

Review

# Review of the Dinosaur Remains from the Middle Jurassic of Scotland, UK

Neil D. L. Clark 

The Hunterian, University of Glasgow, University Avenue, Glasgow G12 8QQ, Scotland, UK;  
neil.clark@glasgow.ac.uk; Tel.: +44-141-330-4221

Received: 10 January 2018; Accepted: 29 January 2018; Published: 5 February 2018

**Abstract:** Dinosaurs are rare from the Middle Jurassic worldwide. The Isle of Skye, is the only place in Scotland thus far to have produced dinosaur remains. These remains consist mainly of footprints, but also several bones and teeth. These Bajocian and Bathonian remains represent an important collection of a basal eusauropod, early examples of non-neosauropod and possible basal titanosauriform eusauropods, and theropod remains that may belong to an early coelurosaur and a possible megalosaurid, basal tyrannosauroid, or dromaeosaurid. The footprints from here also suggest a rich and diverse dinosaur fauna for which further better diagnosable remains are likely to be found.

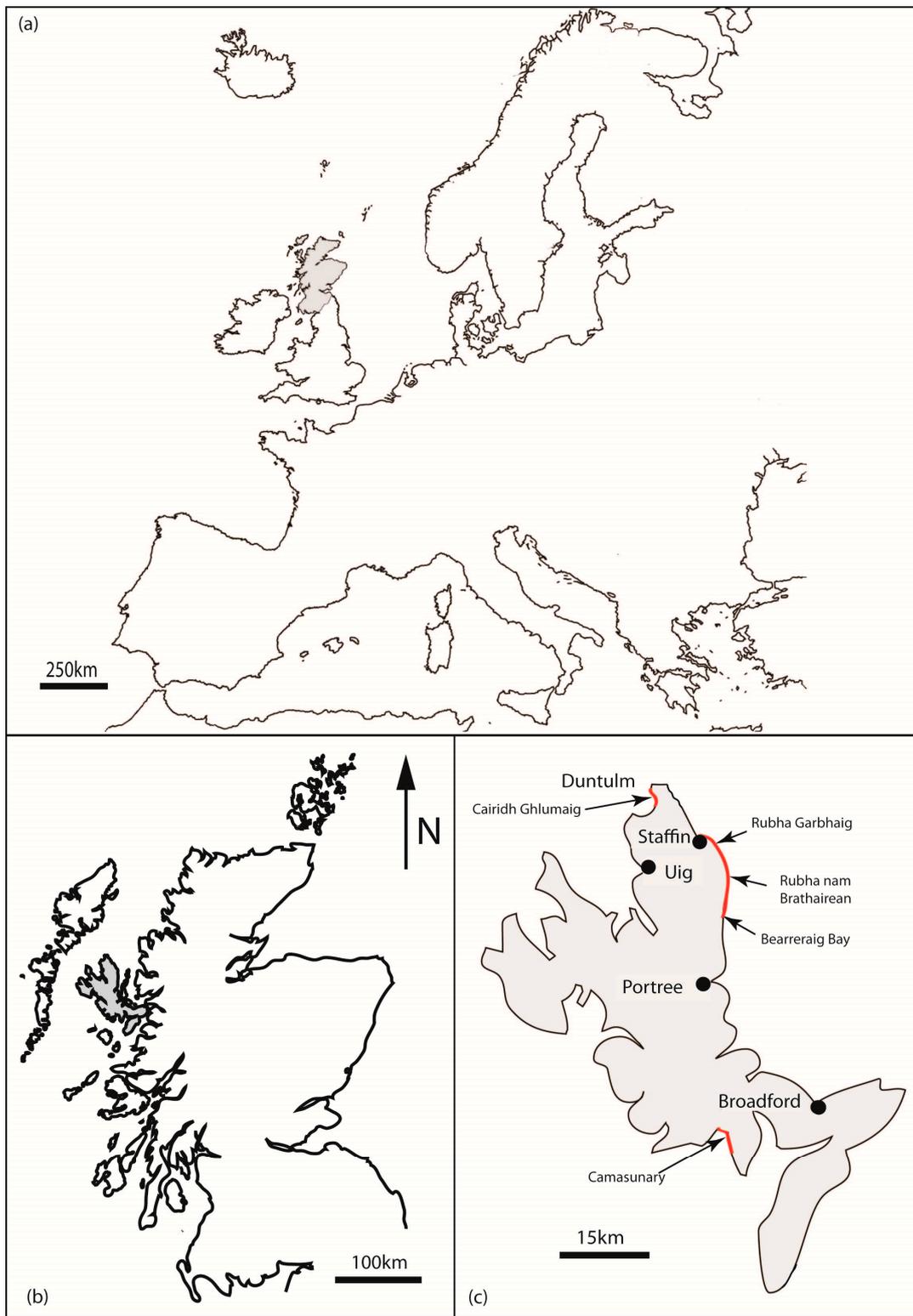
**Keywords:** sauropod; theropod; thyreophoran; Bathonian; Skye; Berreraig; Lealt; Valtos; Duntulm; Kilmaluag

