First dinosaur remains from Ireland

Michael J. Simms[1], Robert S. H. Smyth[2], David M. Martill[2] and Roger Byrne[3]

[1] Department of Natural Sciences, National Museums Northern Ireland, Cultra, Holywood, Co. Down, BT18 0EU, Northern Ireland, UK

[2] School of the Environment, Geography and Geological Sciences, University of Portsmouth, Burnaby Road, Portsmouth PO1 3QL, England, UK.

[3] deceased.

ABSTRACT

Several specimens from the Lias Group (Lower Jurassic) of Northern Ireland have been suspected as dinosaurian in origin. Bone histology and morphology demonstrates that two of these, both from the same locality in Co. Antrim, demonstrably are from dinosaurs. We interpret one as the proximal end of the left femur of a basal thyreophoran ornithischian, and tentatively assign it to cf. *Scelidosaurus*. The other is the proximal part of the left tibia of an indeterminate neotheropod, perhaps a stem-averostran similar to *Sarcosaurus*, or a megalosauroid. These are the first dinosaur remains reported from anywhere in Ireland and some of the most westerly in Europe, and are among only a small number of dinosaurs known from the Hettangian Stage. Two additional specimens are no longer considered to be from dinosaurs. We interpret one as a surangular or mandible fragment from a large marine reptile, perhaps an ichthyosaur or pliosaur; the other is a polygonal fragment of Paleocene basalt.

Key words: Ornithischia, Theropoda, Early Jurassic, Hettangian, Northern Ireland.

1. Introduction

Although dramatic finds from North America, Asia and elsewhere have dominated the literature for decades, Britain remains one of the richest areas in the world in terms of documented dinosaur diversity. Important faunas have been recovered from the Upper Triassic (e.g. Benton et al. 2000, Whiteside et al. 2016), the Jurassic of south central and eastern England (Benton and Spencer 1995) and especially the Lower Cretaceous of the Isle of Wight and the Weald (Martill and Naish 2001), but elsewhere in the UK dinosaur remains are less abundant. Footprints and skeletal remains have been discovered in the Jurassic of Yorkshire (Whyte et al. 2010), in northern England; from the Late Triassic and Early Jurassic of south Wales (Benton and Spencer 1995, Yates 2003, Martill et al. 2016); and the Jurassic of both western and eastern Scotland (Andrews and Hudson 1984, Benton et al. 1995, Clark 2018, dePolo et al. 2018, Young et al. 2018). However, no dinosaur remains have hitherto been recorded from the island of Ireland.

Some might attribute the apparent absence of dinosaur remains from Ireland to the activities of St Patrick, whose apparent success in casting out snakes is well known, but there is a more mundane explanation. The sparsity of dinosaur remains in Britain beyond southern England directly reflects the geology of these regions. Suitable Mesozoic rocks are poorly represented in northern and western Britain where most rocks are too old to contain dinosaur remains, and this is true too across large areas of Ireland. Outside of Northern Ireland there are just a few, largely concealed, patches of Mesozoic inluding Triassic clastics in the Kingscourt Inlier (Simms 2009) and possibly in the Wexford Outlier (Clayton et al. 1986), Jurassic clastics near Cork (Higgs and Beese 1986) and Carrick-on-Suir (Higgs and Jones 2000), and a tiny patch of Upper Cretaceous Chalk in Co. Kerry (Walsh 1966).

Substantial Mesozoic basins are present in the north-east (Larne-Lough Neagh Basin) and north-west (Foyle-Rathlin Basin) of Northern Ireland but they are mostly concealed beneath younger rocks and exposure is confined largely to a narrow strip around the margins of the Paleocene basalt plateau (Fig. 1). Triassic, Jurassic and Cretaceous strata are all represented (Fig. 2) but there is a gap, representing at least 100 million years, between the youngest preserved Jurassic strata (early Pliensbachian) and oldest preserved Cretaceous (early Cenomanian), caused by pre-Cenomanian erosion of earlier Mesozoic strata, and in places the Jurassic is cut out altogether where Cretaceous strata rest directly upon Triassic or even older rocks.

However, despite being of the right age to contain dinosaurs these Mesozoic strata are developed in facies that do not favour the preservation of terrestrial vertebrates. The Jurassic and Cretaceous strata here are entirely of open marine facies in which dinosaur fossils are unlikely to be common, while the Upper Triassic succession is largely non-marine and developed in red-bed facies of the Mercia Mudstone Group (Milroy et al. 2019) in which fossils of any kind are rarely preserved. In short, Ireland's rocks are either of the wrong age or of the wrong type to contain dinosaur fossils.

Palaeogeographic reconstructions (Cope et al. 1992) suggest that at times during the Mesozoic dinosaurs could have walked on dry land across parts of what is now Ireland. However, if any rocks were deposited here at these times they were either removed long ago by erosion, along with any dinosaur remains that they might contain, or they were deposited in environments distant from dinosaur habitats. Finding an Irish dinosaur might seem a hopeless task but, nonetheless, several potential candidates have been identified and are described for the first time here.

2. Occurrence and history of discovery

Several specimens from Northern Ireland, now held in the collections of National Museums NI, have been identified as potentially of dinosaurian origin. One of these (BELUM K1642) was acquired in 1920 from the Belfast Natural History and Philosophical Society, in existence since 1821. Information with the specimen states only that it is from the "Lower Lias, Glenarm, Co. Antrim" and that possibly it was collected in the late 19th or early 20th century by William Gray (1830-1917), a well-known collector of fossils and antiquities and an ardent campaigner for a municipal museum in Belfast. The Lias Group is not exposed in situ in the immediate vicinity of the town of Glenarm but it is seen in landslips adjacent to the coast road at Straidkilly, to the north-west of the town (NI grid ref. D305163; 54.976ºN, -5.96ºW), and Minnis North, to the south-east (NI grid ref. D337137; 54.951ºN, -5.91ºW), and this bone probably originates from one or other of these sites. At Straidkilly the succession extends no higher than the Planorbis Zone but at Minnis North it encompasses the entire Hettangian Stage, and perhaps the base of the succeeding Sinemurian Stage. However, without further information we can state only that the source of this specimen is ‘probably Hettangian’.

The three remaining specimens (BELUM K3998, K12493, K2015.1.54) were recovered from among boulders and shingle on the beach near the Gobbins, on the east coast of Islandmagee, Co. Antrim (Grid ref. J485968; 54.799ºN, -5.690ºW), by the late Roger Byrne between 1980 and 2000. Along the Gobbins coast the Antrim Lava Group basalts (Paleocene) and Ulster White Limestone Formation (Cretaceous, Santonian to Campanian) have slumped on the less mechanically competent lithologies of the Lias Group (Jurassic, Hettangian) and Hibernian Greensands Formation (Cretaceous, Cenomanian to Coniacian) beneath. The succession is highly disturbed but small exposures at the rear of the beach and among the boulders on the foreshore expose sand and silt facies of the Hibernian Greensand Formation lying unconformably upon grey clays and subordinate muddy limestones of the Lias Group (Planorbis Zone) and the upper Cotham Member of the Penarth Group (Triassic, Rhaetian Stage).

The Gobbins beach itself, extending south from the famous Gobbins cliff path, is covered with rounded fragments of basalt and white limestone. Fossil material is sparse and often heavily abraded. The specimens found by Roger Byrne were ex situ and hence might originate from any level in the local Mesozoic succession, but comparison with other vertebrate material from the Northern Ireland Mesozoic is instructive in establishing their probable source. The prevailing colour of the bone in these specimens is a very dark brownish-black, similar to marine vertebrate material recovered from Lias Group mudstones at various sites in Northern Ireland but distinct from the dark chocolate brown colour of bones and teeth found in the Hibernian Greensand or the pale brown colour of those from the Ulster White Limestone. Furthermore, a small patch of grey indurated calcareous mudstone on one of the specimens (K3998), and a pale grey micrite infill of the medullary cavity in another (K12493), resemble Lias Group lithologies but are distinct from lithologies in the Penarth Group or Chalk Group (Ulster White Limestone and Hibernian Greensand formations) exposed hereabouts. Together these lines of evidence suggest that the Gobbins specimens are from the Lias Group, and probably from the Planorbis Zone at the base of the Hettangian Stage, or from Lias Group strata immediately beneath often referred to as the 'Pre-planorbis Beds'.

