Vertebrate tracks from the Triassic Helsby Sandstone Formation at Burton upon Trent, Staffordshire

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Abstract: Triassic vertebrate tracks have been described from several localities in the Burton upon Trent area. The National Brewery Centre Museum in Burton upon Trent holds two slabs showing tracks attributed to *Chirotherium* from a find at Ashby Road in 1912. A natural cast of a print from the same excavation is in a private collection. Slabs bearing *Rhynchosauroides* prints that were purchased by the Natural History Museum in 1848 and 1858 were erroneously listed as coming from 'Staunton' but were actually found at Stanton, close to Burton upon Trent and about 2 km from the Ashby Road finds. Within this ichnoassemblage, the Ashby Road tracks are assigned to *Chirotherium* cf. *barthii* and the Stanton tracks to *Rhynchosauroides rectipes* and *Rotodactylus* isp. The *Chirotherium* tracks have an unusually large digit II and manus. Photogrammetry has been used to enhance details of the *Chirotherium* specimens.

The outcrops adjacent to the eastern end of the old Trent Bridge (Fig. 1) in Burton upon Trent consist of the uppermost part of the Sherwood Sandstone Group. This was formerly known as the Bromsgrove Sandstone Formation, of early Mid-Triassic (Anisian) age. The Anisian Stage extends from 247.2 to 242 Ma (Mundil *et al*., 2010; Cohen *et al*., 2013). The Bromsgrove Sandstone is now incorporated in the Helsby Sandstone Formation (Ambrose *et al*., 2014).

These rocks consist of red, brown and grey sandstone units which are coarser, sometimes even pebbly, at their base and which fine upwards to siltstones and mudstones. They form the steep margin of the Trent Valley, which east-west roads ascend, many with recourse to road cuttings. Similar rocks occur at Brizlincote Hall (Fig.1), where old quarry workings are still evident. These sandstones were used in local building workss.

A few hundred metres to the east of the old Trent Bridge, the Helsby Sandstone is overlain by the Tarporley Siltstone, the lowest formation of the Mercia Mudstone Group. Rocks of this age are, along with younger units elsewhere, the source of the gypsum that hardens the local groundwater on which Burton has depended for its famous beer production. The underlying Helsby Sandstone is the principal aquifer from which this water continues to be drawn. In previous years it was also the source of well water which supplied the nearby village of Winshill (fig. 1). The Tarporley Siltstone was widely used in brick-making (Reeves *et al*, 2006), resulting in several brickyards being opened in Stapenhill and Stanton in the 19th century. The high carbonate content, usually in the form of dolomite (Stevenson & Mitchell, 1955), gave the bricks a characteristic pale buff colour.

