A large Rhomaleosaurid Pliosaur from the Upper Lias of Rutland

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Abstract: The fragmentary remains of a very large rhomaleosaurid pliosaur were retrieved during building works at Barnsdale Hall, Rutland. The limited material prevents clear identification at specific level, though on the basis of similarities of ratios of dimensions it shows closer affinity to Rhomaleosaurus arcuatus and R.victor than to R.cramptoni. Although scaling up from such fragmentary material is unreliable, the estimated length of this animal at 7.5 to 8 metres makes it possibly the largest Rhomaleosaurid pliosaur described to date.

The fossil material

The bones were excavated in 1988 by Mr. Roy Draycott during construction of a retaining wall at Barnsdale Hall, east of Rutland Water, in the county of the same name. An outer whorl of the ammonite *Hildoceras bifrons* was found in association with the bones. It can therefore be placed with confidence in the *bifrons* Zone of the Upper Lias (Lower Jurassic, Toarcian, Whitbian). It is probable that much more extensive remains of the animal were present at the time. No further investigation is possible in the foreseeable future, as it would involve extensive and expensive demolition works.

The material (LEICT G2.1988.1 and .2) consists of a fragment comprising the proximal third of a right femur, and a complete right tibia.

The femoral fragment (Fig. 1) measures 225 mm long and approximately 150 mm wide. At the broken end the shaft is oval in section, 148 mm wide and 96 mm deep. The head is 153 mm broad and 160 mm deep. Orientation can be determined by rugosities from ridges for muscle attachment on the posterior side and the ventral surface. A deep hole in the posterior muscle attachment presumably marks where a ligament was connected to the bone. There is slight taphonomic crushing around the trochanter. The surface is encrusted in places with a pyritised deposit, which shows traces of tracks left by scavengers post-mortem. The internal structure of the bone is preserved, and the broken end shows clearly an outer rim of perichondral bone about 12 mm thick, and the endochondral interior.

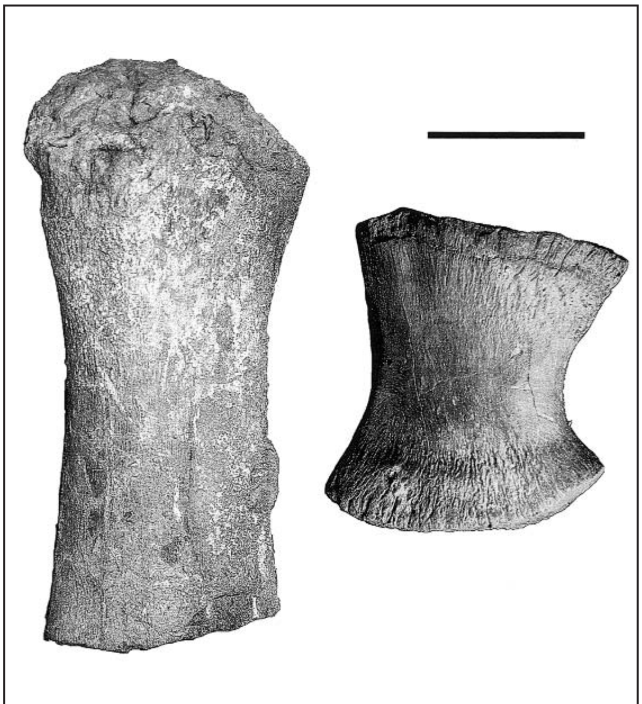

Figure 1. *Rhomaleosaurus. sp.*: left, the right femur (LEICT G2.1988.1), 325mm long; right, the right tibia (LEICT G2.1988.2), 200mm long. The scale bar is 100mm long.

The tibia (Fig. 1) is roughly hourglass shaped, measuring 200 mm long and 180 mm wide, waisting to 120 mm in the middle. Both ends are curved in plan, the distal end rather more so than the proximal. The curvature of the posterior face is greater than that of the anterior. In section it is lens-shaped, the curvature of the ventral face being less than that of the dorsal. It shows some localised crushing at the proximal end which may be due to damage by predation, though is more likely the result of taphonomic processes. The distal end is slightly crushed by taphonomic processes. The surface is clean and shows no traces of post-mortem scavenging. Three foramina on the dorsal surface show a pattern of small indentations around the rim which probably mark the position of small blood vessels. A small, narrow penetration at the distal end of the ventral surface and an associated small raised area of bone may be damage from predation or post-mortem scavengers.