For many years the base of the Jurassic System in Britain was placed at the first appearance of the ammonite *Psiloceras planorbis*, or its assumed correlatives (Warrington et al. 1994, 2008) but in 2007 formal proposals were made to designate a GSSP for this boundary. The Triassic-Jurassic boundary section at Larne, Co. Antrim, was a candidate site (Simms and Jeram 2007) although it was the section at Kuhjoch, in Austria, that ultimately was selected (von Hillebrandt et al. 2013) based on the first occurrence of the ammonite *Psiloceras spelae tirolicum*. Direct biostratigraphic correlation between Northern Ireland and the Kuhjoch section is not possible but the proposed Stage and System boundary, as defined in Austria, corresponds to a significant negative excursion in the carbon isotope curve (Ruhl et al. 2009) that has been recognised in the Larne succession. It indicates that the base of the Jurassic System lies within the 'pre-Planorbis beds' of the Lias Group here, in the lower part of bed 22 (Simms and Jeram 2007) and about three metres below the first appearance of ammonites (*Psiloceras erugatum*) in bed 24, although recent work by Hodges (in press) suggests that the Jurassic may commence lower in the succession.

3. Early Jurassic dinosaurs in western Europe

Dinosaur remains are uncommon in the Lower Jurassic of western Europe so even the fragmentary remains described here are potentially of significance. The best known is the thyreophoran ornithischian *Scelidosaurus harrisoni* from the Sinemurian of the Dorset coast, England. The material on which Owen (1861) based his original description actually encompassed two distinct animals; an armoured ornithischian represented by a near complete skeleton, and a theropod represented by part of a hind limb. Bizarrely it was the latter that was originally designated as the holotype, although it is the armoured ornithischian that now holds the name. Several near complete skeletons of *Scelidosaurus* are now known, all from Dorset. A second questionable thyreophoran, *Lusitanosaurus liasicus* has been described from the Sinemurian of Portugal (Lapparent and Zbyszewski, 1957) and another, *Emausaurus ernsti*, is from the Toarcian of northern Germany (Haubold 1990). Remains of several theropods are known from the Hettangian; *Lophostrophus airelensis* (Cuny and Galton 1993) from Airel, Normandy; *Sarcosaurus* *woodi* from central England (Andrews 1921, Woodward 1908, von Huene 1932, Ezcurra et al. 2020); *Dracoraptor hanigani* from Lavernock, south Wales (Martill et al. 2016); a pedal phalanx and tooth fragment from Luxembourg (Delsate and Ezcurra 2014); and, from the Sinemurian, the partial hind limb to which the name *Scelidosaurus harrisoni* was first applied. A sauropodomorph hind limb, *Ohmdenosaurus liasicus*, has also been described from the Toarcian of Baden-Württemberg (Wild 1978, Stumpf et al. 2015). Much of this material is specifically indeterminate and even some of the named taxa, such as *Ohmdenosaurus,* are so fragmentary that they are perhaps best considered *nomina dubia*.

Slightly older taxa, from the late Triassic (Rhaetian), include a theropod dentary, ?*Megalosaurus cambrensis*, from south Wales (Newton 1899, Galton, 2005); an incomplete melanorosaurid sauropodomorph skeleton, *Camelotia borealis*, from the Penarth Group of Somerset in south-west England (Galton 1985); various taxonomically indeterminate fragments from the Westbury Formation of Newark, Nottinghamshire (Martill and Dawn 1986) and Aust Cliff, near Bristol (Storrs 1994); and the basal sauropodomorphs *Thecodontosaurus* and *Pantydraco* from supposedly Rhaetian fissure fills in south-west England and south Wales (Galton et al. 2007, Riley and Stutchbury 1836, Whiteside et al. 2016). Supposed dinosaur limb bone fragments from the Penarth Group at Aust Cliff, near Bristol (Galton 2005), are probably jaw fragments from giant ichthyosaurs (Lomax et al. 2018).

4. Evidence for dinosaurs in Ireland

In Northern Ireland the Jurassic succession is entirely marine. Bones of marine fish and reptiles, ichthyosaurs and plesiosaurs, have been recovered from many exposures of the Lower Jurassic here and so our initial assumption must be that those bones we consider as potentially dinosaurian in origin are, in fact, from marine vertebrates. This possibility can largely be discounted. Firstly, no Lower Jurassic fish yet discovered attains a size comparable with that indicated by these bones. Secondly, the shape of each of the bone fragments in question does not immediately resemble any of the bones found in ichthyosaur or plesiosaur skeletons, although caution must be exercised here as fragmentary ichthyosaur bones have in the past been mistaken for those of dinosaurs (Lomax et al. 2018). Finally, and most significantly, the fine structure of these bones differs significantly from that found in fish, ichthyosaurs or plesiosaurs/pliosaurs.

4.1. *Bone histology and surface texture*

The bones of Jurassic ichthyosaurs and plesiosaurs, including their long bones and vertebrae, are commonly dominated by a porous or cancellous structure, with little or no medullary cavity, surrounded by a compact peripheral layer (Houssaye et al. 2014, Liebe and Hurum 2012) that typically is relatively thin (less than 20% of bone radius). This is similar to extant cetaceans and reflects their highly evolved aquatic mode of life where overall density of the animal is more critical than the load-bearing properties of the bones. In contrast the load-bearing bones of terrestrial vertebrates, such as dinosaurs, tend to have a more thickened (30-40% of bone radius) outer zone of compact bone around an inner core of cancellous bone and/or a medullary cavity which, in life, contains bone marrow (e.g. Hübner 2012, Redelstorff et al. 2013). A further significant distinguishing character is that the surface texture of dinosaur long bones is very smooth whereas those of marine reptiles, including long bones, ribs and jaws, commonly tend to show a greater rugosity in the form of longitudinal striations subparallel to the bone long axis.

The typically dinosaurian aspects of bone histology seen in K3998 were recognised as early as 1989 by the late Robin Reid of Queens University Belfast, who had developed an interest in dinosaur bone histology (e.g. Reid 1984), and the discovery of this specimen was reported in the local press. It was Roger Byrne himself that recognised the second dinosaur bone fragment from the Gobbins (K12493) based essentially on the same criteria (dense outer bone and large medullary cavity). Two other potential candidates (K1642 and K2015.1.54) have in the past been suggested, or suspected, as being of dinosaurian origin but a closer reexamination reveals that this is not so.

4.2. Morphological descriptions

Bone histology and surface texture can be used to establish if these fragments are from dinosaurs, but it is their shape that we have used in our attempt to identify which bones they are and from broadly which group(s) of dinosaurs they originate. Robin Reid suggested in 1989 (Ulster Museum, unpublished notes) that K3998 was the proximal end of a femur, perhaps from the well-known early Jurassic thyreophoran genus *Scelidosaurus* although his reason for assigning it to that genus may have been based on little more than that it being the best-known early Jurassic dinosaur. With the second fragment (K12493) found at the same site it was, understandably, assumed to be from the same animal as K3998. However, on the basis of their size difference alone it is immediately apparent that this is not the case and the two bone fragments clearly represent different individuals and distinct taxa.

