

The first Lower Jurassic dinosaur from Scotland: limb bone of a ceratosaur theropod from Skye

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Synopsis

A partial right tibia of a carnivorous dinosaur is reported from the Lower Jurassic Broadford Beds Formation of southern Strath, Skye. The bone consists of the proximal end and shaft of a tibia, and this shows characteristic features of the ceratosaur theropods, a group of medium-sized predatory dinosaurs that were widespread during the Early Jurassic. This tibia, and a partial sauropod tibia from the Middle Jurassic of Skye, represent the first clear records of dinosaur body fossils from Scotland.



Introduction

Dinosaur remains are not abundant in Scotland. Indeed, current records of Scottish dinosaurs are restricted to rather equivocal remains. The single skeleton of *Saltopus elginensis* Huene 1910 from the Late Triassic Lossiemouth Sandstone Formation of the area of Elgin, Morayshire has been interpreted as a theropod dinosaur, and possibly a ceratosaur (Huene 1910; Benton and Walker 1985), but the

identification is uncertain since the specimen lacks clearly preserved diagnostic elements (Norman 1990). Further evidence of dinosaurs in the Middle Jurassic has been based on a single large natural cast of a three-toed footprint, probably of a theropod, from the Lonfearn Member of the Lealt Shale Formation of Trotternish, Skye (Fig. 1; Andrews and Hudson 1984).

The specimen reported here is the first dinosaur from the Early Jurassic of Scotland. The identification is based on a single bone, but the specimen shows diagnostic features that determine its identity. The specimen is important in extending the faunal list of Jurassic vertebrates from Scotland, and in providing evidence for a dinosaur from the Early Jurassic, an episode for which records of the group are sparse worldwide.

Soon after the National Museums of Scotland acquired the present specimen, a second, much larger, dinosaur bone was found on Skye, this time a sauropod limb bone referred to *Cetiosaurus*, from the Middle Jurassic (Bathonian) Valtos Sandstone Formation (Fig. 1) from near Valtos, Isle of Skye (Clark *et al.* 1995). Both specimens were publicly announced in January, 1995, as the first Scottish dinosaurs.

Repository abbreviation: NMS, National Museums of Scotland, Chambers Street, Edinburgh EH1 1JF.

Geology

The specimen (NMS.G.1994.10.1) was collected in 1992 from the Broadford Beds Formation by Herr Matthias Metz. The bone was first identified by Dr Rupert Wild of the Staatliches Museum für Naturkunde, Stuttgart, and donated to the National Museums of Scotland with the consent of the landowner, Sir Iain Noble of Fearann Eilean Iarmain. The specimen was collected in southern Strath, on the Isle of Skye (precise locality data are retained in the Geology Department, National Museums of Scotland).

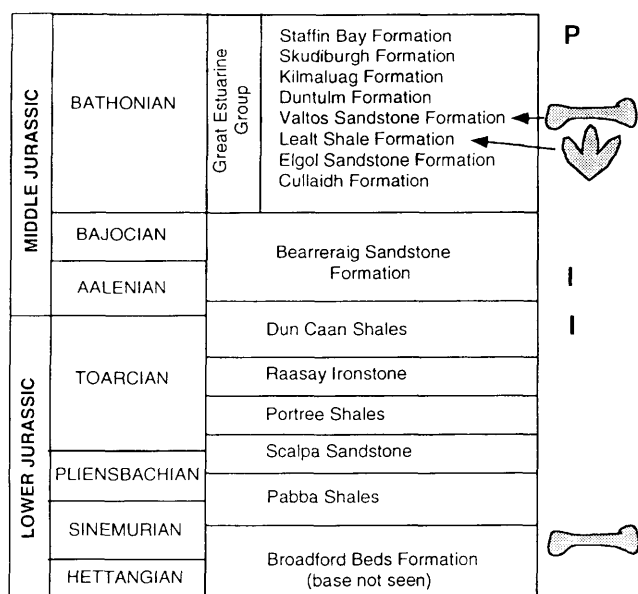


FIG. 1. Outline stratigraphy of the Lower and Middle Jurassic of southern Skye, with horizons of the new dinosaur bones and the dinosaur footprint (Andrews and Hudson 1984) indicated. Marine reptile remains have also been found in this succession, plesiosaurs (P) and ichthyosaurs (I), to be described by Martill (in prep.). Stratigraphy based on Cope *et al.* (1980a, b) and Morton (1989).

