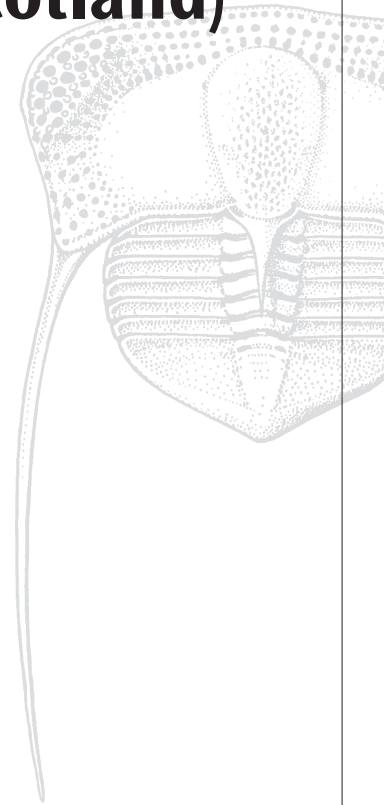


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**The Great Estuarine  
Group (Jurassic, Scotland)**

**John D. Hudson**







## The Great Estuarine Group (Jurassic, Scotland) as a source of vertebrate fossils: some reminiscences and field trips

When I started research at Cambridge in 1956 for my PhD on the Middle Jurassic rocks of the Inner Hebrides, I gave no thought to their potential for vertebrate palaeontology. I quickly became most interested in the Great Estuarine Series (see Hudson and Trewin 2003), as it was then known. Its palaeoenvironment was a challenge, especially as the 'Estuarine Series' in Yorkshire had recently been interpreted as largely deltaic. I knew I had to study its sedimentology and invertebrate fauna, as well as sorting out its stratigraphy, but I was entirely ignorant of vertebrates. At that time, invertebrates were taught in the Department of Geology in Cambridge, led by Bulman, and vertebrates in Zoology, led by Parrington (rumour had it that they didn't get along).

### The Eigg plesiosaur

The story began with Hugh Miller's visits to Eigg in 1844 and 1845. He discovered plesiosaur bones, the first record of these marine reptiles from Scotland, and wrote enthusiastically about them in his Free Church journal, *The Witness*. His writings gained wider circulation in the posthumous publication of *The Cruise of the Betsey* in 1858 (see Hudson 2003). Miller was also remarkably prescient about the palaeoenvironment of what Judd later called the Great Estuarine Series, but while his writings were a great popular success they were largely ignored by later authors, presumably because they were not published in scientific journals. There are scattered mentions of vertebrate finds, mostly of fish, in the Geological Survey Memoirs of the early 20th century, but without emphasis.

My own involvement started in the late 1950s when I visited Eigg and found some well-preserved plesiosaur vertebrae. I showed them to my contemporary, Arthur Cruickshank, at that time a PhD student under Parrington, and he prepared a specimen from its recalcitrant matrix and suggested I send it to Alan Charig at the Natural History Museum in London. The specimens attracted the attention of W. E. Swinton, then curator of vertebrates, who wrote me a rather remarkable letter reminding me of his position, and of Charig's. Shortly after this, Swinton left for Canada and Charig succeeded him. Re-awakened interest led to Barney Newman collecting a great deal of material from Eigg (and reputedly enlivening the social scene there); the collection remains in the NHM. I published a paper on "Hugh Miller's Reptile Bed and the *Mytilus* Shales", rather incongruously written at Caltech in Pasadena, in 1966. This confirmed Miller's observation that the "Reptile Bed", the thin, iron-rich limestone that is the source of all the plesiosaur bones, occurs low in the succession on Eigg, in what we now refer to as the Kildonnán Member of the Lealt Shale Formation. I think this paper played a part in encouraging the next phase of research by David Brown at Newcastle. This has not been fully published, but led to the construction of an excellent model of this small plesiosaur in time for an exhibition at the National Museum of



Scotland, marking the 2002 bicentenary of Miller's birth. I told this part of the story at a gathering in honour of Arthur Cruickshank in 2009.