4.3. Specimen descriptions and interpretation

4.3.1. Specimen BELUM K3998a, b

This specimen (Figure 3a-j) was collected by Roger Byrne on 13th January 1980 and was the first Irish dinosaur bone to be recognised, by Dr Robin Reid in 1989. It is a short fragment of a bone, smooth on its outer surface, abraded at its presumed proximal end and sectioned distally to reveal a thickened bone wall sharply demarcated from a lumen with a very open trabecular bone fill (Fig. 3c, f). There is no evidence of a medullary cavity, perhaps reflecting the proximity of this cut surface to the original bone termination. A glass-mounted thin section of this cut surface is in the Ulster museum collections (BELUM K3998b). The original preserved extent of the bone beyond the cut surface is not known, but it is not believed to be substantial. The outline of the bone, as seen laterally, is roughly quadrate. One face is broadly concave with a prominent sulcus offset to one side and parallel to the long axis of the bone (Fig. 3b, e). On the other side there is a prominent boss, located slightly off-centre, that is higher towards the middle and fades away toward two of the margins of the subquadrate outline (Fig. 3a, d).

Surface texture and histology establish this specimen as a dinosaur bone and we interpret it as the proximal end of a left femur, sectioned across its distal end and with the proximal end abraded and missing the femoral head. What is preserved of the femoral shaft is almost straight, but there is too little remaining to say anything more about shaft morphology. The heavily worn base of the anterior trochanter is present on the anterolateral surface of the femoral shaft (Fig. 3a, d, h). A small area of matrix, on which the accession number is written, remains between the proximal preserved part of the anterior trochanter and the femoral shaft (Fig. 3g) and demonstrates that they were well separated from each other. There is no evidence to suggest that the femoral head was separated from the greater and anterior trochanters by a constriction. The anterior trochanter joins with the femoral shaft via a distally expanding ridge that extends along the preserved portion of the anterolateral edge of the element. A finger-like mound extends proximodistally along the anteromedial surface of the shaft (Fig. 3b, e, h), and presumably this structure was confluent or merged with the distal margin of the femoral head. It suggests that the femoral head would have emerged gently from the shaft of the femur.

The presence of a prominent anterior trochanter, well separated from the femoral shaft, is further evidence that this specimen is from a dinosaur, while thickening of the bone wall with trabecular bone is characteristic of ornithischians. Furthermore, the lack of any indication of a constriction separating the femoral head from the greater and anterior trochanters is a plesiomorphic trait shared by basal ornithischians to the exclusion of more highly derived forms (Butler et al. 2012). BELUM K3998 is relatively large for an Early Jurassic ornithischian, with ornithischian diversity at this time characterised by small-bodied heterodontosaurids (Sereno, 2012) and basal thyreophorans (Norman et al. 2004), with no heterodontosaurid known that approaches a size even close to that of BELUM K3998 (Sereno 2012). The quadrate outline of the femoral shaft of BELUM K3998 in cross-section is also quite unlike the subcircular and elliptical femoral shaft cross-sections seen in other Early Jurassic ornithischians such as *Lesothosaurus* and heterodontosaurids (Butler 2010, Norman 2019), but it does resemble that of the basal thyreophoran *Scelidosaurus.* Among Early Jurassic ornithischians only *Scelidosaurus* and *Lusitanosaurus* are known to attain a size comparable with that indicated by BELUM K3998 (Antunes and Mateus 2003, Norman 2019), and comparison with femora of *Scelidosaurus* (NHMUK R1111 and NHMUK R6704) does show remarkable similarities (Figure 3h, k). The size and morphology of BELUM K3998, the positioning and condition of the anterior trochanter, and the finger-like ridge present on its anteromedial surface, all match closely with *Scelidosaurus* and differ from what is seen in the significantly smaller basal thyreophoran *Scutellosaurus* (Norman 2019, Rosenbaum and Padian 2000).

4.3.2. Specimen BELUM K12493.

This bone fragment (Fig. 4a-h, k, l) was collected by Roger Byrne on 15th April 1981. It is a portion of the shaft of a long bone with a smooth outer surface, abraded proximal articular surface and truncated distal section. It displays a robust lateral crista and has a triangular outline proximally with a sub-rectangular cross section distally (Fig. 4c, d). The proximal cross section is damaged, probably due to post-burial compaction, and reveals a thickened bone wall sharply demarcated from a lumen containing vacuous trabecular bone, with voids tending to be larger toward one side (Fig. 4c, k). The distal cross section reveals a somewhat thicker bone wall with a subcircular lumen (about 50% of bone diameter) that lacks trabecular bone. Most of this cavity is filled with pale grey micritic limestone but about the remaining third contains a pale, off-white, geopetal calcite infill containing small angular bone shards (Figure 4d, l). In both cross-sections the thickened bone displays a number of lines of arrested growth (LAGs) suggesting development under a seasonal climate (*sensu* Köhler et al. 2012). There is a flattened to weakly concave surface along one length of the diaphysis that we presume was occupied by an adjacent bone, as in the case of a tibia-fibula or metatarsal-metatarsal contact.

The surface texture and histology of this specimen establish it as a dinosaur bone, and we interpret it as the worn and truncated proximal portion of a left tibia. The shaft, as preserved, is straight although too little remains to infer much about its intact form. The distal portion of the cnemial crest rises from the anterior surface of the shaft (Fig. 4a, e) but neither medial nor lateral condyles are evident in this specimen, which we attribute to these structures being confined to the, now eroded, proximal-most region of the posterior side of the tibia. A large fibular crest extends proximodistally along the lateral surface of the tibial shaft (Fig. 4b, f). It is somewhat expanded anteroposteriorly at the midpoint of the preserved shaft and tapers towards the proximal and distal ends of the element. It was most likely lens or tear-drop shaped in lateral view but, despite significant wear, there is no evidence of any internal bone texture exposed on the low broad crest suggesting that in life it did not rise to a sharp point.

BELUM K12493 is a heavily abraded bone fragment lacking terminations and hence identification is difficult. It does show some similarities with a proximal metatarsal 4 in the Early Cretaceous theropod *Neovenator salerii* Hutt, Martill and Barker 1996*,* from the Isle of Wight, but this is not an especially good match and it bears little similarity to the same elements in the Late Jurassic theropod *Allosaurus fragilis* Marsh 1877 (see Madsen 1976 fig. 25A). Furthermore, were this the case the size of BELUM K12493 would imply the existence of an Early Jurassic theropod substantially larger than any currently known. Instead its morphology is more consistent with that of a tibia, with the combination of its size, prominent fibular crest, thin bone wall distally with an absence of trabecular bone, and the probable basis for a large cnemial crest, attesting to the theropodan affinities of this specimen. The fibular crest in particular is diagnostic, extending well into the proximal end of the tibia on BELUM K12493. This is the basal condition for theropods and is present in coelophysoids (Spielmann et al. 2007), dilophosaurids (Welles 1984), stem-averostrans such as *Sarcosaurus* (Ezcurra et al. 2020), as well as ceratosaurians (Madsen and Welles 2000, O'Connor 2007). Among tetanurans only some megalosauroids are known to possess such a proximally extended fibular crest (Benson 2010a, Madsen 1976, Malafaia et al. 2018). Of these megalosauroids only a few develop a crest with a low anteroposteriorly broad mound, as seen in BELUM K12493, including *Megalosaurus*, *Piatnitzkysaurus*, *Condorraptor*, and *Magnosaurus* (Benson 2010a, 2010b, Rauhut 2005). In other megalosauroids, including *Eustreptospondylus*, *Spinosaurus*, *Suchomimus* and *Torvosaurus* the fibular crest forms a narrow ridge, more typical of tetanurans (Benson 2010a, Ibrahim et al. 2014, Sadleir et al. 2008). The metriacanthosaurid *Sinraptor* also possesses an oval shaped, mound-like fibular crest, but it is positioned more anteriorly on the tibial shaft and forms a more prominent ridge than in either megalosauroids or BELUM K12493 (Currie and Zhao 1993).

