New discoveries of *Isochirotherium herculis* (Egerton 1838) and a reassessment of chirotheriid footprints from the Triassic of the Isle of Arran, Scotland

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Synopsis
Several *in situ* trackways and individual chirotheriid footprints have been found at a number of locations along the southern coast of the Isle of Arran. A locality on the coast near Sliddery has five trackways with three of over 17 footprints and one locality west of Kildonan also has a trackway with over 10 footprints. They are all from the Triassic Auchenhew Beds, but may belong to several levels within these beds. The state of preservation of the footprints is variable, but a combination of morphological characters and landmark polygons suggests that they belong to *Isochirotherium herculis* (Egerton) 1838. Previously described footprints from Arran, originally described as *Chirotherium barthii* (Clark *et al.* 2002), are reidentified as *I. herculis*.

Introduction
Chirotheriid trackways and footprints from the Triassic of Scotland are rare. Only three localities have been previously identified in the literature. In 1850, Harkness (1850a, b) reported on the existence of *Chirotherium* from near Annan, Dumfriesshire, however, there was neither a detailed description, nor illustration of these footprints that are now lost. These footprints cannot, therefore, be substantiated, but it is hoped that further examples will eventually be discovered in this area. Other footprints found in the Annan area were identified as *Delairichnus* by Haubold (1971a) and are not considered to be chirotheriid. The only substantiated claim of the existence of chirotheriid footprints in Scotland was published by Clark *et al.* (2002) on footprints from two localities on the Isle of Arran. The first footprint was found at Levencorroch Hill and is now in the collections of the Oxford University Museum (OUM G.53) and identified by M. King in 1992 as the left pes of *Chirotherium*. It was initially tentatively identified as dinosaurian (McKerrow and Atkins 1985). The second was on the coast 2.5km northwest of Blackwaterfoot on the southwest coast of Arran near to Cleiteadh nan Sgarbh (NR 886 301) (Clark *et al.* 2002).

The locality at Cleiteadh nan Sgarbh was found to have several trackways and individual footprints including the individual footprint discovered by Peder Aspen near the foot of the old sea-cliff 300m north of Cleiteadh nan Sgarbh (Clark *et al.* 2002).

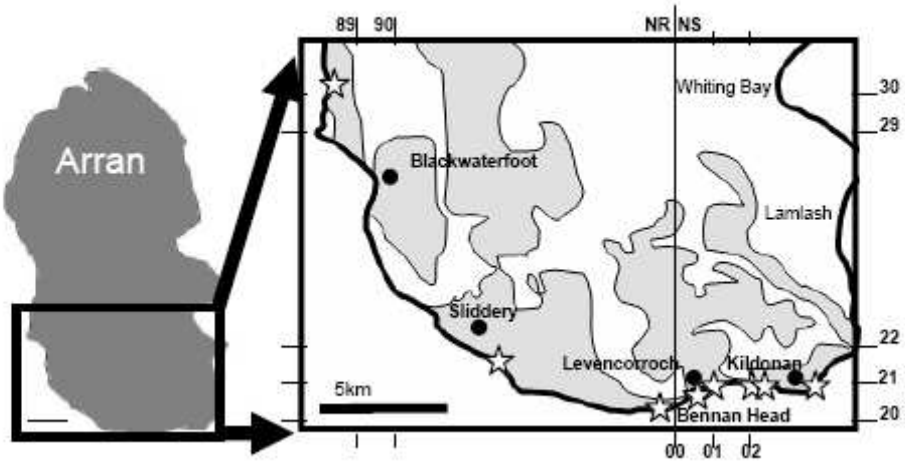

Figure 1. Outline map of Arran with footprint localities marked with a star. The Triassic outcrop is marked in grey on the enlarged map of the south of Arran. (scale bar = 5km).

Since the original descriptions of these chirotheriid footprints and trackways, several new occurrences have been reported by residents and enthusiasts on the Isle of Arran (figure 1). Fiona Gorman of Brodick discovered a footprint of a chirotheriid from the foreshore at Kildonan, southeast Arran that is now in the collections of the Arran Heritage Museum, Brodick. As a result of this discovery a number of other individual footprints and trackways were discovered by the authors in May 2007 on coastal exposures between Port Dearg (NS 032 206) and Port Buidhe (NS 025 208) in the east and Port a'Ghillie Ghlais (NS 003 209) in the west. The second author also later discovered further trackways and footprints near to Levencorroch and Bennan Head (NR 991 022) in July 2007. Further discoveries were made by John and Jean Fitzpatrick of Sliddery on the coast southeast of Port Mór (NR 939 218).

At Kildonan, a total of two single footprints and four trackways were found. The longest trackway had ten discernible footprints. Two probable manus prints were also recorded from this area although one may be a rhynchosauroid footprint. Very few of the footprints were clear enough to be useful in identifying the ichnospecies. The Sliddery trackways were mostly on one level between two dykes that converged seaward. They consisted of at least six trackways with two of them numbering seventeen discernible footprints (SLID_1 and 3). One trackway was on a loose boulder nearby (SLID_6). Most of the footprints here were also poorly preserved and not of taxonomic value. Only one manus footprint was recorded from this locality. A further two previously unrecorded trackways and two individual footprints were found at the Cleiteadh nan Sgarbh. Two manus footprints were also found, one associated with the previously recorded footprint number 16 of trackway 5 of Clark *et al.* (2002).

Setting

Warrington (1973) followed Craig (1965) in ascribing a tripartite lithostratigraphic system for the Permo-Triassic rocks of Arran. This consisted of the Brodick Beds, the Lamlash Beds and the Auchenhew Beds. The Triassic rocks were determined as being the Auchenhew Beds, the lower part of which included the Lag a'Bheith Marls and Cornstones of Tyrrell (1928), and the Lamlash Beds, which included the Machrie Beds of Tyrrell (1928). The Lamlash Beds consist mostly of fluvial and aeolian sands with occasional caliche horizons (Pollard and Lovell 1976). It is from the younger Auchenhew Beds that invertebrate trace fossils were first discovered in 1973 (Lovell 1981, Pollard and Lovell 1976, Pollard and Steel 1978, 1981). The ichnofossils that were present in the Auchenhew Beds were produced by ephemeral invertebrates in shallow fluvial-lacustrine sediments that occasionally contained halite pseudomorphs indicating a continuation of arid conditions from the Lamlash Beds and perhaps a marine influence prior to the onset of marine Rhaetic sedimentation above (Lovell 1981, Pollard and Steel 1978, 1981) (figure 2).

The age of the base of the Auchenhew Beds was determined by miospores to be late Scythian to Anisian (late Early to early Middle Triassic) by Warrington (1973).

