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The tail of the Jurassic fish *Leedsichthys problematicus* (Osteichthyes: Actinopterygii) collected by Alfred Nicholson Leeds – an example of the importance of historical records in palaeontology

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ABSTRACT: The specimen of the tail of *Leedsichthys problematicus*, now in The Natural History Museum, London, was one of the most spectacular fossil vertebrates from the Oxford Clay Formation of Peterborough, but as an isolated find it shares no bones in common with the holotype of the genus and species. However, a letter from Alfred Nicholson Leeds and related documents cast valuable new light on the excavation of the tail, indicating that it was discovered with cranial bones, gill-rakers, and two pectoral fins, thereby including elements that can potentially be compared with those of the holotype. The documents also clearly indicate that The Natural History Museum's specimen is not part of the same individual as any other numbered specimen of *Leedsichthys* as had been speculated on other occasions. The maximum size of the animal represented by The Natural History Museum's specimen was possibly around 9 metres, considerably less than previous estimates of up to 27.6 metres for *Leedsichthys*. Historical documentary evidence should therefore be rigorously checked both when studying historical specimens in science, and in preparing text for museum display labels.

KEY WORDS: The Natural History Museum, London – Callovian – correspondence.

INTRODUCTION

Documentary evidence is invaluable in the earth sciences, whether collectors' field sketches, specimen notes, correspondence, notebooks, draft manuscripts, photographs or specimen conservation records. However, when studying geological material, the specimens themselves, and previously published accounts of them, are of primary importance, and are often the only materials sought by researchers. Unpublished documents are only infrequently taken into consideration, but such original records can provide invaluable information on specimens and their provenance. Unfortunately, unpublished resources often reside separately from specimens, for instance in the stores of libraries or other dedicated archives, and the different wings of an institution may be entirely unaware of the existence and relevance of each other's resources. The relative obscurity of unpublished documents is reinforced by a tendency for historical studies relating to collectors (for example, the Leeds brothers (Leeds, 1956)) and researchers (for example, Adam Sedgwick (Clark and McKenny Hughes, 1890)) to be published separately from the scientific study of their specimens.

As an example of the importance of searching for all possible sources of information when studying geological specimens, we present a letter and supplementary documents which shed considerable light on the most spectacular find of a fish from the Middle Jurassic Oxford

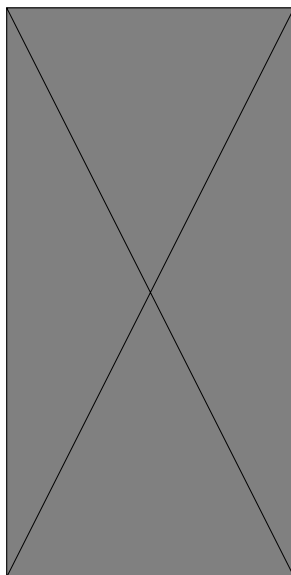


Figure 1. The bones ascribed to the tail of *Leedsichthys problematicus* P.10000. The orientation of the lobes (dorsal or ventral), and the angle at which they met is unknown. Scale bar = 0.5m. Previously figured by Martill (1986: figure 1; 1988: figure 3), and Martill and Hudson (1991: plate 43). Photograph © Rod Branson (reproduced by courtesy of David Martill).

Clay Formation in the vicinity of Peterborough, England – the gigantic tail of *Leedsichthys problematicus* Smith Woodward, 1889a (P.10000; Figure 1).¹

LEEDSICHTHYS PROBLEMATICUS – AN ENORMOUS PROBLEM

Leedsichthys problematicus was a remarkable bony fish, a member of the family Pachycormidae ('thick bodied'), which as a group lie close to the transition from the lower forms of ray-finned fish (Actinopterygii) to the teleosts that dominate today's seas. *Leedsichthys* has been described as "the world's largest fish" (Martill, 1986: 61), but despite (or perhaps because of) its immense size, it remains poorly understood (Liston, in press). This is due, in part at least, to lack of study, the rarity of anything approaching a complete specimen, and incomplete skeletal ossification, resulting in poor preservation potential for significant parts of the body. The gigantic size of *Leedsichthys* and the lack of an ossified axial skeleton (Smith Woodward, 1889b; Martill, 1988) has probably led to finds in the field being regarded as isolated, when in reality articulated remains of the same individual may lie some distance away undiscovered. This perhaps explains why so many specimens of *Leedsichthys* only consist of isolated skeletal portions (see Martill, 1988; Liston, in press (for a supplementary list of finds)). An additional problem is the uncertainty that has attended virtually all osteological identifications of the skeletal elements of *Leedsichthys*, except for the bony fin rays, and the gill-rakers (each approximately 7.5cm long). Although gill-rakers

appear to be the smallest of the bony remains of this fish, they are huge examples of fish gill-rakers, as these structures are usually only a few millimetres long. They line the gill arches of a fish, often facilitating the sorting of food from detritus as water passes through a fish's mouth and out of the gills (Sanderson *et alii*, 2001). The size of these gill-rakers is such that they have been confused with the lower jaws of small tetrapods (for example, pterosaurs²), but they occur with such frequency and are so distinctive in structure that they are considered the most diagnostic part of this fish (Smith Woodward, 1889b; Martill, 1988; Martill *et alii*, 1999). Our understanding of *Leedsichthys* is further clouded by the absence of any maps showing the *in situ* distribution of skeletal elements prior to removal for all but one of the collected specimens (see Michelis *et alii*, 1996), and the tendency for previous workers to ascribe all large, fibrous-textured skeletal elements from the Oxford Clay Formation to *Leedsichthys*, although many pliosaurian and dinosaurian bones also apparently demonstrate such textural features (Martill, 1988; Noè *et alii*, 2003). Furthermore, as noted by Hoffsteter (1957), some workers have ascribed *Leedsichthys* bones to other, non-fish taxa such as dinosaurs and marine reptiles (for example, Hulke, 1887; Huene, 1901) and this has further complicated resolution of the anatomy of this enigmatic fish.