The presence of an anteroposteriorly broad, proximally extended fibular crest on BELUM K12493 is similar to those found on some megalosauroids, specifically the Megalosauridae or Piatnitzkysauridae. It resembles the tibiae of *Magnosaurus* and matches closely those of the Bathonian *Megalosaurus bucklandi* itself (particularly

NHMUK PV R 12557 and OUMNH J.13562), although the latter are substantially larger than that represented by BELUM K12493 (Figure 4i, j). However, BELUM K12493 differs from the tibia of these megalosauroids in other ways besides overall size. While the fibular crest of megalosauroids emerges gently from the tibial shaft to form a low mound, the crest on BELUM K12493 emerges from the tibial shaft much more abruptly. Additionally, the distal termination of the fibular crest in BELUM K12493 is more abrupt than those of megalosauroids which grade more gently into the bone shaft.

In these features BELUM K12493 bears a closer resemblance to *Sarcosaurus woodi* from the Lias Group (Hettangian–Sinemurian) of central England (*sensu* Ezcurra et al. 2020). *Sarcosaurus* was originally referred to Megalosauridae (Andrews 1921, von Huene 1932), but subsequent analyses of the taxon have variously placed it among Coelophysidae/Coelophysoidea (Welles 1984; Carrano et al. 2005), basal Ceratosauria (Ezcurra 2012), Dilophosauridae (Dal Sasso et al. 2018) and, most recently, as stem-Averostra (Ezcurra et al. 2020). The size and morphology of BELUM K12493 and *Sarcosaurus* are consistent. They are recovered from approximately coeval strata within the Lias Group and their localities are within relatively close proximity (~375-390 km). Most likely, BELUM K12493 represents an animal similar to *Sarcosaurus*, but the limitations of the material and absence of shared autapomorphies precludes any definite referral to this taxon. We consider BELUM K12493 to represent an indeterminate neotheropod, likely representing either a stem-averostran or a megalosauroid.

4.4. Additional specimens previously interpreted as dinosaurian

Two further specimens in the collections of the Ulster Museum have, in the past, been suggested as of dinosaurian origin but closer examination reveals these claims to be unfounded.

4.4.1. Specimen BELUM K1642

This specimen (Figure 5a, g-h), which has been in the museum's collection for at least a century, is a straight, roughly cylindrical section of bone approximately 16 cm long and

6.5 cm across. It lacks any terminations, being broken obliquely at one end and terminated by a cut section at the other. In cross section it is roughly D-shaped, with the curved part of the D represented by the intact rounded outer surface of the bone and the straight section corresponding to a fractured surface exposing an area of cancellous bone (Figure 5g). The sectioned end of the bone (Figure 5h) reveals a relatively dense, yet still porous, outer layer extending through about 280˚ and interrupted by a zone of coarsely porous trabecular bone. The outer layer surrounds a relatively small (<40% of diameter) central cavity into which traces of coarse trabecular bone penetrate.

The bone was loaned to Dr Robin Reid in January 1980 and returned, 6 months later, with a section removed from one end but without comment from Dr Reid. He had developed an interest in dinosaur bone histology at this time and so we assume that this section was removed in relation to that project, on suspicion that it might be a dinosaur bone, but he did not convey his thoughts to the Ulster Museum geologists at the time. Superficially this fragment does resemble a dinosaur long bone shaft in its broadly cylindrical shape, albeit with about a fifth of its circumference apparently broken away, and its appearance in section of a distinct central lumen surrounded by relatively dense bone. However, closer examination of the specimen reveals features that are not consistent with this interpretation. The outer surface of K1642 is not smooth, as in dinosaur long bones, but has the striated appearance (Figure 5a, g) characteristic of the ribs, jaws and limb elements of ichthyosaurs (cf. fig 4 of Lomax et al. 2018) and plesiosaurs/pliosaurs. Furthermore, in section the outer bone layer is substantially less dense than is seen in dinosaurs, with a more conspicuously visible pattern of canals and LAGs (Figure 5h, cf. fig. 4d), and coarsely porous trabecular bone that occupies and extends into that section of the circumference where the outer surface appears to have been broken away. This is not what we would expect to find in any dinosaur long bone but invites comparison with the distal end of an ichthyosaur surangular bone, as described and figured by Lomax et al. (2018). Hence, we interpret this fragment as probably a fragment of surangular from a large ichthyosaur, perhaps *Temnodontosaurus*, or possibly a mandible fragment from a pliosaur such as the rhomaleosaurid *Atychodracon*.

4.4.2. Specimen BELUM K2015.1.54

In the year 2000 Roger Byrne discovered a small flat pentagonal object (Figure 5b-f) with a bone-like texture amongst shingle on the Gobbins beach. By association with the presumed scelidosaur femur (K3998) it was assumed that this object might be a scelidosaur osteoderm, although it lacked the point or curved crest typical of osteoderms in *Scelidosaurus harrisoni* (Norman 2019). The identity of this object remained enigmatic for almost two decades. Dinosaur experts were consulted but could see no evidence for dinosaurian affinity, and turtle experts similarly were baffled. It was only through examination by a fresh pair of eyes (DMM) in 2019 that the mystery was finally solved. It is not a bone at all but merely a small pentagonal piece of basalt! Who would have thought, in the land of the Giant's Causeway, that such a remarkably regular fragment of basalt could turn up on an Antrim beach? The lesson to be learned here is that some of us (MJS) were perhaps too influenced by the remarkably regular shape of this object and by its discovery on the same beach from which a dinosaur bone, tentatively assigned to *Scelidosaurus*, had been recovered.

5. Conclusions

Several specimens from Northern Ireland have been suspected, or suggested, as dinosaur bones but just two can be definitely assigned to this group on the basis of their bone histology, surface texture and morphology. Both are from the base of the fully marine Lias Group (Jurassic System, Hettangian Stage, probably Planorbis Zone) of the Gobbins, Islandmagee, Co. Antrim. Although fragmentary and beach-worn these bones retain sufficient characters for them to be identified and tentatively assigned to distinct clades. We interpret BELUM K3998 as the proximal end of a left femur of a thyreopophoran ornithischian, and tentatively assign it to cf. *Scelidosaurus*. If correct this underlines the close association of *Scelidosaurus* with the marine Lias Group and perhaps implies something about its environmental preference. We identify BELUM K12493 as the proximal portion of a left tibia from a neotheropod, and most likely from either a stem-averostran similar to *Sarcosaurus*, or from an indeterminate megalosauroid.

Reexamination of two other specimens reveals that neither are from dinosaurs. A bone fragment from the Lias Group of Glenarm (BELUM K1642), suspected as being part of a dinosaur long bone, is probably a surangular or mandible fragment from a large marine reptile while an enigmatic pentagonal object (BELUM K2015.1.54) from the Gobbins, once thought to be a scelidosaur osteoderm, is nothing more than a small polygonal flake of Paleocene basalt!

Hettangian dinosaurs are rare and represented only by fragmentary material from England (Andrews 1921), Scotland (Benton et al. 1995) and Arizona (Lucas and Heckert 2001), and perhaps also from Morocco (Nicholl et al. 2018), South Africa (McPhee et al. 2015) and Antarctica (Smith et al. 2007). This global rarity emphasises the potential significance of even these fragmentary remains from Northern Ireland for understanding the evolution and biogeography of Early Jurassic dinosaurs.

Declaration of Competing Interest

The authors declare that they have no known competing financial or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank Paul Barratt, Mike Benton, Eric Buffetaut, Sandra Chapman, Angela Milner and David Norman for their comments on these specimens, and the constructive comments of two referees; and Patrick Collins (Queens University Belfast) for producing 3D scans of the two Gobbins bones for the Portsmouth team.

References

Andrews, C.W., 1921. On some remains of a theropodous dinosaur from the Lower Lias of Barrow-on-Soar. Annals and Magazine of Natural History, series 9, 8, 570-576.

Andrews, J.E., Hudson, J.D., 1984. The first Jurassic dinosaur footprint from Scotland. Scottish Journal of Geology 20, 129-134.

Antunes, M.T., Mateus, O., 2003. Dinosaurs of Portugal. Comptes Rendus Palevol 2, 77-

95.