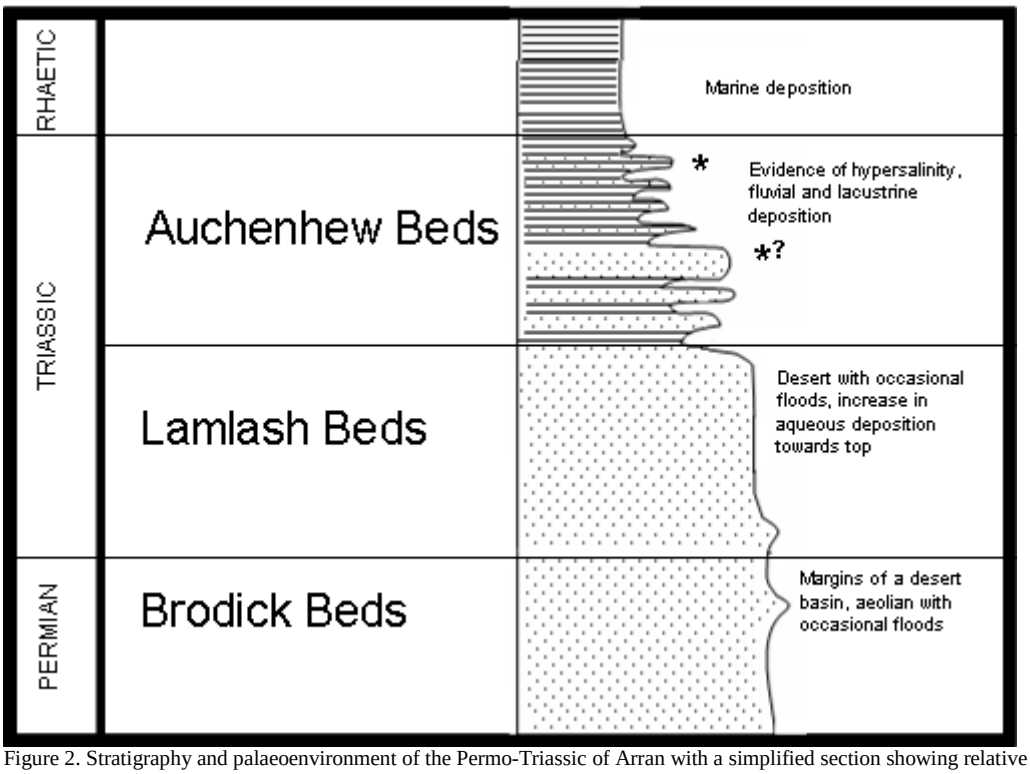

Figure 2. Stratigraphy and palaeoenvironment of the Permo-Triassic of Arran with a simplified section showing relative coarseness of the sediments (coarse to right, fine to left) modified after Warrington (1973), * indicate possible footprintbearing levels.

Method

The location of each trackway or footprint was determined using a Magellan SporTrak GPS except at the second locality at Sliddery, the Levencorroch and Bennan Head localities where a 1:25,000 map (Explorer 361) was used. Photographs were taken of the localities and the footprints to allow landmark analysis to be undertaken following the procedure outlined by Klein and Haubold (2003). As the footprints were generally poorly preserved, the analysis followed the modified procedure 'b' of Klein and Haubold (2003) which looked at five landmark points (figure 3). The landmarks placed at the base of the claw marks of each of the digits I-IV and the intersection between the phalanges of digit IV and the metatarsal pad (figure 3). Few of the specimens examined allowed this to be done as the preservation was too poor in most cases, Landmark data were produced from the photographs using tpsDig version 2 (Rohlf 2004). The resulting polygons were analysed by flipping the left handed footprints to allow a direct shape comparison, and performing a 2D procrustes transform to eliminate orientation and size anomalies using PAST version 1.57 (Hammer *et al.* 2001). The polygons were then subjected to principal component analysis using PAST version 1.57 (Hammer *et al.* 2001) to compare the footprints from different localities in Arran.

Other measurements of the *in situ* trackways taken included the pes length (pL), the manus length (mL), the direction of the trackway, the width of the trackway, pace and stride (tables 1 and 2) following the scheme of Peabody (1948), Haubold (1969, 1971a, b) and Clark *et al.* (2002), as preservation allowed (table 1). The data were then analysed for comparison with other chirotheriid trackways from elsewhere using stride:pL (table 1) and mL:pL ratios (table 2).

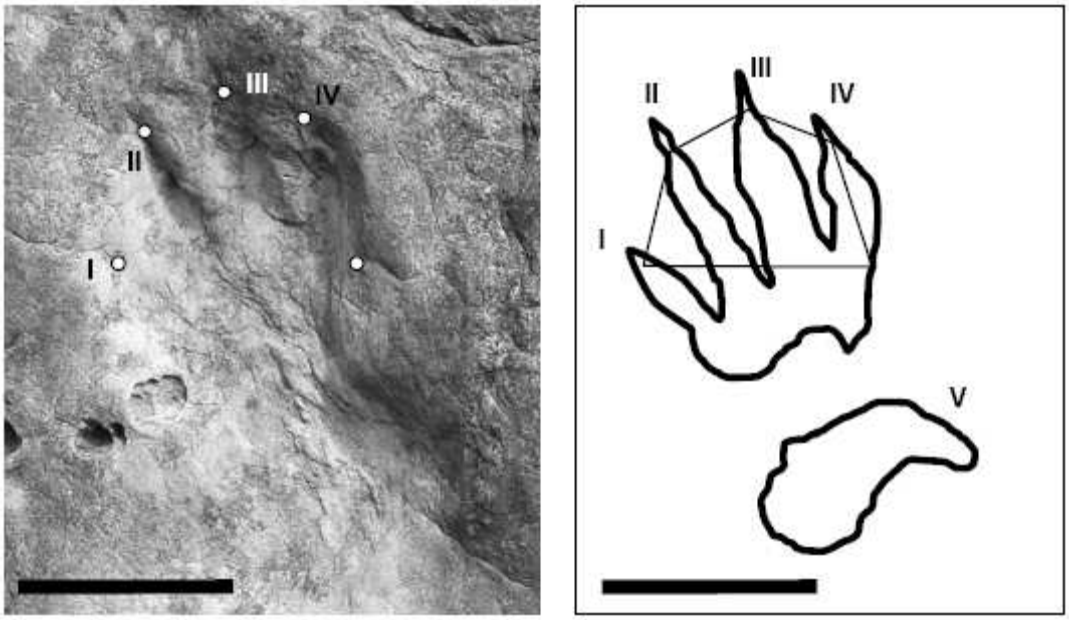

Figure 3. Example of modified procedure 'b' of Klein and Haubold (2003) which looked at five landmark points as carried out on the original of GLAHM 114737 (footprint 1) of Clark *et al.* (2002: figure 5). (scale bar = 10cm). I-IV = digits.

Descriptions

Kildonan

The footprint in the collections of the Arran Heritage Museum is a left pes cast made of a fine grey sandstone. Digits II-V are clearly seen with a recurved digit V and a digit III phalangeal width to length ratio of 0.42 suggest a broad toed pes (figure 4d). A single right manus cast was found *in situ* on the foreshore west of Kildonan (KIL_1: figure 4a, NS 01619 21113). Although worn, the impressions of four digits are distinct and remnants of a possible shorter digit I can also be seen. The curvature of the digits may suggest that this represents the pes of *Rhynchosauroides* morphotype A of Valdiserri and Avanzini (2007), however there were no other associated footprints and it is similar to other manus imprints of the chirotheriids *Isochirotherium herculis* and *Chirotherium barthii* (Haubold 1969). Another single footprint was found further to the east of Kildonan (KIL_4: figure 4c, NS 02717 20864), however not all the digits can be easily determined due to erosion or transmission. Digits I, II, IV and V are the clearest and the full extent of digit III cannot be measured with any certainty, but the full pes length may be as much as 37cm.