The bone was retrieved from a boulder in a stream section in which blocks of muddy limestone rich in *Gryphaea* occur. The specimen was not in a *Gryphaea*-rich block, but from muddy siltstones. Such lithologies both overlie and underlie the *Gryphaea* beds in this region. As the blocks in the stream section are relatively large, and the stream is small, it is assumed that they have not travelled far from the outcrop (and had probably just dropped a vertical distance of one or two metres), and thus all are characteristic lithologies of the *Gryphaea*-bearing part of the succession.

The rocks of this region are the Broadford Beds Formation (Fig. 1; Hallam 1959; Morton 1989), and they comprise a suite of limestones, sandy limestones, and silty mudstones of Early Jurassic age. The Broadford Beds Formation varies in thickness from 50 to 150 m. The base of the formation is late Hettangian in age, but most of it is early Sinemurian (Oates 1978; Morton 1989). In most of the region the Broadford Beds Formation rests with a minor non-sequence on probable Triassic sandstones and conglomerates of terrestrial and fluvial origin, but in the west of the region with marked unconformity on Cambro-Ordovician Durness Limestone. The Broadford Beds Formation here has been intruded by numerous small

basaltic sills and dykes and larger intrusions of felsite, of Palaeogene age.

The maximum thickness recorded for the Broadford Beds Formation here is approximately 150 m, although the base is not seen. The oldest parts of the sequence lie within the *A. bucklandi* Zone and pass up as high as the *A. obtusum* Zone. An ammonite collected from the *Gryphaea* beds of the locality given by the collector of the dinosaur specimen is suggestive of the *A. semicostatum* Zone. Thus the new specimen comes from the Sinemurian (Lower Jurassic), and presumably the Upper Broadford Beds Formation (Cope *et al.* 1980a).

The specimen

Description

The specimen is a right tibia that lacks the distal end. The periosteum is extensive over the anterior face of the bone (Fig. 2a), but it has been largely stripped off the posterior face of the bone (Fig. 2c), and partly off the posteromedial face (Fig. 2d). The medial angle of the proximal expansion of the bone is broken off (br, Fig. 2).