Benson, R.B., 2010a. A description of *Megalosaurus bucklandii* (Dinosauria: Theropoda) from the Bathonian of the UK and the relationships of Middle Jurassic theropods. Zoological Journal of the Linnean Society 158, 882-935.

Benson, R.B., 2010b. The osteology of *Magnosaurus nethercombensis* (Dinosauria, Theropoda) from the Bajocian (Middle Jurassic) of the United Kingdom and a re-examination of the oldest records of tetanurans. Journal of Systematic Palaeontology 8, 131-146.

Benton, M.J., Martill, D.M.,Taylor, M.A., 1995. The first Lower Jurassic dinosaur from Scotland: limb bone of a ceratosaur theropod from Skye. Scottish Journal of Geology 31, 177-182.

Benton, M.J., Spencer, P.S., 1995. Fossil Reptiles of Great Britain. Geological Conservation Review Series No 5, 345 pp.

Benton, M.J., Juul, L., Storrs, G.W., Galton, P.M., 2000. Anatomy and systematics of the prosauropod dinosaur *Thecodontosaurus antiquus* from the Upper Triassic of southwest England. Journal of Vertebrate Palaeontology 20, 77-108.

Butler, R.J., 2010. The anatomy of the basal ornithischian dinosaur *Eocursor parvus* from the lower Elliot Formation (Late Triassic) of South Africa. Zoological Journal of the Linnean Society 160, 648-684.

Butler, R.J., Porro, L.B., Galton, P.M., Chiappe, L.M., 2012. Anatomy and cranial functional morphology of the small-bodied dinosaur *Fruitadens haagarorum* from the Upper Jurassic of the USA. PLoS One 7(4). https://doi.org/10.1371/journal.pone.0031556

Carrano, M.T., Hutchinson, J.R., Sampson, S.D., 2005. New information on *Segisaurus halli*, a small theropod dinosaur from the Early Jurassic of Arizona. Journal of Vertebrate Paleontology 25, 835-849.

Clark, N.D.L., 2018. Review of the dinosaur remains from the Middle Jurassic of Scotland, UK. Geosciences 2018, 8(2), 53.

Clayton, G., Sevastopulo, G.D., Sleeman, A.G., 1986. Carboniferous (Dinantian and

Silesian) and Permo-Triassic rocks in south County Wexford, Ireland. Geological Journal 21, 355-374.

Cope, J.C.W., Ingham, J.K., Rawson, P.F. (eds), 1992. Atlas of palaeogeography and lithofacies. Geological Society Memoir no. 13. xii+153 pp. London, Bath: Geological Society of London.

Cuny, G., Galton, P.M., 1993. Revision of the Airel theropod dinosaur from the Triassic-Jurassic boundary (Normandy, France). Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 187, 261–288.

Currie, P.J., Zhao, X.J., 1993. A new carnosaur (Dinosauria, Theropoda) from the Jurassic of Xinjiang, People's Republic of China. Canadian Journal of Earth Sciences 30, 2037-2081.

Dal Sasso, C., Maganuco, S., Cau, A., 2018. The oldest ceratosaurian (Dinosauria: Theropoda), from the Lower Jurassic of Italy, sheds light on the evolution of the three-fingered hand of birds. PeerJ 6, e5976.

Desalte, D., Ezcurra, M., 2014. The first Early Jurassic (late Hettangian) theropod dinosaur remains from the Grand Duchy of Luxembourg. Geologica Belgica 172, 175-181.

Ezcurra, M.D., 2012. Phylogenetic analysis of Late Triassic - Early Jurassic neotheropod dinosaurs: Implications for the early theropod radiation. Journal of Vertebrate Paleontology, Program and Abstracts 2012 32, 91.

Ezcurra, M.D., Butler, R.J., Maidment, S.C.R., Sansom, I.J., Meade, L.E., Radley, J.D., 2020. A revision of the early neotheropod genus *Sarcosaurus* from the Early Jurassic (Hettangian–Sinemurian) of central England, Zoological Journal of the Linnean Society, , zlaa054, https://doi.org/10.1093/zoolinnean/zlaa054

Galton, P.M., 1985. Notes on the Melanorosauridae, a family of large prosauropod dinosaurs (Saurischia: Sauropodomorpha). Géobios 18, 671-676.

Galton, P.M., 2005. Bones of large dinosaurs (Prosauropoda and Stegosauria) from the Rhaetic Bone Bed (Upper Triassic of Aust Cliff, southwest England. Revue de Paléobiologie 24, 51-74.

Galton, P.M., Yates, A.M., Kermack, D., 2007. *Pantydraco* n. gen. for *Thecodontosaurus caducus* Yates, 2003, a basal sauropodomorph dinosaur from the Upper Triassic or Lower Jurassic of South Wales. Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen 243, 119-125.

Haubold, H., 1990. Ein neuer Dinosaurier (Ornithischia, Thyreophora) aus dem Unteren Jura des nördlichen Mitteleuropa. Revue de Paleobiologie 9, 149-177.

Higgs, K.T., Beese, A.P., 1986. A Jurassic microflora from the Colbond Clay of Cloyne, County Cork. Irish Journal of Earth Sciences 7, 99-109.

Higgs, K.T., Jones, G.Ll., 2000. Palynological evidence for Mesozoic karst at Piltown, Co. Kilkenny. Proceedings of the Geologists' Association 111, 355-362.

von Hillebrandt, A., Krystyn, L., Kürschner, W.M., Bonis, N.R., Ruhl, M., Richoz, S., Schobben, M.A.N., Urlichs, M., Bown, P.R., Kment, K., McRoberts, C.A., Simms, M., Tomãsových, A., 2013. The Global Stratotype Sections and Point (GSSP) for the base of the Jurassic System at Kuhjoch (Karwendel Mountains, Northern Calcareous Alps, Tyrol, Austria). Episodes 36, 162-198.

Hodges, P., in press. A new ammonite from the Penarth Group of south Wales, and the base of the Jurassic System in south-west Britain. Geological Magazine.

Houssaye, A., Scheyer, T.M., Kolb, C., Fischer, V., Sander, P.M., 2014. A new look at ichthyosaur long bone microanatomy and histology: Implications for their adaptation to an aquatic life. Plos One 4. https://doi.org/10.1371/journal.pone.0095637

Hübner, T.R., 2012. Bone histology in *Dysalotosaurus lettowvorbecki* (Ornithischia: Iguanodontia) – Variation, growth, and implications. PLoS ONE 7 (1), e29958. doi:10.1371/journal.pone.0029958

von Huene, F., 1932. Die fossile Reptil-Ordnung Saurischia, ihre Entwicklung und Geschichte. Monographien zur Geologie und Palaeontologie, Serie 1, 1–361.

Hutt, S., Martill, D.M., Barker, M.J., 1996. The first European allosauroid dinosaur (Lower Cretaceous, Wealden Group, England). Neues Jahrbuch für Geologie und Paläontologie Monatshefte,1996, 635-644.

Ibrahim, N., Sereno, P.C., Dal Sasso, C., Maganuco, S., Fabbri, M., Martill, D.M., Zouhri, S., Myhrvold, N., Iurino, D.A., 2014. Semiaquatic adaptations in a giant predatory dinosaur. Science 345, 1613-1616.

Köhler, M., Marín-Moratalla, N., Jordana, X., Aanes, R., 2012. Seasonal bone growth and physiology in endotherms shed light on dinosaur physiology. Nature 487(7407), 358-361.

de Lapparent, A.F., Zbyszewski, G. 1957. Les dinosauriens du Portugal, Mémoires des Services Géologiques du Portugal, nouvelle série 2, 1-63.

Liebe, L., Hurum, J.H. 2012. Gross internal structure and microstructure of plesiosaur limb bones from the Late Jurassic, central Spitsbergen. Norwegian Journal of Geology 92, 285-309.

