probably originates from the same pes as phalanx JR 19, which was identified as I 1. It is very short and therefore must be considered as IV 1. The lateral condyle is strongly laterally extended on the plantar side. The much more complex form of the distal end compared with the middle toe is remarkable.

P e d a l   p h a l a n g e s — *Brachiosaurus brancai*

Fig. 1 a–c. Right I 1 i 7: 1 a dorsal view, 1 b distal view, 1 c proximal contour.
Fig. 2 a, b. Right I 1 JR 19: 2 a dorsal view, 2 b distal view.
Fig. 3 a, b. Left I 2 XX 2: 3 a lateral view, 3 b proximal view.
Fig. 4 a–c. Right II 1 XX 17: 4 a dorsal view, 4 b distal view, 4 c proximal contour.
Fig. 5 a, b. Right II 3 XIV 24: 5 a lateral view, 5 b proximal view.
Fig. 6 a–c. Left III 1 U 11: 6 a dorsal view, 6 b distal view, 6 c proximal contour.
Fig. 7 a–c. Left III 1 TL 4: 7 a dorsal view, 7 b distal view, 7c proximal contour.
Fig. 8 a–c. Right III 1 XX 16: 8 a dorsal view, 8 b distal view, 8 c proximal contour.
Fig. 9 a–c. Right IV 1 XX 15: 9 a dorsal view, 9 b distal view, 9 c proximal contour.
Fig. 10 a–c. Left IV 1 S II 120: 10 a dorsal view, 10 b distal view, 10 c proximal view.
Fig. 11 a–c. Right IV 1 JR 20: 11 a dorsal view, 11 b distal view, 11 c proximal contour.

All figures 1/2 natural size.

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Explanation of figures see page 222 below

Barosaurus africanus

Left pes No. 28; Upper Saurian Marl (Pl. XXIII, Fig. 6). This isolated find was discovered in articulation and with the metatarsals in their original steep position.

Right pes XIII 10; Upper Saurian Marl (Pl. XXIII, Fig. 7).

M e t a t a r s u s (Figs. 25, 26; Suppl. P.)

M e t a t a r s a l I

No. 28: Overall shape short and very stocky. Medial and lateral rims of proximal surface almost parallel. The dorsal surface must have protruded with its incompletely preserved edge quite far over the rather strongly concave lateral surface. The distal end shows a considerable width by the protruding lateral condyle; the condyle is considerably narrowed by a lateral notch for the collateral ligament. The medial condyle is much smaller than the lateral one. — XIII 10: In comparison with the previous metatarsal, it is distally less wide. The proximal surface slopes dorsally even steeper in medial direction. The edge between dorsal and lateral side is distinct, and hasa bulging area and extends 3 cm below the proximal surface.

The similarity with Mt 1 of the plaster reconstruction of *Diplodocus longus carnegiei* is considerable.

M e t a t a r s a l II

No. 28: The overall shape is stocky, considerably longer than in Mt I. The shaft is square, the edge between the plantar and the lateral surface being rounded. The distal end surface has an irregular rectangular contour; on its plantar half, two condyles are developed, separated by a flat sulcus, and protrude to the same extent in the plantar direction. On the dorsal side, a distinct rugose swelling lies laterally and slightly distally from mid-length. — XIII 10: The overall shape is slightly more slender than in the previous Mt II, it is otherwise very similar to it. — The small Mt II St 95, which may well originate from the same animal as the left Mt III St 307 described below which comes from the same trench in the Middle Saurian Marl. It resembles very much the Mt II of XIII 11, only the proximal and distal ends are less distinctly developed; the overall shape is therefore more slender.

It should be mentioned here that the bone end fragment collected by BORNHARDT in the vicinity of the Namgango River 37 km west of Mtschinga, which was considered the distal end of a *Plesiosaurus*-like animal, represents the proximal end of a left Mt II of *Barosaurus*. It corresponds very well with the right Mt II of XIII 11.

M e t a t a r s a l III

No. 28: A middle section of the shaft is missing; the overall shape restored after XIII, is much more slender than Mt II. The proximal end surface is narrow, very irregular square, the end surface slopes significantly behind to the medial edge. The proximal end narrows rather rapidly and grades into the slender shaft, the triangular cross-section of which becomes more roundish-square close to the distal end. The distal facet is about as wide as high, its cylindrical bulge extends medially farther onto the dorsal surface, although on the plantar side a separation into two condyles is indicated. — XIII 11: The overall shape is distinctly more slender than in No. 28. The contour of the proximal end surface is even more wedge-shaped. The distal articulation is simpler, without an indication of a median indentation. — Left Mt III St 307; Middle Saurian Marl. The small metacarpal [*sic*] corresponds very well with Mt III of XIII 10, only that the overall shape is even more slender and the distal facet is slightly higher than wide.

M e t a t a r s a l IV

No. 28: The overall shape is slightly stockier than in Mt III, the proximal end is strongly developed in the dorso-plantar direction. The proximal, distinctly transversely arched end surface is very narrow and irregularly square, it is significantly narrowed in the plantar direction. The distally narrowing shaft exhibits proximally a slightly odd-sided triangular, distinctly semicircular cross-section. The distal end is thicker medially than laterally. The transversely arched end surface protrudes medially far onto the dorsal surface.

On the plantar side, a narrow medial and a wider lateral condyle are indicated. — XIII 10: Overall shape more slender than in No. 28; the proximal end surface is rather different, its dorsal edge being shorter and forming a less obtuse angle with the medial end surface. The shaft has a much narrower cross-section. The distal end is considerably different in contour, representing a much shorter equilateral triangle.

M e t a t a r s a l V

No. 28: As there is a section missing from the shaft, the total length is indeterminable. The overall shape differs entirely from that in the other Mt; it is very stocky; the very wide proximal section narrows considerably distally and has a distinctly triangular cross-section, the plantar being the most extensive, and the narrower medial side forming a rounded, very obtuse angle with the third, wider dorsal side. The distal end is only little widened in the low dorso-plantar direction, its end surface is transversey arched without a distinct facet, the surface curves strongly proximally on the lateral side. — XIII 10: The overall shape is very similar to that in No. 28, only the proximal end surface is more convex and the profile of the distal end is more uniformly rounded and shows an obtusely angled, flatter contour.