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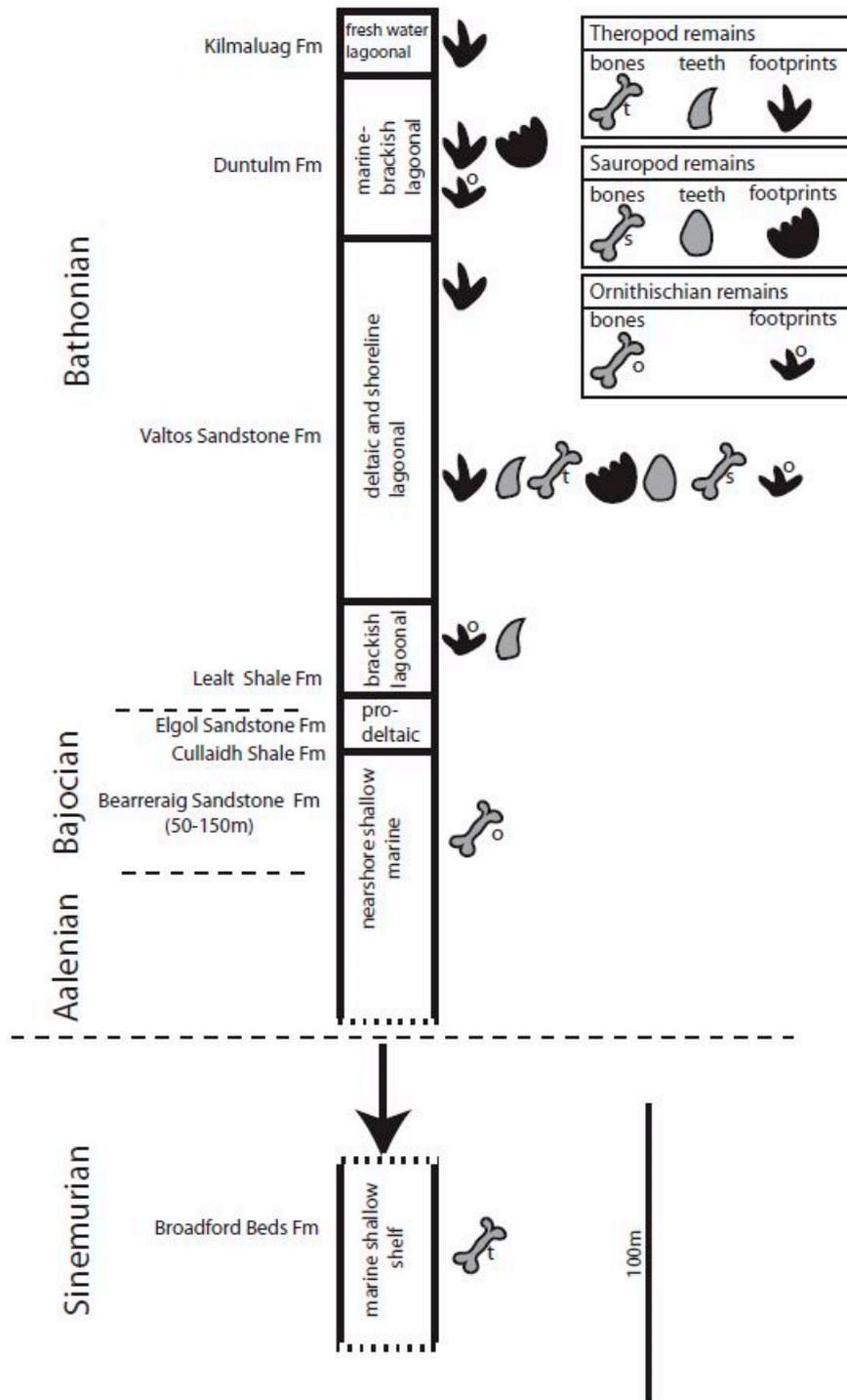
## 1. Introduction

A single footprint of a dinosaur was first found in the Middle Jurassic sediment on the Isle of Skye, Scotland in 1982 [1,2]. It took another ten years before any further discoveries were made. A small theropod tibia was found in Pliensbachian (Lower Jurassic) rocks in the Strathaird Peninsula in the south of the Isle of Skye [3] (NMS.G. 1994.10.1), and a larger sauropod limb bone in rocks of Bajocian-Bathonian (Middle Jurassic) in the Trotternish Peninsula of northern Isle of Skye (Figures 1 and 2) [4]. Since then, many more discoveries of bones and tracks have supplemented our knowledge of Middle Jurassic dinosaurs in Scotland [5–8] and provided an opportunity to study dinosaurs from a period from which there is a paucity of finds worldwide [9,10]. These discoveries could substantially further our understanding of dinosaur lineages at a critical point in the evolution of many of the better-known groups of dinosaurs [11,12].