THE DISCOVERY OF *LEEDSICHTHYS*: THE HOLOTYPE AND BEYOND

A substantial proportion of an enormous fish was discovered in the 1880s in one of the many brick-pits near Peterborough (Leeds and Smith Woodward, 1897; Leeds, 1956). The exact location of this pit is not recorded, but the find was presumably in the Peterborough Member of the Oxford Clay Formation (Cox *et alii*, 1992; Martill, 1986, 1988; Liston, in press), and therefore Callovian (Middle Jurassic) in age. The bones were ascribed to a single disarticulated individual and were found scattered “over an area of probably not less than twelve square yards [*c.* 10m²]” of a single bedding plane (Smith Woodward, 1889b: 452). They were excavated by Alfred Nicholson Leeds (1847–1917) (Smith Woodward, 1917) and were added to his extensive private collection (Leeds, 1956). Misidentified as stegosaurian armour, the material was recognised as “piscine” rather than dinosaur by Othniel Charles Marsh (1831–1899) (Woodward, 1899), when he visited Alfred Leeds in 1888 (Smith Woodward, 1889b) during a tour around Europe to review all key dinosaur material (Marsh, 1889).

Smith Woodward (1889b) named *Leedsichthys problematicus* and described the specimen (P.6921), tentatively identifying the principal bones as a frontal, an angular, a hyomandibular, four branchial arches, a large number of gill-rakers, an incomplete preoperculum or clavicle, eleven branchiostegal rays, and a series of pectoral fin-rays (Smith Woodward, 1889b: 451–454; 1889c; 1890a), although several other interpretations have subsequently been made (Smith Woodward, 1895; Liston, in press). The jaws and axial skeleton were apparently absent. The original description failed to figure any of the material, but did note a few further isolated specimens not associated with the holotype (including one described as “doubtfully forming part of the series” Smith Woodward, 1889b: 453), but considered too fragmentary to be satisfactorily identified (Smith Woodward, 1889b). Two of the distinctive gill-rakers from the holotype were subsequently figured, and the name “conveniently shortened” to *Leedsia problematica* (Smith Woodward, 1890b: 292). However, such a name change, creating an unwarranted junior objective synonym (ICZN, 1999), is not valid and the original name must remain (Martill, 1986, 1988; Liston, in press). Soon afterwards, all of Alfred Leeds' “First Collection” (collected up to about May 1889), including the holotype of

Leedsichthys problematicus, was purchased by the British Museum (Natural History) (now The Natural History Museum, London), in four instalments between 1890 and 1892 (Leeds, 1956). Following its arrival at the BM(NH), the holotype of *Leedsichthys* was assigned the registered number P.6921, and the “doubtfully” associated specimen was given the registered number P.6922.

As well as the holotype of *Leedsichthys*, Alfred Leeds collected the largest caudal fin of a fossil fish on record (P.10000, Figure 1), comprising both caudal lobes, although their orientation (that is, which is superior and which is inferior; Martill, 1988) and the angle at which they met is not known. P.10000 has been referred to *Leedsichthys problematicus*, or its junior synonym *Leedsia problematica* (Smith Woodward, 1905, 1917; Leeds, 1956; Martill, 1986). As preserved, it spans “9 feet” (c. 2.7m) (Smith Woodward, 1917: 480). However, when discovered, the tail measured around “6 feet” (c. 1.8m) along one of the lobes, although the full extent could not be collected because distally the fin-rays became too thin and fragile to gather (Leeds, 1956:73).

A TAIL OF MANY PROBLEMS

P.10000, the tail referred to *Leedsichthys*, presents a number of problems: the size of the original fish; the taxon to which the specimen belongs; the date of collection of the specimen; and historical confusion about possible relationships between it, the holotype and other *Leedsichthys* material.

The holotype of *Leedsichthys problematicus* is undoubtedly P.6921 (Leeds, 1956). Martill (1988) erroneously referred to and described P.10156 as the holotype, for reasons explained later. Confusion has been compounded by a suggestion that P.10000 is part of the same fish as the holotype (Martill, 1988), although this is most likely to be in reference to P.10156, as the true holotype (P.6921) was omitted from the list of material attributed to *Leedsichthys*. Martill *et alii* (1999) also tentatively suggested that the tail is from the same fish as P.10156 (erroneously referred to therein as P.10561), comprising a gill-basket and hyomandibula. More recently Liston (in press) proposed that P.10000 is associated with P.11823, which consists of head bones and fin-rays. Whether these specimens of *Leedsichthys* are parts of one or more individuals is of paramount importance for our understanding of the fossil material, and as P.10000, P.10156 and P.11823 each have different accession numbers (Martill, 1988) this implies they were acquired by the BM(NH) at different times, and were therefore considered discrete individuals when purchased and accessioned.

The date of collection of P.10000 has been cited as 1889 (Martill, 1986: 61) and 1899 (Leeds, 1956: 72; Martill *et alii*, 1999: 249), and this imprecision causes confusion in relation to the tail specimen. It is known that P.10000 was mounted and on display in the BM(NH) fish gallery by 1905 (Smith Woodward, 1905), but details of the specimen and its excavation were not published until long after the death of Alfred Leeds in 1917 (Leeds, 1956). Despite its obvious importance, P.10000 was not figured for more than 80 years after its collection and public display (Martill, 1986), and has never been fully described, although ongoing work (by J.J.L.) aims to rectify this.

Although referred to *Leedsichthys* (Smith Woodward, 1905; Leeds, 1956; Martill, 1986; 1988), the tail (P.10000) as an isolated find (Leeds, 1956), shares no elements in common with the head and pectoral components of the holotype (P.6921; Martill *et alii*, 1999). Indeed, the tail appears to have been assigned to *Leedsichthys* based on its large size, fibrous bone

texture, and fin-rays that branch without segmentation (the latter a diagnostic character of pachycormid fish (Martill, 1988)). However, these criteria are clearly unsatisfactory, and a more precise diagnosis is desirable.

UNPUBLISHED DOCUMENTARY EVIDENCE

In addition to some privately held items, a series of searches of The Natural History Museum archives³ has recently uncovered unpublished documents relevant to these problems. These include a letter from Alfred Leeds, the Museum's purchase and accession registers, and historical photographs showing the labelling of the specimens.