### The Kilmaluag Formation 1: mammals

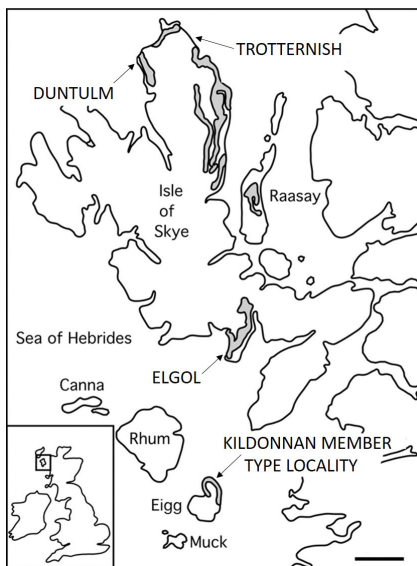
So far, all plesiosaur. That changed dramatically in 1971. For a Jurassic symposium held in 1969, I had written a field guide that mentioned bone fragments could be found in the Ostracod Limestones (now Kilmaluag Formation) at Glen Scaladal, near Elgol on the Strathaird peninsula of Skye. Science teacher Mike Waldman went there with a party from Stowe School to take a look and found a mammal tooth. He immediately told his mentor, Bob Savage from Bristol, who apparently drove all the way to Skye and was on the outcrop by first light. I was told about this, and sworn to secrecy (it seems vertebrate palaeontologists are a competitive bunch). Soon afterwards, a skeleton of the mammal was discovered. On publication in 1972

*Borealestes* was the second named Middle Jurassic mammal in the world (Waldman and Savage 1972); there are many more now.

The Kilmaluag Formation at Glen Scaladal consists of fine-grained, somewhat argillaceous and dolomitic limestone, interbedded with marls, with many levels of deep mudcracks showing emergence (see Andrews 1985). The fine-grained lithology allows faithful preservation, although it is indurated due to slight metamorphism from proximity to the Cuillin plutonic centre. Perhaps this helps with collecting, as the limestones form bold low cliffs that yield many large coherent fallen blocks, and bones weather proud on exposed surfaces. It also means that invertebrate fossils, especially the ostracods that gave the Formation its former name, are poorly preserved at Glen Scaladal. So, in 1980 Jim Harris and I made Kilmaluag in north Skye the type locality (Harris and Hudson 1980). It is of similar facies but unmetamorphosed and yields a sparse macrofauna, mainly of unionid bivalves and the gastropod *Viviparus*, and a microfauna of abundant freshwater ostracods and spinicaudatans (conchostracans). Deposition was in extensive, shallow freshwater lakes (probably close, but not connected, to the sea), that periodically dried up. A strongly seasonal climate is indicated. The absence of rootlet horizons is somewhat surprising, but maybe intervals of emergence were too brief and evaporation too strong. Had we known how important a vertebrate locality it was to become, we might have called it the Scaladal Formation.

### The 1972 field trip

It was partly because of Waldman and Savage's discoveries that I decided to organize a field trip to the Great Estuarine Series to show it to interested friends and colleagues. By then I had made many field visits for my own research and I thought I knew the outcrops reasonably



Map showing the Great Estuarine Group outcrops in grey and some of the main localities, redrawn after Hudson et al. (1995) and Holmden and Hudson (2003). Scale bar is 10 km.