Middle Jurassic dinosaurs are becoming better known from Scotland as more discoveries are made each year along the rocky shoreline of the Isle of Skye [1–17]. Studies of the track diversity from the Isle of Skye have shown that there are several different forms of tridactyl prints of varying sizes. From small theropod footprints (mostly between 6 and 30 cm in length) [5,7,8] to much larger theropod footprints (about 50 cm long) [6,8] as well as large supposed ornithopod footprints [1,2]. More recently there have been trackways and single footprints of sauropods demonstrating that there existed a diverse dinosaur fauna during the Middle Jurassic of north western Scotland [12,13]. The osteological remains also demonstrate a faunal diversity of at least two types of sauropods [4,14,15], two theropods [11] and a thyreophoran [16]. Unfortunately, none of the bones that have so far surfaced provide diagnostic characters that identify the bones and teeth to anything more precise than broad clades within taxonomic orders. They have certainly already provided clues on the early evolution of such clades, but future study and more detailed taxonomic character sets for the individual bones that have already been found may help to identify the remains more precisely.



**Figure 1.** (a) Map of Europe with the position of Scotland highlighted; (b) map of Scotland showing the location of the Isle of Skye and (c) known dinosaur-bearing localities.



**Figure 2.** Succession of Jurassic dinosaur-bearing formations on the Isle of Skye and their approximate age as well as types of dinosaur remains contained within each formation.