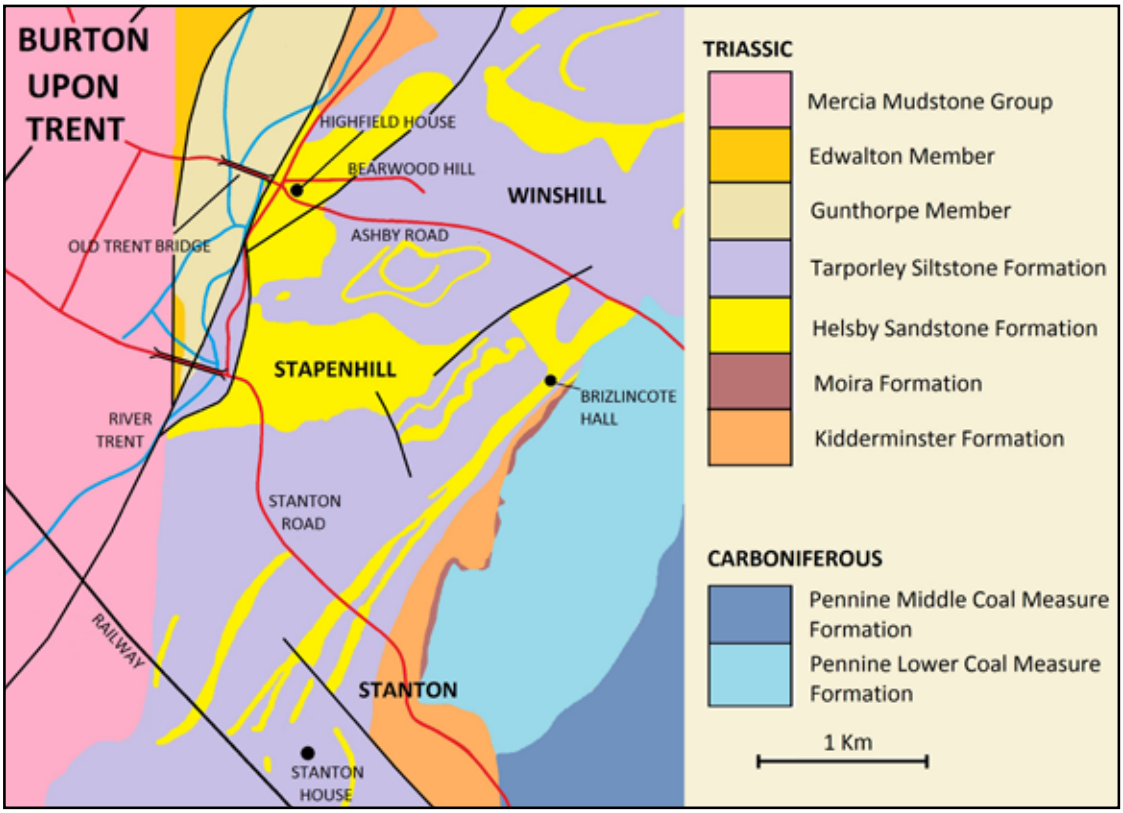

Figure 1. *Bedrock geology in the area around Burton upon Trent (after British Geological Survey). The Edwalton and Gunthorpe members are parts of the Sidmouth Mudstone Formation, and the Helsby Sandstone Formation was known in the past as the Bromsgrove Sandstone.*

The micaceous Helsby Sandstone, in which the *Chirotherium* prints were found, is mineralogically immature with a content of detrital quartz and K-feldspar grains, indicative of fluvial deposition. The orientation of cross-bedding reveals a provenance from the south. These beds have been interpreted as the deposits of a braided river system flowing within well-confined channels (Steel & Thompson, 1983). The upper beds containing the prints are dominated by fine-grained sandstone and mudstone units. They were deposited in channels of higher sinuosity and lower flow and can be interpreted as overbank facies (Warrington, 1970). These river systems probably had large seasonal changes in discharge, evidenced by cross-stratified sandstones deposited at stages of lower flow (Hough, 1997) and fining-upwards cycles indicating ephemeral fluvial conditions and periodically rapid deposition by waning currents (Radley, 2005); such conditions potentially favour the preservation of vertebrate tracks.

Vertebrate remains from the Helsby Sandstone are predominantly those of amphibians and archosaurs, but nothosaurs, *Rhynchosaurus* and prolacertiforms are also present at some localities (Benton *et al.*, 1994). *Chirotherium* prints are probably associated with pseudosuchian archosaurs, perhaps rauisuchians (King & Benton, 1996). *Rhynchosauroides* tracks persist from the Permian through much of the Mesozoic and are likely to be polyspecific in origin. They represent diapsids, probably including prolacertiform reptiles (Avanzini & Renesto, 2002). *Rotodactylus* is thought to be linked to small archosaurs such as *Lagosuchia* which is believed to be closely related to the dinosaurs (Klein & Haubold, 2007, Brusatte *et al.,* 2010).

The history of *Chirotherium* tracks

Chirotherium tracks were first discovered in 1834 in the Lower Triassic Buntsandstein in Thuringia, Germany and named *Chirotherium barthii* by Kaup (1835a) in the erroneous belief that they were mammalian in origin. In England they were first discovered in June 1838 (Tresise, 1989) and quickly reported by John Cunningham (1838), who described the tracks found at Storeton Quarry in Cheshire. According to Swinton (1960) interest from the scientific community continued undiminished into the 20th century, as Beasley and Lomas, the two northwest stalwarts of the British Association '*vied with each other in describing and classifying the specimens*'. Henry Beasley published a series of papers between 1904 and 1908 (Beasley, 1904, 1905, 1906, 1907, 1908) refining a classification system of British Triassic vertebrate tracks and ensuring that *Chirotherium* track discoveries remained in the limelight during the Edwardian era.

It was against this background that *c*.1860 the first footprints from Burton upon Trent attributed to *Chirotherium* were found during the construction of Highfield House on the Ashby Road (Fig.1), about 1.5 km east of the town centre. A cutting was made from the road to the site of the house, exposing a bed of sandstone on which two or three footprints were found.

Molyneux (1869, p165-166) recorded that the same beds: *'may be seen at the base of the road-cutting at Bearwood hill, which affords one of the best sections in the locality for the study of these beds and the group by which they are succeeded. The latter consists of a thin alternation of red, white and mottled arenaceous*

***Figure 2**. Excavations at Highfield, Ashby Road. This photograph was donated to Burton Museum by Frances Lott and represents the 1912 works (NBCM archives).*

beds, overlain by bluish pyritous shale and binds; and flaggy, shaly, micaceous sandstones, light yellow, and brown in colour; and denoting – by the frequent occurrence upon their upper surface of ripple-marks, pittings of rain-drops, and oblique lines due to the action of wind – the shallow and tidal conditions of the waters by which they were deposited. Some few years ago the excavations in these beds, for the road leading to Mr Wardle's house, on the Ashby Road, yielded interesting footprints of a reptilian character, associated with the genus cheirotherium (sic), *and which are now in the possession of Mr. Edwin Brown. So far, however, the equivalents of these beds in the Bearwood hill section have not contributed to these traces of batrachian life, although, did the opportunity occur, there is no doubt similar impressions would be found there. I may add that on one occasion I saw a corresponding footprint, upon a slab of sandstone, which belonged to the lower beds of the series, in the old quarry near Brizlincote Hall '* (Fig. 1).