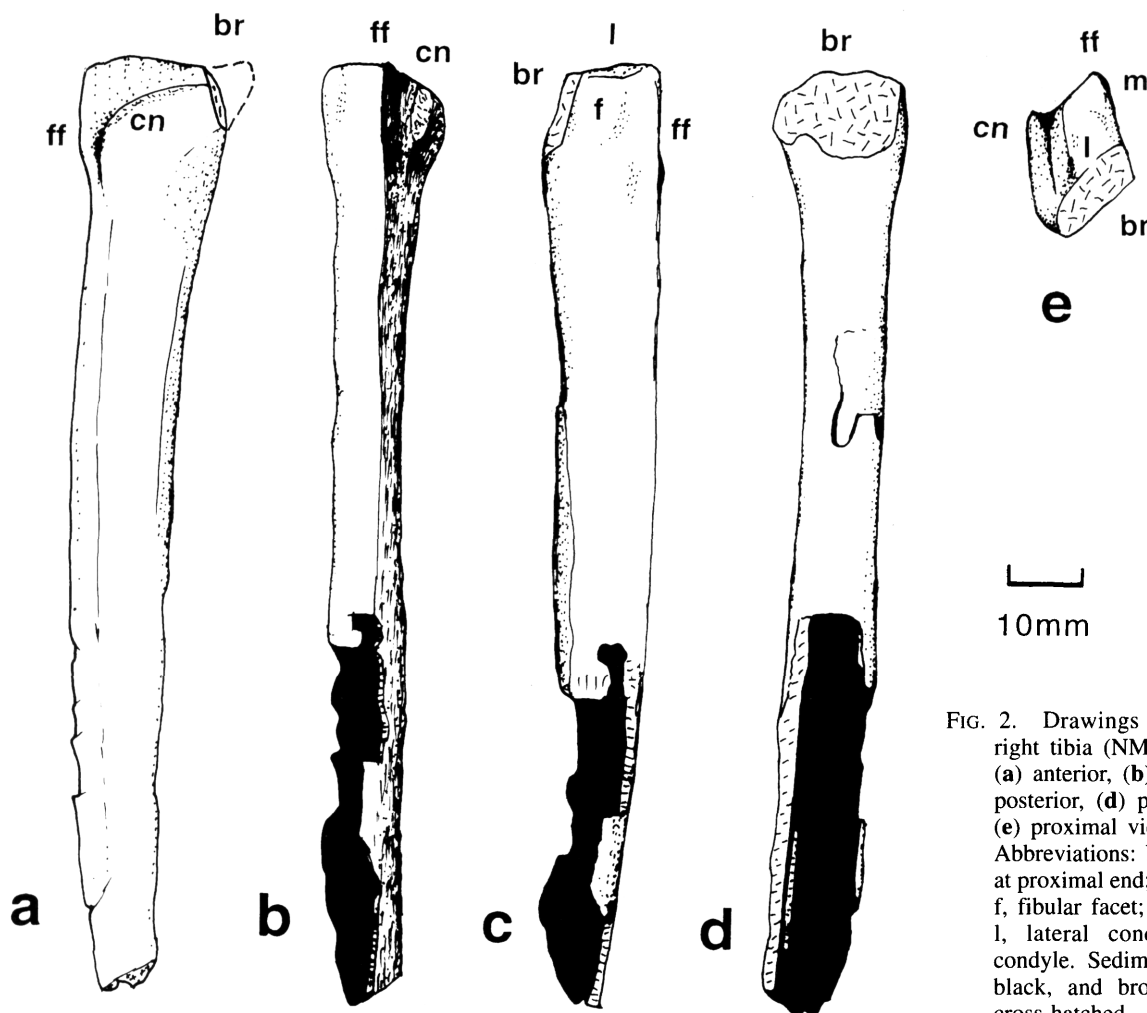


FIG. 2. Drawings of the theropod right tibia (NMS.G.1994.10.1) in (a) anterior, (b) anterolateral, (c) posterior, (d) posteromedial, and (e) proximal views. Natural size. Abbreviations: br, broken portion at proximal end; cn, cnemial crest; f, fibular facet; ff, fibular flange; l, lateral condyle; m, medial condyle. Sediment fill is shaded black, and broken surfaces are cross-hatched.

Bone material has been lost distally from the posterior, medial, and lateral sides of the bone (Fig. 2b–d), exposing the hollow central portion. In the distal portion of the element, the bone material forms a layer 2 mm thick around the hollow central cavity, which is about 9 mm in diameter. The specimen is 127 mm long, but its original total length cannot be estimated since the distal portion is damaged, and there is no sign of the distal expansion.

The proximal end of the tibia is 20 mm wide in anterior view (Fig. 2a), but might originally have measured 25 mm if the missing medial angle were restored. The anterior face of the proximal end bears a prominent projecting cnemial crest (cn, Fig. 2). The proximal face of the cnemial crest bears an ovoid region of rugose sculpture, marking the attachment site for the iliotibialis muscle.