Alfred Leeds' letter

A handwritten letter⁴ from Alfred Nicholson Leeds to Arthur Smith Woodward (1864–1944) (Cooper, 1945), dated 18 March 1898 (Figure 2), announced the discovery of a new specimen of "*Leedsia*":

Dear Woodward –

Leedsia is not quite such a problem to me as it was ten days ago – but still there is very much to learn – the men came across some more of its bones at one of the pits – and sent for me to get them out – I feel certain now that all the bones we thought belonged to the head, are head bones – for they were all mixed up with thousands of gill-rakers – then just beyond the head I found a good distance apart two fins – I got part of one out & can put some of it together – but only some for it was in thousands of pieces – then away back some 12 or 18 feet they came upon the tail – [Figure 2b] as it lay in the clay from A to B, was about 6 ft – & from B to C the same – those long branching bones which you have from 3 ft to 4 ft long from the tail – which from D to E is about 18 inches wide – & about 1¾ thick – I have got a great lot of the tail that I can put together – for though of course it is all separate bones – some three or four feet of it is all in a mass held together by the clay which has turned to stone between the bones and I hope to have a piece of tail, some five feet long & one & a half wide – when I have done – it was quite impossible to do any thing with about a foot quite at the end for the pieces were too small to pick up – much more to fit – At present I have got none of the big rib shaped & long straight bones – but live hoping they may come across them – but it is quite clear they have nothing to do with the head – I incline to the idea that they form the back fin – & that the straight bones may be inside & help to support them – thus [Figure 2c] I have not seen the least sign of any thing that could be called vertebrae – I've a great number of bones to wash yet – & it will take months to fit them – but I'll let you know as soon as they are in condition for your inspection – tell Dr. [Henry] Woodward he will have to keep something in hand for this lot – but I think he will want a larger case to hold them – I do hope I'll get the big rib shaped bones – I've told the men to send for me if they come across them so that I may see how they lie –

Yours very sincerely

Alfred. N. Leeds.

In addition to giving the approximate distances between some elements as they lay in the clay, Leeds drew a roughly dimensioned sketch of the tail (Figure 2b). Unfortunately, despite the hopes of Alfred Leeds, there is no evidence to indicate additional finds of skeletal elements were forthcoming from this site. Although this letter was annotated as being acknowledged on the "21st" March 1898, no reply from Arthur Smith Woodward survives, because the BM(NH) Palaeontology Department outgoing letters archive only began in 1902.

Purchase and accession registers

Purchase and accession registers contain information relevant to some of the issues surrounding P.10000. The purchase register records the acquisition of five batches of *Leedsichthys* bones

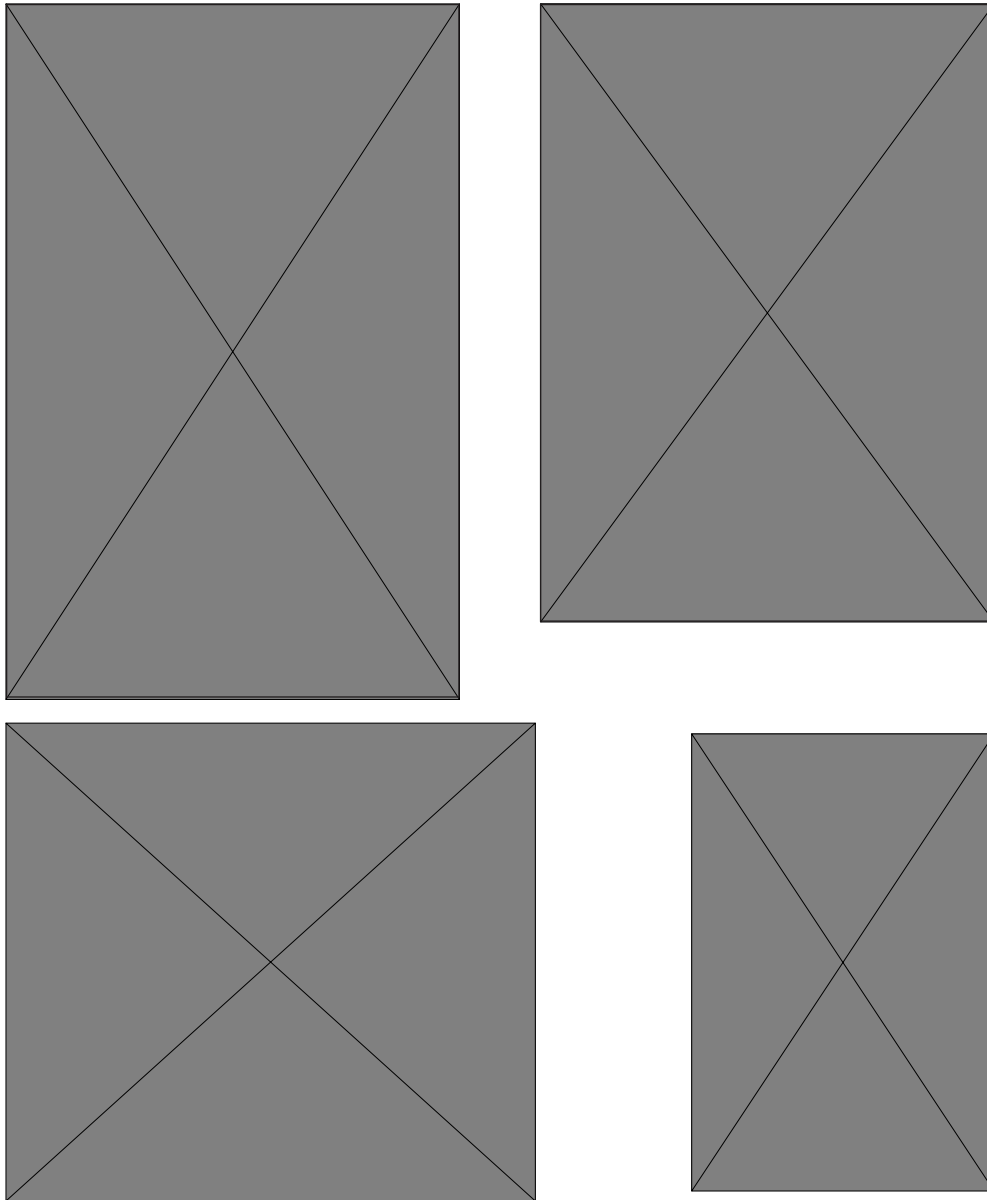
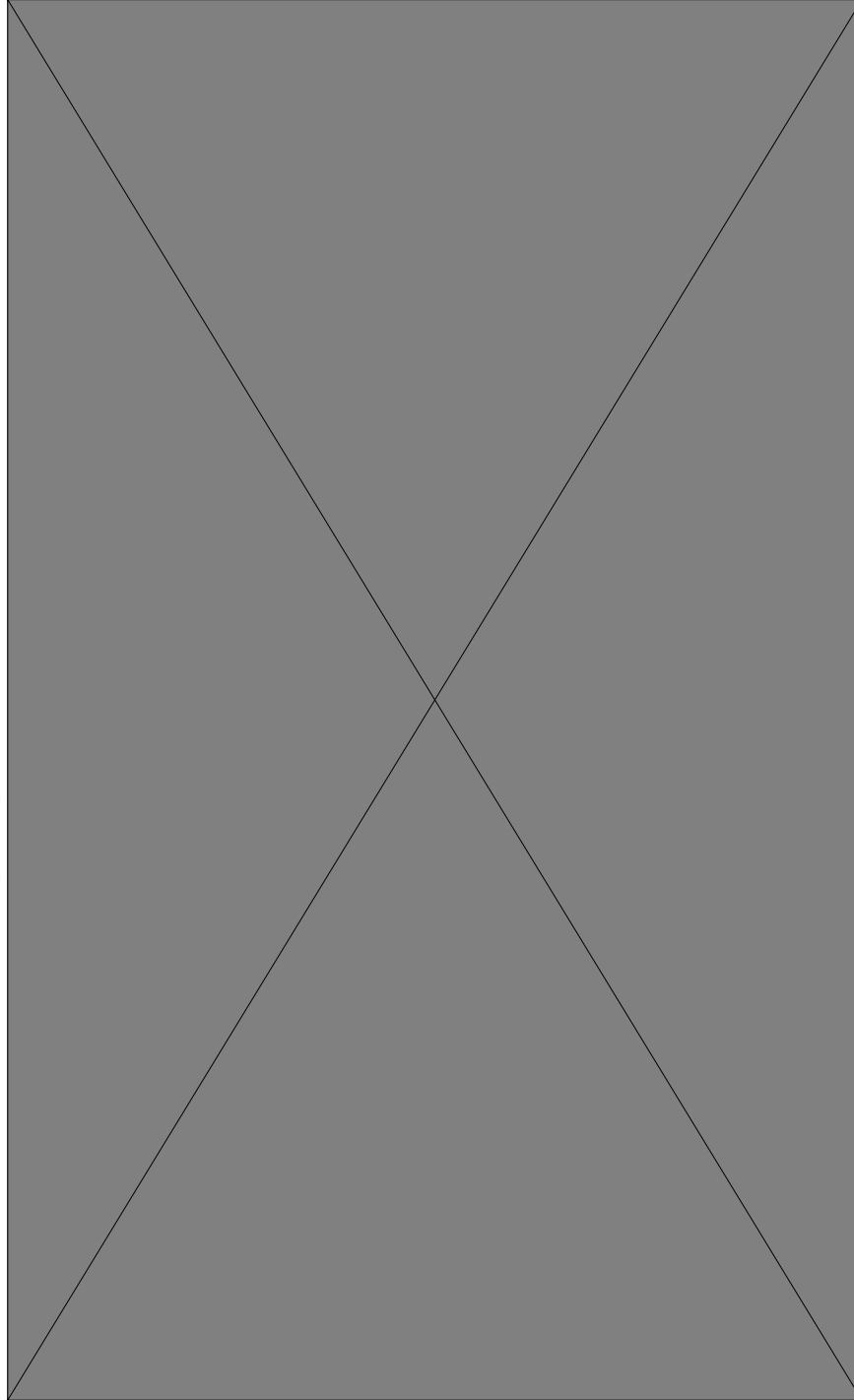