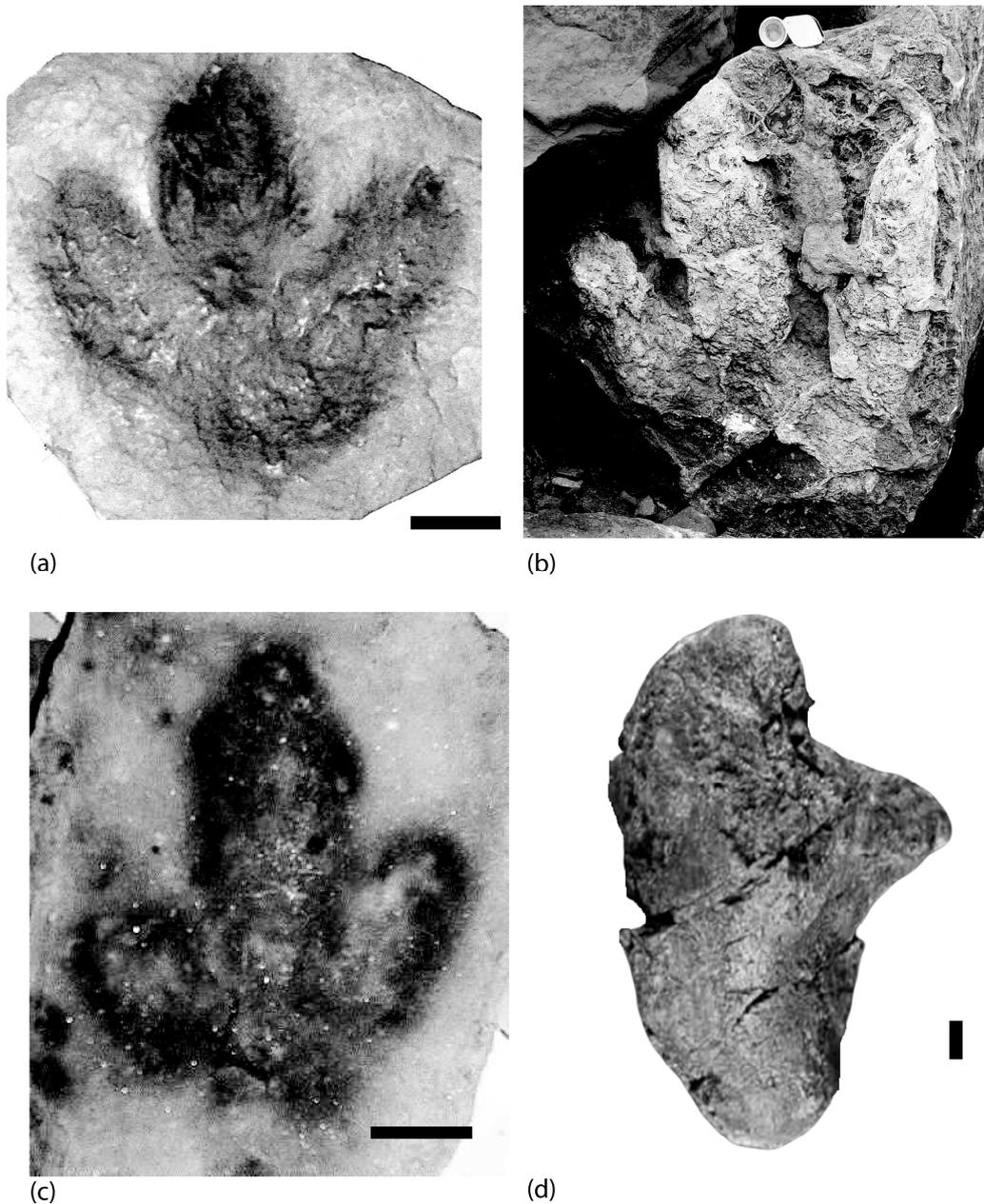
## 2. Materials and Methods

Much of the material mentioned here has been published on elsewhere and exists as either casts, or specimens in the following repositories: The Hunterian, University of Glasgow (GLAHM); the Staffin Museum (SM); National Museums of Scotland (NMS). Some material exists only as photographs of loose boulders or in situ bedding planes.

### 3. Trackways and Footprints

#### 3.1. Ornithopods

The first footprint to be found in Scotland was a large tridactyl footprint from the Lealt Shale Formation at Rubha nam Bathairean in 1982. Originally this footprint was described as a theropod footprint, but later as an ornithopod footprint based on the rounded tips to the digit impressions. The footprint is 48 cm in length and is preserved in a 15 cm thick dark limestone (Figure 3a) [1,2].

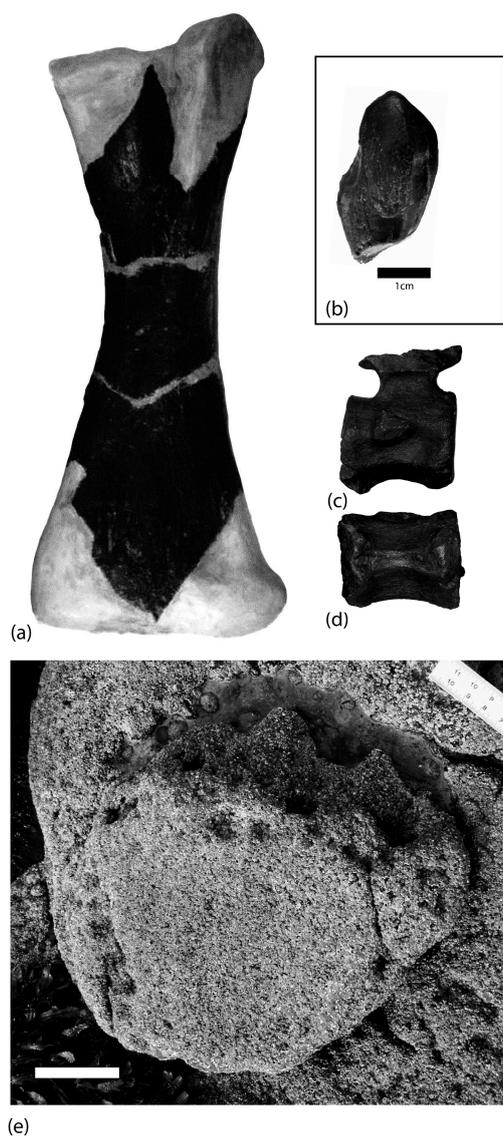


**Figure 3.** Examples of ornithischian remains, and possible ornithopod footprints from the Trotternish Peninsula, Isle of Skye, (a) Lealt Shale Formation footprint (GLAHM V1980); (b) large footprint from the Valtos Formation loose block on foreshore near Dùn Dearg, Valtos; (c) Duntulm Formation level B at An Corran, near Staffin (in the Paul and Cathie Booth private collection, Pitlochry); (d) proximal part of ulna of thyreophoran from the Berreraig Formation in lateral view (SM 1977.1997.1), cast in the Hunterian (GLAHM 114092). Scalebar for (a) and (b) = 10 cm; (c) = 5 cm; (d) = 1 cm.

Similar footprints have also been found in the Valtos Formation near Dùn Dearg in calcareous sandstones on sun cracked surfaces (Figure 3b) [8]. Other smaller possible tridactyl ornithopod footprints were found as a shallow impression in the Duntulm Formation (level B) (Figure 3c) at An Corran near Staffin [6,8] and at Cairidh Ghluimaig near Duntulm Castle (layer 9b) [13].