Footprints were also recorded by Mosley & Brown (1863, p2-3) *'On some slabs of marly sandstone which have been lately excavated on the south side of the Trent, near Burton, footmarks of an unknown reptile are visible, similar to those discovered several years ago at Runcorn in Cheshire.*', and by Coleman (1863 p100) *'These sandstones give evidence of their littoral origin in their ripple-marks, sun-cracks and rain marks. The ripple-marked sandstones sometimes – as at Burton Bridge - exhibit tracks of Labyrinthodon'*. The proximity of Highfield House to Burton Bridge makes it likely that these are reporting the same finds.

In February 1913, Mr Francis E. Lott (1926, p1-4) read a paper to the Burton on Trent Natural History and Archaeological Society and reported that in: *'About 1860, 'Highfield' was built, and, when making the road up to the house, a cutting about 10 feet deep was made, from the Ashby Road. A bed of ripple-marked sandstone was exposed, on which two or three very distinctive foot-marks were found'*. (The deeds to the house show it was constructed in 1854, therefore Lott's date is probably too late). He also noted that: *'In 1877 it was exhibited and described by the late Mr. Molyneux at the first conversazione held by this society, and I have never seen it since. Mr. J O'Sullivan tells me that it was exhibited at the second conversazione, in 1878, and at that time Mr. Molyneux took it to Messrs. Bass and Co.'s laboratory to show it to Mr. C O'Sullivan. This is the last I can hear of the specimen'*.

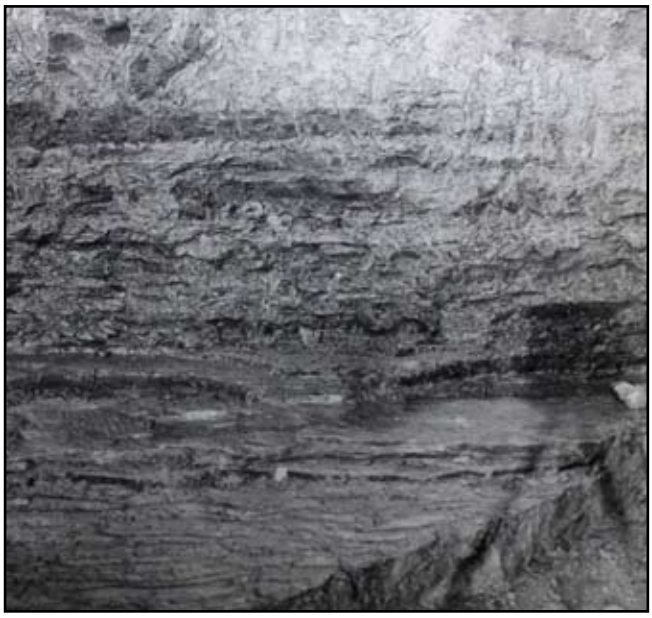

Figure 3*. The footprint beds at Ashby Road in 1912, with ripple bed in the left mid-foreground and the shadow of the camera on the right (NBCM archives).*

Lott was keen to find a specimen himself, having found several slabs with ripple marks in the surrounding area. In 1912 some buildings were erected on the land between 'Highfield House' and the Ashby Road and some new work was done in the area of the drive. He records that on the final day of digging: *'They reached the eastern limit of their excavations, about five of six yards from the drive, and had found nothing. Fortunately the foreman decided to go down a foot deeper, and about seven feet from the surface three slabs bearing footprints were found, and I have little doubt that these footprints were made by the same creature that made those which were discovered fifty years ago'*. He described them as consisting *'of a series of alternate pairs of hand-shaped impressions, the hinder print of each pair being much larger than the one in front, in some cases 8 to 10 inches long whilst the prints were 14 inches apart'*. He later presented the prints to the Burton Museum together with three photographs (Figs. 2, 3 & 7).

Wain (1938, 1968) produced two newspaper articles confirming that the slabs were from the Lott trackway. A partial natural cast of a pes (foot), labelled as coming from the 1912 Highfield site is also in the private collection of one of the authors (CB). This was rescued from a box of geological artefacts destined for the tip in the 1970s.

The history of *Rhynchosauroides* tracks

Sarjeant (1974) listed two slabs purchased by the Natural History Museum in London (NHM) bearing prints from the Burton on Trent area, which he attributed to *Rhynchosauroides*. These were first catalogued by Richard Lydekker (1888) as:

ICHNITES. 219

21834. A small slab containing numerous footprints; from the Keuper sandstone (Upper Trias) of Staunton, two and a half miles from Burton upon Trent, Staffordshire. Purchased, 1848

33156 A small slab with similar tracks; from Staunton. Purchased, 1858

The nearest 'Staunton' to Burton upon Trent is Staunton Harold lying on predominantly Carboniferous bedrock 12 km to the east. It is more likely that Lydekker misspelt Stanton, which straddles the Carboniferous and Helsby Sandstone (Fig.1) and is some 2 km from

the Ashby Road finds. Indeed Lydekker, writing later on the palaeontology of Staffordshire (1908), noted *'Yet other* (casts of footprints) *have been described from Stanton, two and a half miles from Burton on Trent'*.