T o e s (Suppl. Q)

1 . T o e

I 1: No. 28. Short, medially significantly longer than laterally. The distal facet is slightly obliquely positioned, the proximal contour is decidedly triangular and dorsally broader rounded. A low depression separates two flat condyles, which grade into each other dorsally. On the plantar side the lateral condyle protrudes much farther in proximal direction than the medial one. — XIII 10: rather similar to the left phalanx I 1 of No. 28 but significantly lower; the distal facet is positioned even more obliquely.

I 2 (claw): No. 28. The claw has a high cross-section, strongly curved, the proximal facet is a long ellipse, the oval shape is convex. The strong and uniformly curved back is narrowly rounded, the medial surface is very slightly arched, the lateral surface is relatively even; the groove located on the lateral side, onto which the horny sheath extended, originates at about mid-length, approaches the back-line distally in a gentle curve, and disappears near the distal end. The proximally rather flat ventral surface widens distally. The distal end is irregularly worn. — XIII 10: The claw corresponds in essence with that of No. 28. The proximal end surface differs in being wider and having a more concave depression below mid-height. The overall shape is altogether somewhat shorter and higher in comparison with the former.

Several claws from the Upper Saurian Marl are present that resemble the two described above in shape and size.

2 . T o e

II 1: No. 28. Moderately short and stocky, significantly longer than I 1, much longer medially than laterally, medially high, flattening laterally. The low, depressed proximal facet is after restoration a rounded equilateral triangle, the distal facet is strongly oblique. The medial condyle is much wider and very obliquely

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P e s of *Barosaurus africanus* — M e t a t a r s a l s

L e f t p e s No. 28

Fig. 1 a–5 a. Mt I–Mt V dorsal view.
Fig. 1 b–5 b. Mt I–Mt V distal view.

R i g h t p e s X I I I 10

Fig. 6 a–10 a. Mt I–Mt V dorsal view.
Fig. 6 b–10 b. Mt I–Mt V lateral view.
Fig. 6 c–10 c. Mt I–Mt V distal view.
Fig. 11 a–c. Right Mt II St 905: 11 a dorsal view, 11 b proximal contour, 11 c distal view.
Fig. 12 a–c. Left Mt III St 307: 12 a dorsal view, 12 b proximal contour, 12 c distal view.

All figures 1/3 natural size.

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Explanation of figures see page 224 below

positioned. — XIII 10: The overall shape is much lower than in No. 28, the lateral flattening is much more pronounced, the proximal end surface is therefore significantly lower; the plantar rim is broadly notched.

II 2: No. 28. A flat, sharpened disc with a slightly high-elliptical contour, medially thick at the other rims, especially the plantar. Apparently the strongly transversely concave proximal facet articulated essentially with the medial condyle of II 1 only. The distal facet is transversely convex. In the center of the medial surface is a small pit. — XIII 10: Contour more irregularly rhomboidal, medially thicker. Within the proximal facet there is a somewhat more distinct facet for the lateral condyle of II 1.

II 3 (Claw): No. 28. The distal section of the claw is missing; its restoration appears to be too long. The proximal end surface forms a very obliquely positioned, strongly depressed facet. Distally the plantar surface broadens significantly and is positioned very steeply. — XIII 10: The ventral edge is missing over the entire length. The dorsal contour is strongly curved, the overall shape is short and high, very similar to that on II 3 of No. 28.

3. Toe

III 1: No. 28. Overall shape rather short, pillar-like; the contour is relatively square; distal facet very slightly oblique, the right condyle ca. 1/2 as wide as the left. — XIII 10: Lower and more oblique than in No. 28; distinctly flatter laterally. The distal facet is oblique and much lower than in No. 28, the groove between both condyles is more distinct .

III 2: No. 28. A plate of high elliptical contour with a thin rim, thicker medially where a longitudinal swelling runs in slightly medio-plantar direction. The proximal facet is transversely concave, at the same time saddle-shaped, it fits medially onto the distal facet of III 1. Over the overall convex distal facet runs a steeply positioned groove. — XIII 10: The lateral rim is missing. The contour is narrower than in III 2 of No. 28, with an approximately elliptical shape. The proximal facet shows a large concave section for the lateral condyle of III 1.

III 3: No. 28. Contour long, elliptical; distal surface with a central, rounded longitudinal ridge that drops gradually towards the probable medial side.— XIII 10: Overall shape button-like, contour of the proximal surface short, only slightly flattened, egg-shaped; distal surface with broadly rounded longitudinal ridge.

4. Toe

IV: No. 28. Shorter and flatter than III 1; proximal facet weakly concave, the contour is a high semi-circle, in undamaged condition it probably extended laterally. The condyles are only insignificantly developed. — XIII 10: Quite similar to IV of No. 28, but shorter, flatter, and less symmetrical. Proximal facet almost even, oblique, and laterally extended. The medial condyle is small and flat; the indentation between both condyles is wide.

IV 2: no. 28. Not present. — XIII 10: The shape is very similar to a bisected ellipsoid; the elliptical proximal surface is flat, depressed in the center.

5. Toe

V 1: No. 28. The shape resembles a not quite regular ellipsoid, of which slightly less than the proximally half has been cut off. The proximal surface is flat, irregularly depressed in the center. — XIII 10: The shape is very short, egg-shaped, and proximally abbreviated. This proximal end surface is relatively circular and slightly depressed.

Position of the elements of the pedal skeleton of *Barosaurus africanus*

The reassembly of both pedal skeletons results in a flat curve of the metatarsus and a strong divergence of the metatarsals. The distal facet of the first metatarsal points distinctly medially. Nevertheless, the circumstance that the medial side is significantly longer than the lateral side results in the distal facet of the first phalanx facing distinctly laterally.

The claw of the first toe is thus pointing outward, which is enhanced by the oblique position of its proximal facet. In the second toe, the first phalanx of which is also considerably longer medially than laterally, the second plate-like phalanx is also much longer, i.e. thicker on one side. It is most likely that the thicker side is the medial one in this phalanx, as it is in the first phalanx. Furthermore, the second phalanx was certainly articulated with the medial distal condyle of the first phalanx only, as it is too high for an articulation with the lateral condyle. This mode of articulation, and the predominant medial length of both phalanges, results in an increased lateral orientation of the distal facet of the second phalanx.