### 3.2. Sauropods

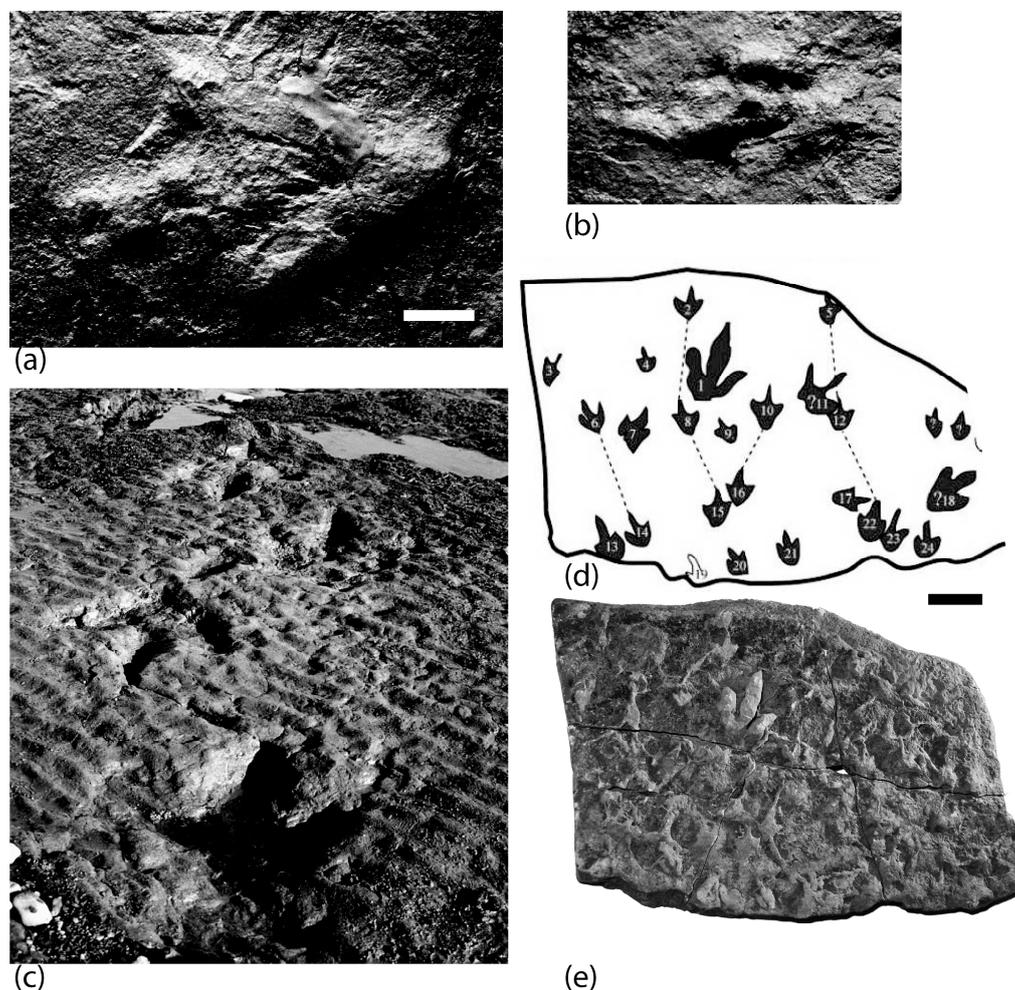
Although sauropod bones have been known of for some time, tracks proved to be elusive until recently. A large number of eusauropod tracks were found in situ in sediments of the Duntulm Formation at Cairidh Ghulmaig at Duntulm Castle (Figure 4e) [13] and a single footprint was recorded on a loose block at Rubha nam Brathairean in rocks of the Valtos Formation [12].



**Figure 4.** Examples of sauropod remains and tracks from the Trotternish Peninsula, Isle of Skye, (a) cast with interpretative reconstruction of sauropod limb bone from the Valtos Formation near Valtos (SM 1977.1994.1) cast in the Hunterian (GLAHM 109385); (b) sauropod tooth from the Valtos Formation near Ellishadder (SM 1977.2007.1) cast in the Hunterian (GLAHM 131151) scale = 1cm; (c) lateral view and; (d) ventral view of the caudal vertebra from the Valtos Formation found on the foreshore north of Ellishadder (SM.1977.1996.1) cast in the Hunterian (GLAHM 109384); (e) in situ sauropod footprint from the Duntulm Formation at Cairidh Ghluimaig near Duntulm Castle. (a,c,d) and (e) to same scale, scalebar = 10 cm.

### 3.3. Theropods

Some of the first dinosaur footprints to be found were described as *Eubrontes* (Figure 5a) and *Grallator*-like (Figure 5b) footprints in the Valtos Formation at Rubha nam Brathairean [5,7,17]. Although *Eubrontes* footprints have been tentatively assigned to a prosauropod trackmaker, the consensus is that they belong to a small theropod trackmaker [18].