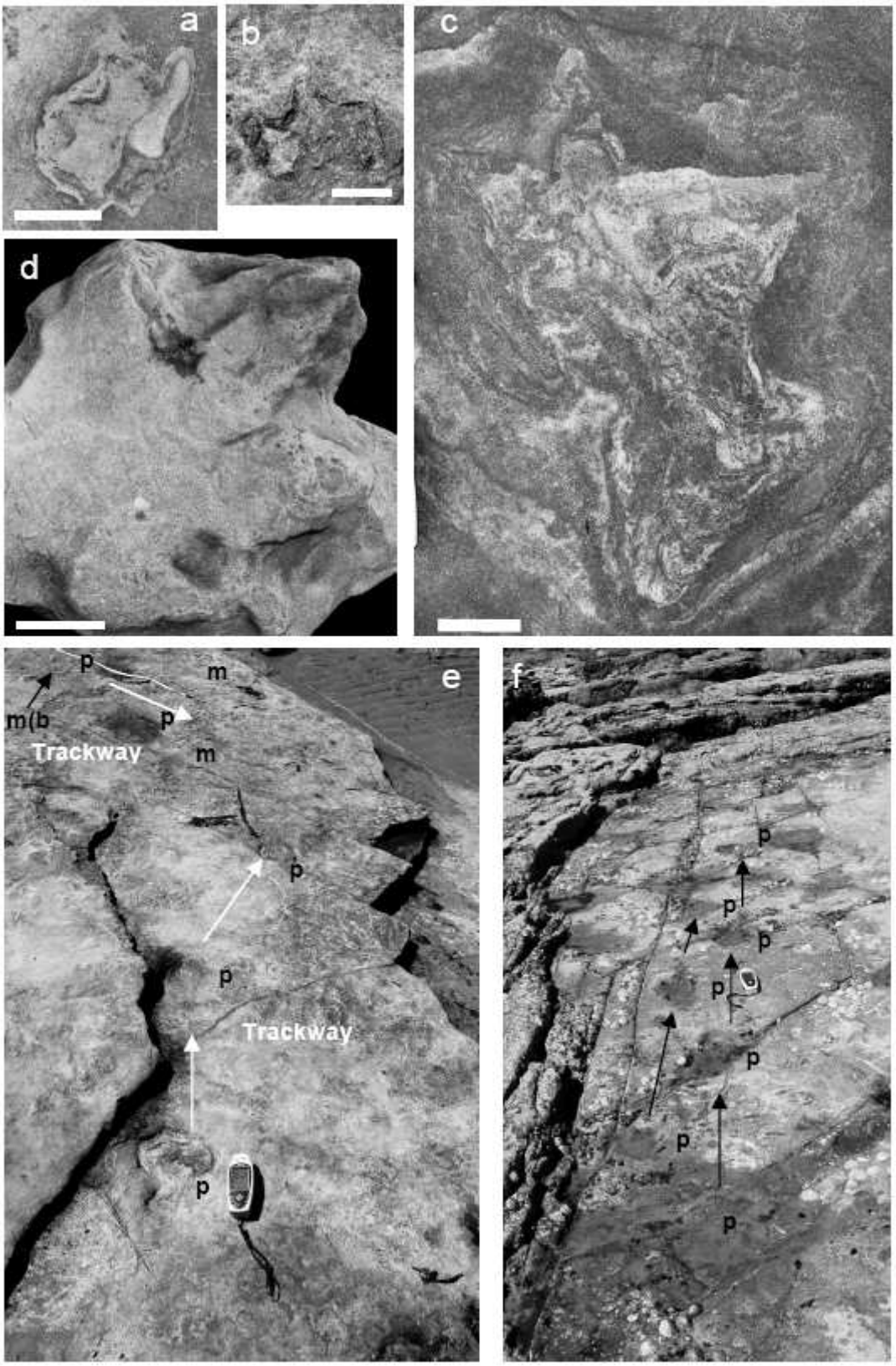

Figure 4. Footprints and trackways found at Kildonan: (a) KIL_1, single manus print of *Isochirotherium herculis* or *Rhynchosauroides* morphotype A of Avanzini and Valdiserri (2007); (b) KIL_2b, manus associated with pes on trackway b of figure 4e (m(b)); (c) KIL_5, large pes with digit III poorly preserved (not used in landmark analysis as this is a transmitted footprint); (d) Large pes in the collections of the Arran Heritage Museum, Brodick; (e) KIL_2, trackways a and b with pes (p) amd manus (m) prints marked. White arrows show direction of movement; (f) KIL_3, pes prints marked (p) and black arrows show direction of movement. (scale bars = 5cm; length of GPS = 14.25cm).

There are at least two trackways cross cutting at locality KIL_2 (figure 4e, NS 01341 21003). Trackway ‘a’ consists of three poorly preserved footprints with only an indication of digits. The narrow width of the trackway (about 23cm) suggests that the animal was walking with its feet directly underneath the body. Trackway ‘b’ is less clear and appears to represent two parallel trackways walking in a southerly direction. Two manus imprints are visible here, although not very well preserved. The footprints were preserved above a red sandstone with small white concretions and were overlain by a cross-bedded sandstone.

At locality KIL_3 (figure 4f, NS 00776 20964) there is a trackway that is represented by ten footprints on a thick grey sandstone. The moulds of the footprints are very worn and only two of the footprints (footprint 6 and 8) were of use in landmark analysis. The animal was walking in an easterly direction. The fourth locality at Kildonan (KIL_4: figure 5, NS 00727 20960) has about six footprints on a single trackway, but is discontinuous. There is a gap of about 150cm between footprint 3 and 4 due to the fragmentary nature, and erosion, of the rock surface. Footprints 5 and 6 were too poorly preserved to include measurements of pL, pace or stride. The animal here was walking in a southerly direction.

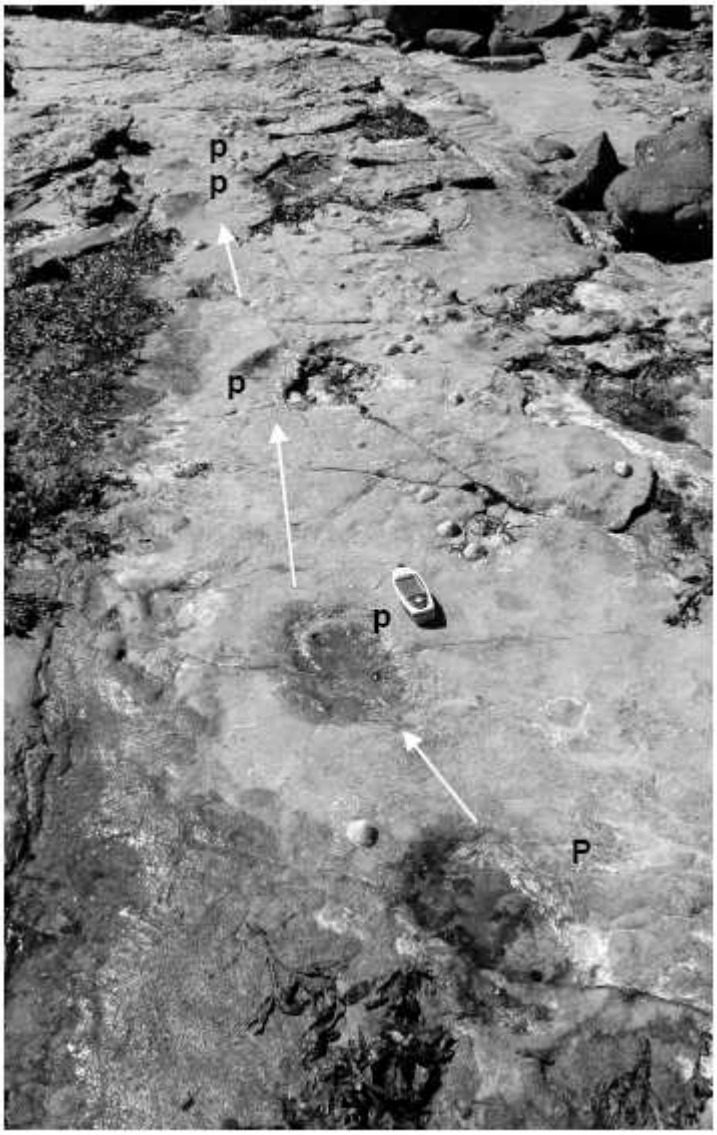

Figure 5. Kildonan trackway, KIL_4, with pes prints marked (p). (length of GPS = 14.25cm). White arrows show direction of movement.

Sliddery

There are two localities at Sliddery that have footprints and trackways. The best locality is on the shore due south of Cnoc Ghloine Ceabhair, and 1.75km southeast of Sliddery (NR 94039 21523). There were five *in situ* trackways recorded and one on a loose block (figure 6). The locality is bound by seawardly converging dykes on either side (figure 6a). Most of the animals appear to be walking in east-west

orientation. Trackways 1,2, 3 and 4 are nearly parallel with measured animal movement directions at 108°, 260°, 112° and 094° respectively, whereas trackway 5 shows an animal moving towards the south (182°). The trackways here are the longest yet found with trackways 1, 3 and 5 and each consisting of 17 footprints. In all these trackways the preservation of the individual footprints is very variable and some gaps occur. The rock in which these trackways are found is a grey blue sandstone with patches of red oxidation. Despite the number of trackways and footprints, there was only one manus impression found here associated with footprint 6 of trackway 1 (figure 6c).