Proximal contours of the metatarsals of *Barosaurus africanus*.
Fig. 25. Left pes No. 28.— Fig. 26. Right pes XIII 10.
All figures 1/3 natural size.

As additionally the proximal facet of the claw is very obliquely positioned, the claw of the second toe points to an especially high degree obliquely laterally. In analogy with the first two toes it is assumed that the plate-like second phalanx of the third toe lay on the medial condyle of the first phalanx, in such a way that the thick side lay medially and the longer axis of the bone was steeply positioned. Such a position, with a steeply sloping vertical axis, can also be assumed for the third phalanx of this toe. The undifferentiated shapes of the second phalanx of the fourth toe and the first phalanx of the fifth toe present no certain indications of their positions in life.

Pes of *Barosaurus africanus* — P h a l a n g e s

A. Left pes No. 28	Right pes XIII 10
I 1 a–V 1 a: dorsal view	I1 a–V 1 a: dorsal view
I 1 b–V 1 b: distal view	I 1 b–V 1 b: distal view
I 2 a (claw): lateral view	I 2 a (claw): medial view
I 2 b (claw): proximal view	I 2 b (claw): proximal view
II 2 a: medial view	II 2 a: medial view
II 2 b: distal view	II 2 b: distal view
II 3 a (claw): lateral view	II 3 a : medial view
II 3 b (claw): proximal view	II 3 b: proximal view
III 2 a: dorsal view	III 2 a–IV 2 a: dorsal view
III 2 b : distal view	III 2 b–IV 2 b: distal view
III 3 a : dorsal view	III 3 dorsal view
III 3 b: distal view	III 3 b : distal view
(IV 2 a not present)	IV 2 a : dorsal view
(IV 2 b not present)	IV 2 b: distal view

All figures 1/3 natural size

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Explanation of figures see page 226 below

Comparison of the two pedal skeletons of *B. africanus*

The comparison of pedal skeleton XIII 10 with No. 28 shows that both were rather similarly built with respect to the proportion of strength of the individual digits to one another. With respect to the metatarsals differ in being continuously more slender and slightly shorter in XIII 10. Remarkably different in both pedes of *Barosaurus africanus* is the distal view of the first phalanx of the four inner digits. The distal VI ends in pes XIII 10 are distinctly lower than in No. 28, and in addition the plantar rims of II 1, III 1 are strongly indented and the contour of the distal facets is therefore distinctly differently shaped, especially in II 1 and III 1. This is such a striking development, which certainly must be regarded as a variant, that it is unquestionable that both pedal skeletons belong to the same species, which is also proved by the similarity in all other essential characters.

Dicraeosaurus hansemanni
(Suppl. R)

Left pes dd 213; Middle Saurian Marl. The preserved elements of the left pes were found tightly cemented together by surrounding matrix, but were displaced in their relative positions to one another. The preservation of some pedal elements is very unfortunate, as they are largely deformed. The referral of the pes to *Dicraeosaurus hansemanni* is based on the lower limb bones that were found articulated, and furthermore on the fact that it differs in some points distinctly from the pedal skeletons of other sauropods from the Tendaguru Beds. A right Mt II (St 593) from the Middle Saurian Marl is also assigned to this species.

M e t a t a r s a l s

M e t a t a r s a l I (Suppl. R Fig. 1 a–c)

dd 213: The bone is little deformed. The overall shape is rather short and wide. The lateral wall becomes very wide proximally, its anterior lateral corner is pointed. On the distal roller the lateral condyle is far more extensive than the medial one, the notch in the lateral condyle for the collateral ligament is only very flat, much less clearly developed than in both pedal morphs of *Barosaurus africanus*. The groove between both condyles is strongly expressed on the plantar side. The dorsomedial corner of the distal roller facet extends as a bulge proximally, and further as a protruding ridge to the proximal surface, which is not the case in *Barosaurus*, but in Mt I O 15 assigned to *Dicraeosaurus sattleri*. The transition from the dorsal surface to the lateral surface is broadly rounded, rather than a rounded edge as in Mt I of *B. africanus*. However, the similarity with the latter specimen is remarkable, all things considered.

M e t a t a r s a l I I (Suppl. R Fig. 2a, b; Fig. 6 a–c)

dd 213: The bone is highly deformed.

St 593 (right); Middle Saurian Marl. Overall shape moderately stocky. The proximal surface is obliquely rectangular, the dorsal edge slightly longer than the plantar edge. The shaft shows four distinct rounded edges. Above to the dorsal rim of the distal facet lies a strong roundish swelling. The distal end is semi-cylindrical, of the same thickness medially and laterally. On the plantar side, the distal condyles are only weakly indicated by a very flat central depression.

Mt II is altogether rather similar to that of *B. africanus;* however, the more robust form, the stronger protruding dorsolateral corner of the proximal end, the much less distinct development of the distal condyles, and the extension of the dorsal rim of the distal facet proximally on the medial side, argue against a referral to this taxon. Therefore, this Mt II can only be assigned to *Dicraeosaurus*, namely to the more robust and older species *D. hansemanni*.

M e t a t a r s a l I I I (Suppl. R Fig. 3)

dd 213: Only the 7.5 cm long proximal half is preserved. The shaft is indented especially on the medial side. The uniformly arched proximal end surface has a parallelogram-like contour with greatest length 10.2 cm and greatest width 6.0 cm. The bone is identified as Mt III by the shape of the proximal end surface.

M e t a t a r s a l I V

dd 213: Strongly crushed and bent out of shape. The 14.5 cm long bone suggests that the proximal section is strongly narrowed in the plantar direction, the distal end apparently hardly showed any indication of condyles. The shaft becoming narrower namely in the plantar direction, and the proximal end surface that is narrower in the plantar direction in the element described as Mt III, argue for an identification as Mt IV.