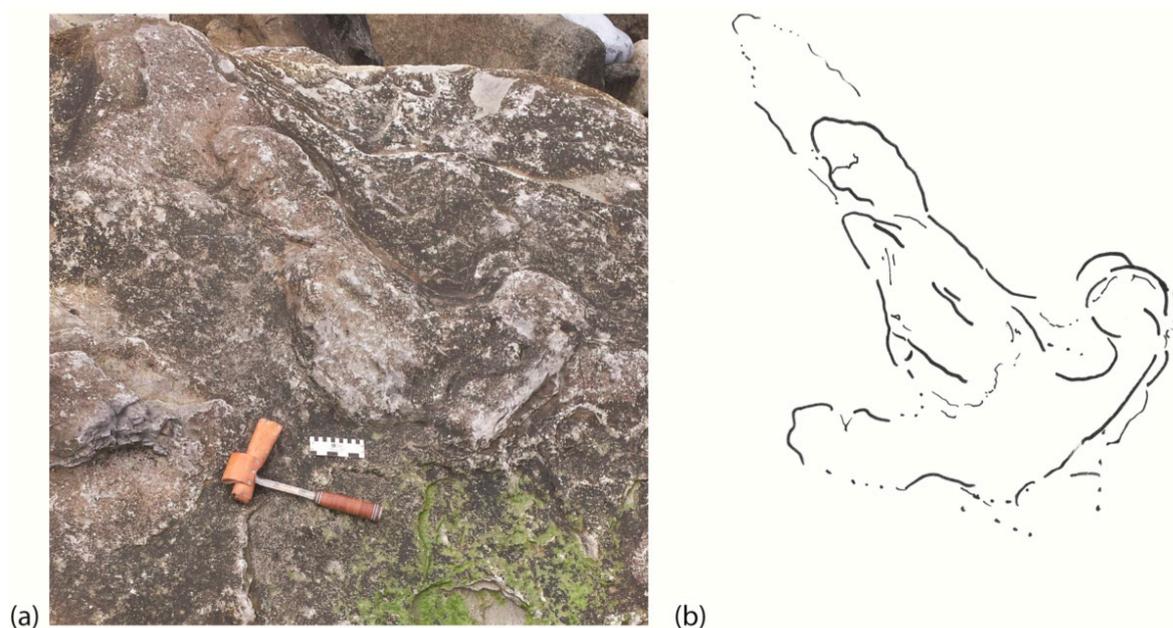


**Figure 5.** Examples of theropod footprints from the Trotternish Peninsula, Isle of Skye, (a) *Eubrontes*-like footprint and; (b) *Grallator*-like footprint from the Valtos Formation at Rubha nam Brathairean (GLAHM 101273); (c) large in situ footprints from the the Duntulm Formation at An Corran near Staffin (cast in the Hunterian (GLAHM 114806); footprint in foreground is 53 cm long); (d) diagram and (e) photograph of slab with many smaller theropod footprints from the Kilmaluag Formation in Score Bay west of Duntulm Castle. Scale for (a) and (b) = 5 cm; scale for (d) and (e) = 20 cm.

There have been many small tridactyl footprints and trackways described from the various formations on the Isle of Skye [5,7,8]. Some appear to have been formed by a similar trackmaker based on morphometric analyses and various measurements of the footprint proportions including the angle of divarication. It is possible to distinguish two different footprint types. One type are the *Grallator*/*Eubrontes* forms (Figure 5a,b) and the other is for the larger tridactyl footprints of the Duntulm Formation at An Corran near Staffin (Figure 5c) [6,8]. These larger footprints were found to be distinct from the large footprints of the Lealt Shale and Valtos Sandstone Formations [8]. The large footprints at An Corran were found to be between 27 cm and 54 cm in length and the distinct, but smaller, footprints of the Valtos and Kilmaluag Formations varied from 1.8 cm and 27 cm [8]. In the

Kilmaluag Formation at Score Bay, an association between a small adult and smaller juvenile footprints of an identical type was noted on a single layer [7]. The footprints appear mostly to be indicating a similar direction of movement (Figure 5d,e).

Larger theropod dinosaurs is evidenced by a single tridactyl footprint found in the Valtos Sandstone Formation with a high divarication angle of over  $105^\circ$  and an impression length of over 100 cm. This is indicative of larger theropods in the Middle Jurassic of the Isle of Skye for which no osteological remains are yet known (Figure 6a,b).



**Figure 6.** Large theropod footprint from the the Valtos Sandstone Formation near Dùn Dearg, Trotternish Peninsula, Isle of Skye, (a) field photograph (not collected from the Dùn Dearg rockfall); (b) diagrammatic interpretation of footprint. Scale card = 13 cm.