Identification

Diagnosis on the basis of such limited material is unreliable. On the basis simply of size and horizon, the material is probably attributable to the pliosaurian genus *Rhomaleosaurus*. The general morphology of the material supports this, in particular the tibia, which is similar in shape to those of *R. cramptoni* (Carte and Baily, 1863) and *R. victor* (Fraas, 1910). Published accounts of pliosaur limb elements are rare, and limited mainly to Callovian and later forms. It is possible that their

		Rhomlaeosaurus sp.	*R.arcuatus*	*R.cramptoni*	*Rhomaleosaurus sp. c.f. R.arcuatus*	*R.victor*
		LEICT G2.1988.2	LEICT G221.1851	BMNH R. 34	WARMB G10875	SMNK 3.7.1
		Measurement by author from specimen	Measurement by author from specimen	Carte and Baily, 1863	measurements by A.R.I Cruickshank and M.A.Taylor	Fraas 1910
H3	Proximal width of femur	153	115	182	105	90
H4	Narrowest portion of femur	120	70	131	70	112
H5	From posterior extreme of widest part of proximal end of femur to centre of ligament insertion mark	190	115	163	100	54
H6	Length of tibia	200	145	165	110	120
H7	Distal breadth of tibia	180	100	127	60	115
H8	Proximal breadth of tibia	180	130	152	107	106
H9	Narrowest portion of tibia	120	87	136	74	84

Table 1. Measured dimensions of *Rhomaleosaurus*.

shape owes more to ontogenetic processes than true taxonomic differences.

As an exercise in the extraction of information from limited material, a metrical approach was taken. Dimensions were collected for five specimens of the genus *Rhomaleosaurus*, from published accounts (Carte and Baily, 1863. Fraas, 1910), unpublished measurements by Arthur Cruickshank and Michael A. Taylor, measurements by the author from the material, and measurements scaled from photographs (Table 1). Seven dimensions can be measured on this and the four other specimens and a data matrix was constructed to show the relative proportion of each to all of the others. The proportion of the logarithm of each of the ratios in the matrix against that for the Barnsdale specimen was calculated. The average of all the resultant ratios for each specimen can therefore be taken as a measure of the 'morphological difference' between them (Table 2). The results were plotted against the averaged length of all seven dimensions of each specimen (Figure 2). This shows that the Barnsdale specimen is morphologically closer to LEICT G221.1851 (*R.. arcuatus* [Cruickshank, pers. comm., formerly *R.. megacephalus*]) and SMNK 3.7.1 (*R.. victor*) than to BMNH R.34 and WARMS R10875 (*R. cramptoni*).

This result should not be interpreted as demonstrating a taxonomic relationship. Ontogenetic changes in plesiosaurs are not well known, and the morphological closeness may owe more to similarity in developmental stage than to taxonomic relationship. Until more is known of pliosaurian ontogeny, no firm conclusions can be drawn from such limited data.

Overall length is known for three specimens, Rhomaleosaurus arcuatus LEICT G221.1851 (The 'Barrow Kipper') (Taylor and Cruickshank, 1989. Cruickshank, 1994a, Cruickshank, 1994b), R. cramptoni type specimen (Cast BMNH R34) (Carte and Baily, 1863), and R.. victor (SMNK 3.7.1). Taking the ratios of measurable dimensions to the overall length and extrapolating from the tibia of the Barnsdale specimen gives an overall length of 7.76m, 8.26m and 6.03m for the three specimens respectively. *R. victor* is a much smaller animal than the other two, and the lower estimated length is attributable to morphological differences due to size. The best estimate for the overall length of the animal

Rhomaleosaurus sp LEICT G2.1988								
		H3	H4	H5	H6	H7	H8	H9
		153	120	190	200	180	180	120
H3	153	0					average	0
H4	120	0	0				sum	0
H5	190	0	0	0				
H6	200	0	0	0	0			
H7	180	0	0	0	0	0		
H8	180	0	0	0	0	0	0	
H9	120	0	0	0	0	0	0	0