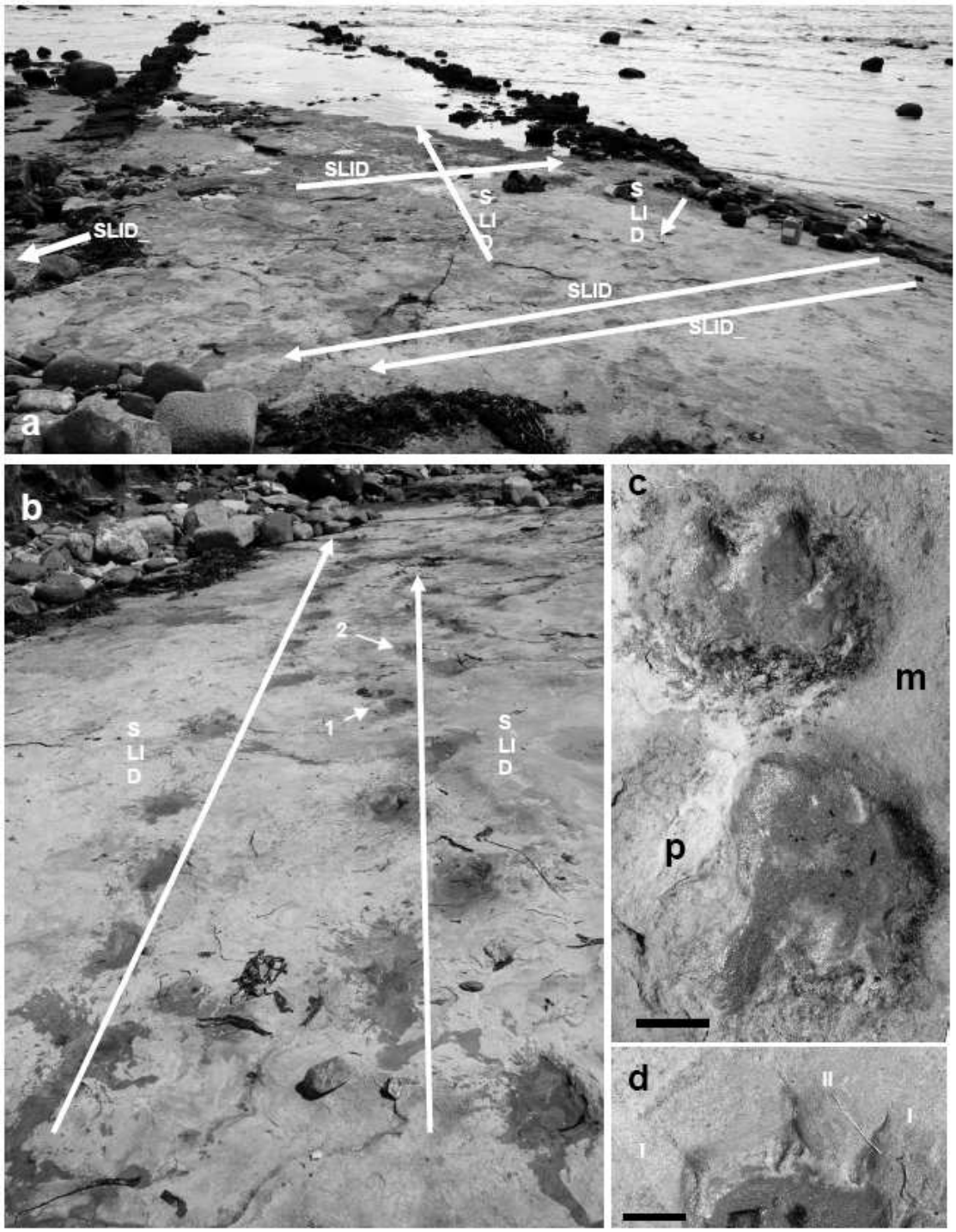

Figure 6. Sliddery trackways: (a) general overview of the location of the various trackways on the foreshore; (b) SLID_1 and SLID_3 trackways; (c) manus and pes of SLID_1 (1) of (b); (d) anterior portion of pes of SLID_1(2) of (b) showing digit III longer than digit II which is longer than digit IV. (scale bar = 5cm). White arrows show direction of movement

The only other trackway to be found at this location was on a loose block. The trackway consists of six footprints each about 22cm long, and a trackway width of about 32cm suggesting a very much upright

stance rather than a sprawling gait. The footprints here are again poorly preserved, but claw marks can be seen on some of them.

The other locality is just south of Port Mór (NR 9375 2158) where two poorly preserved footprints can be seen indicating a north easterly direction of movement (050°).

Blackwaterfoot

Several new footprints and trackways are recorded here from an exposure south of the main platform on which the other trackways were discovered previously (Clark *et al.* 2002). Trackway BWF_2 (NR 88575 30378) consists of seven poorly preserved footprints of which only footprints 2 and 6 had clear claw marks. On the same rock exposure at the same level was another trackway (BWF_3: NR 88579 30380) of five footprints that were not considered well enough preserved for analysis as was a single footprint nearby (BWF_4: NR 88572 30388). The adjacent trackway BWF_6 (NR 88565 30315), however, did contain a number of footprints that showed reasonably preserved digits in three footprints (footprints 3, 4, and 6). A 9.5cm long manus imprint was found associated with footprint 16 in trackway 5 (figure 7a and b) of Clark *et al.* (2002) and another of similar size was associated with a single pes nearby (BWF_7: figure 7c, NR 88543 30372).