Figure 2. **a** (top): The first and last pages of Alfred Nicholson Leeds' letter to Arthur Smith Woodward (NHM-GL DF100/31) giving details of the excavation of P.10000, the tail and associated components ascribed to *Leedsichthys problematicus*. © The Natural History Museum, London. **b** (lower left). Detail of the tail, as drawn by Alfred Leeds (enlarged from f. 3: NHM-GL DF100/31), including original lettering. B the point of attachment of the tail to the body; AB and BC "about 6 feet"; DE "about 18 inches wide and $1\frac{3}{4}$ inches thick". Note the angle at which they are illustrated differs from the way they are mounted (Figure 1, 3 and 4). © The Natural History Museum, London. **c** (lower right). A hypothetical reconstruction of the missing dorsal fin (and supporting structures) of *Leedsichthys problematicus*, as drawn by Alfred Leeds (enlarged from f. 6: NHM-GL DF100/31). © The Natural History Museum, London.

Table 1. Details of *Leedsichthys* specimens bought by the British Museum (Natural History), London, from the family of Alfred Leeds. The respective register entries have been transcribed verbatim, the numeral in parentheses for each accession (under Description (AR)) indicating the total number of component parts for each specimen as received. **PR** = Geological Department annual purchases register volume 2, 1892-1948⁵; **AR** = Palaeontology Department specimen catalogues, additions to the collection of fossils, Pisces volume 3A¹¹.



* Purchased via C. D. Sherborn for Alfred N. Leeds. ** Purchase from Mrs Leeds, after the death of her husband.

from the Leeds family, on 30 May 1892⁵ (the final instalment of his “First Collection”), 28 July 1898⁶, 17 March 1899⁷, 22 July 1905⁸ and 28 June 1920⁹, as well as indeterminate fossil fish plates¹⁰ (see Table 1). The bones of the tail, purchased on the 17 March 1899, were described as “a set of fish remains of *Leedsia problematica* [sic] Oxford Clay Peterborough”. The purchase (for £25) was sanctioned by the Trustees on 25 February 1899.⁶ The accession register records the specimen numbers allocated to material, and also gives indications as to which year this allocation was made in. For example, specimen P.10000 is recorded as “*Leedsia problematica* [sic] Oxford Clay, Fletton, Peterborough, tail and associated bones Purch[ase]d A. N. Leeds, Esq. March 1899”.¹¹ The P.10000 entry in the accession register is out of chronological order with the adjacent lower and higher numbered entries, giving weight to the suggestion that the ‘special’ number P.10000 had been reserved for this spectacular tail (Martill, 1986¹²). There are separate entries in the accession register for all other *Leedsichthys* specimens purchased from Alfred Leeds, the purchase dates recorded closely coinciding with those in the relevant purchase registers (see Table 1). However, these and other non-*Leedsichthys* specimens are also not necessarily numbered in the order in which they were acquired by the Museum, demonstrating that the out-of-sequence occurrence of P.10000 was not in itself a unique event.

Photographs

Two photographs exist of P.10000, as it was mounted for display in the fossil fish gallery of the British Museum (Natural History), revealing details of contemporary labels. The first was taken in September 1937 (Figure 3¹³); the label indicated an estimated length of “30 feet” (c. 9m), the same as the earliest known published estimate (Smith Woodward, 1905, 1917; see also Leeds, 1956). The second photograph (Figure 4¹⁴), taken in July 1985 during a visit by David Martill, shows that the label had been altered, reducing the proposed length of the animal to “25 feet” (c. 7.6m) whilst adding “the tail is part of the holotype described by A. Smith Woodward in 1889”.