Lomax, D.R., De la Salle, P., Massare, J.A., Gallois, R., 2018. A giant Late Triassic ichthyosaur from the UK and a reinterpretation of the Aust Cliff 'dinosaurian' bones. PLoS ONE 13(4): e0194742. https://doi.org/10.1371/journal.pone.0194742

Lucas, S.G., Heckert, A.B., 2001. Theropod dinosaurs and the Early Jurassic age of the Moenave Formation, Arizona-Utah, USA. Neues Jahrbuch für Geologie und Paläontologie Monatshefte 2001, 435-448.

Madsen, J.H., 1976. *Allosaurus fragilis*: A Revised Osteology. Utah Geological Survey Bulletin 109, 177 pp.

Madsen, J.H., Welles, S.P., 2000. *Ceratosaurus* (Dinosauria, Theropoda): a revised osteology. Utah Geological Survey, 89 pp.

Malafaia, E., Gasulla, J.M., Escaso, F., Narváez, I., Sanz, J.L., Ortega, F., 2018. New spinosaurid (Theropoda, Megalosauroidea) remains from the Arcillas de Morella Formation (upper Barremian) of Morella, Spain. Cretaceous Research 92, 174-183.

Marsh, O. 1877. Notice of new dinosaurian reptiles from the Jurassic formations. American Journal of Science (3) 14, 514-516.

Martill, D. M., Dawn, A., 1986. Fossil vertebrates from new exposures of the Westbury Formation (Upper Triassic) at Newark, Nottinghamshire. Mercian Geologist 10, 127-133.

Martill, D.M., Naish, D. (eds), 2001. Dinosaurs of the Isle of Wight. Palaeontological Association,Field Guides to Fossils Series no. 10, 433 pp.

Martill, D.M., Vidovic, S.U., Howells, C., Nudds, J.R., 2016. The Oldest Jurassic Dinosaur: A Basal Neotheropod from the Hettangian of Great Britain. PLoS ONE, 11 (1): e0145713. pmid:26789843

McPhee, B.W., Bonnan, M.F., Yates, A.M., Neveling, J., Choiniere, J.N., 2015. A new basal sauropod from the pre-Toarcian Jurassic of South Africa: evidence of niche-partioning at the sauropodomorph-sauropod boundary. Scientific Reports 5, 13-24.

Milroy, P., Wright, P.V, Simms, M.J., 2019. Dryland continental mudstones: deciphering environmental changes in problematic mudstones from the Upper Triassic (Carnian to Norian) Mercia Mudstone Group, south−west Britain. Sedimentology 66, 2557-2589.

Newton, E.T., 1899. On a megalosaurid jaw from the Rhaetic beds near Bridgend (Glamorganshire). Quarterly Journal of the Geological Society of London 55, 89-96.

Nicholl, C.S.C., Mannion, P.D., Barrett, P.M. 2018. Sauropod dinosaur remains from a new Early Jurassic locality in the Central Hight Atlas of Morocco. Acta Palaeontologica Polonica 63, 147-157.

Norman, D.B., Witmer, L.M., Weishampel, D.B., 2004. Basal thyreophora. In The Dinosauria: Second Edition (pp. 335-342). University of California Press.

Norman, D.B. 2019. *Scelidosaurus harrisonii* from the Early Jurassic of Dorset, England: postcranial skeleton. Zoological Journal of the Linnean Society XX, 1-111.

O'Connor, P.M., 2007. The postcranial axial skeleton of *Majungasaurus crenatissimus* (Theropoda: Abelisauridae) from the Late Cretaceous of Madagascar. Journal of Vertebrate Paleontology 27, 127-163.

Owen, R., 1849-1884. A History of British Fossil Reptiles. Cassell, London. 657 and 199 pp, 2 vols plates.

Owen, R., 1861. A monograph of a fossil dinosaur (*Scelidosaurus harrisonii*, Owen) of the Lower Lias, part I. Monographs on the British fossil Reptilia from the Oolitic Formations 1 pp 14 dePolo, P.E., Brusatte, S.L., Challands, T.J., Foffa, D., Ross, D.A., Wilkinson, M., Yi, H-y., 2018. A sauropod-dominated tracksite from Rubha nam Brathairean (Brothers' Point), Isle of Skye, Scotland. Scottish Journal of Geology 54, 1-12.

Rauhut, O.W., 2005. Osteology and relationships of a new theropod dinosaur from the Middle Jurassic of Patagonia. Palaeontology 48, 87-110.

Redelstorff, R., Hübner, T.R., Chinsamy, A., Sander, P.M., 2013. Bone histology of the stegosaur *Kentrosaurus aethiopicus* (Ornithischia: Thyreophora) from the Upper Jurassic of Tanzania. The Anatomical Record 29, 933-952.

Reid, R.E.H., 1984. Primary bone and dinosaurian physiology. Geological Magazine 121, 589-598.

Riley, H., Stutchbury, S., 1836. A description of various fossil remains of three distinct saurian animals discovered in the autumn of 1834, in the Magnesian Conglomerate on Durdham Down, near Bristol. Proceedings of the Geological Society of London 2, 397–399.

Rosenbaum, J.N., Padian, K., 2000. New material of the basal thyreophoran *Scutellosaurus lawleri* from the Kayenta Formation (Lower Jurassic) of Arizona. PaleoBios 20, 13-23.

Ruhl, M., Kurschner, W.M., Krystyn, L. 2009. Triassic-Jurassic organic carbon isotope stratigraphy of key sections in the western Tethys realm (Austria). Earth and Planetary Science Letters 281, 169-187.

Sadleir R.W., Barrett P.M., Powell H.P., 2008. The anatomy and systematics of *Eustreptospondylus oxoniensis*, a theropod dinosaur from the Middle Jurassic of Oxfordshire, England. Palaeontographical Society Monographs 160, 1–82.

Sereno, P.C., 2012. Taxonomy, morphology, masticatory function and phylogeny of heterodontosaurid dinosaurs. ZooKeys 226, 1.

Simms, M.J., 2009. The Permian and Mesozoic. Pp. 311-332 in C.H.Holland and I.S.Sanders (eds), The Geology of Ireland, 2nd Edition. Dunedin Academic Press, 568 pp.

Simms, M.J., Jeram, A.J., 2007. Waterloo Bay, Larne, Northern Ireland: A candidate

Global Stratotype Sectio and Point for the base of the Hettangian Stage and Jurassic System. ISJS Newsletter 34, 50-68.

Smith, N.D., Makovicky, P.J., Hammer, W.R., Currie, P.J., 2007. Osteology of *Cryolophosaurus ellioti* (Dinosauria: Theropoda) from the Early Jurassic of Antarctica and implications for early theropod evolution. Zoological Journal of the Linean Society 151, 377-421.

Spielmann, J.A., Lucas, S.G., Rinehart, L.F., Hunt, A.P., Heckert, A.B., Sullivan, R.M., 2007. Oldest records of the Late Triassic theropod dinosaur *Coelophysis bauri*. New Mexico Museum of Natural History and Science Bulletin, 41, 384-401.

Storrs, G.W., 1994. Fossil vertebrate faunas of the British Rhaetian (Latest Triassic). Zoological Journal of the Linnean Society 112, 217-259.

Stumpf, S., Ansorge, J., Krempien, W., 2015. Gravisaurian sauropod remains from the marine late Early Jurassic (lower Toarcian) of North Eastern Germany. Geobios 48, 271-279.

Walsh, P.T., 1966. Cretaceous outliers in south-west Ireland and their implications for Cretaceous palaeogeography. Quarterly Journal of the Geological Society London 122, 63-84.

Warrington, G. Ivimey-Cook, H.C., Cope, J.C.W., 1994. St Audrie's Bay, Somerset, England: a candidate Global Stratotype Section and Point for the base of the Jurassic system. Geological Magazine 131, 191-200.