well. I simply wrote to people asking if they were available, and quite a few of them were. It is hard to imagine this happening now. Several participants subsequently had notable careers in diverse fields. They included Waldman, Savage, Tim Palmer, later Executive Officer of the Palaeontological Association, Mike Barker, at one time its Membership Treasurer, Hugh Torrens, now doyen of geological historians, Keith Duff, then my PhD student on Oxford Clay bivalves and ultimately chief scientist of the Nature Conservancy, David Palfaman who also worked on the Oxford Clay, Alastair Robertson, who had mapped Eigg for an undergraduate project and subsequently became an authority on Cyprus and Turkey, Terry Scoffin, who wrote a textbook on carbonate rocks, Rob Raiswell, a geochemist interested in concretions (another prominent feature of Great Estuarine geology), Peter Boyd, a great collector who sadly didn't complete his work on the microfossils, and Roy Clements, curator at Leicester who made a collection of material for our Department. We had a great time and collected a great deal of rock, especially for extracting microvertebrates. Waldman and Savage collected a lot of important material that eventually led to the next phase of investigation.

### **The Kilmaluag Formation 2: small reptiles and more mammals**

I can claim no direct involvement in this next phase, led by Mike Waldman, Susan Evans (University College London), Paul Barrett (Natural History Museum, London) and many colleagues, which led to the most important discoveries of tetrapod fossils (see Evans *et al.* 2006). From a number of field trips the Kilmaluag Formation yielded a remarkably diverse fauna of terrestrial and freshwater aquatic mammals, reptiles, amphibians and fish in at least 22 taxa, including sharks, amiid fish, salamanders, lizards, choristoderes, pterosaurs, crocodiles, turtles, and further mammals and tritylodonts. The most spectacular discovery on the 2004 field trip was an association of several turtles. The assemblage resembles that from roughly contemporaneous horizons in Oxfordshire, but differs in containing several associated specimens, not just isolated teeth.

### **Dinosaurs and their footprints**

In 1982 I was with Julian Andrews, then my PhD student and now Professor at the University of East Anglia, investigating the Lealt Shale Formation at Trotternish, Skye. Julian noticed an inverted block of limestone, fallen from the cliff above, that bore an unmistakable print from a large dinosaur. The block could be assigned to a precise bed in the section by its distinctive lithology. At the time, dinosaur footprints were not known in Scotland, but were becoming well known in the Purbeck Beds of Dorset in rather similar lithologies to those of the Lealt Shale: alternating mudstones and shelly limestones. We consulted Paul Ensom, who had worked on the Purbeck. Later, the block was collected for the Hunterian Museum in Glasgow by Stan Wood, assisted by Julian, and had a small paragraph in *The Scotsman* newspaper. Soon after this, Dugald Ross, a local resident, became interested in fossil collecting and set up a small museum near his home. More footprints were found, this time in the Valtos Sandstone Formation above the Lealt Shale, and dinosaur bones started to turn up too. Ross contacted the Hunterian Museum in Glasgow, as a result of which Neil Clark became involved. Since then both the Valtos Formation and the Duntulm Formation in Trotternish have yielded footprints, including trackways, and Paul Marshall extended the record to Strathaird. The Duntulm dinosaurs must have waded through salty water, as its abundant oysters show that the shallow lagoons were more saline at that time. Trotternish is now promoted as a dinosaur hotspot to tourists, with a



signboard at the Kilt Rock viewpoint erected by the Lochaber Geopark. See Clark (2007) for more on the dinosaur discoveries.

### **The Kildonnan Member: the 1999 field trip**

Many field visits continued, especially in the company of PhD students who studied aspects of the Great Estuarine Group much more intensively than I had been able to. In 1999, as part of the celebrations to mark my retirement from the University of Leicester, I invited some colleagues and former students to join me for a few days on Eigg, my favourite island. It started frustratingly with three days in Arisaig while a gale blew and ferries could not sail, but eventually we made it over and a good time was had by all. We naturally visited the Kildonnan Member section (see Hudson *et al.* 1995 for palaeoecology). The plesiosaur bones all come from one thin bed in the lower part of the Kildonnan Member; another thin bed is distinctive in being packed with fish teeth and scales, especially hybodont sharks. Charlie Underwood, then at Liverpool, joined us and collected a great deal of material from the Fish Bed, as well as other horizons (see Rees and Underwood 2007).