Additional documentation

The minutes of the Trustees’ meeting of 25 February 1899, under ‘Purchases Geology’, noted the sanctioning of a purchase of “a set of huge fish remains” from the Oxford Clay from Mr A. N. Leeds, for £25.¹⁵ Three further documents relate to this meeting and P.10000. A short list, dated 21 February 1899, written and signed by Alfred Leeds¹⁶ offered “a series of large bones of *Leedsia problematica* [including a] fragment of pectoral fin £ 25. 0. 0.” This document also included a rough sketch of what appears to be the pectoral fin in question. A second, undated, note¹⁷ in the hand of Henry Woodward (1832–1921), Keeper of Geology in the British Museum (Natural History) (Anonymous, 1921), probably a very early draft of the next item, indicated that the *Leedsichthys* tail specimen consisted of a

Fine associated set of remains ... comprising several of the head bones of gigantic size, a fragment of the pectoral fin, and the greater part of the tail fin. The latter so far as preserved, measures about 9 ft. [c. 2.7m] in span, and would probably have measured originally at least 12 ft. [c. 3.7m]. It seems to be the largest caudal fin of a fish on record.¹⁷

A third, also undated, but much longer manuscript in the hand of Henry Woodward¹⁸ recommended to the Trustees a series of purchases. In relation to the tail specimen, Henry Woodward stated “Mr Leeds offers a fine associated set of remains of *Leedsia problematica* a gigantic fish from the Oxford Clay of Peterborough”, that the bones were “of enormous

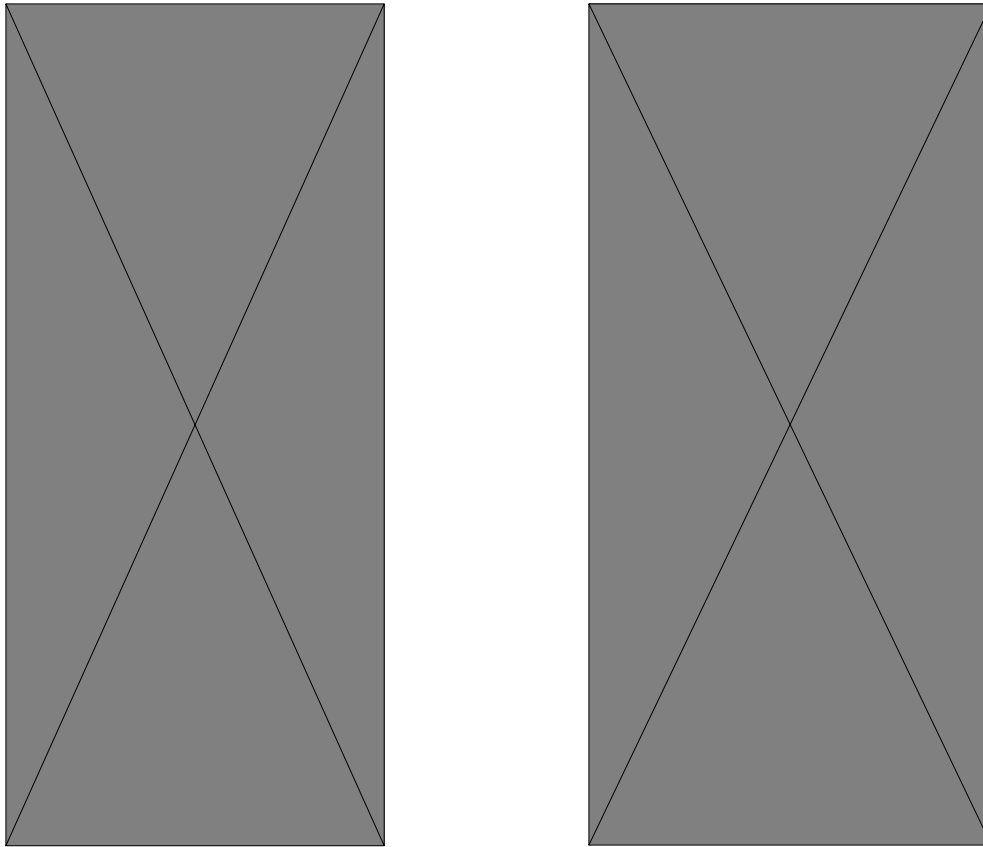


Figure 3 (left). The tail ascribed to *Leedsichthys problematicus* (P.10000) as displayed in the British Museum (Natural History) in 1937 (NHM-ESL negative number 1660). © The Natural History Museum, London.

Note the supposed original outline of the tail and missing skeletal elements painted in around the bones (compare with Figure 1), and the use of the outdated binomial *Leedsia problematica*. The label (bottom left) reads:

Tail of LEEDSIA PROBLEMATICA A. S. WOODW[ARD]. OXFORD CLAY. PETERBOROUGH. This tail measures nine feet in depth, and if the fish to which it belonged were the same proportions as *Hypsocormus* exhibited in Wall-case 13, its total length must have been about thirty feet. *Leedsia* seems to have been toothless and destitute of ossified vertebral centra, but it is known only by fragments such as those exhibited in Wall-case 14 and the adjoining panel ←. [P.10000] (Leeds Collection, March 1899).

Figure 4 (right). The tail of *Leedsichthys problematicus* (P.10000) as displayed in the British Museum (Natural History) in 1985, with David Martill for scale.

The label (bottom left) reads:

Tail of LEEDSICHTHYS PROBLEMATICUS A. S. Woodward. OXFORD CLAY. PETERBOROUGH. This tail measures about nine feet in depth. If the fish to which it belonged were of the same proportions as the *Hypsocormus* exhibited in Wall-case IV, its total length must have been about twenty-five feet. *Leedsichthys* seems to have been toothless and destitute of ossified vertebral centra. The tail is part of the HOLOTYPE described by A. S. Woodward in 1889. A. N. Leeds Collection, purchased 1899. P.10000.

Note the updated binomial and the incorrect emendation (by comparison to Figure 3) stating that the tail is part of the holotype. Photograph © Rod Branson (reproduced by courtesy of David Martill¹⁴).

size”, and gave the dimensions of the tail as “about 9 feet and was probably originally 12 feet in span”. Henry Woodward again noted, of the tail, that “it seems to be the largest caudal fin of a fish on record”. These three documents are indisputably linked in all referring to unique dinosaur material offered and approved for purchase along with the tail and associated bones at the same Trustees’ meeting. As the British Museum (Natural History) would not have been agreeing to purchase a specimen eight months after it had been delivered (there are no examples of Alfred Leeds ever sending material on approval – on the contrary, it appears that Museum staff frequently visited Eyebury to assess new discoveries with a view to possible purchase), it seems most likely that the July 1898 acquisition of material was entirely unrelated to the specimen found by Alfred Leeds in March 1898, and offered for sale the following February.