Warrington, G. Ivimey-Cook, H.C., Cope, J.C.W. 2008. The St Audrie's Bay – Doniford Bay section, Somerset, England: updated proposal for a candidate Global Stratotype Section and Point for the base of the Hettangian Stage and of the Jurassic System. ISJS Newsletter 35, 1-66.

Welles, S.P., 1984. *Dilophosaurus wetherilli* (Dinosauria, Theropoda). Osteology and comparisons. Palaeontographica. Abteilung A, Paläozoologie, Stratigraphie 185, 85-180.

Whiteside, D.I., Duffin, C.J., Gill, P.G., Marshall, J.E.A., Benton, M.J., 2016. The Late Triassic and Eartly Jurassic fissure faunas from Bristol and South Wales. Palaeontologica Polonica 67, 257-287.

Whyte, M.A., Romano, M., Watts, W., 2010. Yorkshire dinosaurs: A history in two parts. Geological Society of London Special Publications 343, 189-207.

Wild, R., 1978. Ein Sauropoden-Rest (Reptilia, Saurischia) aus dem Posidonienschiefer (Lias, Toarcium) von Holzmaden [A new sauropod (Reptilia, Saurischia) from the Posidonienschiefer (Lias, Toarcian) of Holzmaden]. Stuttgarter Beiträge zur Naturkunde, Serie B (Geologie und Paläontologie) 41, 1-15.

Woodward, H.B., 1908. Note on a Megalosaurian tibia from the Lower Lias of Wilmcote, Warwickshire. Annals and Magazine of Natural History, series 8, 1, 257-259.

Yates, A.M., 2003. A new species of the primitive dinosaur *Thecodontosaurus* (Saurischia: Sauropodomorpha) and its implications for the systematics of early dinosurs. Journal of Systematic Palaeontology 1, 1-42.

Young, C.M.E., Hendrickx, C., Challands, T.J., Foffa, D. Ross, D.A., Butler, I.B., Brusatte, S.L., 2018. New theropod dinosaur teeth from the Middle Jurassic of the Isle of Skye, Scotland. Scottish Journal of Geology 55, 7-19.

Figures

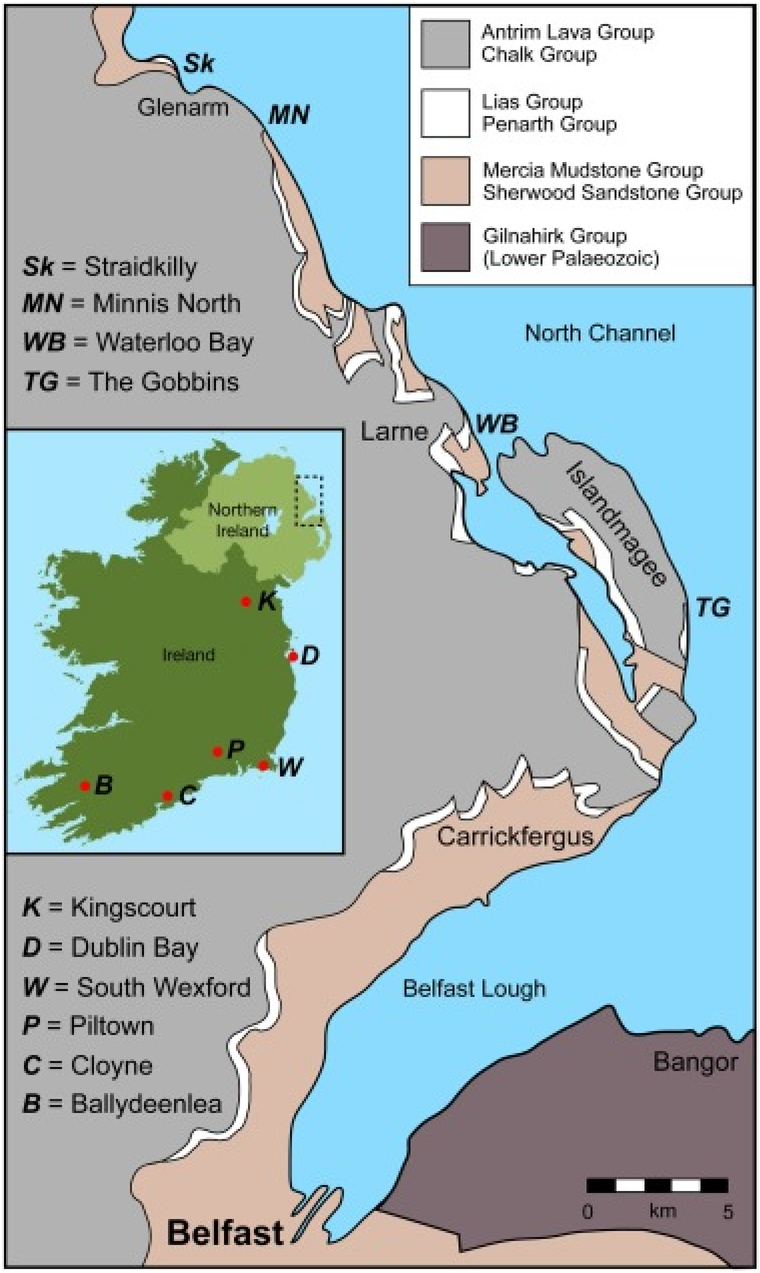

Fig. 1. Map of eastern Co. Antrim, with generalised geology, for locations mentioned in the text. MN = Minnis North; Sk = Straidkilly; TG = The Gobbins; WB = Waterloo Bay. Inset: map of Northern Ireland showing location of area covered by geology map.

CRETACEOUS	**Chalk Group**	Maastrichtian to Santonian	Ulster White Limestone Formation	
		Santonian to Cenomanian	Hibernian Greensands Formation	
	unconformity			
JURASSIC	**Lias Group**	Sinemurian	Waterloo Mudstone Formation	Bucklandi Zone
		Hettangian		Angulata Zone
				Liasicus Zone
				Planorbis Zone
				'Pre-planorbis beds'
TRIASSIC	**Penarth Group**	Rhaetian	Lilstock Formation	
			Westbury Formation	
	Mercia Mudstone Group	Norian to Ladinian	Colin Glen Formation	
			undivided	
	Sherwood Sandstone Group	Ladinian to Scythian	undivided	

Fig. 2. Generalised litho- and chronostratigraphy for the succession exposed on the east Antrim coast.