On the lateral side (Fig. 2b), a sharp-edged process projects, and this sharp edge appears to extend 75 mm or more down the shaft, but the distal parts mark the margin of stripped-off periosteum on the posterior face. The proximal part of this sharp-edged face is probably the fibular flange (ff, Fig. 2) which, in a complete ceratosaur tibia, extended as a low anterolateral crest. In life, the proximal end of the fibula rested behind the proximal end of the tibia, extending over the posterior face of the fibular flange (ff, Fig. 2c) and lodging its medial portion in a slight fibular depression on the posterior face of the proximal end of the tibia (f, Fig. 2c).

The proximal articular end (Fig. 2e) is incomplete, but it shows that there were two condyles for articulation with the paired distal condyles of the femur. The lateral condyle (l, Fig. 2c, e) is complete, but only the lateral portion of the medial condyle (m, Fig. 2e) is present. The two condyles are separated by a slightly elevated ridge of bone.

Identification

The specimen (Figs. 2 and 3) is identified as the right tibia of a ceratosaur theropod on the basis of the nature of the cnemial crest, the evidence for two condyles on the proximal end to meet the two condyles of the distal end of the femur, the evidence for a close fit of the fibula against a sharp crest-like process, and the hollow core of the bone.

The 'prominent cnemial crest' may characterise the Ornithosuchia, a clade containing dinosaurs, birds, pterosaurs, and some Triassic forms (Benton and Clark 1988; Benton 1990), or it may be restricted simply to Dinosauria (Gauthier 1986; Sereno *et al.* 1993), depending on how the character is defined. The presence of two subterminal condyles at the distal end of the femur defines the Ornithodira, the clade containing dinosaurs, birds, pterosaurs, and *Lagosuchus* (Benton and Clark 1988; Benton 1990). Within the clade Saurischia, which is part of the larger clade Dinosauria, the clade Theropoda is characterized by the 'fibula closely appressed to tibia and