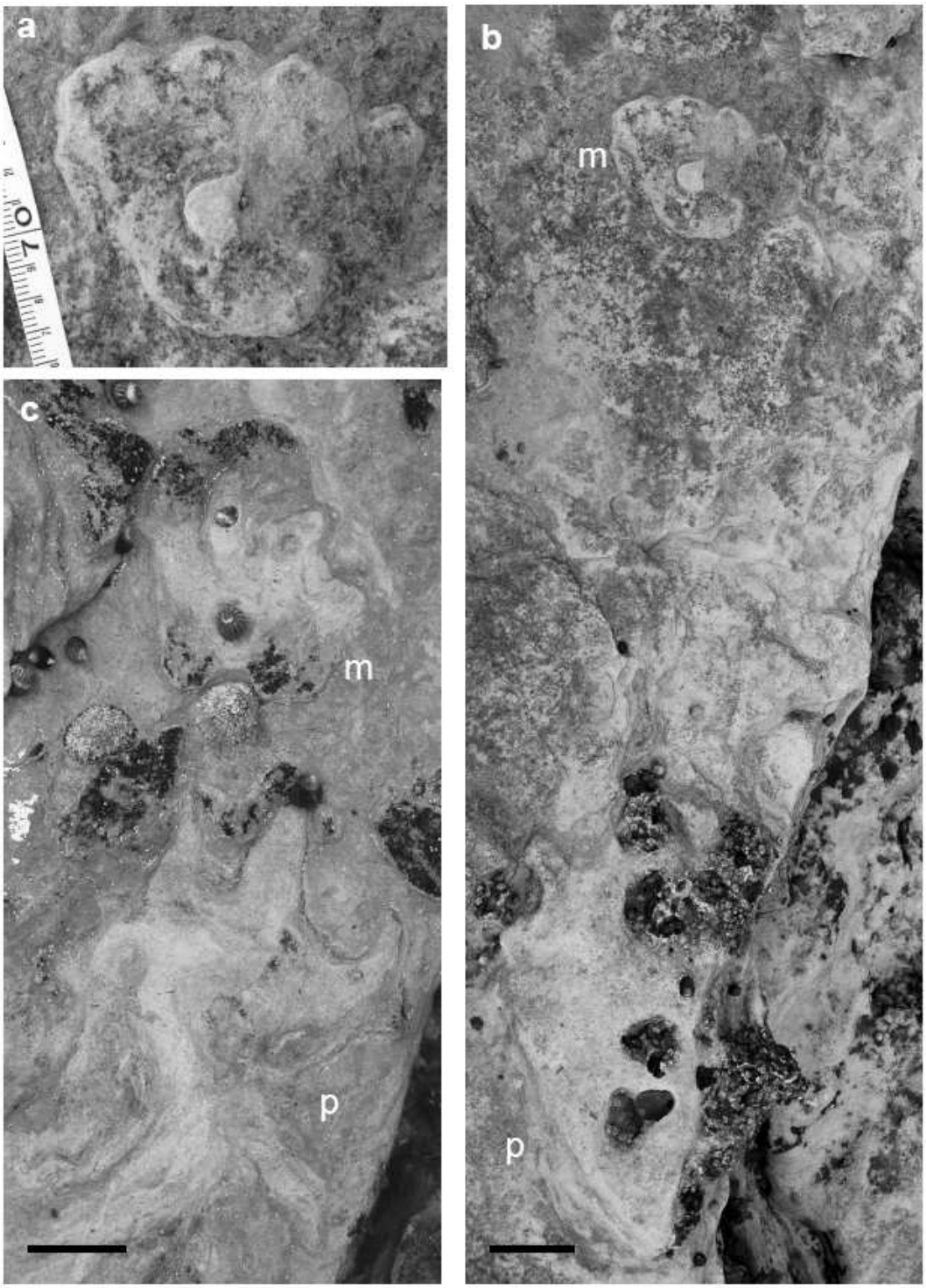

Figure 7. Manus prints associated with pes prints at Blackwaterfoot near to Cleiteadh nan Sgarbh: (a) manus print enlarged from (b); (b) BWF_5, manus and pes (16) from trackway 5 of Clark *et al.* (2002); (c) BWF_7 associated manus and pes print. (scale bar = 5cm).

Trackway	Footprint Number	pL	Pace	Stride	Trackway width	Trackway direction	Stride:pL ratio
BWF_2	1	28				75	
	2	24	78				
	3	21	59	98			4.36
	4	24	62	86			3.82
	5	23	70	94			4.00
	6	22	64	96			4.27
	7	27	55	85			3.47
BWF_6	1	30				335	
	2	30	77				
	3	30	91				
	4	32					
	5	30					
	6	35	84				
SLID_1	1	32				108	
	2	25	70		53		
	3	30	77	105			3.82
	4	30	87	117	48		3.90
	5	30	81	120			4.00
	6	28	97	127	52		4.38
	7	28	85	130			4.64
	8	25	77	116	49		4.38
	9	21	88	118			5.13
	10	31	84	123			4.73
	11	32	88	123	47		3.90
	12	33	84	123			3.78
	13	30	84	120	46		3.81
	14	30			55		
SLID_2	1	35				259	
	2	25	95		47		
	3	31	102	142			5.07
	4	28	97	144	49		4.88
	5	28	105				
	6	38					
	9	30					
SLID_3	1	30				112	
	2	25	77				
	3	30	77	110			4.00
	4	25	74	108			3.93
	5						
	6	28		107			3.82
	7	27	77				
	9	30		107			3.57
	10	24	70				
	11	29	73	102			3.85
	12	24	81	110			4.15
	13	30	73	110			4.07
	16	30					
	17	33	73				
SLID_4	1	27				94	
	2	26	69				
	3	34	77	104			3.47

SLID_6	1	23	44			182	
	2	26	47		34		
	3	22	41	85			3.54
	4	21	44	123	29		5.72
	5	20	36	113	32		5.51
KIL_2	1	24				335	
	2	19	58		23		
	3	16	73	131			5.74
	4	28	70			160	
KIL_3	1	25				102	
	2	21	53		40		
	3	19	60	81			4.05
	4	21	57	84	38		4.20
	5	20	63	86			4.30
	6	20	50	81	38		4.05
	7						
	8	20		79	39		3.95
	9		56	83			
	10		67	88			
KIL_4	2	34	67			210	
	3	35	83	117			3.39
	4	20					
LC1	1	27					
	2	28	68			038	
LC2	1	27					
	2	27	60				
	3	30	73				
	4	27	73			058	
BH	1	19				140	

Table 1. Data obtained for the trackways and footprints at Blackwaterfoot (BWF), Sliddery (SLID) and Kildonan (KIL), Levencorroch (LC), Bennan Head (BH) on the Isle of Arran (see text for locality details). pL = pes length, all measurements in centimetres.

Levencorroch and Bennan Head

One of the first footprints was collected from Levencorroch Hill and has already been described by Clark *et al.* (2002) and was also mentioned in McKerrow and Atkins (1985). Further footprints were found by one of the second author in July 2007. The *in situ* footprints from the foreshore near Levencorroch are not very well preserved, but add to the list of trackways from Arran and provide directional information. Two trackways were found close together (NS 0028 2089) on either side of a NW/SE trending dyke. The first trackway (LC1) consists of two footprints indicating a north-easterly direction of travel (figure 8a). The other trackway (LC2) is longer, consisting of four footprints, also indicates a north-easterly direction of travel (figure 8b). A single pes footprint (BH) was identified at Bennan Head (NR 9876 2019) in which digit V can be seen extending laterally to the left (figure 8c) with another three clearly visible anterior digits. It is not clear which digit is which, but they may represent digits II, III, and IV; the longest digit being digit III. The line through the 'heel' of the footprint and the longest toe indicates a south-easterly direction of travel.

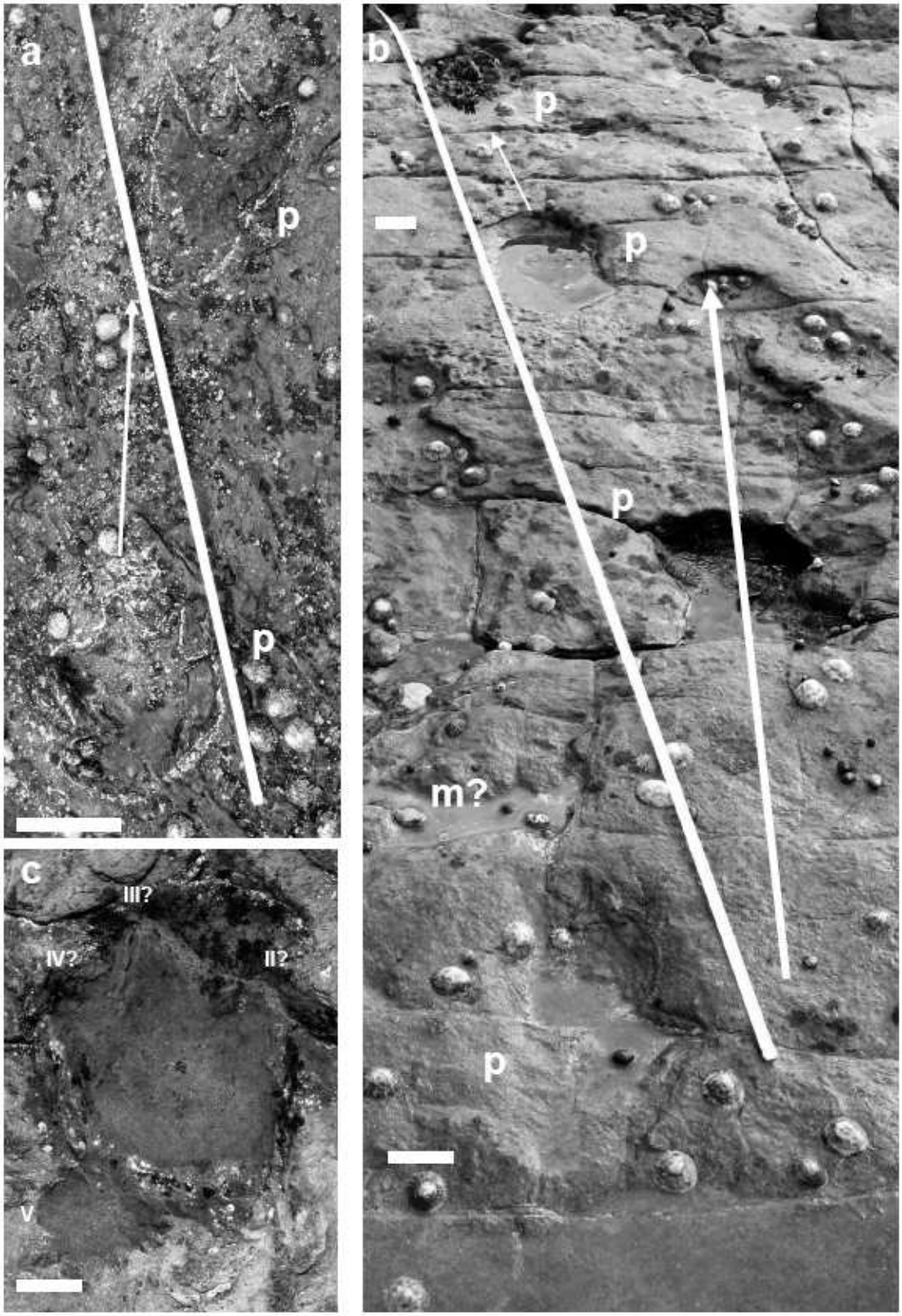

Figure 8. New trackways at Levencorroch and Bennan Head: (a) Trackway A at Levencorroch consisting of two footprints (scale bar = 10cm); (b) Trackway B at Levencorroch with four footprints (pes prints marked with (p) and possible manus print (m?); arrow shows trackway direction; scale bars = 5cm); (c) single footprints at Bennan Head (scale bar = 5cm).