M e t a t a r s a l V (Suppl. R Fig. 4 a–c)

dd 213: Indented on the surfaces in the proximal section; the contours appear not to be significantly changed. Overall shape very stocky, proximally very wide. The proximal end surface and the cross-section of the proximal section form a wide triangle. The distal end is laterally insignificant, with respect to the narrowest part of the shaft medially stronger widened, it bulges in the center of the plantar level on the dorsal side; its rather triangular end surface is in all directions relatively uniformly curved. The Mt is rather similar to Mt V of *Barosaurus africanus,* it is proximally even slightly wider, and the distal end differs by the bulge of the plantar side and by the more regularly rounded profile.

T o e s

I 2 (Claw): dd 213 (Suppl. R fig 5 a, b). The distal half of the claw is slightly deformed, it is high oval, moderately elongated, strongly curved with a plantar rim that is turned inward, and ends in a blunt point. The only slightly oblique proximal end surface is depressed in its plantar two-thirds and dorsally pointed. The medial surface is proximally strongly arched, the lateral surface is in contrast flat throughout. On its surface a strongly curved groove rubs parallel to the rounded dorsal edge. The size ratio to Mt I suggests the assignment of the claw to the first toe.

II 1: dd 213. Severely deformed. Rather short. Proximal surface shows the contour of a nearly equilateral triangle. The distal surface suggests a triangular shape. The lateral condyle is constricted ventrolaterally.

III 3: dd 213. The apparently relatively complete phalanx shows little similarity with the normal shape of the claws. The flat oval 3.9 cm long, 1.8 cm wide facet on one end, the lack of a second facet, and the extended laterally compressed overall shape only allows an interpretation as a claw. A bulging plantar swelling in connection with its irregular structure might indicate a pathologic deformation. The short length of 5.7 cm would argue for a claw of the third toe. — (On the mount of *D. hansemanni* in the Museum für Naturkunde, the pedal skeleton was reconstructed with three claws).

P e s — *Dicraeosaurus hansemanni*

Fig. 1 a–c. Left Mt I dd 113: 1 a dorsal view, 1 b proximal contour, 1 c distal view.
Fig. 2 a, b. Right Mt II dd 113 (proximal section) : 2 a dorsal view, 2 b proximal contour.
Fig. 3. Right Mt III dd 113: dorsal view.
Fig. 4 a–c. Right Mt V dd 113: 4 a dorsal view, 4 b proximal contour, 4 c distal view.
Fig. 5 a, b. Right I 2 dd 113: 5 a medial view, 5 b proximal contour.
Fig. 6 a–c. Right Mt II St 593: 6 a dorsal view, 6 b proximal contour, 6 c distal view.

P e s — *Dicraeosaurus sattleri*

Fig. 7 a–c. Left Mt I O 15: 7 a dorsal view, 7 b proximal contour, 7 a distal view.
Fig. 8 a–d. Left Mt IV bb 7: 8 a dorsal view, 8 b medial view, 8 c proximal contour, 8 d distal view.
Fig. 9 a–c. Left Mt V O 19: 9 a dorsal view, 9 b proximal contour, 9 c distal view.

All figures 1/ 3 natural size.

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Explanation of figures see page 228 below

Dicraeosaurus sattleri

Only a few pedal elements that can be referred to this species from the Upper Saurian Marl are preserved, among them probably also the astragalus ab 18 described above. Regarding metatarsals, excavation site O in the Upper Saurian Marl, from which parts of an individual of this species are derived, yielded a left Mt I (O 13) and a right Mt V (o 19).

M e t a t a r s a l I (Suppl. R fig. 7 a–c)

O 15 (left): Overall shape short and stocky. The proximal surface has parallel medial and lateral rims, it exhibits a very strong slope medially. The dorsal wall grades very broadly rounded into the lateral surface; the lateral surface is proximally rather even, its plantar rim bulges outward below the proximal surface. The distal end shows a low depression between the condyles. The depression for the collateral ligament on the lateral condyle is distinct. A bulge extends from the mediodorsal corner of the medial condyle to the proximal surface, forming an edge in its proximal third. This bulge is very similarly developed to the Mt I in *D. hansemanni*, and the overall shape of this Mt is quite similar to the Mt I of this species; the referral to the younger species *D. sattleri* seems justified.

Length: 9.7 cm; proximal surface: 8.0 x 6.3 cm; distal width 8.0 cm.

M e t a t a r s a l I V (Suppl. R Fig. 8 a–d)

bb 7 (left); Upper Saurian Marl. The overall shape of this left Mt is somewhat stocky. The cross-section at the distal end is narrow, wedge-shaped in the plantar direction, it changes distally into the almost circular, slightly vaulted end surface. Medial and lateral sides are slightly depressed, the dorsal side is vaulted. No condyles are expressed on the plantar side.

Because of the contour of the proximal end surface, this Mt can only represent a Mt IV. The differences with the Mt IV of other species from the Tendaguru Beds are so considerable that an affiliation with *Dicraeosaurus* is likely, namely with *D. sattleri* because of the position of the site in the Upper Saurian Marl.

Length: 9.7 cm; proximal surface: 8.0 x 6.3 cm; distal width: 8.0 cm.

M e t a t a r s a l V (Suppl. R Fig. 9 a–d)

O 19 (right); Upper Saurian Marl. Restoring the missing edges results in a proximally very wide overall shape of the bone. The edge between the medial and the dorsal surface formed in the proximal section apparently of a wide, obtuse-angled triangle. The laterally pointed distal end shows no rounding, but a twice blunted profile-line and is curved on the plantar side. A distinct, over 3.5 cm long rugosity lies medial to the center on the flat plantar side of the proximal section. In the very wide overall shape and the curved plantar surface of the distal end, the metatarsal is more similar to the Mt V of *D. hansemanni* than to that of *Barosaurus africanus*, and seems to be derived from the same individual of *D. sattleri* as the left Mt O 15.

Length: 10.8 cm; distal width: 6.1 cm; smallest width of the shaft: 4.0 cm.

Tornieria robusta

(Pl. XXIII, Fig. 8; after E. FRAAS 1908. Pl. XI, Fig. V)

A complete right pes, which was found in the Upper Saurian Marl at Tendaguru by E. FRAAS in 1907, was thoroughly described by him (E. FRAAS 1908); a repeat description can therefore be omitted here.