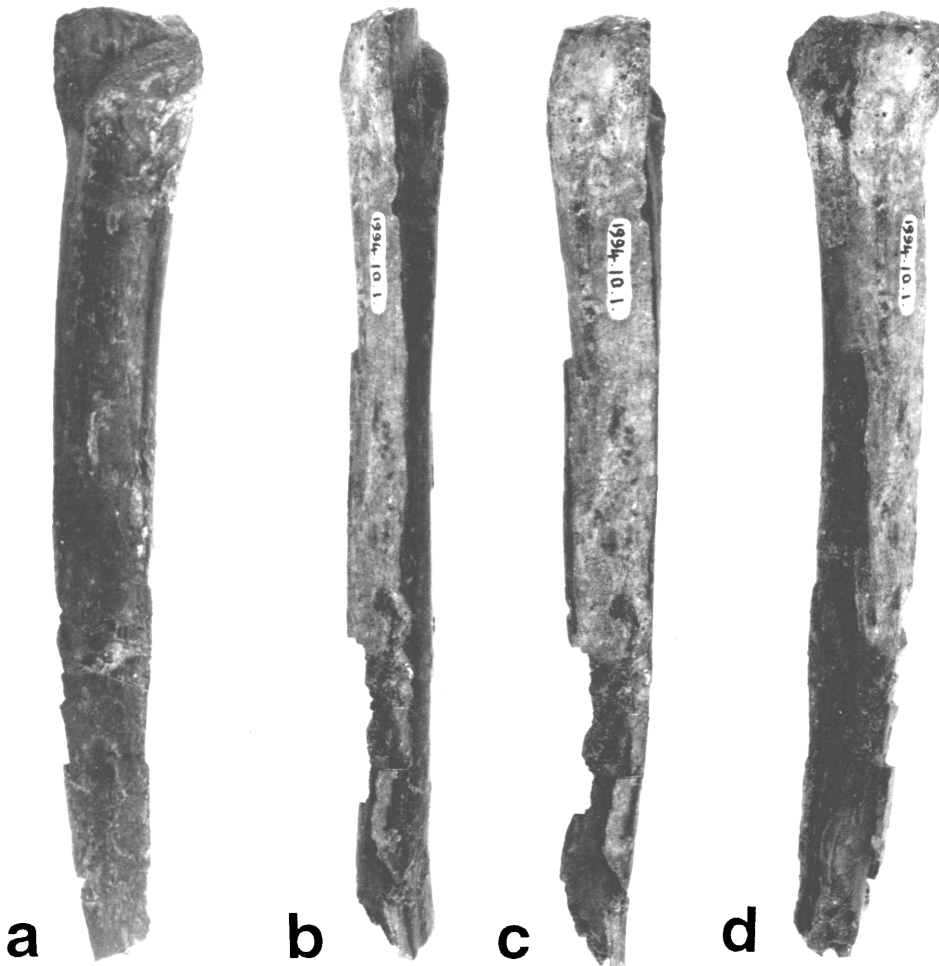


FIG. 3. Photographs of the theropod right tibia (NMS.G.1994.10.1) in (a) anterior, (b) anterolateral, (c) posterior, and (d) posteromedial views. Natural size.

attached to a tibial crest' and by 'thin-walled, hollow, long bones' (Gauthier 1986).

The main group of theropods that spanned the Early Jurassic time interval were the ceratosaurs, a clade of small-to large-sized theropods that are diagnosed by characters of the vertebrae, pelvis, femur, ankle, and foot (Rowe and Gauthier 1990). There is no peculiarly ceratosaur character of the tibia, and hence the present specimen cannot be identified conclusively as ceratosaurian. However, it resembles the tibia of known ceratosaurs, and it differs from the tibia of other Jurassic theropod groups, such as carnosaurs and ornithomimosaurs.

Discussion

Comparison

The present specimen resembles closely the tibia of all ceratosaur dinosaurs where that element is known (e.g. Rowe and Gauthier 1990, fig. 5.9). *Dilophosaurus*, a 6 m-long ceratosaur from the Early Jurassic (?Sinemurian–Pliensbachian) of Arizona, USA, has a tibia of similar shape (Welles 1984, fig. 33) that is over 0.5 m long, some three to four times the size of the Scottish animal. The present specimen is more similar in size to the tibia of *Coelophysis* (Colbert 1989, figs. 81, 82), a 1.5 m-long ceratosaur from the Late Triassic of New Mexico and Arizona, USA. This form has a similar straight tibia with a broad proximal end, prominent cnemial crest, and sharp fibular facet, and the tibial length ranges from 135 to 207 mm in juvenile to adult individuals. The tibia is not preserved, or not figured, for other ceratosaurs.

Ceratosaurs are known from several Early Jurassic examples (Rowe and Gauthier 1990; Cuny and Galton 1993): *Liliensternus airelensis* Cuny and Galton, 1993, Moon-Airel Formation of Normandy, France (?basal Hettangian), *Syntarsus rhodesiensis* Raath, 1969 from the Forest Sandstone of Zimbabwe and the Upper Elliot Formation of South Africa (?Hettangian–Sinemurian), *Sarcosaurus woodi* Andrews, 1921, from the Lias of Leicestershire, England (?Hettangian), *Dilophosaurus wetherilli* Welles, 1970 and *Syntarsus kayentakatae* Rowe, 1989 from the Kayenta Formation of Arizona, USA (?Sinemurian–Pliensbachian), and *Segisaurus halli* Camp, 1936 from the Navajo Sandstone of Arizona, USA (?Sinemurian–Pliensbachian).