The NHM has records showing that slab NHMUK OR21834 was purchased from Messrs Cartwright (quarry owner) and Stone having been found at Mr Cartwight's quarry at 'Staunton' on the road to Measham. The NHM register also records that the original four portions of slab NHMUK OR33156, which were subsequently joined, were purchased from W. Wright in 1858.

The Cartwright family owned mines, quarries and brick-pits at Stanton and it is likely that the above reference is to John Mottram Cartwright, a fire brick maker and quarry owner in Stanton at the time (White, 1857). The family owned the Shoddy Mine in east Stanton so called because of frequent flooding, faults, short seams and shaft collapses. To the west, overlying the mudstone, several brickyards were situated in the mid-19th century (Tringham, 2003), and it is there that the slabs were probably discovered.

The specimens

The two specimens held by the National Brewery Centre Museum (NBCM), formerly the Bass Museum in Burton on Trent, are not accessioned and are referred to as NBCM1 (natural cast) and NBCM2 (print). They were previously figured by King (1997) and King *et al*. (2005). Asymmetrical ripple marks show flow in the direction of the footprints. The slabs have been considered partially overlapping part and counterpart although the angles of the ripples to the long axis of the prints differ significantly in the common region of digit V making this unlikely. The slabs consist of a micaceous yellow-grey sandstone with evidence of cross-stratification. The sandstone containing the prints is coarse but fines upwards on NBCM1. NBCM2 has a thin surface layer of mudstone over sandstone. Dark cavities are visible in the sides of NBCM1 consistent with Lott's (1926) description of hollows containing 'bituminous sand'.

Photogrammetric images were created using Agisoft Photoscan (Mallison & Wings, 2014). Alteration of a virtual light source and false colour generation dependant on elevation was used to highlight structural details to enhance data analysis (Pond *et al*., 2014). Measurements were taken in accordance with King (1997). Pes and digit lengths were measured from the posterior border of the digit V metatarsophalangeal pad.

NBCM2

An impression (concave epirelief) of a left pes and partial manus. Pes length 252mm. Pes digit lengths: II 225mm, digit III 252mm, IV 220mm. Digits II and IV of similar thickness. Digit IV shows poorer preservation. All show evidence of claw casts. Strongly recurved digit V with rounded end. The lateral border is less distinct and no digit I is discernible. The posterior border of the manus is visible and almost abuts the ends of digits III and IV.