The pes is in accordance with the robust construction of the animal, characterized by the robust form of the metatarsals and toe elements; it shows three end phalanges developed as claws, which diminish strongly in size laterally. Especially characteristic for this species is a Mt V that is short and extremely wide at the proximal end.

Table 18: Proportions of limb bones.

Species	Find	Humerus		Ulna		Radius		Femur		Tibia		Fibula		Femur		Humerus	
		cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%	cm	%
Brachiosaurus brancai	S II	214	100	130	61	124	58					119	—				
	To	191	100	122	64	113	59										
	D	160	100					155	100	90	58	94	61	155	100	160	103
	J							161	100	95	59	96	60				
Barosaurus africanus	k	97	100	74	76			134	100	86	64			134	100	97	73
Dicraeosaurus sattleri	O	61	100	40.5	66			98	100	59	60	62	63	98	100	61	62
Dicraeosaurus hansemanni	m							122	100	76	62	80	66				
Tornieria robusta	P	89	100	69	77	61	69	127	100	84	66	87	69	127	100	89	70

Summary of results

A. The sauropod fauna of the Tendaguru Beds and their vertical distribution

The comprehensive study of the limbs and the limb girdles of the sauropods from the Tendaguru Beds has shown that no further species could be identified next to the five known species *Brachiosaurus brancai*, *Barosaurus africanus*, *Dicraeosaurus hansemanni*, *Dicr. sattleri*, and *Tornieria robusta*. The extensive material of *Baros. africanus* allows to characterize, besides the type-species from the Upper Saurian Marl, a second, more gracile variety. As shown in Table 19, out of the six sauropod species—according to the records—*D. hansemanni* is the one species that occurs only in a single horizon, the Upper Saurian Marl. *D. sattleri* is represented in the Middle Saurian Marl and in the Upper Intermediate Beds, as is *Tornieria robusta* and the typical *Barosaurus africanus*, although the “*gracilis*” variety appears slightly lower, in the Middle Saurian Marl and in the Upper Intermediate Beds. *Brachiosaurus brancai* is recorded from the three upper horizons, and also as the only species in the Lower Saurian Marl.

Table 19: Occurrence of sauropods in the Tendaguru Beds.

Species	Lower Saurian Marl	Lower Intermediate Beds	Middle Saurian Marl	Upper Intermediate Beds	Upper Saurian Marl
Brachiosaurus brancai Jan.	X		X	X	X
Barosaurus africanus (E. Fraas)				X	X
Barosaurus africanus var. *gracilis*			X	X	
Dicraeosaurus sattleri Jan.				X	X
Dicraeosaurus hansemanni Jan.			X		
Tornieria robusta (E. Fraas)				X	X

On the basis of a new inspection of the Tendaguru region, E. Hennig (1937) gives the age of the entire series including the Upper Saurian Marl as Oxfordian? to Wealden, or Purbeckian–Portlandian, respectively. The evidence for *B. brancai* already in the Lower Saurian Marl justifies him questioning the

Oxfordian age for the Lower Saurian Marl. Such a long life span, from Oxfordian to Wealden, seems unlikely for a genus as highly specialized as *Brachiosaurus*, rather, a younger age for the Lower Saurian Marl should be assumed.

B. Species variability in the limbs and limb girdles of sauropods

When several of the same elements from the same species could be investigated and compared, a variability was often determined in the limbs and limb girdles, especially . The differences found are in parts quite considerable. In *B. brancai* differences occur in the shape of the scapula, as well as in the strength of the humerus, metacarpals, and anterior phalanges. Differences in the shape of the phalanges are noticeable in the posterior limbs. The different strength of the large limb bones of *B. africanus* is significant, allowing a distinction into a robust and a gracile type. Two pedal skeletons of *B. africanus* show several very remarkable differences, which are especially within the phalanges distinctively developed. The variability in the limbs and limb girdles in sauropods represents a parallel feature to the great range of variation in the dorsal column and the skull in sauropods from the Tendaguru Beds, which could be determined despite the small number of specimen. In *B. brancai* these differences concern the skull morphology including the shape of the teeth, and the cervical vertebrae. In the caudal vertebrae of *D. hansemanni* differences are also present (JANENSCH 1929, 1935).

C. Characterization of the two sauropod family groups by the anatomy of the limbs and limb girdles

The two family groups of sauropods characterized by the shape of the skull and the mode of dentition, *Bothrosauropodidae* and *Homalosauropodidae* (JANENSCH 1935 and Baron F. VON HUENE 1956), differ also in certain characters of their hind limb girdles. In the bothrosauropodids *Brachiosaurus* and *Camarasaurus* the ventral section of the p u b i s measures ventral to the pelvic cavity about 1/3 of the total length of the pubis, in homalosauropodids such as *Barosaurus*, *Dicraeosaurus*, and *Tornieria* form the Tendaguru Beds, the ventral part of the pubis is distinctly longer and accordingly the pelvic cavity is lower in comparison to the abdominal cavity. The most important character is that in bothrosauropodids a troch. ambiens (= ambiens trochanter) is usually very distinctly developed at the anterior rim of the proximal end of the pubis, whereas it is missing or merely indicated in the other group.

In the i s c h i u m there are also remarkable differences between both groups. The distal section is a more or less thin plate in bothrosauropodids, although in the other group—with exception of the far removed *Titanosaurus*—the terminal end thickens distinctly; the terminal view is triangular, band-shaped in bothrosauropodids and narrow in the latter according to the of the strong build (Figs. 9–13).