Carnosaurs spanned the Early Jurassic. The earliest example is a natural mould of a left dentary from the Rhaetic of South Wales, ascribed to '*Megalosaurus*' *cambrensis* (originally called *Zanclodon cambrensis* by Newton 1899). Molnar *et al.* (1990, p. 203) regard the attribution to *Megalosaurus* as possible, but the material is so limited that this cannot be confirmed. One possible carnosaur from the Early Jurassic is some limb elements of a 'megalosaur' from the Lias of Lyme Regis (see below), but the group is known with confidence only from the Mid Jurassic onwards, when true *Megalosaurus* is represented by abundant specimens from England and France (Molnar *et al.* 1990). Carnosaur tibias are much larger than is the new specimen from Skye. The proximal head is wide and

robust, and the cnemial crest generally rises as a distinct process that is separate from the main body of the tibia. The only Jurassic ornithomimosaur, *Elaphrosaurus*, from the Tendaguru Beds of Tanzania (Kimmeridgian), has quite a different tibia, with a more expanded proximal end, and a cnemial crest that projects above the proximal articular face of the bone (Janensch 1925).

The fossil record of dinosaurs during the Early Jurassic is generally poor (Weishampel 1990). Skeletal fossils are rare in rocks of this age, consisting of fewer than ten specimens of ceratosaurs and prosauropods from North America, small dinosaurian faunas from India and China (prosauropods, ?sauropod, ?carnosaur, thyreophoran, ornithopod), assemblages of ceratosaurs, prosauropods, and ornithopods from several localities in southern Africa, and fragmentary materials of ceratosaurs, thyreophorans, and a ?sauropod from four or five locations in England, France, and Germany (see below).

Dinosaurs in ammonite-bearing marine beds

Broadford Beds Formation rocks are entirely marine, shallow shelf deposits. In places, the *Gryphaea* specimens are articulated valves in life position, but in the *Gryphaea* shell beds they are disarticulated, and often the lighter right valves are missing, suggesting removal by winnowing. The shoreline would not have been far away, perhaps less than 2 km, as evidenced by the onlap of the Broadford Beds Formation on to the unconformity surface (Morton 1989). Thus, it is not too surprising that dinosaur remains should occur in the Broadford Beds Formation.

Isolated remains of dinosaurs from marine Lower Jurassic sediments have been reported on a number of occasions. The English materials include Lower Lias (Hettangian–Sinemurian) remains: the pelvic bones and femur of the ceratosaur *Sarcosaurus* from Leicestershire (Andrews 1921), a bulky theropod ('megalosaur') tibia from Warwickshire (Woodward 1908), and a partial theropod ('megalosaur') hindlimb and several specimens of the thyreophoran *Scelidosaurus harrisonii* from Dorset (Owen 1861, 1863; Rixon 1968). A theropod femur was reported from the Upper Lias (Toarcian) of Whitby, Yorkshire, but this specimen has not been re-located (Benton and Taylor 1984). *Ohmdenosaurus*, based on a sauropod tibia and tarsus, has been reported from the marine Posidonienschiefer (Toarcian) of Baden-Württemberg by Wild (1978). A partial skeleton of the theropod *Liliensternus* was found in littoral deposits of Hettangian age in Normandy, France (Cuny and Galton 1993).

Dinosaur fossils are not uncommon in marine sediments (Buffetaut 1994). Considerable numbers are known from the classic Mid- to Late Jurassic marine beds of England. Martill (1988) noted eight genera of dinosaurs from the fully marine Oxford Clay Formation of central and southern England, and he pointed out the close proximity of land. Scattered dinosaur remains, consisting of isolated elements of theropods, sauropods, ornithopods, and stegosaurs, have been reported from dozens of localities in the south of England in Late Jurassic marine beds, including the Kimmeridge Clay and the Portland Beds (Benton and

Spencer 1995). Particularly famous is a partial skeleton of the ornithomimid *Camptosaurus prestwichii* from the Kimmeridge Clay of Cumnor, Oxfordshire (Galton and Powell 1980). A large part of the French dinosaur record, including specimens of Rhaetian, Early, Mid- and Late Jurassic, and Early, Mid- and Late Cretaceous age, have come from marine sediments, and the fossils include articulated as well as disarticulated remains (Buffetaut 1994). Usually, the specimens have been transported only a short distance offshore, but isolated elements can give no guidance to the proximity of land.