Rhomaleosaurus arcuatus LEICT G221.1851 (Barrow Kipper)								
		H3	H4	H5	H6	H7	H8	H9
		115	70	115	145	100	130	87
H3	115						average	0.0096
H4	70	-0.1101					sum	0.2026
H5	115	-0.0941	0.0160					
H6	145	-0.0157	0.0944	0.0784				
H7	100	-0.1313	-0.0212	-0.0372	-0.1156			
H8	130	-0.0173	0.0928	0.0767	-0.0017	0.1139		
H9	87	-0.0157	0.0944	0.0784	0.0000	0.1156	0.0017	

Rhomaleosaurus cramptoni BMNH R.34 (Cast of type)								
		H3	H4	H5	H6	H7	H8	H9
		182	131	163	165	127	152	136
H3	182						average	-0.0353
H4	131	-0.0373					sum	-0.7420
H5	163	-0.1419	-0.1047					
H6	165	-0.1589	-0.1216	-0.0170				
H7	127	-0.2268	-0.1896	-0.0849	-0.0679			
H8	152	-0.1488	-0.1115	-0.0069	0.0101	0.0780		
H9	136	-0.0210	0.0163	0.1209	0.1379	0.2058	0.1278	

Rhomlaeosaurus sp., c.f R.arcuatus WARMS R10875								
		H3	H4	H5	H6	H7	H8	H9
		105	70	100	110	60	107	74
H3	105						average	-0.0306
H4	70	-0.0706					sum	-0.6426
H5	100	-0.1153	-0.0447					
H6	110	-0.0961	-0.0256	0.0191				
H7	60	-0.3136	-0.2430	-0.1984	-0.2175			
H8	107	-0.0624	0.0082	0.0529	0.0337	0.2512		
H9	74	-0.0464	0.0241	0.0688	0.0497	0.2672	0.0159	

Rhomlaeosaurus victor SMNK 3.7.1								
		H3	H4	H5	H6	H7	H8	H9
		90	112	54	120	115	106	84
H3	90						average	0.0170
H4	112	0.2005					sum	0.3568
H5	54	-0.3159	-0.5164					
H6	120	0.0086	-0.1919	0.3245				
H7	115	0.0359	-0.1646	0.3518	0.0273			
H8	106	0.0005	-0.2000	0.3164	-0.0081	-0.0354		
H9	84	0.0755	-0.1249	0.3915	0.0669	0.0397	0.0751	

Table 2. Log of differences in ratios of dimensions of the pliosaur specimens.

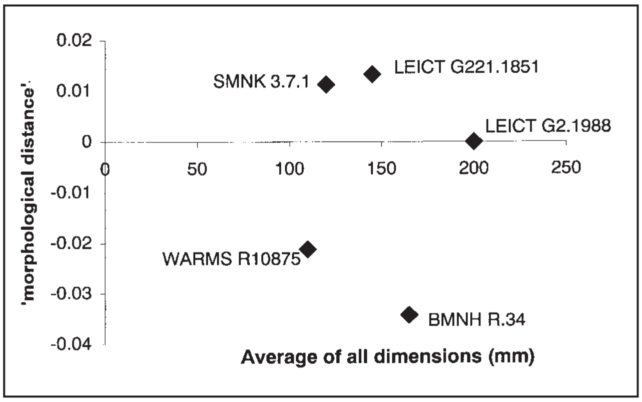

Figure 2. Compaison of sizes and morphological differences of the pliosaur specimens.

from which LEICT G2.1988 came is between 7.5m and 8.0m.

A very rough estimate of the weight of this and other specimens of the genus *Rhomaleosaurus* was made by interpolating between the volumes of plastic models *Liopleurodon* and an elasmosaur. The assumptions were made that the morphology of *Rhomaleosaurus* is more or less mid-way between the two (the of *Rhomaleosaurus* neck is long, but the head and body are large) and the specific gravity is close to that of water - a reasonable assumption for a marine animal. This methodology allows estimation of the animals' weights (Table 3). It is worth noting that the Barnsdale specimen is half as heavy again as the type of R. *cramptoni*, and over three times the weight of the Barrow specimen of R. arcuatus.