Three letters to or from Edward Thurlow Leeds (1877–1955) (MacGregor, 2001), the son of Alfred Leeds and later Curator of the Ashmolean Museum, Oxford, also relate to P.10000. Considerable time was spent by E. T. Leeds amassing information about his father and the Leeds Collection, with a view to publishing a book (Leeds, 1956). Whilst compiling the material, E. T. Leeds wrote numerous letters to the BM(NH) enquiring about the acquisition of the Leeds Collection, dates of visits of Alfred and his brother Charles to the Museum, and requesting photographs of specimens for inclusion in his proposed book. E. T. Leeds¹⁹ requested a photograph of P.10000, but Dr William Dickson Lang (1878–1966) (White, 1966) replied²⁰ that no photograph of the tail specimen had ever been taken, and that it would take some time (probably a few months) for one to be made. A card from E. T. Leeds²¹ indicated that a copy of “the excellent photograph” had arrived, undoubtedly referring to the 1937 photograph¹³ of P.10000 (Figure 3) which is the only photograph of the tail in the NHM archives. Some of the data collected by E. T. Leeds about his father and the Leeds Collection was posthumously edited and published (Leeds, 1956). The original manuscript has recently been traced by the present authors. This discovery will permit further important archival work to be undertaken on the Leeds Collection fossils and has immediately allowed confirmation that the photograph of the tail which E. T. Leeds obtained matches the image held in the NHM archives, thus dating the photograph precisely to September 1937.¹³

DISCUSSION

Alfred Leeds’ 1898 letter and the associated documents resolve some, but not all, of the problems relating to the tail attributed to *Leedsichthys problematicus* (P.10000). That Alfred Leeds’ letter refers to P.10000 is beyond doubt. All the documents indicate that P.10000 was part of the Leeds Collection, and no other tail consisting of more than a single fin-ray attributed to *Leedsichthys* is known, or was collected by Alfred Leeds: E. T. Leeds (1956: 75) referred to it as “the tail”, and recorded the undertaking by the Leeds family never to collect or reconstruct a tail of this fish again. The letter resolves the confusion over the date that P.10000 was collected. Both previously cited dates – 1889 (Martill, 1988) and 1899 (Leeds, 1956; Martill *et alii*, 1999) – are erroneous as P.10000 was excavated during March 1898. The idea of 1899 as the year of collection (Leeds, 1956; Martill *et alii*, 1999) probably arose from the label, visible in the 1937 photograph (Figure 3), which probably referred to the date of arrival noted in the NHM purchase register.⁷ Assuming that it is not the result of a typographical or proof-reading error, the 1889 date (Martill, 1986) is likely to have arisen from the misleading information on the label displayed with the tail during

1985 (Figure 4) indicating that P.10000 formed part of the holotype. The delay between the date of collection (March 1898) and the date of purchase by the BM(NH) (March 1899) is hinted at in Alfred Leeds' letter: "I've a great number of bones to wash yet – & it will take months to fit them"⁴, and this is corroborated by the work required to "fit literally thousands of fragments" by Alfred Leeds and his family (Leeds, 1956: 74).

Associated bones

Alfred Leeds' 1898 letter demonstrates that when collected the tail was associated with other bones, and was therefore not found in isolation, contrary to the description in Leeds (1956). The purchase and accession registers, and the other documents in the NHM, confirm that the associated bones were all acquired by the BM(NH) in March 1899, although the tail, and currently only the tail, has the registered number P.10000. The associated skeletal elements (cranial bones and a partial pectoral fin) have yet to be located, but the specimens clearly reside within the NHM, either unlabelled or under a separate registered number. This assumes that the missing parts have not decayed, been de-accessioned, or otherwise disposed of, although there is no evidence (such as annotations in the accession register) for any of these latter suggestions.

Alfred Leeds' letter and associated documents also resolve the problems of the proposed associations between P.10000 and other NHM *Leedsichthys* material. The tail cannot be associated with the holotype of *Leedsichthys problematicus* (P.6921), which was part of Alfred Leeds' "First Collection" acquired by the BM(NH) between 1890 and 1892 (Leeds, 1956) well before the discovery of P.10000 in March 1898. The probable source of this proposed association (Martill, 1988) is indicated by the differences of labelling on display in 1937 and 1985. Unlike the 1937 photograph of the tail (Figure 3), the label visible in the 1985 photograph (Figure 4) incorrectly described P.10000 as part of the holotype of *Leedsichthys*. There is no record of when this change of labelling took place, but Alfred Leeds' 1898 letter, and the purchase and accession registers for both the holotype (acquired 1892) and the tail specimen (acquired 1899), clearly demonstrate this modification was incorrect. Examination of the NHM purchase and accession registers also precludes the tail (P.10000) from being associated with the gill-basket (P.10156; also incorrectly labelled as the holotype in the BM(NH) in 1985), as understood by Martill (1988). The tail specimen (with its non-tail components) was purchased and transported in its entirety in March 1899, and P.10156 was a separate purchase in July 1905, thus, P.10000 (the tail specimen) and P.10156 have distinct years of purchase and different accession numbers. Thus, speculation that these two specimens are part of the same individual (Martill, 1988; Martill *et alii*, 1999) can be rejected. The confusion probably arose from the incorrect labelling of both P.10000 and P.10156 as the holotype whilst on display. This forms an unusual contrast to the more commonly encountered scenario, as presented for example by Torrens (1979), whereby a type specimen lies unrecognised and presumed lost in a collection. Here we have the far more rare and unlikely situation of a 'cuckoo specimen' usurping the role of holotype, on the basis of no evidence whatsoever, when the real holotype was still safe and known to be in the same institution's collections. The usurper was then unambiguously and publicly advertised as part of the holotype, thus becoming imbued with a taxonomic importance that it simply should not have been accorded (particularly as it appeared to lack any of the components designated in the published description).

The proposed association between P.10000 and P.11823 is more difficult to resolve. The

tail, P.10000, was discovered in March 1898, and P.11823, which apparently contains many of the same elements as the missing parts of P.10000 (Liston, in press), was purchased on 28 July 1898.⁶ P.11823–11826 were described in the purchase register simply as “various bones of *Leedsia* [*sic*] &c”, but the specimens were not allocated accession numbers (nor given individual osteological identifications) in the accession register until after specimens purchased in 1915.⁶ However, the note from Alfred Leeds’ offering the tail specimen for sale¹⁶, the two documents written by Henry Woodward^{17, 18}, and the purchase and accession registers all indicate the tail was purchased with its associated bones; some of the documents corroborate Alfred Leeds’ letter⁴ by specifying head bones and an incomplete pectoral fin, as well as showing that the specimen was purchased at the same time as unique dinosaur material. Thus, despite the lack of detail in the purchase and accession registers, and no additional documents relating to the purchase of P.11823, an association with P.10000 can be rejected. P.10000 and P.11823 must therefore be considered as separate individuals of *Leedsichthys*, contrary to Liston (in press).