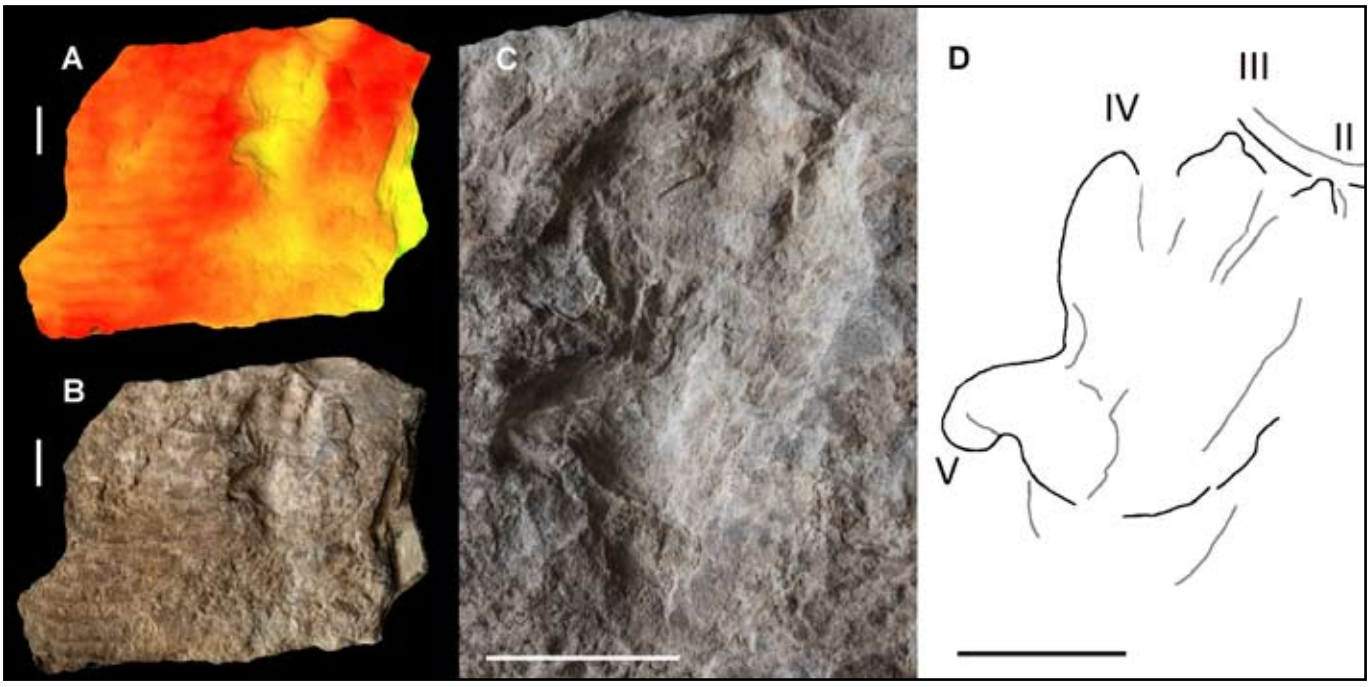

Figure 4. *Specimen NBCM2.*
Photogrammetry images.
A: colour elevation image.
B: high-resolution plain image.
C: high-resolution textured image.
D: drawing based on photography and sketches.
Scale bars are 10 cm.

The manus is the distal part of the fore limb of tetrapods. The pes is the distal part of the hind limb of the same. *Chirotherium*'s pes was typically much larger than its manus.

NBCM1

A natural cast of a left manus-pes set (convex hypo relief). Slab size 610 x 380mm maximum. Pes length 245mm. Manus length 125mm. Manus:pes ratio = 0.51. Pes digit lengths: II 225mm, III 245mm,IV 220mm. The hypex angle between digits IV and III is greater than between digits II and III. Digits II and III are of similar thickness. Digit V is rounded but a weaker trace is indicative of a quite markedly recurved digit. The metatarsophalangeal pad of digit V is ovoid and pronounced. Two phalangeal pads are discernable on digit II and three on digit III. Digits II and III taper distally to triangular points representing quite pronounced claw casts. The medial border of the track is bowed outwards but no definite digit I can be made out. The manus is in front of the pes but medial to its long axis (drawn through digit III). Preservation of the manus is poor with little definition to the digits and no indication of digit V. The posterior border of the manus almost abuts the distal pes.

The Bagshaw specimen

Distal two thirds of pes with digits II, III and IV visible (Fig. 6). Digit on the left is slightly shorter and probably represents digit IV making this a left pes. Digit III appears to have been engraved on its medial border to enhance the appearance.

Despite the Ashby Road prints suffering from relatively poor preservation, photogrammetry has established a pes length of approximately 250mm. Digit V is recurved with a pronounced ovoid metatarsophalangeal pad. Digits II and IV are of similar thickness and length (II being slightly larger than IV) and both are shorter than digit III. Digits II, III and IV taper to a triangular point distally due to claw marks. The manus is poorly preserved with little detail of the digits. This makes the length difficult to establish, but the manus:pes ratio is estimated to be at least 0.5:1. The manus is anterior to the pes and medial to the long axis drawn through digit III.