Discussion

Very large pliosaurs are known from several Jurassic and Cretaceous marine reptile faunas. *Liopleurodon and Simolestes* from the Oxford Clay (Andrews, 1910-13) achieved estimated lengths in excess of 10 m. Fragmentary remains of a very large Callovian pliosaur possibly as long as 17 m were reported by McHenry *et. al.* (1996). Tarlo (1959, 1960) proposed the genus *Stretosaurus* for a large pliosaur from the Kimmeridge Clay (length approximately 15 m), though this material is now ascribed to the genus *Liopleurodon* (Halstead, 1989). *Brachauchenius* (Carpenter, 1996) from the Late Middle Cretaceous of North America reached a comparable size. *Kronosaurus* (Longman, 1924) from the Middle Cretaceous of Australia is the best known of the large pliosaurs. More recent finds from Australia (McHenry, pers. comm.) and Columbia (Hampe, 1992) have shown that the well-known mounted specimen in the Harvard Museum of Natural History (Romer, 1959) is an inaccurate reconstruction in that the body was relatively shorter, though it remains a very large animal.

R. victor (SMNK 3.7.1)	700kg
R. arcuatus (LEICT G211.1851)	2400kg
R. cramptoni (BMNH R. 34)	5600kg
Rhomaleosaurus sp. (LEICT G2.1988)	8000kg

Table 3. Estimated weights of pliosaur species.

A series of very large reptilian marine predators is known from the Triassic to the Upper Cretaceous. Triassic ichthyosaurs, such as the Carnian *Shonisaurus* (Camp, 1976. McGowan and Motani, 1999) reached lengths in excess of 15m. A recently found ichthyosaur from the Upper Triassic of British Columbia (Tyrrell Museum, 1999) is far larger than any previously recorded marine reptile, with a skull length of 5.5 m suggesting an overall length of over 23 m. Specimens of the Liassic *Temnodontosaurus* indicate a body length of about 10m, and there are fragmentary remains of an even larger ichthyosaur from the same stratigraphic level (McGowan, 1997). Pliosaurs seem to have taken on the 'top predator' role for much of the Jurassic and Lower Cretaceous, being replaced in the Upper Cretaceous by the mosasaurs, such as the 17m *Mosasaurus hoffmanni* and the 15m *Hainosaurus bernardi* (Lingham-Soliar, 1995 and 1992).

There is no evidence that pliosaurs possessed any form of echo-location, such as that of modern cetaceans, and it is likely that they located prey by 'smell' (Cruickshank et al., 1991) and used their good binocular vision at close quarters. Taylor (1992) showed that the skull of *Rhomaleosaurus zetlandicus* was 'designed' to resist strong torsional forces, and was well adapted for dismembering large prey by rotational feeding, a common strategy in large modern crocodiles. Although the ichthyosaurs were faster swimmers than the plesiosaurs (Massare, 1988), it is possible that the latter were able to replace the ichthyosaurs in their top predator role by virtue of a more effective sensory system. An analysis of feeding strategies used by pliosaurs from the Oxford Clay biota is given by Martill et al. (1994). Predation by large pliosaurs on smaller, long-necked forms is documented from the Cretaceous of Australia (Thulborn and Turner, 1993).

The disappearance of large pliosaurs in the Turonian, and the appearance of mosasaurs in the Cenomanian (Cruickshank and Long, 1997) may be due to superior predation strategies in mosasaurs, though there is no evidence of this. Williston (1897) suggested from the evidence of re-healed broken bones that mosasaurs 'exhibited an aggressive disposition beyond that of normal predatory behaviour'. Such evidence is by no means conclusive and in any case there can be little doubt from documented pliosaur bite marks (Thulborn and Turner, 1993; Clarke and Etches, 1991) that pliosaurs were themselves highly aggressive. Unpublished research by the author has found in a sample of propodials of the genus *Cryptoclidus* that 75% show bite marks probably attributable to pliosaurs. Any adaptive advantage of mosasaurs has left no fossil record.

The Barnsdale specimen approaches in size the largest Callovian and Kimmeridgian pliosaurs, and dates from the period of transition from the ichthyosaurs to the pliosaurs as top marine predators between the Pliensbachian and the Toarcian. The specimen suggests that it was the development of large size in pliosaurs, and not any environmental disturbance that enabled them to gradually replace the large ichthyosaurs.

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Abbreviations

BMNH -Natural History Museum, London.

LEICT - New Walk Museum, Leicester.

WARMS - Warwickshire Museum, Warwick.

SMNK - Staatliches Museum für Naturkunde, Löwentor Museum, Stuttgart, Germany.

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