D. Relationships of the sauropod species from the Tendaguru Beds to those of other faunas

Among the species of four genera that were identified in the sauropod fauna from the Tendaguru Beds, *Brachiosaurus brancai* and *Barosaurus africanus* share a number of characters with species from other faunas, as demonstrated in the descriptions above. *Br. brancai* is very similar to the North American *Br. altithorax* with respect to the shape of the humerus and ilium, regarding the humerus and astragalus it also resembles the Portuguese *Br. botalaiensis* [*sic: atalaiensis*]; *Br. brancai* shows similarities in the scapula, sternal plate, pubis, ilium (in parts), and femur with the North American genus *Camarasaurus*. In the shape of the humerus, *Br. brancai* is also similar to the English *Pelorosaurus manseli* from the Kimmeridgian and to the probably conspecific *Ornithopsis humero-cristatus*, also from the Kimmeridgian, furthermore to

Pelorosaurus conybeari from the Wealden, which might even belong to the genus *Brachiosaurus*. The femur is similar to that of *Cetiosaurus oxoniensis* from the English Dogger, but also similar to that of *Cetiosauriscus leedsi* from the English Oxfordian, as is the ischium. Finally, the resemblance of the pubis and femur to the same elements in *Bothriospondylus madagascariensis* from the Bathonian of Madagascar is remarkable.

Barosaurus africanus, which I referred to the North American genus on the basis of characters of the vertebral column, cannot be compared with *Barosaurus lentus* with respect to the limb girdles and limbs, as these are poorly known in this species. There is also a substantial similarity of the limb skeleton with the completely known *Diplodocus*, which is related to *Barosaurus africanus*, as shown by the vertebral column and also the skull, this is the case especially for the scapula, humerus, ilium, femur, tibia, and fibula.

I wish to point out a pubis, illustrated as *Gigantosaurus dixeyi* by S. H. HAUGHTON (1928, pl. 2, fig. 1–3), that is interesting because of its geographic occurrence in Nyasaland. The element completely lacks an ambiens trochanter just like *Brachiosaurus*, thus there can be no affinity with FRAAS' species *Barosaurus africanus* and *Tornieria robusta*. On the other hand, the very weak proximal end differs thoroughly from *Brachiosaurus*. In the pubis from Nyasaland it is especially striking that the concave part of the acetabulum is positioned very oblique to the longitudinal axis of the entire bone, and therefore a distinctly anteriorly pointing position has to be assumed. In this character it resembles somewhat the pubis of *Titanosaurus australis* LYD. (see Baron VON HUENE 1929, pl. 14, fig. 1), in which an ambiens trochanter is also absent. It might therefore represent a pubis from a younger time period.

The very large sternal plates also described by S. H. HAUGHTON, which F. DIXEY found together with bones of sauropods in Nyasaland, differ completely from the sternal plates known from sauropods, which was already noticed by S. H. HAUGHTON in comparing them with those of *Triceratops* and *Monoclonius*. These sternal plates, too, prove that the fauna from Nyasaland has nothing in common with the Tendaguru Beds.

References

ABEL, O.: Die Rekonstruktion des *Diplodocus*. — Abh. zool. bot. Ges. Wien **5**, 1–54, Pl. 1–3, 5 Figs., 1910.

FRAAS, E.: Ostafrikanische Dinosaurier. — Palaeontographica **55**, 105–144, Pl. VIII–XII, 1908.

GILMORE, C. W.: A nearly complete articulated Skeleton of *Camarasaurus,* a Saurischian Dinosaur from the Dinosaur National Monument, Utah. — Mem. Carn. Mus. **10**, 347–382, Pl. 13–17, 1925.

—, — On a nearly mounted Skeleton of *Diplodocus* in the United States National Museum. — Proc. U. S. Nat. Mus. **81**, Art. 18, pp. 11–21, Pl. 1–6, 1932.

— , — Osteology of *Apatosaurus,* with special reference to specimens in the Carnegie Museum. — Mem. Carn. Mus. **11**, 1–300, Pl. 1–35, Text-fig. 1–37.

HAUGHTON, S. H.: On some reptilian remains from Dinosaur beds of Nyasaland. — Trans. R. Soc. S. Africa **16**, 70–73, 2 Fig., Pl. 2–5, 1928.

HATCHER, J. B.: Structure of the fore Limb and Manus of *Brontosaurus*. — Mem. Carn. Mus. **1**, 356–376, Text-fig. 1–14, Pl. 19, 20, 1901.

—, — Structure of the Fore Limb and Manus of *Brontosaurus*. — Ann. Carn. Mus. **1**, 356–376, Pl. 19, 20, 14 Textfig., 1902

HENNIG, E.: *Kentrurosaurus aethiopicus,* die Stegosaurier—Funde vom Tendaguru. — Palaeontographica, Suppl. **VII**, Reihe 1, 1, 101–254, Pl. 11–14, 92 Figs., 1924.

—, — Der Sedimentstreifen des Lindi—Kilwa—Hinterlandes (Deutsch—Ostafrika). — Palaeontographica, Suppl. **VII**, Reihe II, 2, S. 99–186, Pl. XIII–XV, 1937.

VON HUENE, Baron F.: Sichtung der Grundlagen der jetzigen Kenntnis der Sauropoden. — Eclogae geologicae Helvetiae **20**, 444–470, Pl. 14–16, 1927.

—, — Los Saurisquios y Ornitisquios del Cretaceo Argentino. — Anal. Mus. La Plata **3**, ser. 2, pp. 1–196, 133 Figs., Altas with 44 Pl., Buenos Aires 1929.

—, — Die fossile Reptil—Ordnung Saurischia, ihre Entwicklung und Geschichte. — Monogr. Geol. U. Palaeont. (1) **4**, Part I Text, 1–361, 41 Figs., Part. II Pl. 1–56, 1932.