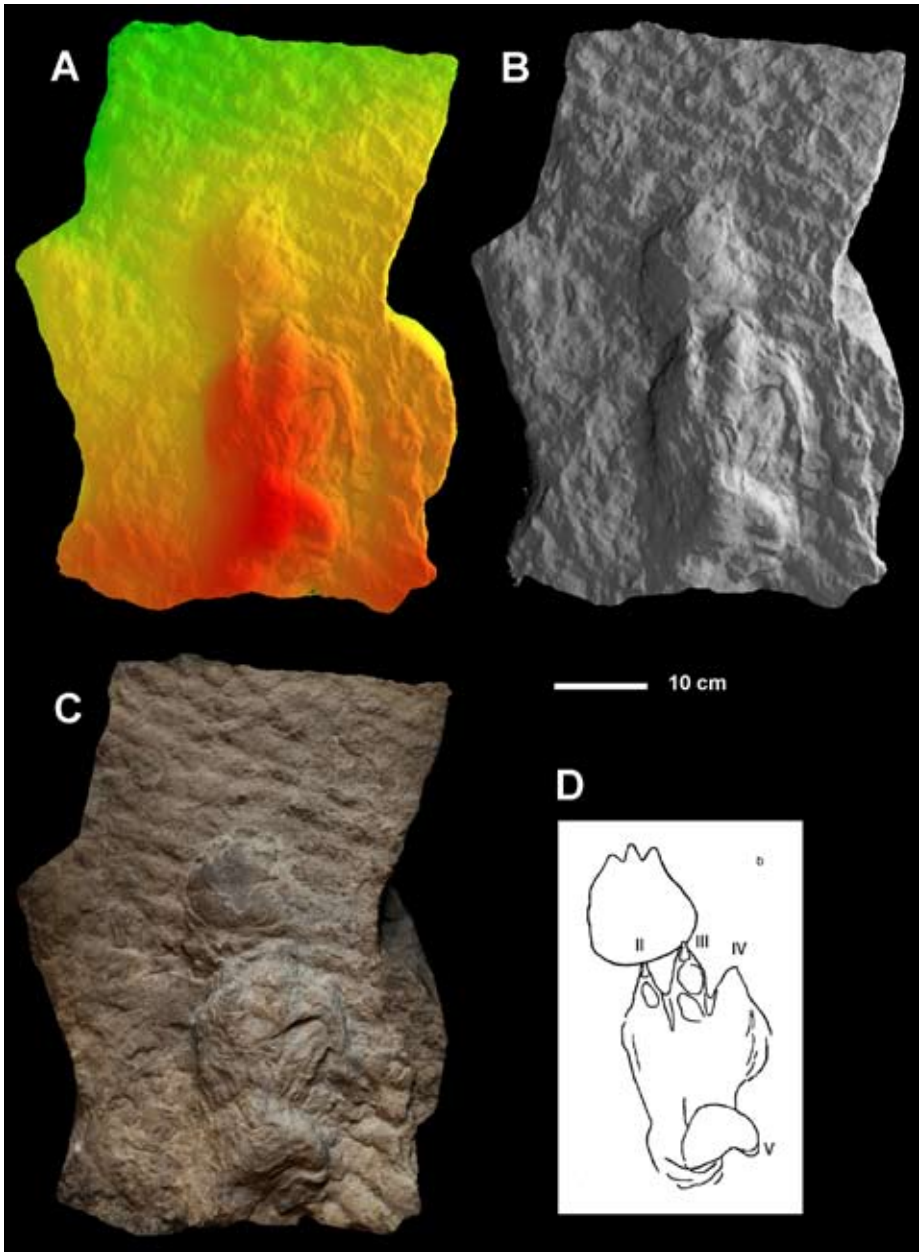

Figure 5. *Specimen NBCM1. Photogrammetry images. A: colour elevation image. B: high-resolution plain image. C: high-resolution textured image. D: drawing based on photography and sketches. Scale bar is 10 cm.*

The prints most closely resemble the ichnogenus *Chirotherium* and show little morphological affinity with other Chirotheriids (*Synaptichnium, Brachychirotherium*, *Protochirotherium* and *Isochirotherium)*. They can be differentiated from *Isochirotherium* as the digits II – IV form a near symmetrical unit with digit III being the most elongate and the manus:pes ratio is considerably above 0.35 (King *et al*., 2005). In the absence of a trackway and well preserved manus, it is difficult to assign an ichnospecies with confidence, although the above features suggest *Chirotherium barthii.*

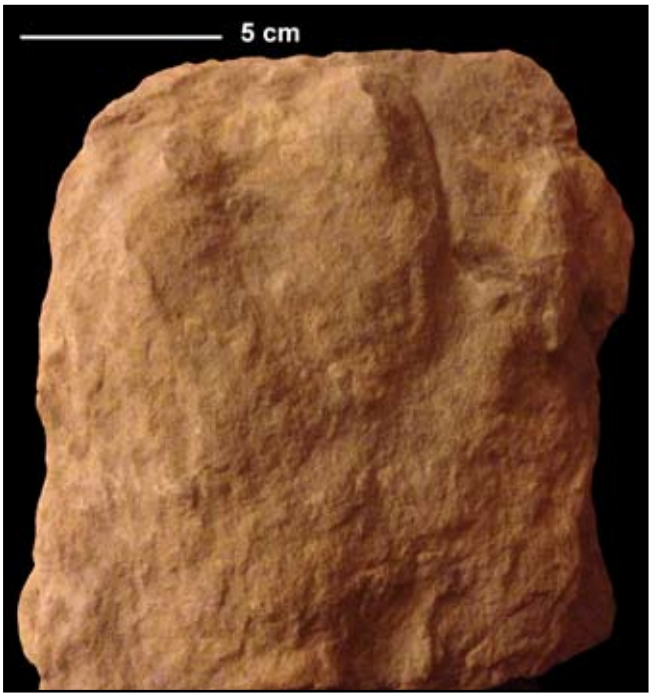

Figure 6*. The Bagshaw specimen.*

The Lott Photograph

Unfortunately there are no surviving records detailing Lott's donation to the Burton Museum. Figure 7 shows two further slabs, which enigmatically show the part and counter part of a possible smaller pes and suggestion of a partial manus. Alternatively it may just represent a large manus.

Without the provenance or the specimens, any interpretation is difficult but it may be that more than one ichnospecies was present at Ashby Road. If a pes, the length is 183mm. Digits II and IV are of equal length; digit I may be present. Digit V is directed laterally but not recurved.

Lott described prints 'in some cases of 8 to 10 inches' (203-254mm) suggesting that there may have been a variation in sizes with some less than 203mm.