Transatlantic involvement has contributed further insight into the Kildonnan Member palaeoenvironment. I had made contact with Bill Patterson, then at Syracuse University, who is an authority on fish otoliths. In 1995 Matt Wakefield and I showed Bill and his student the Kildonnan Member outcrop. The samples he collected yielded the oldest otoliths known still preserved in their original aragonite (see Patterson 1999). Another successful collaboration, with Chris Holmden from Saskatchewan, also built on the exceptional preservation of aragonite at Kildonnan, via analysis of the geochemistry and composition of the bivalves. Although not directly concerned with vertebrates, the results helped to re-interpret the environment, showing that the water in the shallow lagoons in which the sediments accumulated was overwhelmingly freshwater (Holmden and Hudson 2003). Some marine connection is still required to interpret the otoliths of migratory fish, but much less than we used to think. It seems likely that the plesiosaurs, as well as the sharks, were freshwater animals.

### **The 2013 field trip**

In 2011 I met Martin Munt from the Natural History Museum, London, at a PalAss meeting. He had a poster on Chinese freshwater bivalves and I hoped he might use his Chinese contacts to help investigate the possibility that some of those in the Great Estuarine Group had crossed from China via the 'polar route', as I had tentatively suggested. He responded by proposing a field trip, intended to go to Eigg. We were joined from the vertebrate fraternity by Roger Benson from Oxford and David Ward, the authority on sharks. Shades of 1999: we arrived at Mallaig with an easterly gale blowing and no ferries to Eigg, so squeezed back into our small vehicle and drove to Kyle and over the bridge to Skye. I had taken no literature on Skye, but fortunately could remember enough localities to keep us happy for a couple of days. Eventually we made it to Eigg for a curtailed visit, although unfortunately David Ward had to leave, but we collected some Fish Bed samples for him. The others were suitably impressed by the Kildonnan Member section, and several reptile bones were found. The bivalves, however, still await re-interpretation.

### **New blood and more footprints**

Perhaps, as an American, Steve Brusatte won't mind being called the new kid on the block. He is now based in Edinburgh and is a leading light in PalAlba, a group pressing Scotland's claim to be a hotspot for vertebrates, especially dinosaurs and marine reptiles (see Brusatte 2015). It includes



Stig Walsh and Nick Fraser from the National Museum of Scotland, Neil Clark from the Hunterian Museum in Glasgow, and Dugald Ross from Skye. A particularly welcome part of their activities, with Stig Walsh's student, is the long-delayed full description of the *Borealestes* skeleton found by Waldman and Savage in 1971. Brusatte made contact with me in 2014 asking about specimens in Leicester and field localities. He visited in 2015 to give a talk and we had a long chat afterwards. I showed him a piece of bone from the Duntulm Formation, which he decided was the jaw of a small crocodile. I recommended a visit to Duntulm, and while there Steve and others found yet more footprints in outcrops that I must have walked over many times without noticing them.

Research on the Kilmaluag Formation fauna continues. Benson, following up the 2013 trip, returned to Skye in 2014 and 2015 with colleagues: finds included mammal jaws, such as the jaw of the stem therian *Palaeoxonodon ooliticus*, a taxon previously only known from teeth, and new remains of amphibians and reptiles. Most recently (autumn 2015), Julian Andrews and colleagues have found dinosaur prints in the basal part of the Kilmaluag Formation in inland Strathaird. Being a fairly obscure locality I might forgive myself for not visiting it, but surely I should have found more prints and bones than I did, over the decades. My old notes record loadcasts from several horizons within the Great Estuarine Group and I now wonder what applied the load. Fortunately, a field lifetime is short on a geological time scale. Progress is much faster now – long may that continue.

At Kildonnan, the view is of the mountains of the west Highlands; at Duntulm, those of Harris across the Minch; and on Strathaird, most dramatic of all, the Black Cuillin. Can there be more beautiful field localities in the whole world?

**John D. Hudson**

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*The Kilmaluag Formation locality.*