The trackways and footprints from all these locations combined do not appear to offer any preferred direction of travel (figure 9). At Kildonan (n=5), the orientation seems to be mostly north-south, with one animal walking northward, although another is walking eastward. The data from the Levencorroch

trackways and the Bennan Head footprint (n=3) could be included with the Kildonan data as they all belong to the same stretch of coast. If this were done, there would be no preferred direction for these data. At Sliddery (n=5), the orientation of the trackways show animals walking east-west with one walking westward, although one is walking southward. The majority of the trackways were found at Blackwaterfoot (n=14) where ten of the trackways show animals walking north of west to north of east, with only four walking south-westerly or south-easterly. The small number of trackways at these localities, however, makes it impossible to draw any major conclusions from the directional data.

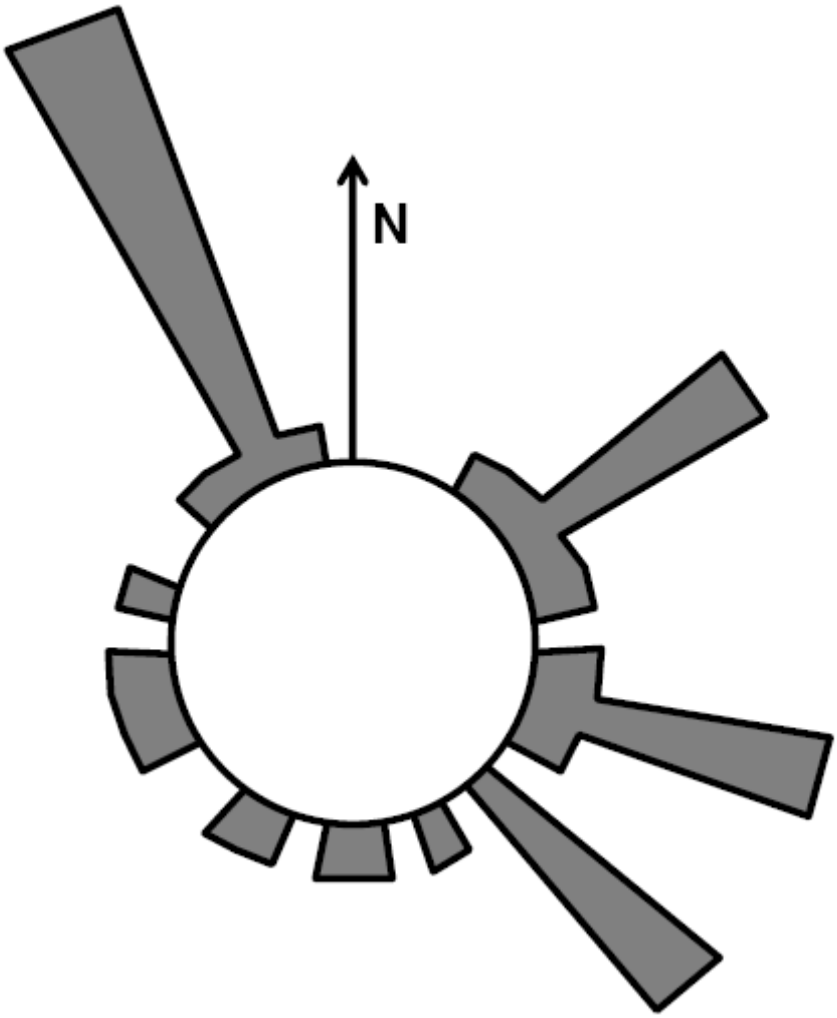

Figure 9. Rose plot of all directional data for the chirotheriid footprints from Arran in 10º sectors (n=27).

Discussion

The identity of the footprints provided in Clark *et al.* (2002) is disputed here. The pes preserved in the loose block near the waterfall north of Blackwaterfoot (Clark *et al.* 2002) (NR 88691 30169) is still the best preserved of the footprints. Digit III was described as the longest followed by IV, II and I respectively and the divergence between digits I and V is between 69° and 104° (Clark *et al.* 2002), but only about 45°-55° between the long axis of digit III and digit V. This is slightly on the low side for the emended diagnosis of *C. barthii* provided by King *et al.* (2005). Digit V is slightly recurved and the ratio of the manus to pes length of between 0.31 and 0.39 is only slightly on the low side, especially for *C. barthii* which normally has a ratio of above 0.45. The pes length for the Arran footprints is between 16 and 38cm which is a little on the large size even for *C. barthii* which the Arran specimens were originally identified as (Clark *et al.* 2002).

Other possible ichnogenera for the form found on Arran, include *Brachychirotherium* and *Isochirotherium*. The diagnoses for both these ichnogenera have also recently been emended (Demathieu & Demathieu 2004, King *et al.* 2005). In *Brachychirotherium*, digit V is not recurved, digits II and IV are about the same length, and the manus to pes ratio is similar to that in *Chirotherium*. In *Isochirotherium*, the manus to pes ratio is less than 0.35 (the manus is rarely well preserved), and