## 4. Bones and Teeth

### 4.1. Ornithopods

Despite the footprints from the Lealt Shale and Valtos Sandstone Formations, no diagnosable ornithopod skeletal remains have been found on the Isle of Skye.

### 4.2. Thyreophora

The elbow joint of the ulna and radius of a thyreophoran dinosaur was discovered in the Bajocian Berreraig Formation sediments at Rubha Sùghar (Figure 3d). Although this was initially considered to be a primitive stegosaur, the lack of diagnostic characters left it as a primitive form within the higher taxonomic clade of the Thyreophora [16]. New material from the same formation being studied at present is hoped to clarify the taxonomic representation within this clade.

### 4.3. Sauropods

Some of the earliest bone material found from the Middle Jurassic of the Isle of Skye is of a primitive sauropod initially considered to be a cetiosaurid [4]. A limb bone with worn distal and proximal ends was discovered in 1994 from the Valtos Sandstone Formation near Valtos. It is unclear which long bone it is, but it appears to be either a partial tibia, or humerus (Figure 4a) [4,15]. Other bones of primitive sauropods have been found in the vicinity including a rib and a caudal vertebra as well as a tooth

(Figure 4b–d) [12,15,19]. The tooth is spatulate and similar to the teeth of the primitive eusauropods, but was not identified further than being from a basal sauropod (Figure 4b) [12].

Another tooth of a primitive sauropod was found in the Kilmaluag Formation near to Camasunary on the Strathaird Peninsula. It has been suggested that this tooth may have come from a basal eusauropod or a basal titanosauriform due to its more peg-like form [14].

#### 4.4. Theropods

Few theropod remains have been found from the Middle Jurassic sediments of the Isle of Skye. A single tooth (Figure 7a,b) and a caudal vertebra (Figure 7c) were both found from sediments of the Valtos Sandstone Formation on the foreshore near to Valtos. The caudal vertebra appears superficially similar to vertebrae of coelophysoids, but a detailed analysis of the bone suggests that it is more likely a primitive coelurosaurian theropod [11].

The tooth may have belonged to a small bodied theropod similar in size to that which left the vertebra. Analysis of the tooth suggests that it may be from a dromaeosaurid or a primitive tyrannosauroid [11]. If it is a dromaeosaurid, then it will be one of the oldest examples of this group known, although it has been shown that this group probably first evolved during the Middle Jurassic [11]. It is also possible that the tooth was from a juvenile of a larger theropod such as *Megalosaurus* [11]. Larger theropods are indicated by the large footprints from the Duntulm Formation at An Corran [6,11].

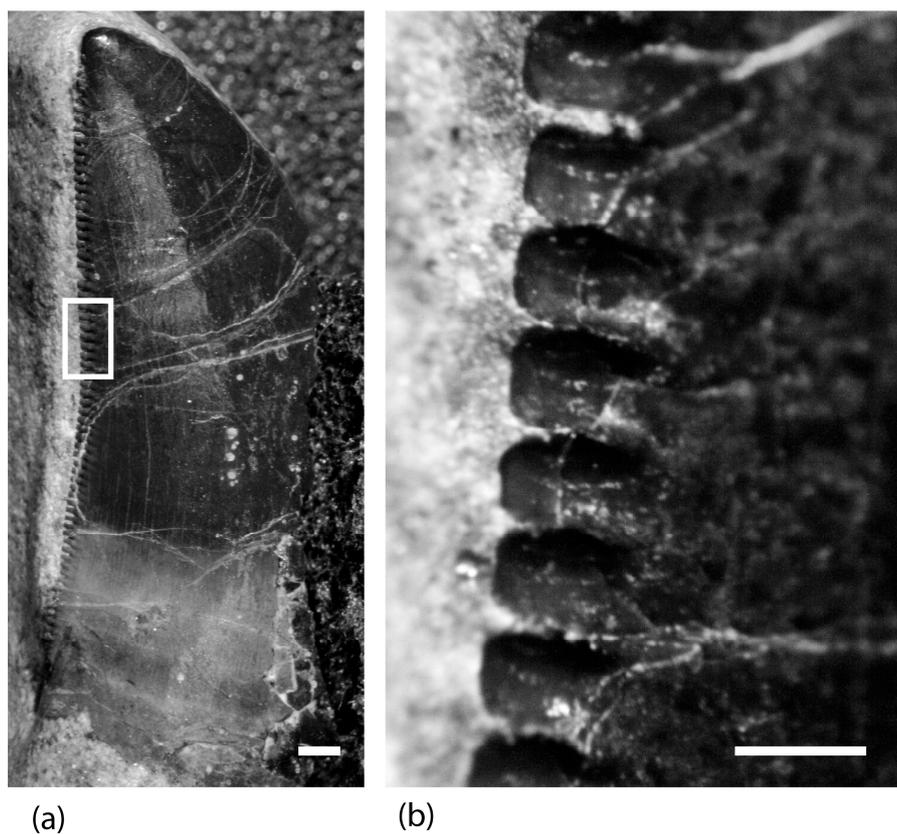
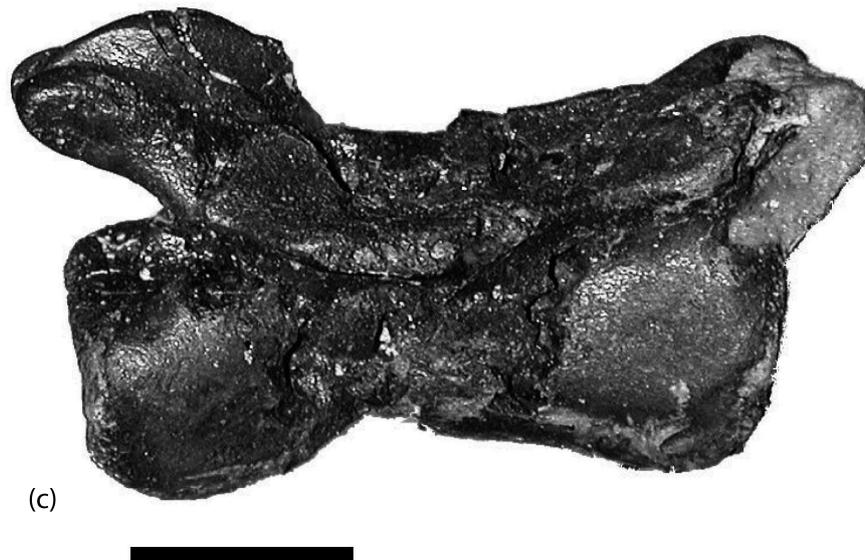