VON HUENE, Baron F.: Paläontologie und Phylogenie der Niederen Tetrapoden. — Jena 1956.
VON HUENE, Baron F., & MATLEY, C. H.: The Cretaceous Saurischia and Ornithischia of the central Provinces of India. Palaeont. Indica, N. S. **21**, 1–74, Pl. 1–24, 33 Figs., 1933.
HULKE, J. W.: Note on a large Saurian Humerus from the Kimmeridge Clay of the Dorset Coast. — Quart. J. Geol. Soc. **25**, 386–389, Pl. XVI, 1869.
—, — Note on a large saurian limb bone adapted for progression upon land, from the Kimmeridge clay of Weymouth, Dorsethire. — Quart. J. geol. Soc. London **30**, 16–17, Pl. 2, 1874.
—, — Note on the Pubis and Ischium of *Ornithopsis eucamerotus*. — Quart. J. geol. Soc. London **38**, 372–376, Pl. 14, 1882.
JANENSCH, W.: Übersicht tiber die Wirbeltierfauna der Tendaguru—Schichten; nebst einer kurzen Charakterisierung der neu aufgefiihrten Arten von Sauropoden. — Arch. Biont. **3**, S. 79–110, 12 Figs., Berlin 1914.
— , — Das Handskelett von *Gigantosaurus* robustus und *Brachiosaurus Brancai* aus den Tendaguru-Schichten Deutsch-Ostafrikas. — Cbl. Miner. 1922, pp. 464–480, 7 Figs., 1922.
— , — Material und Formengehalt der Sauropoden in der Ausbeute der Tendaguru—Expedition. — Palaeontographica, Suppl. **VII,** Reihe I, 2, 1–34, 27 Figs., 1929.
DE LAPPARENT, A. F., & ZBYSZEWSKI, G.: Les dinosauriens du Portugal. — Servo geol. du Portugal (2), Mem. No. 2, 1–63, Pl. 1–36, 1957.
LULL, R. S.: The Sauropod Dinosaur *Barosaurus* MARSH. — Mem. Connect. Acad. Sci. **6**, 1–42, 10 Fig., Pl. 1–7, 1919.
MANTELL, G. A.: On the *Pelorosaurus;* an undescribed gigantic reptile whose remains are associated with those of the *Iguanodon* and other Saurians in the Strata of Tilgate Forest, in Sussex. — Philosoph. Trans. 1850, pp. 379–390, Pl. XXI–XXVI, 1850.
MARSH, O. C.: The Dinosaurs of North America. — 16. Ann. Rep. U. S. Geol. Surv. 1896, Text-fig. 1–66, Pl. 1–85, 1896.
MOOK, C. C.: The Fore and Hind Limbs of *Diplodocus*. — Bull. Amer. Mus. Nat. Hist. **37**, 815–819, 2 Fig., 1917.
OSBORN, H. F., & GRANGER, W.: Fore and Hind limbs of *Sauropoda* from the Bone Cabin Quarry. — Bull. Amer. Mus. Nat. Hist. **14**, 191–208, 161–172, Figs. 1–8, 1901.
OSBORN, H. F., & MOOK, C. CH. : *Camarasaurus, Amphicoelias* and other Sauropods of Cope. — Mem. Amer. Mus. Nat. Hist., N. S. **III,** 249–387, Text-fig. 1–127, Pl. 60–85, 1921.
PARKINSON, J.: The Dinosaur in East Africa. — 1–192, London 1930.
PHILLIPS, J.: Geology of Oxford and the Valley of the Thames. — Oxford 1871.
RIGGS, E. S.: Structure and Relationships of Opisthocoelian Dinosaurs. *Apatosaurus* MARSH. — Field Col. Mus. Publ. **82**, 1–163, Pl. 47–53, 1903.
— , — The Brachiosauridae. — Field. Col. Mus. Publ. **94**, 227–247, Pl. 71–75, 1904.
ROMER, A.: The Ilium in Dinosaurs and Birds. — Bull. Amer. Mus. Nat. Hist. **48**, 141–145, 1923 a.
—,— The Pelvic Musculature of Saurischian Dinosaurs. — Bull. Amer. Mus. Nat. Hist. **48**, 605–617, 1923 b.
SEELEY, H. G.: Note on the Pelvis of *Ornithopsis*. — Quart. J. Geol. Soc. **45**, 391–397, Fig. 1–3, 1889.
THEVENIN, A.: Paléontologie de Madagascar. IV. Dinosauriens. — Ann. Paleont. **2**, 121–136, Pl. I–II, Fig. 1–15, 1907.
WIMAN, C.: Die Kreide-Dinosaurier aus Shantung. — Palaeont. Sinica, Ser. C, **6**, Fasc. 1, 1–67, Pl. 1–9, 9 Fig., 1929.
United States Geological Survey, unpublished lithographic plates of vertebrate fossils for distribution. See H. F. Osborn: Science, July 10, 1931. **74**, No. 1906, 43–44, 1931.
YOUNG, CHUNG-CHIEN: New Sauropods from China. — Vertebrata Palasiatica **2**, 1–28, Figs. 1–116, Pl. 1, 1958.

Explanation of plates

Plate XV

S c a p u l a

Brachiosaurus brancai

Fig. 1. Left scapula Sa 9: lateral view.
Fig. 2 Right scapula Y 18: lateral view.
Fig. 3 a, b. Left scapula Ki 74 with coracoid: 3 a lateral view, 3 b posterior view.

Barosaurus africanus

Fig. 4. Left scapula A 4: lateral view.

Dicraeosaurus sattleri

Fig. 5. Left scapula E 19: lateral view.
Fig. 6. Right scapula O 8: lateral view.

Figs. 1, 2, 4 1/15 natural size; Fig. 5 1/10 natural size.

Plate XVI

H u m e r u s

Brachiosaurus brancai

Fig. 1. Left humerus Y 12: adductor side.
Fig. 2. Left humerus XX 19: adductor side.
Fig. 3. Right humerus t 7: adductor side.
Fig. 4. Right humerus I 1: adductor side.

Barosaurus africanus

Fig. 5. Left humerus VIII 1: adductor side.

Barosaurus africanus var. *gracilis*

Fig. 6. Left humerus Ki 68: adductor side.
Fig. 7. Left humerus Ki 3: adductor side.

Dicraeosaurus sattleri

Fig. 8. Right humerus ab 1: adductor side.

Figs. 1–4 1/12 natural size; Figs. 6–8 1/10 natural size.

Plate XVII

Ulna, radius

Barosaurus africanus

Fig. 1 a–c. Right ulna k 38: 1 a abductor side, 1 b dorsal view onto the medial wing, 1 c proximal view.

Barosaurus africanus var. *gracilis*

Fig. 2 a, b. Left ulna Ki 69: 2 a medial view, 2 b dorsal view onto the medial wing.
Fig. 3. Right ulna Ki 63: proximal view.
Fig. 4. Left radius Ki 69: abductor side.

Dicraeosaurus sattleri

Fig. 5 a–c. Right ulna O 7: 5 a lateral view, 5 b adductor side, 5 c proximal view.
Fig. 6. Left radius G 83: abductor side.