NHMUK OR21834

A slab of yellow sandstone consistent with the local Helsby Sandstone Formation overlain by a thin surface layer of mudstone containing numerous impressions of footprints (concave epireliefs). The prints appear to be haphazardly orientated with no trails discernable. Some fine mud cracks are visible. The slab has been set in plaster (Figs. 8 qnd 9).

Prints vary in size from approximately 20 to 40mm. The longer prints have fairly straight, slim and distinct digits which are ectaxonic with a terminal kink. These conform well to Beasley's type D2 prints (Tresise, 2003) and are assigned to *Rhynchosauroides rectipes* Beasley 1911.

Some of the smaller prints have thicker digits and a digit V mark set well back from the rest of the pes and

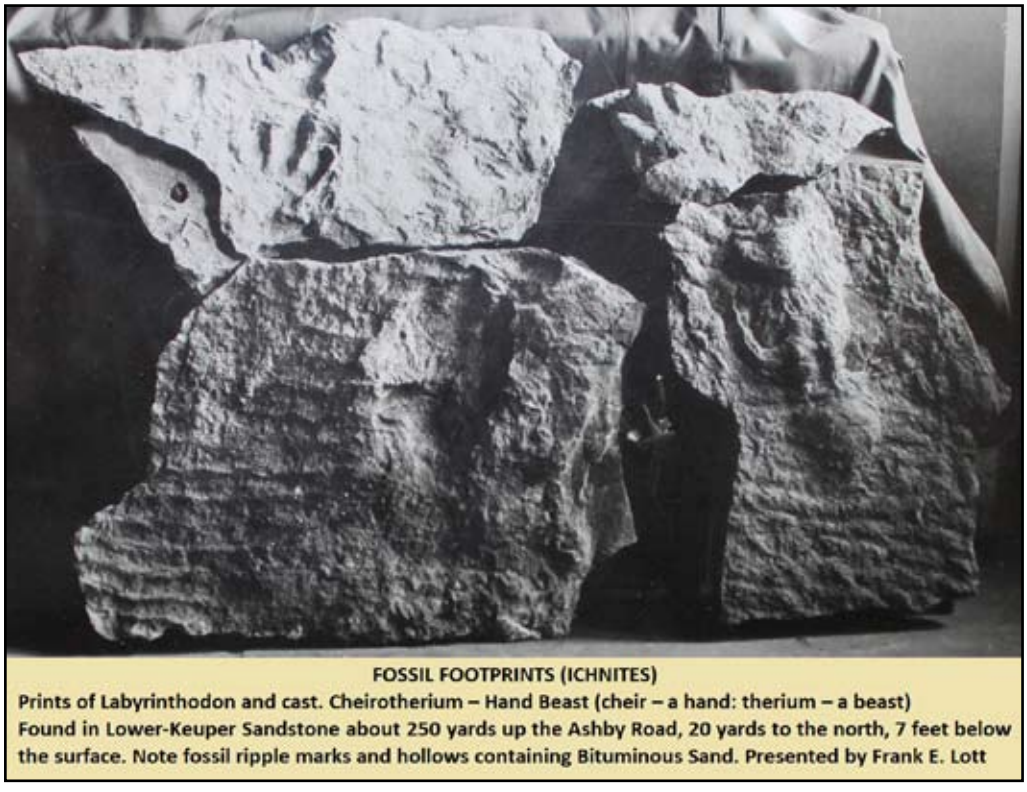

Figure 7*. The photograph of the slabs donated to Burton Museum by Lott, and the text of the label that accompanied them (NBCM archives).*