Alfred Leeds’ recognition of the presence of cranial bones and gill-rakers associated with P.10000, regardless of their current accession numbers, is of considerable importance as these osteological elements coincide with elements of the holotype of *Leedsichthys problematicus* (P.6921). The gill-rakers in particular are of paramount importance, especially as *Leedsichthys notocetes* Martill, Frey, Caceras & Diaz, 1999 was designated solely on the basis of differences in the morphology of gill-rakers preserved in a cluster from east of Antofagasta, in the Atacama Desert of Chile. In addition, Alfred Leeds had carefully collected, washed, and reassembled the bones of the holotype (P.6921), the tail and associated bones (P.10000), and several other specimens of *Leedsichthys problematicus* (see Table 1), learning “to recognise the individual features of every bone with which he had to deal” (Leeds, 1956: 23). Thus, Alfred Leeds was more familiar than anyone else with the bones of *Leedsichthys*, and even in the present-day absence of the P.10000 associated material (which remains to be identified in the NHM), Alfred Leeds’ 1898 letter adds considerable weight to the assignation of P.10000 to *Leedsichthys problematicus*, an assignation we provisionally accept here. However, this proposed assignation can only be confirmed or refuted once the bones associated with the tail have been located, identified, and compared with those of the holotype (P.6921).

In his 1898 letter, Alfred Leeds notes that “I feel certain now that all the bones we [presumably Alfred Leeds and Arthur Smith Woodward] thought belonged to the head, are head bones – for they were all mixed up with thousands of gill-rakers”.⁴ Although the anatomical identities of the individual head bones remain unresolved (Smith Woodward 1889b, 1895; Martill, 1988; Liston, in press), Alfred Leeds’ letter reinforces the opinion that the large flat bones assigned to the cranium (Smith Woodward, 1898a) were indeed derived from the head. Alfred Leeds in his 1898 letter also noted the absence of “big rib shaped & long straight bones”⁴ previously discovered with *Leedsichthys*. Alfred Leeds suggested that these bones have nothing to do with the head, but may form part of the (presumably absent) dorsal fin (Figure 2). It is hoped that ongoing work (by JLL) will confirm or refute this suggestion. Alfred Leeds also noted the absence of vertebrae in this specimen, corroborating the suggestion that *Leedsichthys* had limited ossification of its axial skeleton (Smith Woodward 1889b; Leeds, 1956; Martill, 1988), a trend also observed in other Pachycormid fish.

Estimated size

The size of *Leedsichthys problematicus* is unknown (Martill, 1988), but published estimates

all agree it was “a very large fish” (Smith Woodward, 1889a: 31). The length of *Leedsichthys* was estimated by Smith Woodward as probably being about 9 metres long (“30 feet”: Smith Woodward, 1905, 1917; Leeds, 1956). Subsequent length estimates have ranged from 10.5 metres to 27.6 metres (Martill, 1986), suggesting *Leedsichthys* was “perhaps the largest fish of all time” (Martill and Hudson, 1991: 30). However, the 1986 calculations were derived by scaling up a complete specimen, approximately 1.75 metres long, of the pachycormid putatively identified as *Asthenocormus* (P.61563), to match isolated elements from different specimens of *Leedsichthys* (Martill, 1986, 1988). This scaling exercise is the only published size estimate for *Leedsichthys*, and all subsequent estimates have been based on these calculations (Martill, 1988; Martill and Hudson, 1991; Bardet *et alii*, 1993; Martill *et alii*, 1994, 1999). However, as no substantially complete specimen of *Leedsichthys* has yet been described, and as different parts of the same individual gave sizes ranging from 13.5 metres to 27.6 metres (Martill, 1988), such estimates must remain conjectural. Despite these problems, it is clearly desirable to have more accurate estimates in order to appreciate the anatomy, biomechanics, ecology and trophic position of this colossal fish.

Alfred Leeds’ letter⁴ also provided approximate dimensions for the P.10000 tail specimen of *Leedsichthys* as it lay in the ground. The letter thereby provides only the second *in situ* bone disposition information for a specimen of *Leedsichthys* (see also Michelis *et alii*, 1996), and is a unique record of remains that were evidently substantially complete.

In his March 1898 letter, Alfred Leeds stated that “just beyond the head” and “a good distance apart” were two fins, and that “back some 12 [c. 3.6m] or 18 feet [c. 5.5m] was found the tail”; a sketch of the tail⁴ was provided with dimensions (Figure 2). There are, however, a number of problems with interpretation of the measurements given by Alfred Leeds, the most important of which are as follows: no sense is given of the size of the head or the distribution of the bones; the dimensions given are approximate; and the disposition of the postcranial elements as described could be interpreted in a number of ways. However, by assuming the fish lay articulated in the clay (as Alfred Leeds appears to interpret the remains), and that the two fins referred to were the paired pectorals lying as though still connected to either side of the body, an estimate of how the remains were discovered can be inferred (Figure 5). From this plan, the maximum dimensions of this fish can be estimated by taking 5.5 metres (Alfred Leeds’ “18 feet”) maximum body length and adding 0.5 metres anteriorly for the “short distance” from the head to the fins, 0.5 metres for the proximal length of the pectoral fins, and at least 1.5 metres for the anteroposterior length of the tail. This gives an estimated body length of around 8 metres. A conservative estimate of 1 metre for the length of the head would give an estimated overall length of 9 metres. This figure is remarkably close to the 30 feet estimated for *Leedsichthys* based on P.10000 (Smith Woodward, 1905, 1917; Leeds, 1956); which (if the above interpretation of Leeds’ letter is correct) might suggest the possibility that Smith Woodward’s (1905, 1917) estimate was based on Alfred Leeds’ letter and/or personal communication between the two men.

A recent estimate of 14 metres for *Leedsichthys* has been derived by comparison between the lengths of the caudal fins of P.61563 (*Asthenocormus*) and P.10000 (Martill, 1986). Flaws in the technique are recognised (Martill, 1988) – scaling from a fish (*Asthenocormus*) with tail lobes only 0.25 metres long to a fish (*Leedsichthys*) with tail lobes over 1.8 metres long is fraught with difficulties and potential errors. Thus 14 metres may well be an over-estimate for this individual of *Leedsichthys*.