Tornieria robusta

Fig. 7 a, b. Left ulna P 12: 7a vertical dorsal view onto the medial wing, 7 b proximal view.
Fig. 8. Left radius P 13: abductor side.

Figs. 1, 2, 7, 8 1/6 natural size; Fig. 3 1/5 natural size; Fig. 6 1/6.5 natural size.

Plate XVIII

M a n u s o f *Brachiosaurus brancai*

Left manus R

Fig. 1. The first three digit, mounted.
Fig. 2. The last two digits, mounted.
Fig. 3. Digit I, dorsal view.
Fig. 4. Digit II, dorsal view.
Fig. 5. Digit III, dorsal view.
Fig. 6. Digit IV, dorsal view (without phalanx IV 1).
Fig. 7. Digit V, dorsal view.

Phalanges of the right manus S II

Fig. 8: I 1 distal view.
Fig. 9: I 2 (Claw) lateral view.
Fig. 10: II 1 distal view.
Fig. 11: III 1 distal view.
Fig. 12: IV 1 distal view.
Fig. 13: V 1 distal view.

Figs. 1–7 1/5 natural size; Figs. 8–13 3/10 natural size.

Plate XIX

P u b i s , i s c h i u m

Fig. 1. Left pubis of *Barosaurus africanus* E 6, medial view.

Fig. 2. Right pubis of *Barosaurus africanus* XI 10, lateral view.
Fig. 3. Right pubis of *B. africanus* var. *gracilis* Ki 13, lateral view.
Fig. 4. Left pubis of *Tornieria robusta* B 8, medial view.
Fig. 5 a, b. Left ischium of *Brachiosaurus brancai* T 2: 5 a medial view, 5 b posterior view.
Fig. 6. Left ischium of *Barosaurus africanus* k 44, medial view.
Fig. 7. Right ischium of *Tornieria robusta* B 13, lateral view.

Figs. 1–4, 6, 7 1/8 natural size; Fig. 5 1/10 natural size.

Plate XX

F e m u r

Fig. 1. Right femur of *Brachiosaurus brancai* II 27 e, adductor side.
Fig. 2. Right femur of *Brachiosaurus brancai* XX 5, adductor side.
Fig. 3. Right femur of *Brachiosaurus brancai* (distal section) No. 34, adductor side.
Fig. 4. Left femur of *Barosaurus africanus* e 2, adductor side.
Fig. 5. Left femur of *B. africanus* var. *gracilis* Ki 71 a, adductor side.
Fig. 6 a, b. Left femur of *Dicraeosaurus sattleri* M 2: 6 a abductor side, 6 b adductor side.
Fig. 7 a, b. Right femur of *Tornieria robusta* IX i I: 7 a adductor side, 7 b medial view.

All figures 1/12 natural size.

Plate XXI

T i b i a , f i b u l a

Fig. 1. Right tibia of *Barosaurus africanus* C 13, lateral view.
Fig. 2 a–e. Right tibia of *Barosaurus africanus* K 1 a: 2 a lateral view, 2 b anterior view, 2 c distal section with astragalus, lateral view, 2 d proximal view, 2 e distal view.
Fig. 3 a–c. Right fibula of *Barosaurus africanus* K 1 b: 3 a lateral view, 3 b proximal view, 3 c distal view (belongs together with K 1 a).
Fig. 4. Left tibia of *Barosaurus africanus* var. *gracilis* Ki 11, lateral view.
Fig. 5. Right fibula of *Barosaurus africanus*, lateral view.
Fig. 6. Left fibula of *B. africanus* var. *gracilis* Ki 65, lateral view.
Fig. 7. Right tibia of *Tornieria robusta* after E. FRAAS (1908), lateral view.
Fig. 8. Right fibula of *Tornieria robusta* after E. FRAAS (1908), medial view (belongs together with tibia Fig. 7).

Figs. 1, 2 a–c, 3 a, 4–8 1/10 natural size; Figs. 2 d, e, 3 b, c 1/5 natural size.

Plate XXII

A s t r a g a l u s

Fig. 1. Left astragalus of *Brachiosaurus brancai* X 24, posterior view.
Fig. 2 a, b. Right astragalus of *Brachiosaurus brancai* St 150; 2 a posterior view, 2 b lateral view.
Fig. 3 a–c. Left astragalus of *Barosaurus africanus* K 23: 3 a posterior view, 3 b distal view with healed cracks, 3 c lateral view.
Fig. 4 a, b. Right astragalus of *Dicraeosaurus sattleri* ab 18: 4 a posterior view, 4 b dorsal view.
Fig. 5 a, b. Right astragalus of *Dicraeosaurus sattleri* XIV: 5 a posterior view, 5 b lateral view.
Fig. 6. Left astragalus of *Tornieria robusta* P 4, posterior view.
Fig. 7. Right astragalus of *Tornieria robusta* after E. FRAAS (1908), posterior view.

Figs. 1, 2, 6, 7 1/4 natural size; Figs. 3, 5 b 1/3 natural size; Figs. 4, 5 a 1/2 natural size.

Plate XXIII

Fig. 1 a–c. Right(?) calcaneum of *Brachiosaurus brancai* St 149: 1 a proximal view, 1 b posterior view (?), 1 c medial view.
Fig. 2 a, b. Left posterior claw I 2 of *Br. brancai* G 90: 2 a medial view, 2 b lateral view.
Fig. 3. Left posterior claw II 3 of *Br. brancai* XIV b 24, medial view.
Fig. 4. Right claw No. 14, unidentified (questionable juvenile anterior claw I 1 of *Br. brancai*).
Fig. 5 a, b. Left carpal of *Tornieria robusta* P 11: 5 a anterior view, 5 b proximal view.
Fig. 6. Left pes no. 28 of *Barosaurus africanus*.
Fig. 7. Right pes XIII 10 of *Barosaurus africanus*.
Fig. 8. Right pes of *Tornieria robusta*, after E. FRAAS (1908).

Figs. 1, 3 5 1/3 natural size; Fig. 2 1/5 natural size; Fig. 4 3/5 natural size; Figs. 6–8 1/6 natural size.