Figure 8. *Specimen NHMUK OR21834. Scale bar is 10 cm long (photo: NHM).*

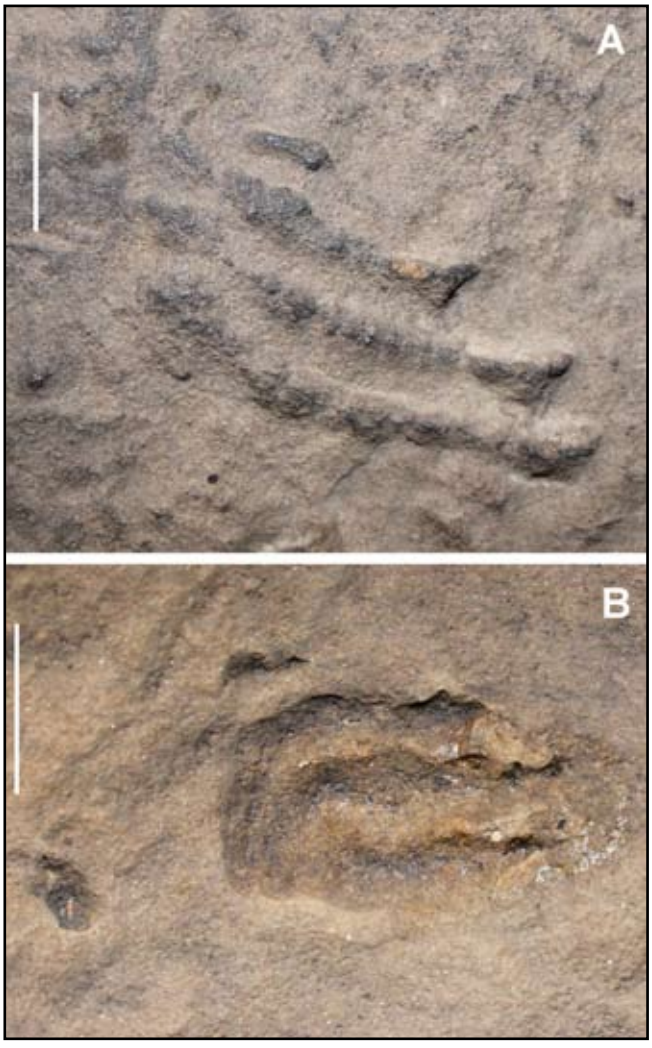

Figure 9. *Two of the individual prints that are on the specimen NHMUK OR21834.*
A. Rhynchosauroides rectipes.
B. Rotodactylus isp. Scale bar is 1 cm.

visible as a small circular impression. This is typical of *Rotodactylus* isp. Other smaller prints, some of which appear quite mesaxonic, may represent manus prints.

NHMUK OR33156

Slab of sandstone consistent with the local Helsby Sandstone Formation overlain by thin surface layer of red mudstone also containing numerous foot prints (Fig. 10). Again the prints appear to be haphazardly orientated with no trails discernable and considerable overprinting. Two types of print are visible, ectaxonic with straight digits and no claws although preservation is poor, (length 40-50mm) and smaller ectaxonic prints with relatively thicker and curved digits (length 20-30mm). These prints are assigned respectively to the pedes and manus of *Rhynchosauroides rectipes.*

Although we have good evidence for *Rhynchosauroides rectipes* and *Rotodactylus* isp., specimens NHMUK OR21834 and NHMUK OR33156 show other morphologies that are less clearly defined. As these morphologies may be affected by pes anatomy, substrate type and the mechanics of registration this can to some extent be expected. However *Rhynchosauroides* taxonomy has been complicated by the erection of at least 32 ichnospecies, and this is an area in need of detailed review (Hunt & Lucas, 2007).

Ichnotaxonomy of the specimens

Due to the poor state of the manus and lack of a trackway it is difficult to attribute a definite ichnospecies to the *Chirotherium* tracks. Of interest however is the large

***Figure 10**. The slab that is specimen NHMUK OR33156; originally in four pieces, it has been set in plaster.*

pes length, the large manus:pes ratio and the length of digit II which slightly exceeds digit IV. These have similarities with *Chirotherium vorbachi* (first erected and figured by Kirchner (1927, 1928) for prints found in the lower Triassic Buntsandstein at Aura an der Saale in Germany), which appears to remain a valid ichnotaxon. Since its erection it has been synonymised with *C. barthii* many times (Peabody, 1948; Kuhn, 1958; Swinton, 1960; Haubold, 1969, 1971). King *et al*. (2005) suggested that it may be a useful taxon to accommodate British *Chirotherium* prints with a pes length above 220mm and a manus:pes ratio over 0.5. However, several recent studies have assigned prints with large pes lengths to *C barthii:* 330mm (Coram & Radley, 2015); 245mm (Xing *et al*., 2013); 230mm (Todesco *et al*., 2008) and 260mm (Valdiserri & Avanzini, 2007). The manus:pes ratio was below 0.5 in the Tedesco *et al*. (2008) study (0.49) and probably in Coram & Radley's and Xing's examples although poor manus preservation make accurate estimations difficult.

Coram & Radley (2015) also noted that in some of these larger specimens further elongation of digit II was evident. King *et al.* (2005) first recognised the positive correlation between pes size and length of digit II. Possibly the relative length of digit II and the size of the manus are subject to positive allometric growth during ontogeny with the *C. vorbachi,* and *C. barthii* (and perhaps smaller prints such as *C. sickleri* Kaup 1835b) holotypes representing different stages of an underlying continuous variation. Currently we are unaware of any studies that have fully researched these relationships and therefore pending further exploration we have assumed *C. vorbachi* and *C. barthii* to be synonyms.

The presence of an ichnoassemblage in the Burton upon Trent area comprising *Chirotherium*, *Rhynchosauroides* and *Rotodactylus* ichnogenera is compatible with rocks of Anisian (early Mid-Triassic) age. Material from the Staffordshire Helsby Sandstone Formation has also previously been referred to both *Rhynchosauroides rectipes* and *Rotodactylus matthesi* Haubold 1967 from the Stradsfield Quarry near Brewood [SJ 897078] (King, 1997). Unfortunately much useful data concerning the Burton upon Trent finds was either never recorded or has been lost. However, with considerable construction work being undertaken on outcrops of the Helsby Sandstone and Tarporley Siltstone formations around the town, there is potential for further discoveries.

Acknowledgements

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