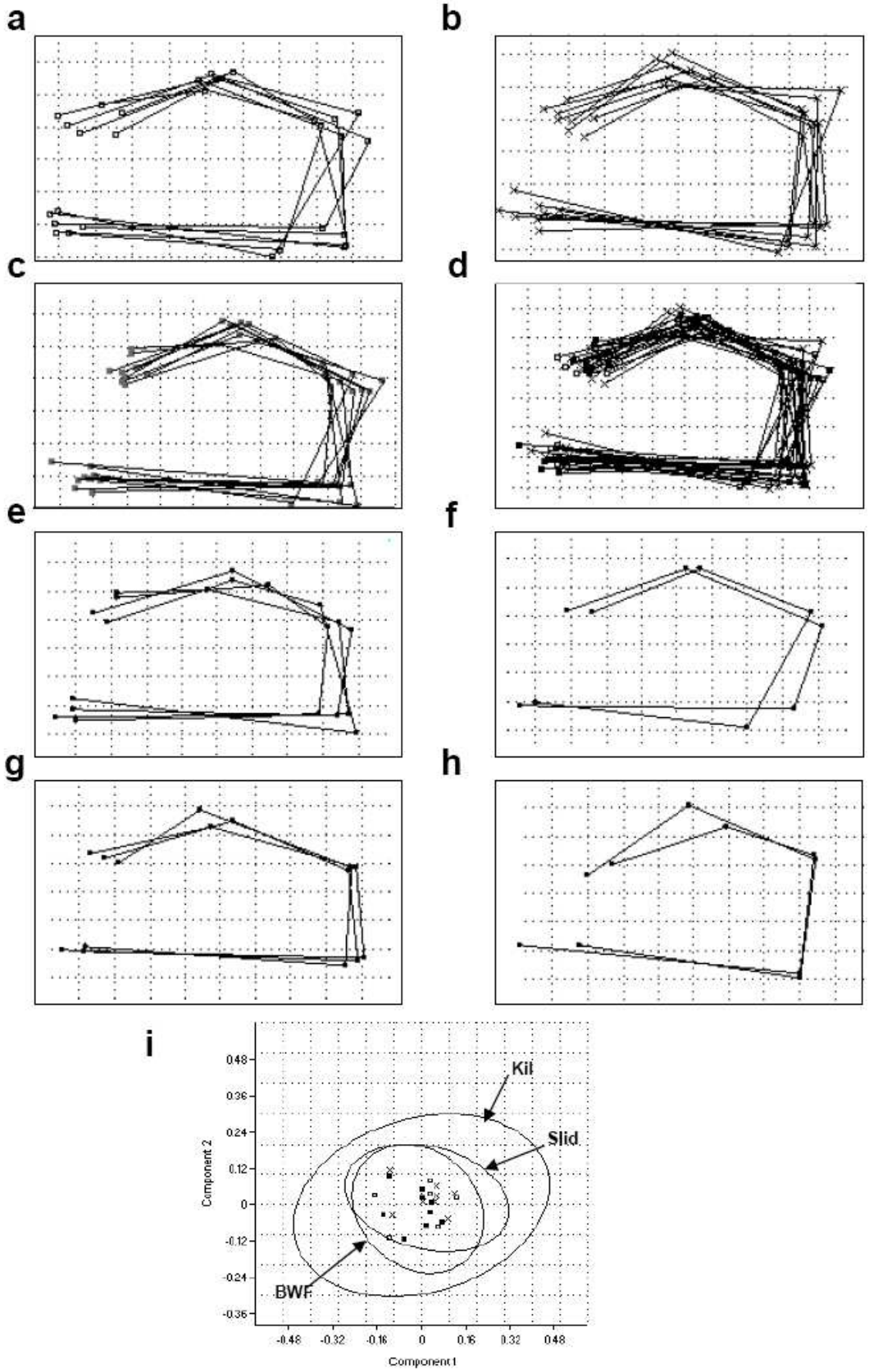

Figure 10. Landmark plots and principal component analysis for the chirotheriid footprints from the Isle of Arran. Overlapping linked landmark plot for: (a) Kildonan (n=6) (□); (b) Sliddery (n=8) (x); (c) Blackwaterfoot (n=9) (■); (d) all data combined (n=23); comparison of footprint landmarks from the same trackways at: (e) Blackwaterfoot trackway 2 (n=4); (f) Blackwaterfoot trackway 6 (n=2); (g) Sliddery trackway 1 (n=3); (h) Sliddery trackway 2 (n=2); (i) principal component analysis showing 95% elipses for each locality (Kil = Kildonan; Slid = Sliddery; BWF = Blackwaterfoot).

digit V of the pes is slightly recurved. The pes length can be as much as 30cm in *I. herculis* which is of the same order of magnitude as the footprints from Arran. Digit II is always longer than digit IV and sometimes as long as digit III in *Isochirotherium* which differs from the original description of the Arran footprints. On looking closer at the best preserved footprint from Arran, for which a copy exists in the collections of the Hunterian Museum (GLAHM 114737), it appears as though the original description was incorrect in stating that digit II was shorter that digit IV, as the reverse seems to be the case (see figure 3). The mean manus to pes length ratio of 0.34 for the four manus specimens associated with a pes from the Arran specimens suggests, in concordance with the other morphological characteristics, that the Arran is an ichnospecies of *Isochirotherium*.

The landmark data also seems to confirm this identification. The linked landmark plots are very closely matched between all the samples analysed indicating that the footprints have a very similar morphology (figure 10). Although certain individual footprints were difficult to measure and produced a splayed appearance to the landmark diagrams, the general shape is that of a short broad footprint. Most of the footprints were recorded from a shoreline which would have contributed to their weathered appearance and made landmark identification more difficult. For this reason, despite some of the trackways containing up to 17 footprints, only very few were analysed from individual trackways (figure 10f-i). Even those from the same trackway show variation in shape indicating that the variation is not due to intraspecific variation. The variation may be interpreted as due to poor preservation or distortion of the footprint as a result of the surface being eroded down to show transmitted footprints (Clark *et al.* 2002). Studies on dinosaur footprints have shown that interdigital angles as well as footprint size can vary with the depth of the transmitted impression (Manning *et al.* 2008). The footprints on Arran lack skin impressions, but some appear to show some phalangeal pad outlines and distinct claw impressions. This suggests that at least some of the footprints represent either weathered surface impressions or shallow transmitted footprints. It is these footprints that are likely to be the most reliable footprints for landmark analysis. Other footprints that are more clearly transmitted footprints with no obvious phalangeal pads or claw impressions were not used in this analysis.

A mean landmark polygon was produced from the footprints analysed. The short length of the resulting polygon indicates that they may represent either an ichnospecies of *Brachychirotherium* (figure 11b) or *Isochirotherium* (figure 11c) rather than *Chirotherium barthii* (figure 11a). The Arran mean polygon is only slightly skewed towards digit IV as they appear to be in *I. herculis* as shown by Klein and Haubold (2003) (figure 11d).

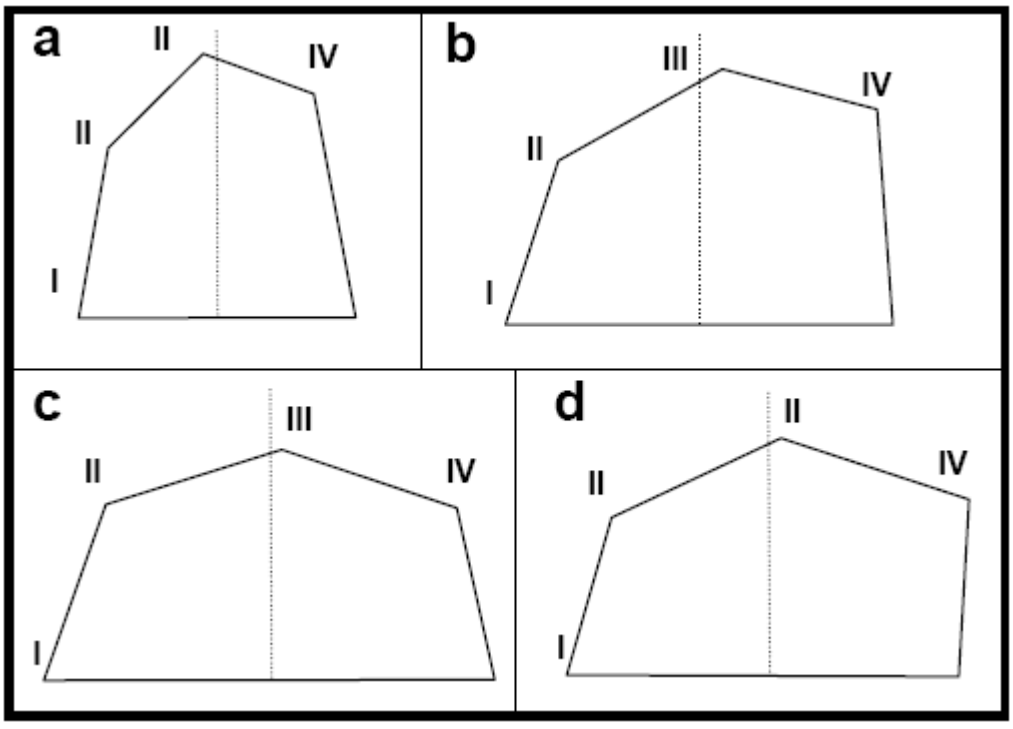

Figure 11. (a-b) polygon shapes for (a) *Chirotherium barthii* specimen MS I Ba2 Fährte b from Klein & Haubold (2003; fig. 4d),

Brachychirotherium, hassfurtense specimen UEN F22 Lectotype from Klein & Haubold (2003; fig. 4f) and (c) *Isochirotherium herculis* specimen MB Rühle VI from Klein & Haubold (2003; fig. 4j); (d) mean polygon shape for all Arran landmark data (n=23).