Dinosaurs in marine sediments may be explained in three ways. Firstly, they might represent the remains of carcasses that drifted out to sea from rivers where the animals had died. Secondly, they could indicate that marine predators had dragged dinosaurs into the sea to drown them, as crocodiles drag modern mammals into fresh waters.

Observations on modern terrestrial reptiles and mammals, as well as on large marine predators, suggest a third possibility. Perhaps some dinosaurs might have entered the sea to feed on plant food, and marine predators might have moved high on the shore in search of prey. The Marine iguana of the Galapagos islands is well adapted for feeding on marine plants, and the North Ronaldsay breed of sheep is an obligate seaweed-eater, failing to thrive and dying if fed on grass alone (Ryder 1983). Red deer paddle in the sea at Kilmory, Isle of Rum, feeding on intertidal marine algae, and they can spend 10–20% of their time on the shore (M.A.T., pers. obs.; Clutton-Brock *et al.* 1982). The killer whale, typically regarded as a fully marine predator, is known to beach itself regularly in its attempts to capture seals, sealions, and other animals on land (Lopez and Lopez 1985; Guinet 1991; Jefferson *et al.* 1991). Some of the Jurassic and Cretaceous dinosaur fossils in marine sediments might be animals that were dragged off the shoreline by beaching pliosaurs.

Other dinosaurs on Skye

Fossil reptiles have been reported from at least five localities on the isles of Skye and Eigg (Benton and Spencer 1995, pp. 131–34), but dinosaur remains are rare, despite a considerable outcrop of non-marine Jurassic strata. Arkell (1933, p. 317) listed dinosaur bones from the Great Estuarine Group of Skye, but did not cite an exact locality or a reference to the whereabouts of the specimen. Andrews and Hudson (1984) reported a dinosaur footprint from the Lonfearn Member of the Lealt Shale Formation of Trotternish, Skye, and Clark *et al.* (1995) note a sauropod tibial fragment from the Valtos Sandstone Formation of Valtos, Skye. Vertebrate remains from the Middle Jurassic of Skye and the Isle of Eigg are reasonably common in shelly lagoonal limestones, but all are isolated and usually represent the remains of resistant teeth, scales, and spines of fishes. On Eigg there is the notable occurrence of plesiosaur bones in the Hugh Miller Reptile Bed (Hudson 1966), but, somewhat surprisingly, dinosaur bones have yet to be recovered from these horizons.

The rarity of dinosaurs in marine beds explains the rarity of the group in the Early Jurassic of Europe, since

marine conditions prevailed. The new theropod tibia is important as one of the few Early Jurassic dinosaurs known from anywhere in the world, and as one of the first dinosaurs from Scotland. The new specimen adds to the slowly growing knowledge of fossil reptiles from Scotland, and it highlights the future potential of the Jurassic sediments of the Hebrides.

Acknowledgements

We thank Herr Matthias Metz for finding the specimen and for donating it to NMS, Dr. Rupert Wild for recognising its significance, and Sir Iain Noble and Fearann Eilean Iarmain (Isleornsay Estates) for enabling NMS to acquire it. We thank Dr. Neil Clark for information and discussion.

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Letter to the Editors

The Editors have received the following communication concerning a previously described example of Scottish Mesozoic vertebrate fauna.

Further note on 'A plesiosaur from the Linksfield erratic (Rhaetic, Upper Triassic) near Elgin, Morayshire' by M. A. Taylor and A. R. I. Cruickshank (*Scottish Journal of Geology* **29, 191–6, 1993).**

Taylor and Cruickshank described eight plesiosaur vertebrae collected by Charles Moore (Bath Geology Museum M198–M198G) as labelled 'Rhaetic of Elgin' and suggested that they came from Linksfield Quarry as the only significant Rhaetic exposure locally. This is now confirmed by the finding of an older label associated with the material, presumably a transcript of Moore's original label, specifically citing Linksfield.

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