Figure 7. Cont.



**Figure 7.** Theropod remains from the Valtos Sandstone Formation Isle of Skye, (a) tooth and; (b) expanded view of denticles (GLAHM 125390a) scale = 1 mm; (c) caudal vertebra (GLAHM 101240), scale = 1 cm.

## 5. Discussion

The Middle Jurassic saw the early development of many groups of dinosaurs. Although the major branches of dinosaurs, such as the Neornithischia, the Thyreophora, the Heterodontosauridae, the Sauropodomorpha and the Neotheropoda, had evolved in the Triassic and Early Jurassic, many of the major suborders appear in the Middle Jurassic. The Middle Jurassic is thought to be when the Europoda split into the Stegosauria and the Ankylosauria; the Iguanodontia evolve at this time; the Dromaeosauroida and the Tyranosauroida as well; and the Eusauropoda have developed by the Lower Jurassic with the Neosauropoda and the Titanosauriformes evolving in the Middle Jurassic [20].

There are a few localities worldwide from which a diverse dinosaur fauna has been obtained. The English Middle Jurassic has produced a few bones of sauropod and theropod and is the geographically closest region to Scotland during the Middle Jurassic for comparative study [21–23]. The rest of Europe has a number of mostly fragment remains including basal megalosauroids, coelurosaurs, stegosaurs, ankylosaurs and basal ornithomimids [20]. The Chinese? Bathonian fauna is probably the best known with stegosaurs, basal cerapodan ornithischians, theropods and sauropods [20,24]. The Bajocian of Australia has a few fragmentary bones of theropod and sauropod [25,26]. Morocco and Algeria have had several sauropods described from the Middle Jurassic rocks there [27,28]. In Madagascar, sauropods and teeth of theropods of Middle Jurassic age have been found in the Isalo III Formation [20,29]. There are several localities in North and South America where Middle Jurassic sediments contain dinosaur tracks, however no dinosaur bones of this age have yet been found in North America [8]. The finds in South America are mostly isolated remains although the fauna from the Cañadón Asfalto Formation of the Chubut Province of Argentina is second only to the Shaximiao Formation fauna of China [20,30,31].

The paucity of Middle Jurassic dinosaur faunas worldwide makes the fauna being uncovered in Scotland of great importance to our understanding of the development of several groups of dinosaurs. The material already discovered on the Isle of Skye provides tantalising glimpses of the potential of future collecting and study in the Inner Hebrides of Scotland.

**Acknowledgments:** Fiona Stevens is thanked for preparation of the sauropod vertebra and the PalAlba Group is acknowledged for their continuing work on the Middle Jurassic fossils of the Isle of Skye. The two anonymous reviewers are also thanked for their insightful and encouraging comments.

**Conflicts of Interest:** The author declares no conflict of interest.

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