The ratio of the manus to pes (table 2) is less than the diagnostic range for *C. barthii* of 0.45:1 to 0.50:1 as suggested by King *et al.* (2005). In *Isochirotherium* the ratio is much less at less than 0.35:1. As the ratios for the Arran specimens fall below the 0.35:1 ratio except for one at 0.39:1, this suggests that the initial identification of the chirotheriid from Arran as *C. barthii* is flawed and that a more likely identification is a species of *Isochirotherium* Haubold, 1971.

manus prints		mL	mL:pL ratio
KIL_1		8	-
KIL_2b	4b	11	0.34
SLID_1	6a	13	0.39
BWF_5		9.5	0.31
BWF_7		9.1	0.31

Table 2. Measurements of manus prints; mL = length of manus print, mL:pL ratio is the ratio of the lengths of the manus and the associated pes (pL), all measurements in centimetres.

I. herculis is a well known ichnospecies first described from the Lower to Middle Anisian (Middle Triassic) sandstones of Storeton and Tarporley, Cheshire (Egerton 1838, Tresise 1991, Tresise and Sarjeant 1997). Further discoveries were made at various localities in the Cheshire Basin from the Helsby Sandstone Formation and the Tarporley Siltstone Formation (Tresise 1991, Tresise and Sarjeant 1997, King *et al.* 2005) at the top of the Sherwood Sandstone Group and the base of the Mercia Mudstone Group. In Europe and North America, *Isochirotherium* has been recorded from Lower and Middle Triassic rocks (Haubold 1971a), but in Britain this ichnogenus has only been confirmed in Middle Triassic rocks (King *et al.* 2005). King *et al.* (2005) also state that, in their opinion, *I. herculis* is an invalid ichnospecies as the holotype of this ichnospecies probably represent a large *Chirotherium* form rather than *Isochirotherium*. They also state that *C. herculis* is still an available ichnospecies, but that many large forms of *Chirotherium* may be placed with *C. rex*. As already stated by Clark *et al.* (2002), *C. rex* would not be an alternative for the specimens form Arran. For the purposes of this paper, the ichnospecies is retained as the specimens described fit the diagnosis for *Isochirotherium*, rather than *Chirotherium*, and have the dimensions that correspond with *I. herculis* as defined by Haubold (1971a) and Klein & Haubold (2003).

On the basis of the diagnostic characters and the landmark polygons, the most likely identification of the Arran chirotheriid footprints is *I. herculis sensu* Haubold (1971a) pending a reassessment of this species.

Conclusions

The ichnospecies of chirotheriid found in the Auchenhew Beds on the Isle of Arran is no longer considered to be *Chirotherium barthii.* A re-examination of the best footprints and the new discoveries show that digit IV is longer than digit II which is a characteristic of *Isochirotherium.* The new discoveries at Kildonan to Bennan Head, Sliddery, and Blackwaterfoot consist of trackways, pes prints and a few manus prints. Landmark analysis of the best preserved footprints, as well as their large size, suggest that the ichnospecies represented on Arran is *I. herculis* as described by Haubold (1971a) and Klein and Haubold (2003) and discussed by King *et al.* (2005).

No certainty can be placed on the age of the rocks other than that offered by Warrington (1973) (Scythian – Anisian, Lower-Middle Triassic) as the footprints are not of precise stratigraphic use.

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References

CLARK, N.D.L., ASPEN, P. and CORRANCE, H. 2002. *Chirotherium barthii* Kaup 1835 from the Triassic of the Isle of Arran, Scotland. *Scottish Journal of Geology,* **38,** 83-92.
CRAIG, G.Y. 1965. Permian and Triassic. *In* G. Y. Craig (ed.), *The Geology of Scotland*. Oliver and Boyd, Edinburgh, 383-400.
DEMATHIEU, G. and DEMATHIEU, P. 2004. Chirotheria and other ichnotaxa of the European Triassic. *Ichnos,* **11,** 79-88.
EGERTON, P.G. 1838. Two casts in sandstone of the impressions of the hind foot of a gigantic *Chirotherium* from the New Red Sandstone of Cheshire. *Proceedings of the Geological Society of London,* **3,** 12-14.
HAMMER, Ø., HARPER, D.A.T. and RYAN, P.D. 2001. PAST: Palaeontological Statistics software package for education and data analysis. *Palaeontologica Electronica,* **4,** 9pp.
HARKNESS, R. 1850a. On the New Red Sandstone of the southern portion of the Valley of the Nith. *Quart. Journal Geol. Soc. London,*. **G,** 389-99.
HARKNESS, R. 1850b. On the position of the impressions of footsteps in the Bunter Sandstone of Dumfries-shire. *Ann. Mag. Nat. Hist.* series 2, **6,** 203-208.
HAUBOLD, H. 1969. *Chirotherium*-Fährten aus dem Buntsandstein im "Mauritianum" in Altenburg. *Abhandlungen u. Berlin Naturkundliche Museum "Mauritianum" Altenburg.* 21-36.
HAUBOLD, H. 1971a. Ichnia Amphibiorum et Reptiliorum fossilium. *In* KUHN, O. (ed.) *Encyclopedia of Paleoherpetology*. **Part 18**, Gustav Fischer Verlag, Stüttgart and Portland, USA. 124pp.
HAUBOLD, H. 1971b. Die tetrapodenfährten des Buntsadsteins in der Deutschen Demokratischen Republik und in Westdeutschland und ihre Äquivalente in der gesamten Trias. *Paläontologische Abhandlungen, Ab A,*. **4** (3)**,** 397-548.
KING, M.J., SARJEANT, W.A.S., THOMPSON, D.B. and TRESISE, G. 2005. A revised systematic ichnotaxonomy and review of the vertebrate footprint ichnofamily Chirotheriidae from the British Triassic. *Ichnos,* **12,** 241-299.
KLEIN, H. and HAUBOLD, H. 2003. Differentiation of selected Chirotherians from the Triassic by landmark analysis. *Hallesches Jahrbuch für Geowissenschaften,* **B25,** 21-36.
LOVELL, J.P.B. 1981. Intertidal sediments in the Auchenhew Beds (Triassic) of Arran. *Scottish Journal of Geology,* **17,** 223-224.
MANNING, P. L., OTT, C. and FALKINGHAM, P. L. 2008. The first tyrannosaurid track from the Hell Creek Formation (Late Cretaceous), Montana, U. S. A. *Palaios,* **23,** 645-647.
MCKERROW, W.S. and ATKINS, F.B. 1985. *Geologists' Association Guide: Isle of Arran.* Geologists' Association, London. 96pp.
PEABODY, F.E. 1948. Reptile and amphibian trackways from the Lower Triassic Moekopi Formation of Arizona and Utah. *University of California Publications Bulletin of the Department of Geological Sciences,* **27,** 295-468.
POLLARD, J.E. and LOVELL, J.P.B. 1976. Trace fossils from the Permo-Triassic of Arran. *Scottish Journal of Geology,* **12,** 209-225.
POLLARD, J.E. and STEEL, R.J., 1978. Intertidal sediments in the Auchenhew Beds (Triassic) of Arran. *Scottish Journal of Geology,* **14,** 317-328.
POLLARD, J.E. and STEEL, R.J., 1981. Intertidal sediments in the Auchenhew Beds (Triassic) of Arran:reply. *Scottish Journal of Geology,* **17,** 225-226.
ROHLF, F. J. 2004. tpsDig, digitize landmarks and outlines, version 2.0. Department of Ecology and Evolution, State University of New York at Stony Brook.
TRESISE, G. 1991. '*Chirotherium herculis*' – problems posed by the first finds. *Annals of Science,* **48,** 565-576.
TRESISE, G. and SARJEANT, W.A.S. 1997. *The Tracks of Triassic Vertebrates: Fossil Evidence from North-West England.* The Stationary Office, Norwich, 204pp.
TYRRELL, G.W. 1928. The geology of Arran. *Mem. Geol. Surv. UK.*
VALDISERRI, D. and AVAZINI, M. 2007. A tetrapod ichnoassociation from the Middle Triassic (Anisian, Pelsonian) of Northern Italy. *Ichnos,* **14,** 105-116.
WARRINGTON, G. 1973. Miospores of Triassic age and organic-walled microplankton from the Auchenhew Beds, south-east Arran. *Scottish Journal of Geology,* **9,** 109-116.