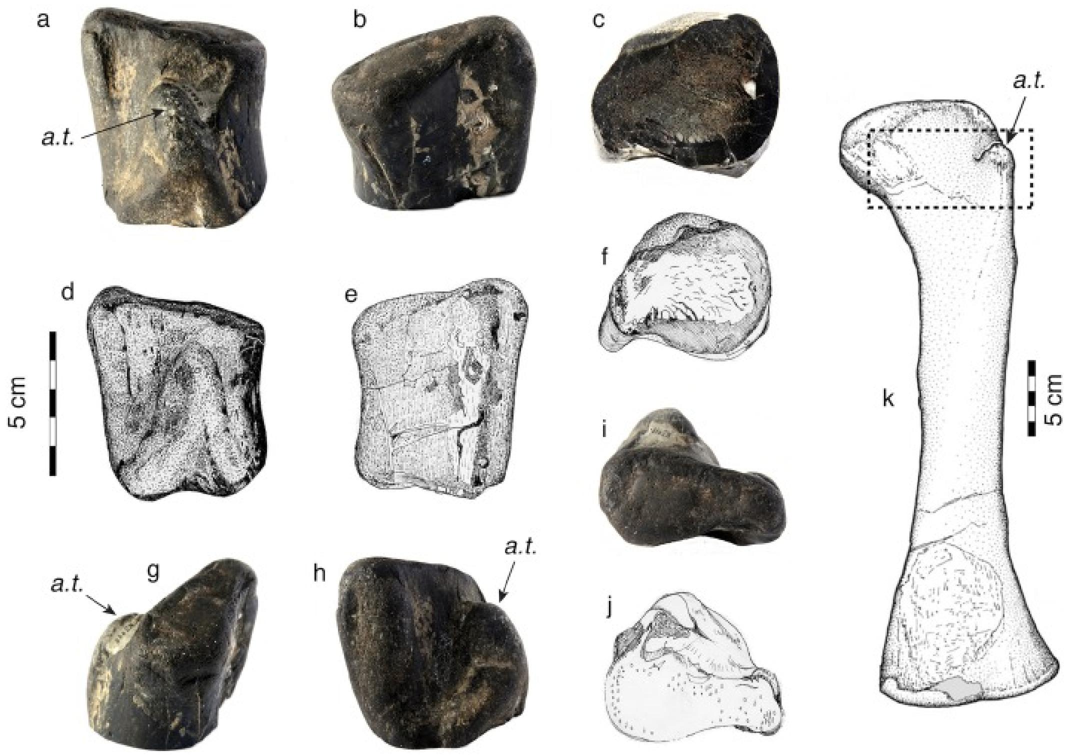

Fig. 3. Proximal fragment of left femur of thyreophoran ornithischian, cf. *Scelidosaurus*, BELUM K3998, from The Gobbins, Co. Antrim . Figures d-f, j drawn by Roger Byrne. a.t. = anterior trochanter.

a, d. Anterolateral view showing worn but conspicuous anterior trochanter at centre.

b, e. Posterior view

c, f. Sectioned surface of distal end with dense outer bones surrounding coarse trabecular bone.

g. Lateral view, with anterior trochanter on left hand side, below accession number.

h. Medial view, with anterior trochanter conspicuous on right hand side.

i, j. Worn proximal end viewed from above.

k. Anterior view of left femur of *Scelidosaurus harrisoni* lectotype (NHMUK R1111), with section represented by K3998 outlined (from Norman 2019, fig. 78).

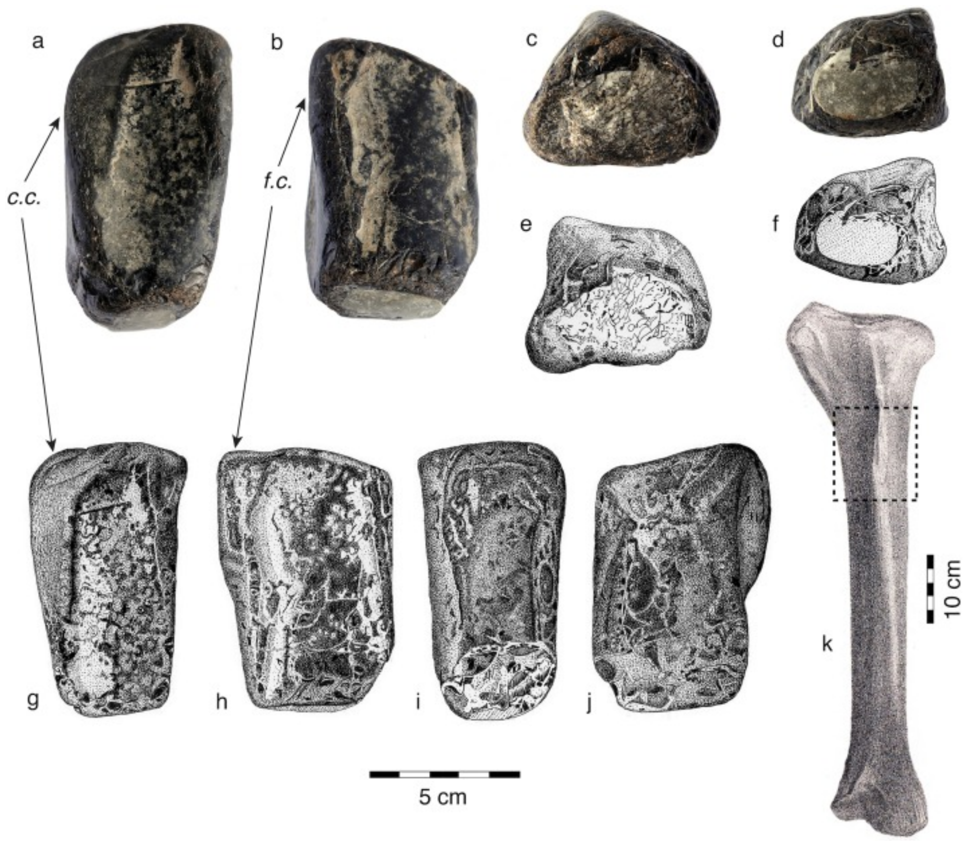

Fig. 4. Proximal fragment of left tibia of indeterminate neotheropod or megalosauroid theropod, BELUM K12493, from The Gobbins, Co. Antrim. Figures e-h, k, l drawn by Roger Byrne. c.c. = cnemial crest; f.c. = fibular crest.

a, e. Lateral view showing worn cnemial crest at upper left.

b, f. Posterior view, showing smooth outer surface of dense bone (cf. Fig 5a, e).

c, k. Proximal end of shaft showing dense outer layer of bone and cavity filled with coarse trabecular bone.

d, l. Distal end of shaft showing medullary cavity infilled with grey micritic limestone and with spalled bone fragments in upper part.

g. Medial view.

h. Anterior view.

i, j. Left tibia of *Megalosaurus bucklandi* with section represented by K12493 outlined (inverted figure of right tibia from Owen 1849-84, Pl. 31).

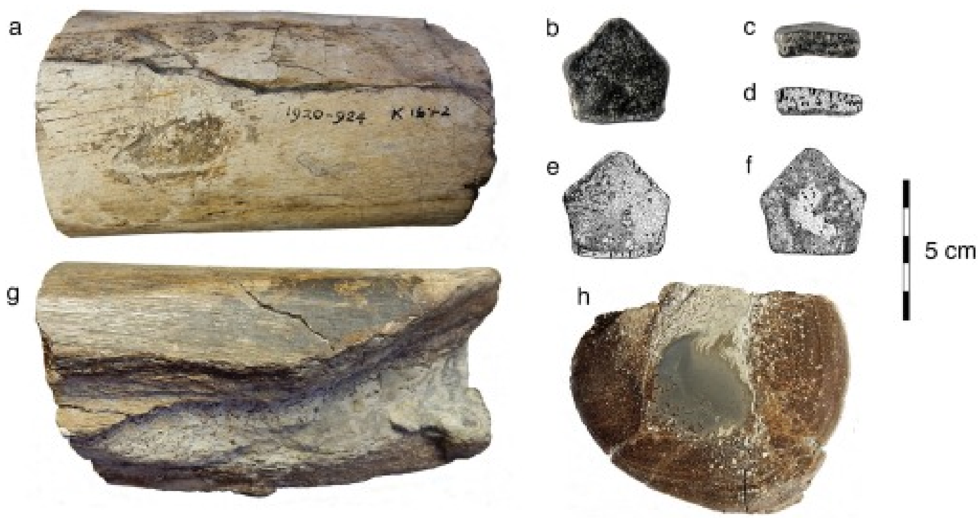

Fig. 5. Objects misinterpreted as of dinosaurian origin, from Glenarm and The Gobbins. Figures d-f drawn by Roger Byrne.

a. 'Outer' lateral view of BELUM K1642, possibly a fragment of ichthyosaur surangular bone, showing striated bone surface.

b-f. Polygonal 'scelidosaur osteoderm' from The Gobbins (BELUM K2015.1.54), reinterpreted as a fragment of basalt.

g. 'Inner' lateral view of BELUM K1642 showing striated outer surface and coarse trabecular bone in interior.

h. Sectioned end of BELUM K1642 showing outer layer of bone with more conspicuous porosity and LAGs than is typical of dinosaur bones (cf. K3998 and K12493, figs 3c and 4c), partial fill of cavity with coarse trabecular bone, and with circumference interrupted by anomalous zone of coarse trabecular bone. Enlarged x1.5 relative to scale.