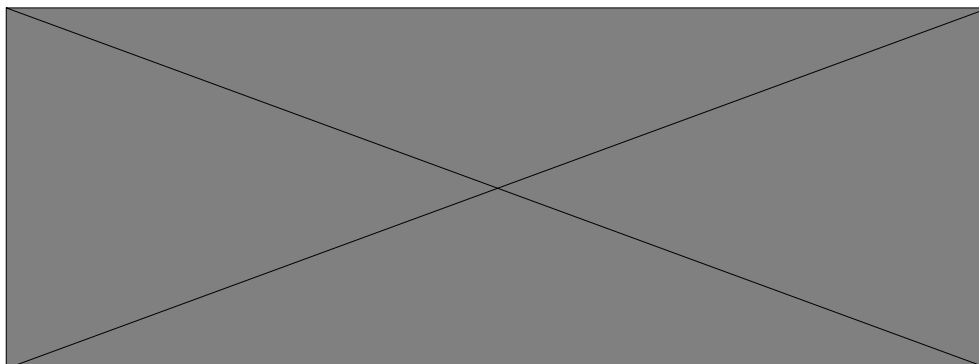


Figure 5. A hypothetical reconstruction of *Leedsichthys problematicus* P.10000 based on the information given by Alfred Leeds in his letter of 18 March 1898 (Figure 2) and estimates of other dimensions not given therein. The size of the head (A) is not known (conservatively estimated at one metre), but just beyond (B; ?0.5m) lay two fins, here interpreted as the paired pectorals (C, the anteroposterior length of the fins proximally; ?0.5m), a good distance apart (D, the width of the body), with the tail up to 5.5m beyond the fins (E). The tail measured 1.5m along each lobe (F) and was just less than 0.5m across the middle of one lobe (G) and nearly 45mm thick. If the anteroposterior length of the tail was originally 1.5m, then the fish may be estimated at about 9m in total length. Outline image by L. F. Noè (modified from Martill (1986): original reconstruction by Paul Policott).

CONCLUSIONS AND WIDER IMPLICATIONS

The documents held in The Natural History Museum (NHM-GL and NHM-ESL) had not previously been recognised as referring to P.10000, the only tail of *Leedsichthys* known. These documents are of considerable importance as they cast valuable new light on the discovery and interpretation of P.10000, and thus add significantly to our understanding of *Leedsichthys problematicus*. A summary of our conclusions follows.

- The date of collection of P.10000 and its associated material was March 1898, refuting previously published collection dates.
- The tail is confirmed as measuring about six feet along each lobe when discovered.
- The tail, now registered under the number of P.10000, was found associated with cranial and pectoral elements, most of which were recovered and probably still reside in The Natural History Museum, London.
- Alfred Leeds, who was intimately familiar with *Leedsichthys*, assigned P.10000 to *Leedsichthys problematicus* based on more than just the tail. However, confirmation of the identity of P.10000 will have to await rediscovery of the associated material and comparison of it with the holotype of *Leedsichthys* (P.6921).
- P.10000 is not part of the same individual as the holotype (P.6921), nor any other numbered individual of *Leedsichthys problematicus* (P.10156, P.11823).
- The bones of *Leedsichthys* believed to belong to the head (Smith Woodward, 1889b) probably do so; other long rib-like bones (lacking in P.10000) may be the dorsal fin supports; the vertebrae were probably cartilaginous with poor preservation potential and hence absent from this specimen.
- The maximum size of P.10000 may have been around 9 metres. Discussion between Alfred Leeds and Arthur Smith Woodward regarding the size of this specimen may well have informed

the earliest published size estimate for *Leedsichthys*.

The estimated size obtained for P.10000, by comparison with the tail of *Asthenocormus* (Martill, 1986), may thus be an overestimate, confirming that the scaling technique used was unreliable.

The importance of Alfred Leeds' letter and the associated documents relating to P.10000 cannot be overstated. Had it not been for the existence of Alfred Leeds' letter to Arthur Smith Woodward, the association of the skeletal elements found with the tail would have been lost forever, and incorrect associations would have continued to be assumed, potentially leading to further unsound conclusions.

The lessons from this palaeontological example of the importance of archival resources can be applied more widely to the earth sciences and beyond. To gain the fullest possible understanding of historical specimens, all sources of documentation, both published and unpublished, should be sought and consulted.

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NOTES

¹ Unless otherwise stated, all material cited is registered in The Natural History Museum, London (NHM) (formerly the British Museum (Natural History) (BM(NH))), Cromwell Road, London SW7 5BD.

² D. M. Martill, pers. comm, 10 November 2003.

³ The Official Archives of The Natural History Museum, held by the General Library (NMH-GL) and Earth Sciences Library (NMH-ESL).

⁴ Alfred Nicholson Leeds to Arthur Smith Woodward, 18 March 1898; Correspondence section NHM-GL DF100/31.

⁵ Geological Department annual purchases register volume 2, 1892-1948; NHM-GL DF102/2: 4.

⁶ NHM-GL DF102/2: 73.

⁷ NHM-GL DF102/2: 79.

⁸ NHM-GL DF102/2: 134.

⁹ NHM-GL DF102/2: 229.

¹⁰ NHM-GL DF102/2: 10.

¹¹ Palaeontology Department specimen catalogues, additions to the collection of fossils, Pisces volume 3A; NHM unnumbered.

¹² D. M. Martill (pers. comm., 6 June 2002) can no longer trace his source for this comment.

¹³ NHM-ESL negative number 1660.

¹⁴ NHM-ESL negative number Acc:2004/2 (from D. M. Martill).

¹⁵ NHM-ESL DF103/40: 25.

¹⁶ A. N. Leeds, "Mr Leeds' Dinosaur", 21 February 1899 (1folio); ms NHM-ESL unnumbered.

¹⁷ H. Woodward, "Fine associated set of remains . . .", not dated (1 folio); ms NHM-ESL unnumbered.

¹⁸ H. Woodward, "The Keeper of Geology has the honour to report ...", not dated (3ff); ms NHM-ESL unnumbered.

¹⁹ E. T. Leeds to W. D. Lang, 21 August 1937; NHM-GL DF100/154/7.

²⁰ W. D. Lang to E. T. Leeds, 25 August 1937; NHM-GL DF100/154/7.

²¹ E. T. Leeds to W. D. Lang, 19 September 1937; NHM-GL DF100/154/7.

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